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Livelihoods Knowledge Exchange Network

RCAP Rural Community Assistance Partnership

# Water and Climate Equity in Rural Water Systems in the United States

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## ABOUT LiKEN

Livelihoods Knowledge Exchange Network (LiKEN) is a nonprofit organization that links communities, organizations, and researchers with one another to build strong, lasting communities. As a link-tank, LiKEN's core mission is to support local economies and community happiness and health by strengthening local resources, encouraging reliable teamwork, and creating open and fair information-sharing groups. We link communities with scholarly expertise and government resources to co-design projects in climate resilience, forest farming, water quality, land use, and cultural narratives. Our current and emerging work focuses on communities affected by environmental injustice and boom and bust economies — primarily in Indigenous communities, Appalachia, and the U.S. South. Our research design is informed by the LiKEN Framework for Collaborative Actionable Research, which features asset-based and appreciative inquiry; empowerment, community science, Participatory Action Research (PAR); and democratic knowledge sharing networks centered on the local. Learn more at www.likenknowledge.org.

## ABOUT THE PACIFIC INSTITUTE

The Pacific Institute envisions a world in which society, the economy, and the environment have the water they need to thrive now and in the future. In pursuit of this vision, the Institute creates and advances solutions to the world's most pressing water challenges, such as unsustainable water management and use; climate change; environmental degradation; food, fiber, and energy production for a growing population; and basic lack of access to fresh water and sanitation. Since 1987, the Pacific Institute has cut across traditional areas of study and actively collaborated with a diverse set of stakeholders, including leading policymakers, scientists, corporate leaders, international organizations such as the United Nations, advocacy groups, and local communities. This interdisciplinary and independent approach helps bring diverse groups together to forge effective real-world solutions. More information about the Institute and our staff, directors, funders, and programs can be found at www.pacinst.org.

## ABOUT RCAP

The Rural Community Assistance Partnership (RCAP) is a national network of nonprofit partners working with small, rural, and Indigenous communities to elevate rural voices and build local capacity to improve quality of life — starting at the tap. Our more than 350 technical assistance providers (TAPs) act as trusted primary care providers in the training and technical assistance they provide. TAPs are locally based and, with deep trust built over time, we meet communities where they are to co-develop solutions for the challenges that matter most to them. Our TAPs annually work in over 2,000 small, rural, and Tribal communities in every U.S. state, the U.S. territories, and on Tribal lands on issues ranging from gaining access to safe drinking water to creating economic development opportunities that can improve livelihoods and long-term individual and community-wide prosperity. Learn more or find assistance at www.rcap.org.

## About the Authors

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Betsy Taylor is Executive Director of LiKEN. She has worked for community-driven development in Appalachia and South Asia — seeking to integrate issues of health, agriculture, forestry, culture, and environmental stewardship. Her many scholarly writings focus on environmental and social justice movements, democratic planning and participatory research, regional development, and sustainability studies. With Herbert Reid, Dr. Taylor co-authored the book, *Recovering the Commons: Democracy, Place, and Global Justice* (University of Illinois Press, 2010). At the University of Kentucky, she served as Co-Director of Environmental Studies, Research Director for the Appalachian Center and on the faculty of the Social Theory program. Dr. Taylor was a research faculty member in the Appalachian Studies program at Virginia Tech. She received her doctorate in Cultural Anthropology from the University of Michigan.

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Shannon McNeeley is a Senior Researcher at Pacific Institute and the Water and Climate Equity Lead. Her work focuses on water and climate equity and justice for frontline communities. This engages an interdisciplinary and cross-cultural co-production approach, incorporating the social and natural sciences along with different ways of knowing to understand human-environment relationships and how people are impacted by and respond to environmental change. Her research has focused on climate change science and policy, water resources and drought preparedness, and climate planning and action, all with a strong focus on supporting those who are overburdened and under resourced through just and equitable solutions. Dr. McNeeley has worked closely for decades with a multitude of different partners, organizations, decision-makers, Tribes and Indigenous peoples, and frontline communities bridging technical research with applied decision support information and tools. Prior to joining the Pacific Institute, she was at the North Central Climate Adaptation Science Center at Colorado State University and before that at the National Center for Atmospheric Research. Shannon holds a master's in International Environmental Policy from the Middlebury Institute of International Studies at Monterey and a doctorate in Environmental Change and Sustainability Science, which integrated anthropology, ecology, and climatology, from the University of Alaska Fairbanks.

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### LAURA LANDES

Laura Landes is RCAP's Associate Director of Research and Data. Her career has been focused on environmental and water topics. She earned a Bachelor of Arts in Economics and Environmental Policy from the College of William & Mary and a Master's in Environmental Management with a concentration in Environmental Economics and Policy from the Nicholas School of the Environment at Duke University. During her time at Duke, she focused on water and wastewater challenges and policy. Laura's research has focused on topics such as regionalization, issues of water, climate, and equity, rural broadband, and rural innovation, and her years at RCAP have expanded her perspective on the challenges and opportunities that rural communities and their water systems face. Laura manages RCAP's research, data and impact, and software engineering teams, which together provide the ability for RCAP and its partners to track, understand, and report on the essential work being done in the field to create more resilient communities.

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Lena Schlichting is a Senior Research Specialist at RCAP. Her research at RCAP includes climate change impacts on communities and their water systems, equitable approaches for funding, emerging contaminants in drinking water, and integrating mapping technologies into RCAP's work. Prior to joining RCAP, Lena worked in the public sector to assist communities in New Mexico with source water protection and drought adaptation, used mapping technologies in the forestry sector for stream and post-fire restoration, and worked on impacts of climate change on flooding and hydrology in Norway. She holds a Master of Geography from the University of Heidelberg, Germany, and has lived and worked in all four-corners states of the American Southwest.

### DEBORAH THOMPSON

Deborah Thompson serves as LiKEN's Impact Director and supervises LiKEN's Community Engagement Coordinators. She holds a doctorate in Geography from the University of Kentucky and a master's in Appalachian Studies from Appalachian State University. Her deep knowledge of Appalachian geography and cultures has been informed by her decades of living, learning, and working in the region, including over 25 years of teaching on the undergraduate level, field research, directing cultural study programs, organizing music and dance events, and performing traditional music and dance. Dr. Thompson's dissertation examines how racialized and gendered scripts and habits in artistic expressions and processes reflect and influence ideas about the Appalachian region. Her peer reviewed articles on these topics have been published in *GeoJournal*, *Journal of Appalachian Studies*, and other scholarly publications.

### RACHEL WILL

Rachel Will joined the Pacific Institute in 2023 as a Researcher in Water and Climate Equity. She co-produces research focused on equitable and climate resilient water systems in rural communities and WASH. Before joining the Pacific Institute, Rachel worked as a regional planner, focusing on social equity and climate resilience projects. She has extensive experience leading and contributing to interdisciplinary research on water equity, environmental justice, and climate resilience issues. Rachel holds a master's in Geography from Kent State University, and a doctorate in Integrative Conservation and Geography from the University of Georgia.

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# Key Terms

**Asset-based:** Values and methods that foreground the positive resources and attributes of a community to affirm and build on the strengths, knowledge, and perspectives of those directly affected by the problem being addressed. The goal is to avoid a focus on negative images of what communities lack and need. This approach is closely related to methods of "appreciative inquiry" that focus first on strengths to build a cascade of transformational changes based on cumulative successes. This avoids an emphasis on community problems that can trap the work within negative and disempowering frameworks.

**Climate resilience:** Defined by the U.S. National Climate Assessment as the capacity of interconnected social, economic, and ecological systems to cope with a climate change event, trend, or disturbance, responding or reorganizing in ways that maintain their essential function, identity, and structure. Climate resilience is a subset of resilience against climate-induced or climate-related impacts.

**Collaborations:** Partnerships to pursue common goals, co-design projects, share and co-produce outputs and deliverables while building trust, relationships, alignment among participants, and values-based accountability to constituents.

**Community scholars or scientists:** Community residents who participate with professional scholars in scientific/humanities research and monitoring, driven and controlled by local communities, and characterized by place-based knowledge, social learning, collective action, and empowerment. (This is closely related to the term "citizen science.")

**Cross-sector:** Refers to work that bridges the sectors of community, civil society organizations (differentiated from "community" by referring to incorporated organizations, vs. the more informal and embedded process of community), specialists (scholars, technical experts, knowledgeable practitioners, and community experts), and governments (including Indigenous governments). Depending on the project needs, it can also include businesses/corporations, philanthropy, and other sectors.

**Frontline communities:** Communities that are overburdened and under resourced who face disproportionate, first and worst impacts of climate change on their water and sanitation systems or access.

**Participatory:** Methods that empower diverse voices, open-ended dialogue, democratic inclusion and decision-making, and co-design and co-production of products and knowledge. The central principle is the idea that affected actors or stakeholders should be "at the table" when core decisions are being made.

**Participatory Action Research:** Draws on well-established, international repertoires of methods for conducting empowering research that mobilizes local knowledge while maintaining high standards of scholarly rigor. Widely used methods in PAR for documenting and visualizing participant's knowledge include timelines, social and power mapping, stakeholder assessments, photovoice, transect walks, pile sorting and ranking, etc.

**Qualitative methods:** Include semi-structured interviews, motivational interviewing, focus groups, and the practice of field notes.

**Safe:** Drinking water that meets or exceeds standards set forth by the federal Safe Drinking Water Act, and by any additional standards established by individual states where geographically applicable. Safe sanitation means that the waste is separated from humans, and transported, treated, and discharged to the environment where it is not a liability or hazard to human, wildlife, or environmental health.

**Sanitation:** The conveyance, storage, treatment, and disposal of human waste. This includes toilets, pipes that remove wastewater from the home, and treatment measures.

**Water equity:** Achieved when all have safe, clean, affordable drinking water and sanitation; are resilient to floods, drought, and other shocks and stresses; can play a role in water-related decision-making in their communities; and share in the economic, social, and environmental benefits of water systems.

**Water resilience:** The ability of water systems to function so that nature and people, especially the most vulnerable, thrive under shocks, stresses, and change.

**Wastewater:** Water that has been used and disposed of, which often contains contaminants, such as untreated human waste, sewage, or sludge.

**Wastewater services (or systems):** The provision of centralized sewer systems and treatment plants, individual septic systems, or other forms of decentralized or on-site). It can also be referred to as sewerage services, as sewer systems are often used in wastewater services to transport wastewater to treatment systems and/or disposal outlets.

# Executive Summary

Rural water and wastewater systems face clear and growing dangers from climate change impacts. Many factors converge to create inequitable risks, and decision-makers must grapple with complex realities when devising and implementing strategies to build resilience. This complexity requires evidence-based approaches to collaborative problem solving. To better understand climate change impacts on water and sanitation in rural frontline communities, the Livelihoods Knowledge Exchange Network (LiKEN), Pacific Institute (PI), and the Rural Community Assistance Partnership Incorporated (RCAP) partnered to form the Water and Climate Equity project. By integrating multiple lenses and forms of expertise across these organizations, the project was co-designed and co-produced to nurture community-centered climate resilience in an era of mounting water crises. The project focuses on rural frontline communities, which often lack sufficient financial, technical, and managerial resources to handle existing challenges, including water affordability, access, safety, inadequate or aging infrastructure, and disaster recovery. Climate models indicate that climate change will exacerbate these issues, necessitating community-specific solutions rooted in local knowledge, leadership, and networks of support. The aim of this project was to document and understand water and climate resilience in rural, frontline communities and investigate opportunities to scale evidence-based decision support information and tools in the future so that additional communities can move toward more equitable, climate-resilient water systems.

## Collaborative Co-Production of Knowledge

The Water and Climate Equity project developed an innovative and scalable model for integrating diverse types of knowledge to analyze multifaceted challenges. The project was designed to include local knowledge to get a grounded understanding of how risks and solutions play out in some rural communities. We held discussions and deep listening in communities and among national networks of technical assistance providers (TAPs) who are immersed in the unique and varied local challenges of water and wastewater management in the rural communities they serve. We worked closely with the TAPs to co-develop resources that help them serve those communities in shared efforts to build and maintain equitable, climate resilient water systems. With local leadership from historic coal-producing counties, we undertook extensive listening activities in Appalachian communities hard hit by job loss, capital flight, persistent poverty, injustices, and climate stressors and disasters. We also conducted a collaborative review of literatures on water and climate vulnerability and resilience, cross-sector knowledge translation, and climate change impacts on small, rural water and wastewater systems.

This report summarizes what we learned from listening to TAPs and underserved communities. We identified recurrent factors that intersect in vicious cycles to amplify inequities and risk in rural communities. The report looks at these patterns that generate community and cross-sector capacity for collaborative co-production of actionable knowledge to help build climate resilience and equity in rural water systems. We did this iteratively through vulnerability and resilience lenses (that identify risks and resilience to prioritize strategies) and with an asset-based approach (that centers existing capacities in communities to build on success and unique local realities). We contextualized this community-based, bottom-up analysis in scholarly and policy literatures, to create an integrative **Water and Climate Resilience Framework** designed to scale laterally for adaptation in other rural contexts and in trans-local comparison that can inform national scale policy innovation.

## Key Findings

1. **Development pathways and legacies of injustice disadvantage many rural water and sanitation systems and make them highly susceptible to the impacts of climate change.**
2. **Climate change is already having devastating impacts on rural water systems and communities through increased weather variability, extremes, unpredictability; extreme heat and cold; heavy precipitation and catastrophic flooding; drought; wildfire; and declining water quality. The scientific community expects these to continue and worsen.**
3. **An integrative community-centered and asset-based approach is necessary for better understanding and addressing climate vulnerability and resilience in rural water systems.**
4. **While significant barriers and challenges exist related to inequities, funding, and technical or managerial capacity, for example, existing community-based social, natural, and physical assets provide opportunities to build on inherent community resilience for achieving equitable, climate-resilient rural water.**
5. **Tailored and easily accessible technical assistance and tools can support rural communities in achieving equitable, climate-resilient water and sanitation systems.**

## From Listening to Action

Building on the insights summarized in this report, the project partners are moving into a new phase in which they will pilot tools and capacity-building for dislodging barriers to equity and resilience. These include educational toolkits, participatory exercises, and communicational materials for community engagement, water and climate resilience, disaster role and scenario-playing. In the next phase of this work (beyond this report), they will also explore policy solutions, strategic actions, and approaches to end the recurrent causal patterns identified in this report that drive inequity and weaken resilience. The project will monitor, evaluate, and learn from the future pilot activities to develop an evidence-based theory of change that is structured to show areas and issues that new policy must address to create durable solutions.

# 1. Introduction

## 1.1 Overview

Climate change is worsening already widespread problems of rural water affordability, access, safety, aging infrastructure, and disaster preparedness and recovery (Pacific Institute and DigDeep 2024). Small systems are common in rural areas, and they often lack sufficient financial, technological, and management resources to handle existing problems, let alone the capacity to prepare for the growing threats from climate-accelerated disasters. Low income, Indigenous, and communities of color are burdened by water inequities that compound and deepen the disproportionate risks they already carry from generational social and environmental injustices. From March 2022 through May 2024, the Pacific Institute (PI), Rural Community Assistance Partnership Incorporated (RCAP), and the Livelihoods Knowledge Exchange Network (LiKEN) have been in dialogue with diverse groups at the frontlines of climate change impacts on rural water and wastewater systems — including technical assistance providers (TAPs), rural community residents, rural water system managers, local and state officials, nonprofits, activists, scholars, and businesses.

It is a privilege to listen to the insights of people at the frontlines of these challenges. Looking from their diverse and ground-level perspectives, we are afforded a close view of causal cycles that reproduce problems and inequities. At the same time, it allows us to identify the deep-rooted sources of community resilience along with possible opportunities and leverage points for change. This report integrates our many layered and diverse investigations, engagement, and learnings from the first two plus years of this multi-year project, titled Water and Climate Equity. It documents entrenched patterns of inadequate funding, planning, maintenance, and management that interact to create ever greater vulnerability to climate-accelerated disasters.

It is, in many ways, a grim picture. However, seen from another angle, focusing on resilience, this report is the first step in our assessment of possible pathways towards equity and climate resilience in water and sanitation systems in rural America. By taking this step, we hope to provide a fresh look into old problems and highlight potential opportunities that could create and sustain more resilient systems. Amidst water challenges, and social and environmental inequities, we have found remarkable openings from which to grow durable solutions rooted in local creativity, knowledge, and leadership supported by sustainable outside webs of support from technical experts, civil society, and government sectors. Working with rural communities, as we move to the next stage of this project, we are developing ways to find points of leverage that bring stakeholders, resources, and TAPs together to create more equitable outcomes. Hence, this project also explores patterns that strengthen community and cross-sector capacity for collaborative co-production of actionable knowledge to help build climate resilience and equity in rural water systems.

We sought to explore the following questions:

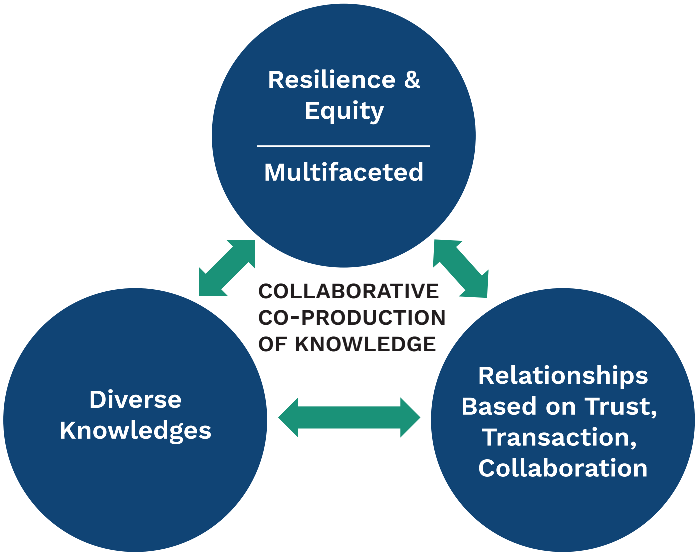
1. How is climate change, in combination with other social factors, already impacting small, rural water systems, and how will future climatic changes exacerbate water stress, insecurity, and existing risks for these communities?
2. What potential barriers and opportunities exist for preparing equitable, climate-resilient water systems in those communities?

## 1.2 Project Rationale, Design, and Partners

As we discuss in detail in section 2, A Framework for Equity and Resilience, there is a growing consensus that climate change is so complex that we need to bring different knowledges together to integrate diverse realities that are not visible from one point of view. There are increasing calls for innovative models for collaborative co-production of knowledge to gather and integrate various kinds of local and technical knowledges for solutions and policy innovations. The outcomes emerge from complex interactions among multiple causal factors (physical, ecological, economic, cultural, and political), and the impacts are unevenly and inequitably distributed (E. Marino et al. 2023). So, one must be able to look iteratively through a multiplicity of lenses that are variously suited to different aspects of a multifaceted reality. Analytic frameworks must also enable nimble movement across scales, because climate change-related outcomes emerge from complex interactions that move between global, national, regional, and local scales. Analytic frameworks must be integrative and be able to skillfully weave together diverse perspectives in real world contexts.

The Water and Climate Equity project responds to the call for robust models for collaborative co-production of knowledge. Developing our approach required the following components: scope diverse knowledges and identify which are needed; build relationships based on trust and collaboration adequate to doing the often-difficult work of translation across differences; co-produce actionable knowledge in decision support products that nurture and deepen resilience and equity (See Figure 1).

**FIGURE 1.** Co-Production of Knowledge




*Source: Original Graphic Design by Phill Barnett*

This project also responded to the need for cross-sector and cross-scalar analysis by building a national team with regional and local partners that coordinated knowledge exchange and product co-production in a highly collaborative and iterative way. This national team was composed of representatives from PI, LiKEN, and RCAP, and as detailed ahead in section 2, the project's structure was co-designed within the core team in a democratic collaboration with these key partners. All partners in the core team share a strong commitment to collaboration and the creation and sharing of knowledge and tools to have positive impacts for rural communities. Our core team functions as a hub to share and integrate learnings among local, regional, and national scales, and across community, expert, and governmental sectors. The strength of our *products* comes from the care with which we co-designed our *process*. Throughout our work, we have taken time to translate between different ways of thinking, knowing, and observing that arise from our various forms of training, disciplines, experiences, languages, and organizational roles and responsibilities. We devoted much time to listening, especially at the beginning, to each other and to our partners. The trust we built through the project allowed each organization to stretch our capabilities and feel supported by the others as we discussed, reviewed, questioned, and revised our work. We enhanced our understanding of each other's point of view throughout this collaboration.

> The strength of our products comes from the care with which we co-designed our process.

Each organization brings distinctive fields of expertise and organizational strengths to this collaboration. RCAP brings a wealth of technical knowledge about rural water and wastewater systems and a nationally interconnected network of technical specialists immersed in local problem solving. LiKEN brings expertise in cross-sector engagement, Participatory Action Research, and community-led change in extraction-impacted regions. The Pacific Institute team members bring climate change and water expertise, deep experience in participatory, community-based co-production of evidence-based research, products, and decision-support tools, along with cross-sector networks working on climate and water resilience, locally, regionally, nationally and internationally.

Project partners undertook extensive listening activities with rural communities in Central Appalachia and with TAPs who serve frontline rural communities throughout the U.S. Our goal was to understand community perspectives on factors shaping their water and sewage systems and to understand the challenges faced by small rural water systems. Project partners also reviewed literature on resilience and vulnerability, cross-sector knowledge translation, and climate change impacts on small water and wastewater systems. The project explores patterns that generate community and cross-sector capacity for collaborative co-production of actionable knowledge to help build climate resilience and equity in rural water systems. Throughout this project, we have moved iteratively between national, regional, and local scales of data gathering and analysis in repeated cycles of ground truthing and multi-scalar contextualization.

## 1.3 Overview of Sections

**Section 2** summarizes the **Water and Climate Resilience Framework** that has emerged from our literature review and listening activities over the past two years. This section also details the approach that we used and the products we created.

**Section 3** looks at **pathways of human development** and how they affect the functioning of small rural water systems. It explores the synergism in frontline communities between inequitable climate impacts, water risks and burdens, and environmental and social injustices. First, focusing on the Southwest and Central Appalachia regions, it analyzes how these risks interconnect and concentrate in places that are rich in natural and cultural assets, but which have suffered marginalization and injustice caused by broader, national, and external factors that impose inequitable risk burdens on these communities. Second, we explore the current state of small systems and their challenges in construction, management, and maintenance, drawing particularly from the process of listening to a network of frontline TAPs.

**Section 4** looks at the interaction between **climate change, extreme weather, and the cumulative impacts and vulnerabilities** of small rural water and wastewater systems. It also examines the impacts of drought and wildfire on community water systems in the Southwest U.S. followed by a section on catastrophic flooding in Central Appalachia and its impact on community water systems.

**Section 5** reflects on our **key findings and lessons learned** as we co-develop ways to nurture community and cross-sector capacity for collaborative co-production of actionable knowledge.

**Section 6** summarizes insights from our engagements and observations in moving toward innovative strategies and solutions that can build resilience and equity in water and wastewater systems.

©USDA Coast Guard overflight of South Carolina flooding

# 2. A Framework for Equity and Resilience

## 2.1 Water and Climate Resilience Framework

This project presented several daunting analytical challenges. Overburdened and underresourced frontline rural communities face water and climate stresses, insecurities, and risks that arise from multiple, cross-cutting causal factors. Social and environmental inequities amplify each other in vicious cycles. How can we distill causal patterns from realities where so many causal factors intersect, and in such synergistic ways? When and how does resilience emerge in virtuous cycles that empower communities to grapple with these many faceted inequities?

To identify important causal patterns and integrate complex data, we needed an overarching conceptual framework. We designed our work to date to distill a framework that could orient resilience-building work at local levels and relate local needs and achievements to trans-local resources. We needed an approach that was:

- able to abstract causal patterns sufficiently to compare diverse local case studies within common, trans-local, analytic frameworks, but
- was also sensitive to unique local histories and contexts and highly multicausal patterns that are difficult to disentangle.

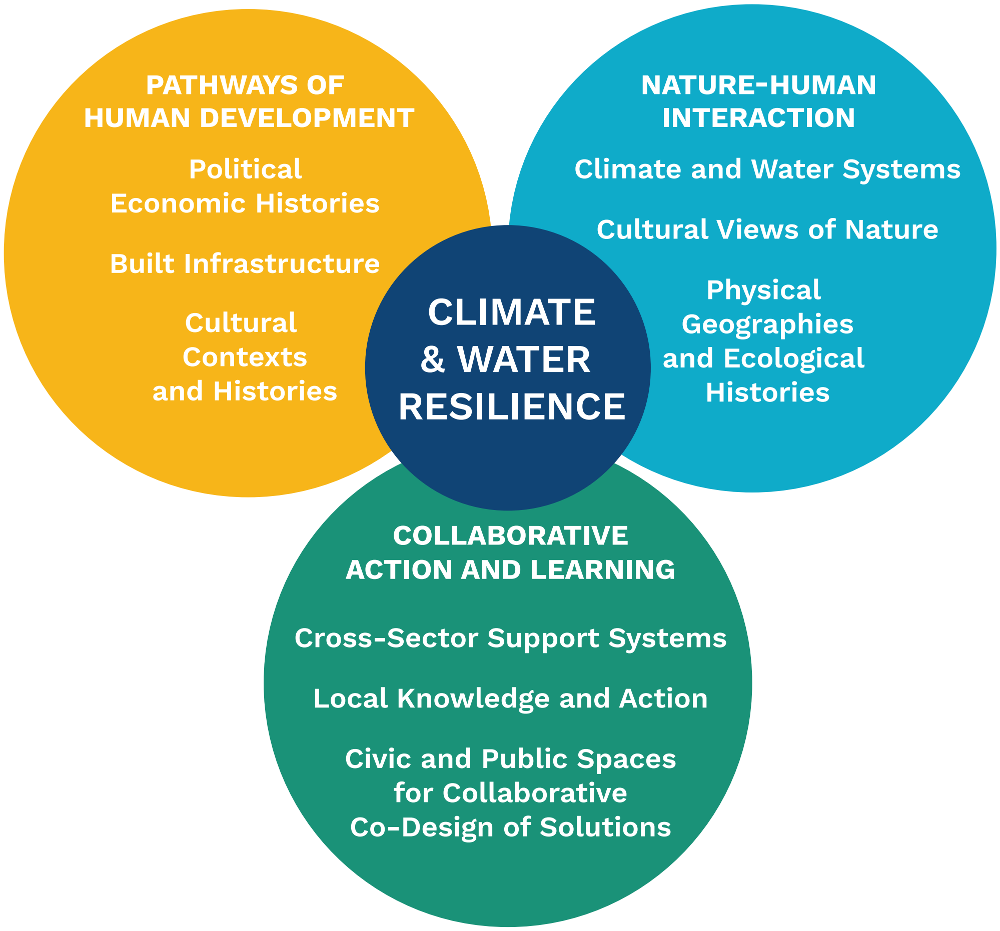
We sought to identify key causal factors that affect the functioning of water and wastewater systems. As we analyzed these factors and how they interact systemically, we reflected on ways in which certain factors cluster together and need to be understood as systems with their own internal logic requiring specialized expertise appropriate to that type of system. For instance, a powerful way to understand climate change is to understand global climate as a complex socio-ecological system with feedback loops that disrupt climate patterns. Climate change is often thought of in terms of the physical sciences, while approaches to water and sanitation problems are often seen as primarily engineering challenges. Both the physical climate and engineering systems perspectives are vital, but they are not enough. When we look at the role of humans in climate and water systems, we find that cultural perspectives fundamentally underpin and shape interactions between humans and nature. Also, cultural frameworks have their own logics that need to be understood on their own terms. So, cultural patterns are, in some ways, independent of natural causal patterns, but the two in many ways are interconnected and shape each other (McNeeley and Lazrus 2014).

In order to weave the human factors into the analysis of physical climate and engineering systems, we used the methods of qualitative social science, we iteratively analyzed the causal factors we found in our initial listening phase of work, and we explored various ways to cluster causal factors to enable us to see recurrent larger patterns. After experimenting with various approaches, we found a framework that is a powerful tool for finding barriers and challenges and identifying points of leverage for system change. This framework (Figure 2) understands resilience to emerge at the intersection of three causal and interconnected subsystems:

- **Unique pathways of development**: Long histories of political, economic, and cultural development lock places and regions into distinctive configurations in the flow of resources and power and set up trajectories in the development of built infrastructure that often have considerable inertia and might require structural change to reorient toward resilience.
- **Interactions of human and natural systems**: A water and wastewater system is dynamically and culturally shaped through interactions between the social context with a place's distinctive climates, physical geographies, ecologies, and natural histories as well as wider phenomena like climate change. Cultural worldviews also shape how people interact with the non-human environment.
- **Collaborative action and learning**: The community capacity to take collective and equitable action emerges in complex ways from prior development pathways and ecological pressures, and the presence (or absence) of available cross-sector support systems. Marginalized communities often bring important local knowledge, civic and cultural resources, and informal systems of mutual aid that are not visible to policy and decision makers. The capacity of communities to take collective action is shaped, and often constrained, by the broad range of assets made available to them by macrostructural forces and past development pathways. However, empowering civic and public spaces for collaborative co-design of solutions can open new solutions for old challenges.

After experimenting with various approaches, we found a framework that is a powerful tool for finding barriers and challenges and identifying points of leverage for system change.

**FIGURE 2.** **Water and Climate Resilience Framework**




*Source: Original Graphic Design by Phill Barnett*

This framework has served us as a heuristic device for periodically reviewing whether we were giving adequate weight to all dimensions. However, this is an analytic technique for holistically understanding causal patterns that are highly entangled. For instance, a key goal is to understand the collaborative action and learning aspects (bottom circle) in this framework. How can frontline communities (in collaboration with technical, civic, and governmental support systems) take evidence-based action to build equity and resilience? But the capacity to take collaborative action and learning arises out of the particular human and natural conditions experienced by that community and shaped by the unique ecological interactions that humans and infrastructure have with nature in particular places and regions (right circle). Communities build from the assets they have, which have been accumulated from long historical pathways of (economic, cultural, political and social) developments (left circle). In short, the capacity of communities to respond, adapt, and act collectively to mitigate climate change is shaped, but not determined by, only development pathways or only human-natural systems. As such, the bottom circle in our framework is continually emerging from the other two circles.

There are many paradoxes here. Underserved communities are at the frontlines of development pathways where injustices often accumulate and where climate disasters hit the hardest. This means they must act on a particular terrain with distinctive challenges. These patterns can be understood as determinants of, and limitations on, adaptive capacity. But, as we will argue, they can also be understood as the enabling context that provides assets for action and learning. There is no one-size-fits-all model for success, rather it comes from action and learning that build on existing community assets. The enabling determinants of adaptive capacity to respond to or prepare for climate change include multiple types of assets such as human, natural, physical, social and political, financial, institutional capitals (Eakin and Lemos 2006; Smit and Pilifosova 2001; Yohe and Tol 2001; Pelling and High 2005). In this report, we draw on the variegated movement for resilience-centered asset-based community development (García 2020; Haines 2014), with particular attention to pathways of development and power dynamics (MacLeod and Emejulu 2014; Maclure 2023). And, we draw from the “community capitals” approach, which pays attention to the aforementioned wide range of types of assets needed by a community to take collective action and solve problems (Emery and Flora 2020; Kais, Shaikh Mohammad and Islam, MD Saidul 2016; Pigg et al. 2020).

## 2.2 Shared Values for a Collaborative Approach

At the core of our approach and methods of social learning was a process of developing long-term, horizontal relationships among our organizations, and the communities they serve. To guide this, we developed a **statement of shared values.** This was the product of reflection on the shared values and missions of each organization. These include:

- **Connecting local knowledge, ways of knowing, and observing with specialized and technical knowledge**: We value local knowledge and believe that people are experts on their own contexts. By connecting place-based local knowledge with specialized and technical knowledge, we seek to facilitate the development of new epistemologies of knowledge that are vital for developing new skills for community members and community leaders that are appropriate for current and future challenges.
- **Prioritizing community needs and concerns**: We share the belief that research is most effective when guided by communities. We commit to working together to integrate all the aims of this project in ways that prioritize community needs and concerns, honors the past of these communities in connection with their own visions of the future, and respects the time communities devote to collaboration.
- **Serving the public good and facilitating action for social justice**: We seek to improve the lives and capacities of those involved in this project. Thus, we agree that no harm should come to the engaged communities, nor should any partner benefit unless the community benefits. Hence, we agree not to accept influence from any source that could trigger or constitute a conflict of interest. We recognize the historical and present forces of oppression, which are at work in the communities we collaborate with, and commit ourselves to principles of inclusiveness, equity and democratic organizing as outlined in the Jemez Principles for Democratic Organizing (December 1996, New Mexico). In addition, we share the belief that research can support social justice and we commit to working collaboratively to mobilize input from communities and other stakeholders directly affected by issues studied and to co-determine appropriate action-oriented outcomes, which are resilience-focused, asset-based, and ensure equitable visibility of engaged communities and ethical accountability of project partners.

- **Sharing accountability**: We believe that consensus decision-making and transparency about our abilities and aims are vital for ensuring a process that is open, honest, and pluralistic. Engaged communities and project partners bring unique knowledge, skills, experiences, and perspectives to the project, and each stand to benefit in unique ways. We commit to realize these possibilities by refining the roles of each partner, reflecting on our practices of knowledge co-production, assessing the adequacy of planning and designing research tools and research products for disseminating information and findings, and seeking feedback and constructive criticism on these by other members of the collaboration. Through sharing accountability on our practices, methods and products of knowledge co-production, we aim to ensure alignment with our shared values and the plurality of the research outcomes and tools we produce. At the same time, we recognize the organic nature of the process and are prepared to be flexible and adaptive, accommodating to changes beyond our control and according to what communities perceive as useful or beneficial.

## 2.3 Rationale for our Methodologies

### 2.3.1 RESILIENCE AND ASSET-BASED APPROACHES

A resilience-centered model enables us to foreground community assets and the potential for empowering and locally adapted solutions. It focuses our analysis on community strengths and the factors that enable communities to build their capacity to solve problems and build trustworthy cross-sector collaborations. Too often, the focus of policy makers and experts is on the needs and deficits of frontline communities. Our model centers on the strength and resilience of communities.

This work was designed to be **ethically accountable** to the perspectives of frontline communities that have disproportionately experienced water and sanitation inequities. Therefore, we foreground participatory community-based and community-driven methods and analytic frameworks that enable us to incorporate community voices and to look from the points of view of frontline communities. For long term structural transformation to undo entrenched inequalities it is important to start with existing community assets and to identify ways to grow them (PolicyLink 2012) while also addressing the constraints, vulnerabilities, and challenges laid down by past patterns of marginalization (Bruursema 2015). This approach can counteract the cultural stereotyping and stigmatization that are part of most forms of social and environmental injustice. It opens space to create **equitable visibility** for communities whose needs, stories, strengths, and traumas have been too long marginalized and factored out of policy. Frontline communities bear inordinate risks that are generated by much wider past and present societal patterns. However, if we primarily describe communities in terms of their problems or vulnerabilities, then the community itself tends to be seen as inherently problematic while potentially eschewing inherent strengths and resilience. Not only does this tend to put community assets and latent capacities into the background, it also can tend to suppress the role of the wider society in creating the problems in the first place while at the same time placing blame on the communities themselves. This happens when vulnerability becomes identified with the “essence” of what a community is. This kind of essentializing of the group identity of a community has multiple ramifying effects. If communities are primarily identified by what they lack, they can be stereotyped primarily by their need. In addition, many of those communities who are considered by outsiders to be highly "vulnerable" are also the strongest because they have had to be.[1] To survive repetitive hardships, communities often self-organize local systems of mutual support and social cohesion based on local bonds of kin and community. These can provide enduring cultural and civic resources for empowerment and collective action. Environmental and social injustices have their origin in complex, society-wide patterns, but they have their greatest impact on frontline communities. If frontline communities are merely defined by their suffering and injury, then realities that they did not create can appear to be their defining characteristic.

### 2.3.2 CO-PRODUCTION OF KNOWLEDGE AS VITAL TO CLIMATE RESILIENCE AND EQUITY

Co-production of knowledge is the "process of producing usable or actionable science through collaboration between scientists and those who use science" (Meadow et al. 2015). This interdisciplinary and iterative process involves building trust, relationships, and communication channels between scientists, stakeholders, and local residents (Gabrielle Roesch-McNally and Holly R. Prendeville 2017; Meadow et al. 2015). An outcome of this process is that "new knowledge and new ways of integrating this knowledge into decision-making and action" can be produced (Galende-Sánchez and Sorman 2021). As co-production involves bringing together multiple perspectives at relevant and local scales, it can be used to identify equitable, climate resilient strategies that are actionable and serve the needs of diverse communities (Gabrielle Roesch-McNally and Holly R. Prendeville 2017).

Progress in climate sciences has been dramatic over the last several decades. However, many note that there are persistent and dangerous gaps in our collective capacity to put this body of knowledge to use (Dilling and Lemos 2011; Ford, Knight, and Pearce 2013; Lemos, Kirchhoff, and Ramprasad 2012; Miles et al. 2006; Tang and Dessai 2012). In large part, these gaps arise from political and cultural divisions, including an enduring legacy of climate change denialism that hinders collective action (McCright and Dunlap 2011; Lewandowsky et al. 2015; Hornsey and Lewandowsky 2022). But, beyond the political and cultural arenas, many argue that climate change is a type of problem for which our knowledge systems are not yet adequate. If so, climate resilience and equity require a knowledge transition as well as an energy transition — one that is more holistic, collaborative, inclusive, and co-produced in contrast to the siloed and disconnected disciplines of the more historically conventional Western academic sciences.

> Complex social-hydrological-climatological systems can better be understood if looked at from multiple points of view.

Complex social-hydrological-climatological systems can better be understood if looked at from multiple points of view. With this work we aimed to integrate interdisciplinary scholarly perspectives and to overcome the siloing of academic and government agency datasets and findings. But it is also vital to develop methods to integrate local knowledges throughout the knowledge-to-action cycle (Hufford, Mary and Taylor, Betsy 2013). As discussed above, there are strong ethical reasons to include local knowledge in research design because it can be a way to

1 As such, the term "vulnerable communities," though still widely used in official capacities, is a highly problematic label and one that we avoid. While we might talk about "vulnerabilities" that is not the same thing as labeling a community as vulnerable.

counteract the forces that historically have marginalized certain communities and locked them into structural inequities (Jasanoff 2004). But local knowledges are also important for epistemological reasons. First, local knowledges are often deeply grounded in place-based experiences and practices in ways that academic sciences typically are not (Hufford and Taylor, 2013). Deep, generational local knowledges and observations provide grounded and tested understandings about the interconnections of nature-human systems as well as environmental and climatic changes over decadal scales (McNeeley and Shulski 2011; McNeeley 2009). Local knowledges and observations can also both guide how science and data are analyzed as well as ground truth and test the findings (McNeeley 2009). Second, context and unique local histories matter and are sometimes determinative of outcomes that hinder or encourage resilience. Complex systems are an interesting combination of circular causalities and the linear causality that is known as "path dependence" (Bennett and Elman 2006; Brenner and Jeddeloh 2024). Once a certain cluster of causal factors converge, they can "lock in" a place, region, or community into a particular pathway that tends to discourage alternative pathways (Bernhardt et al. 2012; Eitan and Hekkert 2023; Goldstein et al. 2023). These place-specific patterns often require **local knowledge** and **grounded inquiry** to identify.

In building relationships across diverse perspectives, it is also vital to understand the cultural worldviews that shape how people understand socio-natural and climate processes and how they understand the relationship between society and nature (McNeeley and Lazrus 2014). Many of the barriers to climate adaptation and mitigation are cultural (Nielsen and Reenberg 2010). People come to common challenges with different understandings of how nature and climate "work," so they lack a common framework for identifying shared interests, goals, and solutions; and they can often fall into conflict (McNeeley and Lazrus 2014; Marco Verweij 2022; M Verweij et al. 2006). But innovative institutions and social spaces can open common civic ground on which to build solutions (McNeeley and Lazrus 2014).

As discussed, there is a mismatch between our climate knowledge and our societal capacity to act on the knowledge. Diverse models are emerging that attempt to integrate knowledges and move them into action, but these efforts are still fragmented and not sufficiently shared across disciplinary siloes (Phuong, Biesbroek, and Wals 2017). To overcome this fragmentation, many argue that it is essential to develop better models for the collaborative co-production of knowledge that bring together, translate across, and integrate multiple knowledges (local, traditional, interdisciplinary, cross-sector) in durable communities of practice based on trust and cross-scalar communication (Kalafatis et al. 2015; Ostrom 2007) committed to the production of actionable knowledge (Dilling and Lemos 2011). Collaborative knowledge production must pay attention to communication among collaborators that enables integration and translation between their disparate experiences, responsibilities, and ways of knowing and feeling. Therefore, new methods and epistemologies of "social learning" are needed that pay attention to the relationships within which knowledge is produced (Pelling and High 2005; Bos, Brown, and Farrelly 2013; Christmann et al. 2015; Keen, Bruck, and Dyball 2005; Owen, Ferguson, and McMahan 2019; Wals and Rodela 2014; Pahl-Wostl et al. 2007) In this approach, the focus shifts from the *products* of knowledge to the *process* of knowledge (Daniels et al. 2020). Knowledge is grounded not in top-down plans, but in the relationships within which social learning takes place.

In climate systems causal impacts traverse scales in complex ways, so models for collaborative knowledge production about climate and water systems need to be open to multilevel and adaptive governance patterns (Gonzales-Iwanciw, Dewulf, and Karlsson-Vinkhuyzen 2020; Pahl-Wostl 2009). To nurture this kind of knowledge production it is also important to build in the mutual accountability generated by innovative structures for monitoring and evaluation (Kalafatis et al. 2015; Ruiz-Mallén et al. 2022; Krishnan, Aydin, and Comes 2021; Williams et al. 2020; Wong-Parodi, Fischhoff, and Strauss 2014). Socio-ecological systems are so complex that it is impossible to exactly predict future causal scenarios. Collaborative production of actional knowledge requires flexibility to be able to respond to uncertainty and surprising outcomes (Ison and Straw 2020). Complex social-ecological systems are driven by interdependent causalities with interconnected, synergistic, and circular causalities (Berkes, Folke, and Colding 1998; Berkes, Golding, and Folke 2003; Gunderson and Holling 2002). In complex and changing conditions, Lee argues we need a "gyroscope" not a "compass" if we are to truly understand the myriad interconnected and overlapping variables and dynamics of social-ecological systems (Lee 1993). Instead of linear progress within stable coordinates towards clearly mapped goals, our knowledge frameworks must arise from adaptive processes and practices in which our picture of the world is continually modified in iterative cycles of experimentation, reflection, adaptation, and reenvisioned action (Karkainen 2003; Kochskamper, Koontz, and Newig 2021; Norton 2005; Thomann et al. 2020).

### 2.3.3 THE VALUE AND LIMITATIONS OF A "VULNERABILITY MODEL" IN CLIMATE AND DISASTER RESEARCH

Some approaches in climate change and disaster studies foreground the vulnerability of communities. This can be valuable if it is oriented to improving disaster preparedness and response, for example. In emergencies, it is important to know who is most at risk and where. However, critics of the concept of vulnerability have pointed out the violence of "otherizing" that can become implicit in the construction of populations, places, or regions as "vulnerable." When a region, a place, or group is identified as vulnerable, people can appear as if lacking agency, while biased stereotypes of communities as corrupt, poor, weak, or passive are perpetuated implying that what is needed is a "cure" provided by external expertise based on the scientific perspective (Marino and Faas 2020; Faas 2016).

The concept of climate change vulnerability has been helpful in many ways, though. In recent decades, it has functioned as a boundary concept that translates between sectors and disciplines, bridging diverse disciplinary approaches, and guiding different engagements with disaster (E. K. Marino and Faas 2020). Its usefulness lies in the critical attention it brought to the fact that climate change impacts, including climate disasters, are not just natural or random phenomena. Instead, while often triggered by natural phenomena, such as extreme weather events, the resultant impacts are socially, politically, and economically constructed (Floriani and De Moura 2021). The social conditions that result in catastrophe typically began long before a catastrophic event with effects that continue long after they subside (O'Keefe, Westgate, and Wisner 1976; Blaikie et al. 1994; Raju, Boyd, and Otto 2022). The concept of vulnerability helped to shift attention to the underpinning factors and processes that make natural events into disasters and create conditions of unequal distribution of risks and hazards (Faas 2016).

For decades, disaster and risk-reduction management and planning conceptualized disasters as “natural” (O’Keefe, Westgate, and Wisner 1976). When disasters were equated with natural hazards, the dominant perspective tended to be technocratic, emerging from applied scientific knowledge oriented towards prediction, warning, and preparedness (Hewitt 2019; Hilhorst 2003). As such, the only actors perceived as fit to dispense knowledge and organize preparedness were the “experts” (historically these were white males in positions of relative power and influence in government or academic institutions) (Hilhorst 2003). This pattern is sometimes referred to as the “savior complex,” and this expertise is often implicitly coded as white and male (Khan, Dickson, and Sondarjee 2023). At the same time, the “nonexperts” who lived in disaster-prone places were characterized as the problem, ignorant of the risks, and thus in need of education and help by the so-called experts (Hilhorst 2003). The mission was to expand perceptions of risk based on the predominant Western scientific, technocratic, and hierarchical worldview and prepare them for compliance to disaster management plans put forward by outside planners and regulators (Wisner 2016). What replaced the natural-hazard paradigm, and the focus on (assumed to be faulty) risk perception and expert-led solutions, has been an increasing consideration of self-awareness and capability to reflect and assess their own local situation and capacities as valuable contributions to social protection and risk reduction (Wisner 2016).

Despite the critical and innovative advances in climate and disaster studies, the concept of vulnerability tends to perpetuate some of the core and problematic tenets of the paradigm that it came to replace (Gaillard 2019). The tendency to view disaster as simply exposure to natural hazards that require technocratic solutions has proven difficult to shake in mainstream decision- and policy making, even within international agencies such as the United Nations or the World Bank (E. K. Marino and Faas 2020; Bankoff 2001).

## 2.4 Our Analytical Approach and Methods

We co-designed our approach and methods to achieve a balance between vulnerability and resilience approaches toward our overarching goals of translation and integration of different kinds of knowledges and experiences. We reviewed and distilled interdisciplinary literature on climate impacts, vulnerability and adaptation, water insecurity, and equity. We focused on rural water climate vulnerability broadly but also focused on two regional profiles — one for the arid Southwest region and one for Central Appalachia. We conducted an initial Rapid Climate Change Vulnerability Assessment by utilizing scientific literature at the national and regional levels. We also explored other data resources and tools to create the two regional profiles of current and projected climate change impacts on rural water systems. This resulted in a blog and two issue briefs released by PI in partnership with RCAP and LiKEN. One focused on climate change and flooding in Central Appalachia, the other focused on climate impacts to rural water systems in the U.S. Southwest. We collated, synthesized, and translated useful existing resources and tailored them, as needed, for the project and our stakeholder or community needs.

> Our community-focused work focused on those affected by environmental injustice and boom and bust economies.

Our community-focused work focused on those affected by environmental injustice and boom and bust economies — primarily in the Southwest and Central Appalachia. LiKEN developed a Framework for Collaborative Actionable Research, the main features of which are asset-based and appreciative inquiry; empowerment, community science, Participatory Action Research (PAR); democratic knowledge sharing networks and collaboration across the sectors of community, scholars, and government; historical, contextual, and iterative analysis of root causes and socio-ecological system change; multi-scalar analysis that is centered on local communities and ethically accountable to them.

LiKEN led listening projects in two counties in eastern Kentucky, Harlan and Martin, with histories of coal mining and persistent poverty, and with water systems that have suffered from entrenched patterns of mismanagement, corruption, and disinvestment. Using PAR methods and methods of cross-sectoral collaborative knowledge production, they examined local water and sewage systems from the perspectives of diverse community stakeholders while opening spaces for the viewpoints of community residents. They devised a collaborative coding and analysis "dance" — that is, a sequence of steps to ensure the weaving of diverse reflections and viewpoints on the data produced by the listening projects into a common analytical framework, which is collaboratively constructed between citizen scientists, LiKEN staff, social scientists and civil society organizations. LiKEN's network of civil society organizations grounded in the Central Appalachian region and staff living in the region provided valuable counterpoints and ground truthing to scholarly and technical points of view, helping to shape a more community-driven response to toolkits, guides, and other materials.

In these listening projects in historic coal mining communities in eastern Kentucky, the following questions were explored in collaboration with their community partners:

1. What causes problems and what leads to success in the provision of safe, affordable, and reliable water and sewage services?
2. How does extreme weather impact communities and systems?
3. Who is particularly at risk and how?
4. What are barriers and where are openings to equity and resilience?

In both Harlan and Martin Counties the work was led by resident Community Engagement Coordinators (CECs) who managed the listening process (Figures 3 and 4). The work was guided by a county advisory group who represented diverse types of stakeholders. In gathering data, the CECs worked along with residents who were hired as part-time community journalists.[2] CECs and Community journalists were trained in PAR and qualitative methods, as developed in LiKEN's Framework for Cross-Sectoral Knowledge Sharing. The qualitative and PAR methods used during the listening sessions were decided in collaboration with local partners according to the research objectives, the different civic landscapes, and the specific challenges each county is facing. In choosing methods, we found that it was very important to attend to steep local inequalities that made it challenging for people to speak publicly about water issues, such as lack of trust in officials and a public culture of silence and fear, entrenched patterns of violence and intimidation, and a sense of despair and powerlessness to actualize change.

2 The term "community journalists" was chosen over "community researchers" as a more palatable term for these communities.

Given the historical marginalization of these communities, we utilized a set of proven PAR methods, such as timelines, power mapping and pile shorts, photovoice, and timelines, which are valued for their empowering, multi-sensory, embodied, and game-like qualities. The aim was to build a positive atmosphere that generates a sense of enjoyment, dignity, capacity-building, and co-ownership of the process of knowledge making, while overcoming the sense of abstraction and distancing that expert-driven methods can create. This also opened the possibility to undo the entrenched distrust that is often engendered by inequality and marginalization. PAR methods are also valued for their ability to create a common conceptual framework for data gathering from diverse locales, hence creating generalizable knowledge, while at the same time being open to diverse cultures and ways of knowing. Most importantly, PAR methods can elicit local knowledge that is often not accessible to outside technical experts or that is outside the scope of the methods specific to their disciplines or agency mandates.

Parallel to the listening projects in Harlan and Martin Counties, we also conducted a regional listening project that focused on longtime organizers from the major nonprofits in Appalachian Ohio, West Virginia, and Kentucky whose work focuses on water issues. In addition, the East Kentucky Water Network (EKWN) served as a community citizens' advisory group. EKWN is a network of organizations and stakeholders working toward clean, reliable, and affordable drinking water and improved watershed quality in eastern Kentucky.

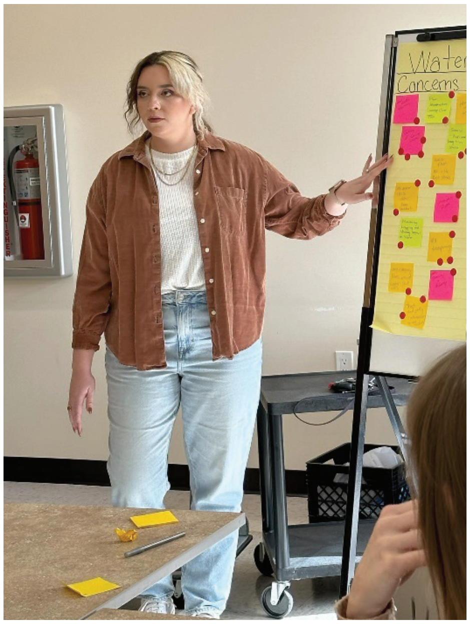
RCAP developed diverse methods for sharing knowledge at the national level with their TAPs who are working at the state and local level in a great diversity of rural settings with diverse challenges. The national team has responsibility to transfer emerging best science and knowledge about policy and regulations to the TAPs throughout the United States, utilizing a network of regional partner nonprofit organizations.

**FIGURE 3. Participatory Action Research in Martin County, Kentucky**

Note: LiKEN Community Engagement Coordinator, Madison Mooney, leads a Participatory Action Research session at a community meeting in Martin County, Kentucky.

*Source: Photo by McKensi Gilliam*

**FIGURE 4. Participatory Action Research in Harlan County, Kentucky**




Note: LiKEN Community Engagement Coordinator, McKensi Gilliam, leads a Participatory Action Research session at a community meeting in Harlan County, Kentucky.

*Source: Photo By Madison Mooney*

RCAP brings a unique ability to apply technical expertise in real life, highly variegated, and locally determined contexts. It is a network for support and ongoing training of experts who provide technical support to managers of small, rural, and Indigenous water and wastewater systems. The local work of RCAP technical experts is coordinated by state partners — supported by regional organizations — and a national team who coordinates national meetings, trainings, and policy and advocacy work. RCAP, therefore, has developed a distinctive organizational capacity to be at the frontlines of difficult, practical, and pressing labors to design and maintain small systems that provide safe, reliable, and affordable drinking water and wastewater services on which the health and economic prosperity of rural America depends. Their relationships are grounded in spending time in rural communities. Their resources often provide a vital linkage between planning and execution of necessary solutions. Their networks of practice connecting across local, state, regional, and national scales allowed for rich connections that catalyzed our relationship building.

RCAP provided well-researched information on how water and wastewater systems work, knowledge of funding streams for water and wastewater systems, and experience in forming partnerships with community leaders and utilities. RCAP created a typology of water providers and the diverse ways they may experience climate change inequity. This work was used to inform ideas for how to serve communities in LiKEN's region in the aftermath of catastrophic flooding. Additionally, RCAP led engagements with TAPs through multiple avenues, including the Disaster and Climate Resilience Working Group, holding office hours, and break-out groups during conference gatherings. These engagements were used to bring TAPs from across the country together to learn from each other's challenges and successes in assisting communities in planning and preparing for disasters and emergencies, building more resilient water systems, funding efforts to increase resiliency or recover from climate impacts, and to brainstorm new ways that TAPs can assist communities with disaster and climate resilience work. Discussions in these engagements provided an opportunity to understand climate- and equity-related challenges in the field and provided an opportunity to align products created for this project with on-the-ground needs.

Additionally, RCAP drew upon the literature and their own expertise to develop ideas on how to incorporate resilience more frequently and more intentionally into technical assistance. This work provided examples of resilience from existing literature, a list of potential funders, and a discussion of potential metrics for community resilience. The work emphasized physical and social measures of resilience and the importance of developing a baseline understanding of where local water systems stand in order to track progress towards resilience over time (Appendix B).

They provided assistance to rural communities, which includes community and economic development as well as technical advice to improve financial systems, infrastructure, and disaster preparedness plans for water and wastewater systems. For instance, this work catalyzed the RCAP Disaster and Climate Resilience Working Group that convenes on a bimonthly basis for knowledge sharing around disaster preparation and climate resilience planning. The group represents all six RCAP regions and provides a space for TAPs to discuss climate related risks, challenges, and mitigation options. The group also helps RCAP team members of this project to understand ongoing challenges in TAP work and get feedback on team deliverables.

# 3. Climate Change and Development Pathways in Rural Water Systems

Here we define "development pathways" as configurations of political, economic, and cultural development that lock places and regions into distinctive configurations in the flow of resources and power and set up trajectories in the historical development of built infrastructure, which can have considerable inertia but are also susceptible to sudden systemic change. This definition draws on three main theoretical concepts: the idea of "lock in" that is found widely in economic theory and the concept of "path dependence," which is widely used in complex adaptive systems theories. We also engage concepts of "transformative agency" found in theories of empowerment (and related concepts, which are variously termed) on the power dynamics and processes that have consequences in terms of who controls decisions and outcomes in communities (Zimmerman 2000).

Across various disciplines, since at least the 1980s, there has been much analysis of the ways in which economic, political, and cultural structures and infrastructures can be locked in to certain patterns that are resistant to change (Goldstein et al. 2023). This is a similar notion of path dependence in complex adaptive systems theory. When the circular causalities converge in stable feedback patterns, they set a system on a unique path that tends to endure over time (Munro and Cairney 2020). For instance, the expense, physical, and constructed nature of much human-built infrastructure means that once built, it is often slow to change because of the effort, resources, and investment required for modification or rebuilding. There is a strong tendency for design and maintenance of water and wastewater systems to fall into locked-in patterns. However, these locked-in patterns are often not suited to adequately prepare for and address the dynamic impacts of climate change on water and wastewater systems in rural communities.

## 3.1 Rural Frontline Communities and Climate Change Impacts

Frontline communities are those that have "experienced systemic socioeconomic disparities, environmental injustice, or another form of injustice" and are "the most vulnerable and will be the most adversely impacted by environmental and climate injustice and inequitable climate actions" (US Congress 2020). Put more simply and specific to this work, we define rural frontline communities as those who are overburdened and underresourced and who face disproportionate, first and worst impacts of climate change on their water and sanitation systems. Many studies are identifying the historical dimensions of such structural disparities and injustices (Akamani 2023; Goldstein et al. 2023), and PI and other partners have published on the intersection of how climate change has disproportionately impacted water and sanitation for frontline communities throughout the United States (Pacific Institute and DigDeep 2024). What emerges from these studies as well as from this report is that current vulnerabilities of frontline communities to climate impacts are the result of long historical pathways. Hence, it is important to understand these pathways to find ways to move towards climate and water equity and resilience.

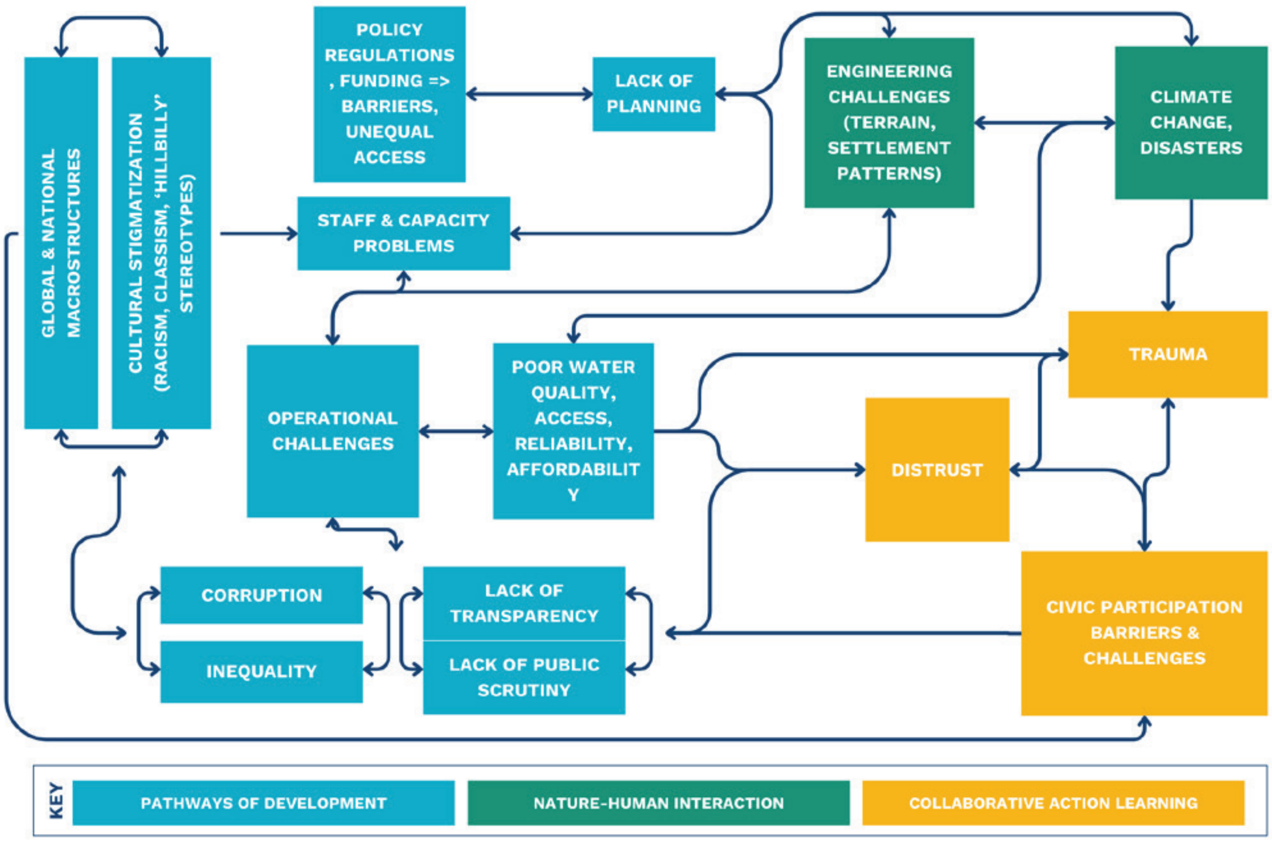
Water and climate risks and vulnerabilities tend to cluster in places where inequalities and poverty also cluster. A 2019 report titled *Closing the Water Access Gap* identified regional hotspots of water insecurity such as California's Central Valley, colonias near the U.S.-Mexico border, the Navajo Nation, the rural South, Appalachia, and Puerto Rico (Roller et al. 2019). These are predominantly rural places that have been on development pathways characterized by political marginalization and waves of investment and disinvestment (Edin, Shaefer, and Nelson 2023). Research has shown that people living in poverty are disproportionately likely to experience climate change impacts because multiple risks and economic stressors compound and make it harder for them to prepare or respond (Ribot 2010; Pacific Institute and DigDeep 2024; US Environmental Protection Agency 2021b). These factors increase vulnerability to climate change, because living with multiple risks makes it harder to navigate the costs and benefits of overlapping natural, social, political, and economic hazards (Ribot 2010; US Environmental Protection Agency 2021b). Strategies to minimize risks and impacts from climate change can further diminish already low incomes, and climate shocks can reinforce poverty by interrupting education, destroying assets, forcing the sale of capital, and deepening social differentiation (Ribot 2010).

Many rural frontline communities are also "hotspots of plumbing poverty" in which households that suffer from limited (or no) access to water and sanitation services are clustered together.

Many rural frontline communities are also "hotspots of plumbing poverty" in which households that suffer from limited (or no) access to water and sanitation services are clustered together (Deitz and Meehan 2019). These clusters of plumbing poverty are a result of disputes over water rights and jurisdiction, environmental racism, lack of infrastructure investment, inconsistent regulation, water scarcity due to climate change, or over-extraction for other human uses (Pacific Institute and DigDeep 2024). Elevated levels of "water hardship" correlate with factors of income, age, poverty, indigeneity, education, and rurality (Mueller and Gasteyer 2021).

It is important to note both the similarities and differences between the histories that have shaped diverse frontline communities. While looking for broad structural patterns, it is also vital to understand rural water and sanitation systems within the context of the unique histories that have brought them to their current condition (Figure 5). Here, we focus on the rural water systems of frontline communities in two regional hotspots of both climate impacts and water insecurity — the U.S. Southwest and Central Appalachia.

**FIGURE 5.** Causal Mapping of Factors Creating Lack of Resilience and Equity in Water and Wastewater Systems in Appalachian Case Studies




*Source: Original Graphic Design by Phill Barnett*

## 3.2 The Southwest Region: Impact of Development Pathways on Rural Water Systems

The U.S. Southwest, which herein is the 6-state region that encompasses Arizona, California, Colorado, New Mexico, Nevada, and Utah, comprises one-fifth of the land area in the United States (Figure 6) (Gonzalez et al. 2018).

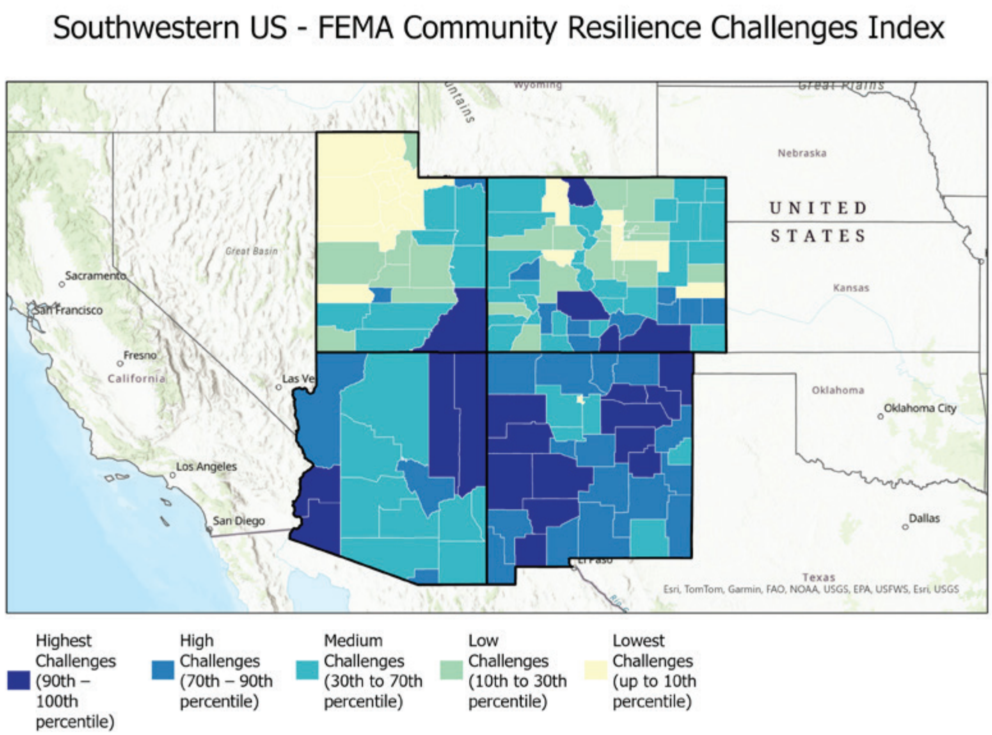
**FIGURE 6.** Map of the Southwest Region


*Source: (U.S. Climate Resilience Toolkit 2022)*

The Southwest is home to diverse ecosystems, cultures, and economies, and numerous frontline communities (Gonzalez et al. 2018; Wilder et al. 2016). The region includes large low-income Hispanic, Latino, and Indigenous populations who have experienced long-term discrimination, inadequate infrastructure, and lack of political representation (Wilder et al. 2016). These communities often experience high levels of poverty and are increasingly affected by a changing climate, including increased incidences of temperature and precipitation extremes, flooding, wildfire, and prolonged drought (US Environmental Protection Agency 2021a; McNeeley, Rigley, and Will 2024). Extreme heat is especially impactful to vulnerable populations such as outdoor laborers, the elderly, and those experiencing homelessness (Pacific Institute and DigDeep 2024). Drought impacts also disproportionately affect low-income communities and communities of color (Pacific Institute and DigDeep 2024).

A number of water insecurity hotspots, which are places with a high concentration of households lacking water and sanitation access, are found in the Southwest region (Roller et al. 2019). Some of these communities have been restricted to lands with limited or poorly functioning water resources (Gonzalez et al. 2018), while others were given federal water rights that have yet to fully materialize (Colby and Hansen 2022). Many populations at high risk in the region live in rented structures or mobile homes, with more than one-third of their income going to rent and utilities; these populations will have trouble paying the higher utility bills for water and energy that are projected in the Southwest as the climate changes (Wilder et al. 2016). These characteristics can pose challenges to resilience (Figure 7).

**FIGURE 7.** **FEMA Community Resilience Challenges Index — Southwestern US**




Note: This figure shows FEMA Community Resilience Challenges indicator for the Southwest United States. This comprehensive indicator combines 22 indicators in six groups for population characteristics, housing, healthcare, economic, and connection to community. Higher percentiles indicate higher potential challenges to resilience.

*Source: (FEMA 2023)*

### 3.2.1 HISPANIC AND LATINO COMMUNITIES

Hispanic and Latino communities throughout the U.S. Southwest are disproportionately affected by climate change and water impacts (US Environmental Protection Agency 2021b). Hispanic and low-income communities often receive low-quality drinking water, have inadequate sanitation services, and have been historically left out of water management processes and decisions (White et al. 2023; Pacific Institute and DigDeep 2024). Hispanics and Latinos also have high labor force participation in weather-exposed industries and face projected loss of labor hours due to extreme temperatures (Pacific Institute and DigDeep 2024).

Three states in the Southwest — New Mexico, Arizona, and California — are home to colonias, which are unincorporated, low-income areas communities along the U.S.-Mexico border that often lack clean water, adequate sanitation, indoor plumbing and water infrastructure, and/or electricity (Roller et al. 2019; Wutich et al. 2022). Colonias have mainly Hispanic or Latino residents most of whom are U.S. citizens, and the communities started often as settlements for immigrant farmworkers. In colonias, water and wastewater services and paved roads were often promised to come soon after the land was sold to residents, which in many cases has still not happened to date (Schlichting, Lena, Landes, Laura, and Buck, Sarah 2022). In Arizona, there are 104 colonias with a combined population of 278,2022; in New Mexico there are 154 colonias with a combined population of 157,408; and there are 35 colonias in California with a combined population of 46,2469 (Wutich et al. 2022). Research has shown that colonias are highly vulnerable to contaminated water from both wet and dry extremes (Rowles III et al. 2020).

California's Central Valley is another water insecurity and climate change hotspot in the region (Roller et al. 2019; Pacific Institute and DigDeep 2024). Rural Hispanic/Latino communities in the Central Valley were historically discouraged from incorporating, and thus, did not receive the same access to infrastructure funding, leaving behind a legacy of water challenges (Roller et al. 2019). These communities often have poorly constructed septic systems and sewers, and many lower-income farmworkers rely on private wells for drinking water as their communities were originally built as labor camps without adequate water systems (Roller et al. 2019). These wells are typically shallow with small pumping capacity and more likely to fail during drought (Pauloo et al. 2020) Even in towns with water and wastewater infrastructure, systems are often managed without community input (Roller et al. 2019). Compounding these water challenges are the climate changes of more frequent drought and extreme precipitation (Pacific Institute and DigDeep 2024).

### 3.2.2 INDIGENOUS COMMUNITIES

The Southwest region has the largest Indigenous population in the United States, including nearly 1.5 million Native Americans and 182 federally recognized and numerous non-federally recognized Tribes (Gonzalez et al. 2018; US Census Bureau 2020). Indigenous communities are on the frontlines of those experiencing climate change (Status of Tribes and Climate Change Working Group 2021). Historically, many Indigenous groups in the Southwest were forcibly displaced and/or restricted to lands with limited water and other natural resources (Gonzalez et al. 2018). This has led to disparities in infrastructure that further exacerbate risks to their water resources and uses. Compared to white households, Native Americans are approximately 19 times more likely to live in a household without indoor plumbing with running water (Deitz and Meehan 2019). For example, the Navajo Nation is facing limited water supply and sanitation access. Approximately 30% of households in the Navajo Nation do not have running water or indoor plumbing and rely on hauling drinking water from distant sources (Lovato, Ny Keely 2022; Roller et al. 2019).

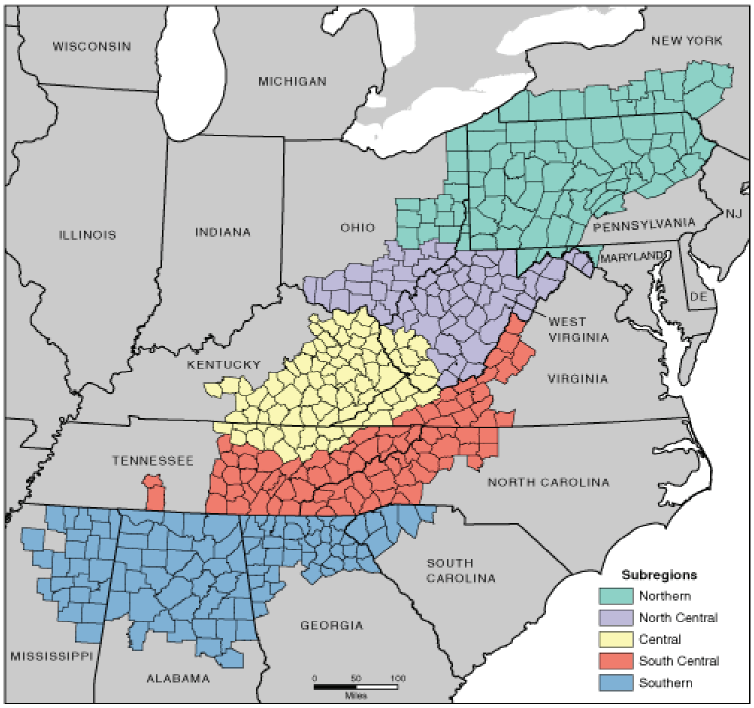
Indigenous peoples in the United States experience lower life expectancies, disproportionate disease burden, and discrimination in the delivery of health services more than other populations (Indian Health Service 2013). In addition, they are more likely to live near contaminated water and lack indoor plumbing, contributing to serious public health risks (Howard 2022). Indigenous livelihoods, subsistence and cultural practices, and economies are closely linked to water resources threatened by climate change (Whyte et al. 2023). Indigenous peoples have continually adapted to climate variations over time, however historical intergenerational trauma, settler colonialism, extractive industries, insufficient infrastructure, and socioeconomic and political pressures have eroded some adaptive capacities to respond to and prepare for current and future climate change (Jantarasami et al. 2018).

Despite these challenges and barriers, Indigenous peoples in the Southwest are continually developing new climate adaptations and actions based on Indigenous knowledges, partnerships with universities and other research institutions, and cultural models focused on relationships (Gonzalez et al. 2018; Jantarasami et al. 2018; Status of Tribes and Climate Change Working Group 2021). Tribes are often at the forefront of climate adaptations, implementing local and scientifically based actions to mitigate climate change, and creating systemic shifts to reconnect people with the environment (Status of Tribes and Climate Change Working Group 2021).

## 3.3 Appalachia: Extraction-Dependent Development Pathways and Impacts on Rural Water Systems

The Appalachian Mountains are referred to as the "water tower" for the many millions downstream from its headwaters, which are richly fed by high rainfall and old aquifers (Taylor 2019). Despite this water abundance, Central Appalachia (Figure 8, area in yellow) is home to numerous communities that are considered highly sensitive to climate change impacts (Pollard and Jacobsen 2022; US Environmental Protection Agency 2021b). Among the water challenges facing communities in rural Appalachia are extreme flooding events, lack of household water access, poor water quality, and lack of wastewater services (discussed in more detail in section 4 Climate Change Impacts on Rural Water Systems) (Roller et al. 2019). Central Appalachia has some of the highest rates in the United States of Safe Drinking Water Act violations and homes without complete plumbing (Mueller and Gasteyer 2021). To understand the challenges and impacts facing water and sanitation systems of each regional hotspot, it is important to understand these systems within the context of their distinctive regional pathway to development.

**FIGURE 8.** Appalachian Subregions

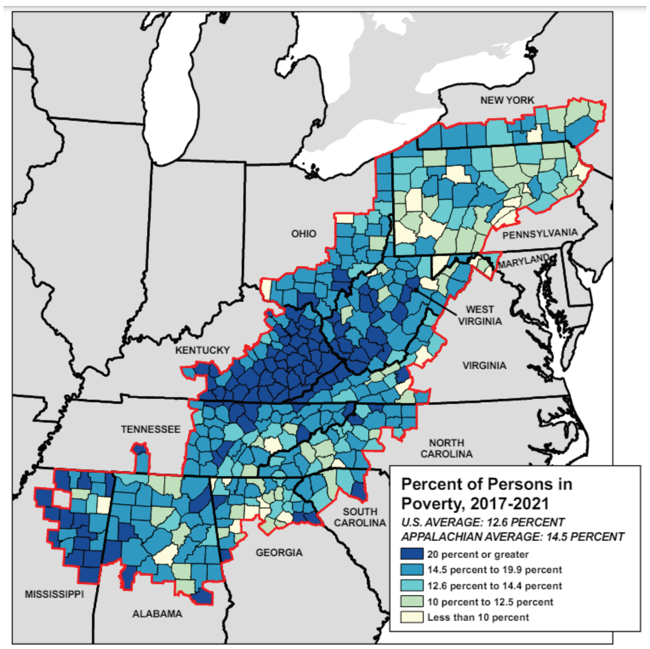



*Source: (Appalachian Regional Commission 2021)*

Extractive industries have dominated economic and political structures for over a century in the coal-rich counties of southern West Virginia, Appalachian Ohio, Southwest Virginia, and eastern Kentucky. Through much of the 20th century, the coal and timber that came from this region were major sources of national wealth. But local communities were early on locked into systemic patterns of persistent poverty (Lewis 1998; Billings and Blee 2000). Multiple causal factors often converge on resource-rich regions to lock them into the path of development that has been called the “rich lands, poor people syndrome” or the “resource curse” (Papyrakis 2017).

Land inequality, the decline of coal industry, increased poverty and unemployment rates combine to create a political culture in which well-connected and property-holding local elites predominate and others are marginalized (Bell 2016; Gaventa 1982; Tarus, Hufford, and Taylor 2017; Taylor, Hufford, and Bilbrey 2017). Economic inequality is extremely high in Central Appalachia. Nearly one-quarter of residents (22.4%) in Central Appalachia live in poverty (Figure 9), compared to 12.5% for all people in the United States and 20% of all people living in U.S. rural areas (Pollard and Jacobsen 2022). Nearly 30% of the residents living in poverty are under the age of 18 — and a similar proportion is 18–24. Poverty rates are even higher in Eastern Kentucky’s Harlan and Martin Counties, at 31.2% and 35.2% respectively, compared to 18.9% across the state (Kentucky Center for Statistics 2016). Central Appalachia also has the highest unemployment rates in Appalachia (6.1%), some of the lowest levels of income and fastest aging populations in the country. Households have a median family income no greater than 67% of the U.S. average and a poverty rate 150% percent or greater of the U.S. average (Appalachian Regional Commission 2021; A. Cohen et al. 2022). And the share of residents aged 65 and over in Appalachia exceeded the national average by more than two percentage points in 2020, with many counties in Central Appalachia having one-quarter of their populations aged 65 and over (Pollard and Jacobsen 2022). When compared with other rural residents in the United States, rural Appalachian residents also have lower levels of access to the internet and education, and higher levels of disability (Pollard and Jacobsen 2022).

**FIGURE 9. Percentage of Persons in Poverty in Appalachia, 2017–2021**

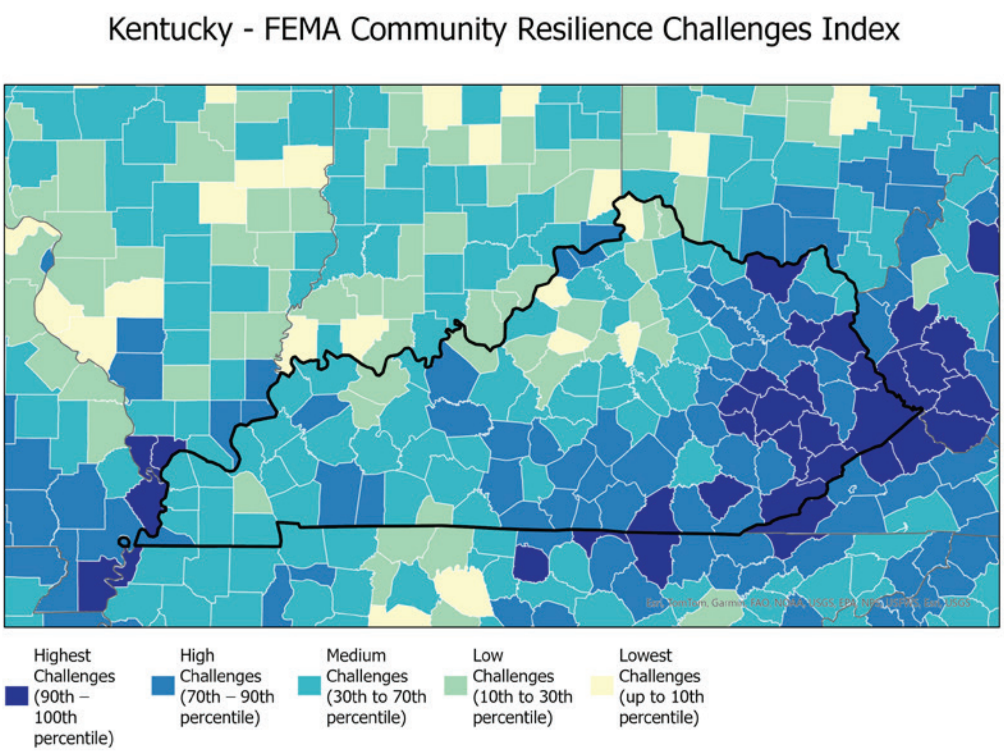



*Source: (Pollard, Srygley, And Jacobsen 2023)*

The regional pathway to development that has locked Central Appalachia into the "rich lands, poor people syndrome" is characterized by a chronic lack of investment in water and sewage infrastructure. Historically, corporate and absentee-owned land, comprising most of the region's land, has been taxed at very low rates (Eller 1982; Appalachian Land Ownership Task Force 1983). As a result of unusually low taxes from land and property received by local governments, most water and sanitation systems maintenance burden fall on rate-paying consumers who are among the poorest in the nation and have higher rates of illness and disability, which make them particularly vulnerable to water outages, unreliability, pollutants, or increases in the cost of water (Shelton, Draper, and Cromer 2023).

In low-income rural areas of the region that lack access to safe, reliable, utility-provided drinking water, many households rely on private well water, bottled water, and roadside springs (A. Cohen et al. 2022). One study of household water quality in Central Appalachia found that, although all participating households had piped well water, nearly two-thirds (67%) reported using bottled water as their primary drinking water source due to water quality concerns (A. Cohen et al. 2022). However, broader understanding of which rural Appalachian regions, communities, and populations have higher risks of exposure to contaminated drinking water is severely limited by a lack of data (A. Cohen et al. 2022). These characteristics can pose challenges to resilience (Figure 10).

**FIGURE 10.** **FEMA Community Resilience Challenges Index for Kentucky**




Note: This figure shows FEMA Community Resilience Challenges indicator for the Southwest United States. This comprehensive indicator combines 22 indicators in six groups for population characteristics, housing, healthcare, economic, and connection to community. Higher percentiles indicate higher potential challenges to resilience. FEMA Community Resilience Challenges Index for Kentucky and surrounding area.

*Source: (FEMA 2023)*

# 4. Climate Change Effects on Rural Water Systems

## 4.1 Climate Stressors on Rural Water Systems

Climate change exposure is defined as the presence of communities and their natural, physical, economic, social, or cultural assets in places that could be adversely affected by the nature and degree to which a system is exposed to significant climatic variations or extremes (Cardona et al. 2012; McNeeley 2009; Adger 2006). How susceptible communities are to those climate exposures is influenced by the development pathways discussed in section 3 Climate Change and Development Pathways in Rural Water Systems that have resulted in that community's physical, economic, social, environmental, and cultural characteristics (Moss, RH and Malone EL 2001). This is linked to equity considerations because past development pathways have created lasting inequalities that contribute to greater vulnerability to climate impacts and disasters because communities are underresourced in housing, education, employment, healthcare and other vital public goods and services. Institutions and networks that support learning, store knowledge, facilitate problem solving, and balance power among interest groups can all shape the adaptive capacity of a community to better prepare for and respond to the impacts of climate change (Brown 2009).

To understand climate change exposures to rural water systems and communities, we give a high-level overview of both observed and anticipated climate change. Anticipated climate change uses computational models that calculate physical interactions between atmosphere, land, ocean, and sea ice, with projections about how likely they are to change in the future (Intergovernmental Panel on Climate Change 2023). Future projections are based on greenhouse gas emissions scenarios, for example carbon emissions from fossil fuels or methane emissions from agriculture, that estimate the amount of heat-trapping gases that will be present in the atmosphere due to human activities. Climate change observations demonstrate that human-caused climate change is already altering temperature and precipitation regimes and leading to more frequent and intense weather events, and the models indicate that these trends are expected to increase as emissions persist or increase and climate change intensifies (Marvel et al. 2023). To plan more resilient community water systems, it is important to understand both current and anticipated climate changes in the context of the communities themselves, so that they can be prepared for and respond to change.

Climate change-related physical and social sciences are important for understanding the vulnerabilities of rural frontline communities broadly across the United States as well as in specific regions (E. Marino et al. 2023). Due to differential vulnerability, depending on the varied community and geographic characteristics, climate change will vary across and even within communities (Thomas et al. 2019). These variations require unique, community-specific approaches to address climate impacts working with the strengths and assets of individual communities.

## 4.2 Climate Change Impacts on Rural Water Systems

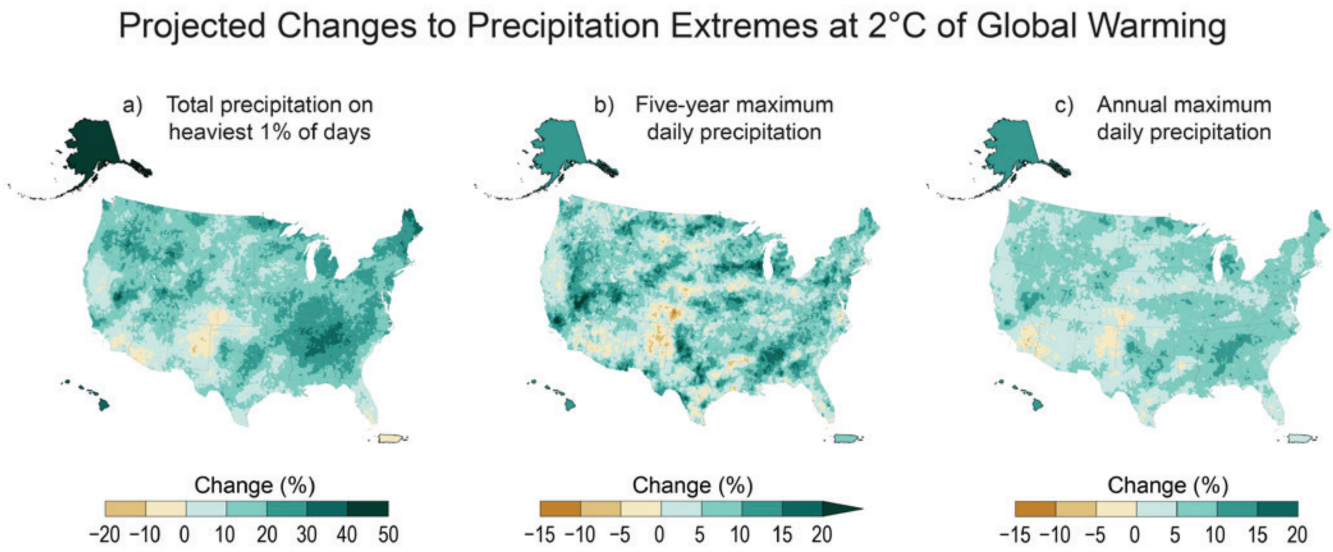
In the United States, climate change impacts such as precipitation, temperature, and other hydrological and ecological changes directly affect rural water and sanitation systems and the communities they serve (Hales et al. 2014; Lall et al. 2018; Payton et al. 2023). Climate change is already significantly impacting drinking water and sanitation access and poses challenges for the future of water supply, availability, and quality in rural communities (Pacific Institute and DigDeep 2024). Rural community livelihoods and social structures are particularly interconnected with natural systems and are characterized by variables that make them especially susceptible to these climate extremes and their impacts (Hales et al. 2014).

### 4.2.1 EXTREME PRECIPITATION AND FLOODING

Climate change has shifted precipitation patterns across the United States (Figure 11), including increased variability and an increased likelihood of extreme rainfall events (Payton et al. 2023). There is evidence that human-caused warming has contributed to an increase in the severity and frequency of the heaviest precipitation events across nearly 70% of the United States (Marvel et al. 2023). Increases in extreme precipitation events lead to more catastrophic flooding events, which can have drastic impacts on water systems and infrastructure, the latter of which was typically built to withstand historic, rather than future or current, precipitation conditions (Pacific Institute and DigDeep 2024; Lall et al. 2018; Payton et al. 2023). Flooding events can cause power and water outages and erosion, mobilize pollutants, and pollute water sources, as well as introduce wastewater into drinking water, contaminating community water systems and compromising water quality (Euripidou and Murray 2004; Rizak and Hrudey 2008).

> Increases in extreme precipitation events lead to more catastrophic flooding events, which can have drastic impacts on rural water systems and infrastructure.

**FIGURE 11. Climate Projections of Extreme Precipitation Across the United States**




*Source: (Marvel et al. 2023)*

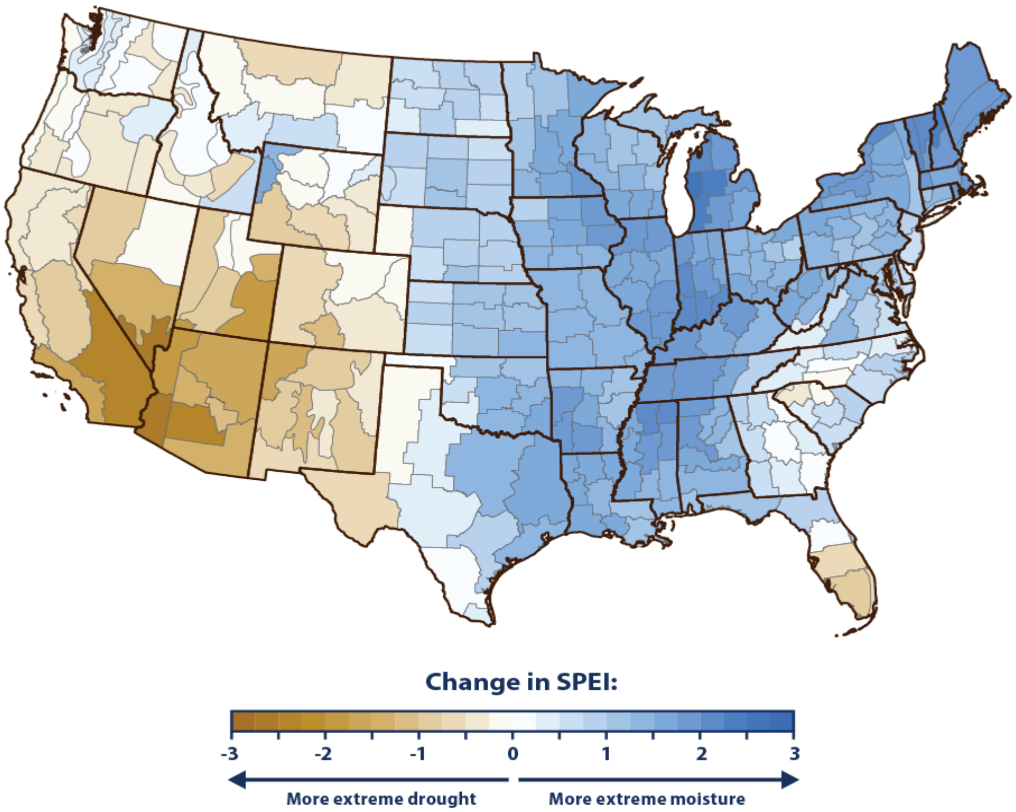
Flooding poses a particular risk to decentralized water systems[3] that are common in rural areas, as private wells may be vulnerable to contamination, such as from fertilizers from agricultural areas, or pathogens and chemicals from industrial and upstream urbanized areas (Pacific Institute and DigDeep 2024). In areas impacted by wildfire and/or natural resource extraction, which can contribute to the destabilization of landscapes, flooding poses an increased risk of landslides (Paul et al. 2022). Flooding impacts water quality in all systems, however rural and low-income populations relying on decentralized systems are particularly vulnerable because they are not regulated by federal drinking water standards, and information and funding assistance for well stewardship is limited (Malecki et al. 2017; Mulhern et al. 2022; Sohns 2023).

### 4.2.2 DROUGHT

In addition to floods, greater precipitation variability due to climate change is increasing the frequency, severity, and duration of droughts throughout the United States, especially in the Southwest region (Figure 12) (Jay et al. 2023). Increasing temperatures and decreasing soil moisture are contributors to the trends of intensified drought impacts (Intergovernmental Panel on Climate Change 2022; Overpeck and Udall 2020). Increasing temperatures and decreasing soil moisture are contributors to the trends of intensified droughts in the United States, though this varies regionally (Wehner et al. 2017; Marvel et al. 2023). Future droughts are expected to be stronger and last longer in most regions; with extremes occurring in the Southwest and Southern Great Plains of the United States (Marvel et al. 2023).

3 We define decentralized water systems here as those that are not connected to centralized systems that rely on a large water treatment facility and pumping station or wastewater treatment plant to perform these same processes. Here decentralized systems primarily refer to private wells and onsite septic system (Pacific Institute and DigDeep 2024)

**FIGURE 12.** Average Change in Drought in the Contiguous 48 States 1900–2020




Note: This map shows the total change in drought conditions across the contiguous 48 states, based on the long-term average rate of change in the five-year SPEI from 1900 to 2020. Data are displayed for small regions called climate divisions. Blue areas represent increased moisture, brown areas represent decreased moisture or drier conditions (US EPA and OAR 2021). The Standard Precipitation Evapotranspiration Index (SPEI) takes into account both precipitation and potential evapotranspiration in determining drought, capturing the main impact of increased temperatures on water demand (NCAR 2024).

*Source: (US EPA and OAR 2021)*

Drought impacts rural water systems in several ways, including reduced snowpack and runoff, an increased reliance on groundwater, and degradation and depletion of groundwater supply (Pauloo et al. 2020; Z. F. Levy et al. 2021). Snowpack is an important natural water reservoir across the Western United States, and it is expected to decline in the future and reduce water availability for downstream communities (Payton et al. 2023). Models indicate that snowpack loss could decrease 20%–30% by the 2050s and 40%–60% by the 2100s (U.S. Department of Energy 2021).

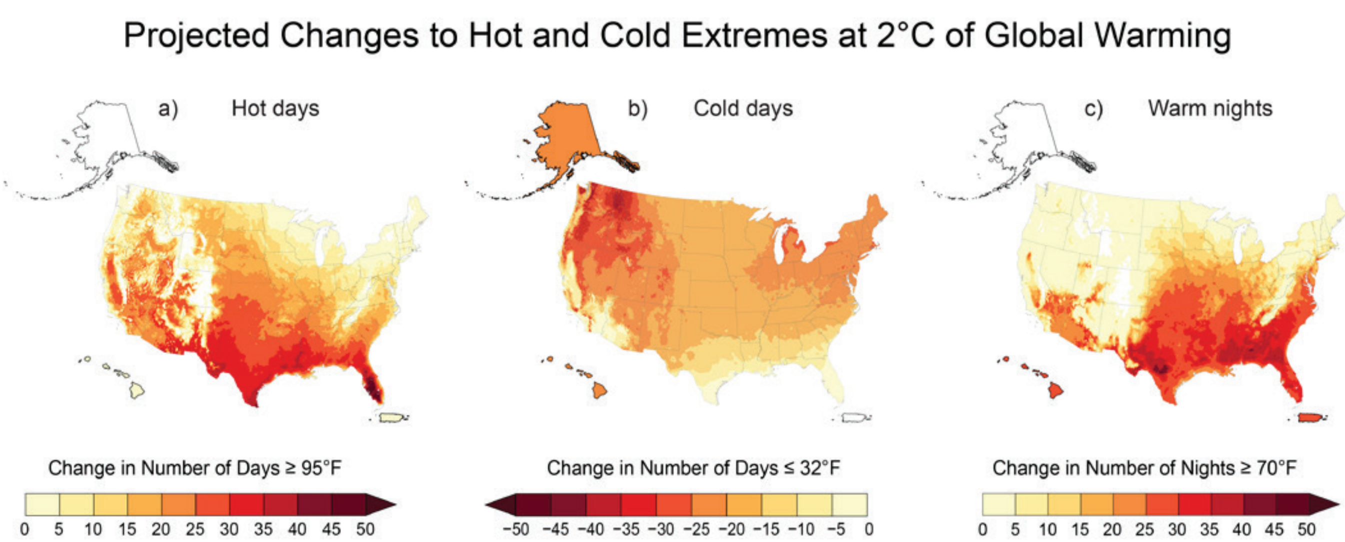
Groundwater decline — due to a combination of overdraw and lack of recharge because of increased severity and duration of droughts — is a concern in many parts of the country with groundwater depletion specifically impacting disadvantaged communities dependent on shallow wells (Payton et al. 2023; Pacific Institute and DigDeep 2024). Droughts can also lead to overreliance on groundwater reservoirs, which can lead to sinking soils that decrease groundwater quality (Lall et al. 2018; Payton et al. 2023). Overdrawing of groundwater has been linked to degradation of groundwater quality, and droughts can increase the amount of contaminants and pollutants in shallow well water (Pauloo et al. 2020).

### 4.2.3 EXTREME TEMPERATURES

Climate change is increasing the frequency, duration, and magnitude of heatwaves in the United States (Figure 13) (Hayhoe et al. 2018; Marvel et al. 2023). Average annual temperatures in the contiguous United States have risen by 2.5 degrees Fahrenheit since 1970, compared with a global temperature rise of nearly 1.7 degrees Fahrenheit during the same period (Marvel et al. 2023). Warming trends, especially extreme heat events, affect rural water quality and supply in several ways. Warmer temperatures exacerbate drought conditions by increasing evapotranspiration and compromising rural water availability and supply (Osezua et al. 2023). Extreme heat can also contribute to algal blooms in surface waters endangering sources of drinking and recreational water (Lall et al. 2018; Payton et al. 2023). It also increases water use and demand, which affects water sufficiency (Pacific Institute and DigDeep 2024).

The impacts of extreme heat can cause disproportionate health impacts for certain populations. For example, people experiencing homelessness are at increased risk of heat-related illnesses, in part, because of the lack of access to sufficient drinking water (Every et al. 2021). Heat-related illness and dehydration are also a major risk for outside laborers exposed to extreme heat (B. S. Levy and Roelofs 2019).

**FIGURE 13. Change in the Number of Days Over 95 Degrees Fahrenheit Across the Continental US**




*Source: (Marvel et al. 2023)*

Extreme cold events can also cause damage to water supply and sanitation systems, cutting off access for the people served by those systems, especially in unprepared or unweatherized geographies (Pacific Institute and DigDeep 2024). Extreme cold events have caused major disruptions to water access due to freezing and rupturing of water pipes and power outages (Fentress and Fausett 2021). When water pipes are ruptured, systems can experience pressure loss, which in turn puts the distribution system at risk of contamination, making water unsafe (Pacific Institute and DigDeep 2024). Small water systems, which often serve rural communities, have had greater challenges coming back online after disruptions due to extreme cold (Pacific Institute and DigDeep 2024). Climate observations and models demonstrate how climatic changes in the Arctic are likely an important driver of a chain of events that involve stratospheric polar vortex disruption, which ultimately can result in more extreme cold events in the mid-latitudes of the Northern Hemisphere (J. Cohen et al. 2021).

### 4.2.4 WILDFIRE

Wildfires have adverse effects on rural water infrastructure and water quality. At the household scale, wildfires can melt and rupture water meters and water pipes (Pacific Institute and DigDeep 2024). At a larger community scale, wildfires can damage water intake systems or water treatment systems (Bladon et al. 2014). In addition, wildfires can render drinking water unsafe. Following a fire, landscapes face erosion and potential landslides, and downstream reservoirs can be contaminated by these sediments (Pacific Institute and DigDeep 2024). Water bodies that are located downstream of fire-impacted forested land see an increase in the concentration of solids, nutrients, heavy metals, and temperature after a fire (Bladon et al. 2014).

Drinking water supplies can be at risk for years following a wildfire (Chow et al. 2019), and while the economic research is limited to date, the costs of wildfire to water systems could be significantly increased for years to come (Wibbenmeyer, Sloggy, and Sánchez 2023; Romero 2022). Decentralized systems common in rural areas such as domestic wells can suffer the same water quality effects after a wildfire, however these systems can face a much slower recovery process (Pacific Institute and DigDeep 2024).

> Drinking water supplies can be at risk for years following a wildfire and rural areas can face a much slower recovery process.

From 1984 to 2015, about half of the increase in burned area across the Western United States is attributable to increases in fuel flammability caused by anthropogenic climate change (Leung et al. 2023). During the period 1979–2020, human-caused warming was responsible for almost 68% of the observed drying of landscapes, making wildfires burn larger areas (Zhuang et al. 2021). The duration of wildfire season in the Western United States has grown longer due to higher temperatures and earlier snowmelt (Vose et al. 2018). The potential for wildfires is increasing in frequency, geographic extent, duration, and severity (Vose et al. 2018; Domke et al. 2023). In the Western U.S., in particular, wildfires have become more frequent and larger with evidence of climate change as a major contributor (Domke et al. 2023).

## 4.3 Regional Climate Change Impacts on Rural Water Systems in the US Southwest and Central Appalachia

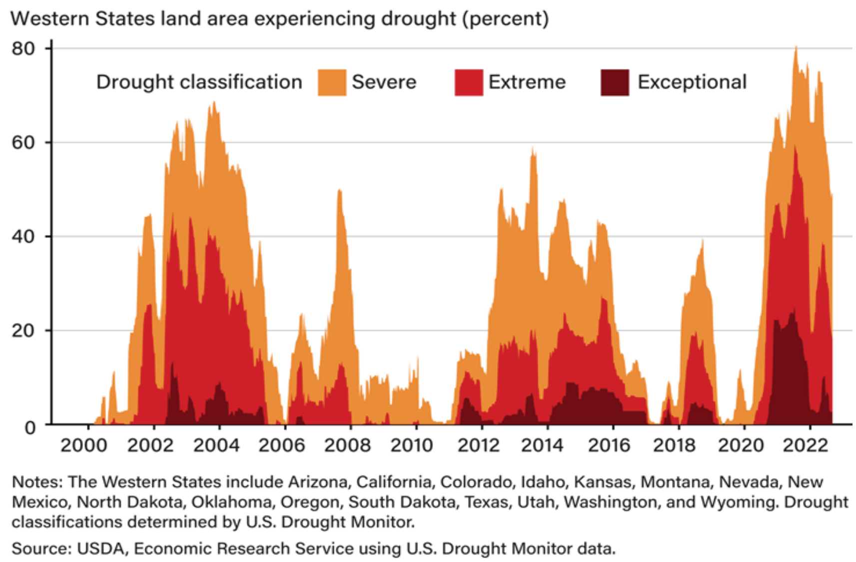
While climate change impacts on rural water systems can be observed across all geographies, here we focus on two climate and water insecurity hotspots: the U.S. Southwest and Central Appalachia. Both regions have high concentrations of households without water and sanitation access and experience unique climate change exposures and sensitivities that make rural water systems particularly vulnerable to the impacts of climate change. By focusing on current and future climate change impacts to rural water in these regions, we can better understand the risks faced by communities and their water systems to support locally appropriate adaptations.

### 4.3.1 THE SOUTHWEST REGION

As a water insecurity hotspot, many communities in the Southwest have high concentrations of households without access to water and sanitation. This lack of access is paired with climate change exposures discussed above, such as precipitation, temperature, and other hydrological and ecological changes that increase the vulnerability of rural water and sanitation systems in the region. Climate impacts, such as prolonged and severe drought conditions and extreme high temperatures paired with groundwater depletion and reduced mountain snowpack, are increasing the risk of water supply shortages in the region (White et al. 2023; Siirila-Woodburn et al. 2021). Climate change models project an increase in temperature and an overall decline in average annual precipitation in the Southwest, though punctuated with extreme precipitation and more damaging flooding events (White et al. 2023). These phenomena are also increasingly happening in quick succession, referred to as "weather whiplash" (Francis et al. 2022).

Since about 2000 to this writing, the region experienced a "megadrought" that was the driest approximately 24 years in 1,200 years (Figure 14) (White et al. 2023; National Oceanic and Atmospheric Administration National Centers for Environmental Information 2024). Climate change has increased evaporative demand and, paired with higher temperatures and increased drought, has reduced water flows in major river basins, like the Colorado River and Rio Grande (White et al. 2023). Reduced water flows, when coupled with growing water demands, have led many of the region's lakes and reservoirs to reach historically low levels (White et al. 2023).

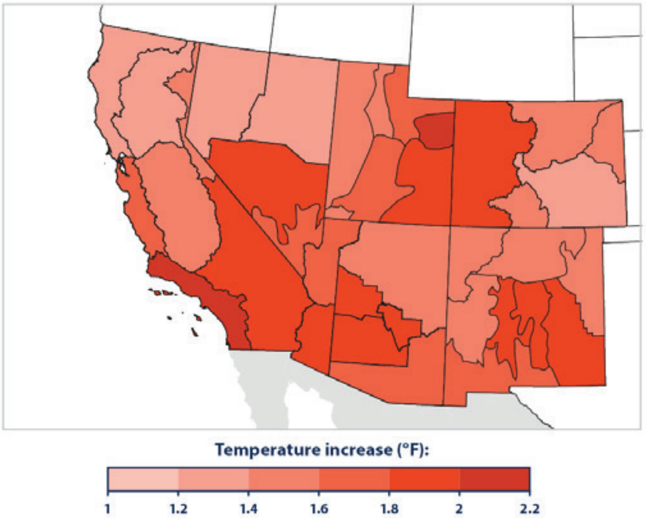
**FIGURE 14.** **Percent of Land Area in Western States Experiencing Drought 2000–2022**




*Source: (USDA Economic Research Service 2022)*

More frequent extreme heat events are expected under continued climate change in the region (Figure 15) (White et al. 2023). Warming trends and extreme heat events affect water quality, availability, and supply. Extreme heat can contribute to algal blooms, impacting water quality (Lall et al. 2018; Payton et al. 2023). Drought combined with extreme heat causes "hot drought," when higher temperatures amplify droughts and result in decreased water availability (Overpeck and Udall 2020). Extreme heat also increases water use and demand as people tend to use more water to keep cool, remain hydrated, and irrigate landscapes, putting additional pressure on water resources (Shafiei Shiva and Chandler 2020).

**FIGURE 15. Average Temperature Differences in the Southwest, 2000–2020 Versus the Long-Term Average (1895–2020)**




*Source: (US Environmental Protection Agency 2021a)*

Warmer and drier conditions such as these also lead to increased wildfire risk. In the Southwest, climate change has caused wildfires to increase in size, severity, and frequency in many areas, and this is expected to continue to put rural water resources at risk (White et al. 2023). Seven of the 10 largest wildfires in the United States from 2020–2021 occurred in the Southwest (White et al. 2023).

Water infrastructure in the arid Southwest is especially complex and largely designed to move water from areas with a surplus to areas with limited supply (Gonzalez et al. 2018). This infrastructure also relies on reservoirs, canal and pump structures, groundwater pumps, hydropower, and water efficiency technologies, as well as engineering to mitigate flooding and other risks (Siirila-Woodburn et al. 2021). Much of this infrastructure was designed to use snowmelt as a primary water source, and it was historically assumed that this snowmelt would always be present and could be relied upon (Siirila-Woodburn et al. 2021; Milly et al. 2008). However, mountain snowpack has declined over the last century due to warming trends from climate change (White et al. 2023). Of additional concern, climate change has accelerated evapotranspiration in the region, greatly reducing runoff that feeds the watershed, even in years of near-normal snowpack (Lang, Mallia, and Skiles 2023). Climate models project the Western United States could experience persistent low-to-no snow conditions in approximately 35–60 years (Siirila-Woodburn et al. 2021).

The Colorado River Basin is a major source of water in the Southwest, and while estimates vary, it serves somewhere between 35–40 million people (M. Cohen 2023; US Geological Survey, n.d.; US Department of Interior Bureau of Reclamation 2021). The Lake Mead and Lake Powell reservoirs are at historically low levels and cannot provide sustainable water supply in the Southwest unless consumption is reduced to match declining water supply levels (Schmidt, Yackulic, and Kuhn 2023). In 2021, the U.S. Bureau of Reclamation declared the first water shortage on the Colorado River after over 22 years of historic drought, climate change, and a growing difference between water supply and demand (White et al. 2023). Water levels in Lake Mead fell to 27% capacity in 2022 compared to 98% capacity in 2000 (White et al. 2023). The Colorado River is fed by snow runoff in the Rocky Mountains, and snowpack that runs off into the basin has been declining in recent years (Siirila-Woodburn et al. 2021). The Colorado River Basin is in one of the most productive agricultural regions in the world, so competition between drinking water and irrigated agriculture, among other uses, also creates water shortage challenges (Cooley et al. 2016). Within the Colorado River Basin, an estimated 70% of water consumption is for the agricultural sector (Wheeler et al. 2022). Increasing drought severity in the Western United States raises overall water demand for irrigation and, in turn, accelerates groundwater depletion (Scanlon et al. 2012).

### 4.3.2 THE CENTRAL APPALACHIAN REGION

Communities in rural Appalachia also face multiple water challenges that climate change is already impacting. Rural water systems in the region are faced with an increase in extreme flooding events, poor water quality, lack of household water access, and lack of wastewater services (Roller et al. 2019; Pacific Institute 2023). As state above, Central Appalachia has some of the highest rates in the U.S. of households with Safe Drinking Water Act violations and without complete plumbing (Mueller and Gasteyer 2021), which makes it a region disadvantaged by lack of water access and safety issues that climate change threatens to make worse (Pacific Institute and DigDeep 2024).

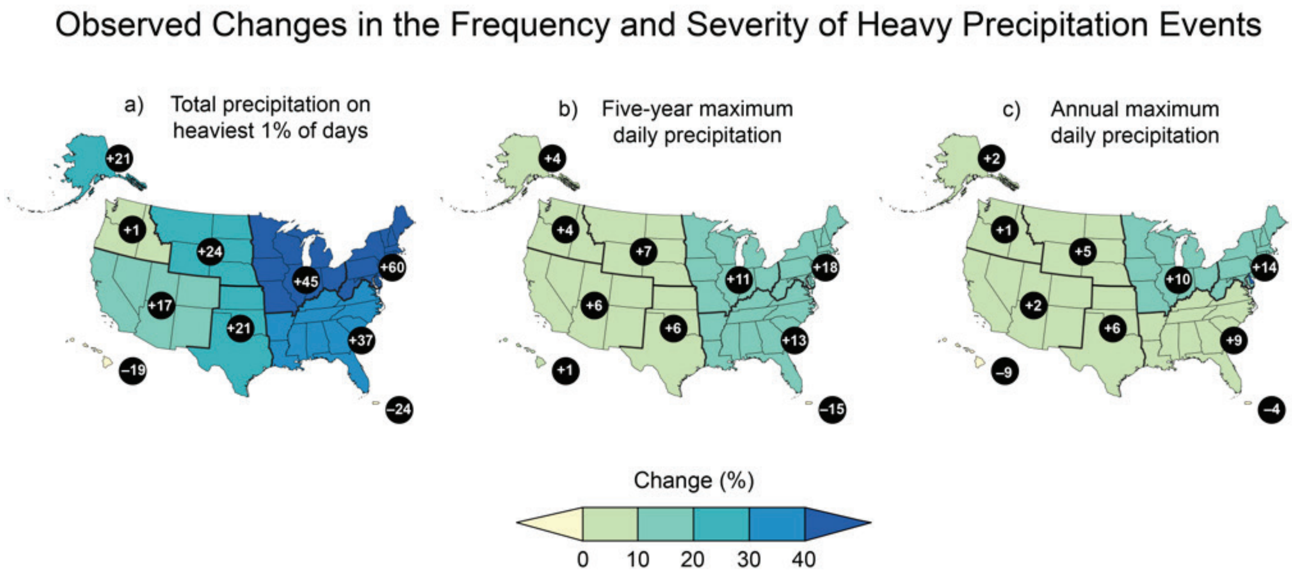
In Martin County, Kentucky in 2024, extreme freezing temperatures resulted in water outages in a system already plagued by inadequate water infrastructure and water unaffordability issues, and many residents went for days without water (GeraldineTorrellas, 2024). One study of regional water issues showed that Martin County pays some of the highest water bills in the area but received some of the poorest water quality in a system plagued by mismanagement, significant leaks in service lines, and water losses (Shelton, Draper, and Cromer 2023). As discussed earlier, climate change could result in more of these types of extreme freezing events leading to disruptions in already stressed rural water systems such as Martin County's.

> Overall increases in precipitation pose a unique threat in the Central Appalachian region given its topography.

Climate change is already resulting in more extreme precipitation and catastrophic flooding events in the region, such as the floods of July 2022 (Figure 15) (Carter et al. 2018; Marvel et al. ; Hoffman et al. 2023). Observations of total precipitation in the region, particularly summer precipitation, demonstrated an upward trend from 2015–2020 (Runkle and Kunkel 2022). Climate models project an increase in extreme precipitation in the future (Carter et al. 2018; Hoffman et al. 2023; Marvel et al. 2023). The frequency of dry days is also projected to increase by 8 to 10 days annually, resulting in a more episodic regime of intense rain with long dry spells between events (Butler et al. 2015).

Overall increases in precipitation (Figure 16) pose a unique threat in the region given its topography. The region's mountainous terrain contributes to orographic (i.e. mountain) and "terrain-locked" thunderstorm systems that are known to produce some of the largest rainfall accumulations in the world (J. A. Smith et al. 2011). Rainfall then collects in the narrow valleys, colloquially referred to as "hollers" (i.e., hollows), where many communities and households are located (Harvey 2022). Additionally, the legacy of extractive industries in the region has removed some natural protections that could help alleviate flood risk (Kenning, Giffin, and Bruggers 2022).

**FIGURE 16. Heavy Precipitation Events Are Becoming More Frequent and Intense Across the Country**




*Source: (Marvel et al. 2023)*

A history of coal mining resulted in the removal of trees, topsoil, and rocks, contributing to erosion and a legacy of decaying infrastructure, all of which can exacerbate runoff and flooding (Kenning, Giffin, and Bruggers 2022; Bruggers 2019). Water and wastewater systems in these areas are uniquely vulnerable to extreme precipitation and flooding. This is because many drinking water treatment plants are located near rivers and lakes (Naishadham, Peterson, and Fassett 2023). In cases of extreme precipitation, these plants often flood first and may also lose power, disrupting service for community members. Extreme precipitation can also overwhelm combined stormwater-sewer systems, leading to the introduction of raw sewage and other contaminants into receiving waters (Payton et al. 2023). Flooding can also mobilize chemicals and pollutants that contaminate water systems (Euripidou and Murray 2004).

The region's flood risks are exemplified by historic flooding that occurred in eastern Kentucky in July 2022 (Figure 17). The area recorded nearly 12 inches of rain from July 25 to 29, with 8 inches falling in a 24-hour period from July 27 to 28 (National Oceanic and Atmospheric Administration National Weather Service 2022). This was categorized as a 1-in-1,000-year event (National Oceanic and Atmospheric Administration National Weather Service 2022). The resulting flooding swept away homes and portions of communities, necessitated hundreds of helicopter and boat rescues, and resulted in dozens of deaths. The flooding also resulted in widespread damage to rural water systems, compromising the availability of safe drinking water and wastewater services (DeCoste 2023). At least three wastewater plants were rendered completely inoperable, and several others had limited operations due to flooding, mudslides, rockslides, and power outages (American Water Works Association 2022). An estimated 18,000 service connections were without water, and an additional 45,600 connections received boil water notices (American Water Works Association 2022). Extreme and life-threatening precipitation and flooding events are expected to increase as climate change accelerates.

**FIGURE 17.** **Flooding Devastation in Southeastern Kentucky, July 2022**


*Source: (Jiménez and Rubin 2022)*

In the Southeast U.S., an increase in frequency of extreme precipitation events paired with a lengthening of dry spells between precipitations events can make water resources unpredictable (Hoffman et al. 2023). The projected increase in extreme precipitation events will lead to intensified soil erosion and sedimentation, which exacerbates the risks of soil destabilization and landslides, especially in the steep mountain grades of the Central Appalachian landscape (Butler et al. 2015). These events can damage already deteriorating water and wastewater infrastructure not designed to withstand these climatic changes because the infrastructure was built to withstand historical conditions rather than current or future conditions (U.S. Climate Resilience Toolkit 2019).

Observed and anticipated climate change exposures can be used to understand the vulnerability of rural water systems to climate change. Integrating climate change exposure with climate sensitivity and adaptive capacity allows for a more comprehensive approach to planning for more resilient rural water systems.

# 5. Key Findings and Lessons Learned from the Water and Climate Equity Project

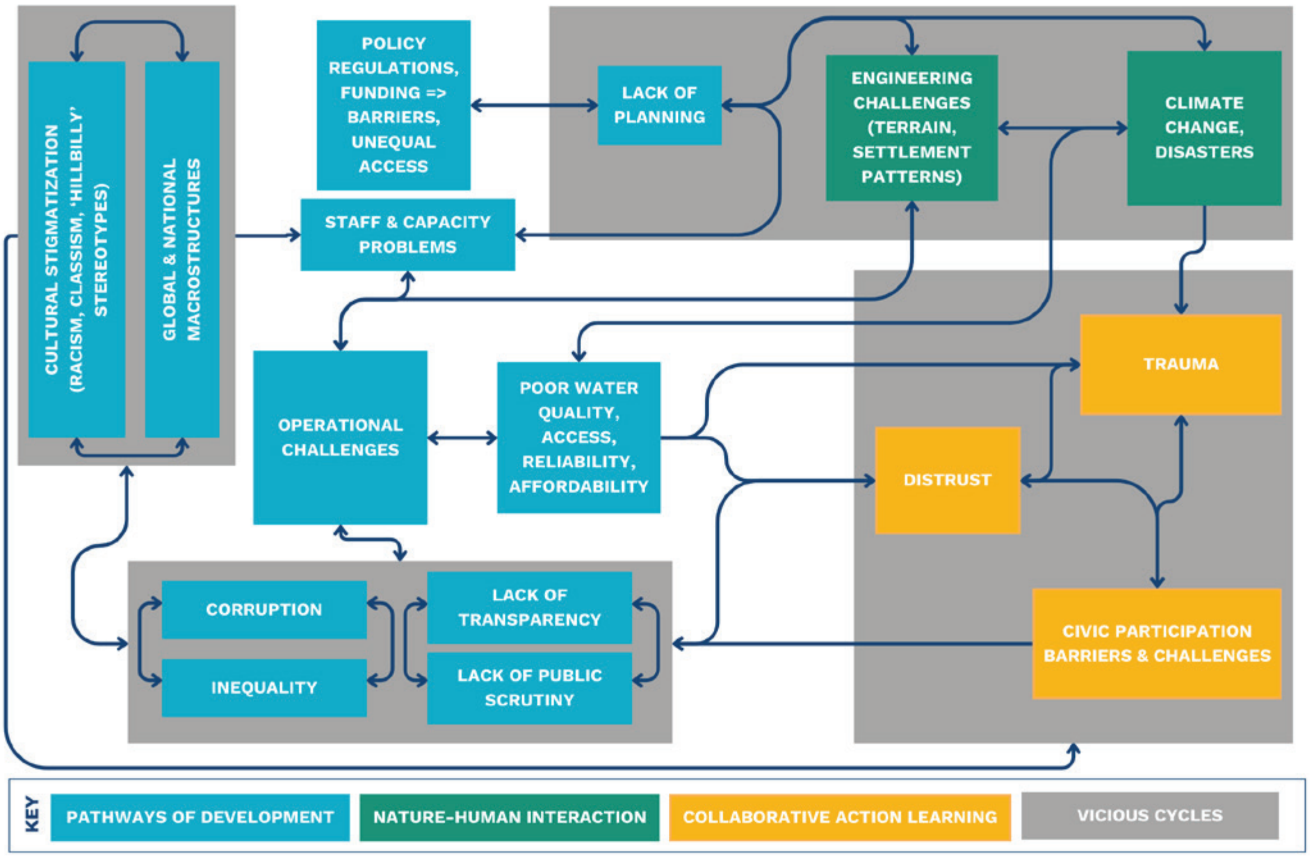
Throughout the two and a half years of assessment, the project team has learned tangible, applicable lessons that will help our research to impact communities and guide our colleagues in community engagement. Some of these findings are listed below, and we will engage these lessons during the pilot phase of the project in 2024–2025 and beyond. The pilot phase will focus on operationalizing the knowledge and tools created by this assessment with the communities and TAPs we engaged.

## 5.1 Development Pathways and Legacies of Injustice Disadvantage Many Rural Water and Sanitation Systems and Make them Highly Susceptible to the Impacts of Climate Change

This research demonstrated social, physical, and technical problems that impact rural water systems. In Central Appalachia, Kentucky's Martin and Harlan Counties experienced frequent line breaks and boil water advisories, the formation and presence of disinfection byproducts due to system design, aging and failing infrastructure, and water loss. The region's water distribution systems are aging and poorly designed, installed, and maintained. The physical characteristics of the Central Appalachia region include mountainous terrain and low population density, both of which hinder communities' abilities to afford or implement new infrastructure. Climate-related disasters and outages (including storm-related power outages, flooding, water line breakage due to freezing) add to the financial burden on these already underresourced systems. Low-income communities are least able to afford necessary improvements (electric generators, alternative sources of supply) that could increase their resilience.

In addition to deep listening activities with TAPs, deep listening to a diverse group of local stakeholders in Harlan and Martin Counties, Kentucky revealed webs of relationships that lead to vicious cycles of self-reinforcing problems (areas in gray in Figure 18) such as the linkages between lack of transparency and lack of public scrutiny, and those between corruption and inequality.

**FIGURE 18. Causal Map of Systemic Patterns in Water and Wastewater Systems in Appalachian Case Studies, Showing Vicious Cycles that Entrench Inequity and Lack of Resilience**




*Source: Original Graphic Design by Phill Barnett*

Key findings from the PAR research to date included the following themes of importance to communities:

- Water governance issues: mismanagement of water systems, lack of transparency, fragmentation and siloing, inadequate resources, poor planning
- Water quality and safety: water pollution, frequent boil advisories
- Water affordability: increasing cost of water and water burden
- Water access and distribution: aging infrastructures and infrastructure failure, water loss, and lack of maintenance

In identifying these problems, we also identify long-term outcomes, potential interventions, and leverage points that can offer hope for improving resilience of these water systems in the face of increasing challenges that come with climate change, outlined in section 6.2 Looking Ahead below. As climate disasters like wildfires, droughts, and floods increase in frequency and intensity, the need for effective, community-first planning and operation of these rural water systems, including contingency planning, is becoming more urgent.

## 5.2 Climate Change Is Already Having Devastating Impacts on Rural Water and Communities

Climate change is already having devastating impacts on rural water and communities through increased weather variability, extremes, and unpredictability, extreme heat and cold, heavy precipitation and catastrophic flooding, drought, wildfire, and declining water quality. The scientific community expects these to continue and worsen. The climate impacts on rural water and sanitation systems include:

- Extreme flooding events lead to power and water outages, erosion and increased risk of landslides, mobilizing of pollutants, polluting of water sources, and contamination of rural community drinking water systems.
- Flooding poses a particular risk to decentralized rural water systems and private wells.
- Drought leads to rural groundwater declines through increased reliance on groundwater combined with lack of recharge.
- Wildfires are increasing in extent, duration, and severity and rural water is impacted by increased erosion, landslides, sediment, and contamination, making water resources and drinking water unsafe.
- Extreme temperatures harm rural water by decreasing water availability as well as contributing to declining water quality.
- Climate change is projected to increase the frequency and severity of extreme precipitation, and in Central Appalachia this will likely leading to more catastrophic floods in the region. Extreme precipitation events such as floods can damage water infrastructure and compromise water quality.
    - These events place rural water systems in the region at risk as already deteriorating water infrastructure can be damaged and water quality can be reduced.
- Climate change is expected to increase the frequency and severity of drought in many areas of the U.S., specifically in the Southwest and Southern Great Plains. These droughts impact rural water systems by reducing snowpack, which directly reduces water availability, increasing concentrations of contaminants in water, and increasing wildfire risk.
    - The Southwest experienced a megadrought over the last two decades, recognized as the driest 24 years of the last 1,200. By 2100, single year droughts could increase by as much as 25%, and multi-year droughts could increase by as much as 50%.

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## 5.3 An Integrative and Collaborative Community-Centered and Asset-Based Approach Is Necessary for Better Understanding and Addressing Climate Vulnerability and Resilience in Rural Water Systems

This assessment integrated a "vulnerability" focus with an asset framing to center community resilience. An asset-based approach illuminates problems, capacities, and potential strategies and solutions for equitable, climate-resilient water and sanitation that would not be visible if you were not looking from the community perspective.

In a resilience-centered framework, the focus is first on the assets that a community already has, working to build on those assets in preparing for climate change impacts on rural water. The role of TAPs, nonprofits, and government agencies provides the support network for bridging resources for communities to act and to envision the change. To co-design and cocreate sustainable water and climate resilience, it is vital to contextualize current work in an understanding of the local conditions, climate patterns, political economic histories, and cultures of places. This assessment has served as a vehicle to portray that transition to more equitable, climate resilient water and sanitation systems for rural communities.

Another theme central to this work was the interdisciplinarity and engaging of multiple perspectives, knowledges, and ways of knowing and observing, which are required to understand both the impacts of and solutions to climate impacts on rural water systems. It requires an understanding of past, current, and future climate realities and how they are likely to affect rural water availability and infrastructure. At the same time, it also requires the understanding of social dimensions in a specific community — including history, culture, demographics, and vulnerability to climate impacts. This project aimed to understand the intersection of these knowledges — technical climate sciences and place-based knowledges — to realize adaptive capacity and potential climate-resilient solutions.

This project approach led to many lessons learned across each partner organization. Each organization learned from one another as well as the TAPs and the communities themselves. Additionally, finding a common language and constant communication were important lessons learned as decision support materials and tools were tailored for new and diverse audiences. The emphasis on local knowledge and community relationships also lent itself to many new insights and better understandings of what communities really needed. Finally, each team reflected on relationship building as a central component of the project and embraced the slow speed and complexity of building trust.

## 5.4 While Significant Barriers and Challenges Exist Related to Inequities, Funding, and Technical or Managerial Capacity, for Example, Existing Community-Based Social, Natural, and Physical Assets Provide Opportunities to Build on Inherent Community Resilience for Achieving Equitable, Climate-Resilient Rural Water

Many rural frontline communities lack the capacity to apply for new federal climate change adaptation and water infrastructure funding or for planning and implementing emergency and climate preparedness and response measures. There is a lot of time required in resilience planning and preparedness — communities often must first focus on more immediate issues. However, models exist for innovative and collaborative support through understanding and leveraging community assets.

Human, social, and natural capital provide important assets upon which to build resilience. An asset-based approach illuminates vital resources and approaches that can be overshadowed if one does not look from the perspective of communities. A key finding from the Appalachian case studies was that government and technical assets are often disconnected from community assets. Past histories of marginalization and injustice have left behind gaps that cut local human, social, and natural capital off from the day-to-day management of public water and sanitation systems. If these gaps were overcome, it could unleash significant new capacities.

We found strong social and human capital within the communities that emerged from past challenges. For instance, over the past century, these communities have experienced repeated flooding, exacerbated by coal mining and now climate change. The economic and psychological traumas from these extreme events have been severe. However, a rich sense of solidarity and a strongly rooted culture of mutual aid among community members has emerged from disaster. During flooding in July 2022, described earlier, through caring and neighborly help, communities' self-organization and collaboration made visible the diverse ways of responding to threats or disasters and alternative responses to risk. Traditional skills, resourcefulness, and ingenuity (human capital) are also evident during disasters, as community members pitch in using chainsaws, mops, buckets, shovels, all-terrain vehicles (ATVs), boats, trucks, and other tools to clear roadways, rescue neighbors from rooftops and trees, or clean affected houses, businesses, and other buildings.

> A rich sense of solidarity and a strongly rooted culture of mutual aid among community members has emerged from disaster.

In small, rural communities, human relationships and personal connections are some of the most important assets. Information exchange can take place rapidly through social media and word of mouth particularly. Local newspapers can also provide information and communications capital and publish information about water board meetings, outages, and our water and climate work. In addition, the presence of civic spaces is important for public discourse, such as locally owned restaurants and cafes that offer space for community meetings to discuss water and climate issues.

Knowing the people in positions of power and authority who are impacting decisions is possible in such small communities. Structures of transparency can provide leverage points for dismantling the obstacles created by local inequality. Personal relationships and connections may also provide a measure of accountability.

An asset-based approach disclosed this history as a history of resilience. Using this approach, our listening project identified multiple examples of community resilience in which community members feel great pride and self-efficacy. Documentation of these successes has laid the foundation for our ongoing work to build climate resilience. In this approach, communities can build on past successes rather than vulnerabilities. By foregrounding community resilience, we can rebuild connectivity both within the community and in relationships across sectors. Distrust can only be overcome by new experiences of empowerment and mutually respectful relationships. Ongoing analysis of data from the Appalachian case studies is identifying the ways in which information flows more effectively across sectors when relational gaps are overcome.

Finally, Central Appalachia's communities have valuable natural capital in the form of abundant rainfall, natural waterways, forests, and natural beauty. Many of these assets are in a degraded state with polluted streams and groundwater, large scale timbering, and a century and a half of coal mining with little regard for its effects. Natural springs are highly valued among people living in Harlan and Martin Counties, as they are in the wider Central Appalachia region, being considered trustworthy — even in times of drought, or when people distrust their tap water, many residents gather drinking water from natural springs, even if they must drive long distances.

If we can reconnect government, technical, and community assets, it could significantly improve management and design. Problems of fiscal mismanagement benefit from the elucidation of citizen participation and oversight. Hard choices regarding consolidation, redesign, and rebuilding benefit from public dialogue that includes local knowledge. Equity and sustainability of solutions depends on relationships in which the felt needs can be expressed without fear or favor across all the diversity of community subgroups (especially the most marginalized and underserved).

## 5.5 Tailored and Easily Accessible Technical Assistance and Tools Can Support Rural Communities in Achieving Equitable, Climate-Resilient Water and Sanitation Systems

TAPs and other water management professionals will benefit from increased understanding of current and projected climate change and its impacts on water management, flexible and adaptive management strategies, and strategic communication with community members and other stakeholders. Technical assistance efforts and methods exist for increasing the resilience of water infrastructure to promote resilience in the face of disasters and climate disruptions, particularly in overburdened, underresourced rural communities. These could include identifying potential climate disruptions within a specific radius of community water systems, providing an overview of and educating the community on the types of disasters that could impact the community's water system, creating a network of water operators in nearby regions to promote connectedness and support during times of disasters, developing educational materials and trainings to future-proof current technologies for water systems, and creating Geographic Information System (GIS) maps of vulnerable water systems in the community based on potential disasters in the region. Appropriate metrics for measuring the success of these resilience methods can be applied and can include the development of a baseline understanding of where local water systems stand in terms of resilience. Conditions can be continually monitored over time to track progress towards resilience and can include creating GIS maps and lists of potential hazards, creating contact sheets for local water operators, and education activities with pre- and post-assessment questionnaires. To be effectively implemented by TAPs, it is recommended that monitoring methods be easily accessible and include qualitative data gathering.

Finally, funding options to support technical assistance efforts towards resilience can include federal, philanthropic, and private funding sources (for more details, see Appendix B).

A summary of key areas of interest identified through our engagement with TAPs throughout the country include:

- More involvement with other agencies and partners (such as universities or states)
- Increased capacity building at the local level
- Building more climate and disaster resilience deliverables into large grants
- Using GIS tools to assess and understand climate change impacts
- Creating resources for pre-and-post-disaster and resilience funding options
- Tailored disaster preparedness and management training
- Identifying a list of potential climate disruptions that could occur within or near a community's water systems
- Providing an overview to educate the community on types of disasters that could impact the community water system
- Creating a list of nearby water operators for support during time of disaster
- Developing educational materials or trainings for future-proofing current water systems
- Creating GIS maps of most vulnerable water systems based on climate disasters


*The archives of the historic Hindman Settlement School on Troublesome Creek in Hindman, Kentucky, destroyed by floodwaters in July 2022 .*

# 6. Conclusion

## 6.1 Wider Significance of the Findings of the Water and Climate Equity Project

Our combined and integrated climate change research, deep listening in and support for affected communities, and work with TAPs revealed a set of physical, technical, financial, and institutional problems. From one angle, these barriers can appear to be unsurmountable. From another angle, these can be seen as potential points of leverage where constructive new forces can be applied to clear the ground for new pathways and potential strategies towards resilience and equity.

The climate change research elucidated that across the United States current and future impacts of climate change can have devastating impacts for rural water systems, local communities, economies, and ecosystems. Water and sanitation systems in rural frontline communities across the country will continue to be among those that experience the impacts of climate change first and worst, including challenges with water and sanitation access, water supply, availability, and quality. Rural communities experience these impacts disproportionately due to many factors, including being overburdened and underresourced and being impacted by historical pathways of development. The focus on Central Appalachia and the U.S. Southwest within this report demonstrate the nexus of these impacts in regional contexts.

This research demonstrated the significance of understanding current and projected climate change impacts on rural water systems in the United States to create adaptive and locally relevant planning and management strategies that take a "community-first" approach. Collecting data to understand and communicate local climate risks to rural water systems is a critical step to increase resilience. Meaningfully including local stakeholders, such as nonprofits and community members, in ongoing climate resilience planning discussions helps ensure that solutions are flexible and uniquely tailored to the local community. Such approaches are needed to build local resilience and capacity as climate change accelerates.

Further, mismanagement, poor governance, and/or lack of institutional capacity can leave these systems in worse financial condition. Some lack capacity for robust financial management and record keeping and are unable to meet requirements to receive federal or state grants and loans. Lack of transparency and trust between water utilities/providers and the communities they serve can hinder the development of institutional capacity and the benefits that can be provided by engaged and involved residents supporting the systems. Thus, low-income communities face much greater hurdles than higher-income communities in developing equitable, climate-resilient water systems. This project has identified promising strategies and plans to test and develop those in the coming project period.

The capacity of these and other rural water systems can be strengthened by building trust within the local community through developing transparency and engaging residents. Based on what we learned through deep engagement with communities and TAPs, a Community Engagement Guide and a Water Resilience Toolkit are being co-developed to engage citizens in learning about and interacting with their water systems. In addition, nonprofits can serve as helpful intermediaries to connect outside stakeholders, community members, water system providers, and regulators.

This research also demonstrated that the capacities of rural water systems can be strengthened through technical assistance. Deep listening to TAPs in rural communities across the United States identified strategies to build capacity within rural water systems. These strategies include collaborating with agencies, partners, and universities; building climate resilience deliverables into large grants; disaster management training and preparation; and educating communities on the types of disasters that can impact water systems. TAPs also discussed the needs to easily understand, find, and sort through resources and tools and for a quick and easy reference guide to explain to various stakeholders and decision-makers why preparation is important to prioritize and invest in. We created useful tools and resources, such as an accessible collection of tools for climate change, water, and environmental justice, toolkits, fact sheets, and issue briefs with input from our partners and TAPs to address the these needs. We have also begun steps towards addressing their needs with a new approach to active, interactive, and inclusive planning and preparation activities for communities and utilities, outlined in section 6.2 Looking Ahead to follow. These efforts will actively help frontline rural communities achieve better outcomes in the face of new climate realities and can be developed and scaled to fit the unique contexts of different rural water systems across the United States.

The disproportionate climate impacts and complex challenges faced by rural water and sanitation systems across the United States can be understood and addressed with more nuance and complexity when framed by different ways of knowing. Working across the distinct but overlapping sets of expertise of LiKEN, RCAP, and PI provided a model for this type of framing, which can be adjusted and scaled for use in other communities and regions. This co-produced report outlines broader climate risks, structural issues, community assets, and barriers to adaptation that affect rural water systems across the country and further demonstrates how this framing can be dialed in at regional and local scales to begin to move towards locally appropriate practices, policies, and solutions to build resilience.

## 6.2 Looking Ahead

The PAR in Central Appalachia revealed some opportunities that have potential to improve the provision of clean, reliable, and affordable drinking water and prepare systems to respond to catastrophic flooding and other climate impacts. Importantly, this would engage and center local community members in matters relating to their water systems. From here, we will be ground testing the decision support information and tools prepared based on the findings of this research. The Community Engagement Guide and the Water Resilience Toolkit should provide, respectively, methods to involve more people in engaging with their water systems and to provide clear, accessible information that will help residents better understand how to prepare those systems for climate change. In addition, LiKEN's Community Engagement Coordinators have painstakingly built relationships and trust with both residents and water system officials, through honest, accurate, and reliable communication that laid the fertile ground upon which this work will continue to grow. These guides and methods provide promising models for improving trust and communication among residents, outside experts, and water systems through formal and informal channels.

We are also developing a new approach to climate and emergency preparedness and response tabletop exercises, activities in which key decision-makers and action-takers gather to practice their response to a simulated climate emergency on their water system. These will be co-developed and piloted with RCAP TAPs in at least two regions to start. The activity is facilitated and led by a trained facilitator, such as a TAP, so that the community can be expertly guided through the experience. The activity takes the form of gathering key personnel, decision-makers, and other relevant municipal, utility, or other staff for an interactive practice session to respond to an emergency. Acting out an emergency scenario forces the utility and community leaders to identify through experience any gaps in their knowledge and plans so, in the future, they can work to close them as well as test their assumptions and identify where they need more robust plans and information prepared. It also makes them feel less panicked in a real-life emergency or extreme scenarios, helping them make better decisions.

The tabletop exercises can also reinforce the need for stronger relationships both within and outside of their existing networks and communities by forcing the question of “who can you call for help with … ” based on gaps identified through the process. In part, the experience also helps them to stress-test their existing emergency response plan and use the experience to improve it for the future. This new approach to tabletop exercises will add a focus on the development of relationships and trust with community members. Rather than simply practicing how to communicate with and between utility staff, community elected officials, or other leaders, tabletop exercises will instruct how to communicate and engage with residents. We believe there is mutual benefit for utilities, municipalities, and residents in building these relationships and establishing lines of communication. Together, these practices of improving preparedness for climate emergencies and improving engagement, communication, and collaboration between the municipality, utility, and members of the community will help the rural water systems we serve to become more equitable and climate resilient.

Our long-term theory of change is to create actionable research aiming to influence and inform policy and practice. The overall long-term outcome envisioned is that water equity and resilience strategies are mainstreamed into policy and practice. Within this there are two interrelated outcomes of 1) enhancing policy to support the creation of more equitable and effective policy and legal frameworks relating to water equity and resilience, and 2) enhancing practice to improve and increase the uptake of climate and water equity and resilience practices for long-term equitable, climate-resilient rural water and sanitation systems for all.

# References


Adger, W. Neil. 2006. "Vulnerability." *Global Environmental Change* 16 (3): 268–81. https://doi.org/10.1016/j.gloenvcha.2006.02.006.

Akamani, Kofi. 2023. "Path Dependence, Community Resilience, and Social Responses to the Implementation of Collaborative Forest Management in Ghana" 17 (1): 22–36. https://doi.org/10.5334/ijc.1171.

American Water Works Association. 2022. "'Utilities Helping Utilities' Bring Water Heroes to Eastern Kentucky Flood Cleanup." *American Water Works Association Connections*, September 7, 2022. https://www.awwa.org/AWWA-Articles/utilities-helping-utilities-bring-water-heroes-to-eastern-kentucky-flood-cleanup.

Appalachian Land Ownership Task Force. 1983. *Who Owns Appalachia?: Landownership and Its Impact*. University Press of Kentucky. https://www.jstor.org/stable/j.ctt130j5d6.

Appalachian Regional Commission. 2021. "Subregions in Appalachia." Research, Evaluations, Maps and Data. 2021. https://www.arc.gov/map/subregions-in-appalachia/.

Bankoff, Gregory. 2001. "Rendering the World Unsafe: 'Vulnerability' as Western Discourse." *Disasters* 25 (1): 19–35. https://doi.org/10.1111/1467-7717.00159.

Bell, Shannon Elizabeth. 2016. *Fighting King Coal: The Challenges to Micromobilization in Central Appalachia*. MIT Press. https://mitpress.mit.edu/9780262528801/fighting-king-coal/.

Bennett, Andrew, and Colin Elman. 2006. "Complex Causal Relations and Case Study Methods: The Example of Path Dependence." *Political Analysis* 14 (3): 250–67. https://www.jstor.org/stable/25791852.

Berkes, Fikret, Carl Folke, and Johan Colding, eds. 1998. *Linking Social and Ecological Systems: Management Practices and Social Mechanisms for Building Resilience*. Cambridge, U.K. ; New York: Cambridge University Press. https://searchworks.stanford.edu/view/3834100.

Berkes, Fikret, Johan Golding, and Carl Folke, eds. 2003. *Navigating Social-Ecological Systems: Building Resilience for Complexity and Change*. Cambridge: Cambridge University Press. https://assets.cambridge.org/052181/5924/sample/0521815924ws.pdf.

Bernhardt, Emily S., Brian D. Lutz, Ryan S. King, John P. Fay, Catherine E. Carter, Ashley M. Helton, David Campagna, and John Amos. 2012. "How Many Mountains Can We Mine? Assessing the Regional Degradation of Central Appalachian Rivers by Surface Coal Mining." *Environmental Science & Technology* 46 (15): 8115–22. https://doi.org/10.1021/es301144q.

Billings, Dwight B., and Kathleen M. Blee. 2000. *The Road to Poverty: The Making of Wealth and Hardship in Appalachia*. Cambridge, UK: Cambridge University Press. https://books.google.com/books?id=W3KPyqOaxCUC&printsec=frontcover&source=gbs_ge_summary_r&cad=0#v=onepage&q&f=false.

Bladon, Kevin D., Monica B. Emelko, Uldis Silins, and Micheal Stone. 2014. "Wildfire and the Future of Water Supply." *Environmental Science & Technology* 48 (16): 8936–43. https://doi.org/10.1021/es500130g.

Blaikie, P, T Cannon, I Davis, and B Wisner. 1994. *At Risk - Natural Hazards, People's Vulnerability, and Disasters*. London: Routledge.

Bos, J. J., R. R. Brown, and M. A. Farrelly. 2013. "A Design Framework for Creating Social Learning Situations." *Global Environmental Change* 23 (2): 398–412. https://doi.org/10.1016/j.gloenvcha.2012.12.003.

Brenner, Thomas, and Sonja Zu Jeddeloh. 2024. "Path Dependence in an Evolving System: A Modeling Perspective." *Cliometrica* 18. https://link.springer.com/content/pdf/10.1007/s11698-023-00266-z.pdf.

Brown, H. Carolyn Peach. 2009. "Climate Change and Ontario Forests: Prospects for Building Institutional Adaptive Capacity." *Mitigation and Adaptation Strategies for Global Change* 14 (6): 513–36. https://doi.org/10.1007/s11027-009-9183-8.

Bruggers, James. 2019. "Appalachia's Strip-Mined Mountains Face a Growing Climate Risk: Flooding." *Inside Climate News*, November 21, 2019. https://insideclimatenews.org/news/21112019/appalachia-mountains-flood-risk-climate-change-coal-mining-west-virginia-extreme-rainfall-runoff-analysis/.

Bruursema, Cherry Stoltenberg. 2015. "Asset-Based Community Development: A Path Troward Authentic Community Development Practice." *SPNHA Review* 11 (1). https://scholarworks.gvsu.edu/cgi/viewcontent.cgi?article=1046&context=spnhareview.

Bullard, Robert D. n.d. "Environmental Justice." Accessed July 1, 2024. https://drrobertbullard.com/.

Butler, Patricia R., Louis Iverson, Frank R. Thompson, Leslie Brandt, Stephen Handler, Maria Janowiak, P. Danielle Shannon, et al. 2015. "Central Appalachians Forest Ecosystem Vulnerability Assessment and Synthesis: A Report from the Central Appalachians Climate Change Response Framework Project." U.S. Department of Agriculture, Forest Service, Northern Research Station. https://search.informit.org/doi/10.3316/agis.20211218058598.

Cardona, Omar Dario, Maarten K. Van Aalst, Jörn Birkmann, Maureen Fordham, Glenn Mc Gregor, Perez Rosa, Roger S. Pulwarty, et al. 2012. "Determinants of Risk: Exposure and Vulnerability." In *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation: Special Report of the Intergovernmental Panel on Climate Change*, 65–108. Cambridge University Press. https://doi.org/10.1017/CBO9781139177245.005.

Carter, Lynne M., Adam Terando, Kirstin Dow, Kevin Hiers, Kenneth E. Kunkel, Aranzazu Lascurain, Douglas C. Marcy, Michael J. Osland, and Paul J. Schramm. 2018. "Chapter 19 : Southeast. Impacts, Risks, and Adaptation in the United States: The Fourth National Climate Assessment, Volume II." U.S. Global Change Research Program. https://doi.org/10.7930/NCA4.2018.CH19.

Chow, Alex T., Kuo-Pei Tsai, Timothy S. Fegel, Derek N. Pierson, and Charles C. Rhoades. 2019. "Lasting Effects of Wildfire on Disinfection By-Product Formation in Forest Catchments." *Journal of Environmental Quality* 48 (6): 1826–34. https://doi.org/10.2134/jeq2019.04.0172.

Christmann, Stefanie, Aden Aw-Hassan, Toshpulot Rajabov, and Abdullo Rabbimov. 2015. "Collective Action for Common Rangelands Improvement: A Climate Change Adaptation Strategy in Uzbekistan." *Society & Natural Resources* 28 (3): 280–95. https://doi.org/10.1080/08941920.2014.933927.

Cohen, Alasdair, Md Rasheduzzaman, Amanda Darling, Leigh-Anne Krometis, Marc Edwards, Teresa Brown, Tahmina Ahmed, et al. 2022. "Bottled and Well Water Quality in a Small Central Appalachian Community: Household-Level Analysis of Enteric Pathogens, Inorganic Chemicals, and Health Outcomes in Rural Southwest Virginia." *International Journal of Environmental Research and Public Health* 19 (14): 8610. https://doi.org/10.3390/ijerph19148610.

Cohen, Judah, Laurie Agel, Mathew Barlow, Chaim I. Garfinkel, and Ian White. 2021. "Linking Arctic Variability and Change with Extreme Winter Weather in the United States." *Science* 373 (6559): 1116–21. https://doi.org/10.1126/science.abi9167.

Cohen, Michael. 2023. "Managing the Unmeasured - Colorado River." *Pacific Institute* (blog). January 31, 2023. https://pacinst.org/managing-the-unmeasured-colorado-river/.

Colby, Bonnie G., and Hannah Hansen. 2022. "Colorado Basin Incentive-Based Urban Water Policies: Review and Evaluation." *JAWRA Journal of the American Water Resources Association* 58 (6): 1098–1115. https://doi.org/10.1111/1752-1688.13041.

Cooley, Heather, Michael Cohen, Rapichan Phurisamban, and Guillaume Gruère. 2016. "Water Risk Hotspots for Agriculture: The Case of the Southwest United States." Paris: OECD. https://doi.org/10.1787/5jlr3bx95v48-en.

Daniels, Elizabeth, Sukaina Bharwani, Åsa Gerger Swartling, Gregor Vulturius, and Karen Brandon. 2020. "Refocusing the Climate Services Lens: Introducing a Framework for Co-Designing 'Transdisciplinary Knowledge Integration Processes' to Build Climate Resilience." *Climate Services* 19. https://doi.org/10.1016/j.cliser.2020.100181.

DeCoste, Sam. 2023. “Tragedy in the Mountains: Bridges, Water Systems Still under Repair after 2022 Eastern Kentucky Flooding.” *WOWK 13 News*, June 28, 2023. https://www.wowktv.com/news/kentucky/tragedy-in-the-mountains/tragedy-in-the-mountains-bridges-water-systems-still-under-repair-after-2022-eastern-kentucky-flooding/.

Deitz, Shiloh, and Katie Meehan. 2019. “Plumbing Poverty: Mapping Hot Spots of Racial and Geographic Inequality in U.S. Household Water Insecurity.” *Annals of the American Association of Geographers* 109 (4): 1092–1109. https://doi.org/10.1080/24694452.2018.1530587.

Dilling, Lisa, and Maria Carmen Lemos. 2011. “Creating Usable Science: Opportunities and Constraints for Climate Knowledge Use and Their Implications for Science Policy.” *Global Environmental Change*, Special Issue on The Politics and Policy of Carbon Capture and Storage, 21 (2): 680–89. https://doi.org/10.1016/j.gloenvcha.2010.11.006.

Domke, G.M., C.J. Fettig, A.S. Marsh, M. Baumflek, William A. Gould, J.E. Halofsky, L.A. Joyce, et al. 2023. “Ch 7. Forests.” In *Fifth National Climate Assessment*. Washington, DC, USA: U.S. Global Change Research Program. https://nca2023.globalchange.gov/chapter/7/.

Eakin, Hallie, and Maria Carmen Lemos. 2006. “Adaptation and the State: Latin America and the Challenge of Capacity-Building under Globalization.” *Global Environmental Change* 16 (1): 7–18. https://www.researchgate.net/publication/222579992_Adaptation_and_the_State_Latin_America_and_the_Challenge_of_Capacity-Building_under_Globalization.

Easterling, D.R., K.E. Kunkel, J.R. Arnold, T. Knutson, A.N. LeGrande, L.R. Leung, R.S. Vose, D.E. Waliser, and M.F. Wehner. 2017. “Precipitation Change in the United States.” In *Climate Science Special Report: Fourth National Climate Assessment*, edited by D.J. Wuebbles, D.W. Fahey, K.A. Hibbard, D.J. Dokken, B.C. Stewart, and T.K. Maycock, Volume I:207–30. Washington, D.C.: US Global Change Research Program. https://science2017.globalchange.gov/chapter/7/.

Edin, Kathryn J., Luke H. Shaefer, and Timothy J. Nelson. 2023. *The Injustice of Place*. New York and Boston: Mariner Books. https://www.harperacademic.com/book/9780063239500/the-injustice-of-place.

Eitan, Avri, and Marko P. Hekkert. 2023. “Locked in Transition? Towards a Conceptualization of Path-Dependence Lock-Ins in the Renewable Energy Landscape.” *Energy Research & Social Science* 106 (December):103316. https://doi.org/10.1016/j.erss.2023.103316.

Eller, Ronald D. 1982. *Miners, Millhands, and Mountaineers: Industrialization of the Appalachian South, 1880-1930*. Univ. of Tennessee Press. https://utpress.org/title/miners-millhands-mountaineers/.

Emery, Mary, and Cornelia Flora. 2020. “Spiraling-Up: Mapping Community Transformation with Community Capitals Framework.” In *50 Years of Community Development Vol I*. Routledge.

Euripidou, E., and V. Murray. 2004. “Public Health Impacts of Floods and Chemical Contamination.” *Journal of Public Health* 26 (4): 376–83. https://doi.org/10.1093/pubmed/fdh163.

Every, Danielle, Jim McLennan, Elizabeth Osborn, and Chris Cook. 2021. “Experiences of Heat Stress While Homeless on Hot Summer Days in Adelaide.” *The Australian Journal of Emergency Management* 36 (4): 55–61. https://doi.org/10.3316/informit.194205791860536.

Faas, A. J. 2016. "Disaster Vulnerability in Anthropological Perspective." *Annals of Anthropological Practice* 40 (1): 14–27. https://doi.org/10.1111/napa.12084.

FEMA. 2023. "FEMA Community Resilience Challenges Index (CRCI) Counties - Overview." May 15, 2023. https://www.arcgis.com/home/item.html?id=ff17676850114091b28cb4c502e9fb4e.

Fentress and Fausett. 2021. "'You Can't Bathe. You Can't Wash.' Water Crisis Hobbles Jackson, Miss., for Weeks." The New York Times. https://www.nytimes.com/2021/03/12/us/jackson-mississippi-water-winter-storm.html.

Floriani, Lidia Mara, and Edilberto Nunes De Moura. 2021. "The Social Construction of Natural Disasters: A Systematic Review of the Literature." In *Integrating Social Responsibility and Sustainable Development*, edited by Walter Leal Filho, Ubiratã Tortato, and Fernanda Frankenberger, 309–20. World Sustainability Series. Cham: Springer International Publishing. https://doi.org/10.1007/978-3-030-59975-1_20.

Ford, James D., Maggie Knight, and Tristan Pearce. 2013. "Assessing the 'Usability' of Climate Change Research for Decision-Making: A Case Study of the Canadian International Polar Year." *Global Environmental Change* 23 (5): 1317–26. https://doi.org/10.1016/j.gloenvcha.2013.06.001.

Francis, Jennifer A., Natasa Skific, Steven J. Vavrus, and Judah Cohen. 2022. "Measuring 'Weather Whiplash' Events in North America: A New Large-Scale Regime Approach." *Journal of Geophysical Research: Atmospheres* 127 (17): e2022JD036717. https://doi.org/10.1029/2022JD036717.

Gabrielle Roesch-McNally and Holly R. Prendeville. 2017. "Making Sense of Coproduction: What Is It Good For?" Northwest Climate Hub.

Gaillard, JC. 2019. "Disaster Studies inside Out." *Disasters* 43 (S1): S7–17. https://doi.org/10.1111/disa.12323.

Galende-Sánchez, Ester, and Alevgul H. Sorman. 2021. "From Consultation toward Co-Production in Science and Policy: A Critical Systematic Review of Participatory Climate and Energy Initiatives." *Energy Research & Social Science* 73 (March):101907. https://doi.org/10.1016/j.erss.2020.101907.

García, Ivis. 2020. "Asset-Based Community Development (ABCD): Core Principles." In *Research Handbook on Community Development*, edited by Rhonda Phillips, Eric Trevan, and Patsy Kraeger. Edward Elgar Publishing. https://www.researchgate.net/publication/370181273_Asset-Based_Community_Development_ABCD_core_principles.

Gaventa, John. 1982. *Power and Powerlessness: Quiescence and Rebellion in an Appalachian Valley*. University of Illinois Press. https://www.press.uillinois.edu/books/?id=p009853.

Goldstein, Jenny E., Benjamin Neimark, Brian Garvey, and Jacob Phelps. 2023. "Unlocking 'Lock-in' and Path Dependency: A Review across Disciplines and Socio-Environmental Contexts." *World Development* 161 (January):106116. https://doi.org/10.1016/j.worlddev.2022.106116.

Gonzales-Iwanciw, Javier, Art Dewulf, and Sylvia Karlsson-Vinkhuyzen. 2020. "Learning in Multi-Level Governance of Adaptation to Climate Change – a Literature Review." *Journal of Environmental Planning and Management* 63 (5): 779–97. https://doi.org/10.1080/09640568.2019.1594725.

Gonzalez, Patrick, Gregg M. Garfin, David D. Breshears, Keely M. Brooks, Heidi E. Brown, Emile H. Elias, Amrith Gunasekara, et al. 2018. "Southwest." In *Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment*, edited by David R. Reidmiller, David R. Easterling, Kenneth E. Kunkel, Kristin L.M. Lewis, Thomas K. Maycock, and Brooke C. Stewart, Volume II:1101–84. Washington, DC, USA: US Global Change Research Program. https://doi.org/10.7930/NCA4.2018.CH25.

Gunderson, Lance H., and C.S. Holling, eds. 2002. *Panarchy: Understanding Transformations in Human and Natural Systems*. Washington: Island Press. https://archive.org/details/panarchyundersta0000unse.

HAINES, ANNA. 2014. "Asset-Based Community Development." In *An Introduction to Community Development*, 2nd ed. Routledge.

Hales, D., W Hohenstein, M.D. Bidwell, C Landry, D McGranahan, J. Molnar, L.W Morton, M. Vasquez, and J Jadin. 2014. "Ch. 14: Rural Communities." In *Climate Change Impacts in the United States: The Third National Climate Assessment*, 333–49. U.S. Global Change Research Program. http://nca2014.globalchange.gov/report/sectors/rural-communities.

Harvey, Chelsea. 2022. "'We Are Climate Zero.' Why Appalachia Faces Perilous Floods." *E&E News*, August 3, 2022, sec. Climatewire. https://www.eenews.net/articles/we-are-climate-zero-why-appalachia-faces-perilous-floods/.

Hayhoe, Katharine, Donald J. Wuebbles, David R. Easterling, David W. Fahey, Sarah Doherty, James P. Kossin, William V. Sweet, Russell S. Vose, and Michael F. Wehner. 2018. "Chapter 2 : Our Changing Climate." In *Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment Volume II*, 72–144. Washington, DC, USA: U.S. Global Change Research Program. https://doi.org/10.7930/NCA4.2018.CH2.

Hewitt, K. 2019. *Interpretations of Calamity: From the Viewpoint of Human Ecology*. Routledge.

Hilhorst, Dorothea. 2003. "Responding to Disasters: Diversity of Bureaucrats, Technocrats and Local People." *International Journal of Mass Emergencies & Disasters* 21 (1): 37–55. https://doi.org/10.1177/028072700302100102.

Hoffman, J.S., S.G. McNulty, C. Brown, K.D. Dello, P.N. Knox, A. Lascurain, C. Mickalonis, et al. 2023. "Ch 22. Southeast." In *Fifth National Climate Assessment*. Washington, DC, USA: U.S. Global Change Research Program. https://nca2023.globalchange.gov/chapter/22/.

Hornsey, Matthew J., and Stephan Lewandowsky. 2022. "A Toolkit for Understanding and Addressing

Climate Scepticism." *Nature Human Behaviour* 6 (11): 1454–64. https://doi.org/10.1038/s41562-022-01463-y.

Hufford, Mary and Taylor, Betsy. 2013. "Edgework and Boundary Crossings: Assessing Foundations for Public Ecology in the Appalachian Region." In *Environmental Considerations in Energy Production*, 99–110. Society for Mining, Metallurgy, and Exploration, Inc.

Indian Health Service. 2013. "Disparities | Fact Sheets." Newsroom. January 1, 2013. https://www.ihs.gov/newsroom/factsheets/disparities/.

Intergovernmental Panel on Climate Change. 2022. "Climate Change 2022: Impacts, Adaptation, and Vulnerability." In . Cambridge, UK and New York, NY, USA: Cambridge University Press. https://report.ipcc.ch/ar6/wg2/IPCC_AR6_WGII_FullReport.pdf.

Intergovernmental Panel On Climate Change. 2023. *Climate Change 2022 – Impacts, Adaptation and Vulnerability: Working Group II Contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. 1st ed. Cambridge University Press. https://doi.org/10.1017/9781009325844.

Ison, Ray, and Ed Straw. 2020. *The Hidden Power of Systems Thinking: Governance in a Climate Emergency*. Routledge.

Jantarasami, Lesley, Rachael Novak, Roberto Delgado, Christopher Narducci, Elizabeth Marino, Shannon McNeeley, Julie Raymond-Yakoubian, Loretta Singletary, and Kyle Powys Whyte. 2018. "Chapter 15 : Tribal and Indigenous Communities. Impacts, Risks, and Adaptation in the United States: The Fourth National Climate Assessment, Volume II." U.S. Global Change Research Program. https://doi.org/10.7930/NCA4.2018.CH15.

Jasanoff, Sheila, ed. 2004. *States of Knowledge : The Co-Production of Science and Social Order.* Routledge Taylor&Francis Group. London. https://www.taylorfrancis.com/books/edit/10.4324/9780203413845/states-knowledge-sheila-jasanoff

Jay, Alexa K., Allison R. Crimmins, Christopher W. Avery, Travis A. Dahl, Rebecca S. Dodder, Benjamin D. Hamlington, Allyza Lustig, et al. 2023. "Overview: Understanding Risks, Impacts, and Responses." Edited by A.R. Crimmins, C.W. Avery, D.R. Easterling, K.E. Kunkel, B.C. Stewart, and T.K. Maycock. *Fifth National Climate Assessment*. Washington, DC, USA: U.S. Global Change Research Program. https://doi.org/10.7930/NCA5.2023.CH1.

Jiménez, Jesus, and April Rubin. 2022. "8 Dead as Flash Flooding Swamps Parts of Kentucky." *The New York Times*, July 28, 2022, sec. U.S. https://www.nytimes.com/2022/07/28/us/kentucky-flash-flooding.html.

Kais, Shaikh Mohammad and Islam, MD Saidul. 2016. "Community Capitals and Community Resilience to Climate Change: Conceptual Connections." Google Docs. December 6, 2016.

Kalafatis, Scott E., Maria Carmen Lemos, Yun-Jia Lo, and Kenneth A. Frank. 2015. "Increasing Information Usability for Climate Adaptation: The Role of Knowledge Networks and Communities of Practice." *Global Environmental Change* 32:30–39. https://www.sciencedirect.com/science/article/abs/pii/S0959378015000266.

Karkainen, Bradley C. 2003. “Collaborative Ecosystem Governance: Scale Complexicy and Dynamism.” *Virginia Environmental Law Journal* 21:189–243.

Keen, M, T Bruck, and R Dyball. 2005. “Social Learning: A New Approach to Environmental Management.” In *Social Learning in Environmental Management: Towards a Sustainable Future*, 3–21. London, UK: Earthscan.

Kenning, Chris, Connor Giffin, and James Bruggers. 2022. “‘I Can’t Do It Again’: Can Appalachia Blunt the Devastating Impacts of More Flooding, Climate Change?” *USA Today*, August 8, 2022. https://www.usatoday.com/story/news/nation/2022/08/07/kentucky-flooding-appalachia-climate-change/10215762002/.

Kentucky Center for Statistics. 2016. “Poverty Rates by County.” Frankfort, KY: Kentucky Center for Statistics. https://kystats.ky.gov/Reports/ShowReports?ReportId=Map_PRC&publishDate=20161201.

Khan, Themrise, Kanakulya Dickson, and Maika Sondarjee, eds. 2023. *White Saviorism in International Development: Theories, Practices, and Lived Experiences*. Wakefield, Quebec, Canada: Daraja Press. https://www.tandfonline.com/doi/full/10.1080/02255189.2023.2253967.

Kochskamper, Elisa, Thomas M. Koontz, and Jens Newig. 2021. “Systematic Learning in Water Governance: Insights from Five Local Adaptive Management Projects for Water Quality Innovation.” *Ecology and Society* 26 (1). https://doaj.org/article/602aca6dcb6c484a95f78ed9f886c2a5.

Krishnan, Supriya, Nazli Yonca Aydin, and Tina Comes. 2021. “Planning Support Systems for Long-Term Climate Resilience: A Critical Review.” In *Urban Informatics and Future Cities*, edited by S. C. M. Geertman, Christopher Pettit, Robert Goodspeed, and Aija Staffans, 465–98. The Urban Book Series. Cham: Springer International Publishing. https://research.tudelft.nl/en/publications/planning-support-systems-for-long-term-climate-resilience-a-criti.

Lall, Upmanu, Thomas Johnson, Peter Colohan, Amir Aghakouchak, Sankar Arumugam, Casey Brown, Gregory J. Mccabe, and Roger S. Pulwarty. 2018. “Chapter 3 : Water. Impacts, Risks, and Adaptation in the United States: The Fourth National Climate Assessment, Volume II.” U.S. Global Change Research Program. https://research.tudelft.nl/en/publications/planning-support-systems-for-long-term-climate-resilience-a-criti.

Lang, Otto I., Derek Mallia, and S. McKenzie Skiles. 2023. “The Shrinking Great Salt Lake Contributes to Record High Dust-on-Snow Deposition in the Wasatch Mountains during the 2022 Snowmelt Season.” *Environmental Research Letters* 18 (6). https://www.researchgate.net/publication/370664423_The_shrinking_Great_Salt_Lake_contributes_to_record_high_dust-on-snow_deposition_in_the_Wasatch_Mountains_during_the_2022_snowmelt_season.

Lanikque Howard. 2022. “Addressing Water and Wastewater Challenges in Tribal Nations.” August 25, 2022. https://www.acf.hhs.gov/blog/2022/08/addressing-water-and-wastewater-challenges-tribal-nations

Lee, Kai N. 1993. *Compass and Gyroscope. Integrating Science and Politics for the Environment*. Washington, DC: Island Press. https://islandpress.org/books/compass-and-gyroscope.

Lemos, Maria Carmen, Christine J. Kirchhoff, and Vijay Ramprasad. 2012. "Narrowing the Climate Information Usability Gap." *Nature Climate Change* 2:789–94. https://www.nature.com/articles/nclimate1614.

Leung, L.R., Adam Terando, R. Joseph, G. Tselioudis, L.M. Bruhwiler, B. Cook, C. Deser, et al. 2023. "Ch 3. Earth Systems Processes." In *Fifth National Climate Assessment*. Washington, DC, USA: U.S. Global Change Research Program. https://nca2023.globalchange.gov/chapter/3/.

Levy, Barry S., and Cora Roelofs. 2019. "Impacts of Climate Change on Workers' Health and Safety." In *Oxford Research Encyclopedia of Global Public Health*. https://doi.org/10.1093/acrefore/9780190632366.013.39.

Levy, Zeno F., Bryant C. Jurgens, Karen R. Burow, Stefan A. Voss, Kirsten E. Faulkner, Jose A. Arroyo-Lopez, and Miranda S. Fram. 2021. "Critical Aquifer Overdraft Accelerates Degradation of Groundwater Quality in California's Central Valley During Drought." *Geophysical Research Letters* 48 (17): e2021GL094398. https://doi.org/10.1029/2021GL094398.

Lewandowsky, Stephan, Naomi Oreskes, James S. Risbey, Ben R. Newell, and Michael Smithson. 2015. "Seepage: Climate Change Denial and Its Effect on the Scientific Community." *Global Environmental Change* 33:1–13. https://doi.org/10.1016/j.gloenvcha.2015.02.013.

Lewis, Ronald L. 1998. *Transforming the Appalachian Countryside: Railroads, Deforestation, and Social Change in West Virginia, 1880-1920*. Univ of North Carolina Press. https://uncpress.org/book/9780807847060/transforming-the-appalachian-countryside/.

Lovato, Ny Keely. 2022. "Legal Mapping for Resilience Navajo Nation." Student paper. Program on Human Rights and the Global Economy, Northeastern University School of Law.

MacLeod, Mary Anne, and Akwugo Emejulu. 2014. "Neoliberalism With a Community Face? A Critical Analysis of Asset-Based Community Development in Scotland." *Journal of Community Practice* 22 (4): 430–50. https://doi.org/10.1080/10705422.2014.959147.

Maclure, Liam. 2023. "Augmentations to the Asset-Based Community Development Model to Target Power Systems." *Community Development* 54 (1): 4–17. https://www.tandfonline.com/doi/pdf/10.1080/15575330.2021.2021964.

Malecki, Kristen M. C., Amy A. Schultz, Dolores J. Severtson, Henry A. Anderson, and James A. VanDerslice. 2017. "Private-Well Stewardship among a General Population Based Sample of Private Well-Owners." *Science of The Total Environment* 601–602 (December):1533–43. https://doi.org/10.1016/j.scitotenv.2017.05.284.

Marino, Elizabeth K., and A.j. Faas. 2020. "Is Vulnerability an Outdated Concept? After Subjects and Spaces." *Annals of Anthropological Practice* 44 (1): 33–46. https://www.researchgate.net/publication/339440068_Is_Vulnerability_an_Outdated_Concept_After_Subjects_and_Spaces.

Marino, Elizabeth, Keely Maxwell, E. Eisenhauer, A. Zycherman, C. Callison, E. Fussell, M.D. Hendricks, et al. 2023. "Ch 20. Social Systems and Justice." In *Fifth National Climate Assessment*. Washington, DC, USA: U.S. Global Change Research Program. https://nca2023.globalchange.gov/chapter/20/.

Marvel, Kate, W Su, Roberto Delgado, S Aarons, A Chatterjee, M.E Garcia, Z Hausfather, et al. 2023a. "Ch 2. Climate Trends." In *Fifth National Climate Assessment*. Washington, DC, USA: U.S. Global Change Research Program.

McCright, A M, and R E Dunlap. 2011. "Cool Dudes: The Denial of Climate Change among Conservative White Males in the United States." *Global Environmental Change-Human and Policy Dimensions* 21 (4): 1163–72. https://doi.org/10.1016/j.gloenvcha.2011.06.003.

McNeeley, Shannon M. 2009. "Seasons Out of Balance: Climate Change Impacts, Vulnerability, and Sustainable Adaptation in Interior Alaska, Ph.D. Dissertation." *Department of Anthropology*. Dissertation, Fairbanks: University of Alaska Fairbanks. https://www.academia.edu/7378703/Mc_Neeley_2009_Seasons_Out_of_Balance_Climate_Change_Impacts_Vulnerability_and_Sustainable_Adaptation_in_Interior_Alaska_PhD_Dissertation.

McNeeley, Shannon M., and Heather Lazrus. 2014. "The Cultural Theory of Risk for Climate Change Adaptation." *Weather, Climate, and Society* 6 (4): 506–19. https://doi.org/10.1175/WCAS-D-13-00027.1.

McNeeley, Shannon M., and Martha D. Shulski. 2011. "Anatomy of a Closing Window: Vulnerability to Changing Seasonality in Interior Alaska." *Global Environmental Change* 21 (2): 464–73. https://doi.org/10.1016/j.gloenvcha.2011.02.003.

McNeeley, Shannon, Rigley, Jackie, and Will, Rachel. 2024. "Climate Change and Rural Water for Frontline Communities in the Southwest United States." Pacific Institute. https://pacinst.org/publication/climate-change-and-rural-water-for-frontline-communities-in-the-southwest-united-states/.

Meadow, Alison M., Daniel B. Ferguson, Zack Guido, Alexandra Horangic, Gigi Owen, and Tamara Wall. 2015. "Moving toward the Deliberate Coproduction of Climate Science Knowledge." *Weather, Climate, and Society* 7 (2): 179–91. https://doi.org/10.1175/WCAS-D-14-00050.1.

Miles, E. L., A. K. Snover, L. C. Whitely Binder, E. S. Sarachik, P. W. Mote, and N. Mantua. 2006. "An Approach to Designing a National Climate Service." *Proceedings of the National Academy of Sciences* 103 (52): 19616–23. https://doi.org/10.1073/pnas.0609090103.

Milly, P. C. D., Julio Betancourt, Malin Falkenmark, Robert M. Hirsch, Zbigniew W. Kundzewicz, Dennis P. Lettenmaier, and Ronald J. Stouffer. 2008. "Stationarity Is Dead: Whither Water Management?" *Science* 319 (5863): 573–74. https://doi.org/10.1126/science.1151915.

Moss, RH and Malone EL. 2001. "Vulnerability to Climate Change: A Quantitative Approach." *Pacific Northwest National Laboratory* PNNL-SA-33642:155–67. https://www.researchgate.net/publication/240403615_Vulnerability_to_Climate_Change_A_Quantitative_Approach.

Mueller, J. Tom, and Stephen Gasteyer. 2021. "The Widespread and Unjust Drinking Water and Clean Water Crisis in the United States." *Nature Communications* 12 (1): 3544. https://www.nature.com/articles/s41467-021-23898-z.

Mulhern, Riley, Javad Roostaei, Sara Schwetschenau, Tejas Pruthi, Chris Campbell, and Jacqueline MacDonald Gibson. 2022. "A New Approach to a Legacy Concern: Evaluating Machine-Learned Bayesian Networks to Predict Childhood Lead Exposure Risk from Community Water Systems." *Environmental Research* 204 (March). https://doi.org/10.1016/j.envres.2021.112146.

Munro, Fiona Robertson, and Paul Cairney. 2020. "A Systematic Review of Energy Systems: The Role of Policymaking in Sustainable Transitions." *Renewable and Sustainable Energy Reviews* 119. https://www.sciencedirect.com/science/article/pii/S1364032119308068.

Naishadham, Suman, Brittany Peterson, and Camille Fassett. 2023. "Rising Flood Risks Threaten Many Water and Sewage Treatment Plants across the US." *AP News*, 2023. https://apnews.com/article/climate-change-flood-risks-infrastructure-vermont-7bd953f513035468ee74f8f7c619bb8e.

National Oceanic and Atmospheric Administration National Centers for Environmental Information. 2024. "Monthly Drought Report for Annual 2023." January 12, 2024. https://www.ncei.noaa.gov/access/monitoring/monthly-report/drought/202313.

National Oceanic and Atmospheric Administration National Weather Service. 2022. "Historic July 26th-July 30th, 2022 Eastern Kentucky Flooding." NOAA's National Weather Service. 2022. https://www.weather.gov/jkl/July2022Flooding.

NCAR. 2024. "Standardized Precipitation Evapotranspiration Index (SPEI)." In . Climate Indices. https://climatedataguide.ucar.edu/type/climate-indices/drought/spei.

Nielsen, Jonas Østergaard, and Anette Reenberg. 2010. "Cultural Barriers to Climate Change Adaptation: A Case Study from Northern Burkina Faso." *Global Environmental Change* 20 (1): 142–52. https://doi.org/10.1016/j.gloenvcha.2009.10.002.

Norton, B.G. 2005. *Sustainability: A Philosophy of Adaptive Ecosystem Management*. Chicago: University of Chicago Press.

O'Keefe, Phil, Ken Westgate, and Ben Wisner. 1976. "Taking the Naturalness out of Natural Disasters." *Nature* 260 (5552): 566–67. https://doi.org/10.1038/260566a0.

Osezua, Michael, Shree Om Bade, Emmanuel Gyimah, and Olusegun Stanley Tomomewo. 2023. "Impact of Climate Change on the Water Resources, Lake Powell, United States." *American Journal of Water Resources* 11 (3): 103–11. https://doi.org/10.12691/ajwr-11-3-3.

Ostrom, Elinor. 2007. "A Diagnostic Approach for Going beyond Panaceas." *Proceedings of the National Academy of Sciences* 104 (39): 15181–87. https://doi.org/10.1073/pnas.0702288104.

Overpeck, Jonathan T., and Bradley Udall. 2020. "Climate Change and the Aridification of North America." *Proceedings of the National Academy of Sciences* 117 (22): 11856–58. https://doi.org/10.1073/pnas.2006323117.

Owen, Gigi, Daniel B. Ferguson, and Ben McMahan. 2019. "Contextualizing Climate Science: Applying Social Learning Systems Theory to Knowledge Production, Climate Services, and Use-Inspired Research." *Climatic Change* 157:151–70. https://doi.org/10.1007/s10584-019-02466-x.

Pacific Institute. 2023. "Climate Change and Flooding in Central Appalachia." Issue Brief. https://pacinst.org/wp-content/uploads/1989/11/Central-Appalachia-Issue-Brief_Final.pdf.

Pacific Institute, and DigDeep. 2024. "Climate Change Impacts to Water and Sanitation for Frontline Communities in the United States: Water, Sanitation, and Climate Change in the United States, Part 1." 1. Oakland, CA: Pacific Institute. https://pacinst.org/publication/water-sanitation-climate-change-us-part-1/.

Pahl-Wostl, C. 2009. "A Conceptual Framework for Analysing Adaptive Capacity and Multi-Level Learning Processes in Resource Governance Regimes." *Global Environmental Change-Human and Policy Dimensions* 19 (3): 354–65. https://doi.org/10.1016/j.gloenvcha.2009.06.001.

Pahl-Wostl, C, M Craps, A Dewulf, E Mostert, D Tabara, and T Taillieu. 2007. "Social Learning and Water Resources Management." *Ecology and Society* 12 (2). https://www.jstor.org/stable/26267868.

Papyrakis, Elissaios. 2017. "The Resource Curse - What Have We Learned from Two Decades of Intensive Research: Introduction to the Special Issue." *The Journal of Development Studies* 53 (2): 175–85. https://doi.org/10.1080/00220388.2016.1160070.

Paul, M. J., S. D. LeDuc, M. G. Lassiter, L. C. Moorhead, P. D. Noyes, and S. G. Leibowitz. 2022. "Wildfire Induces Changes in Receiving Waters: A Review with Considerations for Water Quality Management." *Water Resources Research* 58 (9). https://pubmed.ncbi.nlm.nih.gov/36968177/

Pauloo, R A, A Escriva-Bou, H Dahlke, A Fencl, H Guillon, and G E Fogg. 2020. "Domestic Well Vulnerability to Drought Duration and Unsustainable Groundwater Management in California's Central Valley." *Environmental Research Letters* 15 (4): 044010. https://doi.org/10.1088/1748-9326/ab6f10.

Payton, E.A., A.O. Pinson, T. Asefa, L.E. Condon, L.A.L. Dupigny-Giroux, B.L. Harding, J. Kiang, et al. 2023. "Ch 4. Water." In *Fifth National Climate Assessment*. Washington, DC, USA: US Global Change Research Program. https://doi.org/10.7930/NCA5.2023.CH4.

Pelling, Mark, and Chris High. 2005. "Understanding Adaptation: What Can Social Capital Offer Assessments of Adaptive Capacity?" *Global Environmental Change* 15 (4): 308–19. https://doi.org/10.1016/j.gloenvcha.2005.02.001.

Pendergrass, Angeline G., Reto Knutti, Flavio Lehner, Clara Deser, and Benjamin M. Sanderson. 2017. "Precipitation Variability Increases in a Warmer Climate." *Scientific Reports* 7 (December). https://doi.org/10.1038/s41598-017-17966-y.

Phuong, Thi Hong Le, G. Robbert Biesbroek, and Arjen E.J. Wals. 2017. "The Interplay between Social Learning and Adaptive Capacity in Climate Change Adaptation: A Systematic Review." *NJAS: Wageningen Journal of Life Sciences* 82 (1): 1–9. https://doi.org/10.1016/j.njas.2017.05.001.

Pigg, Kenneth, Stephen P. Gasteyer, Kenneth E. Martin, Kari Keating, and Godwin P. Apaliyah. 2020. "The Community Capitals Framework: An Empirical Examination of Internal Relationships." In *50 Years of Community Development Vol I*. Vol. 1. Routledge.

PolicyLink. 2012. "Community Campaigns for Infrastructure Equity: A Review of Four Case Studies." Report Prepared for the Commission on San Diego Regional Infrastructure & Equity. https://www.policylink.org/sites/default/files/Community%20Campaigns%20for%20Infrastructure%20Equity.

Pollard, Kelvin, and Linda A Jacobsen. 2022. "The Appalachian Region: A Data Overview from the 2016-2020 American Community Survey Chartbook." Appalachian Regional Commission, Population Reference Bureau. https://www.arc.gov/wp-content/uploads/2022/08/PRB_ARC_Chartbook_ACS_2016-2020_FINAL_2022-09.pdf.

Pollard, Kelvin, Sara Srygley, and Linda A Jacobsen. 2023. "The Appalachian Region: A Data Overview from the 2017-2021 American Community Survey," June. https://www.arc.gov/wp-content/uploads/2023/05/PRB_ARC_Chartbook_ACS_2017-2021_FINAL_2023-06.pdf.

Raju, Emmanuel, Emily Boyd, and Friederike Otto. 2022. "Stop Blaming the Climate for Disasters." *Communications Earth & Environment* 3 (1): 1. https://doi.org/10.1038/s43247-021-00332-2.

Ribot, Jesse. 2010. "Vulnerability Does Not Fall from the Sky: Toward Multiscale, pro-Poor Climate Policy." In *Social Dimensions of Climate Change: Equity and Vulnerability in a Warming World*, by Robin Mearns and Andrew Norton. DC: World Bank. https://openknowledge.worldbank.org/handle/10986/2689.

Rizak, S., and Steve E. Hrudey. 2008. "Drinking-Water Safety – Challenges for Community-Managed Systems." *Journal of Water and Health* 6 (S1): 33–41. https://iwaponline.com/jwh/article/6/S1/33/341/Drinking-water-safety-challenges-for-community.

Roller, Zoë, Stephen Gasteyer, Nora Nelson, WenHua Lai, and Marie Carmen Shinge. 2019. "Closing The Water Access Gap In The United States: A National Action Plan." Dig Deep and U.S. Water Alliance. https://urbanwaterslearningnetwork.org/resources/closing-the-water-access-gap-in-the-united-states-a-national-action-plan-nov-2019/.

Romero, Simon. 2022. "How New Mexico's Largest Wildfire Set Off a Drinking Water Crisis." *The New York Times*, September 26, 2022, sec. US. https://www.nytimes.com/2022/09/26/us/new-mexico-las-vegas-fire-water.html.

Rowles III, Lewis Stetson, Areeb I. Hossain, Srijan Aggarwal, Mary Jo Kirisits, and Navid B. Saleh. 2020. "Water Quality and Associated Microbial Ecology in Selected Alaska Native Communities: Challenges in off-the-Grid Water Supplies." *The Science of the Total Environment* 711 (April):134450. https://doi.org/10.1016/j.scitotenv.2019.134450.

Ruiz-Mallén, Isabel, Mar Satorras, Hug March, and Francesc Baró. 2022. "Community Climate Resilience and Environmental Education: Opportunities and Challenges for Transformative Learning." *Environmental Education Research* 28 (7): 1088–1107. https://doi.org/10.1080/13504622.2022.2070602.

Runkle, J., and K.E. Kunkel. 2022. "Kentucky State Climate Summary 2022." NOAA Technical Report NESDIS 150-KY. Silver Spring, MD: NOAA/NESDIS. https://statesummaries.ncics.org/chapter/ky/.

Scanlon, Bridget R., Claudia C. Faunt, Laurent Longuevergne, Robert C. Reedy, William M. Alley, Virginia L. McGuire, and Peter B. McMahon. 2012. “Groundwater Depletion and Sustainability of Irrigation in the US High Plains and Central Valley.” *Proceedings of the National Academy of Sciences* 109 (24): 9320–25. https://doi.org/10.1073/pnas.1200311109.

Schlichting, Lena, Landes, Laura, and Buck, Sarah. 2022. “2021-2022 Colonias Report: Current and Future Needs in Colonias and Recent Work on the Ground by RCAP,” November. https://www.rcap.org/wp-content/uploads/2022/11/2021-2022-Colonias-Report-Final.pdf.

Schmidt, John C., Charles B. Yackulic, and Eric Kuhn. 2023. “The Colorado River Water Crisis: Its Origin and the Future.” *WIREs Water* 10 (6). https://doi.org/10.1002/wat2.1672.

Shafiei Shiva, J., and D. G. Chandler. 2020. “Assessing Impacts of Heatwaves on Urban Water Distribution Systems: Planning for a Resilient Design Approach.” In . American Geophysical Union. https://ui.adsabs.harvard.edu/abs/2020AGUFMGC0560013S.

Shelton, Rebecca, Ricki Draper, and Mary Cromer. 2023. “Drinking Water Affordability in Kentucky.” *Appalachian Citizens’ Law Center.* https://aclc.org/wp-content/uploads/2024/02/Drinking-Water-Affordability-in-Kentucky-1.pdf.

Siirila-Woodburn, Erica, Alan Rhoades, Benjamin Hatchett, Laura Huning, and Julia Szinai. 2021. “A Low-to-No Snow Future and Its Impacts on Water Resources in the Western United States.” *Nature Reviews Earth & Environment* 2 (October):800–819. https://doi.org/10.1038/s43017-021-00219-y.

Smit, Barry, and Olga Pilifosova. 2001. “Adaptation to Climate Change in the Context of Sustainable Development and Equity.” https://www.ipcc.ch/site/assets/uploads/2018/03/wg2TARchap18.pdf.

Smith, James A, Mary Lynn Baeck, Alexandros A. Ntelekos, Gabriele Villarini, and Matthias Steiner. 2011. “Extreme Rainfall and Flooding from Orographic Thunderstorms in the Central Appalachians.” *Water Resources Research* 47 (4). https://doi.org/10.1029/2010WR010190.

Sohns, Antonia. 2023. “Differential Exposure to Drinking Water Contaminants in North Carolina: Evidence from Structural Topic Modeling and Water Quality Data.” *Journal of Environmental Management* 336 (June):117600. https://doi.org/10.1016/j.jenvman.2023.117600.

Status of Tribes and Climate Change Working Group. 2021. “The Status of Tribes and Climate Change Report.” Flagstaff, AZ: Institute for Tribal Environmental Professionals, Northern Arizona University. http://nau.edu/stacc2021.

Tang, Samuel, and Suraje Dessai. 2012. “Usable Science? The U.K. Climate Projections 2009 and Decision Support for Adaptation Planning.” *Weather, Climate, and Society* 4 (4): 300–313. https://doi.org/10.1175/WCAS-D-12-00028.1.

Tarus, Lyndsay, Mary Hufford, and Betsy Taylor. 2017. “A Green New Deal for Appalachia: Economic Transition, Coal Reclamation Costs, Bottom-Up Policymaking (Part 2).” *Journal of Appalachian Studies* 23 (2): 151–69. https://doi.org/10.5406/jappastud.23.2.0151.

Taylor, Betsy. 2019. "'Energy Transitions and the First West: The Complex Histories of Appalachia's Emerging Futures'." Presented at the Effects of Energy Transition on Opportunities in Rural America., Geographical Sciences Committee of the National Academy of the Sciences. Washington DC.

Taylor, Betsy, Mary Hufford, and Kendall Bilbrey. 2017. "A Green New Deal for Appalachia: Economic Transition, Coal Reclamation Costs, Bottom-Up Policymaking (Part 1)." *Journal of Appalachian Studies* 23 (1): 8–28. https://doi.org/10.5406/jappastud.23.1.0008.

Thomann, Jason A., Adrian D. Werner, Dylan J. Irvine, and Matthew J. Currell. 2020. "Adaptive Management in Groundwater Planning and Development: A Review of Theory and Applications." *Journal of Hydrology* 586.

Thomas, Kimberley, R. Dean Hardy, Heather Lazrus, Michael Mendez, Ben Orlove, Isabel Rivera-Collazo, J. Timmons Roberts, Marcy Rockman, Benjamin P. Warner, and Robert Winthrop. 2019. "Explaining Differential Vulnerability to Climate Change: A Social Science Review." *WIREs Climate Change* 10 (2): e565. https://doi.org/10.1002/wcc.565.

Torrellas, Geraldine. 2024. "Martin County Water Struggles: 'System Is Broken and Has Been for over 20 Years.'" *Spectrum News 1*, 2024. https://spectrumnews1.com/ky/louisville/news/2024/02/04/martin-county-water.

US Census Bureau. 2020. "Race and Ethnicity in the United States: 2010 Census and 2020 Census." Census.Gov. 2020. https://www.census.gov/library/visualizations/interactive/race-and-ethnicity-in-the-united-state-2010-and-2020-census.html.

U.S. Climate Resilience Toolkit. 2019. "Infrastructure and the Built Environment." U.S. Global Change Research Program. https://toolkit.climate.gov/regions/great-lakes/infrastructure-and-built-environment.

———. 2022. "Map of the Southwest Region." U.S. Climate Resilience Toolkit. July 24, 2022. https://toolkit.climate.gov/image/3649.

US Congress. 2020. *Climate Equity Act of 2020*. Vol. Senate Bill S. 4513. https://www.govinfo.gov/content/pkg/BILLS-116s4513is/html/BILLS-116s4513is.htm.

U.S. Department of Energy. 2021. "What a Low-to-No-Snow Future Could Mean for the Western U.S." *Environmental System Science Program* (blog). October 2021. https://ess.science.energy.gov/highlight/what-a-low-to-no-snow-future-could-mean-for-the-western-u-s/.

US Department of Interior Bureau of Reclamation. 2021. "Colorado River Basin." Water Reliability in the West - 2021 SECURE Water Act Report. https://www.usbr.gov/climate/secure/docs/2021secure/factsheets/Colorado.pdf.

US Environmental Protection Agency. 2020. "EJ 2020 Glossary." https://www.epa.gov/system/files/documents/2024-02/ej-2020-glossary.pdf.

———. 2021a. "A Closer Look: Temperature and Drought in the Southwest." Reports and Assessments. Climate Change Indicators. 2021. https://www.epa.gov/climate-indicators/southwest.

———. 2021b. "Climate Change and Social Vulnerability in the United States: A Focus on Six Impacts." EPA 430-R-21-003. US EPA, Office of Atmospheric Programs. https://www.epa.gov/cira/social-vulnerability-report.

US EPA, and OAR. 2021. "Climate Change Indicators: Drought." Reports and Assessments. April 2021. https://www.epa.gov/climate-indicators/climate-change-indicators-drought.

US Geological Survey. n.d. "Colorado River Basin Studies." Accessed February 23, 2024. https://www.usgs.gov/centers/utah-water-science-center/science/colorado-river-basin-studies.

USDA Economic Research Service. 2022. "Drought Conditions in Western States in Summers of 2021, 2022 Were the Most Intense in 20 Years." September 27, 2022. http://www.ers.usda.gov/data-products/chart-gallery/gallery/chart-detail/?chartId=104849.

Verweij, M, M Douglas, R Ellis, C Engel, F Hendriks, S Lohmann, S Ney, S Rayner, and M Thompson. 2006. "Clumsy Solutions for a Complex World: The Case of Climate Change." *Public Administration* 84 (4): 817–43. http://books.google.com/books?id=LYVrQgAACAAJ.

Verweij, Marco. 2022. "Clumsy Solutions and Climate Change: A Retrospective." *WIREs Climate Change*, October. https://doi.org/10.1002/wcc.804.

Vose, J.M., D.L. Peterson, G.M. Domke, C.J. Fettig, L.A. Joyce, R.E. Keane, C.H. Luce, et al. 2018. "Forests." In *Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment*, edited by D.R. Reidmiller, C.W. Avery, D.R. Easterling, K.E. Kunkel, T.K. Maycock, B.C. Stewart, and K.L.M. Lewis, Volume II:232–67. Washington, D.C.: U.S. Global Change Research Program. doi: 10.7930/NCA4.2018.CH6.

Wals, Arjen E. J., and Romina Rodela. 2014. "Social Learning towards Sustainability: Problematic, Perspectives and Promise." *NJAS - Wageningen Journal of Life Sciences*, Social learning towards sustainability: problematic, perspectives and promise, 69:1–3. https://doi.org/10.1016/j.njas.2014.04.001.

Wehner, Michael F., Jeff R. Arnold, Thomas Knutson, Kenneth E. Kunkel, and Allegra N. LeGrande. 2017. "Droughts, Floods, and Wildlife." In *Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment*, edited by Donald J. Wuebbles, David W. Fahey, Kathy A. Hibbard, David J. Dokken, Brooke C. Stewart, and Thomas K. Maycock, Volume I:231–56. Washington, DC: US Global Change Research Program. https://science2017.globalchange.gov/chapter/8/.

Wheeler, Kevin G., Brad Udall, Jian Wang, Eric Kuhn, Homa Salehabadi, and John C. Schmidt. 2022. "What Will It Take to Stabilize the Colorado River?" *Science* 377 (6604): 373–75. https://doi.org/10.1126/science.abo4452.

White, D.D, E.H Elias, K.A Thomas, C.E Bradatan, M.W Brunson, A.M Chischilly, C.A.F Enquist, et al. 2023. "Ch. 28 Southwest." In *Fifth National Climate Assessment*, 1–470. Washington, DC, USA: U.S. Global Change Research Program. https://nca2023.globalchange.gov/chapter/28/.

Whyte, Kyle, Rachael Novak, M.B Laramie, M.G Bruscato, Dominique M. David-Chavez, M.J Dockry, M.K Johnson, C.E Jones, and K Leonard. 2023. “Ch 16. Tribes and Indigenous Peoples.” In *Fifth National Climate Assessment*. Washington, DC, USA: U.S. Global Change Research Program. https://nca2023.globalchange.gov/chapter/16/.

Wibbenmeyer, Matthew, Matthew R Sloggy, and José J Sánchez. 2023. “Economic Analysis of Wildfire Impacts to Water Quality: A Review.” *Journal of Forestry*, April, fvad012. https://doi.org/10.1093/jofore/fvad012.

Wilder, Margaret, Diana Liverman, Laurel Bellante, and Tracey Osborne. 2016. “Southwest Climate Gap: Poverty and Environmental Justice in the US Southwest.” *Local Environment* 21 (11): 1332–53. https://doi.org/10.1080/13549839.2015.1116063.

Williams, David Samuel, María Máñez Costa, Dmitry Kovalevsky, Bart van den Hurk, Bastian Klein, Dennis Meißner, Manuel Pulido-Velazquez, Joaquín Andreu, and Sara Suárez-Almiñana. 2020. “A Method of Assessing User Capacities for Effective Climate Services.” *Climate Services* 19. https://doi.org/10.1016/j.cliser.2020.100180.

Wisner, Benjamin. 2016. “Vulnerability as Concept, Model, Metric, and Tool.” *Oxford Research Encyclopedia of Natural Hazard Science*. https://tinyurl.com/naturalhazardscience

Wong-Parodi, Gabrielle, Baruch Fischhoff, and Ben Strauss. 2014. “A Method to Evaluate the Usability of Interactive Climate Change Impact Decision Aids.” *Climatic Change* 126:485–93. https://doi.org/10.1007/s10584-014-1226-9.

Wutich, Amber, Wendy Jepson, Carmen Velasco, Anais Roque, Zhining Gu, Michael Hanemann, Mohammed Jobayer Hossain, et al. 2022. “Water Insecurity in the Global North: A Review of Experiences in U.S. Colonias Communities along the Mexico Border.” *WIREs Water* 9 (4). https://doi.org/10.1002/wat2.1595.

Yohe, G.W., and R.S.J. Tol. 2001. *Indicators for Social and Economic Coping Capacity - Moving towards a Working Definition of Adaptive Capacity, Research Unit Sustainability and Global Change*. FNU. Hamburg University, Hamburg: Centre for Marine and Climate Research. https://research.vu.nl/en/publications/indicators-for-social-and-economic-coping-capacity-moving-towards-2.

Zhuang, Yizhou, Rong Fu, Benjamin D. Santer, Robert E. Dickinson, and Alex Hall. 2021. “Quantifying Contributions of Natural Variability and Anthropogenic Forcings on Increased Fire Weather Risk over the Western United States.” *Proceedings of the National Academy of Sciences* 118 (45): e2111875118. https://doi.org/10.1073/pnas.2111875118.

Zimmerman, Marc A. 2000. “Empowerment Theory.” In *Handbook of Community Psychology*, edited by Julian Rappaport and Edward Seidman, 43–63. Boston, MA: Springer US. https://doi.org/10.1007/978-1-4615-4193-6_2.

# Appendices

# Appendix A
# Extended Glossary of Shared Terms

**Acceptable**: Water is acceptable if the color, odor, and taste are considered appropriate for personal or domestic use (United Nations 2014), as defined by the user of that water. This standard may vary by a person's culture, gender, and other factors.

**Affordable:** In general, water service is affordable when a household can afford the cost of essential water and sanitation, including operating and maintaining their own systems, without foregoing other essential goods and services, such as housing, healthcare, food, and other utilities (Teodoro 2019; Feinstein 2018).

**Asset-based:** Values and methods that foreground the positive resources and attributes of a community to affirm and build on the strengths, knowledge, and perspectives of those directly affected by the problem being addressed. The goal is to avoid a focus on negative images of what communities lack and need. This approach is closely related to methods of appreciative inquiry that focus first on strengths in order to build a cascade of transformational changes based on communities' assets and on cumulative successes. This avoids an emphasis on community problems that can trap the work within negative and disempowering frameworks.

**Climate change:** A change of climate that is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and that is in addition to natural climate variability observed over comparable time periods (United Nations Framework Convention on Climate Change 1994).

**Climate equity:** The EPA defines climate equity as the goal of recognizing and addressing the unequal burdens made worse by climate change, while ensuring that all people share the benefits of climate protection efforts. Achieving equity means that all people — regardless of their race, color, gender, age, sexuality, national origin, ability, or income — live in safe, healthy, fair communities.

**Climate resilience:** The U.S. National Climate Assessment defines it as the capacity of interconnected social, economic, and ecological systems to cope with a climate change event, trend, or disturbance, responding or reorganizing in ways that maintain their essential function, identity, and structure. Climate resilience is a subset of resilience against climate-induced or climate-related impacts.

**Collaborations:** Partnerships to pursue common goals, co-design projects, share and co-produce outputs and deliverables while building trust, relationships, alignment among participants, and values-based accountability to constituents.

**Collaborative agreement**: A written statement among partner organizations that summarizes the nature of their collaboration. Components could include: short description of the project that will be used by all parties in public-facing documents (and collaboratively agreed upon name for the project); protocols and mechanisms for co-design and co-production of project; role definitions; statement of values; evaluation frameworks; ownership of deliverables; benefits to participants and stakeholders (especially underserved or marginalized community partners).

**Community scholars or scientists**: Community residents who participate with professional scholars in scientific/humanities research and monitoring driven and controlled by local communities, and characterized by place-based knowledge, social learning, collective action and empowerment. (This is closely related to the term "citizen science.")

**Community water system:** A public water system that supplies water to the same population year round (U.S. Environmental Protection Agency 2015d).

**Cross-sector:** Work that bridges the sectors of community, civil society organizations (differentiated from "community" by referring to incorporated organizations, vs. the more informal and embedded process of community), specialists (scholars, technical experts, knowledgeable practitioners, and community experts), and governments (including Indigenous governments). Depending on the project needs, it can also include businesses/corporations, philanthropy, and other sectors.

**Disadvantaged communities (DACs):** The White House Climate and Economic Justice Screening tool identifies census tracts that are overburdened and underserved. This also includes Federally Recognized Tribes, including Alaska Native Villages. Under the Safe Drinking Water Act, each state is responsible for self-identifying disadvantaged communities. Thus, Clean Water and Drinking Water State Revolving Fund benefits for disadvantaged communities are at the discretion of each state.

**Environmental justice**: The principle that all people and communities have a right to equal protection and equal enforcement of environmental laws and regulations (Dr. Robert D. Bullard)

The just treatment and meaningful involvement of all people — regardless of income, race, color, national origin, tribal affiliation, or disability — in agency decision-making and other Federal activities that affect human health and the environment so that people:

- are fully protected from disproportionate and adverse human health and environmental effects, risks, and hazards, including those related to climate change, the cumulative impacts of environmental and other burdens, and the legacy of racism or other structural or systemic barriers; and
- have equitable access to a healthy, sustainable, and resilient environment in which to live, play, work, learn, grow, worship, and engage in cultural and subsistence practices (EPA).

**Equitable water access**: Safe, sufficient, acceptable, accessible, affordable and non-discriminatory access to water and wastewater services to all people (adapted from Dig Deep and Gleick 1999).

**Frontline communities:** Communities that are overburdened and under resourced who face disproportionate, first and worst impacts of climate change on their water and sanitation systems or access.

**Human Right to Water and Sanitation (HR2W):** Access to water and sanitation are recognized by the United Nations as human rights — fundamental to everyone's health, dignity, and prosperity. The right to water entitles everyone to have access to sufficient, safe, acceptable, physically accessible, and affordable water for personal and domestic use. The right to sanitation entitles everyone to have physical and affordable access in all spheres of life to sanitation that is safe, hygienic, secure, socially and culturally acceptable, and provides privacy and ensures dignity (United Nations 2014).

**Indigenous peoples:** Self-determining societies whose political and cultural foundations pre-exist the formation of the United States, regardless of their recognition status by the U.S. government. Indigenous peoples in the United States include the 574 federally recognized Tribes (as of 2023), Native Hawaiians, Pacific and Caribbean islanders, state-recognized Tribes, and unrecognized Tribes and peoples. More specific terms will be used where the particular government, legal, cultural, or diplomatic situation is being referenced. Indigenous peoples' self-determination can be best respected by using terminology that acknowledges Indigenous governance systems and sovereignty (Status of Tribes and Climate Change Working Group 2021).

**Indoor plumbing:** The presence of hot-and-cold running water, a shower or bath, and a flush toilet inside the home.

**Overburdened communities:** Minority, low-income, Indigenous populations, or in certain geographic locations in the United States that potentially experience disproportionate environmental harms and risks. The term describes situations where multiple factors, including both environmental and socioeconomic stressors, may act cumulatively to affect health and the environment and contribute to persistent environmental health disparities (US Environmental Protection Agency 2020).

**Participatory:** Methods that empower diverse voices, open-ended dialogue, democratic inclusion and decision-making, and co-design and co-production of products and knowledge. The central principle is the idea that affected actors or stakeholders should be "at the table" when core decisions are being made. (For more, see LiKEN's Framework for Knowledge Sharing.)

- Participatory methods in project management and community development emphasize inclusive, empowering, and democratic techniques for: co-creating agendas and work plans; facilitating meetings; building teamwork and relationships; designing community outreach and engagement; report-backs to and benefits for constituents; and communication campaigns and products. These methods build local capacity, leadership, and sense of ownership.
- Participatory Action Research (PAR) draws on well-established, international repertoires of methods for conducting empowering research that mobilizes local knowledge while maintaining high standards of scholarly rigor. Widely used methods in PAR for documenting and visualizing participant's knowledge include timelines, social and power mapping, stakeholder assessments, photovoice, transect walks, pile sorting and ranking, etc. In addition, LiKEN has developed methods that are helpful for community development: (government) agency mapping, seasonal round, root cause analysis for system change.

**Physically accessible:** For water to be physically accessible it must be available in the home, in sufficient volumes to meet domestic needs, at hot and cold temperatures, 24 hours per day. Similarly, accessible sanitation is when toilets are private, located in a home, safe to visit, and available when needed.

**Public water system:** A water system that provides drinking water through pipes or other conveyance to at least 15 service connections or an average of 25 people for at least 60 days per year. A public water system may be publicly or privately owned. There are three types of public water systems: community water systems, non-transient non-community water systems, and transient non-community water systems (U.S. Environmental Protection Agency 2015d).

**Qualitative methods:** Qualitative methods include semi-structured interviews, motivational interviewing, focus groups, and the practice of field notes. These methods are described in more detail on the LiKEN Research Portal.

**Safe:** Drinking water that meets or exceeds standards set forth by the federal Safe Drinking Water Act, and by any additional standards established by individual states where geographically applicable. Safe sanitation means that the waste is separated from humans and transported, treated, and discharged to the environment where it is not a liability or hazard to human, wildlife, or environmental health.

**Sanitation:** The conveyance, storage, treatment, and disposal of human waste. This includes toilets, pipes that remove wastewater from the home, and treatment measures (Roller et al. 2019).

**Small water systems**: Defined under the Safe Drinking Water Act as community water systems serving 10,000 or fewer people.

**Sufficient:** The World Health Organization considers 50–100 liters (approximately 13–26 gallons) per person per day to be the minimum necessary to ensure most basic needs are met. However, this amount may not be sufficient for broader uses of water that are necessary for healthy, resilient households and communities; this represents the bare minimum for health purposes (Feinstein 2018; Gleick 1996).

**Underresourced community:** The historical disinvestment experienced by some communities. Underresourced communities may include economically disadvantaged populations, racial and ethnic minorities, the elderly, and the uninsured. A majority of residents of underresourced communities are people of color. These communities experience greater barriers to social, economic, and healthcare resources (ICIC, Providence, American Medical Association).

**Wastewater:** Water that has been used and discharged or disposed of, which often contains contaminants such as untreated human waste, sewage, or sludge.

**Wastewater services (or systems):** The provision of centralized sewer systems and treatment plants, individual septic systems, or other forms of decentralized or on-site systems (Roller et al. 2019).

**WASH:** The acronym used to refer to water, sanitation, and hygiene, the three basic human requirements for water.

**Water access gap**: The disparity in access to water and sanitation between most Americans and the communities that still lack access (Roller et al. 2019).

**Water equity:** What is achieved when all have safe, clean, affordable drinking water and sanitation; are resilient to floods, drought, and other shocks and stresses; can play a role in water-related decision-making in their communities; and share in the economic, social, and environmental benefits of water systems.

**Water insecurity:** Inadequate or inequitable access to clean, safe, and affordable water for drinking, cooking, sanitation, and hygiene. Water insecurity results from a combination of social and physical conditions, including climate change (Schimpf and Cude 2020).

**Water resilience**: The ability of water systems to function so that nature and people, especially the most vulnerable, thrive under shocks, stresses, and change.

# Appendix B– Climate Disruptions and Resiliency: Supporting Technical Assistance to Promote Resilient Water Systems

## Introduction

Climate disruptions take the form of a variety of extreme weather events — drought, flooding, wildfires, and hurricanes, to name a few. These impact many aspects of society, but especially water infrastructure. Climate disruptions can impact water systems, leading to lack of clean, safe water for communities. There is a growing need to build the resilience of these water systems to prevent this from occurring. Existing literature highlights the impacts these climate disruptions have on water infrastructure and ways to build resilience, but there is often a lack of discussion around these topics that pertain specifically to technical assistance. Technical assistance providers (TAPs) have been working on building resilience within the water systems in the communities they serve for many years and are aware of the necessary upgrades and maintenance that are needed to promote resiliency for these systems. However, due to the constraints of funding sources for most technical assistance programs, they may not be able to or have time to directly address resiliency. There is a need for technical assistance program funders to prioritize water system resilience when considering projects and to dedicate resources to these specific goals. This report first discusses the current literature on resilience and water, and then outlines potential suggestions and a list of deliverables in ways TAPs can continue to be supported in their ongoing work to address climate disruptions in their communities. The report ends with an overview of how to measure these potential deliverables, as well as discussions over resilience-specific funding.

### 1) Examples of resilience in prior research

The importance of nonprofit organizations in mitigation and resilience during disasters and climate disruptions has been noted in prior literature. Nonprofits have a history of networking and connecting with the most vulnerable communities, especially during times of disaster. Due to the prior identification of these vulnerable communities, during times of disasters, resources and aid can be quickly delivered and valuable information disseminated amongst these communities.[4, 5] There are variations within nonprofit organizations and their effectiveness following a disaster. While smaller nonprofits may receive less aid and resources than a larger nonprofit organization, they tend to be more connected to the community and involve them in decisions surrounding

4 Jenkins, P., Lambeth, T., Mosby, K., & Van Brown, B. (2015). Local non-profit organizations in a post-Katrina landscape: help in a context of recovery. American Behavioral Scientist, 59(10), 1263-1277. doi:10.1177/0002764215591183.

5 Demiroz, F., & Hu, Q. (2014). The Role of Nonprofits and Civil Society in Post-disaster Recovery and Development. (317-330). Springer, Cham.

recovery following a disaster.[6] Due to this, often there is push towards cross-sector collaboration, as it is impossible for one organization at any scale to address the needs and issues of a community following a disaster alone.[7] While nonprofits have shown their importance in mitigation and resilience, there is further research needed on how to transfer the knowledge of nonprofits effectively and efficiently to these various disaster preparation stages.[8] There is even less literature on the role of TAPs specifically.

Although articles discuss the significance of incorporating resilience into emergency and disaster plans, research is often lacking on how to incorporate resilience through technical assistance and water systems specifically. Resilience is achieved through both social and technical/physical capacities. By ensuring social resilience of a community is addressed, such as having information disseminated equally to all communities before, during, and after a disaster, those especially vulnerable may have the appropriate resources to withstand an incoming disaster.[9] Social networks and resilience can also expand beyond the general public — this includes the connections that water operators have with one another to support each other during times of crisis.[10] While infrastructural resilience is important, it is also necessary to consider the importance of social cohesion and resilience, especially when opportunities for funding for infrastructural resilience are low.

However, this is not to say that the literature does not explicitly discuss the importance of physical resilience through infrastructure. Examples of how the infrastructure can be remodeled to promote higher resilience standards include raising any electric components a few feet off the ground in case of flooding, insulating pipelines during harsh freezes to prevent pipe bursts, and ensuring that there are extra generators available at all water systems in the case of a power outage.[11, 12] In terms of technical assistance specifically, Kettle et al (2023) discusses the importance of providing training opportunities for water operators in rural Alaska and Louisiana to promote resilience. However, they recommend that remote training opportunities also be available to combat high travel costs, as well as potentially mailing computer-based resources for asynchronous training for those who may not have internet access.

However, one major piece missing from the literature is that many of these recommendations do not provide specifics on what exactly needs to be done. For example, although Kettle et al (2023) discuss in detail the importance of providing training opportunities that can be accessed remotely,

6 Chandrasekhar, D., Garcias, I., & Khajehei, S. (2021). Recovery capacity of small nonprofits in post-2017 Hurricane Puerto Rico. Journal of the American Planning Association, 88(2), 206-219. doi: 10.1080/01944363.2021.1938637.

7 Simo, G., & Bies, A. (2007). The Role of Nonprofits in Disaster Response: An Expanded Model of Cross-Sector Collaboration. Public Administration Review, 67, 125-142.

8 Jenkins, P., Lambeth, T., Mosby, K., & Van Brown, B. (2015). Local nonprofit organizations in a post-Katrina landscape: help in a context of recovery. American Behavioral Scientist, 59(10), 1263-1277. doi:10.1177/0002764215591183.

9 Kettle, P., Trainor, S., Edwards, R., Antrobus, D., Baranowski, C., Buxbaum, T., Berry, K., Brubbaker, M., De Long, K., Fries, S., Holen, D., Keim, B., Meeker, D., Penn, H., Rosa, C., Walsh, J., & Zhang, J. (2023). Building resilience to extreme weather and climate events in the rural water and wastewater sector. JAWRA, 1-18. doi: 10.1111/1752-1688.13151.

10 Payton Scally, C., Marx, R., Polonius, I., & Davis, A. (2021). Preparing Rural Water Systems for Extreme Weather and Climate Disasters. Urban Institute: Metropolitan Housing and Communities Policy Center, 1-17.

11 Kettle, P., Trainor, S., Edwards, R., Antrobus, D., Baranowski, C., Buxbaum, T., Berry, K., Brubbaker, M., De Long, K., Fries, S., Holen, D., Keim, B., Meeker, D., Penn, H., Rosa, C., Walsh, J., & Zhang, J. (2023). Building resilience to extreme weather and climate events in the rural water and wastewater sector. JAWRA, 1-18. doi: 10.1111/1752-1688.13151.

12 Payton Scally, C., Marx, R., Polonius, I., & Davis, A. (2021). Preparing Rural Water Systems for Extreme Weather and Climate Disasters. Urban Institute: Metropolitan Housing and Communities Policy Center, 1-17.

they do not provide insight on what training they view as important to build this resilience.[13] Another challenge is that often these recommendations for resilience are very vague and broad and may say things such as "need to increase funding for water systems and technical assistance." However, the recommendations fail to provide further detail on where funding for water systems and technical assistance can be found, as well as recommendations on whether funding should be allocated to these communities from the federal, state, or local level. Very little literature discusses the way that individuals can benefit from resilience. However, this is assuming that recommendations even explicitly mention the role of technical assistance specifically in building resilience. As mentioned previously, some work mentions the need to train water operators, yet does not give specifics on the type of trainings that were or should be performed remotely and asynchronously. Although the existing literature does not explicitly discuss resilience and technical assistance in detail, within the technical assistance network it is a known topic that TAPs work to address as much as they can. The following section provides a few recommendations on how TAPs c be further supported by providing explicit ways to incorporate resiliency as deliverables.

## 2) Potential deliverables for TAPs

Although there may not be much existing literature on how resilience can be incorporated into technical assistance, the literature was still informative, and combined with RCAP's knowledge of existing technical assistance efforts and background on how resilience can be overall improved with water infrastructure, we were able to translate into technical assistance needs. Below is an introduction to five potential deliverables that can provide TAPs explicit ways to promote resilience more frequently and more intentionally, each touching on different aspects such as social resilience and physical resilience:

### *1. Identify a list of potential climate disruptions that could occur within a certain mile radius of the community's water systems*

Prior to identifying ways to improve resilience through social or infrastructural means, it is crucial to have a full understanding of what types of climate disruptions the water systems will face. As part of many existing RCAP workflows and activities with communities, such as the Water System Emergency Response Plan & Security Vulnerability Assessments and the Small Systems Risk and Resilience Assessment, TAPs are asked to identify potential disasters and hazards the community may face. To assist in identifying these potential risks, it would be extremely beneficial to increase and train TAPs on utilization of existing FEMA climate projections, to get a uniform assessment among the TAPs on the types of disasters a region may face. FEMA has published a short fact sheet page on their role in addressing climate change, which includes three key resources.[14]

There are three existing online tools that can help assess climate risk, each with their own different focus. The first is climate.gov's Climate Mapping for Resilience and Adaptation. One of their most helpful features is that it displays climate-related hazards that are currently occurring, acting as an

13 Kettle, P., Trainor, S., Edwards, R., Antrobus, D., Baranowski, C., Buxbaum, T., Berry, K., Brubbaker, M., De Long, K., Fries, S., Holen, D., Keim, B., Meeker, D., Penn, H., Rosa, C., Walsh, J., & Zhang, J. (2023). Building resilience to extreme weather and climate events in the rural water and wastewater sector. JAWRA, 1-18. doi: 10.1111/1752-1688.13151.

14 FEMA and the Changing Climate Fact Sheet

incredibly useful tool and resource for those who may need to learn of any immediate dangers that need to get addressed for the water system.[15] The second tool is the Climate Risk and Resilience Portal. The unique factor of this tool is that it is beneficial to learn about local future climate projections for a region.[16] This can help the TAPs and the community be proactive in planning for resilience against any future threats. The final tool is FEMA's National Risk Index, which creates a hazard risk index based on what has historically been a threat to the community.[17] There are incredibly important merits for all three of these toolkits — combined, they provide context for climate disruptions that are currently impacting communities, what will impact communities in the future, and what has impacted them in the past — and having this knowledge will continue to help TAPs and communities better prioritize resilience plans.

The radius for which potential climate disruptions should be determined may depend on the region, or may be determined in future conversations with TAPs.

### *2. Provide an overview and educate the community on the types of disasters that could impact the community's water system*

Although there are current tasks that TAPs can and do use to encourage communities/utilities to partake in relating to community-building, such as holding an information session, town hall, forum, or other event that is open to the public and identifying motivated local leaders and form groups to get input from cross-section of community. These tasks can be adjusted to be specific to discussing potential climate events that could impact the community. As previously noted, social resilience is extremely important and begins by ensuring that all those who may be impacted are aware of any potential vulnerabilities that their water systems face. These educational resources can hold value in two ways. For one, creating an understanding of what potential vulnerabilities the water systems face can create a sense of urgency and garner support in moving forward with funding for any physical infrastructure resilience projects that the community may be considering. Another benefit is that often, there are certain measures that households themselves can participate in during a disaster to promote the resilience of their water supply. For example, in Winter Storm Uri that impacted Texas in 2021, there were instances where households could have contributed to the resilience of the water system by insulating exposed pipelines around houses.[18] However, this may not be common knowledge to many households as they may not have had a lot of prior background knowledge on how to handle deep freezes.

Holding either educational panels and meetings, or simply creating pamphlets or brochures that can be distributed to the community is an important step toward resilience that can be built even at the household scale. To assist communities in this process, in 2020 FEMA released a report titled *A Guide to Supporting Engagement and Resiliency in Rural Communities* that discusses on page 20 how technical assistance can help communities better understand their resources and incorporate

15 Climate Mapping for Resilience and Adaptation (CMRA) Assessment Tool

16 Climate Risk and Resilience Portal (ClimRR)

17 FEMA National Risk Index Map

18 Payton Scally, C., Marx, R., Polonius, I., & Davis, A. (2021). Preparing Rural Water Systems for Extreme Weather and Climate Disasters. Urban Institute: Metropolitan Housing and Communities Policy Center, 1-17.

hazard data into their assessment plans.[19] In fact, the FEMA report provides estimated timelines for what action items need to address at what point in time, for both pre- and post-meeting preparations. An example from Appendix 1 is below:

## Planning Timeline for all Rural Community Engagement Touchpoints

| PHASE: | ACTION ITEM: | TIMELINE: |
|---|---|---|
| BEFORE THE MEETING: GET TO KNOW THE COMMUNITY | Call the community to ascertain capabilities for holding and joining a meeting, whether in person or virtual. Asking about audio, internet, or space constraints, as well as how their personal or community level of comfort using different technologies or traveling at certain times of the day, will shape how meetings come together. | **6 weeks** before target meeting date |
| | Coordinate with the community to identify a meeting space that meets location and space needs and will be well-received by meeting attendees. This can include government buildings, schools, churches, and/or community centers. Ensure that the meeting space is within a 1-hour drive for all participants, is "neutral," and does not inhibit certain meeting attendees from participating. Consider a childcare or family-friendly arrangement. | **5-6 weeks** before target meeting date |
| | Schedule the meeting, send invite emails, and make follow-up calls to confirm that these materials were received. Ideally, have a local leader do this outreach. | **4 weeks** before target meeting date |
| | When practical, make one-on-one phone calls with meeting invitees to ensure that they understand the meeting's purpose and what their role is in the meeting; confirm that they are the right person to attend and, if not, reach out to their recommended contacts. | **2 weeks** before target meeting date |
| | Send a copy of the meeting agenda to key decision makers and partners, and schedule a call to review, answer questions, and make amendments. Send a revised copy to decision makers, partners, and scheduled attendees. | **1-2 weeks** before target meeting date |

19 FEMA's A Guide to Supporting Engagement and Resiliency in Rural Communities Report

| PHASE: | ACTION ITEM: | TIMELINE: |
|---|---|---|
| MEETING DAY | Call influencers, partners, and vocal community leaders to remind them of the meeting, and re-send the meeting reminder email to all attendees. | **12-24 hours** before the meeting |
| | Take detailed notes, connecting the dots between local discussions and Risk MAP support. Share all federal, state, and partner contacts and resources with the community for follow-up. | During the meeting |
| | Ask meeting attendees to leave with one action item they plan to take. This creates optimism after complex discussions. | During the meeting |
| | Clearly share why FEMA is working with the community and work to better understand – and share based on pre-meeting conversations – how that activity aligns with and supports local community goals, including economic development, natural resource conservation, and resilience. Clarify what FEMA is going to do, what the community will do, and who will help manage the process and communications. | During the meeting |
| POST-MEETING FOLLOW-UP | Send final meeting notes, including specific follow-up action items and responsibilities for each action item listed. | **1 week** after the meeting |
| | Call participating communities to answer any questions about meeting materials and to discuss capacity issues for implementing action items from the meeting. | **2 weeks** after the meeting |

Although this and other timelines provided by FEMA are merely suggestions and can be adjusted for each community based on the types of disasters they face, it can be another excellent resource for TAPs, as it helps break down the task of creating these educational seminars and meetings. TAPs have the local knowledge on how to best cater to their communities and how they will respond to these outreach efforts. Locally based TAPs are crucial in that they are the most attuned to the best methods and communication styles for the community to be receptive to these educational seminars and meetings. With the resiliency-explicit angle of this deliverable, it supports TAPs efforts to have these necessary discussions around climate disruptions within their communities.

### *3. Create a list/network of water operators in nearby regions, to promote connectedness and support during times of disasters*

While it is important to build a connection between the public and the water system, it is also important to build community among water operators. Although on existing RCAP Water System Emergency Response Plan & Security Vulnerability Assessments, section 4 does have emergency notification contacts that also include service/repair notifications, not all systems have a specific list with the contact information of nearby systems and their operators who are acquaintances and peers of the impacted water system and its operators. Community network is important in the journey to resilience, including among neighboring water system staff. Often, many rural water systems are faced with challenges surrounding small numbers of full-time staff, lacking both the labor and equipment to quickly repair systems when damaged.[20] By having an easily accessible list of potential nearby contacts and sources of aid during a disaster among the water operator community, systems, operators, and communities could continue to foster a sense of aid with one another. This furthers the goals of RCAP pertaining to regionalization by promoting informal cooperation among communities.[21] There are additional established processes for finding contacts or assistance during disasters and emergencies, such as the state Water/Wastewater Agency Response Network (WARN), which RCAP also recommends systems join and become familiar with prior to an event.[22, 23] It is important for communities and water operators to have and develop these networks, both more formalized through a WARN or informally through lists of nearby water operators. TAPs can continue to promote regionalization through these methods. Plus, having this information documented is important in case of a change in or lack of availability of specific staff. Often in small water systems, much information lives only in the mind of a seasoned, long-standing operator — but in an emergency or a serious event, that information may not be available to a different or new staff member.

While RCAP TAPs often foster (or attempt to foster) relationships between neighboring water systems and their staff and/or community leaders, a recognition of the importance of these relationships and network-building is crucial. There should be more support specifically for these efforts, to allow TAPs to build informal relationships between communities as well as assist the communities with documenting and sometimes formalizing those connections and relationships to promote resiliency.

### *4. Develop educational materials/trainings for future-proofing current technologies for water systems*

As with any topic surrounding resilience of water systems, the physical infrastructure must also be updated and maintained to be able to withstand climate change. Many of these water systems were built more than 50 years ago, and infrastructure might not be built to withstand current and future climate hazards. By utilizing one of the three tools (from deliverable #1) and identifying what potential hazards are, the most vulnerable infrastructure can be prioritized and "future-proofed."[24] For example, in communities that are identified as at-risk for flood zones, FEMA offers suggestions on solutions to combat this for public utilities. This includes elevating critical equipment and electrical wiring to be above the height of flood-potentials and strengthening the structure of the surrounding water systems to withstand flooding forces.[25] Other common ways that water systems can be upgraded to be more resilient include having spare generators and back-up power supplies for any electrical outages, and even investing in new technologies, such as temperature-controlled

20 Payton Scally, C., Marx, R., Polonius, I., & Davis, A. (2021). Preparing Rural Water Systems for Extreme Weather and Climate Disasters. Urban Institute: Metropolitan Housing and Communities Policy Center, 1-17.

21 RCAP Regionalization: RCAP's Recommendations for Water and Wastewater Policy Executive Summary

22 EPA Water/Wastewater Agency Response Network (WARN)

23 RCAP Regionalization: RCAP's Recommendations for Water and Wastewater Policy Executive Summary

24 American Water Works Association – Buried No Longer: Confronting Americas Water Infrastructure Challenge

25 FEMA Hurricane and Flood Mitigation Handbook for Public Facilities Fact Sheet (2022)

pipes that control and detect water leaks that are occurring, which is especially important for water lines that are underground and harder to monitor[26] This technology allows water operators to quickly identify where these leaks are occurring based on temperature differences and to shut off the water supply before a larger catastrophe happens, such as the pipe bursting, increasing both the cost of repair and time without a water supply.

Based on which climate hazards the community identified as its greatest vulnerabilities, there are many FEMA resources on potential mitigation and resilience solutions for utilities. This deliverable is a two-step process that begins with the national office first receiving trainings and information to help deepen the knowledge for TAPs on potentially relevant future-proofing technologies. To gain all the proper knowledge on these climate-proofing technologies, it would be best to solicit information on a topic like this from someone who is an expert at resilience and climate disruptions, such as a staff member from FEMA. National staff from RCAP and individuals from the regional offices can have the opportunity to learn about these future-proofing technologies at a variety of platforms, such as through an online or in-person training or a session/workshop at a future RCAP National Conference.

While TAPs are already very knowledgeable on potential infrastructural solutions, creating trainings for resilient-focused infrastructure provides more resources for the topic. Once TAPs are fully aware of and comfortable with the various available technologies, these can be presented to the communities and water systems with options discussed in the most effective manner. Often, these infrastructural or technological updates can be expensive, and careful thought must go into figuring out funding mechanisms to acquire said future proofing technologies and selecting one that will promote the most beneficial long-term resilience for the community. Therefore, before making any large-scale decisions that could cost hundreds of thousands of dollars to the community to upgrade the resilience of their physical water systems, it is important that proper research is done into the available technologies for the types of disasters that the community faces.

### *5. Create GIS maps of the vulnerable water systems in the community based on potential disasters in the region*

Although there are many Geographic Information System (GIS) tasks that occur within TA, a process to prioritize and identify which water systems are more vulnerable than others because of climate change is valuable for increasing resiliency. As mentioned previously, due to often having fewer funds available for resilience projects, it is unlikely that all water systems in the community will be properly addressed, have the opportunity to increase their physical resilience, or receive technical assistance. To help prioritize the systems that are most vulnerable, creating an interactive GIS map of the existing water systems and their corresponding hazard(s) could be beneficial. This can be accomplished through a multi-step process. The first step is to further encourage the task that TAPs are currently undertaking with GIS-related projects, particularly those identifying spatial locations of critical assets like pipelines and hydrants. There needs to be further emphasis on the

26 Kettle, P., Trainor, S., Edwards, R., Antrobus, D., Baranowski, C., Buxbaum, T., Berry, K., Brubbaker, M., De Long, K., Fries, S., Holen, D., Keim, B., Meeker, D., Penn, H., Rosa, C., Walsh, J., & Zhang, J. (2023). Building resilience to extreme weather and climate events in the rural water and wastewater sector. JAWRA, 1-18. doi: 10.1111/1752-1688.13151.

importance of gaining a better understanding of the exact assets that each system has, and there should be more capacity, time, and funding built up to do more of this work.

The second step involves TAPs further focusing on the specific surrounding vulnerabilities to climate change in the region. To help identify what potential climate events could impact the region, TAPs can first utilize the three tools from the deliverable #1 to identify what climate events could be a hazard. From there, GIS can help contextualize how these climate events could affect the community's water systems. For example, in the case of flooding, there are many publications and resources from FEMA that demonstrate flood zones. There is even a National Flood Hazard Layer, which is a geospatial database that displays flooding risks.[27] By creating a map that demonstrates where water systems are in comparison to flood zones and risks, the water systems in these hazardous areas can be prioritized to elevate the necessary equipment from floods. This same kind of assessment can be done via GIS with virtually any climate disruption.

For this deliverable to be most effective, TAPs must first assess what climate disruptions are most likely to occur in the community (deliverable #1), so they can help identify what climate vulnerabilities could impact these systems as well as which systems may be at greatest risk. Then, in order to understand the specific risks to those systems, the work done to map the system's assets will be very useful. A GIS map can be created by having the two layers combined, so that the water system assets are overlay with the layer containing climate hazards for the region. By combining the GIS layer and creating one map, this can further the TAPs and community's awareness of what sort of physical infrastructure changes would need to occur based on which water systems are the most vulnerable.

### 3) Appropriate metrics for measuring success of resilience

There are two ways that measuring the success of these efforts to improve resilience can be done. The first is through the outputs of the deliverables, and the second is by measuring resilience of the water systems itself.

## Measuring Deliverables

To measure each of the five deliverables from section 2, there would be a mixture of outputs, ranging from the creation of beneficial maps, to documentations to help keep lists in order.

### 1. IDENTIFY A LIST OF POTENTIAL CLIMATE DISRUPTIONS THAT COULD OCCUR WITHIN A ## MILE RADIUS OF THE COMMUNITY'S WATER SYSTEMS

This deliverable involves the utilization of the three tools recommended by FEMA, and these tools offer interactive maps to help the TAPs identify what hazards can impact the community. With the Climate Mapping for Resilience and Adaptation tool, this can be used by TAPs during ongoing climate events to identify where these events are occurring and how close in proximity they may be to the community. With the Climate Risk and Resilience Portal, the interactive map can help

27 FEMA National Flood Hazard Layer (NFHL)

show the future local projections surrounding things such as temperature, heat index, wildfire, precipitation, and wind. With the FEMA National Risk Index, the county that the community resides in can be selected and a risk index is calculated, such as hazard type risk ratings (e.g. coastal flooding, drought, heat wave, tornados, etc.). Along with these interactive maps, data pertaining to these three tools can also be downloaded and used for GIS (this downloaded data can then be used for deliverable #5). The usage of both the interactive map and downloadable data can have two different outputs for a deliverable from the TAPs. An extensive list of possible hazards should be created in collaboration with the water operator to understand the full extent of climate disruptions, along with the information that is provided with the interactive tool. For example, with the FEMA National Risk Index, it creates ranks for the hazard type risk ratings on a percentile basis, and the TAPs can report what the percentile each hazard type listed on the index is at. This can help demonstrate the severity of each potential climate hazard. Creating a list of potential hazards and their level of severity that is easily accessible is beneficial for TAPs and water operators, so the operators do not have to continuously refer to the online tool. The data that is downloaded from these interactive maps should also be recorded so that it can be easily accessed for deliverable #5.

### 2. PROVIDE AN OVERVIEW AND EDUCATE THE COMMUNITY ON THE TYPES OF DISASTERS THAT COULD IMPACT THE COMMUNITY'S WATER SYSTEM

This deliverable focuses on education on the types of climate disruptions that could impact the water system. TAPs can help arrange these meetings and market them however they will be best received within the community (e.g. deciding if it should be framed as a climate-focus meeting, resilience-focused, extreme weather-focused, etc.). Additionally, attendance numbers can be tracked. To help also track the effectiveness of the meetings, a quick pre- and post- assessment/ questionnaire can be completed by attendees to measure the effectiveness in understanding the topics discussed at these meetings.

### 3. CREATE A LIST/NETWORK OF WATER OPERATORS IN NEARBY REGIONS, TO PROMOTE CONNECTEDNESS AND SUPPORT DURING TIMES OF DISASTERS

This deliverable is rooted in ensuring that the water operator has a clear list of contacts for outreach during a climate disruption. A list of contacts should be created that offers clear documentation of the name, phone numbers, and any relevant information to how this contact can be of assistance during a climate event. This documentation should have both virtual and hard copies to ensure that the operators always have access to this information. TAPs can also report how many contacts and connections they were able to help facilitate.

### 4. DEVELOP EDUCATIONAL MATERIALS/TRAININGS FOR FUTURE-PROOFING CURRENT TECHNOLOGIES FOR WATER SYSTEMS

Appropriate metrics for this deliverable are still to be determined, based largely on what approach is used to solicit or develop and utilize training and educational materials. However, it is likely that attendance and potentially also pre- and post-assessments of knowledge can be utilized.

### 5. CREATE GIS MAPS OF THE VULNERABLE WATER SYSTEMS IN THE COMMUNITY BASED ON POTENTIAL DISASTERS IN THE REGION

This deliverable can have two outputs for completion. The first pertains to the continued mapping of critical assets of a water system, such as pipelines and hydrants. The second pertains to undertaking deliverable #1 (identifying climate disruptions for the region), and then using that information to identify what systems in the region are most vulnerable to future climate events and prioritizing those for resilience-building. With both datasets — the critical assets layer and the climate hazards layer — a final product of one GIS map can be created for the community to identify their most vulnerable systems.

## Measuring System Resilience

While TAPs have been recording issues around water systems and resiliency in their work already, and although the prior proposed deliverables have their own individual ways to be measured, such as through the creation of GIS maps and expanding contact sheets for local water operators, it is also likely necessary to assist TAPs by creating a universally used baseline understanding of where the water system stands in terms of resilience. By measuring these baseline conditions, it allows for the water systems to continue to be monitored over time and comparisons to be made on their progress towards resiliency.[28, 29]

Some could argue that there is an over-inundation of metrics that measure the resilience of communities to disasters and climate change. However, for a metric to be implemented by TAPs to measure resilience, it must be both easily accessible and doable among these communities and be relevant to water infrastructure. Therefore, though many metrics were heavily focused on quantitative analysis and upon seeing the requirements for data collection, the focus shifted to metrics with more qualitative data gathering. Below is a brief overview of the five metrics that were deemed to be potentially the most applicable to the goals of measuring resilience for TAPs but were later deemed to not be the right options for this project.

28 Cutter, S., Burton, C., & Emrich, C. (2010). Disaster Resilience Indicators for Benchmarking Baseline Conditions. Journal of Homeland Security and Emergency Management, 7(1), 1-22. doi:10.2202/1547-7355.1732

29 Horney, J., Dwyer, C., Chirra, B., McCarthy, K., Shafer, J., & Smith, G. (2018). Measuring Successful Disaster Recovery. International Journal of Mass Emergencies and Disasters, 36(1), 1-22.

| Model | Authors | Year | Short Overview | Why not applicable | Reference |
|---|---|---|---|---|---|
| **DROP** | Cutter et al. | 2010 | Stands for Disaster Resilience of Place (DROP) — focuses on five components of disaster resilience: social, economic, institutional, infrastructural, and community capital resilience. Scores are calculated min-max rescaling schemes and aggregated, creating visualization of low and high resilience for each of the five components of disaster resilience. | DROP emphasizes the importance of learning baseline indicators, which is relevant but is a very quantitative-heavy focus and would be difficult to gain all the necessary data. | Cutter, S., Burton, C., & Emrich, C. (2010). Disaster Resilience Indicators for Benchmarking Baseline Conditions. Journal of Homeland Security and Emergency Management, 7(1), 1-22. doi:10.2202/1547-7355.1732. |
| **CART** | Pfefferbaum et al | 2013 | Stands for the Communities Advancing Resilience Toolkit (CART) — focuses on community involvement and participation in establishing resilience. It's an interactive survey and questionnaire intended for use in four stages: generating preliminary sponsors and partners in community, identifying gaps in assessment of community, developing strategic plans and objectives, and identifying/implementing plans. | This metric had a lot of potential due to being more qualitatively focused and a questionnaire but would not be applicable for two reasons. One, we need more than a community-focused resilience metric and two, the questionnaire is no longer available online. | Pfefferbaum, R., Pfefferbaum, B., Van Horn, R., Klomp, R., Norris, F., & Reissman, D. (2013). The Communities Advancing Resilience Toolkit (CART): development of a survey instrument to assess community resilience. Journal of Public Health Management and Practice, 19(3), 250-258. doi: 10.2307/48566841. |
| **CDRI** | Peacock et al | 2010 | Stands for Community Disaster Resilience Index (CDRI) — this metric focuses on disaster management and community capital (including social, economic, physical, and human capital). After identifying important practices necessary for each phase of disaster management (mitigation, preparedness, response, recovery), the necessary community capital resources are outlined. CDRI indices are created using various statistical measures. | CDRI is incredibly quantitative-heavy with a large background in statistical analysis needed to successfully utilize. This metric also does not focus solely on resilience, but on all four stages of disaster management. | Peacock, Walter. (2010). Advancing the Resilience of Coastal Localities: Developing, Implementing and Sustaining the Use of Coastal Resilience Indicators: A Final Report. 1-148. Doi:10.13140/RG.2.2.35146.80324. |

| | | | | | |
|---|---|---|---|---|---|
| **CARE** | Balaei et al | 2020 | Stands for Water Supply Comprehensive Aggregated Resilience Measure (CARE) model — this metric is specific to water supply and system resilience, and views resilience and robustness equating to the system's vulnerability, redundancy, and criticality. Indices are calculated within each category, and a statistical formula is created from these indices that calculates the robustness and physical resilience of the water supply. | This metric was useful in that it discussed how to promote resilience with water systems and water supply specifically, but the heavy quantitative nature of the data that is required makes it not as easily accessible to TAPs. It also heavily focuses only on the physical aspects of resilience. | Balaei, B., Wilkinsom S., Potangaroa, R., & McFarlane, P. (2020). Investigating the technical dimension of water supply resilience to disasters. Sustainable Cities and Society, 1-11. doi: 10.1016/j.scs.2020.102077. |
| **ARC-D** | Clark-Ginsburg et al | 2010 | Stands for Analysis of Resilience of Communities to Disasters (ARC-D) toolkit — the goal of this metric is to act as a way for community resilience to be measured through resilience-building interventions. They operate off the assumption that eight systems are interconnected (education, economic, environmental, policy and government, health, infrastructure, social and culture, and disaster risk management), and the toolkit has 30 resilient questions pertaining to these systems for the users to answer using the one (minimal resilience) to five (full resilience) scale. | Table 1 in this article provides an excellent overview of the types of questions that TAPs should consider when assessing their resilience. This article was also insightful with how they measured their one-to-five scale. However, this metric was ultimately categorized as not applicable due to being slightly too broad, and not focused enough on water supply resilience. | Clark-Ginsberg, A., McCaul, B., Bremaud, I., Caceres, G., Mpanje, D., Patel, S., & Patel, R. (2020). Practitioner approaches to measuring community resilience: the analysis of the resilience of communities to disaster toolkits. International Journal of Disaster Risk Reduction, 1-10. doi: 10.1016/j.ijdrr.2020.101714. |

Even though the metrics in the table above were determined to be not applicable to this project, they may still hold some value. For example, though the ARC-D toolkit is too broad and does not have a more specific focus on water, their one-to-five scale on how they measured resilience within their questions is something to keep in mind when working on our own metrics. Another example can also be with the CART model, for which, when we are addressing community resilience in the deliverables for the TAPs, there are key takeaways in the article on how to properly address and involve community members in discussions surround climate resiliency.

There were three metrics, however, that seemed to potentially be the most applicable to the goals of measuring resilience of water systems for TAPs. Two utilized Likert scales and a Water Provision Indicator, while the one that could be the most applicable was the Hazard Resilience Index.

## 1. LIKERT SCALES

In Howard et al.'s (2021) publication, "The how tough is WASH framework for assessing the climate resilience of water and sanitation," the authors utilized a Likert scaling system to measure how resilience of water and sanitation services are being impacted by climate change, focusing on six categories: water supply and sanitation infrastructure, environmental setting, water and sanitation management, community governance and engagement, institutional support, and supply chain.[30] Using a one-to-five Likert scaling system, scores were calculated within each category for a particular water/sanitation focus.

Below is a screenshot of an example table taken from Howard et al.'s (2021) publication, where they demonstrate the descriptions used to measure on the one-to-five scale. For this table, the author's ran this on piped water supply in the region.

**Table 2 Scoring framework for Resilience domains: piped water supply.**

From: The how tough is WASH framework for assessing the climate resilience of water and sanitation

| Score | Domain | | | | | |
|---|---|---|---|---|---|---|
| | Infrastructure | Catchment | Water supply management | Community governance and engagement | Institutional support | Supply chain |
| 1 (very low) | No protective measures against the risk of damage and inundation in place, no data on trends in yield or evidence of declining yield, very high sanitary risks at source and within the distribution system, major damage and leaks in the distribution network, numerous raised tanks at risk from wind | The source is downhill of extensive, steeply sloping built-up land/bare soil, or is in an area frequently (annually) inundated with river or seawater, with no flood protection measures, and/or is in a densely populated setting with open defecation and pit latrines at high risk of inundation, other water users severely impact on water availability | No effective management, including financial, with no action taken to resolve problems in supply, no understanding of climate-adaptive management, no participation in risk assessments, untrained and unskilled operators, no representation of women | Minimal social cohesion, civic engagement, interpersonal trust, participatory behaviour demonstrated by lack of involvement of community members in decision-making; exclusion of marginalized groups from WASH decision making | No formal risk management programme in place in local government, no steps taken to support water supply managers to develop adaptive measures, substantial delay in procuring parts or technical support after an emergency | Only one source of consumables and parts, only one route exists between the community and the market with a high risk of damage to roads, bridges, or mobile communication networks from natural hazards, user committees do not store surplus parts needed to carry out repairs |
| 2 (low) | Limited protective measures against the risk of damage and inundation, substantial seasonal declines in yield and an overall decline in yield, high sanitary risk at source and within the distribution system, some damage and leaks in the distribution network, some raised tanks at risk from wind | The source is downhill of some steeply sloping built-up land/bare soil, or is in an area regularly (once every 3–5 years) inundated with river or seawater, with partial flood protection measures, and/or is in a densely populated setting with some open defecation or pit latrines at medium risk of inundation other water users impact on water availability | Management is weak, including financial, with actions to address problems ad hoc and rarely in good time, a basic understanding of climate change and adaptive management, no participation in risk assessments, operators with limited partial training with limited skills, minimal representation of women | Limited social cohesion, civic engagement, interpersonal trust, and participatory behaviour demonstrated by only occasional involvement by community members in decision-making; limited inclusion of some marginalized groups in WASH decision making | No formal risk management programme in place in local government, but ad hoc support for water supply managers is provided to develop and undertake adaptive measures, some delay in procuring parts or technical support | Limited sources of consumables and parts, only one route exists between the community and the market, medium risk of damage to roads, bridges, or mobile communication networks from natural hazards, user committees do not store parts needed for repair |
| 3 (medium) | Partial protective measures against risks of damage and inundation in place, relatively small seasonal declines in yield but evidence of overall decline, medium sanitary risk at source and within the distribution system, minor damage and leaks in the distribution network, few raised tanks at risk from wind | The source is downhill of moderately sloping managed or cultivated land, or is in an area occasionally (once every 10 years) inundated with river or seawater, with flood protection measures, and/or is in a densely populated area with no open defecation but pit latrines at medium risk of inundation, other water users have limited impact on water availability | Management is reasonably good, including financial, with actions taken when problems arise although not necessarily in good time, limited understanding of climate change and adaptive management, limited participation in risk assessments, operators with basic training with a moderate range of skills, moderate community engagement, and support, some representation of women but none in a leadership position | Intermediate social cohesion, civic engagement, interpersonal trust, participatory behaviour demonstrated by a regular but limited involvement of community members in decision making; limited inclusion of most marginalized groups in WASH decision making | The local government has a limited risk management programme and provide limited risk management training to water supply managers, but does not provide support to implement adaptive measures and no coordination with other sectors, slight delay in procuring parts or technical support after an emergency | Limited sources of consumables and parts, multiple routes exist between the community and the market, medium risk of damage to roads, bridges, or mobile communication networks from natural hazards, user committees have some surplus parts needed to carry out repairs |

30 Howard, G., Nijhawan, A., Flint, A., Baidya, M., Pregnolato, M., Ghimire, A., Poudel, M., Lo, E., Sharma, S., Mengustu, B., Mekbib Ayele, D., Geremew, A., & Wondim, T. (2021). The how tough is WASH framework for assessing the climate resilience of water and sanitation. npj CLean Water, 4(39), 1-10. doi: 10.1038/s41545-021-00130-5.

| | | | | | | |
|---|---|---|---|---|---|---|
| 4 (high) | Protective measures against risks of damage and inundation in place, little seasonal decline in yield and little evidence of overall decline, low sanitary risk at source and within the distribution system, limited leakage, no raised tanks at risk from wind | The source is downhill of gently sloping managed or cultivated land, or is in an area rarely (once in 20 years or more) inundated with river or seawater, with flood protection measures, and/or is in a densely populated area with no open defecation but pit latrines at limited risk of inundation, other water users may have minor impact on water availability | Competent management, including financial, with actions taken in a timely manner to address supply problems, moderate understanding of climate change and adaptive management, moderate participation in risk assessments, operators with extended training and skills, good community engagement and support, equal representation of women on committees but few in leadership positions | Good social cohesion, civic engagement, interpersonal trust, general participatory behaviour; demonstrated by regular engagement of community members in decision making; moderate inclusion of most marginalized groups in WASH decision making | The local government has a developed risk management programme and provides risk management training to water supply managers and some limited support to implement adaptive measures and has limited coordination with 1–2 other sectors, no delay in procuring parts or technical support after an emergency | Multiple sources of consumables and parts, multiple routes exist between the community and the market with low risk of damage to roads, bridges, or mobile communication networks from natural hazards, user committees store most surplus parts needed to carry out repairs |
| 5 (very high) | Comprehensive protective measures against risks of damage and inundation in place, no evidence of a seasonal or overall decline in yield, no evidence of reducing yield, very low sanitary risk at source and within distribution system leakage within national limits, no raised tanks at risk from wind | The source is downhill of gently sloping natural land, has flood protection measures and is in an area never inundated with river or seawater, and/or is in an area with no open defecation and pit latrines at no risk of inundation, other water users have negligible impact on water availability | Strong management, including financial, system able to anticipate problems and prevent these from disrupting supply, a good understanding of climate change and adaptive management, active participation in risk assessments, well-trained operators with a range of skills, women take an equal number of leadership and decision-making roles | Strong social cohesion, civic engagement, interpersonal trust, participatory behaviour demonstrated by active engagement by community members in all decision making; inclusion of all marginalized groups in WASH decision making | The local government has a comprehensive risk management programme and provides risk management training to water supply managers and ongoing support for adaptive measures with cooperation with all other sectors, no delay in procuring parts or technical support after an emergency | Multiple sources of consumables and parts, multiple routes exist between the community and the market, no risk of damage to roads, bridges, or mobile communication networks are from natural hazards, user committees store most or all parts needed to carry out repairs |

Howard et al. utilized the Likert scale at the community level, which can be replicated for use with TAPs. It also allows flexibility on understanding resilience and amending language to reflect the specific disasters that may occur in the different regions that TAPs work in. This is a useful potential metric that TAPs can use alongside RCAP's existing Small Systems Risk and Resilience Assessment, where TAPs can work with communities to assess their water system's resilience level.

## 2. WATER PROVISION INDICATOR

The Water Provision Indicator (WPI) is technically a proposed indicator for measuring sustainability and not necessarily a metric. Nonetheless, it seems like an important possible measurement of resilience as it also specifically deals with water resilience. Published by Milman and Short (2008) in "Incorporating resilience into sustainability indicators: An example for the urban water sector," the indicator uses a scaling system to identify vulnerabilities in water systems that could potentially prevent communities accessing water in the future or due to a disaster.[31] Based off the six categories (supply, finances, infrastructure, service provision, water quality, and governance), the questionnaire is completed by an individual who has a prior connection to and background knowledge on the water system, which could easily describe TAPs.

After scores are calculated, the categories are then color coordinated based on their scores. A red code indicates that the score is below 25% and that this category requires serious attention. A yellow code indicates that the score is between 25% and 75%, and that there may be some short- and long-term things that need consideration and action. A green code is one where the score is above 75%, and while it does not necessarily mean that the water system does not have any vulnerabilities, it is not the most prioritized category to build resilience. Although this points-based scoring metric is beneficial in terms of ease and a focus on water, it does not necessarily address disaster-specific considerations with water resilience. It also was originally designed for urban water systems, so there may be some difficulties in scaling for rural water systems.

31 Milman, A., & Short, A. (2008). Incorporating resilience into sustainability indicators: An example for the urban water sector. Global Environmental Change, 758-767. doi: 10.1016/j.gloenvcha.2008.08.002.

## 3. HAZARD RESILIENCE INDEX

Despite the usefulness that the Likert scale and Water Provision Indicator provides, our favorite measurement system under consideration is the Justice Institute British Columbia's Hazard Resilience Index (HRI). This index focuses on how communities can become more resilient to local and regional hazards and offers a plethora of surveys. However, for this project the two we focused on are the HRI's survey on Atmospheric Hazards and on Power/Water Outages.

The Atmospheric Hazards survey provides 17 different categories of hazards that can be completed: blizzards; climate change; drought; extreme cold; fog; frost; hailstorms; heat waves and heat domes; hurricanes and post-tropical storms; ice fogs, ice storms, and freezing rain; lake-effect storms; lightning and thunderstorms; microbursts; sea storms and sea surges; seiche; snowstorms; tornadoes and waterspouts; windstorms. This diversity is especially beneficial, as TAPs are located all throughout the U.S. and different communities face different environmental challenges.

However, all the atmospheric hazard surveys outline different factors that are often associated with that climate disruption, and it is meant to be assessed by an individual familiar with the needs of the systems. Below is a screenshot of an example of what one of these atmospheric hazard surveys look like:

| **Hazard Resilience Rating** | High Resilience ☐ | Low Resilience ☐ | Need More Info ☐ | Not Applicable ☐ |
|---|---|---|---|---|

| Yes | No | Need More Info | Not Applicable | FACTORS | This factor is important to my community |
|---|---|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ | Building designs can withstand extreme cold and freezing temperatures. | ☐ |
| ☐ | ☐ | ☐ | ☐ | Community-based cold-weather exercises have taken place in schools and the community-at-large (e.g., table-top or full-scale exercises). | ☐ |
| ☐ | ☐ | ☐ | ☐ | In case of an extended power failure, there are plans to allow residents to evacuate to a designated shelter with back-up power. | ☐ |
| ☐ | ☐ | ☐ | ☐ | Most homes have well insulated windows, walls, attics and pipes and roofs that are maintained in good condition. | ☐ |
| ☐ | ☐ | ☐ | ☐ | Most residents check regularly with weather and storm forecasting agencies such as Environment Canada and take care to follow warnings and/or use Subject Matter Experts or Traditional Knowledge to assess weather prior to heading out onto the land. | ☐ |
| ☐ | ☐ | ☐ | ☐ | Most residents have heating sources that do not require power and/or have alternate power sources (e.g., generator) and are aware of its safe operation and ventilation needs. | ☐ |
| ☐ | ☐ | ☐ | ☐ | Most residents have winter tires and winter emergency kits (including rock salt, shovels, blankets, food and water) in their vehicles. | ☐ |
| ☐ | ☐ | ☐ | ☐ | There is a cold-weather shelter in the community that is accessible to transient, migrant, homeless and visiting people. | ☐ |
| ☐ | ☐ | ☐ | ☐ | There is a warning system in place to notify emergency response personnel of extreme cold conditions. | ☐ |
| ☐ | ☐ | ☐ | ☐ | There is a warning system in place to notify residents of extreme cold conditions. | ☐ |
| ☐ | ☐ | ☐ | ☐ | There is a warning system in place to notify transient, migrant, homeless and visiting people of extreme cold conditions. | ☐ |
| ☐ | ☐ | ☐ | ☐ | Existing homeless shelters have made provisions for increased capacity and hazard specific conditions. | ☐ |
| ☐ | ☐ | ☐ | ☐ | The community has in place a means to discuss extreme cold with Subject Matter Experts or Traditional Knowledge holders about traditional warning systems and effective responses. | ☐ |

A disadvantage of using this survey is that while it is specific to disasters and climate hazards, it is not specific to water. However, the HRI also has a separate survey for power/water outages. Below is an example of the kind of survey that the HRI reports on with water outages:

## Water Outages

This section has been separated into two sets of factors; one for those communities connected to a community water/wastewater system, and a separate one for communities where most OR all households are not connected to the community water/wastewater system.

### Communities with Water/Wastewater Systems Supplying ALL Householders

| **Hazard Resilience Rating** | High Resilience ☐ | Low Resilience ☐ | Need More Info ☐ | Not Applicable ☐ | |
|---|---|---|---|---|---|
| Yes | No | Need More Info | Not Applicable | FACTORS | This factor is important to my community |
| ☐ | ☐ | ☐ | ☐ | Back-up generators are in place at pump stations to ensure equipment continues to operate in an extended power outage. | ☐ |
| ☐ | ☐ | ☐ | ☐ | Community-based water outage exercises have taken place in schools and the community-at-large (e.g., table-top or full-scale exercises). | ☐ |
| ☐ | ☐ | ☐ | ☐ | Community Environmental Health Inspectors perform regular safety checks of individual and personal farm and residential wells. Commercial farms are inspected by the appropriate federal, territorial or provincial authority. | ☐ |
| ☐ | ☐ | ☐ | ☐ | Inspectors perform regular safety checks of water reservoirs or silos. | ☐ |
| ☐ | ☐ | ☐ | ☐ | Inspectors perform regular safety checks of water treatment and distribution systems. | ☐ |
| ☐ | ☐ | ☐ | ☐ | The community has replaced all gray cast iron pipes. | ☐ |
| ☐ | ☐ | ☐ | ☐ | The community has plans in place for water distribution should the community experience a loss of potable water. | ☐ |
| ☐ | ☐ | ☐ | ☐ | The community has policies in place to limit non-essential water usage (e.g., watering lawn) during times of drought. | ☐ |
| ☐ | ☐ | ☐ | ☐ | The community has updated old and worn-out pipes and infrastructure to prevent pipeline failure in the future. | ☐ |

Like all the previously mentioned metrics, the HRI is not a perfect fit for the needs of this project. However, it shows the most potential for a process for accomplishing the desired goal. There are some serious drawbacks to this metric — it does not combine both the atmospheric hazard survey with the water outage specific survey, and it is also based in Canada and therefore some of the factors are not applicable to U.S.-based TAPs. Because the HRI is the intellectual property of the Justice Institute British Columbia, there are also questions around how much revisioning can be done on these specific documents and implemented for use with TAPs.

To move forward with this metric, we would need to create our own version of the HRI, one that specifically fits the goals of implementation with TAPs, using its framework as our inspiration. There simply are not many metrics that accomplish the goal of measuring the resilience of water systems without being too focused on either physical or social resiliency, or being too quantitative-heavy. However, using the HRI as a base model, combined with existing research in academic articles and recommendations from FEMA, there is merit in collaborating with TAPs on what they believe are also indicators of resilience for both the community and water systems and creating our own list of "factors" that combine the climate hazards and water outages into one. One of the most key elements of the HRI is that it does create a broad applicability aspect because it covers 17 different climate hazards, and if we were to create our own version, we should also ensure that a survey is created for a diverse range of disasters.

Although this may appear to be an arduous task, it is incredibly important. This metric can serve as a starting guide for the proposed deliverables. This HRI-like measurement system can be potentially taken pre- and post-survey and intended to be taken every few years to assess if there are any changes in resilience after the implementation of the deliverables. The deliverables themselves have their own measurements of success — e.g. the creation of GIS maps. But to fully know if this is benefitting the community or not by increasing their overall resilience, having a baseline is important for comparisons as time passes.[32, 33] By using a survey as the first step in the resiliency plan, it can help TAPs continue to identify where there is low resilience and help prioritize the deliverables that can be done to improve these low-resilience areas. Following the pre-survey, taking the survey every few years again can help show the progression of the community in becoming more resilient and reassess where TAPs will now need to focus to continue building resilience. It holds the community and TAPs accountable in understanding what areas may be lacking in resilience, figuring out what deliverables to prioritize for the community, and cataloging the progression in improvements over the course of years.

## 4) POTENTIAL FUNDERS

One of the biggest roadblocks in discussions surrounding the incorporation of resilience, especially one that TAPs have been encountering consistently, is the question of funding. Although the cost of physical resilience upgrades and maintenance is often the majority of the cost of resilience, it is important to also consider the issues surrounding the costs of technical assistance. TAPs are valuable in all aspects of resilience (physical or social), and funding for TAPs' labor is also crucial. However, many rural and small communities do not have the necessary funds to address the costs tied to new resilience infrastructure.[34] Although TAPs are well aware of the need to increase the resiliency of these water systems, they often do not have the funding to focus on doing so, and it is becoming even more crucial to find funding sources as climate disruptions increasingly impact communities. Therefore, to continue to implement and encourage building towards a resilient water system, additional funding is needed. Funding opportunities are generally available through governmental agencies or through philanthropic, private donors and foundations. To aid in the assessment of appropriate funders, the EPA has also created the Water Finance Clearinghouse, which allows for individuals to customize searches for funding opportunities offered at any government agency as well as many private funding opportunities. The search can be further filtered by sector of topic, scope, and even eligible applicants.[35] By searching for key words surrounding climate/disasters, resilience, and water, TAPs and community/utility members/leaders can see what kinds of grants and foundations have historically funded projects in their regions.

32 Cutter, S., Burton, C., & Emrich, C. (2010). Disaster Resilience Indicators for Benchmarking Baseline Conditions. Journal of Homeland Security and Emergency Management, 7(1), 1-22. doi:10.2202/1547-7355.1732.

33 Horney, J., Dwyer, C., Chirra, B., McCarthy, K., Shafer, J., & Smith, G. (2018). Measuring Successful Disaster Recovery. International Journal of Mass Emergencies and Disasters, 36(1), 1-22.

34 Kettle, P., Trainor, S., Edwards, R., Antrobus, D., Baranowski, C., Buxbaum, T., Berry, K., Brubbaker, M., De Long, K., Fries, S., Holen, D., Keim, B., Meeker, D., Penn, H., Rosa, C., Walsh, J., & Zhang, J. (2023). Building resilience to extreme weather and climate events in the rural water and wastewater sector. JAWRA, 1-18. doi: 10.1111/1752-1688.13151.

35 EPA Water Finance Clearinghouse Portal

## *1. Federal Funds*

There are two federal funding opportunities that do provide options for those who want technical assistance-specific options on water and resilience:

| Name | Agency | Short Description | Comments | Links |
|---|---|---|---|---|
| Training and Technical Assistance for Wastewater Treatment Works (Clean Water Act Section 104(b)(8)) | EPA | “The objective is to provide technical assistance and training to rural, small, and tribal municipalities to: (1) plan, develop, and obtain financing for Clean Water State Revolving Fund (CWSRF) eligible projects; (2) protect water quality and achieve and maintain compliance with the requirements of the Clean Water Act; and (3) provide information on planning, design, construction, and operation of publicly owned treatment works and decentralized wastewater treatment systems” | Although originally does not appear to be relevant to resilience, page 11 indicates that new priorities are shifting towards inclusion of resilience and how to manage with disasters | Link here and Link here |
| Building Resilient Infrastructure and Communities Direct Technical Assistance | FEMA | “Building Resilient Infrastructure and Communities (BRIC) Direct Technical Assistance (DTA) gives full support to communities that may not have the resources to begin climate resilience planning and project solution design on their own. Through process-oriented, hands-on support, BRIC DTA will work to enhance a community’s capacity to design holistic, equitable climate adaptation solutions that advance numerous community-driven objectives. FEMA will give wide-ranging support to BRIC DTA communities including climate risk assessments, community engagement, partnership building, mitigation and climate adaptation planning, and BRIC program requests throughout the grant lifecycle. Support for BRIC DTA communities will be given from pre-application activities to grant closeout.“ | Seems like a great resource to consider | Link here |

Although the aim is to find funding sources that offer funding to incentivize involvement of technical assistances for resilience measures, there are a few key funding sources that, while they may not specifically be for technical assistance or resilience measures, could still be important to consider when looking at funding opportunities:

| Name | Agency | Short Description | Comments | Links |
|---|---|---|---|---|
| Drinking Water System Infrastructure Resilience and Sustainability Program SDWA 1459A(l) | EPA | "The purpose of this grant program is to increase drinking water system resilience to natural hazards. Grant funding can be used to assist in the planning, design, construction, implementation, operation, or maintenance of a program or project that increases resilience to natural hazards." | Although not specific to technical assistance (TA), still has an emphasis on water systems | Link here |
| Emergency Community Water Assistance Grants | USDA | "To help rural residents who have experienced a significant decline in quantity or quality of water, due to an emergency event (such as drought, earthquake, hurricane or tornado), to obtain adequate quantities of water that meet the standards of the Safe Drinking Water Act." | Although not specific to TA and may not help with long-term resilience, an important resource for immediate aid following a disaster | Link here |
| Flood Mitigation Assistance | FEMA | "The Flood Mitigation Assistance grant program is a competitive program that provides funding to states, local communities, federally recognized tribes and territories. Funds can be used for projects that reduce or eliminate the risk of repetitive flood damage to buildings insured by the National Flood Insurance Program." | Although not TA or relevant to all water systems, FMA is one of the big funders for FEMA mitigation efforts | Link here |
| Hazard Mitigation Grant | FEMA | "FEMA's Hazard Mitigation Grant Program provides funding to state, local, tribal and territorial governments so they can develop hazard mitigation plans and rebuild in a way that reduces, or mitigates, future disaster losses in their communities. This grant funding is available after a presidentially declared disaster." | Although not TA or relevant to all water systems, HMG is one of the big funders for FEMA mitigation efforts | Link here |
| Pre-Disaster Mitigation | FEMA | "The Pre-Disaster Mitigation (PDM) grant program makes federal funds available to state, local, tribal and territorial governments to plan for and implement sustainable cost-effective measures designed to reduce the risk to individuals and property from future natural hazards, while also reducing reliance on federal funding from future disasters. The program is authorized by Section 203 of the Stafford Act." | Although not TA or relevant to all water systems, PDM is one of the big funders for FEMA mitigation efforts | Link here |

A recent analysis on the role of FEMA's Hazard mitigation Action programs was done looking at usage for water-related projects. During the 2012–2017 fiscal years, it was found that out of 6,360 projects funded, there was a distinct lack of funding for water utilities, with potential implications that the water sector is not properly applying for these FEMA programs. Out of the total value of all 6,360 projects funded equaling to $6.3 billion, water utilities received only $83.9 million.[36] While philanthropic and private donors are also a potential avenue for funding for resilience, it is important to also consider how we can further leverage FEMA and federal funding as well.

### *2. Private Funding Sources*

Alternatively, TAPs could also look for funding for resilience measures from private, philanthropic donors. However, there are some inherent differences with this. For one, many of these private funding sources tended to not be application-based, but more on an as-needed basis and with prior connections with the foundation. Below is an example of one major organization that is involved with disaster recovery:

| Name | Organization | Region or Nationwide? | TA? | Short Description | Link |
|---|---|---|---|---|---|
| Not-grant specific | Center for Disaster Philanthropy | Nationwide | No, but seem to imply that they have in the past | "With our emphasis on medium- and long-term recovery and equity-focused disaster giving, we:<br>• Direct financial and technical support where it is needed most.<br>• Provide expert and timely advice from professionals with deep disaster planning, response and preparedness expertise, and experience as philanthropists.<br>• Offer educational resources so you can make informed decisions about where and when to give." | Link here |

Although the Center for Disaster Philanthropy is not based on grant-specific application and the website is for donations to be made, it can still be valuable to create these connections with large organizations that are focused on funding around disasters. Although many of the current grants are for ongoing disasters, they are actively creating new grants that may be more applicable for resilience and for TAPs in the future. It is important to identify other large disaster-focused organizations so that potential networking can occur and become potential funding opportunities.

However, for a focus on funding and grants that pertain specifically to technical assistance, this is much more difficult to find on a large-scale, often only region-specific. It is important to keep in mind that although these grants may be region-specific, there may be funding sources that are similar. For example, although the HEB Disaster Relief Program is specific to Texas as it is a Texas-based grocery chain, it may be valuable to TAPs to see if their community's grocery chains have

36 Brodmerkel, A., Carpenter, A., & Morley, K. (2020). Federal financial resources for disaster mitigation and resilience in the US water sector. Utilities Policy, 67, 1-8, doi: 10.1016/j.jup.2020.101015.

similar disaster programs. TAPs can help the communities search for private funders, especially by utilizing the EPA's Water Finance Clearinghouse. Although it may be difficult to find them specifically for technical assistance, there can still be arguments made on why resilience-focused grants can still be applicable to technical assistance, as it is still with the intention of promoting resilience for the broader community. Below is a table of the some of these TA grants within a region as examples of the forms of organizations that address technical assistance:

| Name | Organization | Region | TA? | Short Description | Link |
|---|---|---|---|---|---|
| Technical Assistance Fund | Crossroads Funds | Chicago Metropolitan area | Yes | "The Technical Assistance (TA) Fund supports specific technical assistance needs of smaller organizations. This grants program focuses on projects that reach beyond a group's regular, ongoing work to build the organization's internal capacity. The maximum grant in this program is $10,000 and priority is given to organizations that have been funded by Crossroads Fund in the last two years. Examples of projects funded through the TA Fund: purchasing, upgrading or training for technology; attending skills-building training for board and/or staff; organizing or attending conferences; paying a membership fee for a resource organization; hiring a consultant or facilitator for evaluation, planning or a retreat. Open to organizations, groups, and coalitions with annual expenses less than $500,000" | Link here |
| Technical Assistance Grants | PATH Foundation | Virginia | Yes | "Technical Assistance grants may be used to offset the cost of a consultant, tool or skill that a nonprofit wants to strengthen or add, allowing it to operate more effectively. These grants strengthen organizations serving Fauquier, Rappahannock, and Culpeper Counties. Areas of Focus: Advancement of Technology, leadership expertise, planning efforts for effective organizations, collaborative strategies." | Link here |

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|---|---|---|---|---|---|
| Technical Assistance Grants | The Ford Family Foundation | Oregon | Yes | "The Ford Family Foundation's open grants invest in programs and projects across Oregon and Siskiyou County that are important to your community. Some grants are small; some are big. Sometimes funding is needed urgently; sometimes it's part of a longer term plan. We are standing by to support the needs of your organization or rural community. Technical Assistance grants: Strengthen your organization's internal capacity to make a positive impact with a Technical Assistance grant. These grants can be used to attend a conference, develop leadership expertise, engage in strategic planning or hire an outside consultant with specialized expertise. You will typically hear from us in six to 10 weeks." | Link here |
| Technical Assistance | Santa Ana Watershed Project Authority | Santa Ana, CA | Yes | "Of the $6.3 million awarded to the DCI grant program, $2.9 million have been set aside for the provision of Technical Assistance. The purpose of these monies is to support the development of projects and programs that address the needs of disadvantaged and underrepresented communities. In 2019, the SAWPA Commission approved $2.9 million in technical assistance funding for fifteen projects throughout the watershed. These projects address the opportunities and challenges outlined in the Community Water Ethnography Report and SAWPA's OWOW Plan Update 2018." | Link here |

| | | | | | |
|---|---|---|---|---|---|
| Immediate Disaster Relief Grant Program | The San Francisco Foundation (TSFF) | Bay Area, CA | None currently, but have in past | "The Foundation supported technical assistance on disaster planning for all organizations in the Immediate Disaster Relief Grant Program. These organizations committed to developing, maintaining, and practicing robust disaster plans to recover their operations and provide services to their clients and community in the aftermath of a large Bay Area disaster. The Foundation will continue to supporting technical assistance by local intermediaries for this purpose through June 2017." | Link here |
| HEB Disaster Relief Program | HEB | Texas | No | "Providing aid in times of need is the cornerstone of H-E-B's Helping Here philosophy, which promises to stand by communities during times of crisis. For more than 100 years, the company has demonstrated its commitment to communities in crisis by donating financial support, emergency supplies, drinking water and food, as well as providing efficient ways for customers to assist those affected by a natural disaster." | Link here |

In Kettle et al (2023), the authors also published a list of organizations and agencies that worked with rural water and wastewater in both Alaska and Louisiana.[37] Below is a screenshot from the article, showing the different agencies involved:

**TABLE 3** Some organizations and agencies supporting rural water and wastewater management in southern Louisiana.

| Scope | Entity | Program | Function |
|---|---|---|---|
| Federal | FEMA | Public Assistance Program | Provide post-disaster support for water utilities, including human capacity (electricians), supplies (generators and fuel) |
| State | State of Louisiana | Louisiana Dept. of Health | Provide low-interest loans and technical assistance to public water systems in order to assist with state and federal compliance; management training |
| | | Governor's Office of Homeland Security and Emergency Preparedness (GOHSEP) | Coordinates the State's efforts throughout the emergency management cycle to prepare for, prevent where possible, respond to, recover from and mitigate against to lessen the effects of man-made or natural disasters |
| | | State Emergency Operations Center (SEOC) | A unit of GOHSEP that oversees activities during the most extreme events; communicates and coordinates with Parish-level officials |
| | Louisiana Rural Water Association | | Provide training, on-site technical assistance, and operator certification |
| Regional | Louisiana Conference on Water and Sewer Annual Conference | | Provide training and information exchange for operators in order to provide safe drinking water and protect the environment |
| Local | Parish-level Office of Homeland Security and Emergency Preparedness (OHSEP) | | Coordinate disaster and emergency preparation, response, recovery, and mitigation |
| | Parish-level Emergency Operations Center (EOC) | | A unit of Parish-level OHSEP that coordinates activities during extreme events |
| | Local authorities, officials, law enforcement, and fire department | | Assist with emergency response (personnel, equipment) |

Although these are not all applicable, similar to the HEB grocery store grants, it may be helpful for TAPs to see examples of what agencies are being utilized in other's respective states and how this could be potentially beneficial to their community for funding and outreach.

37 Kettle, P., Trainor, S., Edwards, R., Antrobus, D., Baranowski, C., Buxbaum, T., Berry, K., Brubbaker, M., De Long, K., Fries, S., Holen, D., Keim, B., Meeker, D., Penn, H., Rosa, C., Walsh, J., & Zhang, J. (2023). Building resilience to extreme weather and climate events in the rural water and wastewater sector. JAWRA, 1-18. doi: 10.1111/1752-1688.13151.

## 5) Conclusion

Building resilience is not an easy task, especially when pertaining to resiliency to future climate disruptions and disasters. It is inevitable that efforts must continue to be made so that communities can have a reliable and sustainable source of water, but there must first be an establishment of how resilience can be measured, and what TAPs can do to help communities improve the resilience of the water systems from the current baseline conditions. TAPs have been promoting resiliency of water systems in their work, but having more resilience-focused deliverables that are encouraged from the top-down can further support their ongoing efforts. While TAPs can take part in resilience-focused deliverables, the question of funding for these projects and necessary upgrades of water systems continues to act as a roadblock. There needs to be a shift in priority for funding agencies by offering resilience-specific funds, both to provide TAPs support in their ongoing work of providing technical assistance on this topic and to finance the infrastructure upgrades and other updates needed. The solution may also come from a combination of utilizing both federal and private funding sources, with technical assistance as the focus of these funds to further establish the resilience of the community's water system.


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