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Summary of Strategies for Resilient Rural Water and Sanitation in the United States

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ABOUT THE AUTHORS

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Shannon McNeeley is the Associate Director, Water and Climate Equity at the Pacific Institute. 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 underresourced 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. Dr. McNeeley holds a master's degree in international environmental policy from the Middlebury Institute of International Studies at Monterey and a doctoral degree in environmental change and sustainability science, which integrated anthropology, ecology, and climatology, from the University of Alaska Fairbanks.

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Jessica Dery is a Senior Research Associate at the Pacific Institute. Her work addresses impediments and incentives for the use of recycled water in agriculture by merging science, policy, and outreach to promote communication and trust. Jessica has worked on a variety of interdisciplinary projects related to water quality and water reuse including agriculture and food safety, water treatment technologies, power generation, and public perception. Her experience includes conducting synthesis research, co-developing outreach products, and working directly with agriculture communities, utilities, and regulatory agencies. She received a bachelor's degree in microbiology from Arizona State University and a master's degree in soil, water, and environmental science from the University of Arizona.

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DEDICATION

We dedicate this report to the rural communities who feel the impacts of climate change first and most strongly.

Water is life.

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Summary

Many rural communities across the United States face persistent challenges in accessing safe, affordable, and reliable water and sanitation. In some rural areas, households lack running water or basic plumbing, while others rely on systems that do not consistently meet health and safety standards. As described in Water and Climate Equity in Rural Water Systems in the United States, climate change further exacerbates these disparities, with rising temperatures, droughts, floods, wildfires, and sea level rise threatening rural water and sanitation infrastructure (Taylor et al. 2024; Pacific Institute and DigDeep 2024). These challenges not only hinder efforts to expand access but also increase the risk of backsliding, where climate disruptions cause communities to lose previously secured water services (Pacific Institute and DigDeep 2024; Roller et al. 2019).[1]

In defining "rural" for this report, we take an inclusive approach to recognize the wide range of communities and contexts this term can encompass. Our focus is on rural water and sanitation systems in the US, which are typically small in scale and often serve fewer than 10,000 people. These may include either centralized or decentralized systems, such as private wells and septic systems. Rural water systems frequently contend with limited funding, aging infrastructure, and capacity constraints that can hinder their ability to consistently provide safe and reliable services.

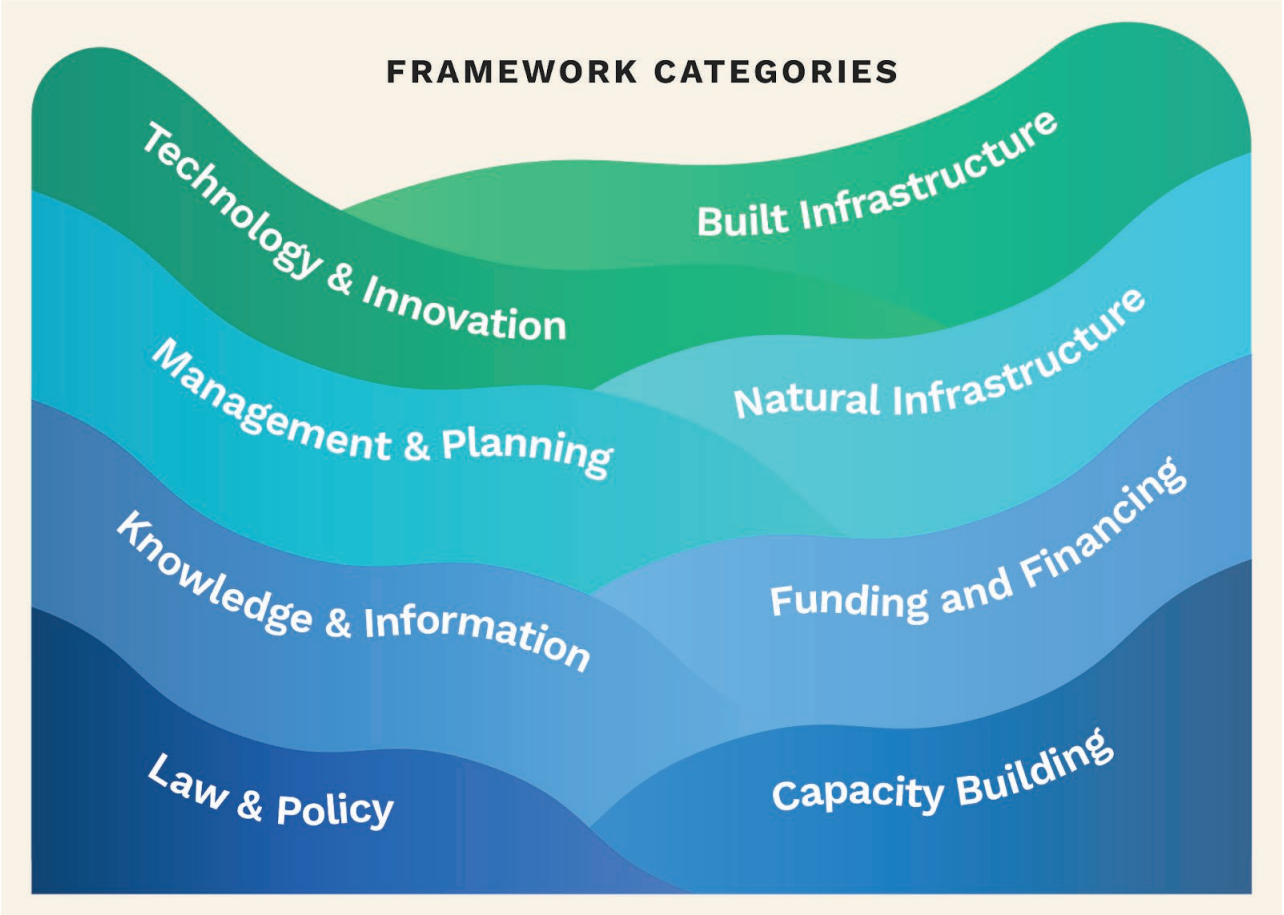
In spite of the obstacles, rural communities are leaning on their strengths and assets to create equitable, climate-resilient water and sanitation (Taylor et al. 2024). This report identifies strategies and approaches that address systemic inequities and increasing climate change impacts on rural water and sanitation systems. To do this, we asked three questions:

1. **What is equitable, climate-resilient rural water and sanitation?**
2. **What are the characteristics or attributes of equitable, climate-resilient water and sanitation in rural communities?**
3. **What are the strategies and approaches rural communities are taking to achieve this?**

1 Initial use of the term backsliding in the water sector comes from the Clean Water Act (CWA), where it refers to a prohibition of a state's adoption of less stringent water quality guidelines. More recently, DigDeep and US Water Alliance use it in Closing the Water Access Gap (2019) to describe a concerning trend in certain states where the number of homes without water and wastewater access has increased. In this report we are examining how climate change is contributing to that trend, and therefore we use backsliding to refer to the process by which a climate phenomenon causes a home or a community to lose access to safe drinking water or a functioning sanitation system, either temporarily or permanently. We discuss backsliding caused directly or indirectly by climate change through damage or destruction to water and wastewater infrastructure, reduction of water availability at its source in time and quantity, or contamination of water such that it is no longer safe to use.

To answer these questions, we built upon a framework developed in Achieving Equitable, Climate-Resilient Water and Sanitation for Frontline Communities (McNeeley et al. 2025). Through a review of the literature, government and NGO reports, and online tools, as well as direct input from practitioners, the framework identifies eight categories of equitable, climate-resilient water and sanitation. These include built infrastructure, natural infrastructure (NI), technology and innovation, management and planning, funding and financing, knowledge and information, capacity building, and law and policy (see Figure S1). Within each category, we identified key attributes of equitable, climate-resilient water and sanitation along with documented strategies for achieving them. For this report, we reassessed the previously identified attributes and strategies by McNeeley and co-authors for applicability in rural communities. We then refined and updated them to better align with the unique characteristics, challenges, and opportunities in rural places. Here we present 37 attributes and over 130 strategies for equitable, climate-resilient rural water and sanitation in the US.[2]

FIGURE S1. Framework for Achieving Equitable, Climate-Resilient Water and Sanitation



Source: McNeeley et al. 2025

2 The Law and Policy category differs from the rest of the report because this is a higher-level review of the laws and policies relevant to the provision of drinking water and sanitation in rural contexts. A forthcoming report on the law and policy strategies will be published in the fall of 2025. Therefore, in this report, this section does not go into detail on the strategies, resources, tools, and rural case examples as are found in the rest of the report.

Here we summarize the key findings on the 130+ strategies for equitable, climate-resilient rural water and sanitation across eight categories of the report. See the full report for details on case examples and resources for each attribute.

BUILT INFRASTRUCTURE

This category describes new or improved built infrastructure aimed at providing equitable, climate-resilient water and sanitation for rural communities.

TABLE S1. Built Infrastructure Attributes

ATTRIBUTES	ATTRIBUTE DEFINITION
Access to water and sanitation infrastructure and services	Rural communities have access to drinking water and sanitation infrastructure and services that allow them to perform basic tasks and maintain personal hygiene in their homes.
Reliable performance under a range of climate change impacts	Built infrastructure performs reliably under a wide range of climate conditions to deliver safe, sufficient, and acceptable water and sanitation for rural communities.
Inclusive and climate-resilient siting, design, and construction	Processes for siting, designing, and constructing climate-resilient water and sanitation infrastructure are inclusive and equitable to center rural community values and needs.
Equitable, climate-resilient operations and maintenance (O&M)	The O&M of water and sanitation improve climate resilience and facilitate equitable outcomes for rural communities.

Strategies to enhance access to water and sanitation infrastructure services include:

1. Initiate and support community-led water and sanitation infrastructure projects with nonprofit organizations and other entities dedicated to closing the water and sanitation access gap in rural areas.
2. Create programs to connect rural households and communities with water and sanitation systems at risk from climate impacts to more climate-robust centralized water and/or sanitation systems.

Strategies to help ensure built infrastructure performs reliably under a range of climate impacts include:

1. Create and utilize tools and frameworks for rural water and sanitation systems staff to evaluate the climate resilience of existing water and sanitation infrastructure.
2. Improve rural water reliability through water reuse, water efficiency, recharging aquifers (with floodwater where possible), and deepening groundwater wells.

3. Consider consolidation through a range of partnership forms to improve supply reliability during climate emergencies.
4. Update and/or elevate centralized and decentralized water and wastewater infrastructure to protect it from sea level rise and inland flooding.
5. Adapt rural infrastructure to be better prepared for wildfire by adding backflow prevention devices on service lines, installing meters with the ability to automatically shut off, and keeping plastic infrastructure away from heat sources.
6. When necessary, relocate rural community water stations and other infrastructure to protect them from damage and destruction.

Strategies for inclusive and climate-resilient siting, design, and construction of rural water and sanitation infrastructure include:

1. Create and utilize practical guidance for utilities and other groups involved in infrastructure projects that address equity and climate resilience.
2. Incorporate direct input from rural communities when siting and designing climate-resilient water and sanitation.

Strategies for equitable, climate-resilient operations and maintenance (O&M) of rural water and sanitation infrastructure include:

1. Identify specific O&M tasks that must be performed or adapted to protect infrastructure from climate impacts.
2. Put emergency response systems in place to help operators perform necessary actions during climate emergencies.
3. Work with technical assistance providers to perform regular O&M so that rural infrastructure remains in good condition to withstand climate disruptions.
4. Use materials, trainings, and tools from technical assistance providers and other supporting entities to learn about O&M tasks needed for improving climate resilience.
5. Engage directly with rural communities by prioritizing O&M work that addresses long-standing inequities in service from racism, disinvestment, and marginalization.

Expanding access to safe, reliable, and climate-resilient water and sanitation infrastructure is essential for ensuring rural communities can meet basic daily needs and adapt to the growing challenges of climate change. Built infrastructure in rural settings, like dams, water distribution systems, and treatment plants must be adapted so that they can reliably function under an increasingly broad range of climatic conditions and disruptions. Through these efforts, the engineers, contractors, utilities, and other agencies that lead the siting, design, and construction processes need to ensure that water and sanitation infrastructure is climate resilient. To do so equitably requires the inclusion and centering of rural communities throughout the process. Finally, the ongoing O&M of water and sanitation systems needs to be made more inclusive and equitable and must help build climate resilience for rural communities.

TECHNOLOGY AND INNOVATION

This category describes innovative technologies that help to develop or expand climate resilience and equitable outcomes for rural water and sanitation access and systems.

TABLE S2. Technology and Innovation Attributes

ATTRIBUTES	ATTRIBUTE DEFINITION
Equitably implemented climate-resilient water and sanitation technologies	Sustainable, climate-resilient rural water and sanitation technologies are equitably implemented at the community level, with attention to factors such as local cultures and values, financial context, and ecological benefits.
Cost-effective water-saving technologies for rural communities	Water fixture upgrades, water-saving appliances, and other water-saving technologies are equitably installed to save water and reduce cost burden on utility bills of rural households.
Sustainable, equitable water and sanitation technologies for large-scale water users and operations	Sustainable water-use and sanitation technologies are implemented for large-scale water users and operations, like commercial and industrial users, and increase equity and climate resilience for rural communities.
Tested and safe water and sanitation technologies	New, innovative climate-resilient water technologies are tested and evaluated to help ensure dependability and safety for rural communities.

Strategies for sustainable, climate-resilient, and equitably implemented water technologies include:

1. Engage with stakeholders, paying special attention to local values and cultures, when designing and implementing rural water and sanitation technologies and innovations.
2. Develop respectful partnerships between universities, technology companies, and rural communities to co-develop technologies tailored to community needs.
3. Implement knowledge sharing about climate-resilient technologies, especially to communities with unequal access to information.
4. Integrate equity-centered frameworks in the planning and design of technologies.

Strategies for cost-effective, water-saving technologies for rural communities include:

1. Develop water efficiency programs tailored to low-income residents so that they benefit from cost-saving technologies.
2. Partner with community-based organizations to build trust within rural communities and enhance participation in tailored low-income water efficiency programs.
3. Leverage corporate investments to implement water and cost-saving technologies in rural communities, such as affordable housing complexes.

Strategies for sustainable and equitable water and sanitation technologies implemented at the commercial and industrial scale include:

1. Establish laws and policies that promote the large-scale adoption of water technologies, offering broad climate-resilience benefits for rural communities.
2. Utilize existing support programs to scale up the implementation of innovations across sectors, such as university extension support programs for agricultural producers to install efficient irrigation technologies.
3. Utilize water and wastewater technologies to close gaps in access to services after climate disruptions.
4. Design and pilot large-scale water technologies and innovations collaboratively with nongovernmental organizations (NGOs) and technology companies.

Strategies to implement tested and safe water and sanitation technologies include:

1. Engage the community during the pilot phase of a new technology to understand local conditions, values, cultures, and needs before widespread implementation.
2. Apply a systematic and integrated management approach, such as Integrated Water Resource Management, to prioritize the safe and effective deployment of climate-resilient innovations within the intricate framework of water and sanitation systems.

Water and sanitation technologies and innovations offer significant potential to enhance the climate resilience of rural communities. However, their success depends on equitable design and implementation. These technologies must be culturally appropriate, socially acceptable, affordable, and sustainable, while also addressing the specific barriers faced by rural communities. Strategies like robust stakeholder engagement, equity-centered frameworks, and partnerships are important to ensure that rural communities benefit from technology and innovations. In addition, water efficiency and reuse technologies can reduce costs for rural communities, although challenges like high upfront costs persist. In addition, large-scale water users and operations have a major role in advancing equity and resilience by adopting technologies that reduce water demand and improve water quality for rural communities. This can be facilitated through relevant policies, partnerships, and support programs. Finally, the effective deployment of these innovations requires a deep understanding of rural contexts and a systematic planning approach to avoid maladaptation.

NATURAL INFRASTRUCTURE

This category describes how nature and natural functions and processes can be used to build and protect equitable, climate-resilient rural water and sanitation systems.

TABLE S3. Natural Infrastructure Attributes

ATTRIBUTES	ATTRIBUTE DEFINITION
Removing constraints for natural infrastructure (NI) implementation	Governance, policy, legal, and financial constraints for NI implementation are addressed and removed through context-specific practices to support equitable climate resilience in rural communities.
Centering communities in NI planning	Rural communities and equity are centered in NI planning for climate resilience.
NI projects proactively remove displacement risks	Displacement risks of rural NI projects are identified and addressed at the outset.
NI benefits valued for achieving equitable climate resilience	Context-specific approaches to the valuation of NI for equitable, climate-resilient rural water and sanitation are used in decision making.

Strategies for removing constraints for NI implementation include:

1. Create integrated NI management plans to coordinate knowledge and information exchange, planning, and management across departments, sectors, and jurisdictions.
2. Implement policies to overcome constraints to equitable NI project outcomes.
3. Form strong partnerships, coalitions, and interdisciplinary working groups to build NI project support and consensus.
4. Use innovative and diverse funding sources appropriate to the local context.

Strategies for centering communities in NI planning include:

1. Incorporate definitions and principles of equity and justice in NI projects.
2. Use community-led decision making for NI planning and implementation.
3. Incorporate transparency, trust building, and mutual learning in community engagement.
4. Form partnerships with trusted individuals or organizations.

Strategies for NI projects proactively removing displacement risks include:

1. Utilize and adapt existing toolkits to identify local risk factors for displacement.
2. Implement locally appropriate and feasible anti-gentrification and displacement policies and practices prior to project construction.

Strategies for NI benefits to be valued for achieving equitable climate resilience include:

1. Utilize comprehensive economic valuation methodologies that center climate resilience, human and ecological well-being, and benefits for multiple sectors and stakeholders.
2. Use complementary tools to understand and communicate the benefits and tradeoffs of NI projects for rural communities.
3. Incorporate nonmonetary valuations that center equity.

Natural infrastructure can be designed to support equitable and climate resilient water and sanitation systems in rural communities. While not every strategy outlined in this section will be appropriate for all rural communities, they can be used as a guide to generate ideas for context-appropriate and locally tailored NI. Governance, policy, legal, and financial constraints to NI implementation can be removed to create more supportive conditions for NI projects. Communities and equity can be centered in each stage of NI planning and implementation to help ensure the needs and priorities of rural community members are meaningfully addressed. Potential displacement risks from NI projects can be identified and avoided prior to implementation. This will allow rural community members to remain in their homes and benefit from the enhanced climate resilience provided by NI. Finally, the potential benefits and tradeoffs of NI projects can be assessed through economic valuation, nonmonetary valuation, or other context-appropriate approaches, to understand how projects will impact equity and climate resilience and to guide decision making.

MANAGEMENT AND PLANNING

This category describes how equity is centered in the way source water protections, community input, financial sustainability, climate impacts and risks, cross-sector coordination, and monitoring and evaluation are incorporated into rural planning and management of water and sanitation.

TABLE S4. Management and Planning Attributes

ATTRIBUTES	ATTRIBUTE DEFINITION
Source water protections incorporated into water, sanitation, and climate plans and programs	Source water protections are part of water and sanitation planning and management to increase rural community resilience to climate change.
Rural communities centered in climate, water, and sanitation planning and management	Equitable involvement and empowerment of community members in planning and management are achieved by centering rural community priorities.
Rural water and sanitation providers financially sound in the face of climate change	The financial health of rural utilities and communities is supported by proactive, long-term planning and management strategies that result in accessible, affordable, and climate-resilient water and sanitation.
Rural water and sanitation systems prepared for climate disasters and inequitable impacts	There is regular planning and management for climate disasters and inequitable climate disruptions to rural water and sanitation systems.
Cross-sectoral coordination to achieve equitable, climate-resilient water and sanitation	Equitable and climate-resilient management and planning efforts are coordinated across sectors, departments, agencies, plans, and different scales of government in rural communities.
Equitable, climate-resilient planning and management continually monitored and evaluated for effectiveness	Water planners and managers continually monitor and evaluate plans and programs to support equitable and climate-resilient outcomes for rural communities.

Strategies for incorporating source water protections into water, sanitation, and climate plans and programs include:

1. Develop locally tailored source water protection plans by leveraging existing support programs that connect community members and local organizations in collaborative, proactive efforts to safeguard water quality.
2. Include technologies and innovations, such as managed aquifer recharge, in plans and programs to enhance source water security.
3. Collaborate with rural communities, scientists, and managers to co-produce tools, plans, and programs that safeguard source water.
4. Integrate education, awareness, and support for private well water quality testing into management frameworks.

Strategies to center rural communities in climate, water, and sanitation planning and management include:

1. Begin with a visioning stage to incorporate rural community insights into climate-resilient water and sanitation planning from the outset.
2. Utilize resources and support from community-based organizations to improve the representation of rural communities in climate adaptation and water and sanitation planning.
3. Foster collaborative research partnerships that provide a boundary function, connecting rural communities with regional and national planning efforts while developing locally tailored resources for self-reliance.
4. Take proactive measures to encourage participation, such as stipends, to empower rural community members to meaningfully engage in management and planning processes.

Strategies to help ensure rural water and sanitation providers are financially sound in the face of climate change include:

1. Include asset management in long-term planning that takes into consideration climate change impacts to water and wastewater infrastructure.
2. Conduct demand forecasting to help ensure that future water demand projections account for both climate change scenarios and efficiency initiatives.
3. Employ proactive rate setting to prevent reactive rate increases that could render water and sanitation services unaffordable for rural communities.

Strategies for preparing rural water and sanitation systems for climate disasters and inequitable impacts include:

1. Create emergency response plans that address climate disruptions and prioritize equitable access to water and sanitation for rural communities.
2. Develop and utilize local tools on climate disruptions to rural water and sanitation systems to inform residents, encourage participation in planning, and bolster community preparedness.
3. Include community input in risk assessments to inform climate-preparedness plans and programs that equitably address the needs of those most affected.
4. Participate in training and workshops, focused on equity, to prepare water and sanitation systems for climate disruptions.
5. Incorporate a diverse range of water sources into programs and plans to enhance redundancy and resilience, especially for rural communities.

Strategies for cross-sectoral coordination to achieve equitable, climate-resilient water and sanitation include:

1. Align management and planning processes strategically, using integrated and collaborative frameworks.

2. Include interagency and cross-sector working groups in climate disaster response programs and plans to clarify roles, establish coordinated technical assistance programs for rural communities, and incorporate equitable community input into plans.
3. Integrate coordinated frameworks between government agencies and nonprofits to address and manage cross-sector, complex water and sanitation challenges together.
4. Participate in specialized training and exercises to learn how to address climate impacts on rural communities equitably and collaboratively across sectors.

Strategies for equitable, climate-resilient planning and management continually monitored and evaluated for effectiveness include:

1. Involve community members and community-based organizations in the design and implementation of monitoring frameworks to promote inclusive, attainable, and locally informed processes.
2. Use equity-focused indicators to track climate resilience outcomes of water and sanitation plans and programs effectively across rural communities.
3. Allocate specific funding for monitoring and evaluation in climate adaptation planning efforts so that small and underresourced communities have the financial capacity to monitor and evaluate climate, water, and sanitation initiatives.
4. Apply monitoring and evaluation to both new initiatives and existing practices to comprehensively address systemic inequities and enhance accountability.

The management and planning strategies outlined in this section are important for enhancing the climate resilience of rural communities. Protecting the source water for rural water systems is critical. These communities face challenges to access drinking water and sanitation that are now exacerbated by climate change. Actively engaging rural communities helps to ensure that their needs, cultures, and priorities are centered in planning processes and management efforts. Rural water and sanitation providers can implement strategies like asset management, proactive rate setting, and demand forecasting to maintain financial stability and provide affordable services for low-income populations in the face of climate change. Additionally, integrating disaster preparedness into planning is essential. Incorporating community input helps to identify vulnerabilities and design adaptive strategies tailored to rural community needs. Cross-sector coordination can help bridge silos and foster collaboration among stakeholders. This enhances the effectiveness and climate-resilient outcomes of rural water and sanitation plans and management initiatives. Finally, embedding monitoring and evaluation frameworks within climate, water, and sanitation strategies promotes accountability and transparency and tracks progress toward equitable water access, ultimately improving resilience for rural communities.

FUNDING AND FINANCING

The funding and financing category describes adequate, sustainable, and equitable funding, financing, and disaster insurance for rural communities to build, adapt, maintain, and restore climate-resilient water and sanitation.

TABLE S5. Funding and Financing Attributes

ATTRIBUTES	ATTRIBUTE DEFINITION
Funding and financing for capital investments in climate-resilient rural water and sanitation infrastructure	Climate-resilient infrastructure projects for water and sanitation systems serving rural communities and households can obtain and sustain funding and/or financing.
Funding and assistance for climate-resilient operations and maintenance (O&M)	Climate-resilient O&M for water and sanitation systems in rural communities has adequate and sustainable funding and assistance.
Funding, financing, and disaster insurance for climate disruptions	Rural communities have access to adequate funding, financing, and disaster insurance for disaster preparation, response, and restoration so that water and sanitation can be equitably restored after a climate disaster.
Funding and financing for alternative approaches to equitable, climate-resilient water and sanitation	Alternative approaches such as nature-based solutions (NBS), green infrastructure (GI), water efficiency, and water reuse have sustainable, adequate funding sources to support climate-resilient water and sanitation in rural communities.
Affordable climate-resilient water and sanitation for rural households	Rural communities can afford climate-resilient water and sanitation in their homes without compromising their ability to pay for other necessities, like food, housing, health care, and transportation.

Strategies for funding and financing for climate-resilient rural water and sanitation infrastructure include:

1. Increase the amount of funding available through federal and state programs, including the Clean Water State Revolving Fund (CWSRF) and Drinking Water State Revolving Fund (DWSRF), that can be used to build and adapt climate-resilient rural water and sanitation infrastructure.
2. Ensure that funding and financing are accessible and do not have barriers for rural communities to identify, apply for, and use to build and adapt climate-resilient water and sanitation infrastructure.
3. Enact policies so that rural communities are receiving an equitable amount of benefits from climate and infrastructure funding.
4. Implement technical assistance programs to address barriers experienced by rural communities in identifying, applying for, and using funding for climate-resilient water and sanitation infrastructure.

5. Offer programs to help construct climate-resilient, onsite water and sanitation infrastructure and/or to connect rural homes and communities with decentralized infrastructure to more climate-robust centralized systems.

Strategies for funding and assistance for climate-resilient O&M include:

1. Create and fund grant programs that explicitly name climate resilience and O&M as funding priorities for water and sanitation systems.
2. Work with free technical assistance (TA) providers with climate knowledge and expertise to reduce the financial burden of O&M.
3. Offer programs that provide grants or assistance for income-qualified households to test well water, repair wells or septic systems, or train onsite system owners on O&M.
4. Provide free training and other resources that inform owners on well and septic system operations and maintenance to enhance climate resilience.

Strategies for funding, financing, and disaster insurance for disruptions include:

1. Increase funding available through federal community preparedness and climate hazard mitigation programs for protect-in-place, managed retreat, and relocation, and consolidate funding to improve access to these programs for rural communities.
2. Dedicate funds for declared emergencies in rural areas and simplify and expedite the approval process so funds are delivered quickly.
3. Prevent climate disaster response and recovery efforts from exacerbating or increasing wealth inequality.
4. Fill gaps in government aid with local efforts by grassroots coalitions and NGOs to create local financing options and climate disaster recovery.
5. Designate funds for rural households to repair damage caused by disasters, including for repairs to wells and septic systems.
6. Expand eligibility for federal flood insurance programs to cover all rural, Tribal, and currently unmapped households and communities.

Strategies for funding and financing for alternative approaches to equitable, climate-resilient water and sanitation include:

1. Increase the amount of funding available through federal and state programs that can be used to design and build alternative approaches to climate resilience.
2. Ensure that funding and financing for alternative approaches are accessible and do not have barriers for rural communities to identify, apply for, and use the assistance.
3. Enact policies so that rural communities are receiving an equitable amount of benefits of funding for alternative approaches.
4. Offer programs to incentivize or pay for measures that enhance climate resilience of onsite water and sanitation in households in rural communities.

Strategies for affordable climate-resilient water and sanitation for rural households include:

1. Create and offer utility customers assistance programs and other affordability interventions like leak detection and repair for income-qualified households.
2. Reinstate and fund federal water and wastewater assistance programs so that customers of all water and wastewater utilities have access to financial assistance for paying their utility bills.
3. Enact laws at the state, local, or federal level that prevent water disconnections during extreme weather or climate events.
4. Create and fund programs to help rural households find leaks and replace inefficient fixtures and appliances to help save on their water, wastewater, and energy bills and support climate resilience.

One of the main barriers to creating equitable, climate-resilient rural water and sanitation systems is inadequate and inaccessible funding. Rural water and sanitation systems need more financial support (e.g., grants and loans) that help them to build and adapt existing infrastructure, improve their ability to operate and maintain their systems, and rebuild and restore after climate emergencies. Rural communities that are dependent on onsite systems, such as wells and septic, also need funding and financing to help them afford costly upgrades and repairs to help protect them from droughts, floods, sea level rise, wildfires, and other climate disasters. This funding is needed to help reduce the cost burden of climate adaptation on rural communities and households, so that they can continue to afford to have running water and adequate sanitation in their homes.

KNOWLEDGE AND INFORMATION

This category describes equitable, transparent, accessible integration and application of technical and community knowledges,[3] data, and information to achieve equitable, climate-resilient rural water and sanitation systems.

TABLE S6. Knowledge and Information Attributes

ATTRIBUTES	ATTRIBUTE DEFINITION
Usable water and climate data at appropriate scales for rural communities	Water, climate, and other relevant data are at the appropriate temporal and spatial scales and readily accessible to decision makers, water managers, and rural communities.
Inclusivity in the use of climate data, projections, and assessments	Climate data and projections are used with the inclusion of rural communities to inform water and sanitation and water resources risk assessments, planning, management, and development.
Incorporation of local and technical knowledges and ways of knowing	Local, place-based knowledges, Indigenous knowledges, and different ways of knowing and observing are equally respected, supported, and incorporated with technical data and information for equitable, climate-resilient water and sanitation.
Equitable data and information translation, communication, and dissemination	Data and information collection centers the needs and perspectives of rural communities and is shared openly and in culturally appropriate formats and languages that are accessible to rural communities.

Strategies for usable water and climate data at appropriate scales for rural communities include:

1. Focus water and climate research and information on community needs and values instead of those of outsiders.
2. Make sure data and tools are scaled appropriately and meaningfully at the community level whenever possible.
3. Make data and information free, understandable, and easily accessible.
4. Use a co-production approach to ground technical data and information in local knowledge and expertise.
5. Increase access to trusted support and expertise to increase capacity and overcome technical, legal, and policy barriers.

3 Although “knowledge” is considered a singular, uncountable noun, we intentionally use the plural “knowledges” to indicate that there is no one monolithic knowledge to understand and address complex issues at the nexus of water and climate equity and that problems and solutions to address climate change require many types of knowledges from myriad disciplines and sources, including local and Indigenous knowledges.

Strategies for inclusivity in the use of climate data, projections, and assessments include:

1. Use an end-to-end co-production approach in assessing climate risks to include rural communities in design, research, and development of decision-support information and tools.
2. Apply citizen science as an inclusive strategy for engaging locals in data gathering and monitoring to incorporate local observers and empower communities to build climate resilience.
3. Ensure adequate funding for communities to engage in knowledge co-production and sharing.
4. Recognize and address barriers and capacity constraints at the outset of any water and climate risk assessments by providing culturally appropriate community-centered technical assistance.

Strategies for incorporation of local and technical knowledges and ways of knowing include:

1. Ensure that local experts and knowledge holders have consultation and leadership roles in any community research, data gathering, and monitoring efforts.
2. Use collaborative, participatory, and/or co-production approaches for equitable incorporation or integration in knowledge creation and sharing.
3. Use appropriate protocols and agreements to protect local knowledge and rural communities.

Strategies for equitable data and information translation, communication, and dissemination include:

1. Present a positive vision for the future and emphasize ongoing progress, rather than relying on fear appeals.
2. Connect climate issues to real-world concerns that people already care about, by framing challenges within their local cultural, socioeconomic, or geographic context, as well as aligning with their values and worldviews.
3. Embrace uncertainty by focusing on what is known and highlighting scientific consensus, while remaining open to new and improved information.
4. Utilize storytelling to effectively convey data, acknowledging and respecting the emotions and psychology of the target audience while validating their experiences.
5. Use credible sources when incorporating climate change into rural water and sanitation initiatives to provide clarity and slow the spread of misinformation.

By valuing and incorporating diverse worldviews and knowledges, barriers can be overcome through inclusive governance structures and collaborative partnerships. Ultimately, these approaches not only enhance the ecological and social resilience of rural communities but also foster a deeper understanding and respect for the interconnectedness between humans and their environment. Integration of local, place-based knowledges with technical data and information is essential for achieving equitable, climate-resilient water and sanitation systems in the rural US. This, along with accessible and usable water and climate data at appropriate temporal and spatial scales, inclusivity in the use of climate data for risk assessments, as well as equitable data and information translation, communication, and dissemination can help build capacity for rural communities to achieve equitable, climate-resilient water and sanitation.

CAPACITY BUILDING

This category describes ways to build the capacity of rural water and sanitation professionals, communities, and households with the training, skills, and support they need to equitably adapt to climate change.

TABLE S7. Capacity Building Attributes

ATTRIBUTES	ATTRIBUTE DEFINITION
Climate-literate and robust water and sanitation workforce representative of their community	The water and sanitation workforce in rural communities is climate-literate, robust, and representative of the communities being served.
Rural community empowerment in water, climate, and sanitation decision making	Rural communities are supported and have sufficient capacity for inclusive, equitable, and culturally appropriate participation in climate, water, and sanitation decision making.
Capacity to work with interdependent sectors for climate resilience	People managing water and sanitation systems have the ongoing capacity to coordinate with people in sectors with whom they are interdependent for climate resilience.
Technical, managerial, and financial (TMF) skills for equitable climate resilience	Water managers are empowered with the TMF and leadership skills to equitably create, adapt, and maintain climate-resilient water and sanitation systems for their communities.

Strategies to support climate-literate and robust water and sanitation workforce representative of their community include:

1. Take advantage of climate adaptation training, programs, and tools to increase climate literacy in the water and sanitation workforce.
2. Provide opportunities for recognition and networking for upcoming utility leaders, especially those from underrepresented groups.
3. Educate students and other career-ready individuals about the water and sanitation sector and recruit the next generation of water and wastewater utility professionals.

Strategies for rural community empowerment in water, climate, and sanitation decision making include:

1. Build trust between rural communities and water and wastewater utilities serving them by promoting transparency, inclusivity, and community engagement.
2. Co-produce information and co-develop strategies and educational tools for climate-resilient water and sanitation with rural communities using community-based participatory research and an asset-based approach.
3. Develop partnerships between rural community members, community-based organizations, and other NGOs to advance community-driven water and sanitation policies.

Strategies to enhance capacity to work with interdependent sectors for climate resilience include:

1. Leverage existing tools and resources, such as the Community-Based Water Resilience Guide, to understand interdependent sectors and initiate conversations.
2. Foster partnerships between neighboring water and wastewater utilities to provide mutual aid and support to recover from climate disruptions.
3. Develop local or regional climate adaptation initiatives that foster education, information sharing, and communication across sectors to enhance preparation and response to climate impacts.

Strategies to support technical, managerial, and financial (TMF) and leadership skills for equitable climate resilience include:

1. Require TMF trainings for water system board members.
2. Establish formal and informal social networks among underserved systems to share information and resources to help overcome capacity challenges and prepare for climate impacts.
3. Consider consolidation and regionalization of small, underresourced water and wastewater systems to enhance capacity.
4. Take advantage of leadership and TMF training and assistance programs to build capacity to advance climate-resilient strategies.

Capacity building strategies can be implemented to help advance equitable and climate-resilient water and sanitation systems in rural communities. For example, when the water and sanitation workforce in rural communities is representative of the community being served, climate-literate, and robust, the workforce will have better capacity to represent community needs and enhance climate resilience. Culturally appropriate, equitable, and inclusive participation mechanisms can bolster the capacity of rural community members to participate in water, sanitation, and climate decision making. When water and sanitation managers have the capacity to coordinate with interdependent sectors, such as energy and transportation, they increase their ability to prepare for climate impacts and enhance resilience. Finally, empowering water managers with TMF skills can increase their capacity to equitably create, adapt, and maintain climate-resilient water and sanitation systems for their communities.

LAW AND POLICY

The law and policy category describes laws and policies that enable more equitable, climate-resilient construction, operation, and management of rural water and sanitation systems.

TABLE S8. Law and Policy Attributes

ATTRIBUTES	ATTRIBUTE DEFINITION
Laws set structural standards for reliability of services	Federal, Tribal, state, and local governments adopt siting, design, and construction requirements and standards for rural water and wastewater services and infrastructure that explicitly address the impacts of climate change.
Laws protect rights, allocations, and uses of water for domestic purposes	Water rights, laws, and policies are adaptive and flexible so that during times of scarcity, sufficient, safe, physically accessible, acceptable, and affordable water is available for domestic use in rural communities.
Laws require water and wastewater utilities as well as state and local governments to conduct climate resilience planning	The law requires rural water and wastewater systems and government agencies to adopt climate resilience plans to guide water resource management and asset management.
Laws require the creation, collection, and publication of data and information	Laws across all jurisdictions create requirements to monitor and collect data and information critical to preparing rural water and sanitation services and infrastructure for climate change.
Laws appropriate and equitably distribute funding for water and wastewater services and infrastructure	Federal, state, and local laws equitably appropriate and distribute financial resources to fund and finance the rehabilitation of existing and construction of new climate-resilient rural water and wastewater infrastructure.
Laws are enforceable and enforced	Federal, state, and local laws create enforcement mechanisms for drinking water and sanitation systems serving rural communities to meet legal and regulatory standards and include consequences commensurate with noncompliance to reduce risk of harm from climate change impacts to water resources and systems.

For laws to help build more equitable, climate-resilient water and wastewater services and infrastructure in rural communities, they need to set structural standards to ensure reliability of services; protect rights, allocation, and uses of water for domestic purposes; require utilities, states, and local governments to conduct climate resilience planning; require the creation, collection, and publication of information; and appropriate and equitably distribute funding. Furthermore, these laws must be enforceable and enforced.

The law currently takes a largely hands-off approach with decentralized water and sanitation infrastructure, in part because this infrastructure is located on private property. However, this approach minimizes oversight to the detriment of consistency and reliability in providing safe, reliable services over its lifetime, even as the climate changes.

CONCLUSION

We hope that the information herein remains relevant in the future to provide ongoing support to rural communities. Though we recognize some of the strategies may be time-bound or dependent on available opportunities that could change after this report is published.[4] Notably, many federal resources and funding opportunities related to climate resilience and equity were no longer available under the new White House administration starting in late January 2025. For those programs that have already disappeared from federal sites, we have included archived versions where possible. We also made note of resources and funding programs and mechanisms that are subject to change in the future.

Case examples are included throughout the report to demonstrate the strategies in action in rural communities across the country. Not all case studies presented demonstrate complete feasibility or success. Rather, they are based on available documentation and some perspectives and experiences may not be captured. In addition to sharing case examples for each attribute, we also include resources, such as reports, online toolkits, trainings, and more, to further support rural communities. These resources provide a starting point, though they are only a subset of the many available resources available.

The strategies and approaches identified in this report are for a range of audiences. These include rural communities, their supporters, such as community-based organizations or nonprofits, water resource managers, water and wastewater utilities, policy and law makers, and Tribal, federal, state, and local governments. We recognize the diversity across rural America and, as such, the strategies presented serve as examples of what can be achieved or implemented, not one-size-fits-all solutions. We hope that the information, examples, and resources included in this report can support advancement toward the goal of strengthening the climate resilience of rural water and sanitation in many different locations. Although this will require careful consideration of how to adapt strategies and approaches from one community to another.

More work is needed to better understand and support the needs of and opportunities for rural communities to build and maintain climate-resilient water and sanitation systems. For a full list of gaps and future research directions, see the Conclusion Section 12 in the full report. Until those needs and opportunities are at the center of efforts to adapt and transform water and sanitation in the face of climate change, any potential solutions will fall short of achieving the goal of equitable, climate-resilient water and sanitation. We present this report as a foundation upon which to build practical solutions for the rural communities who need them the most.

4 The report reflects programs and funding available as of April 2025.

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