S. Hrg. 118–370

RURAL WATER: MODERNIZING OUR COMMUNITY WATER SYSTEMS

HEARING

BEFORE THE

SUBCOMMITTEE ON
RURAL DEVELOPMENT AND ENERGY

OF THE

COMMITTEE ON AGRICULTURE, NUTRITION, AND FORESTRY
UNITED STATES SENATE

ONE HUNDRED EIGHTEENTH CONGRESS

FIRST SESSION

July 19, 2023

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C O N T E N T S

Wednesday, July 19, 2023

RURAL WATER: MODERNIZING OUR COMMUNITY WATER SYSTEMS

Wednesday, July 19, 2023

U.S. SENATE
Subcommittee on Rural Development and Energy
COMMITTEE ON AGRICULTURE, NUTRITION, AND FORESTRY
Washington, DC.

The subcommittee met, pursuant to notice, at 3 p.m., in room 328A, Russell Senate Office Building, Hon. Peter Welch, Chairman of the Subcommittee, presiding.

Present: Senators Welch [presiding], Stabenow, Booker, Luján, Tuberville, Hyde-Smith, and Braun.

Also Present: Senators Booker and Hyde-Smith.

STATEMENT OF HON. PETER WELCH, U.S. SENATOR FROM THE STATE OF VERMONT

Senator WELCH. I call the hearing of the U.S. Senate Subcommittee on Rural Development and Energy to order. First of all, it is wonderful to have the witnesses here, and I just want to start off by acknowledging what is happening in Vermont. We have had tremendous flooding, a great deal of suffering, homes and businesses, and our water systems have been, in many cases, the town of Johnson I will speak about a little bit, a bit overwhelmed.

It is a timely hearing because there is a lot of vulnerability in a lot of our water and septic systems, especially in rural America, all around the country. Many of our town—Johnson, Richmond, Woodstock, Morrisville, and Barre—are under boil-water orders right now, and that is pretty tough on folks.

On Friday, with Senator Sanders and Congresswoman Balint we toured Johnson, Vermont, and the wastewater treatment plant was a complete loss. It was amazing. The plant was underwater for two days. They had eight feet of water on the first floor. That is after the basement was flooded. The plant typically takes in 270,000 gallons in a day. It was taking in 1.25 million. The system was outdated. That is just one example where we had that terrible rain, but many of the communities that you all represent could probably report outdated systems as well.

You know, these weather events, with climate change are getting more and more frequent, and it is more and more urgent that we try to make our systems resilient.

If there was one bright spot in the flooding last week is that some of the resiliency work that was done after we had Tropical Storm Irene—that was in 2011—actually made a big difference. FEMA did something where we were able to build back to higher standards as opposed to just what we had. It is a real argument, I think, for resilience going forward, anticipating the scope of storms that we may have to contend with.

These well-functioning water systems, as you all know, are absolutely essential to rural communities, the health and the safety and the economy of rural communities. Some of our rural communities have aging or insufficient systems. That is particularly true in lower-income communities, many of which have significant challenges facing, and in many cases, are communities of color. Many of these systems are facing obstacles, and this is true in all of our rural communities, where they have small systems, little funding, challenges make regular investments in infrastructure impossible in managing and governing capacity. All of those are big challenges, and when you do not have a tax base to be able to get the resources you need it makes it very, very tough.

We have got some terrific witnesses here today. Joe Duncan, it is good to have you, President of Green Mountain Water Environment Association, and Jennifer Day, Director of Development. You have first-hand experience with these issues in Vermont, and we look forward to hearing from you. One of our witnesses today, Catherine Coleman Flowers, has spent years fighting for her own community in Lowndes County, Alabama.

I just want to acknowledge your presence and the work you have done over all these years. What I understand is one of the incredible effects of not having proper water and septic systems is that there can be real illness, and I understand 34 percent of the county residents tested positive for hookworm because of the pollution. That is a situation that we do not want anywhere.

The USDA Rural Development Program has programs to help small and rural communities to maintain and improve their water systems. Among those programs is technical assistance, which is in real demand in these small communities, where they do not have the technical capacity, and it is helpful in evaluating and planning drinking water and wastewater infrastructure. There are also some grants and loans for construction, although not enough, and communities at every step of the process can benefit from the USDA water programming.

In the farm bill I am hopeful that we can increase funding where we can and protect funding where we need to. There is a money issue here—how do you afford to do what needs to be done?

We look forward to hearing from our witnesses, and before we do I want to turn it over to my colleague, the Ranking Member, Senator Tuberville. Thank you, Senator.

STATEMENT OF HON. TOMMY TUBERVILLE, U.S. SENATOR FROM THE STATE OF ALABAMA

Senator TUBERVILLE. Thank you, Mr. Chairman, and first I would like to start by saying I want to send my condolences to people in Vermont and all of the Northeast. What a catastrophe that was last week. We all saw the pictures on TV, and sometimes even the pictures do not make it, you know, what it actually is. A lot of people out of their homes and it is tough.

Senator WELCH. Thank you.

Senator TUBERVILLE. I always appreciate working with you here, and what an important topic this is today. We cannot do without water. It is so important that we probably should be spending more time on this than not.

I want to extend a special welcome to two Alabamians, Mr. Rob White and Ms. Catherine Flowers. Thanks for being here today. I look forward to our discussion about ways to ensure Americans in rural areas have access to water infrastructure needed to keep them and their families safe and healthy, a topic which impacts constituents in Alabama and really all over the world, not just our country but all over the world.

Every American deserves access to water that is clean and safe to drink, and a functioning water system that safely disposes of sewage and waste. It does not matter where you live or what background you have, clean drinking water and sanitary waste disposal systems are a necessity that are directly linked to better health outcomes for all Americans. However, communities across the Nation face constant threats to their water services, due to various contaminants, cybersecurity risk, work force challenges, aging infrastructure, and funding shortages.

What is this Committee's role in the overall rural water discussion? To prioritize rural communities in the farm bill discussion we must help rural communities access the resources they need to achieve economic success, prosperity, and better health and educational outcomes, ensuring they are not left behind their urban counterparts.

This is my goal as we continue to look at ways to improve and modernize the various funding and technical assistance programs within the USDA Water and Environmental Programs Division. In Alabama, there are 503 permitted community water systems. Out of over 500 systems in the State, 75 percent of these serve communities with a population of less than 10,000. Many of these are in what we call the Black Belt. However, all communities have access to public water or wastewater systems.

In fact, Quality Water Association states that approximately 23 million households—23 million households—across the country rely on private wells to deliver their water. In Alabama, over 212,000 households rely on private wells. Private Wells are a necessity for rural areas as a public water system, and they may not be feasible due to location or funding. Considering these private wells are not subject to the same regulatory oversight as public systems, we must ensure these rural areas have the same access to water treatment systems as the more populated areas.

According to the U.S. Census Bureau, approximately 21.7 million households resort to using a septic tank or a decentralized system to remove sewage, as a public sewer system is unavailable. In Alabama, many residents throughout the Black Belt rely on these decentralized waste systems. We cannot forget these citizens. No matter your ZIP code, all Americans deserve the same access to safe drinking water and wastewater systems.

I have heard the challenges from rural communities across Alabama who struggle to secure the necessary financing and technical assistance to continue operating their water and wastewater systems. In addition to funding concerns, I hear about work force challenges. Labor shortages continue to be top of mind across not only Alabama but across our Nation. Many certified water operators across the country are aging toward retirement, and there are not enough qualified applicants to fill the positions. We are facing a growing knowledge gap in the future of the water and wastewater industry. We need to close the gap.

To comply with numerous Federal regulations, small and rural systems are being forced to outsource to private companies as they do not have the staffing capacities or knowledge to perform activities in-house. This is unacceptable.

I will be looking for ways to modernize the regulatory environment at USDA so that water systems are able to safely serve all Americans while complying with regulations based on science, not politics or activism. We must find the delicate balance between updating and maintaining critical infrastructure, treating water to safe levels, preparing for natural disasters and cybersecurity threats, and maintaining a fiscal budget. I believe this Committee can find that balance.

I look forward to this, Mr. Chairman, and I look forward to talking to our witnesses today and learning as much as we possibly can about their areas. Thank you.

Senator WELCH. Thank you, Senator Tuberville, and I am delighted that the Chair of our Committee, Senator Stabenow, from Michigan, has joined us. Senator.

Chairwoman STABENOW. Well, let me just say thank you so much for this important hearing, and I am so appreciative of all the wonderful work the Subcommittee is doing. Thank you to you, Chairman Welch, and Ranking Member Tuberville. I very much appreciate it.

I also just want to extend my deepest condolences to your home State of Vermont for the ongoing flooding conditions. It is just horrendous. I have not had the opportunity to be there, but looking at the picture it is unbelievable. I know you are going to continue to be a champion for the recovery in Vermont, and I know that my colleagues will join me in saying we will do everything we can to help.

Senator WELCH. Thank you so much. That matters. There is so much the USDA can do to help.

Chairwoman STABENOW. So much.

Senator WELCH. I thank you very much for that.

Chairwoman STABENOW. I am so appreciative of everyone who is here today. Thank you.

Senator WELCH. Thank you, Senator.

Our witnesses, we will start with Jennifer Day, who has over two decades of experience in community and economic development, including capacity building, managing projects, water system operation. She and her organization provide very critical technical, financial, and managerial support in progress for sustainability of rural communities.

We have Joseph Duncan, who is the General Manager of the Champlain Water District. It is a renowned regional water supplier, renowned for those of us in the community and those of us in Vermont, that received the first Excellence In Water Treatment Award in the United States, the very first. With a master's degree in environmental engineering, Joe is responsible for overseeing all operations and business activities in his district.

Catherine Coleman Flowers, internationally recognized environmental activist, author, and MacArthur Genius Grant recipient. She has dedicated her life to advocating for environmental justice, particularly equal access to clean water, and functional sanitation for communities in the United States. Her work includes founding the Center for Rural Enterprise and Environmental Justice, serving on the boards of various organizations, and being appointed as Vice Chair of the White House Environmental Justice Advisory Council. In 2023, she was recognized as one of Time's 100 Most Influential People in the World. That is pretty amazing.

I will now turn to Senator Tuberville to introduce our other witnesses.

Senator TUBERVILLE. Thank you. First I would like to introduce Ms. Pauli Undesser. Did I pronounce that correct?

Ms. UNDESSER. You did.

Senator TUBERVILLE. Awesome. She serves as the Chief Executive Officer of the Water Quality Association. She spent several years as WQA's Director of Regulatory and Technical Affairs before becoming the CEO, and is a recognized leader with a vast knowledge of water treatment technologies, standards codes, and regulations. Through WQA she works to promote the betterment of quality water around the globe.

She is also the CEO of the Water Quality Research Foundation, a nonprofit that sponsors relevant academic and professional research to advance the knowledge and science of high-quality, sustainable water. In 2016, Ms. Undesser was named to the Association Forum's 40 Under 40 List, and in 2018, she was honored with the Association Forum's Inspiring Leader Award. Congratulations. She holds a bachelor's degree in chemistry from the University of Illinois, and a master's degree in biochemistry from Northern Illinois University. Thanks for being here today.

Next is Mr. Rob White. Our next witness, he is from Wetumpka, Alabama. Rob is the Executive Director of the Alabama Rural Water Association, which represents over 450 water and wastewater utilities across our great State of Alabama. He was born in Troy, spent considerable time in the watergrass region of the State so he knows the ins and outs of rural Alabama. Rob has over two decades of experience in improving the water and wastewater industry and works hard to ensure all Alabamians have access to clean water.

He is a certified specialist in many fields, including water and wastewater operations, a commercial efficiency auditor, and training specialist, and the FEMA National Incident Management System. For over a decade he has helped implement Alabama's rural waters and emergency response programs, which oversees response efforts across various natural disasters and pandemics. Additionally, he manages a loan program for water and wastewater utilities, helps utilities seek diverse funding sources, and provides technical assistance to hundreds of systems across the State.

I am grateful for the hard work rob has done so far to deliver water and wastewater in our rural communities through Alabama, and I look forward to seeing his continued work. Thanks for being here today, Mr. White.

Senator WELCH. Thank you. Ms. Jennifer Day, you are recognized for five minutes.

STATEMENT OF JENNIFER DAY, DIRECTOR OF DEVELOPMENT, RCAP SOLUTIONS, WORCESTER, MA

Ms. DAY. Thank you, Chairman Welch, Ranking Member Tuberville, and members of the Subcommittee, for this opportunity to discuss the importance of the U.S. Department of Agriculture's Rural Development suite of programs and services that foster rural economic development and prosperity. USDA-RD is the only Federal agency dedicated solely to rural America and plays a key role in improving access to capital to ensure rural areas remain great places to live and thrive.

I also want to thank this Committee for their work on writing the next farm bill and for prioritizing water as part of your schedule today.

My name is Jennifer Day, and I am the Director of Development with Rural Community Assistance Partnership (RCAP) Solutions, the Northeast and U.S. Caribbean RCAP. I am very proud of my five years both in the field and as the Director of Community and Environmental Resources, responsible for a team of 30 technical assistance providers serving rural communities across all New England, New York, New Jersey, Pennsylvania, Puerto Rico, and the U.S. Virgin Islands.

RCAP is a national network of nonprofit partners working to provide technical assistance, training, and resources for rural communities in every State, territory, on Tribal lands, and in the colonias. Through our network of more than 350 technical assistance providers, they build capacity that leads to sustainable and resilient infrastructure and strengthens rural economies. Our approach is grounded in long-term, trusted relationships in those communities.

For 50 years, this network has partnered with multiple Federal agencies, including USDA-Rural Development, to bridge the gap between Federal programs and the communities they serve. We help communities understand how to properly manage and operate their infrastructure in a fiscally sustainable manner and ensure that Federal borrowers meet the terms of their loans.

RCAP supports robust reauthorization of USDA-Rural Development water, wastewater, and solid waste grant and loan programs and their associated technical assistance programs, including the Water and Environment Programs, or WEP, in the next farm bill, programs whose impact can be demonstrated in every State and territory, including in Vermont, where flooding last week and the major disaster declaration highlights the importance of the long-term, managerial, and financial work that is RCAP's specialty, enabling small systems to prepare for and recover from emergencies.

In Vermont, the WEP funding allowed RCAP solutions to work directly with 25 communities in the past few years, on a range of critical water and wastewater needs. We helped board members who were previously proud of not having raised rates in over a decade see the light and understand the need to have sustainable rates that cover their true operating expenses. We work with water and wastewater system managers to document system failures, communicate the importance of system upgrades, and provide public education to ensure that all stakeholders can make informed decisions when it comes time to vote on measures.

The need to plan for systems upgrades and comply with regulations does not discriminate based on system size, and technical assistance providers like RCAP help fill the capacity gap of the small rural systems.

In most cases it takes multiple years of predevelopment planning and multiple funders to successfully implement each project. The small systems rely on federally funded predevelopment grants and technical assistance like USDA-Rural Development and the RCAP network provides. We assist with community engagement, application assistance, and affordability qualifications.

Continued support, increased funding, and State office oversight of the SEARCH and WEP funds would increase applications to WEP to make sure that no rural systems are left behind.

Our funding application assistance and other related tasks helps communities in the Northeast and Caribbean receive 57 awards in Fiscal Year 2022 alone, resulting in over $88 million in grants and low-interest loans. Across the country we did $400 million in infrastructure funding.

I want to thank the Committee for their work to reauthorize the critical USDA RD programs in the next farm bill, and we look forward to working with you to ensure that the rural communities and USDA have the tools that they need to promote improved quality of life for rural America.

Thank you.

[The prepared statement of Ms. Day can be found on page 28 in the appendix.]

Senator WELCH. Thank you.

Joseph Duncan.

STATEMENT OF JOSEPH DUNCAN, PROFESSIONAL ENGINEER, CHAMPLAIN WATER DISTRICT/GREEN MOUNTAIN WATER ENVIRONMENT ASSOCIATION, SOUTH BURLINGTON, VT

Mr. DUNCAN. Thank you, Chair Welch, Ranking Member Tuberville, and the members of the Committee. I want to thank you for having me here to speak to what I believe is, in my mind, the most important thing out there—water, safe drinking water. If anybody can live without it, I ask you to raise your hand.

One of the things that Senator Welch touched upon was how the reactive measures during Irene in 2011, helped to address and eliminate, abate some of the issues that occurred in the 2023 flooding that just occurred here in Vermont, and that is wonderful. It is wonderful that things like that happen where you can put stuff in place and avoid incidents in the future.

A lot of our water systems operate that way. They wait for something bad to happen, and when something bad happens that is when they make a reactive investment in it. That reactive investment is typically not one that is the most prudent way to go about it, for users and investors in the system. People are paying rates to keep their systems up. There is a reason it is called operation and maintenance. A lot of times what happens is, especially in

Vermont, people are just keeping their rates, as Jennifer said, keeping their rates low thinking that they are helping out their fellow citizens, when in reality they are not doing them any favors. Inflation, as well as all the supply chain issues and cost increases that we saw with COVID have caught up very quickly on that.

In Vermont alone, I mean, we are an extremely small State, extremely small systems. Ten thousand is the cutoff for USDA Rural Development funding. We have about 1,300 public water systems in Vermont, serving about 59 percent of our 647,000 residents in Vermont. Of that size, there is even a smaller amount of systems that are less than 1,000. Ninety-five percent of our systems are less than 1,000 people. We are an extremely rural State, and so I know what it looks like to try and overcome some of the challenges that a lot of these small systems are seeing.

We need to look at USDA as one of the ways to help our water systems understand how to do stuff in a proactive manner. We have to do it both with our assets and our infrastructure on an investment basis, as well as stopping to take a look at how do we address the changes in climate that are affecting us, whether it is impacting your source waters with hot, dry weather so that you do not have the ability to access water to deliver to people. Perhaps it is rain events that are impacting infrastructure by flooding them, or washing stuff away, and how do you get yourself to be more resilient to deal with that. As well as—which USDA plays a role in—the electric grid, which I am not here to speak to, but there is not a water system in the country, that I am aware of, that does not need the electric grid to operate. We not only need to look at that from a water system perspective with our own infrastructure but how we, with our partners, produce our water.

To me, looking at the farm bill, it is something that comes up every five years, we have an opportunity to, one, make some investments in it. One of the things I know, in talking to our Vermont residents as well as people in the water industry, there is a concern that the recent ARPA money, as well as BIL money, is going to give everything that we need to address all of our water infrastructure needs, and that is not the case, especially in rural States like Vermont. We need that money to help fund infrastructure on a very small scale, and USDA is a great place, a great source of that.

It is also one of the only funding sources that I am aware of that is also not a regulatory compliant piece. The EPA is great with providing funds, but the EPA is a regulatory agency, and that scares a lot of people in Vermont utilities. The ability to continue the Circuit Rider program, because boots on the ground has been incredible for this recent event as well as other events, trying to look at climate resiliency and funding that, as well as asset management, is critical for our water systems.

Then the last thing I will say is that there does need to be a look at—and it is in my testimony so I will leave it at that—that bonding is a real challenge in Vermont, the way that the program is set up. There are some ways, I think, that the SRF handles it that perhaps USDA Rural Development could look at so that bonding becomes more of a certainty for accessing funding.

I thank you.

[The prepared statement of Mr. Duncan can be found on page 56 in the appendix.]

Senator WELCH. Thank you.

Catherine Coleman Flowers.

STATEMENT OF CATHERINE COLEMAN FLOWERS, FOUNDER AND CEO, THE RURAL CENTER FOR ENTERPRISE AND ENVIRONMENTAL JUSTICE, HUNTSVILLE, AL

Ms. FLOWERS. Thank you, Chairperson Welch, Ranking Member Tuberville, and all the members of the Subcommittee for the opportunity to testify. My name is Catherine Coleman Flowers. I am a disabled veteran and founding director of the Center for Rural Enterprise and Environmental Justice in Huntsville, Alabama.

I also serve as the practitioner in residence at Duke University, a member of the boards of the Natural Resource Defense Council, the American Geophysical Union, and the Climate Reality Project. In 2020, I was awarded a MacArthur Fellowship in Environmental Health, and I authored the book entitled Waste: One Woman's Fight Against America's Dirty Secret.

In my book I uncovered the extent in which rural America has been denied access to sustainable and resilient wastewater infrastructure. Too many people in this country lack safe, reliable, functioning sanitation. About 1 in five households are not able to send their sewage to a centralized wastewater treatment plant. These families rely on onsite sanitation systems that are more likely to fail. This impacts people across the country. For example, areas like the colonias and Tribal nations lack indoor plumbing.

In Hawaii, 88,000 aging cesspools are leaking 53 million gallons of untreated waste into streams, oceans, and drinking water every day. Across Appalachia, raw sewage flows past people's homes. Centreville, Illinois, and Miami, Florida, are facing well-publicized struggles with sanitation issues. These systems are absent or failing small rural communities, from the Central Valley in California to native villages in Alaska. In Puerto Rico, communities struggle to rebuild wastewater and septic systems damaged by hurricanes.

As a Lowndes County, Alabama, native, I am too familiar with the way sanitation failures affect families. Located between Selma and Montgomery, the soil and rising water tables in this area are not suitable for conventional septic systems. It is common for families to have failing systems that cause raw sewage to back up into their homes or into their yards. A 2017 peer-reviewed study found evidence of hookworm and other tropical parasites in rural residents exposed to raw sewage.

Failing systems degrade people's quality of life, take a toll on mental health, and cause economic harm by making it difficult to attract businesses. Data gaps make it difficult to understand the true extent of the problem and the people that it affects. However, all communities do not equally share these burdens. Low-income and rural areas are more likely to lack a centralized wastewater treatment system and are disproportionately affected by inadequate sanitation.

This underinvestment in sustainable infrastructure goes back decades, and is being worsened by the climate crisis, as we have heard today what is happening in Vermont and rural towns across that State who have lost access not only to safe drinking water but also to sanitation because of intense flooding.

We can make America a model of ingenuity and have a resilient infrastructure for everyone. The farm bill funds several USDA programs that could help, including the Rural Decentralized Water Systems Program. This program helps low- and moderate-income families in rural areas finance the cost of onsite assistance.

Senators Booker and Capito have introduced a bill to reauthorize the program and make it work better. This bill is a positive step toward addressing critical rural sanitation needs across the Nation. A strengthened version of it should be included in this year's farm bill, with the following improvements.

One of the things that I really want to make sure I cover this before I run out of time, all sanitation systems funded with this program must be required to carry a warranty of up to 10 years. We know from experience that these systems fail often. Manufacturers and installers need to be held accountable instead of blaming rural residents. This is the only thing that I know where people spend this kind of money, and it goes into the ground, and if it fails the homeowners are blamed. Rural America deserves better.

My written testimony has additional recommendations, and I appreciate the opportunity to speak today, and I look forward to continuing this conversation about sanitation equity for all.

[The prepared statement of Ms. Flowers can be found on page 62 in the appendix.]

Senator WELCH. Thank you very much.

Pauli Undesser.

STATEMENT OF PAULI UNDESSER, CHIEF EXECUTIVE OFFICER, WATER QUALITY ASSOCIATION AND WATER QUALITY RESEARCH FOUNDATION, LISLE, IL

Ms. UNDESSER. Thank you, Chairman Welch and Ranking Member Tuberville and all of the members on the Subcommittee. Thank you for inviting me to testify and be a synergistic resource as you are working through your leadership on modernizing community rural water systems. My name is Pauli Undesser, and I am honored to be here and address the Subcommittee as the CEO of the Water Quality Association and the Water Quality Research Foundation.

WQA is a not-for-profit association that amplifies and unites a voice of over 2,500 member companies, mostly headquartered on U.S. soil, and employ hundreds of thousands of workers. For over 75 years, our members have manufactured, distributed, and installed water quality improvement solutions in homes and in businesses. WQA upholds ethics and integrity while serving as an educator for water treatment professionals, a certifier for water treatment products, and an information source for the public.

The Water Quality Research Foundation is the industry's not-for-profit data-generating powerhouse that advances the mission of water quality by sponsoring peer-reviewed academic research.

Modernizing water systems, whether public, private, or otherwise, is critical for millions of Americans across the United States facing drinking water contamination from various sources, including lead, arsenic, nitrates, PFAS, and others. I applaud the Federal

Government's recent efforts to combat these concerns and ensure safer drinking water for all Americans. Congress, through the leadership of this Subcommittee, should continue these efforts in the 2023 Farm Bill to ensure that rural communities are not left behind.

Congress, EPA, and the CDC have all recognized that point-of-use and point-of-entry-technology are effective solutions. Most options treating water closest to the point of consumption can be installed faster than centralized treatment systems, meaning people are protected sooner. More specifically, those living in rural communities served by private wells, like me and my family for the past 20 years, in-home solutions are coveted as the proven solution to improved water quality.

USDA's Rural Development suite of Water and Environmental Programs has been incredibly successful in improving the safety of rural communities' drinking water, but more needs to be done, more to educate residents on their water quality and more to make funding available under current programs. By creating new program offerings, USDA can provide flexibility for these communities to leverage proven solutions. WQA strongly encourages this Subcommittee to prioritize the implementation of point-of-use and point-of-entry solutions as a key tool for modernizing rural water systems.

WQA is particularly supportive of S. 806, which is known as the Healthy H2O Act, and urges the Subcommittee to include this essential legislation within the 2023 Farm Bill. This bipartisan, bicameral legislation would provide grants to low- and moderate-income households and licensed childcare facilities in rural communities to conduct water quality testing and to fund the purchase, installation, and maintenance of water treatment solutions. These treatment solutions would be required to meet national performance standards for any contaminants identified during testing and installed service maintained by qualified professionals.

The Healthy H2O Act already has the support of many members, both from the House and Senate Agriculture Committees, and we anticipate all Subcommittee members will be eager to join supporting this bipartisan, commonsense solution.

Availability of high-quality drinking water is a cornerstone for fortifying prosperous communities. It is of critical importance for rural communities to be afforded the same opportunity to enhance their quality of life through reliable and affordable access to quality drinking water equal to their urban and suburban counterparts. Technologies installed closest to the point of consumption are crucial components in this effort.

I thank the Subcommittee for your time, attention, and thoughtful review of including the Healthy H2O Act in the 2023 Farm Bill. I am a subject matter expert for the betterment of water quality, and I am available as a resource in your leadership for modernizing rural water systems. Thank you.

[The prepared statement of Ms. Undesser can be found on page 70 in the appendix.]

Senator WELCH. Thank you.

Robert White.

STATEMENT OF ROBERT N. WHITE IV, EXECUTIVE DIRECTOR, ALABAMA RURAL WATER ASSOCIATION, MONTGOMERY, AL

Mr. WHITE. Thank you. Good afternoon, Chairman Welch, Ranking Member Tuberville, and esteemed members of this Committee. I am honored to be here today to offer my insights on the U.S. Department of Agriculture Rural Development Water and Environmental Programs and their crucial technical assistance initiatives which are integral for offering affordable and sustainable services to rural America.

I would like to extend my gratitude to Senator Tuberville for his invitation, and more importantly, his stalwart leadership and advocacy for Alabama's rural water and wastewater sector.

I serve as the Executive Director of the Alabama Rural Water Association, a nonprofit organization that advocates for small and rural water and wastewater systems across Alabama. I am also here on behalf of the National Rural Water Association, which represents over 31,000 rural systems throughout the country.

Our rural systems have their roots in the 1960's Farmers Home Administration, and they continue to benefit from assistance and support from its successor agency, Rural Development. If I may, I would like to express my gratitude to this Committee for its unwavering commitment to these successful initiatives.

USDA Rural Development, designed by Congress, is key to supporting rural America, especially since 91 percent of the Nation's water systems serve communities with less than 10,000 residents. Rural Development's mission is to expand and modernize water infrastructure, and rural water provides the critical technical assistance needed to sustain these services.

Many communities in Alabama have access to safe and affordable water service today that their grandparents never had, thanks to the resources authorized by this Committee. Thank you.

I will now quickly review a few of our top priorities for your consideration as you draft the 2023 Farm Bill.

First, the Circuit Rider program, established by this Committee in 1980, is our pioneer initiative aimed at offering solutions and hands-on support to rural communities. Water Circuit Riders offer a wide range of onsite, hands-on assistance and training.

On a national scale, last year alone Water Circuit Riders made a direct impact on the health and safety of over 24 million individuals, constituting 41 percent of rural America. Circuit Riders respond immediately to calls for assistance, whether they concern disaster management, sourcing disinfection supplies, design and construction advice, or system operation and maintenance, to make sure water service is available every second of every day. We humbly request this Committee reauthorize this flagship program.

Second, the NRWA and State Rural Water Associations have been at the forefront of emergency disaster response for decades. Last year, during a historic cold front, Alabama Circuit Riders were responding to utilities on Christmas Day, finding and fixing leaks and distributing six truckloads of bottled water to communities without water service, at no cost to those utilities. We propose that this Committee consider extending authorities to enhance preparedness activities to aid systems in recovery outside the scope of immediate disaster response and ensure a more resilient water sector.

Another ongoing project of note is the Closing America's Wastewater Access Gap Community Initiative. ARWA has partnered with USDA and EPA to mitigate wastewater issues in Lowndes and Greene County, Alabama. This pilot project was announced in White Hall, Alabama, last August, to introduce a variety of wastewater treatment solutions for communities that lack sufficient sewer service. The latest estimates indicate that roughly $1.4 billion are needed to implement decentralized wastewater treatment technologies and resolve individual septic tank issues across Alabama's Black Belt alone.

Next I would like to discuss the latest cybersecurity issues facing rural water. In Alabama, system regulatory inspections occurring after October 1, 2023, will require a cybersecurity audit. Unfortunately, given the scope and complexity of cybersecurity, the reality is most rural utilities lack the financial resources and in-house expertise to secure themselves from cyber threats.

We suggest this Committee consider providing funding for cybersecurity Circuit Riders to help rural water systems protect their utility and its customers. We also recommend modernizing the Rural Development Water and Wastewater Programs to better address current utility needs with additional affordable financing and servicing options. This should include zero and one percent loans to disadvantaged or economically distressed communities. EPA and the Rural Housing Service already have similar authorities.

Finally, we recommend advancing voluntary consolidation of rural communities by allowing a contiguous system to apply for a grant or loan on behalf of a neighboring underserved community. This authority show be narrow and ensure that the additional subsidy is targeted entirely to the community in need.

In summary, USDA's Rural Development Water and Environmental Programs are critical in keeping rural America's water and wastewater services areas economically viable while also providing the resources to support underserved communities. With the current backlog of around $4 billion, demand remains high. ARWA and NRWA are honored to continue and strengthen the successful partnership with USDA Rural Development and this Committee.

Thank you for the opportunity to participate today.

[The prepared statement of Mr. White can be found on page 364 in the appendix.]

Senator WELCH. Thank you, and I want to thank all the witnesses for their excellent testimony. I am the last Senator before a vote closes so I am going to have to leave temporary to vote, and I am going to turn the gavel over to Senator Cory Booker, and I will be right back.

Senator LUJÁN. [Presiding.] Well, with that comes the privilege to questions, I believe, so thank you, Mr. Chairman, for letting me dig in there real quick as the gavel is going to switch to another hand, so I am going to jump on this opportunity.

My first question, Ms. Day, surrounds colonias, so I appreciate you raising those as well. I appreciate the testimony of Mr. White with the importance of being able to apply for neighboring communities that may be in need as well and how you can get them support. One of the challenges with colonias is they are unincorporated communities, and so it is hard to do that.

My question to you is, looking at New Mexico, specifically, home to about 129 colonias—and for those that do not know what they are, these are unincorporated communities. They often have economic challenges. They are generally economically distressed. They are along the U.S.-Mexico border, in the United States, and they lack access to safe drinking and sanitary wastewater systems. In 2022, USDA announced a $13 million investment to expand access into these areas, so we support these and we appreciate them, specifically, as you pointed out, Ms. Coleman Flowers, to colonias, rural and Tribal communities as well.

These investments are vital to ensuring that at-risk communities are able to take advantage of these funds. My question to you, Ms. Day, is as colonias are unincorporated they do not have a mayor or a council. Often they do not have a voice in State or Federal Government. How can Federal programs such as USDA Water and Environmental Program better catch our colonias and rural communities so they do not fall through the cracks when it comes to providing essential utilities?

Ms. DAY. Thank you, Senator Luján. I appreciate the opportunity to talk to this. We know that this area, the environmental impact of weather will continue to make this issue worse for these communities. I know that when RCAP technical assistance providers are working in a community we are empowering them to make decisions on their own. We hear often that we are giving them the tools that they need and then they are using those tools.

In colonias we are looking at continued technical assistance and funding. It is critical to maintain those water systems. We are often there when boards transition after a big project, so for us it feels like that is the place that we can have the most impact is helping even communities that are underfunded continue to find a way forward. We will be there for 10 years if that is what it takes.

Senator LUJÁN. I appreciate that. Ms. Coleman Flowers, you mentioned colonias as well in your testimony. Do you have some thoughts to the question that I presented to Ms. Day?

Ms. FLOWERS. Yes, and I think that first of all a lot of people do not know what the colonias are and they do not know they are there, aver 2,177 communities from Texas to California. A lot of these areas are dealing with the same problems that we see in Lowndes County, Alabama, and I think that there should be more of an emphasis on that. As the Co-Chair of the White House Environmental Justice Advisory Council my suggestion to everybody—just as when I first met Senator Booker I invited him to come to Lowndes County to see for himself—I think that the only way we can even come up with positive solutions to those areas is going to visit and convene people in those communities to try to get this work done.

I know that in California, for an example, they have just instituted a program where they are trying to find out how many people are on septic or do not have systems at all, so that they can come up with policies and ways in which to address this. I think one of the ways we can do this is to fund USDA to actually do the type of studies or collect that data to close those gaps so that policymakers can make the type of policies to address these issues.

Senator LUJÁN. I appreciate that. I have some other questions, but I will submit them into the record. I am reminded, to your testimony, Ms. Coleman Flowers, you cannot unsee what your eyes show you, and it is the power of seeing and feeling because you understand people's stories and plights as well when you go down there and see for yourself. I thank you for that reminder. I yield back.

Senator BOOKER. [Presiding.] By the power vested in me by Senator Welch I hereby decree that Senator Braun shall go next.

Senator BRAUN. Thank you, Senator Booker. I have gotten water, ever since I moved back to my hometown, from a rural water district, Patoka Lake, an Army Corps lake. Several utilities get water from it. I am not sure about it, but at least 10 places across our State we have had PFAS showing up in the water at levels above the Federal guidelines.

Ms. Undesser, you talked about that. How can these rural districts use point-of-use and point-of-entry systems? Is that economically viable for them to address an issue that I think we are all going to be more worried about in the future?

Ms. UNDESSER. Thank you, Senator Braun. I appreciate the question. PFAS is very complex. It is a moving target, adding new compounds all the time. However, one thing that is great to know today is that there are solutions that are certified products that can remove specific PFAS compounds, and those products can be installed in rural water communities by qualified individuals that would take care of the installation, service, and maintenance of those as well.

The solutions are available today. The Healthy H2O Act would help in the areas of low- to moderate-income areas where having access to reliable and affordable technologies is a real challenge. Including that in the farm bill is something that will be key going forward.

Senator BRAUN. Then another question for you and then Mr. White. Oftentimes I hear that there are guidelines, regulations in actually building out a water system that are difficult. I would like each of you to maybe talk about the one or two that you would hear most often about, whether it makes sense, or whether they are over-burdening, and apply it again to the smaller water districts that might not have the resources to navigate through all of that.

Ms. UNDESSER. As the Water Quality Association, the biggest burdens we hear about when it comes to creating a new centralized system is the time to get the solutions in and the costs to be able to get the solutions there as well. But, there are certified products and decentralized solutions that are able to do things today, and in a timely manner as well.

Senator BRAUN. Mr. White, is the regulatory framework that we have got in place, does it hit the sweet spot, making sure that we adhere to them, or are there any instances where it is over the top?

Mr. WHITE. There are definitely challenges with some of the regulations. Lead in drinking water, getting the lead out, that is one that many water systems are struggling to kind of wrap their hands around as far as how they are going to address this and get the resources into the local systems and be able to put those into the field.

PFAS is another emerging contaminant that is causing a lot of questions and consternation with rural water systems especially. As this emerging contaminant is found within various water sources, it is very costly to remove these chemicals. Some of the rural systems just simply would likely not have the capacity to be able to implement upgrades required in order to remove those chemicals.

Senator BRAUN. Is there something beyond remediating contaminants? I am talking about just the general construction of water systems. Or do you feel that the guidelines we give when we cost-share here, is it reasonable in terms of actually building out a water system in the first place?

Mr. WHITE. I believe so. One of the largest problems that we have in Alabama, and I am sure across the Nation, is supply chain disruptions. We work with a lot of systems, trying to get projects designed and get funding from, say, USDA or SRF into the community. The project have been extended for months and months. The turnaround time on these has just been extended out years in some cases, and the cost is ever-increasing. Oftentimes we get the project obligated and by the time we put those funds out for bid to the communities, those cost overruns are to the extent that they have to go back to USDA, apply for more money to even complete the project that was originally designed.

Senator BRAUN. Thank you.

Senator BOOKER. I will go next because I have got the gavel and Mr. Tuberville is a generous man. Thank you, sir.

First of all, I am grateful for the Ranking Member and the Chairman for holding this Committee. I cannot tell you about the urgency, and I think it was reflected in a lot of the comments that were made beforehand. I am, frankly, when I finally started doing the research when I got into the Senate I did not realize how much of a crisis many areas of our Nation have by just having not access to clean water or to septic systems.

I was telling the Ranking Member that my roots go down into Alabama, and I owe that State so much of my life. When I went down to meet with you, Catherine, when you challenged me to come down and actually see for yourself, I was really stunned. It started because I was meeting with a doctor who was telling me that we have these tropical diseases that many doctors do not know exist in many areas of this country that have these kinds of straight piping because they have no septic systems or wastewater systems at all. When you see it for yourself and you meet with people who are struggling with this, it just makes you think it is a shame of our Nation, a nation this strong, this powerful, this wealthy, that could not do something about it.

That is why I am glad this is a bipartisan issue, which is reflected in the comments from all the witnesses as well as from many of my colleagues. I have had the privilege of working with Senator Capito, who has been a great partner, in addressing these issues, and we were able to create authority for the USDA to provide loans and grants to low-income households to install individual wastewater systems.

Now in the upcoming farm bill, Senator Capito and I are looking to make improvements to the program that we were able to get established, and I am going to direct my questions to, sincerely, one of my great American heroes. Catherine, you have inspired me more than you know, and I am just grateful.

One of the changes that Senator Capito and I are pushing for in the farm bill is for a program to provide funding for warranties to accompany these septic systems. Can you talk about the warranties and why they are so important?

Ms. FLOWERS. Yes. Thank you, Senator Booker.

Senator BOOKER. She calls me Cory when we are not in public.

Ms. FLOWERS. Yes. I cannot do that today. It is very important because what happens is once a septic system is put in—and we paid for a lot of them in Lowndes County—the liability is transferred to the homeowner. When they fail, the homeowner has to fix it, and a lot of them cannot afford to do that.

We are finding, not just in Alabama but across the country, these systems are failing within two years, and some of them, when they do fail, it is very costly to fix, and people do not fix it. That is when they start straight-piping or they do something else to come up with some remedy that is not legal in order to make sure that the sewage does not come back into their homes. When they come back into their homes it comes back either through a bathtub, it can come back through a sink. I mean, those of us that are pet owners know that a dog would not sleep on a bed that has been fouled. Why do we expect humans to live that way?

I think the only way we can really change the way this works is to have warranties in place. It can inspire research and development and improvement. I mean, I am old enough to know when a car would not last more than two years, but when we had competition and we had to look at cars that were being made in other countries that were lasting longer, American cars got better too. Likewise with warranty systems for these wastewater systems, that people have to have.

I spoke with Ranking Member Tuberville earlier. He talked about the importance of water. Sanitation is also important and is a part of water, and we have to have that for health and safety.

Having these warranties in place, I think, would ensure health and safety for all homeowners, and certainly those in rural communities that should not be left to fix this on their own.

Senator BOOKER. Thank you, Catherine. I had a brief brush with power, which I am not about to lose to the great Senator Welch. I did not even get to slam the gavel down. I will ask you just one more question before I surrender the position I have, that has most of the people here in awe.

Despite authorizing both grants and loans, we know that the USDA has administered this program strictly as a loan program. Now the folk I saw in Alabama, and now have seen in other places, are not the folks that can really afford these programs. Can you talk to me a little bit about how important it is that low-income households, which are usually the households affected, receive grants to install these systems?

Ms. FLOWERS. Yes. I think that is a very important point, not only low-income households but also for a lot of the communities.

When I first got involved doing this work I remember talking with Senator Sessions years ago about why rural communities, although the money was available, could not get it because they could not come up with a match. Likewise with loans. A lot of these families are struggling. They cannot afford that. Everybody in this country, I believe that we are a great nation, and we everybody in this country should have the right to sanitation, and they should not be able to be without it simply because they cannot afford a loan. That is why grants would be very important to a lot of poor families across the U.S.

Senator BOOKER. Mr. Chairman, Catherine said that eloquently, but I had this wonderful, beautiful moment with Senator Shelby, in the gym of all places. He and I used to work at odd times and became really good friends because we were the only two people in the gym, and nobody was there to make fun of how little work we were doing in the gym. When I told him about your problem, Catherine, he said the exact same thing, that these are good folk that should have what is basic and did a lot on his position to deal with the issue. I am glad that we have Alabama Senators that have the same heart to address these issues and that this has been such a bipartisan space for me to work in, and I am just really grateful. Thank you, Mr. powerful Chairman.

Senator WELCH. [Presiding.] Thank you, and by the way, I want to acknowledge the letter that you are working on to get data that we need in order to focus where we need to have the allocation of resources. Thank you very much, and I look forward to working with you on that.

Senator Tuberville.

Senator TUBERVILLE. I yield to my colleague, Senator Cindy Hyde-Smith.

Senator HYDE-SMITH. Thank you very much because I do have a couple of questions, and thank you for hosting this important meeting. Thank you for coming to testify. This is so valuable to hear from folks, and I know sometimes it is hard to come up here and do that. It takes a lot of time, and I just appreciate your willingness to do that.

Mr. White, the Rural Water Association provides so much technical service that is very valuable for the training of our small utility providers. When the tornadoes blew through Mississippi just a couple of months ago, the Rural Water Association responded instantly to help. You know, they were so knowledgeable.

You have already talked about this some, the Circuit Rider program. Can you kind of elaborate on that, like in disasters such as this tornado, how valuable it is and how the communities benefit so much from this technical support?

Mr. WHITE. Yes, absolutely. Thank you so much for the opportunity. In Rural Water we have a robust emergency response program, and it exists across the Nation. National Rural Water is a leader overall in emergency response, and the States joined together to support that effort. The States, we actually own and operate a lot of our own equipment—generators, bypass pumps, and just a variety of equipment that we pull together in times of need.

Even now, the flooding in Vermont, my counterpart, Liz Royer, I know she has got her team out responding to systems now, and she knows that if she needs assistance she would be able to reach out to our national network of emergency responders, and we will show up when necessary.

One additional resource that would be very helpful, from this Committee and the farm bill, is building upon the emergency response network. Having a Circuit Rider that could be dedicated to emergency response would be invaluable to the States across the Nation. Right now we can respond to disasters as they occur. When the tornadoes occur we move our teams in. We help get those communities put back together as quickly as possible and bridge the time where those communities will be without commercial power so that we can set generators and keep the water plants up and running so people can cleanup and move forward while the commercial power industries get those resources put together for the communities.

In times of blue sky, we refer to, there is a lot of work that can be done that we generally cannot focus on in those days. If we had the resourcing ability to have a full-time Circuit Rider position that could go around and network with State and Federal agencies, work with the communities, ensure that they have all of their hazard requirements on hazard mitigation lists and county emergency networks, those are required for when a disaster moves through the community for the community to be able to access the money that immediately precedes that disaster.

In addition, the administrative efforts are quite intense for any community that is going through a disaster, and to be able to support tracking all of the expenses and filing all the required documents with the appropriate agencies afterwards in order to get money that is made available back into the community and not leave any of that on the table would be of huge benefit to those rural systems.

Senator HYDE-SMITH. Thank you very much because we sure benefited from it then. You know, I understand in your testimony that work force recruitment and development is a challenge for Rural Water Associations. I am really passionate about keeping young people in rural areas, but we have got to provide something for them. One way to do that is promoting and encouraging careers and technical education to help us out here. It is great to see the Water Apprenticeship Program in Mississippi. It is taking off down there.

How can Congress help ensure these work force challenges are met in rural America's water industry, particularly when it comes to recruitment and with training and retention, and keeping these people here?

Mr. WHITE. Yes, thank you. The apprenticeship program is growing, and we are certainly proud of it. Alabama is one of the 34 States now that have developed an apprenticeship program. We have recently started ours. We are looking for our first graduate next April, so hopefully that will go smooth.

Additionally, just continuing to support the resources that are available now with training that is offered through the technical assistance provisions in the farm bill is a huge asset to rural water systems throughout the country, really. The apprenticeship program is going to continue to grow. It gives us the opportunity to promote the industry where we have not been able to before. In Alabama we are going to engage in career centers and be able to get the word out to people so that they can engage with our industry in a proactive manner. Then also provide a structured platform to move those people from curious about water and wastewater work into the career that we all know it could be, a very rewarding career.

Senator HYDE-SMITH. Another thing that has been discussed a lot is the challenges that communities face when navigating the funding application process. You know, we get calls on that for water and wastewater projects, and we may want to talk about that. I know my time is out right now, if you will indulge, but how can the administrative burden for small and rural water communities be alleviated when participating in the USDA funding programs for water and wastewater projects? We are going to have to be fast because I am a minute over.

Mr. WHITE. I will try to be quick. The most success that we have in the State, when rural communities reach out and they are looking to apply to USDA for a project, is we will send a team out. They will go and they can help kind of navigate and cut a lot of the red tape, or the initial burden of engaging with USDA's online RD Apply system, for instance. There are a few complications in there that are required. They have to be registered with SAM.gov, and sometimes there can be some back and forth. In fact, that one can be difficult at times.

Having the technical assistance available to be able to move into a community, get all the registrations registered, get the team pulled together, and then have to have an e-authentication credential in order to engage with the system, the individual roles have to be set up, you have got to bring the engineers in, the accountants, and all of that to the table.

Having the technical resource able to come in and help organize and get all that together so that we could kick the project off, or the application off, seems to be of great assistance to those communities.

Senator HYDE-SMITH. Makes sense. Thank you very much, and we have five votes going on, so I apologize that the table looks empty. They just called the second vote, and I am going to go vote. Thank you.

Senator WELCH. Thank you very much.

Mr. Duncan, I appreciate the help you are giving us in Vermont to assess what the damage has been. Do we need to make any changes to give USDA more flexibility to upgrade the resilience factors to accommodate the reality of the more extreme weather events that are occurring?

Mr. DUNCAN. Yes. You know, my take on things is to always look to find proactive ways to do things as opposed to the reactive ways, and I think that USDA Rural Development can play a role in doing that. I know EPA has a "CREAT" I believe they call it, for climate resiliency evaluation tool.

What you are looking for is those small communities that do not know where to begin at all with any of this, let alone the aging infrastructure needs that they have, they do not really have a sense of where to go, so planning assistance is very valuable there. That also applies for how to understand where their weak points are in their system when it comes to any kind of extreme weather event, and how to prepare for that, whether it is a large infrastructure investment or whether it is a small infrastructure investment. Providing the technical resources to allow for that, to get ahead of it, in my mind is a way that USDA Rural Development, through their Water and Environment programs, can play a role in making sure that as extreme events do occur, we are more buffered and——

Senator WELCH. By the way, does that also get to where the Circuit Riders are able to provide that kind of support and help that small communities do not have the resources for?

Mr. DUNCAN. Yes, that is correct. I mean, the Circuit Riders in Vermont, I know, and it sounds very similar for Bob White in Alabama and I am sure in the rest of the rural water world, where those Circuit Riders are out there talking about not only the day-to-day stuff but, especially in Vermont I know it will be a big topic for a while, on how can we avoid this in the future and what can we be doing to——

Senator WELCH. Let me ask you. You mentioned bonding, and it is a really big deal for communities to have to assess themselves when they already feel overtaxed, and you cannot spread that out. What are the concrete suggestions you would make? Because what I understand is the apprehension people have that the bond amount is not going to cover the cost of the project, so they are reluctant to vote for something where they do not know what the bottom line is going to be. What could we do to address that?

Mr. DUNCAN. At least in Vermont, the way that is handled is a first come, first served basis for USDA Rural Development loan and grant funding, and obviously the grant funding element is based upon median household income and your rates where they stand. What happens is USDA Rural Development will give you an estimate of what they believe their loan and grant package will be, at which point the users of the system have to conduct a bond vote to try and pass the financial will of the system to cover that loan amount. Then you have to put the application in and hope that the package that they told you that you might get will actually be there and available for you when you actually get the application into them. Providing certainty is key.

Senator WELCH. Thank you.

Ms. Coleman Flowers, you said that there should be a 10-year warranty. That actually makes a lot of sense to me. I mean, what has been the practice for folks who put money out, and they come together to do it, it is a big decision, and they want to get that problem solved. Is it the standard practice that there is no warranty for the construction and building of these systems?

Ms. FLOWERS. Well, we were engaged in discussions with some manufacturers early on. This is actually prior to COVID, and we talked about this. Right now the warranties, generally, through some home warranty companies, the homeowner has to take the responsibility themselves. Some insurance companies will cover it. Why is it transferred from the manufacturers? I think there should be a manufacturer's warranty. That is the only thing that is going to encourage research and development and improvement.

Why it is like that, I do not know, but for something that is so important we need to change it.

Senator WELCH. All right. You know, I listened to you, Senator Tuberville. One of the things I thought I heard you say was trying to target that money to the places that need it the most, in the rural areas. Maybe you could comment on that, Ms. Flowers.

Ms. FLOWERS. Yes. I think that in terms of rural communities there are numerous ways in which we should look at how we get money to them. I think I heard my colleagues today talk about the challenges of getting to these communities, these funds. A lot of funds are available now, but they need the technical assistance to be able to access it. I think that we need to come up with a process in which—when I first got started doing this work, over 20 years ago, there was a USDA office that was open in Lowndes County, where someone came at least once a week. Now that person is no longer there, and people have to travel long distances. I think we have to find a way in which to make it accessible to people in rural communities where they can get these funds.

We also have to keep in mind that part of the problem, too, is a lot of these communities do not have broadband. If you have to register for SAMS.gov in order to even apply for the funds, that is the first hassle, to get to the funds.

We have to make sure that rural communities, a lot of these gaps are closed, not just the wastewater gap but a lot of these gaps are closed in rural communities so they can get access to technical assistance that you do make available.

Senator WELCH. Thank you. Just to let you know, Senator Tuberville and I have made it a major priority about broadband in rural America for this Committee to focus on, so thank you for that.

Ms. Day, I want to ask you a little bit about the Technical Assistance Program. You have done a great job on that. How do the TA providers help communities before and after the natural disasters? You know, we are having one right now, but can you just elaborate a bit on that?

Ms. DAY. Thank you, yes. There are emergency response plans and vulnerability assessments that are part of the USDA loan requirements. USDA helps us to get those done in the communities so that these planning documents that might have been sitting on a shelf, actually we take them down, we work through them with the community, and make sure that they are up-to-date and accurate and are a viable document to work on pre and post disasters.

Senator WELCH. How can we be developing some more managerial capacity? Senator Hyde-Smith was asking about the training and the availability of a work force, and we want to have opportunities for young people who would like to stay in a rural community or come there, to be able to have a good job. How do we do that?

Ms. DAY. We will take any opportunity to work on work force development. We have some foundation work and some other work that we have been able to combine together to really raise the position of these water operators in the communities. I work on so many consent orders, when I started in this field, for the elderly manager of the system, who was a volunteer, who was operating a system without the correct licenses.

There is a lot that can be done around regionalization, and if there are some more planning dollars available to help the small, disadvantaged communities who are strapped anyway, without accurate coverage for operators, then those larger systems could actually do eligibility criteria too, to get the grants from USDA, because the smaller system is probably more eligible for grants, and then that can work to bring the lack of operators that we have, making sure that there are more of them to go around.

Senator WELCH. Thank you.

Senator Tuberville, and take the time you want. I went over a little bit.

Senator TUBERVILLE. No problem.

Senator WELCH. I do not want to shortchange you.

Senator TUBERVILLE. No problem. The problem we are having, obviously, in the rural areas too is educating, getting enough people educated to do the work in the rural areas. Urban areas are fine. You know, they will struggle, but we are really struggling in the rural areas.

I am going to ask everybody this one question, in 20 seconds or more. Just do not make it long, if you have got a perspective on this. What is the most critical element in ensuring the operation of safe public drinking water supply? Rob, what do you think the most critical element is?

Mr. WHITE. I would say the most critical element would be your trained operators who have to oversee these systems and actually put in place, abide by all the regulations, and create the plans, and assess the systems, make sure that the system is rehabilitated when necessary and has a plan to move forward, and remains in compliance and within the regulatory bounds every day.

Senator TUBERVILLE. Ms. Undesser.

Ms. UNDESSER. The most critical item as far as looking at safe public drinking water supply certainly is how do we think about water differently going forward. It is a complex world, and it only getting more complex as we are sitting here right now. We really need to think differently and really leverage all of our solutions that are out there.

Senator TUBERVILLE. Keep it simple, stupid, right? That is what we need.

Ms. Flowers.

Ms. FLOWERS. I think that the most critical element, if we are under-resourced and underserved communities, is access to funding.

Senator TUBERVILLE. Thank you. Mr. Duncan.

Mr. DUNCAN. The answer is definitely trained operators, but playing off of that a little bit is having the resources for those operators, being able to give them technical assistance as well as being able to allow them to plan for how to manage and operate the infrastructure that they have to work with and keep in good condition, whether it is something that is aging and knowing when to make those changes and having the investments to do so or whether it is understanding the risks, both cyber, climate, and whatever, to be able to address the needs and create a sustainable water future.

Senator TUBERVILLE. Thank you. Ms. Day.

Ms. DAY. I would add educated and informed board members who actually run the systems and make the decisions, that they are informed about the technical aspects of running the wastewater and water system.

Senator TUBERVILLE. Thank you. Mr. White, 91 percent of our Nation's water systems serve communities with populations of 10,000 or less. I said that in my opening statement. In Alabama, 75 percent of the people we serve are 10,000 or less. In your experience, what suggestions do you believe could improve program operations and services for small system operators? Do not say money either. I do not want to hear that.

[Laughter.]

Mr. WHITE. Well, that was the short answer, is money.

Well, one thing I would like to comment on is what is working now, what is available under the farm bill and the resources that are being utilized, at least in the State of Alabama. We have three water Circuit Riders, we have two wastewater specialists, an energy efficiency technician, numerous training staff, all working together, a source water assessment person. They all work together every day within all of the rural communities in Alabama to put in place all of these resources and technical assistance.

We meet regularly. Our partnerships with USDA, locally, within the State, are strong. We meet quarterly with USDA, SRF, ADECA, other funding partners, and provide technical assistance reports, and we really get around the table and hammer out all of the concerns for the water and wastewater systems in Alabama. Those partnerships are critical, and they really help bring everybody to the table, and we do not duplicate work. That way we can find the targeted resources for those areas.

To improve, I would say giving USDA more flexibilities. The financing options that were discussed in my written testimony, that would be critical in helping some of the rural, poorer areas in Alabama, being able to have the zero and one percent loans, refinancing options. That would help Uniontown, that we are working with on the west side of Alabama now, if we had that opportunity.

Additional authorities for addressing cybersecurity and more resources for emergency response would also be helpful.

Senator TUBERVILLE. Ms. Day, can you answer that one?

Mr. DUNCAN. Day or Duncan?

Senator TUBERVILLE. Either one of you. Have at it. Hey, I have got all time. I am the last one.

[Laughter.]

Mr. DUNCAN. Well, thank you. You know, I think the funding alternatives are definitely a way to do it, if you are looking at it without additional moneys to throw in there. I do think a shift in the paradigm is critical in how we operate our facilities today. The run-to-failure mode is where we are at, so whatever abilities and resources can be put toward systems, especially those small systems. I think if you went and talked to any operator in any small system, in any State around the country, they would tell you what their problems are. They do not have the capacity, knowing what they know that needs to be addressed, nor the ability to go and address it.

Continuing to promote the Circuit Rider program to help them find that path forward, education to boards, and education and promoting the value of water is also critical because it is one of the cheapest utilities out there with the highest value in life, but yet we undervalue it incredibly.

Anything along those lines, absent actual money, would be the way to go forward, I think, in helping to give those operators, as well as the system owners, which is the public, an understanding of how to create systems that will be more resilient going forward, will be more affordable to run. Any of those tools in the toolbox that can be promoted within the USDA WEP program are critical, in my mind.

Senator TUBERVILLE. I have got one last question, and I would like all of you to answer it, kind of like the first one, kind of short. Let's start with Ms. Day. All these natural disasters we are having, how do we prepare for those for our water system? In your mind. I mean, because we are having more and more. We are having hurricanes, tornadoes, what we saw in Vermont this week, it is a disaster, and we have to have water. How do we prepare for that?

Ms. DAY. We plan. I have to say that the USDA predevelopment dollars for the really small, rural, disadvantaged systems are the only predevelopment dollars that are available to them, and they cannot do a feasibility study without that. Vermont does a good job with SRF dollars getting out to those small communities, but not every State does. They may have an idea of what to do to make their system better, but they need that $35,000 of predevelopment to actually make a change in the system. Thank you.

Senator TUBERVILLE. Mr. Duncan.

Mr. DUNCAN. The No. 1 answer, in my mind, is stop fighting Mother Nature and taking a look and understanding climate change. One of the things that is a real challenge is a lot of our systems are built in lowland areas, at least in Vermont, so it is a real challenge. That is not going to change overnight, but taking a look at what the risks and liabilities are associated with each of those different events that come at us, and then identifying paths to resiliency and redundancy is really the only way to move that forward, as opposed to keep getting knocked down and standing back up and taking it on the chin again.

Senator TUBERVILLE. Ms. Flowers.

Ms. FLOWERS. You know, I actually live in Tornado Alley in north Alabama.

Senator TUBERVILLE. I know you do.

Ms. FLOWERS. We had a tornado last night. I think that, first of all, planning, and then in terms of dealing with resilience, we have to have resilient infrastructure. I agree. We cannot build the way that we have built before and think things are going to change. Things are actually getting worse. Building a more resilient system. Just an example of a system that was built, this was in an urban area, and they did not prepare for the lights going out. When the lights went out, then the wastewater treatment stopped, and then the communities were flooded with raw sewage.

I think we have to start looking at what we could probably do in terms of renewable energy, to use it as a backup energy source for when the power goes out, to make sure that we can continue to have water and sanitation.

Senator TUBERVILLE. Ms. Undesser.

Ms. UNDESSER. Thank you. I absolutely echo the resiliency planning. That is No. 1. I would add on to it the emergency planning as well, and making sure that those emergency plans leverage all solutions that are available, and again, that we think differently about it rather than just kind of staying in the lane, but how do we leverage all of the solutions that are available to us?

Senator TUBERVILLE. Rob.

Mr. WHITE. I would say training and partnerships. We need to continue to train. It is ongoing. There are new resources and regulations that come around each year. Plus the work force is changing, so new folks get into those administrative positions, making sure they are aware of what is available to them. Then partnerships with not only Federal and State agencies and resources but do you know your neighbor systems. Do you have mutual aid agreements with those? Do you know your access to resources through our associate members, companies that are in the State that can maybe go ahead and prepare a contract for service during an emergency so you can lock in prices and ensure that you have a number of items available to you during that time?

That is what I would say, training and partnerships.

Senator TUBERVILLE. Thank you all for being here. It has been very good.

Senator WELCH. Yes, it has been an excellent hearing. Thank you. You know, as our country is facing these wild weather events, climate change, more severe and frequent storms, we have got to make sure that the water in our communities is safe and available. That is true particularly in rural communities of color and rural economically disadvantaged communities. They often struggle with robust water infrastructure and are very vulnerable to the effects of these wild climate-induced storms. Climate resilience and equity have to be very much at the forefront of our efforts.

I look forward to continuing to work with all of you. You know, you are doing like real work, practical work, and our job is to try to help get you the resources that you need in order to help our communities back home. We have a hard job, but you have a harder job. I just want to acknowledge that and express to you the gratitude that I think every member of this Committee has for the work you are doing back home. We all really deeply care about rural America. That is what kind of binds this Committee and makes it one of the most nonpartisan, bipartisan committees in Congress. Thank you.

The record will remain open for five business days for any members that wish to submit any additional questions or statements, and the meeting is adjourned.

[Whereupon, at 4:27 p.m., the hearing was adjourned.]

A P P E N D I X

July 19, 2023

Testimony to the
Subcommittee on Rural Development and Energy
"Rural Water: Modernizing our Community Water Systems."

Committee on Agriculture
United States Senate

Ms. Jennifer Day
Director of Development

RCAP Solutions, Inc.
Northeast & US Caribbean affiliate of

Rural Community Assistance Partnership Incorporated

July 19, 2023

Introduction & About RCAP

Thank you, Chairman Welch, Ranking Member Tuberville, and members of the subcommittee for this opportunity to discuss the importance of the U.S. Department of Agriculture's Rural Development (USDA-RD) suite of programs and services in fostering rural economic development and prosperity. USDA-RD is the only federal agency dedicated solely to rural America and plays a key role in improving access to capital while working alongside trusted partners to ensure rural areas remain great places to live and thrive. I also want to thank the committee for their work on writing the next Farm Bill.

My name is Jennifer Day, and I am the Director of Development with RCAP Solutions, the Northeast and US Caribbean RCAP. Prior to this position I was the Director of Community and Environmental Resources responsible for grants and contract compliance for a team of 30 Technical Assistance Provider serving rural communities in New England, New Jersey, New York, Puerto Rico, and the U.S. Virgin Islands. The Rural Community Assistance Partnership (RCAP) is a national network of non-profit partners working to provide technical assistance (TA), training, and resources to rural and Tribal communities in every state, U.S. territory and on Tribal lands and in the Colonias. Through our network, more than 350 technical assistance providers build capacity that leads to sustainable and resilient infrastructure and strengthens rural economies. Our approach is grounded in long-term, trusted relationships with thousands of rural, Tribal, and Colonias communities across the country.

For 50 years, the RCAP network has partnered with multiple federal agencies including USDA-RD to bridge the gap between federal programs and the communities they serve. RCAP assists rural communities with funding applications and every phase of the project planning and development process, as well as providing training and technical assistance. We help communities understand how to properly manage and operate their infrastructure in a fiscally sustainable manner and ensure that federal borrowers meet the terms of their loans.

Last year, RCAP served more than 3.5 million rural and Tribal residents in more than 1,650 of the smallest, most distressed communities. The average population of these communities was 1,520, with a Median Household Income (MHI) of less than two-thirds the national MHI. We served almost 300,000 individuals from Indigenous communities. In addition, we served more than 1 million people of color.

USDA-RD water, wastewater, and solid waste grant and loan programs and their associated technical assistance programs directly benefit communities with safe and affordable drinking water and sanitation services. Additionally, these programs are important to the health and safety of rural Americans and the economic vitality of their communities. RCAP supports robust reauthorizations of the Water and Environmental Programs (WEP) in the next Farm Bill, programs whose impact can be demonstrated in every U.S. state and territory – including in Vermont, where flooding last week and the major disaster declaration highlights the importance of the long-term managerial and financial work that is RCAP's specialty, including enabling small systems to prepare for, and recover from, emergencies.

In Vermont, WEP funding allowed RCAP Solutions to work directly with 25 communities in the past few years on a range of critical water and wastewater needs. The systems we work with are small and typically low-income. In Vermont, those 25 communities have an average population of 578 and an MHI of $46,731. Water and wastewater systems in communities of this size are typically managed by volunteer board members with little or no experience in the technicalities of taking chlorine samples, infrastructure planning, or hiring an operator.

With WEP funding, we provide training, both online and in-person, to system managers and operators alike. We help board members who were previously proud of not having raised rates in a decade, see the light and communicate the need to have sustainable rates that cover their true operating expenses. These expenses include a reserve account to cover future upgrades and, in the process of explaining the necessary rate adjustment to customers, helps gain public support. We help communities hire engineers, train volunteers on their roles and responsibilities as board members, and in places like Pownal and Craftsbury Vermont help the public to understand the next steps once Per- and Polyfluorinated Substances (PFAS) has been detected in the water supply. We work with water and wastewater system managers to document system failures, communicate the importance of system upgrades, and provide public education to ensure that all stakeholders can make informed decisions when it comes time to vote on bond measures. The need to plan for system upgrades and comply with regulations does not discriminate based on system size, and technical assistance providers like RCAP help to fill the capacity gap.

In Bristol, Vermont, we're helping the town address high-strength wastewater that has limited the potential for adding connections to the system. In Alburgh, we're working as a liaison between the Village Trustees and the primacy agency to communicate the ramifications of new permit conditions on the community, in the process helping the village to access state planning loans.

We're helping to protect USDA-RD investments after major projects completed for fire districts in Coventry, East Berkshire, and Burke resulted in a near complete turnover of board members, a common occurrence with small systems where volunteers get "burned out". In each of these communities, RCAP Solutions is helping build managerial capacity by assisting the new boards with budget projections, adjustments in water rates and policies, public outreach efforts, and leveraging additional state and federal funding opportunities. TA providers are often the glue holding things together during a transition of system management, serving as trusted advisors and often, helping to find and train replacement board members.

The RCAP Technical Assistance Providers (TAPs) do this work across the country in partnership with local USDA-RD offices. Project referrals can come from local USDA-RD offices in each state. RCAP meets frequently with these offices and state regulatory agencies to discuss priority systems and topical issues for technical assistance and training. During in-person and online training events for boards on sustainable utility management and application assistance, RCAP and the USDA-RD staff talk about the services that we can offer at no charge to the community as they are supported by the federal technical assistance grants. While there are professional Rural Development staff members working to assist these communities, their capacity can be limited so partnerships with technical assistance providers in the field magnifies the impact of USDA-RD's field staff. This field structure is especially helpful to communities and utilities that lack the human and financial capacity to access and administer available funding. RCAP works in partnership with USDA-RD to directly assist underserved rural communities including access to the Tribal and Colonias funding set-asides.

Local USDA-RD offices often connect communities to RCAP because of our ability to demonstrate an accurate median household income for a water or wastewater service area. Criteria for receiving grants through WEP and other federal funding programs are often based on census data and affordability criteria, measures that fail to represent non-traditional systems and manufactured housing communities. For the Shattuck Hill Mobile Home Park in Newport, Vermont, failing septic systems required immediate action to protect public health and the environment. RCAP Solutions performed an income survey to demonstrate that the MHI for the community was just $20,544, allowing USDA to provide a grant for 75% of the $484,000 cost to upgrade the wastewater system and address regulatory compliance issues. Following completion of the income survey and funding award, RCAP Solutions helped the community comply with the award terms and conditions, including helping to complete the required Emergency Response Plan and Vulnerability Assessment. Similar stories can be told about the Sunset Lake Cooperative in Hinesburg, the town of Randolph, and the East Thetford Water Company. It can be told for thousands of systems across the country. RCAP's funding application assistance and other related tasks helped communities in the Northeast and U.S. Caribbean receive 57 funding awards in FY22 alone, resulting in over $88M in grants and low-interest loans.

The RCAP network is the sum of six regional partners across the U.S. that collectively cover every state and U.S. territory, including Tribal lands and Colonias:

- Communities Unlimited (CU) – The Southern RCAP
    - Serving Alabama, Arkansas, Louisiana, Mississippi, Oklahoma, Tennessee, and Texas.
- Great Lakes Community Action Partnership (GLCAP) – The Great Lakes RCAP
    - Serving Illinois, Indiana, Kentucky, Michigan, Ohio, West Virginia, and Wisconsin.
- Midwest Assistance Program (MAP) – The Midwest RCAP
    - Serving Iowa, Kansas, Minnesota, Missouri, Montana, Nebraska, North Dakota, South Dakota, and Wyoming.
- Rural Community Assistance Corporation (RCAC) – The Western RCAP
    - Serving Alaska, Arizona, California, Colorado, Hawaii, Idaho, Nevada, New Mexico, Oregon, Utah, and Washington.
- RCAP Solutions (RSOL) – The Northeastern and Caribbean RCAP

- Serving all six New England States, New York, New Jersey, Pennsylvania, Puerto Rico, and the U.S. Virgin Islands
- Southeast Rural Community Assistance Project (SERCAP) – The Southeastern RCAP
    - Serving Delaware, Florida, Georgia, Maryland, North Carolina, South Carolina, and Virginia.

In line with RCAP's mission of even further expanding its impact in rural communities in the years to come, laid out in the sections below are some of RCAP's key recommendations for the 2023 Farm Bill. Also included are some relevant case study examples of RCAP's work in these areas.

Rural Utilities Service Water and Environmental Programs (WEP)

RCAP Water and Environmental Programs Farm Bill Recommendations:

- Reauthorize the **Water & Waste Disposal Technical Assistance & Training Grant Program** to the maximum amount (Section 306(a)(14)(A) of the Consolidated Farm and Rural Development Act 7 U.S.C. 1921 et seq.), set-aside no less than 10% of funding for expanded technical assistance and capacity building. RCAP also requests additional language for emergency response technical assistance to meet the growing need in assisting rural communities to plan for and recover and rebuild after natural disasters.

- Reauthorize the **Water & Waste Disposal Loan & Grant Program** (Section 306 of the Consolidated Farm and Rural Development Act).

- Reauthorize the **SEARCH -Special Evaluation Assistance for Rural Communities and Households Program**, include additional matching flexibility under the program to include in-kind or waivers in cases of extreme need.

- Reauthorize the **Water & Waste Disposal Predevelopment Planning Grant Program**, include additional matching flexibility under the program to include in-kind or waivers in cases of extreme need.

- Reauthorize the **Solid Waste Management Grant Program** (Section310B of the Consolidated Farm and Rural Development Act) at $20 million a year over five years.

RCAP has been providing on-the-ground technical assistance and training to small and rural water and waste systems for 50 years in all 50 states and the U.S. territories. Through our partnership with USDA-RD, RCAP and our regions in one year alone helped rural and Tribal communities from across the country leverage approximately $400 million in infrastructure funding from a variety of federal, state, local, and private funding sources. Through these programs we also conducted 140 training workshops, serving more than 1,300 systems and reaching about 2,500 participants.

Water & Waste Technical Assistance

RCAP has been a leader in the regionalization space, especially when it comes to sustainable solutions for small, rural, and Tribal communities. In addition to intensive technical assistance, and training work as a neutral third-party facilitator helping communities navigate what is often a complicated undertaking, RCAP developed a process to help guide both TA providers and communities through the ins and outs of regional collaboration. RCAP also developed two helpful research products: one outlining ten lessons learned from communities across the country who have participated in activities across the regionalization spectrum; and another, outlining local, state, and federal policy recommendations that would help incentivize and ease the pathway to sustainable and resilient regional solutions. Regionalization is not a silver bullet, but we believe it should always be on the table for consideration, especially as the water workforce dwindles, regulations become more stringent and disasters more intense and frequent — no one must go it alone.

Across the United States, we see communities facing threats to their drinking water from several harmful contaminants, such as lead and PFAS. Rural communities have historically been overlooked by federal investments when it comes to addressing water challenges, especially the nearly 23 million households who rely exclusively on groundwater delivered through private wells for their drinking water. In Massachusetts RCAP Solutions partnered with the Health Foundation of Central MA on a 3-year study of 500 wells across the state and found that at time of testing one third of the wells had contaminants that exceeded state standards for drinking water. We then worked with legislative partners to propose statewide legislation to protect the public health of well owners. As other states move to enact similar legislation, the need for the USDA-RD Rural Decentralized Water Systems Grant Program will increase, and continued access to these funds for low- and moderate-income homeowners will protect the health of their households, giving them equitable access to safe drinking water.

Beyond those on small water systems and private wells, we also know that many communities are hauling water by hand as a practice in Tribal areas and the Colonias. Lack of access to water and sanitation, a result of both historical and geographical factors, is most prevalent in Alaska, the Dakotas, and northern New England, but there are additional pockets of this issue throughout the U.S.

A report from DigDeep and the US Water Alliance shows that gradual improvements are being made in this space, but that the rate of progress is declining. The population without complete plumbing in the United States was reduced from 1.6 million people in 2000 to 1.4 million in 2014. For comparison, those lacking complete plumbing dropped from 27 percent in 1950 to 5.9 percent in 1970. This data suggests that communities making up the remaining access gap face particularly entrenched challenges. (Closing the Water Access Gap in the United States by Dig Deep and US Water Alliance)

One solution to help drive positive public health benefits for millions of rural Americans is The Healthy H2O Act, introduced by Senator Baldwin and Senator Collins. This bipartisan legislation would improve quality of life in the communities we serve by having USDA-RD provide direct assistance to households and licensed childcare centers on private wells in low-income, rural communities to test drinking water for contaminants and fund filtration technology for proper remediation.

Water and Environment Program Loans including Predevelopment

I am a committee member on the Franklin County MA Comprehensive Economic Development Strategy (CEDS) working group facilitated by the Franklin Regional Council of Governments. In 2022 we reviewed a study of Franklin County water and wastewater systems. The report assessed $300 million total infrastructure upgrade needs at 12 public wastewater and 16 public water districts. It would cost another $52 million to provide 3 wastewater and 3 drinking water systems for the identified unsewered or private well only communities. This $350 million need in one of the most rural counties in Massachusetts, with only 24 towns and one city, is more than 25% of the $1,334 million dollars in water/wastewater funding available for the entire state. As more needs are identified and as construction costs climb, the funding gap will continue to widen, even with the significant influx of funds from the Bipartisan Infrastructure Law over the next few years.

In most cases, it takes multiple years of predevelopment planning and multiple funders to successfully implement each project. Big cities have planners and engineers on staff or have access to predevelopment funding to hire consultants to help design projects and estimate costs. The small systems have volunteer boards, part time clerks, and operators that rely on federally funded predevelopment grants and technical assistance, like the RCAP network provides, to assist with multiple tasks – including but not limited to community engagement, application assistance, and affordability qualifications. Continued support, increased funding and state office oversight of the SEARCH and Water and Waste Predevelopment grant funds will support more successful applications to WEP. This should also continue to increase funding in the next five years to leverage the predevelopment and infrastructure dollars spent by the Environmental Protection Agency (EPA) as part of the Bipartisan Infrastructure Law to make sure that no small and/or rural systems are left behind.

In addition to planning, technical assistance after a large construction project is completed, helps to make sure the community adapts to their new reality. Examples include increasing water rates and the public outreach necessary to support it; adjusting the capital improvement plan and budget to include appropriate contributions to reserve funds for replacement of new equipment; and helping to develop financial monitoring procedures to meet the conditions of the USDA-RD construction loan.

Solid Waste

RCAP has been providing solid waste management services to low-income small, rural, and Tribal communities for decades. Since 2014, with funding from the USDA-RD, RCAP has assisted more than 160 rural communities (26 of which were Tribal), serving more than 1 million rural residents in 30 states and the Caribbean territories. Of those served, 28% were low-income and 45% were people of color. RCAP has more than 20 highly experienced staff who provide solid waste management technical assistance and support across the nation.

Puerto Rico has twenty-nine (29) landfills, and many of them are unable to address critical regulatory compliance issues around the Resource Conservation and Recovery Act. The EPA is focused on closing those open dumps which pose the greatest threat to the environment and to people's health. Without new, compliant environmental systems in place, there will be more pressure on the remaining facilities - many of them already limited in capacity. RCAP Solutions' work in Puerto Rico supports efforts to limit illegal dumping, find sustainable solutions, and increase recycling rates in Puerto Rico, which are commonly cited in the 7-12% range and significantly lower than the nationwide rate of 32% reported by EPA.

Waste generation on the island exceeds landfill capacity, and is expected to, for years to come. Solid waste and debris from increasingly frequent hurricanes exacerbates the issue. Waste diversion and recycling presents challenges for most municipalities, largely due to the cost of exporting materials, the lack of infrastructure, and the lack of diversion management facilities. This situation increases the illegal dumping of debris, appliances, and construction and demolition materials. Illegal dumping, difficult to monitor and control in rural areas, creates both public health and environmental problems. The education of communities, municipal staff, and stakeholders is a priority. Many communities are also transitioning from municipal management of the landfill facilities to private companies who are overseeing the compliance and operations. Time will tell if this approach is working, but municipalities must continue to participate in planning for the future of waste solutions in Puerto Rico.

Lajitas is a small sector in Barrio Guayabal, Juana Diaz, Puerto Rico. The community has suffered due to littering and illegal dumping, creating environmental and public health hazards. Basketball courts and surrounding areas were used for dumping and the areas alongside the roads were severely impacted by littering and improper management of solid waste. The community is near the Guayabal Water Reservoir, shorelines of which have fallen victim to waste from the Jacaguas river. The illegal dumping and litter build up have been overwhelming.

The community called RCAP Solutions seeking help and we were able to facilitate meetings and suggested the formation of a community organization. RCAP Solutions worked to empower community members to implement coordinated actions with the municipality. The municipality eventually adopted a ticket system for the collection of debris and bulky waste. Insufficient waste collection by a private hauler was also addressed, an issue RCAP Solutions helped to document and present to the municipality.

In the Paso Hondo sector of Lajitas, waste collection had never been offered by the municipality due to narrow roads and steep terrain. RCAP Solutions and Fundación Wepa! invited the municipal administrator to a site visit, and an agreement was reached in which the municipality would direct the private hauler to implement curbside collection using a small waste compactor truck. To ensure the effectiveness of the new collection program, they promised to give each household a 55-gallon drum to be used as a trash can. For one resident of the Paso Hondo neighborhood, *"I've been living in this community for more than 45 years and [this] is the first time I have seen a garbage truck coming for our waste. I used to carry the garbage to the collection area all my life and the area was full of flies and bad odors. I am really happy that this is happening."*

Rural Housing Service Community Facilities Programs

RCAP Community Facilities Programs Farm Bill Recommendations:

- Reauthorize the **Community Facilities Technical Assistance and Training Program** (Section 306(a)(26) of the Consolidated Farm and Rural Development Act), set-aside no less than 10% of funding for national multi-state technical assistance and capacity building, and to create additional flexibility under the program by removing caps on funding.
- Reauthorize the **Community Facilities Direct Loan & Grant Program** (Sec. 306(a)(19) of the Consolidated Farm and Rural Development Act).
- Authorize a **Community Facilities Connect Program** to provide five-year direct community facilities technical assistance in each state and territory, to help underserved rural areas access the Community Facilities Direct Loan and Grant Program, plus other funding sources.

One of RCAP's most recent new initiatives was through a Community Facilities (CF) Technical Assistance Cooperative Agreement with USDA-RD. Community Facilities Technical Assistances consists of enriching resources and leveraging funding to improve, expand, or build necessary community facilities, such as healthcare facilities, city halls, fire stations, schools, etc. Over a two-year pilot period, RCAP actively worked with 42 communities in 22 states, reaching eligible rural areas with an average population of 4,461 people and a median household income significantly below the national median. With $400,000 in funding through this cooperative agreement, RCAP was able to leverage an additional $51 million in funding for communities from USDA-RD and other sources for these projects.

Under the pilot program, RCAP Solutions was able to assist the town of Shoreham, Vermont with evaluating and prioritizing projects to utilize ARPA (American Rescue Plan Act) funding. We acted as facilitator through a public input process, integrating new project ideas with the town's existing Capital Improvement Plan, and identified and ranked criteria for selection (such as the reach of impact to residents or availability of funds from other sources). This process allowed the town to implement an independent and transparent process to allocate ARPA funds to projects that are practical, achievable, and self-sustainable–and at the same time helped the Selectboard consider other funding sources for important community projects.

Additionally, RCAP was able to provide disaster recovery technical assistance under the Community Facilities Technical Assistance and Training Program (CF-TAT), which was authorized in the 2014 Farm Bill. Over the course of the project, RCAP provided technical assistance to 29 federally-declared disaster impacted communities in five states and one territory. RCAP had the ability to scale to more states and impacted communities but was limited due to funding constraints under the program. The eligible rural communities served had an average population of 2,389 people and a median household income around half of the national median. RCAP unlocked and leveraged ~$1 million from USDA-RD and other funding sources for six communities with direct disaster funding application assistance through TA.

RCAP's expertise, on-the-ground networks, and long-standing relationships make us a valuable resource for rural and Tribal communities trying to access USDA-RD Community Facility financing by providing technical assistance and support at every step of the process, from planning to implementation and leveraged funding. RCAP works with communities to integrate disaster resilience and mitigation strategies into their projects. RCAP also targets rural low-income communities and persistent poverty communities, frequently addressing common barriers to accessing and utilizing federal funds.

Currently, RCAP as a National network does not have any CF-TAT funding to meet the on-the-ground rural community need in this issue area. Program changes through the next Farm Bill and increased dedicated funding would directly allow RCAP and other qualified organizations to provide much needed technical assistance in multiple states and to model CF technical assistance programs after other successful programs at USDA-RD.

Rural Investment Initiative

RCAP Rural Investment Initiative Farm Bill Recommendations:

- Authorize a **Community Facilities Technical Assistance and Training Program** with dedicated resources in the Rural Development Title to support locally driven capacity building and financing for small towns and rural communities across all missions areas of USDA-RD.

Lastly, RCAP supports the authorization of a Rural Investment Initiative (RII), which, if enacted would be a locally-driven, flexible capacity building and financing program to support all mission areas of Rural Development: rural utilities, rural housing, and rural business. Many USDA-RD programs that help unlock private investment are difficult for rural towns and organizations to access. Local governments and non-profit organizations often lack the staff and technical expertise to apply for grants. It is also exceptionally challenging for often part-time local government officials and their limited staff to track and advocate for their community's fair share of funds from states or apply for federal grants directly. The RII would match rural communities and their needs to a cohort of local, regional, and national technical assistance providers, making it easier for communities to access right-sized technical assistance and ensuring better access to all USDA-RD programs, financing, and services. The RII would be designed to provide financial capital directly to communities and strengthen human capital to unlock new investment, including public private partnerships, that would improve the capacity, economic health, and overall well-being of local communities.

RCAP is in support of the Administration's Rural Partners Network (RPN) concept but believes Congress should further codify and shape RPN to make lasting policy changes in the next Farm Bill. The RII could accomplish this, as much can and should be done to help with low USDA staffing levels and agency technical upgrades. Strong USDA-RD authorizations with dedicated resources through the next Farm Bill will ensure the agency's ability to deliver timely services, staffing, and financing to rural America while making it easier for communities to apply and access funding.

Closing

I would like to thank the committee for their work to reauthorize critical USDA-RD programs in the next Farm Bill. RCAP looks forward to working with each of you to ensure USDA-RD and rural communities have the tools they need to promote improved quality of life for rural America. On a national level, RCAP is on the steering committee of two advocacy coalitions working together on policy solutions geared towards lasting change in rural —The Rural Network and the Reimagining Rural Assistance Network. Both coalitions stand ready to work with you on a strong Rural Development Title that works for all rural places and people.

RCAP works with communities and partners across the country to advocate for and generate economic opportunities for rural areas. The services provided through these programs deliver critical assistance in the small and disadvantaged communities where it is most needed. I thank the committee for inviting me to testify today, and I look forward to working with you and your colleagues to ensure rural people and places have the resources they need to be successful.

RCAP

2023 Farm Bill Priorities

Who Is RCAP?

RCAP is a non-profit national network of **six** regional organizations that provide technical assistance and training to leaders in rural communities throughout the United States

We help communities develop, operate, and maintain viable water and wastewater systems; maintain compliance with federal/state regulations; **protect public health** and the environment; and build local leadership capacity

RCAP serves more than **2,503** unique rural communities every year RCAP employs more than **300** engineers, operators, accountants, former mayors and other experts who are out in the field assisting rural leaders

For over **45 years**, RCAP has worked with USDA and EPA to improve the quality of life in rural America

Contact Maranda Saling with RCAP for more information:

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The Rural Community Assistance Partnership (RCAP) supports the enactment of a robust and comprehensive Rural Development Title in the reauthorization of the Farm Bill. RCAP calls on Congress and the Administration to emphasize rural development programs and strategies that will create opportunities for all rural Americans including underserved places. RCAP supports several key priorities in the Farm Bill that will boost rural economies, create jobs, and improve the quality of life in rural America:

Rural Utilities Service: Water and Environmental Programs

- Reauthorize the **Water & Waste Disposal Technical Assistance & Training Grant Program** to the maximum amount (Section 306(a)(14)(A) of the Consolidated Farm and Rural Development Act 7 U.S.C. 1921 et seq.), set-aside no less than **10%** of funding for expanded technical assistance and capacity building, and include additional language for separate emergency response technical assistance activities under emergency disaster supplementals from Congress.
- Reauthorize the **Water & Waste Disposal Loan & Grant Program** (Section 306 of the Consolidated Farm and Rural Development Act).
- Reauthorize the **Solid Waste Management Grant Program** (Section 310B of the Consolidated Farm and Rural Development Act) at **$10 million** a year over five years, create additional flexibility under the program by removing caps on funding.
- Reauthorize the **Rural Decentralized Water Systems Grant Program** (Section 306E of the Consolidated Farm and Rural Development Act), include additional program eligibility and flexibility by raising the income eligibility requirements from **60%** of statewide median household income up to **100%** in cases of extreme need.
- Reauthorize the **Revolving Funds for Financing Water and Wastewater Projects Program** (Section 306 of the Consolidated Farm and Rural Development Act).
- Reauthorize the **SEARCH -Special Evaluation Assistance for Rural Communities and Households Program**, include additional matching flexibility under the program to include in-kind or waivers in cases of extreme need.
- Reauthorize the **Water & Waste Disposal Predevelopment Planning Grant Program**, include additional matching flexibility under the program to include in-kind or waivers in cases of extreme need.

Flexible Technical Assistance Services and Coordination Across USDA-Rural Development Mission Areas

- Authorize a flexible program for expanded capacity building and flexibility across all USDA-Rural Development mission areas, including adequate resources to implement modern plans, community broadband access, create jobs, and leverage new infrastructure development to increase the resiliency of rural communities.

Rural Housing Service: Community Facilities Programs

- Reauthorize the **Community Facilities Technical Assistance and Training Program** (Section 306(a)(26) of the Consolidated Farm and Rural Development Act), set-aside no less than **10%** of funding for expanded technical assistance and capacity building and create additional flexibility under the program by removing caps on funding.
- Reauthorize the **Community Facilities Direct Loan & Grant Program** (Sec. 306(a)(19) of the Consolidated Farm and Rural Development Act).

RCAP Solutions · Great Lakes Community Action Partnership · MAP · RCAC www.rcac.org · Midwest Assistance Program · Communities Unlimited · RCAP Rural Community Assistance Partnership

Rural Community Assistance Partnership

USDA Community Facilities Cooperative Agreement

RCAP REQUESTS the continuation of funding for its Community Facilities Technical Assistance Cooperative Agreement with USDA given the success and community impact of the pilot program, which ended on September 30, 2022.

RCAP currently is seeing continuing demand for our services and for flexible funding under a national community facilities technical assistance co-op program supported by USDA. The pilot funding allowed RCAP to work with towns of populations less than 5,000 and provided communities with much needed local capacity to plan for and leverage funding for the construction or improvements of crucial community facilities such as health clinics, community centers, fire stations, libraries, and other public facilities.

42 Projects In **22** States

4,461 Average Population

$43,099 Average Median Household Income

$400,000 2-Year Cooperative Agreement

$51 Million* Funding from USDA & Other Sources

RCAP IS SEEKING **$600,000 over a 2-year period** to continue this program with a national scope This program has shown itself to be incredibly useful to our technical assistance providers and the rural communities they serve. It has been a resource that fills in the gaps other existing Technical Assistance and Training programs cannot.

It funds the time, resources, and capacity necessary to leverage and implement new funding for crucial community facilities in towns with America's lowest populations and lowest incomes.

With an unprecedented amount of funding coming to communities through the Infrastructure Investment and Jobs Act (IIJA), this program will help ensure that rural and disadvantaged communities have the necessary capacity to access and implement this funding in the areas that need it most.

In one project alone, RCAC (the western RCAP) staff leveraged a total of $1,980,000 in USDA loan funds, a $100,000 CF Economic Impact Grant, and a $13,000 State CF Grant for a total of $2,093,000 in funds. This helped the **Foundation for Little Colorado Revitalization (FfLCR)**, a non-profit organization located in Springerville, Arizona with their community facility for their "Local Food System Regionalization" project.

Rural Community Assistance Partnership

USDA Community Facilities Disaster Relief Technical Assistance and Training

RCAP REQUESTS the continuation of funding for its Community Facilities Disaster Relief Technical Assistance and Training program with USDA given the success and community impact of the pilot program, which ended on September 30, 2022.

RCAP currently is seeing continuing demand for our services and for flexible funding under a national community facilities technical assistance program in disaster relief areas. The previous funding allowed RCAP to work with towns of populations less than 5,000 and provided communities with much needed capacity to plan for and leverage funding for the repairs, replacement, and construction of essential community facilities like city halls, fire stations, police stations, and health centers that were affected by natural disasters such as hurricanes, tropical storms, floods, and forest fires. These disasters are not slowing down as we have seen with recent hurricanes Fiona and Ian as well as the continuous forest fires in the Western U.S so the need will continue to be there and RCAP stands ready to assist.

29
Projects
(5 states + 1 territory)

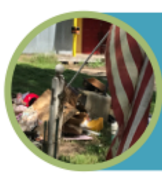
2,389
Average Population

$35,806
Average Median Household Income

$250,000
2-Year Cooperative Agreement

$526,760
Funding from USDA & Other Funders

RCAP IS SEEKING $600,000 over a 2-year period to continue to provide community facilities-related disaster relief in communities that need it most due to a lack of capacity to access typical federal aid dollars due to low population, low income and limited resources. Under this current program we were only able to fund 3 of our regional partners due to the $250,000 funding cap so with the the requested funding increase we would be able to fund up to 6 total regional partners covering the entire U.S. and the territories including Puerto Rico which needs additional disaster recovery technical assistance right now. We could only serve communities that had disasters within the years 2018-2019. This left communities experiencing new disasters outside of eligibility for this program. If we changed the requirements to serve communities that experienced federally declared disasters within the last 5 years from the project start date, we would also be able to respond to newer disasters while continuing to serve communities that need help with long term recovery from previous disasters.



The disaster relief program was managed by the Maryland and Delaware State RD office despite being a national program. The Community Facilities Technical Assistance and Training Program was created in the 2014 Farm Bill (Section 6006) with the intention of the program being a national program that is managed and coordinated by the National USDA-RD Office. Congress also reaffirmed this intention in the 2018 Farm Bill found here on page 664. It would be incredibly beneficial to see this program housed for the purpose of coordination between national service providers and multiple states impacted by a disaster.

Rural Community Assistance Partnership

RCAP Solid Waste Management Programming

The Rural Community Assistance Partnership (RCAP) is a network of seven nonprofit organizations working together to provide training, technical assistance, and capacity building to small, rural and Tribal communities in the areas of water, wastewater, solid waste and community and economic development. RCAP has been providing solid waste management services to low-income small, rural and Tribal communities since 2004. Since 2014, with funding from the US Department of Agriculture (USDA), RCAP has assisted more than 160 rural communities and counties (26 of which were Tribal), serving more than 1 million rural residents in 30 states and the US Caribbean. Of those served, 28% were low income and 45% were people of color. RCAP has over 350 technical assistance providers located throughout the 50 states and the US Territories who live and work in the rural and Tribal communities they serve, including more than 20 highly experienced staff who provide solid waste management support.

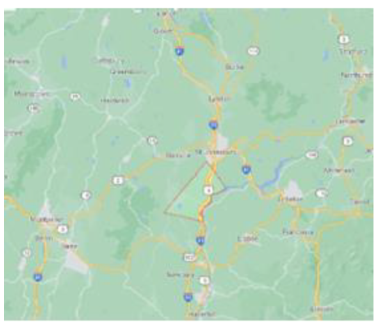
RCAP's wide variety of solid waste services are targeted to meet the specific needs of rural communities with an end goal of improved solid waste management and planning, while reducing potential pollution of water resources. Through this work, RCAP seeks to improve public and environmental health as well as the quality of life for rural communities. The goal of our Solid Waste staff is to reduce the use of disposable items, teach reuse of products within the communities they serve, and promote recycling and composting best practices which protect natural resources and valuable landfill space.

RCAP's approach to hands on training and in-depth technical assistance is to concentrate on local capacity building so that the communities served have the tools and resources to be successful and sustainable for years to come.

Some of the categories of typical services provided include but are not limited to:

- **Community and school waste stream reduction through education and program development on re-use and recycling;**
- **Safety and operations, including the handling and management of Household Hazardous Waste;**
- **Development of school and community composting programs, including vermicomposting, to reduce food waste entering the waste stream;**
- **Training and technical assistance surrounding emerging contaminants including but not limited to PFAS and pharmaceuticals;**
- **Illegal dumping site identification, mapping, prevention, and alleviation strategies;**
- **Solid waste best management practices, budgeting and rate analyses, and funds leveraging for equipment needs and facility upgrades; and**
- **Introduce communities to the concept of Integrated Solid Waste Management Systems and help develop the infrastructure to implement these best practices.**

Barnet Fire District Avoids Water Violation



Location: Barnet, VT
Population: 1,663 (205 connections)
Household Income: $36,089
Region: RCAP Solutions, Inc.
Funder: USDA RD Technitrain, 19-20
Author & Date: Mark Johnson, 2018
Services:

- Increased Managerial Capacity
- Financial Sustainability

BACKGROUND

Despite recent source water and treatment plant improvements made by Barnet Fire District #2 (BFD2), maintaining regulatory compliance is a real challenge - as it is for many rural communities. The water system, which serves about 205 customers, had been under a boil-water advisory since 2004 due to long-term source water deficiencies. In 2014 members of the community expressed a desire to acquire the system from its private owner, and RCAP Solutions facilitated several steps in this process. The goal of the purchase was to give the community more control over the fate of its water system. As a publicly owned water system, BFD2 would be able to access federal funding sources for long overdue improvements.

THE CHALLENGE

Barnet Fire District #2 lacks adequate technical, managerial, and financial capacity to address the many challenges facing small water systems. Despite recent source water improvements, the system has struggled to maintain compliance with applicable Safe Drinking Water Act regulations, address distribution system deficiencies, or to build up reserves for future system improvements.

THE APPROACH & SOLUTION

In February of 2017, BFD2 completed a major source water improvement project. This should have marked an important milestone for the community, as they were able to lift the decades old boil water advisory following the improvements and installation of a new disinfection process. It was not the end of their infrastructure concerns, however; frequent distribution system failures were crippling the system's operating budget. To address issues in the distribution system, RCAP Solutions provided an action plan to the board, which included the recommendation to apply for a planning grant to prioritize water main replacement – including the replacement of a critical, aging water main crossing a river in the village. In addition to securing a planning grant, however, the board would need to gain the support and trust of the community for any new projects. For a system the size of BFD2, taking on more debt – which requires community support - will be a likely scenario considering their lack of reserves and mounting infrastructure concerns. For the system's board, it was more important than ever that they build on the achievements of the source water improvement project. Unfortunately, operational issues with the new chlorination system, coupled with the lack of local capacity for diagnosing and resolving those issues, contributed to a violation in late 2017 for failing to maintain adequate microbial treatment. After becoming aware of the treatment violation and continued problems with the chlorination system, RCAP Solutions responded after-hours to the treatment plant and spent the next day successfully re-establishing a chlorine residual in the system.

THE IMPACT

This action helped the system to avoid a second violation, which is critical; every violation or misstep for the board reduces the likelihood that they will be able to gain the community trust necessary for future improvements. In the weeks that followed, RCAP Solutions provided practical guidance to the system's operator and treatment plant engineer on how to improve the treatment system. RCAP Solutions has also helped community members to identify common issues with their plant equipment and to provide the system's board members with the knowledge they need to maintain compliance with state and federal regulations.

Overall, RCAP Solutions provided the board with a prioritized action plan, attended numerous board meetings to provide guidance on system operation, stressed the importance of community engagement, helped the system avoid additional treatment violations, and educated community members on treatment requirements to maintain compliance.

Revival from the Brink of Receivership

Location: Fire District #1, East Berkshire, VT
Population: 184 (63 connections)
Household Income: $56,964
Funder: USDA Technitrain 23
Author & Date: John Kiernan, 2023

Services:

- Budgeting and Rate Assistance
- Funding Applications
- Project Development - New Source
- Engineering Procurement

BACKGROUND

Approximately 50,000 Vermonters are served by Fire Districts, which are special independent units of government, with the same authority and responsibility as an incorporated town or village, primarily serving small water systems. Many Fire Districts are struggling throughout Vermont with significant technical, managerial, and financial challenges. The East Berkshire Fire District No. 1 is no exception; USDA considers the District a “troubled asset”, at risk of defaulting on their debts and falling into receivership without technical assistance.

THE CHALLENGE

A recent construction project involved a significant capital investment in distribution system infrastructure without addressing the lack of water source capacity. As a result, customer rates increased from $300 to over $1,000 per year, and the system's spring sources still periodically dry up requiring conservation and boil water notices, leaving the customers frustrated. In addition, the Prudential Committee had full turnover of all Board members since the completion of construction, with no continuity and leaving the new Board overwhelmed with significant financial issues, primarily a significant increase in unanticipated operating costs due to the supply shortages, coupled with an increasing number of delinquent customers refusing to pay their water bills.

THE APPROACH & SOLUTION

RCAP assisted the District by developing a prioritized list of actions for the Board to focus on, with a breakdown that included an opinion of the costs, anticipated duration/schedules, and potential funding sources for each action. RCAP is now supporting the District with implementation – by assisting with 1) selection of an engineering consultant to resolve the technical issues, 2) preparation of applications for approximately $700,000 in grant funds from various sources to help resolve issues without incurring additional debt, and 3) development of a financial plan to reconcile their overdue accounts payable to vendors and funding agencies. This help has given the Board some traction to visualize a transition to a system that will build reserves for emergencies and ongoing maintenance.

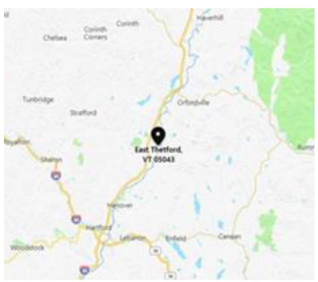
"RCAP has helped us get back on track, providing guidance with many aspects of water system planning and management. We view RCAP as a trusted advisor."

- **Andy Hoadley, Prudential Committee Chair**

THE IMPACT

Since RCAP engaged with the community, the District has communicated with the funding agencies and have made progress in making past due debt payments. With help from the Vermont Department of Environmental Conservation, efforts have begun to identify potential well sites for a supplemental source. In conversations with customers and the system's operator, two major leaks were found and corrected to help reduce or alleviate the need for bulk water hauling this summer. The system still has a long road ahead, but RCAP has provided the tools and helped the Board and interested parties see there is a path to sustainability for the system.

A Timely Solution to a Public Health Threat



Location: East Thetford, VT
Population: 250
Household Income: $50,000
Region: RCAP Solutions, Inc.
Funder: USDA Technitrain 19-20
Author & Date: Mark Johnson, 2020
Services:

- Facilities Development,
- Financial Management

BACKGROUND

East Thetford Water Company provides drinking water to a village in the Connecticut River Valley of rural Vermont. In 2019, the village experienced an emergency water shortage after their primary well failed. RCAP worked with the volunteer water board to ensure they obtained financing for a replacement well.

THE CHALLENGE

East Thetford Water Company found themselves without a reliable source of water when their primary well suddenly stopped producing enough water to serve their 42 connections. Businesses and homes in the village were severely impacted.

THE APPROACH & SOLUTION

The system operator temporarily gained control of the situation by activating an emergency spring and repairing a leak in the system. With the help of the state's primacy agency, an engineer, and RCAP, system managers were able to navigate a boil water order, identify potential long-term solutions, and document income in the community to ensure that a more permanent solution could be found. Due to the small size of the village, documenting income proved to be a significant hurdle; regulations require a response rate of 90% to achieve a valid survey. As with any critical infrastructure effort, community outreach can make the difference between a successful project and a frustrating roadblock. RCAP's efforts to educate the community about the project ensured successful completion of the income survey to secure critical funding.

THE IMPACT

Less than a year after running dry, residents and business owners in the village are relieved to have a new bedrock well to rely on. RCAP helped the system achieve a timely solution to a problem that threatened public health. Without an income survey, the Median Household Income (MHI) for ETWC would have used the 2017 American Census for the entire town (~$70k). With the survey, we showed the service area of ETWC to be $50k. This is significant because it moves ETWC into the disadvantaged category for the State Revolving Fund (DWSRF) loan program (with the survey, now ETWC comes in under the statewide MHI of about $57k). ETWC should now be eligible for up to 50% forgiveness of the anticipated loan value, 30-year financing instead of 20-year, and a reduction in fees.

Finding Wastewater Solutions in a Vermont Village

Location: Grafton, VT
Population: 650
Median Household Income: $51,667
Region: RCAP Solutions, Inc.
Funder: USDA Technitrain 20-21
Author & Date: Mark Johnson, 2022
Services: WW Facilities Development

BACKGROUND

Grafton is one of 170 villages without a public water or wastewater system in the state of Vermont. As septic systems and drinking water wells continue to approach - or go beyond - their life expectancies, the village is facing the reality that there is little space to add new septic systems or to drill new wells. This limitation impacts economic growth within the village, creates a public health issue and threatens the environment.

THE CHALLENGE

RCAP became involved with Grafton through Vermont's Village Wastewater Solutions Initiative, an interagency committee consisting of regulators, funders and nonprofits that have come together to address challenges facing villages without sewers. A Wastewater Study Commission consisting of volunteers had been formed in Grafton, but their work was stymied by a lack of understanding of available resources and how to map possible solutions.

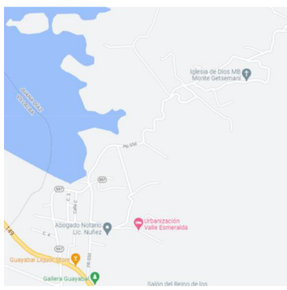
THE APPROACH & SOLUTION

RCAP's initial assistance included a review of past water and wastewater engineering studies and the development of a plan for community education and engagement. RCAP acquired water sampling kits through a partnership with the Dept. of Health, and with the Commission, held a village-wide well testing event to determine whether failed septic systems were impacting private drinking water sources. We surveyed the community on important water and wastewater issues, achieving a 94% response rate and beginning an important conversation about the future of the village. Results were compiled into a report by RCAP and presented at several public meetings.

THE IMPACT

In 2021, a major milestone was achieved toward finding a wastewater solution when RCAP helped the Commission access funds for an updated engineering study. After working with the Commission to help them understand the qualifications-based selection process, the Town has hired an engineer and is in the process of identifying decentralized wastewater options that could help guide future growth and community revitalization efforts.

"Wepa! Foundation" Reduces Waste Stream



Location: Lajitas, Juana Diaz, PR
Population: 1,651
Low-Income population: 1,209
Household Income: $13,531
Funding: PR, Solid Waste - USDA
Author: Edwin Vazquez-Asencio, 2022
Services:

- Sustainable Materials Management Specialist
- SW Technical Assistance

BACKGROUND

Lajitas is a small sector in Barrio Guayabal, Juana Diaz, Puerto Rico. The community has been suffering due to littering and illegal dumping. The basketball court surroundings were used for dumping and the areas alongside the PR-550 were severely impacted by littering and improper management of solid waste.

THE CHALLENGE

"Without your help, I don't know how Barrio Guayabal would be able to address many of its problems."
Vanessa Perez-Pacheco, Fundación Wepa!

The community is near the Guayabal Water Reservoir and the edges of the lake have fallen victim to the waste from the Jacaguas river. Illegal dumping and litter have been overwhelming.

THE APPROACH & SOLUTION

The community called RCAP TAP looking for technical assistance. The leaders were taught about the importance of a community organization and the opportunities to empower their members in order to implement coordinated actions with the municipality to ultimately address the situation. The TAP helped them create a community organization that established a connection between the municipality and the community. They started to create activities and formalized the new community entity as “Fundación Wepa!”

THE IMPACT

Today they are implementing solutions and the areas are in recovery. They performed small cleanups, saved the basketball court, adopted a segment of the road, built a Neighborhood Cluster Mailboxes in a recovered area. We are now looking forward to participating in the municipal recycling program. Community participation has been increasing and the communication among them is better every day. There are still challenges to overcome, but RCAP will be providing a series of trainings about a number of useful topics like reduce, reuse, repurpose, recycling, composting and pfas. This community is empowered and RCAP is leading them to sustainable solutions.

Jennifer (Jenna) Day, Director of Development, at RCAP Solutions is located in rural Western Massachusetts and has been with RCAP Solutions since 2018. With over two decades of working in community and economic development, she brings with her a diverse skill set that includes building individual and community capacity and supporting the progress and sustainability of rural communities. Her experience as Town Coordinator in Heath, Massachusetts, as Director of the Housing Consumer Education Center at the Franklin County Regional Housing and Redevelopment Authority, and her tenure on the local Heath Board of Health provides critical technical, financial, and managerial expertise including extensive project management and contract compliance experience. Ms. Day's expertise also includes operating a non-transient, non-community water system. Before her promotion to Director of Development, she was the Director of Community and Environmental Resources responsible for grants and contract compliance for a team of 30 Technical Assistance Provider serving rural communities in New England, New Jersey, New York, Puerto Rico, and the U.S. Virgin Islands. She also served as a Community Specialist for New England. She has a degree in Environmental Education from Goddard College, Plainfield VT.

Testimony of Joseph Duncan, PE
General Manager, Champlain Water District
and
President, Green Mountain Water Environment Association

United States Senate Committee on Agriculture, Nutrition, and Forestry
Subcommittee on Rural Development and Energy
"Rural Water: Modernizing our Community Water Systems"
328A Russell Senate Office Building

July 19, 2023

Introduction

Chair Welch, Ranking Member Tuberville, and members of the Committee, thank you for the opportunity to testify today. On behalf of the Green Mountain Water Environment Association (GMWEA), our water resource professionals, and the communities we serve, we are grateful for the opportunity to share our perspective and we thank the Committee for their keen interest in the issues facing rural communities across the country.

My name is Joe Duncan, and I am the General Manager at the Champlain Water District (CWD), a regional municipal organization supplying drinking water to (12) municipal water systems in (9) communities in northwestern Vermont. CWD is an award-winning regional water supplier having the distinction of receiving the first in the Nation "Excellence in Water Treatment Award" from the Partnership for Safe Water. Prior to joining CWD, I worked for 18 years as a consulting engineer on municipal water resource projects throughout the great state of Vermont.

I am also currently the President of GMWEA, a nonprofit membership organization that supports Vermont's drinking water, wastewater, and storm water sectors - serving water quality professionals, preserving the environment, and protecting public health through technical trainings, public education, and policy advisories. We are the people that design, construct, and maintain the infrastructure necessary to keep the taps running, toilets flushing, and stormwater runoff pollutant free. Our members help keep Vermont's surface and ground waters clean, safe, and beautiful to serve our water use needs, recreation, and precious ecosystems.

I have served in the water resources sector in Vermont for over 25 years from working with very small water systems as a consultant to providing wholesale water with CWD to 83,000 people in Chittenden County to volunteering my time at GMWEA with fellow water professionals to promote and support the industry. My background and experience have given me great insight into what it takes to operate and maintain water and wastewater systems throughout the small and rural state of Vermont.

As of 2023, Vermont's drinking water assets included approximately 1,343 active public water systems serving 59% of the state's 647,000 residents. Most water systems in Vermont are not expanding in size or demand and their aging infrastructure needs to be replaced. A 2021 University of North Carolina study found the median water utility in Vermont collects operating revenue of $296,000, which barely funds its $284,000 annual expenses – before counting capital projects. Under the American Rescue Plan Act (ARPA), the Vermont Agency of Natural Resources allocated about $100 million to a variety of water quality initiatives with most of this money designated for new projects rather than upgrading existing infrastructure. The State of Vermont expects to receive $355 million in drinking water funding over five years from the 2021 Bipartisan Infrastructure Law (BIL) – compared to a $374 million funding need primarily consisting of projects focused on aging infrastructure. The majority of the BIL funds are allocated to address emerging contaminants and lead service line replacements. While the ARPA and BIL funding are significant they do not provide the funding required to address our aging drinking water infrastructure. Unfortunately, Vermont's wastewater systems are in the same position.

Vermont's water and wastewater aging infrastructure requires significant investment, and all funding programs are of extreme value to our systems. Being a rural state, Vermont benefits greatly from the United States Department of Agriculture (USDA) Rural Development (RD) Water and Environmental Programs (WEP). This is one of the few programs our small systems can access that provides long-term, low-interest loans with the possibility of a grant to keep user rates affordable. Our rural systems have a fear that Congress will assume that ARPA and BIL will provide the funding necessary to address Vermont's aging infrastructure and not fund the USDA RD WEP in the next Farm Bill.

As the Committee considers the upcoming Farm Bill, there are a few key points we respectfully request you consider as you work to reauthorize USDA RD programs:

- **Funding for the USDA RD WEP** in the Farm Bill at a significant level is necessary for rural systems because ARPA and BIL do not scratch the surface of what is needed to address aging infrastructure.
- **Circuit Riders** are critical in helping rural systems manage and operate their utilities and funding that program is vital to them.
- **Integrating Asset Management with Resilience & Adaptation** is the path to a sustainable water future and USDA RD needs to require it, and fund it, for any infrastructure constructed under the WEP.
- **Workforce Development** is required to address the critical need for skilled workers in our rural systems and we recommend including financial resources and policy for that in the next Farm Bill.
- **Modernization of RD WEP** is necessary to better address current needs with additional affordable financing and servicing options.

Funding for the USDA RD WEP

Ensuring sustainable and affordable water and wastewater service to customers is the primary shared mission of our systems and RD. Many of our small and rural systems operate on a thin margin, meaning only 1.5% to 2.0% revenue over expenses. Maintaining this margin has become difficult over the past few years as they have absorbed inflationary costs associated with supplies such as piping increasing by 230% and chemicals like chlorine increasing at least 95%. Rural communities must have the ability to modernize their water and wastewater infrastructure, much of which is approaching or past its useful life. The continued operation of these systems is essential, especially since 91% of the country's drinking water systems serve communities with fewer than 10,000 persons. In Vermont, that percentage is even larger, with 99.5% of our water systems serving populations under 10,000 and 92.7% serving under 1,000.

The importance of low-cost loans and grant funding under the USDA RD WEP for small rural systems cannot be overstated. Through the USDA RD WEP water systems across the country obtain financing for important infrastructure projects of all sizes. It is critical that our rural systems know that USDA RD WEP will continue to be a trusted lender for our critical water and wastewater improvements.

As previously mentioned, there is a fear that Congress will assume that ARPA and BIL will provide the funding necessary to address Vermont's aging infrastructure and not fund the USDA RD WEP in the next Farm Bill. Given the majority of the BIL funds have been allocated to address emerging contaminants and lead service line replacements, there is not the ability to significantly address our aging infrastructure needs. Over the next 10 years, Vermont municipalities, ratepayers and property owners will face costs exceeding $1 billion to upgrade our aged wastewater, drinking water, and stormwater systems. And over the next five years, the Vermont drinking water sector will require $374M to address our immediate aging infrastructure challenges. About $182M (51.3%) of the $355M BIL funding to be received in Vermont over the next five years has been allocated to emerging contaminants and lead service line replacements. This leaves a major funding gap for addressing aging infrastructure in our State.

There is also concern that funding levels for the USDA RD WEP will continue at pre-COVID allocations. The worry lies not only in the funding gap but also in the significant increases in construction costs. Inflation over the past few years, combined with supply chain issues, a limited workforce, and contractor pool (especially in rural areas), have significantly driven up construction costs. Funding of the USDA RD WEP at pre-COVID allocations will limit the number of projects that can be built to address our aging infrastructure needs and continue to move our water and wastewater systems in the wrong direction.

One of the major challenges for rural water systems in utilizing available construction funding is the lack of a plan for what is needed. Most small water systems know they need to do something, but they just do not know how to move it forward both financially and technically. The USDA WEP does offer planning funds, but they are in the form of loans. Providing grant funding specifically for planning can play a key role in advancing projects. We recommend that the Committee consider specifically allocating planning grant funding under the USDA WEP.

Lastly, we support providing additional funding to increase staffing for the USDA RD WEP. For our region, a staff of 12 USDA RD employees administer funding for both Vermont and New Hampshire. They work to deliver a $750 million portfolio that includes improvements across a multitude of sectors (i.e., water/wastewater, hospitals, energy, and Town Halls). The USDA RD engineer we work with on water projects in Vermont is also managing projects across two States for a wide variety of projects. That person does an excellent job but is spread very thin given the scale of work being administered.

Circuit Riders

One of the most successful approaches for overcoming past and current challenges in rural America has been the "Circuit Rider" program, which was created by this Committee. This program provides a nationwide pool of experienced hands-on water experts to provide peer-to-peer direct assistance to help rural systems manage and operate their utility. Circuit Riders are rural America's boots on the ground for troubleshooting issues and solving problems at water systems.

I have witnessed that firsthand in Vermont, with our Circuit Riders providing the training, certification, financial management, environmental compliance, governance, and on-site technical assistance necessary to ensure that water facilities operate at the highest level possible. This assistance actually saves money and protects the community and the government's investments by ensuring efficient and sustainable practices are followed. This training and education empower operators, board members, elected officials, and communities with the support and knowledge they need to understand every aspect of their water system and facilities. Many of these communities lack the staff, capacity, funding, or expertise to address technical water and wastewater issues. The mission of the program is to restore and improve the public health, environment, and sustainability of these small communities or in other words to give them a level playing field with our urban counterparts so rural Americans can live the lives they want. We respectfully ask this Committee to reauthorize this program.

Integrating Asset Management with Resilience & Adaptation

Much of Vermont's rural water infrastructure was originally constructed or upgraded in the 1970s with the passage of the Safe Drinking Water Act. At that time, significant grant sources were used to fund the improvements. The grants helped to keep rates low while constructing the improvements necessary to provide safe drinking water. Unfortunately, since that time most communities have implemented a "run to failure" model by not maintaining and investing in the original water systems. This has not only resulted in failed infrastructure, but unsustainably low user rates as well. Instead of increasing water rates to account for necessary operation and maintenance (O&M) and capital costs, water systems have historically flat lined them thinking it was in the best interest of the users.

We have reached a point where this "run to failure" approach is not sustainable. To make matters worse, the country is experiencing extreme weather patterns that affect our water systems. The impacts range from severe heat drying up source waters to heavy wind and rain events damaging water infrastructure, as well as the energy sources that power those facilities. America's water systems need to develop more resilient infrastructure and adapt to extreme weather patterns. To change the historical practice away from "run to failure" we recommend that any projects funded through USDA RD WEP include an asset management program integrated with resilience and adaptation implementation measures.

Asset Management programs use asset inventories, life-cycle cost analyses, risk assessments, and financial planning to set priorities and help meet level of service goals in a cost-effective manner. Asset management is a way of thinking – of seeing the infrastructure world from an asset-centered perspective as opposed to operations centered. It allows utilities to direct limited resources to where they are most needed, and it is the basis for both short- and long-term investment planning and rate setting – as well as for building public support for these decisions. To effectively manage water infrastructure, utilities must answer the question: Is it the right work and the right investment at the right time and for the right reason? The more utilities understand about their assets – the demand, the condition and remaining useful life, the risk and consequence of failure, the feasible renewal options (repair, refurbish, replace), and the cost of these options – the higher the confidence there is in investment decisions.

Having a clear understanding of risks associated with extreme weather events is critical for identifying potential long-term adaptation options for decision-making related to implementation and infrastructure financing. Combining an asset management program with an understanding of what is needed for long-term resilience and adaptation is the start down a path of sustainable water infrastructure. Funding and policy through the USDA RD WEP for integrating Asset Management with Resilience & Adaptation is recommended.

Workforce Development

Today, attracting and retaining capable, licensed water and wastewater system operators is the biggest challenge facing the rural water industry in Vermont and across the nation. First, water and wastewater operator salaries have not kept pace with their responsibilities in complying with the ever-changing governmental regulatory requirements. Second, modern water systems have state-of-the-art SCADA control systems, complicated variable-frequency drive electrical motors, and computerized control valves. This requires operators to have strong technical skills and the mental capability to pass the required training to receive a waterworks license.

It is even more concerning for smaller water systems that have financial limitations that make competing for employees even more challenging. Employment data indicates up to 50% of this workforce will leave the water industry within the next 10 years. Rural water and wastewater utility owners and operators need a pipeline of skilled workers to help ensure clean and safe water for the public and to maintain the water infrastructure necessary to keep rural service areas economically viable.

The vast majority of the country's small community water systems have extremely limited staff, sometimes only employing one part-time or one full-time paid operator. Unfortunately, the limited economies of scale and technical expertise in rural water utilities are compounded by the scarcity of qualified operators. This challenge increases the difficulty small and rural communities have complying with complicated federal mandates and providing safe/affordable drinking water and sanitation.

We suggest financial resources and policy be included in the 2023 Farm Bill to provide mentorship and training to address these workforce challenges specific to USDA RD borrowers and potential borrowers. A long-term solution is critically needed to enhance water workforce participation and retention in small and rural communities, protect the significant federal investment in rural America's water and wastewater systems, and improve these vital services and basic civic necessities on which our customers depend.

Modernization of RD WEP

USDA RD is the only federal agency created by Congress specifically to serve rural communities. The sole focus of the WEP is to serve communities under 10,000 population. These rural systems operate on small margins of revenue over expenses, coupled with a lack of economies of scale, increasing the challenges to provide affordable rates for lower-income residents. It is recommended that the USDA WEP be modernized to better address current needs with additional affordable financial and servicing options. New affordable financing options should include the ability for USDA RD to offer zero and one percent loans to disadvantaged or economically distressed communities. This should be a limited authority targeted to lower-income communities to ensure affordable water and wastewater services to those residents. Regarding the servicing options, USDA RD should be provided with the ability to financially stabilize a current borrower within communities where their customers have been suffering an economic downturn at no fault of their own.

One of the challenges we face in Vermont is getting small rural water systems to utilize USDA RD WEP funding due to the timing for confirmation of funding. A positive bond vote by the municipality is required to get approved and locked in on a funding package through the USDA RD WEP. USDA RD provides an estimate of the potential loan and grant funding, but it is not guaranteed. As a result, the bond vote language presented to the voters typically includes the total project cost and states the final cost to the users will be subject to reductions in grants and aid. With other funding sources like the DWSRF, the municipalities speak confidently during the bond vote informational hearings about the specific funding package they will receive because there is a priority list and bypass process. During bond votes with USDA RD funding the municipalities need to say this is the funding package we hope to get as there is no certainty that the funding will be available since monies are allocated on a first come first served basis. I have been involved in many projects across Vermont that have failed bond votes due to the public's skepticism for receiving the potential USDA RD WEP funding package. The ability to temporarily lock in funding with a bypass process is recommended to provide more certainty to municipalities when pursuing USDA RD WEP funding.

Conclusion

In closing, the USDA RD Development Loan and Grant funding for water and wastewater systems is critical in addressing critical infrastructure needs in many communities in rural and small-town America, while helping to maintain affordable user rates. Despite the recent ARPA and BIL funding, the demand for water and wastewater infrastructure funding in our rural communities remains high. The direct technical assistance from USDA RD and the Circuit Rider program provides the capacity and experience to protect both the federal government's investment and the communities' mission to provide safe, sustainable, and affordable water and wastewater service. USDA RD plays a critical role in creating a sustainable water future for our rural water and wastewater systems and we support any efforts by the Committee to strengthen that role.

As the Committee considers the upcoming Farm Bill, we look forward to working together in our shared goal of providing safe drinking water and sanitary waste disposal, which is vital to public health and the economic vitality of rural America.

Thank you for the opportunity to participate. I am happy to answer any questions you may have.

Testimony of Catherine Coleman Flowers
To the Senate Committee on Agriculture, Nutrition, and Forestry
Subcommittee on Rural Development and Energy
July 19, 2023

Thank you, Chairperson Welch, Ranking Member Tuberville, and all the members of the Subcommittee for the opportunity to testify. My name is Catherine Coleman Flowers. I serve as the founding director of the Center for Rural Enterprise and Environmental Justice in Huntsville, Alabama. I also serve as a practitioner in residence at Duke University, a member of the board of advisers for the Center for Earth Ethics at Union Theological Seminary, as well as the boards of the Natural Resource Defense Council, the Climate Reality Project, and the American Geophysical Union. In 2020 I was awarded a MacArthur Fellowship in Environmental Health, and I authored the book entitled *Waste: One Woman's Fight Against America's Dirty Secret*.

Rural Households Across America Lack Effective Sanitation

In my book I uncovered the extent to which rural America has been denied access to sustainable and resilient wastewater infrastructure. Too many people in this country lack safe, reliably functioning sanitation. According to the Census Bureau's American Housing Survey, 18 percent of all U.S. households – about 1 in 5 homes – are not able to send their sewage to be treated by a centralized wastewater system.[1] About 22 million households use a decentralized wastewater system such as a septic tank or cesspool, 180,000 households use rudimentary sewage disposal approaches like outhouses and chemical toilets, and 35,000 households have no form of wastewater treatment at all.[2]

For these families, wastewater treatment is unreliable at best and a health crisis at worst. Decentralized forms of wastewater treatment are more likely to break down and fail. This problem is acute in many regions of the country.

For example, my home of Lowndes County in Alabama's Black Belt is a rural area where homes must rely on on-site sanitation, yet the region's impermeable soil and rising water tables are not

[1] U.S. Environmental Protection Agency, Office of Water, *Report to Congress on the Prevalence Throughout the U.S. of Low- and Moderate-Income Households Without Access to a Treatment Works and the Use by States of Assistance Under Section 603(c)(12) of the Federal Water Pollution Control Act* (July 2021), 4, https://www.epa.gov/system/files/documents/2022-01/low-mod-income-without-treatment_report-to-congress.pdf.
[2] *Id.* at 6, Table 2.

suitable for conventional septic systems.[3] Treatment systems that are engineered to function in low permeable soils are available, but they are expensive.[4] They also involve mechanical technologies with components that eventually wear down or malfunction, requiring costly repairs. As a result, many of our region's residents are simply unable to afford any functioning means of waste treatment. It is all too common for homes to have either malfunctioning septic systems that cause human waste to back up into dwellings or "straight pipes" discharging untreated waste into their yards. When the Administrator of the Environmental Protection Agency (EPA), Michael Regan, visited this area in March 2022, he called the situation "unacceptable."[5]

Wastewater treatment failures have also been a problem in other regions such as Hawaii, where 88,000 aging cesspools are leaking 53 million gallons of untreated waste into streams, oceans, and drinking water every day, leading to contamination and illness.[6] Centreville, Illinois and Mount Vernon, New York have been facing their own well-publicized struggles with sanitation as well. Across Appalachia, wastewater-contaminated streams flow past people's homes.[7] In Puerto Rico, communities struggle to rebuild wastewater and septic systems damaged by hurricanes.[8] Colonias and Tribal nations in the Southwest disproportionately lack indoor plumbing.[9] Sanitation systems are absent or failing in small, rural communities from California's Central Valley to Native Villages in Alaska.

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[3] Jiajie He et al., *Assessing the Status of Onsite Wastewater Treatment Systems in the Alabama Black Belt Soil Area*, 28 Envt'l Engineering Sci. 693, 697-99 (2011), https://www.liebertpub.com/doi/10.1089/ees.2011.0047.

[4] *See* Maxwell Izenberg et al., *Nocturnal Convenience: The Problem of Securing Universal Sanitation Access in Alabama's Black Belt*, 6 Envt'l Justice 200, 202 (Dec. 2013), https://www.liebertpub.com/doi/10.1089/env.2013.0036.

[5] *See* Dennis Pillion, "'This Is Unacceptable: EPA Chief Visits Failing Sewage Systems in Alabama Black Belt," *AL.com*, Mar. 5, 2022, https://www.al.com/news/2022/03/this-is-unacceptable-epa-chief-visits-failing-sewage-systems-in-alabama-black-belt.html.

[6] Hawaii Department of Health, Cesspools in Hawai'i, https://health.hawaii.gov/wastewater/home/cesspools/.

[7] *See* University of North Carolina Environmental Finance Center and Appalachian Regional Commission, *Drinking Water and Wastewater Infrastructure in Appalachia* (2005), https://www.arc.gov/wp-content/uploads/2020/06/DrinkingWaterandWastewaterInfrastructure.pdf.

[8] *See* FEMA, "FEMA Approves More than $100 Million for Improvements to PRASA Sewer Systems," Mar. 10, 2022, https://www.fema.gov/press-release/20220310/fema-approves-more-100-million-improvements-prasa-sewer-systems (announcing grant funds to repair wastewater system damage that still had not been repaired five years after Hurricane Maria).

[9] Dig Deep & U.S. Water Alliance, *Closing the Water Access Gap in the United States* (2019), https://uswateralliance.org/sites/uswateralliance.org/files/publications/Closing%20the%20Water%20Access%20Gap%20in%20the%20United%20States_DIGITAL.pdf.

Climate change is making these problems worse across the country. Heavy precipitation events and extreme storms are growing more frequent, and our infrastructure is struggling to keep up. Higher temperatures increased heavy precipitation events, and sea level rise affect the performance of decentralized wastewater systems by reducing the volume of unsaturated soil and oxygen available for treatment, which may result in system failure.[10] This is prevalent in Florida. Moreover, the impacts of climate on our water systems are not limited to sanitation. Right now, in Vermont, towns across the state have lost access to safe drinking water due to intense flooding. Boil water and do not drink water notices have been issued due to water system failure, resident complaints about water quality, and pump control failure.[11]

Failing water and wastewater systems put communities' health at risk every day. Encountering unsafe water and untreated waste increases the risk of gastrointestinal illnesses, tropical diseases, antimicrobial resistance, anemia, miscarriage, and preterm births.[12] Untreated or inadequately treated sewage can contaminate the groundwater used for drinking water wells, creating an elevated risk of waterborne disease.[13]

These health risks cause serious economic harm. It is extremely difficult to attract businesses to a community that lacks adequate wastewater treatment.[14] More fundamentally, inadequate on-site sanitation degrades people's quality of life and takes a toll on mental health.[15] The smell from sewage on the ground can be a near-constant nuisance. Some residents dread the sound of rainfall because it means wastewater could start to back up in their homes. Others will not let children play in their yards because of the risk of exposure to human waste. These conditions

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[10] Jennifer A. Cooper at al., "Hell and High Water: Diminished Septic System Performance in Coastal Regions Due to Climate Change," PLoS ONE (2016), https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0162104.
[11] Vermont Agency of Natural Resources, Storm-Related Boil Water and Do Not Drink List, https://anrweb.vt.gov/DEC/DWGWP/license.aspx?Report=Boil.
[12] *E.g.*, George McGraw, *Draining: The Economic Impact of America's Hidden Water Crisis* (2022), 36, https://www.digdeep.org/draining; Global Communities, *Closing the U.S. Sanitation Equity Gap: Exploring Opportunities to Learn from the Global Sanitation Sector Experience* (Sept. 2021), 3, https://globalcommunities.org/wp-content/uploads/2022/01/GC_Tech_Brief_US_Sanitation_Equity_Landscape_Analysis_Final_Sept2021.pdf;
ACRE, *Flushed and Forgotten*, at 6; Megan L. McKenna et al., *Human Intestinal Parasite Burden and Poor Sanitation in Rural Alabama*, Am. J. of Tropical Medicine & Hygiene (Sept. 2017), https://pubmed.ncbi.nlm.nih.gov/29016326/.
[13] U.S. Environmental Protection Agency, Septic System Impacts on Water Sources, https://www.epa.gov/septic/septic-system-impacts-water-sources.
[14] *See* Alexis Okeowo, *The Heavy Toll of the Black Belt's Wastewater Crisis*, New Yorker (Nov. 30, 2020), https://www.newyorker.com/magazine/2020/11/30/the-heavy-toll-of-the-black-belts-wastewater-crisis.
[15] ACRE, *Flushed and Forgotten*, at 6.

undermine human dignity and cause deep psychological harm. It is a disgrace that entire communities have endured this injustice for decades.

Yet we must also recognize that these burdens are not borne equally by all kinds of communities. Low-income households are more likely than others to lack access to a centralized treatment system.[16] Nationwide, inadequate and failing sanitation systems disproportionately impact rural areas.[17] In 2019, one out of every eight homes of Native Americans and Alaska Natives lacked access to adequate sanitation.[18]

Data gaps make it difficult to understand the true extent of the problem and the people that it affects. The EPA has stated that existing information sources do not provide the data necessary to characterize the use of decentralized systems nationally, or to allow for estimates at the state and local levels.[19] For example, the American Housing Survey's methodology uses a small sample size that is not representative of regional variations, and it excludes Puerto Rico, where about 40 percent of homes are connected to substandard or failing septic systems.[20]

Despite these gaps, the EPA has recognized that rural, minority, and economically disadvantaged communities struggle to address these impacts of inadequate sanitation given their limited financial capacity.[21]

We have the opportunity to right these wrongs. Our rural communities should not be left to their own devices as they struggle to cope with the lack of investment in sustainable infrastructure that goes back decades and is being exacerbated by the climate crisis. We can make America a

[16] EPA, *Report to Congress on the Prevalence Throughout the U.S. of Low- and Moderate-Income Households Without Access to a Treatment Works*, at 4.
[17] Alabama Center for Rural Enterprise (ACRE) et al., *Flushed and Forgotten: Sanitation and Wastewater in Rural Communities in the United States* (May 2019), 18, https://www.humanrightscolumbia.org/sites/default/files/Flushed%20and%20Forgotten%20-%20FINAL%20%281%29.pdf; Dig Deep & U.S. Water Alliance, *Closing the Water Access Gap in the United States* (2019), https://uswateralliance.org/sites/uswateralliance.org/files/publications/Closing%20the%20Water%20Access%20Gap%20in%20the%20United%20States_DIGITAL.pdf.
[18] Indian Health Service, *Annual Report to the Congress of the United States on Sanitation Deficiency Levels for Indian Homes and Communities: Fiscal Year 2019*, 7, https://www.ihs.gov/sites/newsroom/themes/responsive2017/display_objects/documents/FY_2019_RTC_Sanitation_Deficiencies_Report.pdf.
[19] EPA, *Report to Congress on the Prevalence Throughout the U.S. of Low- and Moderate-Income Households Without Access to a Treatment Works*, at 5, 8.
[20] *Id.* at 5, 11-12.
[21] U.S. Environmental Protection Agency, *Financing Decentralized Wastewater Treatment Systems: Pathways to Success with the Clean Water State Revolving Fund Program* (January 2022), 4, https://www.epa.gov/system/files/documents/2022-02/financing-dwts.pdf.

model of ingenuity where we have clean water, safe sanitation, and resilient infrastructure for everyone.

Current Assistance for On-Site Sanitation Should be Expanded and Improved

The Farm Bill, which this Committee is in the process of developing for 2023, includes several USDA programs that can help provide people with affordable, reliable sanitation systems. One of those programs is the Rural Decentralized Water Systems Program.[22] This program helps low- and moderate-income households in rural areas finance the costs of household water wells and decentralized wastewater systems. Through the program, USDA distributes grants to nonprofit entities and Tribes to establish revolving funds that provide loans and sub-grants to households. Recipients may use the funds to construct, refurbish, rehabilitate, or replace individually owned water well systems and wastewater systems.

This program has the potential to make progress toward rural sanitation equity, but it is currently underfunded and not reaching the people who need assistance the most. Although it is currently authorized at $20 million per year, it received only $5 million in Fiscal Year 2023.[23]Significantly more funding is needed given the scope of the rural sanitation equity and justice problem across the country.

Senators Booker and Capito have introduced S. 1233, a bill to reauthorize the program and make it work better (the Rural Decentralized Water Systems Reauthorization Act.[24] This bill is a welcome first step toward addressing critical rural sanitation needs across America, providing increased funding, higher income eligibility for loans, and recognition of the legitimate need for warranties on sanitation systems. S. 1233 should be included in this year's Farm Bill with several key improvements. These are:

[22] Consolidated Farm and Rural Development Act § 306E; 7 C.F.R. Part 1776; U.S. Department of Agriculture, Rural Decentralized Water Systems Grant Program, https://www.rd.usda.gov/programs-services/water-environmental-programs/rural-decentralized-water-systems-grant-program.
[23] FY 23 Omnibus Bill Explanatory Statement: Division A – Agriculture, 37, https://www.appropriations.senate.gov/imo/media/doc/Division%20A%20-%20Agriculture%20Statement%20FY23.pdf.
[24] S. 1233, A bill to amend the Consolidated Farm and Rural Development Act to modify provisions relating to rural decentralized water systems grants, https://www.congress.gov/bill/118th-congress/senate-bill/1233.

1. Considering the significant unmet needs for working sanitation across the country, Congress should increase the program's annual authorization level to $25 million in Fiscal Year 2024, and $50 million in each of the following years.

2. While the bill allows funds to be used to cover the cost of decentralized wastewater system warranties of at least 5 years, Congress should go further. When advanced treatment systems fail, manufacturers, contractors, and government entities can blame residents for failures, absolving those who supplied and installed the system of all responsibility. Creating an adequate and fair system of accountability through a warranty requirement is vital to ensure working sanitation for participating households. Congress should require that all sanitation systems funded through this program carry a manufacturers and installers' warranty for a minimum of 10 years. It is critical that systems installed in peoples' homes – often in remote locations – be reliable.

3. While S. 1233 would increase the household income eligibility for loans from this program to 100% of median household income (up from 60% in current law), Congress should also consider increasing the income eligibility threshold to at least 80% for grants as well. Families earning 80% of median household income are still struggling and may be unable to take on the repayment responsibility of a new loan.[25]

4. The bill raises the dollar limit on grants and loans made through the program from $15,000 to $20,000 each. However, in many locations this is not enough to support the infrastructure required for public health and safety. In common contexts across the country, where tight soils, rising water tables, and other environmental challenges preclude the use of conventional septic tanks, more costly on-site treatment systems are needed to provide effective sanitation. These necessary engineered systems can cost up to $50,000.[26] Congress should raise the dollar limit for sanitation systems to $35,000 for sites where soil or water conditions rule out the installation of conventional septic systems.

Further Efforts Needed to Achieve Sanitation Equity

[25] *See* Rural Health Information Hub, Median Household Income, 2021 – Alabama, https://www.ruralhealthinfo.org/charts/58?state=AL, showing that the 2021 median non-metropolitan household income in Alabama was $46,000. 80% of this income level would be $36,800, an income leaving little for repayment of an interest-bearing loan for a new sanitation system.
[26] *See* PremierTech, How Much Does an Ecoflo Septic System Cost?, https://www.premiertechaqua.com/en-us/wastewater/ecoflo-septic-system-cost.

In addition to the expansion and improvement of this small USDA program, the lack of effective sanitation is such a wide-spread and persistent problem for millions of Americans that a wider response is necessary. We need new information, new strategies, and new technology to fully make this essential service a reality for all households, including the most economically challenged.

To secure better information to support sanitation solutions, Congress should consider directing the USDA to compile and regularly update the status of sanitation at unsewered households nationwide. In most states, there is no central recordkeeping of the presence and effectiveness of on-site sanitation systems. USDA compiles data on an enormous range of topics of importance to Rural America. The Indian Health Service compiles such information concerning tribal communities in an annual report to Congress.[27] A truly nationwide census and condition assessment of residential on-site sanitation, with regular updates, would be a huge step forward in the search for solutions.

Secondly, where unsewered households can be served by an extension of municipal sewers, we need new strategies to overcome the barriers that have blocked their access. The Rural Utilities Service should prioritize wastewater projects that extend sewer service primarily to low- and moderate-income households with failing or non-existent on-site systems. While such projects may be expensive, effective on-site systems can also be expensive, and the cost and indignity of a household without effective sanitation is the most expensive option of all. A set-aside within the Water and Waste Disposal Loans and Grants program, like the Section 306C program directing assistance to Colonias, Tribal lands, and Alaska native communities, could serve this purpose.

Third, Congress should fund research into new or modified technologies that can provide more reliable and affordable on-site waste treatment. Colleges and universities with a demonstrated commitment to underserved rural areas, such as Historically Black Colleges and Universities, could be enlisted as research partners and project managers. Both EPA and USDA have extensive research programs on a wide range of topics and technologies, yet this most basic of human needs remains absent from the federal research portfolio. Ironically, I believe that NASA has done more research on this topic than either of these two major departments. Congress should remedy this oversight in the upcoming Farm Bill.

[27] Indian Health Service, Reports to Congress, https://www.ihs.gov/newsroom/reportstocongress/.

I thank you for this opportunity to speak before you today. It is an honor, and I look forward to continuing the conversation about environmental justice and functioning wastewater systems for all people.

Testimony to the
Subcommittee on Rural Development and Energy

Committee on Agriculture, Nutrition, and Forestry
United States Senate

Rural Water: Modernizing our Community Water Systems

Ms. Pauli Undesser
Chief Executive Officer
Water Quality Association and Water Quality Research Foundation

July 19, 2023

Introduction

Thank you, Chairman Welch, Ranking Member Tuberville, and members of the subcommittee, for the opportunity to testify on the importance of the U.S. Department of Agriculture's Rural Development (USDA-RD) programs and their impact in supporting economic development and public health improvements in communities across rural America, in part through investments in improved drinking water quality.

My name is Pauli Undesser, a water quality subject matter expert with decades of experience in the fields of chemistry, biochemistry, and toxicological risk management, as it relates to water treatment technologies, standards, codes, and regulations. I am testifying before the committee in my role as CEO of both the Water Quality Association (WQA) and the Water Quality Research Foundation (WQRF).

Founded in 1974, WQA is a not-for-profit association representing the residential, commercial, and industrial water treatment industry. WQA has more than 2,500 member companies around the globe, including over 1,800 companies in the U.S. Our membership is comprised of equipment manufacturers, suppliers, dealers, and distributors of water quality improvement products and services.

The association is dedicated to improving awareness and knowledge of water quality that enhances the quality of life through sustainable technologies and services. Our member companies manufacture, distribute, and sell third-party certified, cost-effective point-of-use (POU) and point-of-entry (POE) solutions that have been improving water quality for decades and are increasingly being relied upon to help remove or significantly reduce emerging contaminants such as PFAS, among others. POU devices, such as reverse osmosis, ultraviolet or carbon-based technologies, treat water at the point of consumption and are commonly referred to as water filters. These technologies provide a final barrier to the contaminants of concern before the water is consumed or used. POE systems, including water softeners, are whole-house treatment systems mainly designed to reduce contaminants in water intended for showering, washing dishes and clothes, brushing teeth, and flushing toilets.

WQA also serves as a trainer and educator to water treatment professionals, an ANAB-accredited certifier of water treatment products, a public resource, and the voice of the water quality improvement industry.

Through our Gold Seal Product Certification Program, WQA helps manufacturers ensure their products conform to national consensus safety and performance standards through independent laboratory testing, literature reviews, and material assessments.

We also provide education and training to thousands of professionals in the water treatment industry through our one-of-a-kind Professional Certification Program, which is designed to uphold the high standards of performance needed to assure customers have confidence in the people providing and servicing their treatment solutions.

WQA's research arm, the Water Quality Research Foundation (WQRF), is a not-for-profit foundation that advances the mission of water quality by sponsoring peer-reviewed academic studies and professional research. A universally recognized, independent scientific body, WQRF has funded millions of dollars in studies in partnership with universities and other organizations that have generated important and timely information on water quality for industry stakeholders, policymakers, regulators, and the general public.

Rural Drinking Water Challenges

Across the United States, communities face threats to their drinking water from various contaminants, including lead, arsenic, nitrates, volatile organic compounds (VOCs), PFOA, PFOS, hexavalent chromium-6, and others. Cumulative exposure to certain chemical contaminants in drinking water is known to elevate risks of adverse health effects, including various cancers. Further, exposure to waterborne microbes can cause immediate acute, chronic, and fatal effects. It is important for people to have potable water that is also palatable. At times, odor, taste, and other aesthetic issues can be so significant that it may prevent the ability for it to be consumed.[1]

Under the oversight of federal and state regulatory entities, public water systems monitor for these threats and treat water before it is distributed to points of consumption. However, more needs to be done to help these systems in rural communities and the residents they serve. According to the EPA's Safe Drinking Water Information System (SDWIS) data, between 2008 and 2018, 2720 small community water systems experienced at least one maximum contaminant level (MCL) violation, with a total of 31,127 MCL violations reported. Of those, 68% were very small systems providing water to less than five people, many of which were chronic violations.[2]

Moreover, nearly 23 million households are not served by a public water system and instead rely exclusively on groundwater delivered through private wells. This water is not subject to the same regulatory oversight and testing for contamination as water supplied by public water systems, and this can delay the identification of and response to these health threats. Households reliant on private wells are predominantly situated in rural areas, and for many, connection to a community water system is not geographically or economically feasible.

It is critical that this population is not left behind in the federal government's efforts to ensure safe, high-quality drinking water is available to all Americans, regardless of the community they live in. Congress, through the leadership of the Agriculture Committee, and in particular this subcommittee, should ensure that USDA is providing the resources and flexibility needed to address this issue and protect water quality for the millions of rural Americans. This should include third-party certified point-of-use (POU) and point-of-entry (POE) water treatment systems – cost-effective final barrier technologies that are already being utilized by many individuals, households, and businesses to improve their drinking water quality.

These solutions can also be beneficial for rural households that are already organized under a community water system. Community water systems serving small, rural communities tend to struggle with a unique set of drinking water challenges due to their smaller number of ratepayers

[1] https://pubmed.ncbi.nlm.nih.gov/33328368/
[2] https://www.researchgate.net/publication/368994706_Triple-bottom-line_approach_for_comparing_point-of-use_point-of-entry_to_centralized_water_treatment

relative to a system serving a larger town or city. This can lead to difficulties in building the staffing or funding capacity needed to make often costly, but necessary infrastructure investments to ensure the ongoing provision of safe drinking water. These challenges are only anticipated to grow as scientific knowledge of harmful emerging contaminants such as PFOA and PFOS progresses and regulatory compliance requirements for their remediation lead to increased costs.

Implementing POU and POE technologies may be a beneficial, cost-effective short- and long-term solution for households served by small systems struggling to build the capacity needed to remain in regulatory compliance. Research has shown that most POU and POE options can be installed much quicker than centralized system upgrades can be completed, providing risk reduction to communities in an expedited fashion. This does not factor in the approval processes for using POU and POE options in community systems, which can be hindered by state regulations. These remediation options can also offer additional long-term human health safeguards, often protecting against a broader range of contaminants, including emerging contaminants, than centralized upgrades.[3]

It is important to emphasize that Congress, the EPA, and the CDC have all recognized the value of POU and POE options. The 1996 amendments to the Safe Drinking Water Act (SDWA), explicitly allowed small public water systems to install these treatment devices for the purpose of achieving compliance with some of the MCLs established in the EPA's National Primary Drinking Water Regulations (NPDWRs). Furthermore, the EPA has found that the cost-saving nature of POU and POE devices may enable systems to provide more protection to their customers than they might otherwise be able to afford through centralized treatment.[4]

POU and POE solutions have also been shown to be beneficial options specifically for the remediation of lead and PFAS. According to the EPA, third-party certified POU and POE devices can provide effective and relatively inexpensive treatment barriers for PFAS removal in homes if a household's water system is designed well to meet factors, including source water characteristics and the concentration and type of PFAS found within water.[5] The CDC also acknowledges the use of these technologies to reduce exposure to lead and provides information about these systems for private well treatment.[6] [7]

As the public becomes more aware of health contaminants in their water supply, resources for testing and monitoring drinking water quality will be crucial. Especially for rural households, we need to bring more awareness and access to cost-effective testing and treatment technologies at the point of consumption.

USDA Rural Development's suite of Water and Environmental Programs has been incredibly successful in improving rural communities' access to high-quality drinking water service, but expanding this assistance will be essential in meeting growing challenges. Programs such as the

[3] https://pubmed.ncbi.nlm.nih.gov/33328368/
[4] https://www.epa.gov/dwreginfo/point-use-and-point-entry-treatment-devices
[5] https://www.epa.gov/sciencematters/epa-researchers-investigate-effectiveness-point-usepoint-entry-systems-remove-and
[6] https://www.epa.gov/system/files/documents/2021-07/epa-3ts-guidance-document-english.pdf
[7] https://www.cdc.gov/nceh/lead/prevention/sources/water.htm?CDC_AA_refVal=https%3A%2F%2Fwww

Rural Decentralized Water Systems Grant Program, have helped fund projects in these communities, but more needs to be done to educate residents on their water quality and the availability of funding under current programs. And by creating new program offerings, USDA and the committee can help ensure that there is sufficient flexibility for these communities to leverage all filtration technology options that may suit their remediation needs.

Assistance and Support

For the reasons outlined above, WQA strongly encourages the committee, in its crafting of the 2023 Farm Bill, to prioritize the implementation of POU and POE technologies as one of many tools to assist rural communities with the improvement of drinking water quality.

While the aforementioned USDA Rural Decentralized Water Systems Grant Program serves an important purpose in creating revolving loan funds to provide low interest loans to rural homeowners who need to construct or maintain their well or septic system, there are many people in rural communities who do not fall into this narrow category.

To fill this important gap, WQA is particularly supportive of *S. 806 - The Healthy Drinking Water Affordability Act* – also known as the Healthy H2O Act – and urges the committee to include this important legislation into the Farm Bill this year. This bipartisan, bicameral legislation recognizes the need to close the drinking water quality gap for rural Americans served by struggling small community water systems and private wells by directing resources toward testing and remediation solutions.

The bill would authorize funding to be appropriated for a USDA Rural Development program that would provide grants to conduct water quality testing for households and licensed child-care facilities, and, if deemed necessary based on the results of testing, fund the purchase, installation, and maintenance of POU or POE water treatment systems that remove or reduce health-based contaminants from drinking water. Treatment solutions funded through the program would be required to be third-party certified in alignment with NSF/ANSI standards for the given contaminant identified during testing.

This program would take a targeted approach, providing assistance only to low and moderate-income recipients within rural communities. This targeted approach will allow for households to be prioritized based on need of assistance and otherwise may not be able to afford the costs of adequate testing and treatment.

This legislation already has the support of members of both the House and Senate Agriculture Committees, and it is our hope that all members of this panel will join in supporting this bipartisan, commonsense solution.

Beyond the Healthy H2O Act, WQA is supportive of the 2023 Farm Bill including a Rural Development title that has the most robust practicable support for rural drinking water upgrades. RD's existing suite of Water and Environmental Programs, including grant and low-cost loan funding as well as technical assistance authorities, have proven effective in generating improved water quality outcomes in thousands of rural communities. This support should be expanded to meet a growing list of costs and challenges.

The availability of high-quality drinking water is a foundational building block needed to foster the growth of healthy, resilient, and prosperous communities, and without it, other key factors, such as economic development, are stymied. It is of the utmost importance for our rural communities to be afforded the same access to safe, reliable, and affordable water as their urban and suburban counterparts. Robust and flexible resources through USDA Rural Development, including access to treatment technologies at the point of consumption, are a fundamental component of this effort.

I thank the subcommittee for the opportunity to testify, and I look forward to fielding your questions.

Supplementary resources related to my testimony are included as addenda. These are as follows:

- **Addendum A:** The executive summary of a January 2019 study conducted by the University of Arizona titled – Cost Benefits of Point-of-Use Devices in Reduction of Health Risks from Drinking Water
- **Addendum B:** A June 2022 study conducted by Corona Environmental Consulting titled – Drinking Water Crises in the United States Phase 2: Predictive Modeling
- **Addendum C:** An April 2022 study conducted by the University of Massachusetts, Amherst, titled – Sustainability Comparison Study: Accessing Centralized Treatment Upgrades and POU/POE Treatment for Small System Compliance to the SDWA

Cost Benefits of Point-of-Use Devices in Reduction of Health Risks from Drinking Water

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3 January 2019

EXECUTIVE SUMMARY

Project scope

The goal of this project is to provide an assessment of the cost benefits of point-of-use (POU) water treatment at the tap in terms of protection from contaminants in drinking water. While POU water treatment benefits have been demonstrated, the cost benefit relationship has not been characterized previously. This study is novel in that a holistic approach was used to document individual and population benefits of single and multiple contaminant removal. Both chemical and microbial contaminants were considered.

Contamination risks exist in all water supplies no matter how well they are treated. This is because of treatment failures, post-treatment intrusion of microbes and chemicals, and regrowth of pathogenic organisms in the distribution system. The inability of treatment plants to remove all contaminants all of the time, require the use of a final POU treatment barrier to minimize exposure risks.

Risk of chemicals in water usually takes years or most of a lifetime to result in adverse effects. Municipal drinking water is typically regulated so that the level of cancer risk from a contaminant is less than one in a million per lifetime. Such rare events mean that the investment of lifetime POU costs to prevent an already small amount of illness must be considered in the routine cost benefit. However, occasionally accidental contamination of drinking water supplies occur, resulting in higher risk probabilities, such as with the recent lead contamination event in Flint, MI.

Exposure to waterborne microbes may cause acute, chronic or fatal effects, resulting in large associated costs. Unlike chemical risks, which usually take years or most of a lifetime of exposure to have an adverse effect, risk of illness from microorganisms are immediate. Thus, the benefit of a POU barrier is also immediate, ultimately resulting in greater benefits relative to POU investment costs. Since even one pathogen ingested is capable of causing disease, there is no level in water that is considered safe. Thus, the USEPA set the MCLG for pathogens in water at zero. To control waterborne disease pathogens in drinking water, the USEPA has set treatment standards to reduce the numbers of pathogens so the risk of infection is no greater than 1:10,000 per year.

Municipal water systems as well as unregulated private supplies are consistently linked to drinking water outbreaks. Even when water supplies meet regulatory standards and guidelines, additional POU treatment further reduces the risk of exposures and adverse outcomes since federal maximum contaminant levels (MCL) are based on acceptable risk limits and not elimination of risk.

Approach

Publically available data from various field water monitoring and treatment efficacy studies were used to determine risks of exposure pre- and post-POU treatment. Data was accessed from peer-reviewed literature and government or non-profit stakeholder websites, whenever possible. From these sources, optimal treatment and associated costs relative to target contaminants (arsenic, nitrates, lead, chromium, disinfection by-products, and microorganisms) and POU treatment technologies (reverse osmosis, activated carbon, UV treatment, adsorptive media, pour-through granular activated carbon pitcher filter, distillation, and ion exchange softeners) were examined. In addition, NSF/ANSI optimal contaminant efficacy requirements were evaluated.

Adverse health outcomes were also assessed from various publically available, peer-reviewed literature and government or non-profit stakeholder websites. Given that health outcomes vary based on population and regional variations, average risk values were considered in addition to 95% upper and lower confidence intervals.

Costs of POU devices were calculated from a number of sources in the public literature and are known to vary widely. Cost calculators are provided with this report so that the tools can be modified to reflect specific treatment and cost benefit analyses. For some contaminants (i.e., arsenic) calculating the cost benefit of a POU intervention included the cost of the POU (initial investment plus maintenance and unit replacement projections) compared to savings due to averted costs of disease burden. Costs per unit risk reduction were considered with a lifetime (70 years) POU investment and a 5 year replacement rate. For microbes, annual POU costs were averaged over a 5 year estimated product lifetime and compared with yearly associated health costs.

Costs and benefits were considered on both an individual and population level where appropriate and as permitted by theoretical estimates considering adverse outcome probabilities and evaluations of certain adverse outcomes (i.e., a 100% chance of occurrence).

Results

Arsenic. Individual and cumulative cost benefits were calculated for select chemical and microbial contaminants. Based on the available health information, the population savings related to POU usage and averted cancer due to arsenic totals $1.6B per year. The cost to implement a national POU intervention is estimated at $169.8B the first year. Thus, under water quality conditions that meet the USEPA arsenic MCL, it would not be cost-effective to supply a

POU device in every U.S. household for arsenic removal alone. However, for the individual who experiences the one in a million chance of cancer, preventing illness has the benefit of $36,388 for averting the costs of that cancer case.

Nitrate. Nitrate exposures leading to documented adverse health outcomes are extremely rare. Even though POU devices remove up to 95% of nitrates from tap water supplies, exposures in the most high risk group (i.e., infants less than 6 months old) rarely exceed acceptable risk standards or measurable health effects. Given low risk, there is little benefit to POU applications for nitrate risk reduction and costs outweigh any anticipated benefits.

Lead. There is no safe level of lead in drinking water and any exposure results in unacceptable risks. However, lead is a common water contaminant at low levels. Reduction of lead exposures is always beneficial to health but may not always be cost beneficial. In this study we examined data that relates lead levels in water to human illnesses and cognitive development impacts considering typical U.S. concentration scenarios and also levels reported in the Flint, MI outbreak, where a change in source water and treatment protocols resulted in a dramatic spike in lead exposures for the local community. Increased benefits of POU removal of lead relative to costs are dependent on initial water lead concentrations. In general, the economic breakeven points occur when the initial water lead concentrations are $\geq$37.4 µg/L. While more than 3% of the population is estimated to drink water that exceeds the lead action level of 15 µg/L, exceeding the breakeven cost concentration is considered rare. Recently, the breakeven point was exceeded for the community of Flint, MI. Cost associated with this case study approaches a lifetime economic loss of $269M or $2,695 per person. A community wide POU intervention for lead removal would have cost just $52M.

Little information is available relative to costs and benefits of POU water treatment for the many emerging contaminants identified in water. Chromium VI was evaluated for cost benefit reduction in this study. While the literature was reviewed and background and discussion presented, the lack of reported adverse health outcomes stemming from hexavalent chromium due to drinking water consumption in humans makes it difficult to calculate POU risk reductions or cost benefit. Cr^6 exposures are considered higher via the inhalation route, suggesting the need for future studies on POE/POU interventions targeting showerhead filtration.

Similar to arsenic, carcinogenic effects from disinfection by-products are rare in the U.S. population and occur over long periods of time. Researchers estimate THM exposure cancer risks to be 29 per million resulting in a total medical cost of $108.8M per year for the U.S. population. In this study we considered reported and NSF/ANSI certified POU removal efficacies for disinfection by-products in water. Cost per POU risk reduction was ≥$260M. With such small risks and associated POU benefits for THM removal, costs outweigh the benefits on a population level. On an individual level and assuming a certainty of cancer occurring, the savings related to POU usage and averted cancer (bladder and colorectal) due to disinfection by-products in water averages $197,284 per case compared to the individual's lifetime costs for a POU intervention at ≥ $7,644.

Microorganisms resulted in the greatest cost benefit in this study, considering gastrointestinal illnesses, chronic sequelae and mortality caused by drinking water contaminants. Risk assessment and epidemiological studies indicate that more than 9M cases of acute gastrointestinal illness, 618,047 sequelae cases, and 1,470 mortalities associated with drinking water occur annually. POU treatment is expected to reduce these outcomes by at least 35% and a single POU device may remove a variety of viruses, bacteria and protozoa from water, increasing the cost benefit. Thus, the highest cost-effectiveness is seen when the totality of disease burden (acute, chronic sequelae, and mortality) from all pathogens is considered, resulting in an overall cost per averted disease case of $3,784 annually. The commonality of waterborne disease makes it cost-effective to prevent such illness with the relatively low-cost purchase of a POU device ($380 per year per household).

Conclusions

Consideration of all contaminants listed in this study shows that POU device use in the U.S. is cost beneficial given the wide range of contaminants potentially present in drinking water. Much of the economic benefit is driven by reduction of microbial pathogen exposures. However, POU devices with the capability to remove multiple contaminants offer the greatest benefit.

Some of the data presented here may be an underestimation of risk and benefit since random events or unmonitored private water supplies- where high level exposures might occur unnoticed- are not always captured. Further, risk is non-linear throughout an individual's life. Therefore, the cost benefit from operating a POU device would be even greater for a household with young, immunocompromised, or elderly residents.

CORONA ENVIRONMENTAL CONSULTING

Drinking Water Crises in the United States Phase 2: Predictive Modeling

Final Report

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Overview

The Water Quality Research Foundation (WQRF) Drinking Water Crisis in the United States Phase 2 Predictive Modeling Study follows the Phase 1 effort to identify drinking water crisis which occurred in the United States between 2009-2019. The resulting Phase 1 data set includes nearly 250,000 qualified cases, defined by the following:

- The contamination event occurred between 2009-2019 in a public or private water supply
- The contaminant is known, or suspected, to cause adverse health effects (acute or chronic) in humans
- The contaminant could be federally regulated or unregulated
- The population served by the contaminated water supply was at least 100 people

The Phase 2 Predictive Modeling Study aims to meet the following objectives:

1. Collect and assess all available and relevant data to identify historical and current drinking water contamination events
2. Develop a qualitative model to describe likely future drinking water contamination events
3. Assess how POE and POU devices can be utilized to protect public health in the event of likely future drinking water contamination events

Methodology and Results

1: Review WQRF's Phase 1 Database

The Phase 1 Database (Wang & Chen 2020) includes two data sets, one for regulated contaminants and one for unregulated contaminants. The Phase 1 Regulated Contaminant data set includes data for the following:

- Health-based violations to the U.S. EPA's National Primary Drinking Water Regulations (NPDWR) for public water systems (PWSs) serving populations of 100 or greater that occurred between 2009 and 2019
    - Maximum contaminant level (MCL) or maximum residual disinfectant level (MRDL) violations
    - Treatment technique (TT) violations
    - Action level exceedances (ALE) for lead and copper
- Qualified cases from CDC's Waterborne Disease and Outbreak Reporting System (WBDOSS)
- Qualified cases from news/media occurrences

The Phase 1 unregulated contaminant data set includes data from EPA's Unregulated Contaminant Monitoring Rule (UCMR), including UCMR2, UCMR3, and UCMR4, as well as qualified cases from a news/media search.

Regulated Contaminants: Health-based NPDWR violations

The Phase 1 Regulated Contaminants data set includes NPDWR health-based violations for four violation categories, including MCL violations, MRDL violations, TT violations, and ALE occurrences. Table 1 provides a summary of the health-based violations by violation category, ordered by number of violations. The summary table and subsequent summary tables for health-based violation data include the number of violations, the duration of the violation in days, the number states with PWSs with violations, the number of PWS with violations, the total population served by the PWSs with violations, and the average of the median household incomes for populations served by the PWSs with violations as reported by the Phase 1 Regulated Contaminants data set. Note that some drinking water contaminants may not affect the entire population served by a PWS with a violation. For example, a PWS may have one well where a contaminant was found above the MCL (i.e., nitrate, arsenic, total coliform, etc.), and that well may only serve a portion of the PWS's distribution system. Another example is for disinfection byproducts (DBPs), which can continue to form within the distribution system when a disinfectant residual is present. As a result, only a portion of the distribution system may have occurrences of DBPs exceeding the MCL. Yet another example is lead and copper as lead and copper levels at a customer's tap can depend on service line materials and even in-home plumbing, as well as water quality. Lead and copper levels at a customer's tap vary from one home to the next.

There were approximately 76,000 MCL violations for DBPs, inorganic contaminants, organic contaminants, and radionuclides. MCL violations can be caused by a single sample result above the MCL or based on an average of several sample results above the MCL depending on the contaminant and violation type. These violations were widespread, occurring in all 50 states and the District of Columbia and in approximately 17,000 PWSs. MCL violations account for the greatest number of health-based violations compared to other violation categories. The ten contaminants that each account for more than 10,000 violations are summarized in Table 2, ordered by number of violations. While not included in the table, coliform bacteria violations under the Revised Total Coliform Rule (RTCR) accounted for 770 violations, which could be grouped together with the Coliform violations under the Total Coliform Rule (TCR) that account for the greatest number of MCL violations. The contaminants listed in table below are the highest priority for the predictive model based on MCL violations. Other contaminants not shown in Table 2 will still be considered for the predictive model.

Three disinfectant types, including chloramines, chlorine dioxide, and chlorine, led to a total of 83 MRDL violations. The MRDL violations are summarized in Table 3, ordered by number of violations. While maintaining a disinfectant residual in drinking water provided to consumers is critical to protect against pathogen growth, a MRDL violation identifies occurrences of disinfectant residuals exceeding the highest level allowed in drinking water. The MRDL violations occurred in only 42 PWSs located across 16 states and the District of Columbia. Compared to the other violation categories, MRDL violations account for the least number of health-based violations. These violations are specific to treatment through the application of disinfectants and are not a priority concern for the predictive model of drinking water crises.

There were almost 16,000 TT violations, which are a result of a failure in a required process intended to reduce the level of a contaminant in drinking water. TT violations occurred in all but one state as well as the District of Columbia and in over 6,000 PWSs. Table 4 summarizes the TT violations included in the Phase 1 Regulated Contaminants data set, ordered by number of violations. Overall, TT violations are widespread and have occurred in several thousands of PWSs. For the purposes of the predictive model, the TT violations can be used to understand the extent of drinking water issues that may be caused by operational, treatment, and/or managerial problems.

The Lead and Copper Rule (LCR) requires that 90% of lead and copper samples for a PWS in each compliance period must be below the corresponding action level (AL). There were over 10,000 ALEs for lead and copper in all 50 states and in over 5,000 PWSs. Table 5 provides a summary of the ALEs in the Phase 1 Regulated Contaminants data set, ordered by number of violations. Lead ALEs have occurred in over 3,000 PWSs across all 50 states, and copper ALEs in over 2,000 PWSs in 49 states. Due to the widespread ALEs, lead and copper are both identified as contaminants of concern for the predictive model.

Table 1 NPDWR health-based violations by violation category

Violation Category	No. of Violations	Average Duration of Violation (days)	No. of States* w/ Violations	No. of PWSs w/ Violations	Total Population Served by PWSs w/ Violations	Average Reported MHI
Maximum Contaminant Level (MCL)	76,017	455	51	17,202	253,687,004	$46,770
Treatment Technique (TT)	15,839	215	50	6,191	85,499,841	$46,417
Action Level Exceedance (ALE)	10,533	466	50	5,162	50,175,703	-
Maximum Residual Disinfectant Level (MRDL)	83	435	16	42	312,119	$47,816

MHI = Median Household Income reported in Phase 1 database
- = Data not available
*States include the 50 states and the District of Columbia

Table 2 Summary of MCL violations for contaminants with over 10,000 violations

Contaminant	No. of Violations	Average Duration (days)	No. of States*	No. of PWSs	Total Population Served	Average Reported MHI
Coliform (TCR)	22,885	206	51	12,343	63,508,615	$51,623
TTHM	18,029	457	49	2,513	79,839,352	$40,718
Arsenic	10,292	751	43	934	23,248,474	$48,078
HAA5	7,469	428	45	1,430	34,675,419	$40,532
Nitrate	4,796	650	33	842	5,308,850	$48,129
Combined Radium (-226 & -228)	3,045	619	34	335	15,109,507	$45,958
Gross Alpha	2,135	584	30	243	11,837,967	$45,534
Uranium	2,032	722	25	186	2,084,894	$47,211
Fluoride	1,794	829	23	104	5,261,929	$45,651
Total nitrate and nitrite	1,078	491	12	162	841,781	$43,578

*States include the 50 states and the District of Columbia

Table 3 Summary of MRDL violations

Contaminant	No. of Violations	Average Duration (days)	No. of States*	No. of PWSs	Total Population Served	Average Reported MHI
Chlorine Dioxide	38	324	10	24	281,581	$42,271
Chlorine	38	537	9	15	28,108	$51,278
Chloramines	7	404	4	4	3,810	$68,577

*States include the 50 states and the District of Columbia

Table 4 Summary of treatment technique (TT) violations

Description of Violation	Rule Violated	Contaminant Impacted	No. of Violations	Average Duration (days)	No. of States*	No. of PWSs	Total Pop. Served	Avg. Reported MHI
Failure to Address Deficiency	LT2ESWTR, GWR	*Cryptosporidium*, Fecal bacteria	4,344	515	37	1,774	7,045,164	$44,520
Treatment Technique	LT2ESWTR, GWR, SWTR	*Cryptosporidium*, Fecal bacteria, Other pathogen	4,205	34	44	1,314	39,176,056	$48,364
Monthly Turbidity Exceedance	LT1ESWTR	*Cryptosporidium*	1,810	30	35	560	9,230,443	$41,140
Startup Procedures	RTCR	*E.coli*	1,471	261	32	1,112	412,370	$50,601
Level 1 Assessment	RTCR	*E.coli*	1,050	189	40	960	1,177,644	$51,914
No Certif. Operator	DBP Stage 1	DBP	934	307	27	521	1,988,925	$41,646
Single Turbidity Exceedance	LT1ESWTR	*Cryptosporidium*	856	29	37	400	11,547,674	$40,876
Failure to Filter	LT2ESWTR, GWR, SWTR	*Cryptosporidium*, Fecal bacteria, Other pathogen	404	652	24	184	3,479,382	$43,831
Level 2 Assessment	RTCR	*E.coli*	401	183	24	314	449,319	$61,151

Description of Violation	Rule Violated	Contaminant Impacted	No. of Violations	Average Duration (days)	No. of States*	No. of PWSs	Total Pop. Served	Avg. Reported MHI
Corrective/Expedited Actions	RTCR	*E.coli*	296	188	24	193	110,708	$50,661
Failure to Submit Treatment Requirement Rpt	LT2ESWTR	*Cryptosporidium*	45	676	8	45	1,002,944	$39,649
Failure to Address Contamination	GWR	Fecal bacteria	16	333	6	15	4,611	$53,028
Uncovered Reservoir	LT1ESWTR, LT2ESWTR	*Cryptosporidium*	4	455	3	4	9,873,300	-
No Prior State Approval	LT1ESWTR	*Cryptosporidium*	3	877	2	2	1,301	$38,864

DBP = disinfection byproduct
DC = District of Columbia
GWR = Groundwater Rule
LT1ESWTR = Long Term 1 Enhanced Surface Water Treatment Rule
LT2ESWTR = Long Term 2 Enhanced Surface Water Treatment Rule
RTCR = Revised Total Coliform Rule
SWTR = Surface Water Treatment Rule
*States include the 50 states and the District of Columbia
- = Data not available

Table 5 Summary of action level exceedances (ALEs) for lead and copper

Contaminant	No. of Violations	Average Duration (days)	No. of States*	No. of PWSs	Total Pop. Served	Avg. Reported MHI
Copper	5,370	399	49	2,393	10,301,800	-
Lead	5,163	535	50	3,350	39,873,903	-

Regulated Contaminants: Qualified Cases from WBDOSS and News/Media

The Phase 1 Regulated Contaminants data set includes 76 data records identified as "WBDOS/NEWS". These data records include locational information including state, county or place, and zip code, but do not include a public water system ID (PWSID) to identify the PWS. They do include system specific information, though, including the system type, source water type, and population served. These records also include a contaminant name, but do not provide contextual information to understand the incident or occurrence of the contaminant leading to the identification of these qualified cases. As a result, it is not clear how to interpret these data records or how to incorporate them in the predictive model. Table 6 provides a summary of the qualified cases from WBDOSS and news/media from the Phase 1 Regulated Contaminants data set by contaminant with more than one case. In addition to the contaminants shown in the table, there are 17 contaminants each corresponding with one data record. Some of these could be grouped together, though, such as "DBP", "DBPs", "HAA5", Trihalomethanes", which each corresponded with one qualified case.

Table 6 Summary of qualified cases from WBDOSS and news/media by contaminant with more than one case

Contaminant	No. of Cases	No. of States w/ Cases	No. of Places w/ Cases
Nitrate	14	4	14
Lead	13	9	13
Norovirus	10	5	10
Radium	7	2	7
Cyanotoxin(s)	5	3	4
DBPs*	4	3	4
Arsenic	3	2	3
Uranium	3	3	3
Campylobacter	2	2	2
Cryptosporidium	2	2	2

*DBPs includes DBP, HAA5, and Trihalomethanes, which each corresponded with one qualified case

Unregulated Contaminants

The Phase 1 Unregulated Contaminants data set includes data records from EPA's Second Unregulated Contaminant Monitoring Rule (UCMR2), UCMR3, and UCMR4, along with data records from a media search. The EPA's UCMR is mandated under the 1996 Safe Drinking Water Act (SDWA) amendments that require EPA to issue a new list once every five years of no more than 30 unregulated contaminants to be monitored by PWSs.

UCMR2 required monitoring for 25 contaminants between 2008 and 2010. The 25 contaminants were broken up into two lists: 10 List 1 contaminants for Assessment Monitoring and 15 List 2 contaminants for a Screening Survey. All PWS serving more than 10,000 people and 800 representative PWSs serving 10,000 or fewer people were required to monitor for the List 1 contaminants. All PWSs serving more than 100,000 people, 320 representative PWSs serving 10,000 to 100,000 people, and 480 representative PWSs serving 10,000 or fewer people were required to monitor for the List 2 contaminants. A comparison was made between the Phase 1 data set for UCMR2 data and the UCMR2 data set publicly available for download from EPA's website (https://www.epa.gov/monitoring-unregulated-drinking-water-contaminants/occurrence-data-unregulated-contaminant#2) that verified the Phase 1 UCMR2 data set includes all detected results based on a collection date of January 1, 2009 or after. Table 7 summarizes the contaminants detected in UCMR2, ordered by the number of detections. Of the 10 List 1 contaminants, two were detected and included in the Phase 1 Unregulated Contaminants data set. Of the 15 List 2 contaminants, nine were detected and included in the Phase 1 Unregulated Contaminants data set. Aside from N-nitroso-dimethylamine (NDMA), the UCMR2 contaminants have relatively few detections. NDMA will be considered as a greater priority for a potential contaminant of concern for the predictive model as compared with other UCMR2 contaminants.

Table 7 Summary of UCMR2 detected contaminants included in Phase 1 Unregulated Contaminants data set

Contaminant	Contaminant Type	No. of Detections	No. of States w/ Detection	No. of PWS w/ Detection
N-nitroso-dimethylamine (NDMA)	List 2 (Nitrosamine)	1,283	40	236
N-nitroso-diethylamine (NDEA)	List 2 (Nitrosamine)	32	8	17
Metolachlor ethane sulfonic acid (ESA)	List 2 (Acetanilide Degradate)	30	9	14
N-nitroso-di-n-butylamine (NDBA)	List 2 (Nitrosamine)	6	3	4
N-nitroso-pyrrolidine (NPYR)	List 2 (Nitrosamine)	5	3	4
Metolachlor	List 2 (Parent Acetanilide)	3	3	3
Alachlor ethane sulfonic acid (ESA)	List 2 (Acetanilide Degradate)	2	2	2
N-nitroso-methylethylamine (NMEA)	List 2 (Nitrosamine)	2	2	2
Terbufos sulfone	List 1 (Insecticide)	1	1	1
Hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX)	List 1 (Explosive)	1	1	1
Acetochlor ethane sulfonic acid (ESA)	List 2 (Acetanilide Degradate)	1	1	1

*DBPs includes DBP, HAA5, and Trihalomethanes, which each corresponded with one qualified case

UCMR3 required monitoring for 30 contaminants (28 chemicals and two viruses) between 2013 and 2015. All PWSs serving more than 10,000 people and 800 representative PWSs serving 10,000 or fewer people monitored for 21 List 1 Assessment Monitoring contaminants. All PWSs serving more than 100,000 people, 320 representative PWSs serving 10,001 to 100,000 people, and 480 representative PWSs serving 10,000 or fewer people monitored for seven List 2 Screening Survey contaminants. Additionally, EPA selected 800 representative PWSs that serve 1,000 or fewer people, do not disinfect, and have wells located in areas of karst or fractured bedrock to monitor for two List 3 viruses. Overall, the UCMR3 data set includes 44 contaminants due to indicators (total coliforms, *E.coli*, *Enterococci*, bacteria phages – somatic phage and male specific phage, and aerobic spores) for PWS monitoring for List 3 contaminants, two methods for Enteroviruses (Enterovirus cell culture and Enterovirus RT-qPCR), three methods for Noroviruses (Norovirus genogroup I with RT-qPCR primer set A, Norovirus genogroup I with RT-qPCR primer set B, and Noroviruses genogroup II).

A comparison was made between the Phase 1 data set for UCMR3 data and the UCMR3 data set publicly available for download from EPA's website (https://www.epa.gov/monitoring-unregulated-drinking-water-contaminants/occurrence-data-unregulated-contaminant#3) to verify that the Phase 1 UCMR3 data set includes all detected results. The Phase 1 UCMR3 data set includes 89,423 detected results for 44 contaminants, while the UCMR3 data set downloaded from the EPA website includes 253,259 detected results for 40 contaminants. There were 4 contaminants that did not have any detected results, including equilin, estrone, sec-butylbenzene, and tellurium, which are included in the Phase 1 UCMR3 data set. It's also noteworthy that both the Phase 1 UCMR3 data set and the downloaded UCMR3 data set include data records for sec-butylbenzene, n-propylbenzene, germanium, manganese, and tellurium, which are not listed as part of UCMR3 based on EPA's list of contaminants (https://www.epa.gov/dwucmr/third-unregulated-contaminant-monitoring-rule). The Phase 1 UCMR3 data set includes 61,584 data records where the Analytical Results Sign is equal to "<" indicating a non-detect result. Based on the documentation describing the Phase 1 UCMR data collection, only detected results should be included as qualified cases. The other main discrepancy between the Phase 1 UCMR3 data set and the downloaded UCMR3 data set is that the Phase 1 UCMR3 data set contains data records for systems in only 33 states and Puerto Rico, as opposed to the downloaded UCMR3 data set which contains data records for detected contaminants in systems in all 50 state plus 16 territories, tribal nations, or EPA regions. The states missing from the Phase 1 UCMR3 data set appear to be due to an alphabetical cut off, as they start with letters from A-L. Based on the results of this comparison, the summary provided in Table 8 are based on detected results from the downloaded UCMR3 data set for systems in the 50 US states and the District of Columbia (DC). Table 8 orders the UCMR3 contaminants by number of detections. The UCMR3 contaminants with the most widespread detections are the metals, i.e., strontium, chromium-6, vanadium, and chromium, as well as chlorate. Additionally, there were numerous detections of the VOCs, inclusive of 1,2,3-trichloropropane, which will be of interest for the predictive model due to specific state regulations. There were also over 4,000 detections of 1,4-dioxane. The PFAS detections were limited due to relatively high method reporting limits, but we know now that PFAS occurrences are more widespread than UCMR3 data suggests due to better analytical methods and more recent state and system specific sampling programs.

Table 8 Summary of UCMR3 detected contaminants

Contaminant	Contaminant Type	No. of Detections	No. of States* w/ Detection	No. of PWS w/ Detection
Strontium	List 1 (Metal)	61,466	51	4,815
Chromium-6	List 1 (Metal)	46,435	51	4,303
Vanadium	List 1 (Metal)	36,661	51	3,528
Chlorate	List 1 (Oxyhalide Anion)	33,994	51	3,323

Contaminant	Contaminant Type	No. of Detections	No. of States* w/ Detection	No. of PWS w/ Detection
Chromium	List 1 (Metal)	30,928	51	3,579
Molybdenum	List 1 (Metal)	25,195	51	2,510
1,4-Dioxane	List 1 (SOC)	4,180	45	1,066
1,1-Dichloroethane	List 1 (VOC)	830	38	241
Cobalt	List 1 (Metal)	828	35	245
Chlorodifluoromethane (HCFC-22)	List 1 (VOC)	810	37	280
Bromochloromethane (Halon 1011)	List 1 (VOC)	646	39	303
Perfluorooctanoic acid (PFOA)	List 1 (PFAS)	377	27	116
Aerobic spores	List 3 Indicator	317	15	252
Chloromethane	List 1 (VOC)	278	23	133
Perfluorooactanesulfonic acid (PFOS)	List 1 (PFAS)	275	24	91
1,2,3-Trichloropropane	List 1 (VOC)	247	13	62
Perfluorohelptanoic acid (PFHpA)	List 1 (PFAS)	228	22	82
Perfluorohexanesulfonic acid (PFHxS)	List 1 (PFAS)	191	22	52
Bromomethane	List 1 (VOC)	115	12	49
4-Andostene-3,17-dione	List 2 (Hormone)	99	28	75
Testosterone	List 2 (Hormone)	68	25	61
Total coliforms	List 3 Indicator	57	10	53
Enterococci	List 3 Indicator	41	8	41
Perfluorononanoic acid (PFNA)	List 1 (PFAS)	19	7	14
Perfluorobutanesulfonic acid (PFBS)	List 1 (PFAS)	17	4	7
Bacteriophage - male specific phage	List 3 Indicator	14	5	14
Enteroviruses (RT-qPCR)	List 3 (Virus)	6	3	6
Bacteriophage – somatic phage	List 3 Indicator	5	3	5
17-alpha-ethynylestradiol (ethinyl estradiol)	List 2 (Hormone)	4	4	4
Noroviruses GIA	List 3 (Virus)	4	3	4
Noroviruses GII	List 3 (Virus)	4	3	4
17-beta-estradiol	List 2 (Hormone)	3	1	1
16-alpha-hydroxyestradiol (estriol)	List 2 (Hormone)	3	2	3

Contaminant	Contaminant Type	No. of Detections	No. of States* w/ Detection	No. of PWS w/ Detection
E.coli	List 3 Indicator	3	2	3
Noroviruses GIB	List 3 (Virus)	2	1	2
Enteroviruses (cell culture)	List 3 (Virus)	2	2	2
1,3-Butadiene	List 1 (VOC)	1	1	1

PFAS = Per- and polyfluoroalkyl substances
SOC = synthetic organic compound
VOC = volatile organic compound
*States include the 50 states and the District of Columbia

UCMR4 required monitoring for 30 contaminants (10 cyanotoxins and 20 additional chemicals) between 2018 and 2020. All surface water (SW) and groundwater under direct influence of surface water (GWUDI) PWSs serving more than 10,000 people were required to sample for the 10 cyanotoxins and all PWS serving more than 10,000, including SW, GWUDI, and groundwater (GW) PWSs, were required to sample for the additional 20 chemicals. The 20 chemicals include 3 brominated haloacetic acids (DBPs), 9 pesticides, 3 alcohols, 3 semivolatile chemicals, and 2 metals. Additionally, 800 randomly selected SW or GWUDI PWS serving 10,000 people or less were required to sample for the 10 cyanotoxins and a different group of 800 randomly selected PWSs serving 10,000 people or less were required to sample for the 20 additional chemicals.

A comparison was made between the Phase 1 data set for UCMR4 data and the UCMR4 data set publicly available for download from EPA's website (https://www.epa.gov/monitoring-unregulated-drinking-water-contaminants/occurrence-data-unregulated-contaminant#4) to verify that the Phase 1 UCMR4 data set includes all detected results sampled before the end of 2019. Consistent with the Phase 1 UCMR3 data set, there are no data records for PWSs in states that begin with letters between A-L. For completeness, the summary provided in Table 9 is based on the UCMR4 data that was directly downloaded from the EPA website, for samples collected by PWSs in the 50 US states and DC through December 31, 2019 with detected results. The table shows that brominated HAAs, which are classes of DBPs, occur in virtually all PWSs, and manganese occurrence is detectable in drinking water in every state across the country. These contaminants with be prioritized in the predictive model, and all detect contaminants will be considered in the model development.

Table 9 Summary of UCMR4 detected contaminants in samples collected through December 31, 2019

Contaminant	Contaminant Type	No. of Detections	No. of States* w/ Detection	No. of PWS w/ Detection
HAA5	List 1 (Brominated HAA)	45,679	51	4,045
HAA6Br	List 1 (Brominated HAA)	45,675	51	4,045
HAA9	List 1 (Brominated HAA)	45,658	51	4,045
Manganese	List 1 (Metal)	19,491	51	3,671
Germanium	List 1 (Metal)	2,062	41	524
1-Butanol	List 1 (Alcohol)	235	34	160
Anatoxin-a	List 1 (Cyantoxin)	117	17	41

o-Toluidine	List 1 (Semivolatile Chemical)	104	25	73
Quinoline	List 1 (Semivolatile Chemical)	75	23	48
2-Methoxyethanol	List 1 (Alcohol)	57	19	46
2-Propen-1-ol	List 1 (Alcohol)	27	13	18
alpha-Hexachlorocyclohexane	List 1 (Pesticide)	22	14	22
Total permethrin	List 2 (Pesticide)	14	8	12
Cylindrospermopsin	List 1 (Cyanotoxin)	11	4	11
Butylated hydroxyanisole	List 1 (Semivolatile Chemical)	7	5	6
Oxyfluorfen	List 1 (Pesticide)	7	6	7
Dimethipin	List 1 (Pesticide)	5	4	5
Ethoprop	List 1 (Pesticide)	5	4	5
Total microcystin	List 1 (Cyanotoxin)	4	4	4
Profenofos	List 1 (Pesticide)	3	3	3
Tebuconazole	List 1 (Pesticide)	3	2	3
Tribufos	List 2 (Pesticide)	3	2	3
Chlorpyrifos	List 1 (Pesticide)	1	1	1

HAA = Haloacetic Acid
*States include the 50 states and the District of Columbia

2: Assess Water Quality Sampling Data

The *Task 2: Assess Water Quality Sampling Data* used the comprehensive water quality database developed as part of the WQRF Contaminant Occurrence Study. The Contaminant Occurrence Study database contains data records that were collected from 46 state regulatory agencies in 2019-2020. The data records are predominantly for samples collected between 2009 through mid-2019. Initially, the database of quality checked (QC'd) data included 57 analytes based on contaminants with an MCL greater than the maximum contaminant level goal (MCLG) and specific aesthetic analytes that can impact taste, odor, and color of drinking water. Later phases of the Contaminant Occurrence Study included QC of data records for additional drinking water analytes that were collected as part of the original study's data collection effort. The database now includes data for 169 drinking water quality analytes that are available for use in this Predictive Modeling Study.

The Contaminant Occurrence Study database was used for this task because it is currently the most comprehensive and current database of national drinking water quality data. Despite the advantages of using this database, there are still some limitations that are important to note. While water quality data were requested from all 50 states, data were received from 46 states. Besides data records that were incorporated into the database from EPA's UMCR4, the database does not have data available for Indiana, Kansas, South Dakota, or Tennessee. Additionally, the number of drinking water analytes for which data were available differed by state, so for a given analyte, there may be data available for less than 46 states. Microbial data were reported in different formats from various states, including some presence/absence data and some count quantity data. Some states reported microbial data in the same format as chemical data, while other states provided separate data tables for microbial data with different data fields to describe the data results. Due to the different inconsistencies with the microbial data, this analysis in this task excludes microbial data. Based on the high frequency of Total Coliform Rule (TCR) violations identified in Task 1 of this project, we would expect that this task would identify total coliform as a top contaminant based on the occurrence of total coliform positive data if the methodology was inclusive of microbial data.

Our methodology for this task focuses on whether the occurrence level of these analytes is approaching (i.e., 80% or greater) or exceeding a regulatory limit (i.e., federal or state MCL) or health-based goal (i.e., MCLG) and if the occurrence level is increasing over time. The first step to accomplish this objective was to create a comprehensive table of all federal and state MCLs and health goals. The table we developed as part of this task includes 714 up-to-date state MCLs, secondary MCLs, action levels, health advisory levels, and health goals, and 108 federal MCLs, secondary MCLs, action levels, and health goals. These levels are used as reference levels for identifying drinking water quality contaminants for the predictive model.

We have then developed an R script to review contaminant data by:

1. Identifying all contaminants that have occurrences at levels equal to 80% of the federal MCL or greater in the period from 2009 through 2019
2. For contaminants identified in (1) above, identifying contaminants with increasing trends based on the Mann -Kendall non-parametric statistical test for monotonic trends

The script also creates visual representations of the data for contaminants identified in (1) and (2) in the form of yearly boxplots. After this process was completed for federal MCLs, we utilized the same methodology for state specific MCLs using contaminant data for only systems in the corresponding states.

Federally regulated contaminants

Occurrence data for the period from 2009 through 2019 for federally regulated contaminants were evaluated to determine contaminants with occurrences at 80% of the MCL or greater in the period from 2009 through 2019. Based on available occurrence data, all federally regulated contaminants except dalapon, glyphosate, di(2-ethylhexyl) adipate, hexachlorocyclopentadiene, 2,4,5-TP (Silvex), and 1,2,4-trichlorobenzene had at least one reported occurrence at or above 80% of their respective MCLs. The remaining federally regulated contaminants, except for diquat, oxamyl (vydate), and xylenes (total), all had at least one reported occurrence above their MCLs.

Contaminants were then ranked based on the number of public water systems (PWSs) with occurrence above the MCL. The top ten contaminants based on the number of PWSs that had occurrences above the MCL are summarized in Table 10. In addition to the number of PWSs with occurrence greater than the MCL, the table also shows the sum of the population served by PWSs with occurrence greater than the MCL. All PWS types, including community water systems (CWSs), non-transient non-community water systems (NTNCWSs), and transient non-community water systems (TNCWSs), are included in this summary so the total population served could count individual people more than once.

Lead was found as the top contaminant in terms of the number of PWSs with occurrence greater than the action level of 15 µg/L. Over 13,000 PWSs reported occurrence greater than 15 µg/L based on available data. These systems serve a total population of 112 million. Total trihalomethanes (TTHM) resulted in the second most PWSs with occurrence greater than the MCL of 80 µg/L with over 8,000 PWSs reporting occurrence greater than 80 µg/L. These systems serve a total population of 133 million, which is more than the population served by systems with lead occurrence greater than the action level. In the case of disinfection byproducts, i.e., TTHM and the sum of five haloacetic acids (HAA5), the systems with occurrence greater than the MCL were predominantly systems using surface water as the primary source water type. For all other contaminants in Table 10, the percent of surface water systems and groundwater systems represented were relatively consistent. Since there are more groundwater systems in the US as compared with surface water systems, the number of groundwater PWSs with occurrence above the MCL was greater than the number of surface water PWSs with occurrence above the MCL.

An exceedance of the MCL does not necessarily cause a system to be in violation because in most cases, compliance is based on a running annual average or in the case of lead and copper, the 90th percentile result in a compliance period. As part of this project, contaminants resulting in the most health-based violations were summarized as part of Task 1. The results for the top ten federally regulated contaminants based on number of PWSs with occurrence above the MCL shown in Table 10 were also identified as top contaminants of concern in Task 1.

Table 10 Top ten federally regulated contaminants based on number of PWSs with occurrence greater than the MCL or Action Level

Contaminant	MCL or Action Level	Number of PWSs w/ occurrence > MCL	Percent of PWSs w/ data and w/ occurrence > MCL	Sum of population served by PWSs w/ occurrence > MCL*
Lead	15 µg/L (AL)	13,020	23%	112 M
TTHM	80 µg/L	8,169	17%	133 M
Copper	1.3 mg/L (AL)	5,510	10%	28.3 M
HAA5	60 µg/L	5,343	12%	97.7 M
Arsenic	10 µg/L	2,669	5.1%	16.3 M
Nitrate	10 mg/L as N	2,602	2.5%	8.03 M
Nitrate + Nitrite	10 mg/L as N	1,239	1.8%	3.74 M
Radium	5 pCi/L	1,008	4.6%	6.19 M
Fluoride	4 mg/L	437	0.8%	1.34 M
Uranium	30 µg/L	378	2.3%	2.21 M

For the top ten contaminants shown in Table 10, Table 11 provides a summary of the PWSs with data above the MCL or Action Level by system size category based on the population served. Specifically, the table shows the number of PWSs with occurrence above the MCL or Action Level and the percent of PWSs with data available that had occurrence above the MCL or Action Level by system size category. In general, there are a greater number of smaller PWSs than larger PWSs, so there are typically a greater number of smaller systems with occurrence above the MCL or Action Level, while the percentages provide a more normalized comparison across system sizes. For the DBPs (TTHM and HAA5), the percentages are higher for the larger systems likely due to a greater percent of surface water systems as compared with groundwater systems and larger distribution systems, where DBP formation continues after the application of a disinfectant. The percentages of PWSs with data over the Action Level for lead were also higher for larger systems as compared with smaller systems.

Table 11 Summary of PWSs with occurrence greater than the MCL or Action Level by system size category for top ten federally regulated contaminants

Contaminant	Number (and Percent) of PWSs by Size Category with Occurrence Above MCL/Action Level				
	Very Small (<500)	Small (500-3,300)	Medium (3,300-10,000)	Large (10,000-100,000)	Very Large (>100,000)
Lead	6,050 (17%)	3,483 (29%)	1,558 (40%)	1,443 (50%)	180 (51%)
TTHM	2,338 (8.4%)	2,660 (21%)	1,388 (32%)	1,368 (41%)	216 (53%)
Copper	2,966 (8.5%)	1,534 (13%)	450 (12%)	363 (13%)	43 (12%)
HAA5	1,374 (5.5%)	1,777 (15%)	1,003 (23%)	943 (26%)	144 (34%)
Arsenic	1,863 (5.4%)	412 (4.2%)	133 (4.1%)	126 (4.9%)	23 (6.6%)
Nitrate	2,062 (2.5%)	232 (2.1%)	27 (0.9%)	52 (2.2%)	21 (6.2%)
Nitrate + Nitrite	915 (1.8%)	124 (1.5%)	11 (0.4%)	13 (0.7%)	7 (2.8%)
Radium	551 (4.1%)	254 (5.1%)	100 (5.3%)	75 (5.6%)	6 (3.4%)
Fluoride	285 (0.8%)	82 (0.8%)	42 (1.3%)	22 (0.9%)	2 (0.7%)
Uranium	268 (2.6%)	61 (1.8%)	23 (1.6%)	15 (1.3%)	5 (2.5%)

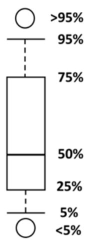
For the top ten contaminants shown in Table 10, Table 12 provides a summary of the PWSs with data above the MCL or Action Level by primary source water type. Specifically, the table shows the number of PWSs with occurrence above the MCL or Action Level and the percent of PWSs with data available that had occurrence above the MCL or Action Level by primary source water type. In general, there are a greater number of groundwater PWSs than surface water PWSs, so there are typically a greater number of groundwater systems with occurrence above the MCL or Action Level, while the percentages provide a more normalized comparison between groundwater and surface water PWSs. For the DBPs (TTHM and HAA5), the percentages are notably higher for the surface water systems as surface water tends to have higher concentrations of organic matter, which are DBP precursors. The percentages of PWSs with occurrences over the Action Level for lead were also higher for surface water systems as compared with groundwater systems, while the percent of PWSs with occurrences over the MCL for arsenic, radium, and uranium were higher for groundwater systems.

Table 12 Summary of PWSs with occurrence greater than the MCL or Action Level by primary source water type for top ten federally regulated contaminants

Contaminant	Number (and Percent) of PWSs by Primary Source Water Type with Occurrence Above MCL/Action Level	
	Groundwater	Surface Water
Lead	9,727 (21%)	2,985 (35%)
TTHM	2,383 (6.3%)	5,585 (51%)
Copper	4,468 (9.9%)	888 (10%)
HAA5	1,129 (3.3%)	4,109 (37%)
Arsenic	2,403 (5.3%)	154 (2.8%)
Nitrate	2,271 (2.5%)	123 (1.9%)
Nitrate + Nitrite	1,015 (1.7%)	55 (1.1%)
Radium	913 (4.9%)	72 (2.3%)
Fluoride	394 (0.8%)	39 (0.8%)
Uranium	327 (2.4%)	45 (1.7%)

The next step in this effort included an investigation of how the occurrence of these contaminants may be changing over time. Identifying trends over time may help to understand which contaminants are most likely to be of the greatest concern for the next 5-10 years. Trends over time were analyzed visually using yearly boxplots for the period from 2009 – 2018 and using the Mann-Kendall non-parametric statistical test for monotonic trends. Figure 1 shows a key for the boxplots. For all figures with yearly boxplots, the y-axis is limited to three times the MCL to show the distribution of results for the majority of the data. Data with results below the lower limit of the y-axis (i.e. pH) and above the upper limit of the y-axis are not included in these figures. The Mann-Kendall test assumes that data used for the test are consistently spaced over time. To address this requirement and to focus on the occurrences that represent a greater health concern, annual 95th percentiles from 2009 through 2018 were used for each contaminant. The outcome of the test includes an alpha value and a test statistic. Based on a 95% confidence level, an alpha value less than 0.05 was identified as a statistically significant trend, while an alpha value equal to or greater than 0.05 was identified as not statistically significant. A positive test statistic indicates an increasing trend, while a negative test statistic indicates a decreasing trend. Results for the top ten contaminants from Table 10 are presented below grouped by the trend test outcome.

Figure 1 Boxplot legend



Increasing trend

No contaminants were found to have an increasing annual 95th percentile values over the period from 2009 through 2018.

No significant trend

Three of the top ten contaminants (Table 10) were found to have no significant trend over time. Those contaminants include nitrate, HAA5, and nitrate + nitrite.

Yearly boxplots for HAA5 occurrence data are shown in Figure 2. Annual 95th percentile HAA5 values are close to the MCL of 60 µg/L. The only annual 95th percentile that exceeded the MCL in the period of interest was in 2009. Although the Mann-Kendall test did not find a statistically significant monotonic decreasing trend over the period of 2009 through 2018, the comparison of the annual 95th percentile value in 2009, which is greater than the MCL, with 2018, which is below the MCL, suggests some decrease over time. The numerous occurrence data that exceed the MCL in all years suggests that HAA5 will likely remain a contaminant of concern for the next 5-10 years.

Yearly boxplots for nitrate are shown in Figure 3. The figure shows national finished water nitrate levels were consistent over time from 2009 through 2018. The annual 95th percentile values are close to 75% of the MCL over the analysis period, with occurrences up to three times the MCL. Nitrate is an acute contaminant, so any occurrence above 10 µg/L could pose a potential health risk. Based on occurrence data exceeding the MCL, we believe that nitrate will remain a contaminant of concern for the next 5-10 years.

Yearly boxplots for nitrate + nitrite occurrence data are shown in Figure 4. While there's not a statistically significant trend in annual 95th percentile values for nitrate + nitrite, the annual 75th percentile value in 2018 is higher than in 2009, suggesting some increase in concentrations over time is possible. As mentioned above, nitrate is regulated as an acute contaminant and any occurrence above the MCL of 10 mg/L for nitrate or nitrate + nitrite could pose a health risk. Therefore, it is likely that nitrate + nitrite will remain a contaminant of concern for the next 5-10 years.

Figure 2 Yearly boxplots of HAA5 occurrence data (2009-2018)

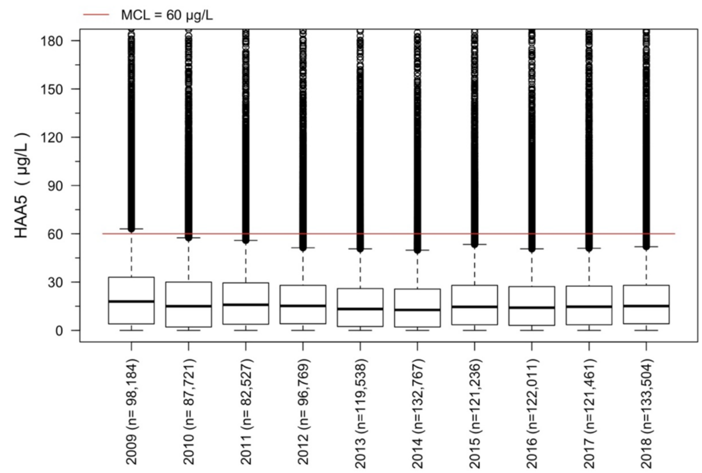


Figure 3 Yearly boxplots of nitrate occurrence data (2009-2018)

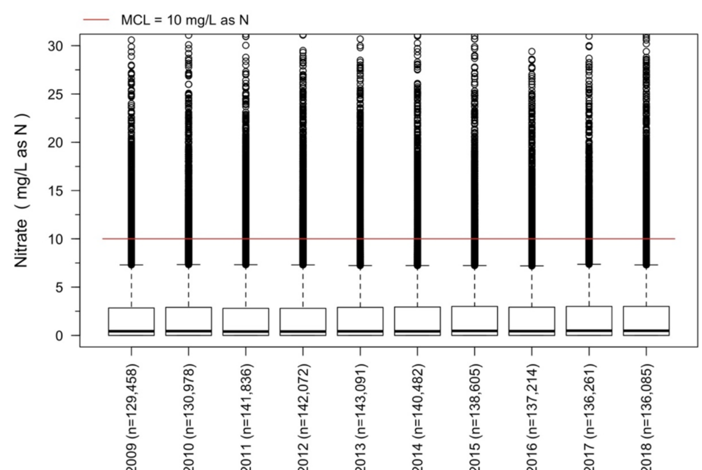
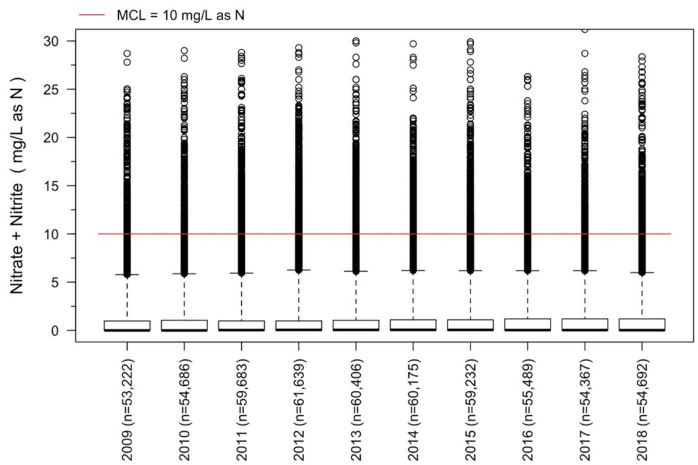


Figure 4 Yearly boxplots of nitrate + nitrite occurrence data (2009-2018)



Decreasing trend

The remaining contaminants in Table 10, including lead, TTHM, copper, arsenic, radium, fluoride, and uranium were found to have decreasing annual 95th percentile values over the period from 2009 through 2018.

Yearly boxplots of lead occurrence data are shown in Figure 5. Annual 95th percentile values are close to half the action level of 15 µg/L, although there are numerous occurrences exceeding the action level. Due to the frequency of occurrences exceeding the action level and the well-known health risks due to lead contamination, lead is expected to be a contaminant of concern for the next 5-10 years.

Yearly boxplots of TTHM occurrence data are shown in

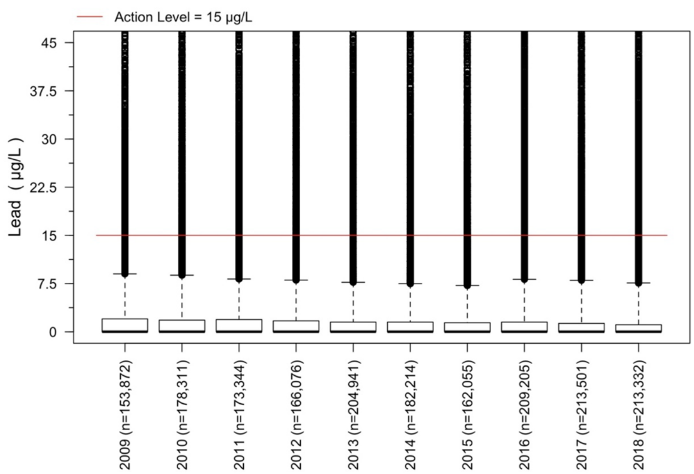


Figure 6. Annual 95th percentile values decreased over the period to approximately equal to the MCL of 80 µg/L. Despite the decrease in annual 95th percentile values, the frequency of occurrence above the MCL suggests that TTHM will likely remain a contaminant of concern over the next 5-10 years.

Yearly boxplots of copper occurrence data are shown in Figure 7. Decreasing annual 95th percentile values remain close to approximately half of the action level of 1.3 mg/L during the period of interest. Similar to lead and TTHM, the frequency of occurrence data exceeding the action level suggest that copper will likely remain a contaminant of concern over the next 5-10 years.

Yearly boxplots for arsenic occurrence data are shown in Figure 8. Annual 95th percentile values showed a decrease over the period, from approximately 14 µg/L to 10 µg/L, equal to the MCL. The figure shows the high frequency of occurrences above the MCL, which suggests that arsenic will likely remain a contaminant of concern for the next 5-10 years.

Yearly boxplots of radium occurrence data are shown in Figure 9. Despite the decreasing trend, annual 95th percentile values exceeded the MCL of 5 pCi/L in all years of interest. Variability in the distribution of yearly radium occurrence data shown by varying boxes in the boxplots may be a result of different monitoring schedules. Some systems may monitor yearly, while others may monitor every 3 years, for example. The frequency of occurrence data exceeding the MCL suggest that radium will likely remain a contaminant of concern over the next 5-10 years.

Yearly boxplots of fluoride occurrence data are shown in Figure 10. Annual 95th percentile concentrations are well below the MCL of 4 mg/L. Relative to other contaminants identified in Table 10 there are few occurrences exceeding the MCL, likely isolated to certain regions where naturally occurring fluoride may be problematic. Particularly in areas of high fluoride concentrations, it is likely that fluoride will remain a contaminant of concern for the next 5-10 years.

Yearly boxplots of uranium occurrence data are shown in Figure 11. Despite the decreasing trend, annual 95th percentile values exceeded that MCL of 30 µg/L in all years of interest. As mentioned above for radium, different monitoring frequencies for systems are likely the reason for the variability in the data distributions from year to year. The frequency of occurrence data exceeding the MCL suggest that uranium will likely remain a contaminant of concern over the next 5-10 years.

Figure 5 Yearly boxplots of lead occurrence data (2009-2018)

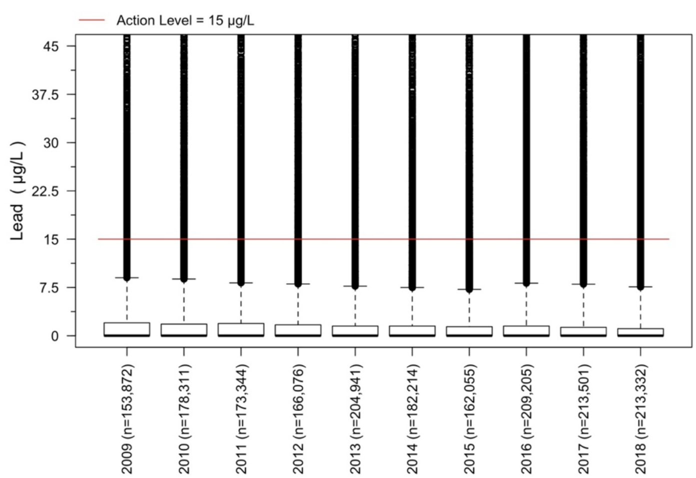


Figure 6 Yearly boxplots of TTHM occurrence data (2009-2018)

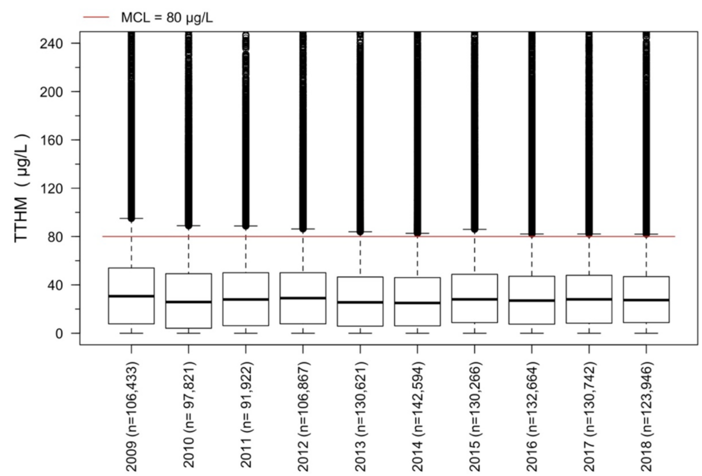


Figure 7 Yearly boxplots of copper occurrence data (2009-2018)

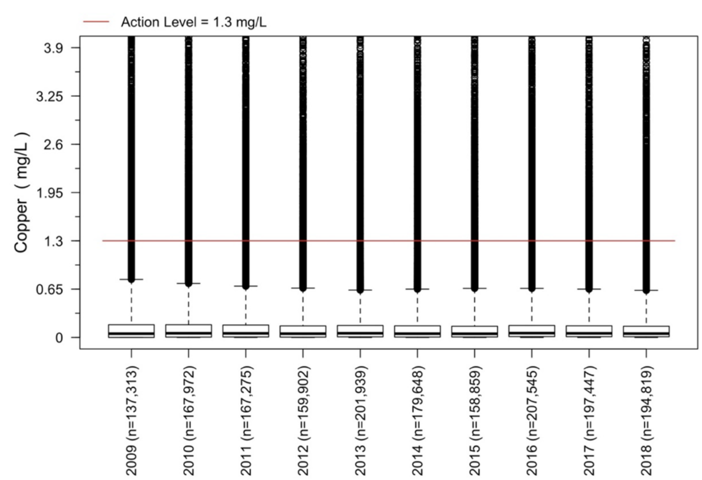


Figure 8 Yearly boxplots of arsenic occurrence data (2009-2018)

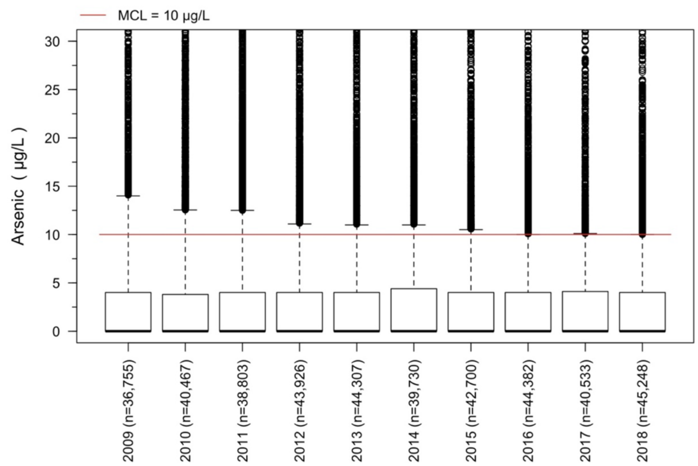


Figure 9 Yearly boxplots of radium occurrence data (2009-2018)

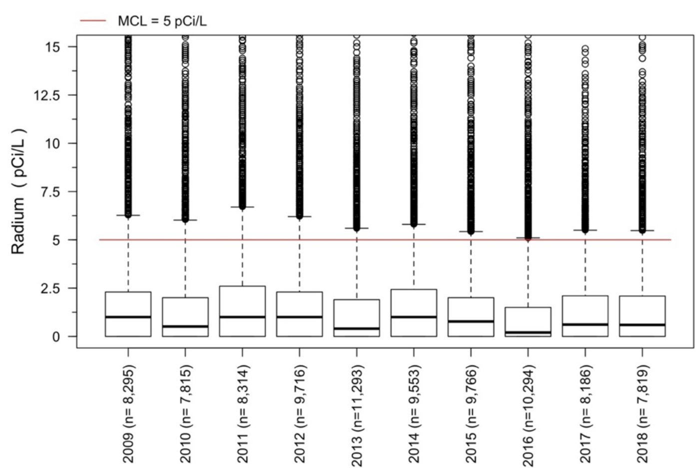


Figure 10 Yearly boxplots of fluoride occurrence data (2009-2018)

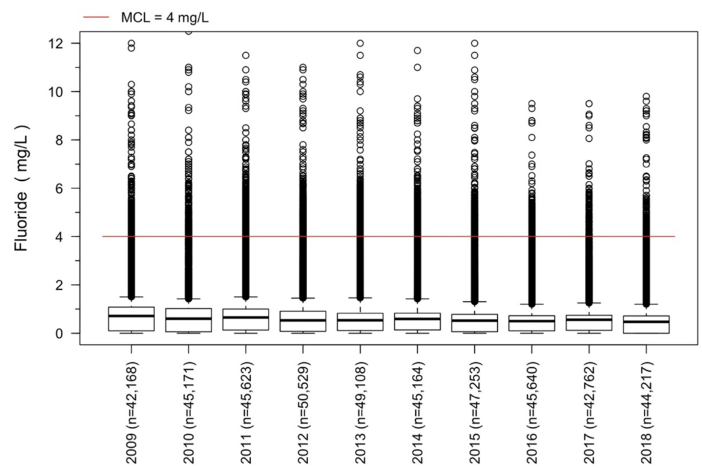
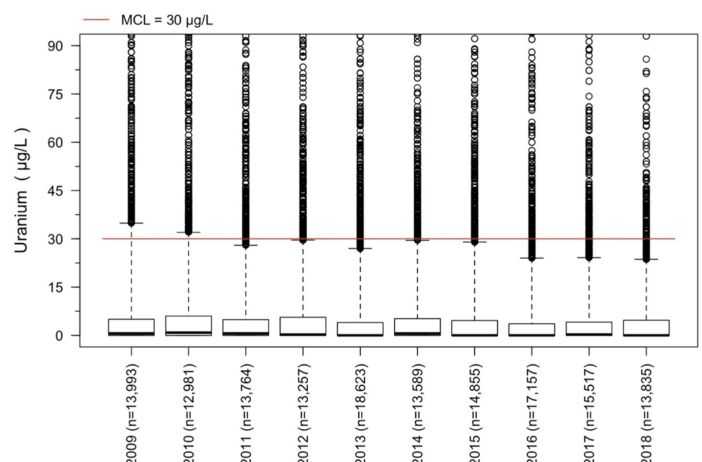


Figure 11 Yearly boxplots of uranium occurrence data (2009-2018)



State-specific regulated contaminants

Occurrence data for the period from 2009 through 2019 for state-specific regulated contaminants were evaluated to determine contaminants with occurrences at 80% of the MCL or greater in the period from 2009 through 2019. Based on available occurrence data, Table 13 summarizes the top ten state-specific regulated contaminants based on the number of PWSs with occurrence greater than the MCL or action level. Some of these contaminants are also federally regulated but certain states have imposed a more stringent regulation (i.e., arsenic and tetrachloroethylene in New Jersey), and some contaminants have non-enforced federal secondary standards based on aesthetic impacts on drinking water while states impose an enforced MCL (i.e., iron and manganese in North Carolina and New York).

A noteworthy group of contaminants that are regulated by several states that are missing from Table 13 is per- and poly-fluoroalkyl substances (PFAS). The reason for the exclusion of PFAS is largely due to data availability outside of UCMR3, which is summarized as part of Task 1. Due to recent and upcoming regulatory changes for PFAS, it is expected that PFAS analytes would likely be captured here if this process is repeated in the future when more data are available.

Table 13 Top ten state-specific regulated contaminants based on number of PWSs with occurrence greater than the MCL

Contaminant	State	MCL	No. of PWSs w/ occurrence > MCL	Percent of PWSs w/ data and occurrence > MCL	Sum of population served by PWSs w/ occurrence > MCL*
Iron	NC	300 µg/L	670	28%	1,166,394
Manganese	NC	50 µg/L	584	25%	1,750,973
Iron	NY	300 µg/L	453	23%	1,449,173
Chloride	NY	250 mg/L	384	20%	143,060
Manganese	NY	300 µg/L	258	13%	702,746
Arsenic	NJ	5 µg/L	71	5.3%	251,293
Chloride	CT	250 mg/L	65	5.7%	22,125
Fluoride	NY	2.2 mg/L	38	2.8%	43,522
Zinc	NY	5 mg/L	38	1.0%	86,381
Tetrachloroethylene (PCE)	NJ	1 µg/L	29	2.1%	436,190

For the top ten contaminants shown in Table 13, Table 14 provides a summary of the PWSs with occurrence above the MCL by system size category based on the population served. Specifically, the table shows the number of PWSs with data above the MCL by system size category and the percent of PWSs with data available that had occurrence above the MCL by system size category. As mentioned above in respect to Table 11, there are a greater number of smaller PWSs than larger PWSs, so there are typically a greater number of smaller systems with occurrence above the MCL, while the percentages provide a more normalized comparison across system sizes.

Table 14 Summary of PWSs with occurrence greater than the MCL by system size category for top ten state-specific regulated contaminants

Contaminant (State)	Number (and Percent) of PWSs by Size Category with Occurrence Above MCL				
	Very Small (<500)	Small (500-3,300)	Medium (3,300-10,000)	Large (10,000-100,000)	Very Large (>100,000)
Iron (NC)	492 (27%)	120 (40%)	18 (21%)	23 (22%)	3 (19%)
Manganese (NC)	453 (25%)	84 (28%)	9 (10%)	19 (18%)	2 (13%)
Iron (NY)	352 (23%)	58 (22%)	16 (22%)	14 (21%)	4 (33%)
Chloride (NY)	336 (23%)	29 (12%)	4 (5.6%)	2 (2.8%)	0
Manganese (NY)	201 (14%)	34 (13%)	8 (11%)	9 (9.4%)	1 (6.7%)
Arsenic (NJ)	46 (5.3%)	13 (5.2%)	3 (3.7%)	9 (7.4%)	0
Chloride (CT)	59 (6.0%)	5 (4.4%)	0	1 (3.1%)	0
Fluoride (NY)	18 (0.7%)	7 (1.3%)	2 (1.7%)	3 (3.3%)	0
Zinc (NY)	31 (3.2%)	4 (1.9%)	0	2 (3.2%)	0
Tetrachloroethylene (PCE) (NJ)	12 (1.3%)	0	5 (6.0%)	12 (9.8%)	0

Also, for the top ten contaminants shown in Table 13, Table 15 provides a summary of the PWSs with data above the MCL by primary source water type. Specifically, the table shows the number of PWSs with data above the MCL by primary source water type and the percent of PWSs with data available that have data above the MCL by primary source water type. As mentioned above in respect to Table 12, there are a greater number of groundwater PWSs than surface water PWSs, so there are typically a greater number of groundwater systems with data above the MCL, while the percentages provide a more normalized comparison between groundwater and surface water systems. The percent of PWSs with occurrences above the MCL for iron, manganese, and chloride were greater for groundwater systems, while the percent of PWSs with occurrences above the MCL for fluoride and tetrachloroethylene (PCE) were greater for surface water systems.

Table 15 Summary of PWSs with occurrence greater than the MCL by primary source water type for top ten state-specific regulated contaminants

Contaminant (State)	Number (and Percent) of PWSs by Primary Source Water Type with Occurrence Above MCL	
	Groundwater	Surface Water
Iron (NC)	617 (29%)	38 (19%)
Manganese (NC)	528 (25%)	37 (18%)
Iron (NY)	405 (24%)	38 (15%)
Chloride (NY)	347 (21%)	22 (9.4%)
Manganese (NY)	223 (14%)	29 (11%)
Arsenic (NJ)	65 (5.3%)	6 (5.4%)
Chloride (CT)	64 (5.9%)	1 (2.0%)
Fluoride (NY)	22 (0.8%)	8 (1.8%)
Zinc (NY)	30 (2.7%)	7 (3.2%)
Tetrachloroethylene (PCE) (NJ)	21 (1.6%)	8 (7.0%)

Increasing trend

The only contaminant in the top ten state-specific regulated contaminants shown in Table 13 that was found to have an increasing trend over time using the Mann-Kendall statistical test was chloride in Connecticut. Yearly boxplots of chloride occurrence data in Connecticut are shown in Figure 12. The USEPA has a non-enforceable secondary standard of 250 mg/L for chloride. Chloride is regulated in the state of Connecticut with an MCL of 250 mg/L, equivalent to the federal secondary standard. From 2009 through 2018, there was a steady increase in annual 95th percentile chloride concentrations from below the MCL of 250 mg/L to more than double the MCL.

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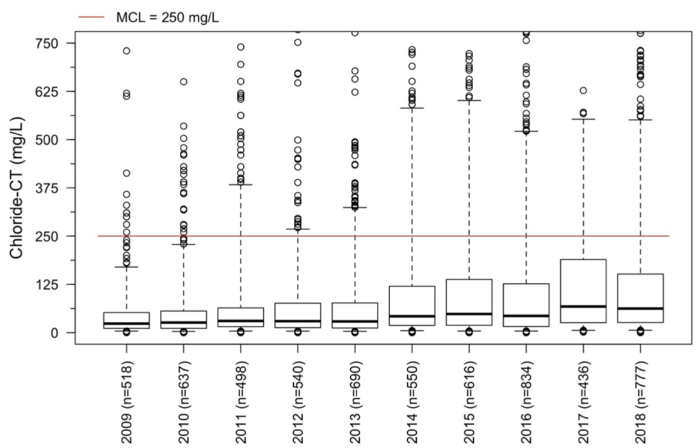
Figure 12 Yearly boxplots of chloride occurrence data in Connecticut (2009-2018)



No statistically significant trend

Several contaminants with state-specific regulations included in Table 13 did not have a statistically significant trend over time based on annual 95th percentile values. These contaminants include iron in North Carolina (Figure 13), manganese in New York (Figure 14), arsenic in New Jersey (Figure 15), chloride in New York (Figure 16), and tetrachloroethylene (PCE) in New Jersey (Figure 17). Iron and manganese have federal secondary standards of 0.3 mg/L and 50 µg/L, respectively. In the case of iron in North Carolina and chloride in New York, the states regulate these contaminants at the level of their secondary standard. In the cases of manganese, New York has a health-based regulation of 300 µg/L, well above the non-health-based secondary standard of 50 µg/L. Both arsenic and PCE are federally regulated with MCLs of 10 µg/L and 5 µg/L, respectively. New Jersey regulated these contaminants with lower MCLs of 5 µg/L and 1 µg/L.

Although there was no statistically significant trend, annual 95th percentile values for iron in North Carolina, manganese in New York, and chloride in New York were consistently above their MCLs. This suggests these contaminants may remain contaminants of concern within these states. The annual 95th percentile values for arsenic and PCE were generally below their MCLs, but occurrence above the MCLs suggests they may still be a concern for public health in New Jersey.

Figure 13 Yearly boxplots of iron concentration data in North Carolina (2009-2018)

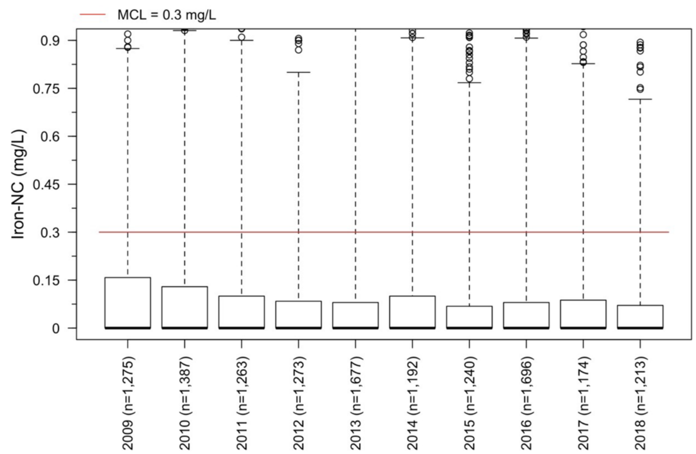


Figure 14 Yearly boxplots of manganese occurrence data in New York (2009-2018)

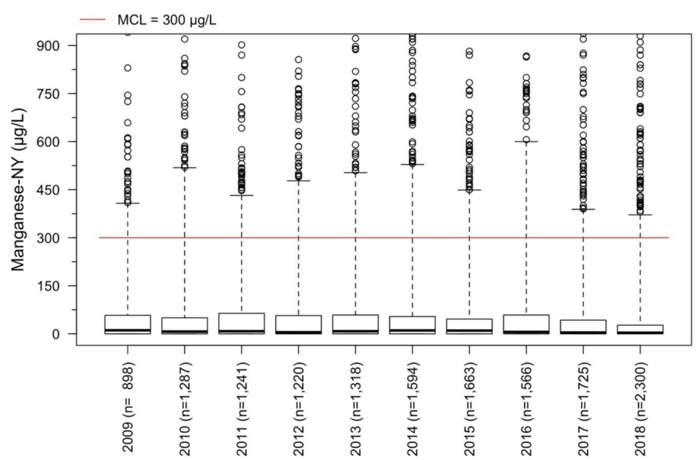


Figure 15 Yearly boxplots of arsenic occurrence data in New Jersey (2009-2018)

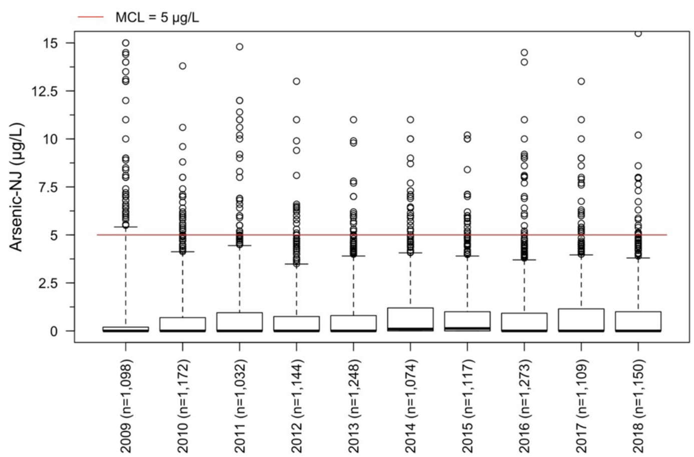


Figure 16 Yearly boxplots of chloride occurrence data in New York (2009-2018)

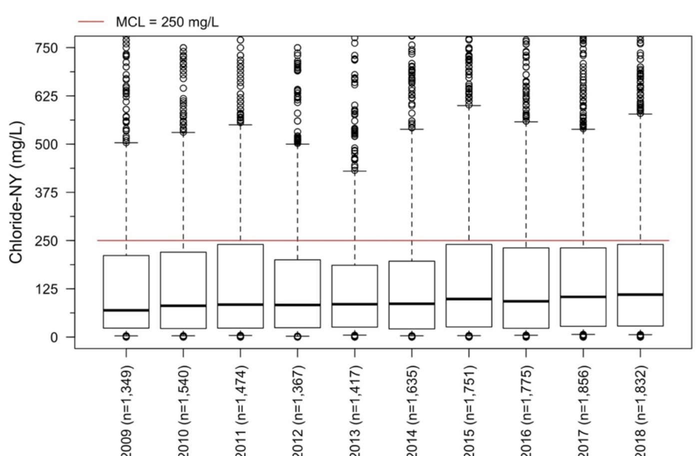
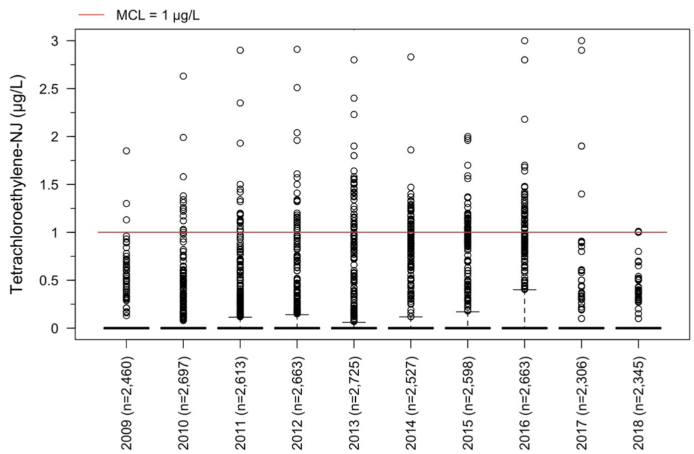


Figure 17 Yearly boxplots of tetrachloroethylene (PCE) occurrence data in New Jersey (2009-2018)



Decreasing trend

The remaining contaminants shown in Table 13 were found to have a decreasing trend from 2009 to 2018 based on their annual 95th percentile values. These contaminants include iron (Figure 18), fluoride (Figure 19), and zinc (Figure 20) in New York. As mentioned above, there is a federal secondary standard for iron of 0.3 mg/L. New York regulated iron at the same level as the secondary standard. Fluoride is federally regulated with an MCL of 4 mg/L. New York regulates fluoride with a lower MCL of 2.2 mg/L. Similar to iron, New York regulates zinc at a level equivalent to its federal secondary standard of 5 mg/L. Annual 95th percentile iron concentrations were well above the MCL of 0.3 mg/L, despite a decrease over time. This suggests iron may remain a contaminant of concern in New York in the next 5-10 years. Annual 95th percentile values for fluoride and zinc were well below their respective MCLs and there were limited occurrences over the MCL suggesting these contaminants may be of less concern.

Figure 18 Yearly boxplots of iron concentration data in New York (2009-2018)

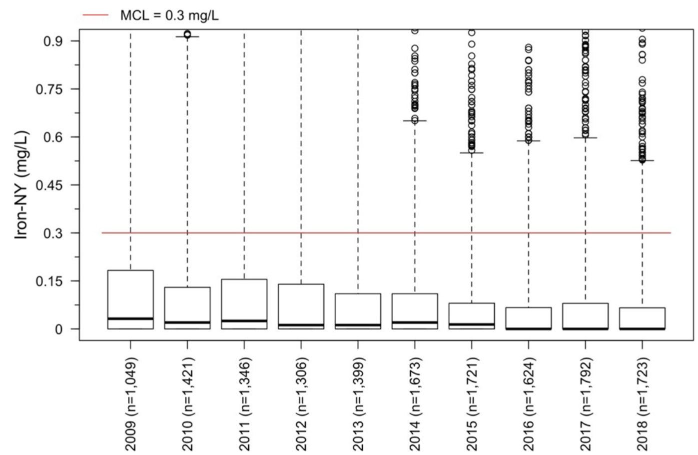


Figure 19 Yearly boxplots of fluoride occurrence data in New York (2009-2018)

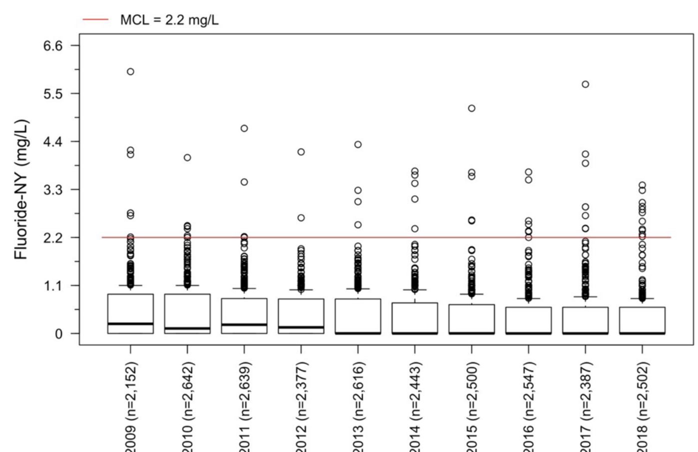
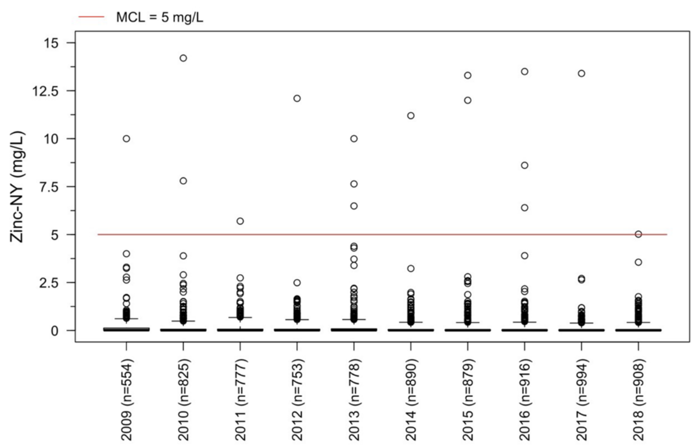


Figure 20 Yearly boxplots of zinc occurrence data in New York (2009-2018)



3: Evaluate Data Gaps

The objective of Task 3 is to explore other resources outside of violation data and UCMR data sets that were used in Task 1 and occurrence data that were used in Task 2 to identify contaminants likely to be a concern for the next 5-10 years. Concern for contaminants can be generated from regulatory changes, which identify the health risks of contaminants as well as the potential for an increase in violations, at least temporarily, while systems respond to changes in standards. Concern can also be generated through academic research, publications, and news articles, which can inform the public about drinking water contaminants and potential health risks. This task explores the upcoming regulatory horizon through a review of EPA's draft Fifth Contaminant Candidate List (CCL5), revisions to the lead & copper rule (LCR), future federal PFAS regulations, and potential Microbial and Disinfectant & Disinfection Byproduct (M/DBP) Rule revisions, among other state-specific potential regulatory changes and emerging contaminants of regulatory interest. Additionally, recent publications and news articles were reviewed to identify top contaminants for research interest and causing public consumer concerns.

EPA's Draft Fifth Contaminant Candidate List (CCL5)

The USEPA's Contaminant Candidate Lists (CCLs) are lists of contaminants that are:

- Not currently subject to any proposed or promulgated national primary drinking water regulations (NPDWRs)
- Known or anticipated to occur in public water systems
- May require future regulations under the Safe Drinking Water Act

The current Draft CCL was released on July 19, 2021 (USEPA 2021a). The draft list includes 66 chemicals, three chemical groups (PFAS, cyanotoxins, and DBPs), and 12 microbes. The contaminants were selected from known chemicals used in commerce, pesticides, biological toxins, disinfection byproducts, and waterborne pathogens. The full draft CCL5 chemical list is shown in Table 16. The full DBP list and microbial list are shown in Table 17 and Table 18, respectively.

Table 16 EPA's Draft CCL5 Chemical List

1,2,3-Trichloropropane	Desisopropyl atrazine	Oxyfluorfen
1,4-Dioxane	Desvenlafaxine	Per- and polyfluoroalkyl substances (PFAS)
17-alpha ethynyl estradiol	Diazinon	Permethrin
2,4-Dinitrophenol	Dicrotophos	Phorate
2-Aminotoluene	Dieldrin	Phosmet
2-Hydroxyatrazine	Dimethoate	Phostebupirim
4-Nonylphenol (all isomers)	Disinfection Byproducts (DBPs) (see Table 17)	Profenofos
6-Chloro-1,3,5-triazine-2,4-diamine	Diuron	Propachlor
Acephate	Ethalfluralin	Propanil
Acrolein	Ethoprop	Propargite
alpha-Hexachlorocyclohexane (alpha-HCH)	Fipronil	Propazine
Anthraquinone	Fluconazole	Propoxur
Bensulide	Flufenacet	Quinoline
Bisphenol A	Fluometuron	Tebuconazole
Boron	Iprodione	Terbufos
Bromoxynil	Lithium	Thiamethoxam
Carbaryl	Malathion	Tri-allate
Carbendazim (MBC)	Manganese	Tribufos
Chlordecone (Kepone)	Methomyl	Tributyl phosphate
Chlorpyrifos	Methyl tert-butyl ether (MTBE)	Trimethylbenzene (1,2,4-)
Cobalt	Methylmercury	Tris(2-chloroethyl) phosphate (TCEP)
Cyanotoxins	Molybdenum	Tungsten
Deethylatrazine	Norflurazon	Vanadium

Table 17 EPA's CCL5 DBP List

Group	Chemical
Haloacetic Acids	Bromochloroacetic acid (BCAA), Bromodichloroacetic acid (BDCAA), Dibromochloroacetic acid (DBCAA), Tribromoacetic acid (TBAA)
Haloacetonitriles	Dichloroacetonitrile (DCAN), Dibromoacetonitrile (DBAN)
Halonitromethanes	Bromodichloronitromethane (BDCNM), Chloropicrin (trichloronitromethane, TCNM), Dibromochloronitromethane (DBCNM)
Iodinated Trihalomethanes	Bromochloroiodomethane (BCIM), Bromodiiodomethane (BDIM), Chlorodiiodomethane (CDIM), Dibromoiodomethane (DBIM), Dichloroiodomethane (DCIM), Iodoform (triiodomethane, TIM)
Nitrosamines	Nitrosodibutylamine (NDBA), N-Nitrosodiethylamine (NDEA) N-Nitrosodimethylamine (NDMA), N-Nitrosodi-n-propylamine (NDPA), N-Nitrosodiphenylamine (NDPhA), Nitrosopyrrolidine (NPYR)
Other	Chlorate, Formaldehyde

Table 18 EPA's CCL5 Microbial List

Microbial Class	Microbial Class
Bacteria	*Campylobacter jejuni, Escherichia coli (O157), Helicobacter pylori, Legionella pneumophila, Mycobacterium abscessus, Mycobacterium avium, Pseudomonas aeruginosa, Shigella sonnei*
Protozoa	*Naegleria fowleri*
Virus	Adenovirus, Caliciviruses, Enteroviruses

The most notable contaminants in the draft CCL5 based on potential future federal or state regulatory actions or current state regulations, as well as public and research interest, include 1,2,3-trichloropropane, 1,4-dioxane, cyanotoxins, DBPs especially unregulated haloacetic acids, *Legionella pneumophila,* manganese, and PFAS. Currently, 1,2,3-trichloropropane is regulated in California, Hawaii, and New Jersey, 1,4-dioxane is regulated in California and New York, and manganese is regulated in California New York, and North Carolina. Cyanotoxins, manganese, and unregulated haloacetic acids were recently included in EPA's UCMR4. EPA is currently obligated to propose revisions to microbial, disinfectant and disinfection byproduct (M/DBP) rules, which is described further in the section on M/DBP rule revisions below. Potential M/DBP rule revisions may include unregulated haloacetic acids and *Legionella pneumophila*.

Lead & Copper Rule Revisions

The EPA's Lead and Copper Rule Revisions (USEPA 2021b) (LCRR), published on January 15, 2021, became effective as of December 16, 2021 with a scheduled compliance date of October 16, 2024. The LCRR keeps the action level of 15 µg/L for lead, and it establishes a 10 µg/L "trigger level". At this trigger level, systems that currently treat for corrosion are required to re-optimize their existing treatment and systems that do not currently treat for corrosion will be required to conduct a corrosion control study. Systems above the trigger level may also be required to increase their lead service line (LSL) replacement rate. The revised rule also requires community water systems to conduct testing for lead in drinking water and public education in schools and childcare facilities. The most relevant update to the Lead and Copper Rule for the POU/POE industry is that the revised rule now allows community water systems serving populations equal to or less than 10,000 and all non-transient non-community water systems to achieve compliance through the provision and maintenance of POU devices that are certified to reduce lead concentrations (USEPA 2019, WQA 2022).

EPA also published their Review of the National Primary Drinking Water Regulation: Lead and Copper Rule Revisions (USEPA 2021c) on December 17, 2021. In their review, EPA describes their intention to propose a new rule to revise the LCRR to meet goals of replacing 100% of lead service lines (LSLs), equitably improve public health protection for those who cannot afford to replace the customer-owned portions of their LSLs, improve the methods to identify and trigger action in communities that are most at risk of elevated drinking water lead levels, and explore ways to reduce the complexity of the regulations.

The regulatory developments around the lead and copper rule (LCR) and its revisions demonstrate the level of importance and urgency around the topic of lead in drinking water. The removal of 100% of LSLs could dramatically reduce lead concentrations in drinking water, but even in the best possible scenario it will take many years to complete. Lead, as well as copper, will therefore remain major contaminants of concern for the next 5-10 years.

Federal and State PFAS Regulations

The US EPA is currently working towards setting drinking water regulations for PFAS, with developments planned for the next several years. Table 19 summarizes past, current, and planned future federal actions on PFAS, starting with UCMR3 monitoring during 2013 through 2015. Plans for 2022 and 2023 include the release of health advisories for GenX and PFBS, proposed and final regulations for PFOA and PFOS, and the start of UCMR5, which will require PWSs to monitor for 29 PFAS analytes.

Beyond federal regulations, states including California, Connecticut, Illinois, Massachusetts, Michigan, Minnesota, New Hampshire, New Jersey, New York, North Carolina, Vermont, and Washington have set their own regulations or health advisories levels. State regulations include different PFAS analytes and different MCLs.

Based on the current and future regulatory framework for PFAS, as well as the upcoming UCMR5 monitoring, it is anticipated that PFAS will remain a major contaminant group of concern for the next 5-10 years. UMCR5 is expected to provide the most comprehensive PFAS occurrence data to date, which will provide a better understanding of the extent of contamination as well as treatment needed to meet future regulatory levels and health-based goals.

Table 19 Timeline of past, current, and planned future federal actions on PFAS

Date	Action
2013 – 2015	EPA required PWSs to monitor for 6 PFAS analytes as part of UCMR3
May 25, 2016	EPA released lifetime health advisory levels for two PFAS analytes, PFOA and PFOS
June 20, 2018	US Department of Health and Human Services' Agency for Toxic Substance & Disease Registry (ATSDR) released their Toxicological Profile for Perfluoroalkyls draft for public comment
March 3, 2021	EPA published the Fourth Regulatory Determinations (USEPA 2021d), with a final determination to regulate PFOA & PFOS in drinking water
May, 2021	The ATSDR released their final Toxicological Profile for Perfluoroalkyls
October 18, 2021	EPA announced a PFAS Strategic Roadmap
Fall 2021 and ongoing	EPA to publish final toxicity assessment for GenX and five additional PFAS – PFBA, PFHxA, PFHxS, PFNA, and PFDA
2022 and ongoing	EPA plans to restrict PFAS discharges from industrial sources through a multi-faceted Effluent Limitations Guidelines program
June 15 2022	EPA released interim health advisories for PFOA (0.004 ppt) and PFOS (0.02 ppt) and final health advisories for GenX (10 ppt) and PFBS (2,000 ppt)
Fall 2022	EPA expects to issue a proposed regulation for PFOA & PFOS
2023 – 2025	EPA will require PWSs to monitor for 29 PFAS analytes as part of UCMR5
Fall 2023	EPA expects to issue a final rule for PFOA & PFOS

Potential Microbial and Disinfectant & Disinfection Byproduct (MDBP) Rule Revisions

In 2020, EPA reached a settlement agreement with the Waterkeepers Alliance, Inc. that commits EPA to propose revisions to the current primary standards for chlorite, *Cryptosporidium*, *Giardia lamblia*, haloacetic acids, heterotrophic bacteria, *Legionella*, TTHM, and viruses, by Nov. 31, 2024 unless action is delayed by EPA seeking data through an information collection rule or input from a federal advisory committee. EPA hosted an initial two-day workshop in October 2020 followed by a series of MDBP Stakeholder Meetings throughout 2021 to solicit input on improving public health protection from M/DBPs in drinking water. DBPs, including unregulated haloacetic acids, and *Legionella*, in particular *Legionella pneumophila*, as well as minimum disinfectant residual requirements, distribution system and storage tank management, and building water system quality were all topics of interest throughout these meetings.

In November 2021, EPA requested that the National Drinking Water Advisory Council (NDWAC), a Federal Advisory Committee (FAC) established under the Safe Drinking Water Act (SDWA), provide the agency with advice and recommendations on key issues related to potential revisions to MDBP rules. The inclusion of the NDWAC is expected to delay any proposed revisions until 2025. As a result, MDBPs, especially *Legionella*, TTHM, and haloacetic acids are anticipated to be contaminants of concern for the next 5-10 years.

Other Evidence for Identifying Contaminants of Concern

General research was conducted by reviewing recent publications, conference presentations, news articles, and shared information among the drinking water community to identify contaminants of the greatest concern. The sources of information and summary of results are presented in Table 20. Top contaminants of concern identified include PFAS, lead, arsenic, DBPs, nitrate, *Legionella*, pesticides/insecticides, harmful algal blooms, fluoride, microplastics, perchlorate, 1,2,3-trichloropropane, 1,4-dioxane, chromium-6, and vanadium.

Table 20 Summary of general research to identify drinking water contaminants of concern

Sources of Information	Summary of Results
Web search utilizing key words: "drinking water", "drinking water contaminants"	• PFAS regulations (federal and various state-specific) • Lead contamination (various locations) • Responses to the Environmental Working Group's (EWG) tap water database (multiple contaminants, including PFAS, arsenic, lead, DBPs, nitrate, etc.) • Nitrate and impact of climate change • Boil water orders and infrastructure issues • Taste & odor related issues, i.e., chemical smell, brown water, etc. • Nanomaterials • Other contaminants, including radium and fluoride
Review of recent peer-reviewed publications and conference presentations	• PFAS (treatment, regulations, risk communication, sources, analysis) • Lead (solubility, pipe scales, lead service line detection, reduction, sampling) • Pesticides/insecticides (occurrence, exposure, health risks, removal) • Plastics/microplastics (occurrence, removal) • Harmful algal blooms • DBPs (nitrosamines, regulated, nitrogenous DBPs, formation and control) • Other topics: Affordability, *Legionella pneumophila*, nitrate, arsenic, fluoride, and vanadium
Other potential state-specific regulatory changes	• California's Department of Drinking Water (DDW) released a new revised draft regulation for chromium-6 on March 21, 2022 (California Water Boards 2022)
Drinking water community shared information	• The American Water Works Association (AWWA) held a virtual roundtable *Legal and Regulatory Issues in the Water Space: An Update As 2021 Comes to a Close* on December 10, 2021 that discussed developments with emerging contaminants including PFAS, perchlorate, 1,2,3-trichloropropane, NDMA and other nitrosamines, and 1,4-dioxane • The Association of State Drinking Water Administrators (ASDWA) highlights three contaminants in their special topics pages of their website: lead, PFAS, and *Legionella* • A list of emerging contaminants that consumers are aware from WQRF's Emerging Contaminants Consumer Study by Dr. Marcia Silva at UWM identified the following top ten contaminants: pesticides/herbicides, pharmaceuticals, microplastics, personal care products, PFAS, antimicrobial resistant bacteria, algal blooms, mycobacteria, 1,4-dioxane, and flame retardants

4: Review Chemical Production and Release Databases

The objective of Task 4 was to review EPA's Toxic Substances Control Act (TSCA) Chemical Data Reporting (CDR) and Toxics Release Inventory (TRI) datasets for chemical production, use and release quantities and trends.

The TSCA CDR database includes basic production and exposure-related information for substances produced domestically and imported into the United States. The EPA requests this information every four years from manufacturers, most recently in 2016 (the 2020 data are not yet released). Small manufacturers and certain chemicals are exempt from reporting, and the identity or other information may be withheld from the publicly available dataset if it is claimed as Confidential Business Information and approved by EPA.

The TSCA CDR dataset was used in this analysis to answer the following questions to inform the predictive model:

1) Which chemicals are most commonly produced or imported to the US?
2) Which chemicals are newly produced or imported to the US?
3) Which chemicals have increasing or decreasing trends in production volumes?
4) Which of the most commonly produced chemicals are regulated in drinking water?

The TRI dataset includes information reported by certain specified industries (e.g., manufacturing, chemical manufacturing, hazardous waste treatment) relating to the quantity of toxic chemicals released to the environment or for disposal, reuse or further waste processing. Many of these releases are regularly occurring planned releases related to the management of waste products, but unintended spills or releases are also recorded if the reporting threshold is tripped. The program is intended to provide the public with information about releases of toxic chemicals in their communities and support emergency planning. TRI data are submitted by industries annually and include information about the identity and quantity of material released as well as the release pathway (e.g., air, land, water). Most petroleum mixtures (i.e., gas and diesel) are not directly reportable to the TRI program, although certain common components of petroleum mixtures are on the TRI chemical list (e.g., toluene, benzene). From other data sources, such as the EPA's National Response Center, petroleum mixtures are reported to be among the most commonly released substances. These substances may be under-represented releases in the TRI dataset.

The TRI dataset was used in this analysis to answer the following questions to inform the predictive model:

1) Which toxic chemicals are most commonly released to the environment?
2) Which toxic chemicals are released in the greatest volumes?
3) Which toxic chemicals have increasing or decreasing trends in release volumes?
4) Which of the most commonly released toxic chemicals are regulated?

Methods

TRI and TSCA CDR datasets were downloaded to cover multiple years in the last decade. TRI is released yearly, with the most recent data from 2020. A total of nine years, from 2012 to 2020, were downloaded and processed. The latest dataset for TSCA CDR is 2016 with updates from 2020, but each iteration of the TSCA dataset includes production volume values from past years. The 2016 TSCA CDR dataset includes production volumes from 2016, 2014, 2013 and 2012.

TSCA CDR Data Processing

The TSCA CDR dataset contains four separate files related to different aspects of chemical production. Production information is separated into Consumer and Commercial Use, Industrial Processing and Use, and Manufacturing Information, and the EPA also provides a dataset of nationally aggregated production volumes. The first three files were combined and reduced to a single record per chemical at a facility. The physical forms of each reported chemical were provided, and facilities that only reported chemicals in a solid or gaseous form were excluded from the analysis.

The National Aggregate file provides a range or single value for the national production volume for each chemical. This value is presumed to include production volumes redacted in the public facility dataset as CBI. Chemical ranges in this dataset were not standardized (e.g., some facilities reported a range of 1-10,000 while others reported 1-5,000 or 5,000-10,000). A set of standardized ranges was produced that covered the range of reported volumes. The file was then processed to sort all entries into the applicable range. The low end of each reported range value was used as a single value to sort each chemical into the new standardized ranges to evaluate national production from the National Aggregate file.

Annual production statistics were also evaluated in more detail for each chemical by compiling facility level data. Reported production volumes from individual facilities were aggregated into national and statewide totals to facilitate ranking production volumes within the standardized bins. Facilities reporting a range for production volumes were removed from calculation, as well as entries redacted for confidentiality. Results for the most commonly produced chemicals, chemical categories (see below) and chemicals in the available drinking water quality database (Task 2) are presented below along with statistics for the greatest production volumes.

TRI Data Processing

The TRI dataset consists of one file with many fields covering the breakdown of release pathways. Each yearly file was filtered to applicable columns and output into a single file covering 9 years. The data were then aggregated to national and state release totals by chemical and chemical category (see below). Results for the most commonly released chemicals and chemical categories were calculated along with statistics for the greatest release volumes.

To understand the distribution of both manufactured and released chemicals, chemical names for both the TRI and TSCA CDR datasets were placed into categories using a database developed by Corona for an EPA assessment of acute contamination threats to public water supplies in the United States. These categories were broadly developed to reflect general chemical characteristics most relevant to drinking water systems, such as human health toxicity and treatability. The TRI dataset is limited to toxic chemicals, which are generally those causing cancer or other chronic human health effects, significant adverse acute human health effects or significant adverse environmental effects. The TRI list currently contains 770 chemicals and 33 chemical categories, many of which were encountered during development of the EPA chemical category matching dataset. This overlap lead to the majority of chemicals in the merged TRI dataset being successfully matched to a chemical category by chemical abstract service number (CAS) or chemical name. After a review of the unmatched chemicals, only one chemical name out of 595 was left unmatched. In contrast, the TSCA CDR dataset contains any substance produced or imported into the United States above the reporting threshold regardless of toxicity. Only 48% of the total chemicals in the TSCA CDR dataset were successfully matched using the previously developed EPA database. However, it is expected that most of the contaminants of greatest interest to the drinking water community would be among the list of contaminants that were matched to a category.

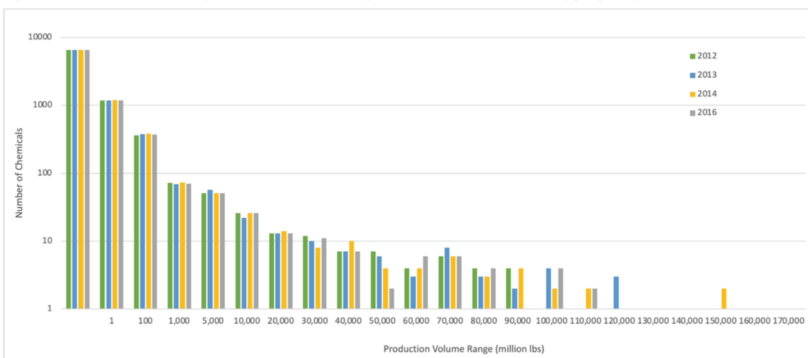
The TRI dataset includes data for releases to multiple air, water and ground pathways. Releases to air may be expected to have a different magnitude of impact on drinking water quality than releases to water or ground due to the additional fate and transport mechanisms involved in air transport and deposition. To investigate whether any of the top contaminants released by volume and occurrence were dominated by releases to air, the top 10 list was reviewed for the set of facilities with no releases to air. Releases to air were defined as the sum of the 'Fugitive Air' and 'Stack Air' data fields from the TRI dataset. (Products sent to incinerators are considered 'off-site treatment' and are not included the release totals in the TRI dataset.)

Results

TSCA CDR Results

The TSCA CDR dataset included 8,316 unique chemicals, covering over 35,000 entries at specific facilities. Overall chemical production was relatively similar across the four years included in the dataset (Figure 21). Seventy-eight percent of chemicals were produced at quantities under 1 billion pounds.

Figure 21 Annual number of TSCA CDR chemicals for each binned national aggregate production volume



When aggregated by chemical category, the greatest production volumes in 2016 were for petroleum products (excluding diesel and gasoline), organic chemicals and inorganic chemicals (Figure 22). However, the total production volume of chemicals that were not matched to any category was second only to petroleum products in total production volume. A quick skim of the list of uncategorized contaminants revealed a wide variety of chemicals and mixtures. Additional research would be required

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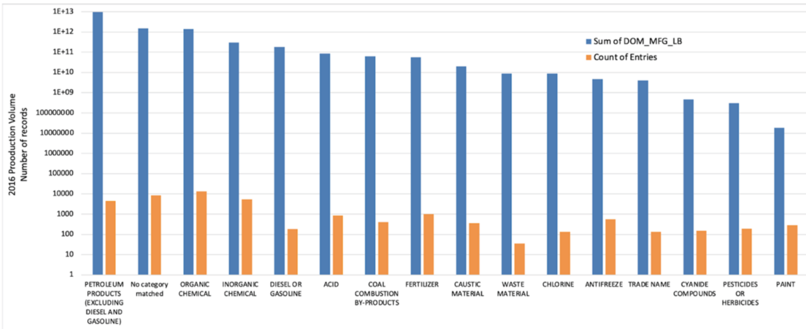
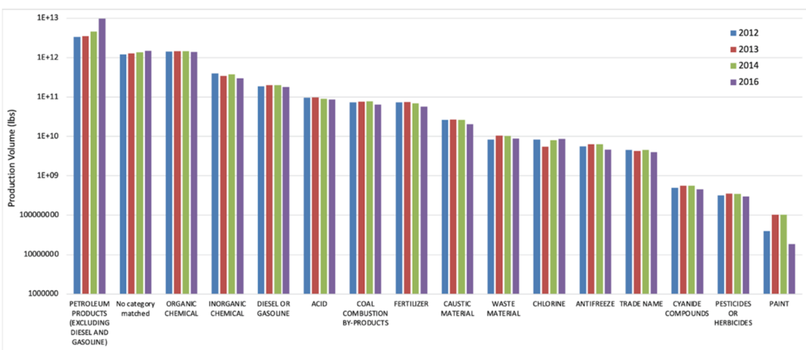
to confidently place these substances into one of the established chemical categories. Several of the chemical categories with the largest production volumes are likely to contain substances with state or federal drinking water regulations, such as Cyanide Compounds, Pesticides or Herbicides, Organic Chemicals, etc.

Figure 22 TSCA CDR total production volume and frequency of production for 2016 aggregated by chemical category



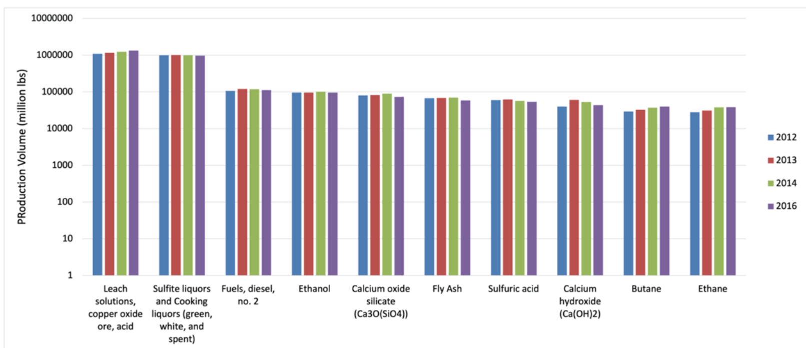
Chemical production volumes by category remained relatively stable over the 4-year study period, except for paint, which had variable production volume from year to year and petroleum products, which showed an increasing trend in production volume over time (Figure 23).

Figure 23 The TSCA CDR production volume aggregated by chemical category over 4 years



Annual production data for the top ten chemicals produced in the greatest volumes in the United States are displayed in Figure 24. Production volumes for each of the top 10 chemicals remained relatively constant over the study period, with the exception of a slight increase in butane and ethane. Leach solutions, a byproduct of mining/metallurgy operations, and sulfite liquors, a byproduct of paper pulp manufacturing, exceeded production in the other categories by approximately an order of magnitude. None of the top 10 chemicals by production volume have federal MCLs, although leach solutions, sulfite liquors and fly ash (a chemically diverse byproduct of coal combustion) are mixtures that may contain federally regulated substances. Butane and ethane are generally gaseous at under atmospheric pressure and temperature and thus are not anticipated to pose a significant threat to drinking water quality.

Figure 24 Annual production volumes for the top ten chemicals produced in the greatest volumes in 2016



The 60 chemicals produced or imported in 2016 that were not previously reported in 2012, 2013 or 2014 are listed below. Further review of the fate, transport, potential health impacts and treatability of these substances may identify a set of contaminants that could become priorities farther in the future, as the drinking water quality and public health impacts of many of these substances are likely not well understood.

- 1-Butanol, 3-methyl-
- 1-Hexadecanol, 1-(dihydrogen phosphate), potassium salt (1:1)
- 1-Propene, 1-chloro-3,3,3-trifluoro-, (1E)-, manufacturing of, residues
- 1,2-Benzenedicarboxylic acid, 1,2-dihexyl ester
- 1,2-Benzenedicarboxylic acid, di-C11-14-branched alkyl esters, C13-rich
- 2-Butenedioic acid (2Z)-, 1-dodecyl ester
- 2-Naphthalenesulfonic acid, 6-hydroxy-5-[2-(2-methoxy-5-methyl-4-s ulfophenyl)diazenyl]-, sodium salt (1:2)
- 2-Propen-1-amine
- 2-Propen-1-amine, N-2-propen-1-yl-
- 2-Propen-1-amine, N-ethyl-2-methyl-
- 3,8-Dioxa-4,7-disiladecane, 4,4,7,7-tetraethoxy-

- 4-Undecanol, 7-ethyl-2-methyl-
- 7-Octen-2-ol, 2-methyl-6-methylene-, 2-acetate
- 9-Octadecenoic acid (9Z)-, 2,3-dihydroxypropyl ester
- Acetic acid, ammonium zinc salt (1:?:?)
- Aliphatic glycol (PROVISIONAL)
- Alkanes, C10-13-branched and linear
- Alkanes, C12-15-branched and linear
- Alkanes, C14-16-branched and linear
- Alkanes, C15-19-branched and linear
- Alkanes, C18-24-branched and linear
- Alkanes, C8-11-branched and linear
- Alkanes, C9-12-branched and linear
- Alkanes, C9-13-branched and linear
- Benzene, octyl-
- Benzenepropanal, .alpha.,.alpha.-dimethyl-
- Benzenesulfonic acid, C16-24-alkyl derivs.
- Benzothiazole, 2-[(chloromethyl)thio]-
- Betaines, C10-16-alkyl(2-hydroxy-3-s ulfopropyl)dimethyl
- Carbon fluoride
- Chromium, 4-hydroxy-3-[2-(2-hydroxy-1-n aphthalenyl)diazenyl]benzenesulfonamide N-[7-hydroxy-8-[2-(2-hydroxy-5-n itrophenyl)diazenyl]-1-n aphthalenyl]acetamide lithium sodium complexes
- D-Fructose
- Distillates (petroleum), naphtha-raffinate pyrolyzate-derived, gasoline-blending
- Fatty acids, C18-unsatd., dimers, reaction products with diethylenetriamine
- Fatty acids, tall-oil, compds. with oleylamine
- Fatty acids, tall-oil, reaction products with 2-[(2-aminoethyl)amino]ethanol
- Fatty acids, unsaturated, reaction products with unsaturated heterocycle (PROVISIONAL)
- Fatty acids, vegetable-oil, reaction products with diethylenetriamine, acetates
- Glycine, N,N'-1,2-ethanediylbis[N-(carboxymethyl)-, potassium salt (1:4)
- Hexanoic acid, 3,5,5-trimethyl-, 1,1'-[2-ethyl-2-[[(3,5,5-trimethyl-1-o xohexyl)oxy]methyl]-1,3-propanediyl] ester
- Isononanoic acid, 2-ethylhexyl ester
- Isononanoic acid, C16-18-alkyl esters
- Isononanoic acid, triester with 2,2'-[oxybis(methylene)]bis[2-(hydroxymethyl)-1,3-propanediol] tris(2-ethylhexanoate)
- Magnesium, chloromethyl-
- Maleate mixed esters with straight and branched alkyl alcohols (PROVISIONAL)
- Morpholine, 4-ethyl-
- Morpholinium, 4-dodecyl-4-ethyl-, ethyl sulfate (1:1)
- Morpholinium, 4-ethyl-4-hexadecyl-, ethyl sulfate (1:1)
- Phosphinic acid, calcium salt (2:1)
- Phosphorous acid, tris(methylphenyl) ester
- Polyaromatic organophosphorus compound (PROVISIONAL)

- Propanoic acid, 2,3,3,3-tetrafluoro-2-(1,1,2,2,3,3,3-heptafluoropropoxy)-
- Propanoic acid, 2,3,3,3-tetrafluoro-2-(1,1,2,2,3,3,3-heptafluoropropoxy)-, ammonium salt (1:1)
- Pyridine, alkyl derivs., acetates
- Quaternary ammonium compounds, (oxydi-2,1-ethanediyl)bis[coco alkyldimethyl, dichlorides
- Reaction product of alkylthioalcohol and substituted phosphorus compound (PROVISIONAL)
- Sulfonic acids, C15-20-alkane hydroxy and C15-20-alkene, sodium salts
- Sulfurized hydrocarbon
- Tetradecane, naphthalenediylbis-
- Tetradecane, naphthalenetriyltris-

The EPA allows companies to redact certain Confidential Business Information (CBI) from the publicly available TSCA CDR dataset. The identity of the chemical may not be withheld but other production and facility information may be claimed as CBI and withheld (Table 21). Information about the parent company is withheld at a rate nearly twice that of the site company. More than one third of production volumes for 2016 are redacted as CBI. Over the four-year record, the percentage of redacted production volumes decreased by 8%.

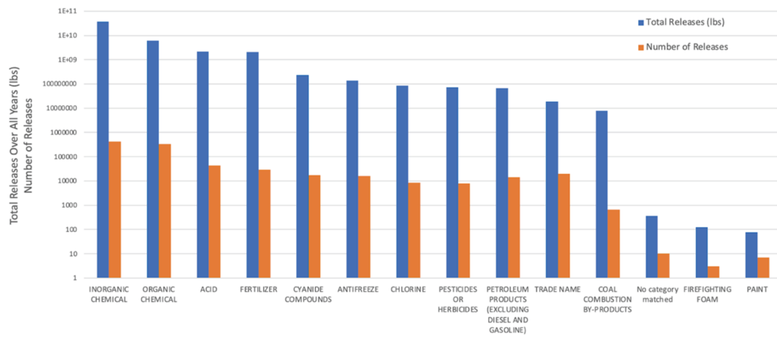
Table 21 Number and Percent of Confidential Business Information (CBI) entries in the TSCA CDR dataset for 2016

Data Field	Number of CBI Records	Percent of CBI Records
CASRN	0	0
Chemical Name	0	0
2016 Domestic Production	12991	37
2014 Domestic Production	14961	42
2013 Domestic Production	12899	42
2012 Domestic Production	15587	44
Parent Name	4131	12
Parent Address	4131	12
Parent State[1]	4131	12
Site Name	2223	6.3
Site Address	2223	6.3
Site State	2223	6.3

TRI Results

The total mass of releases over the 9-year study period from 2012-2020 generally follows the same distribution as the number of releases (Figure 25). Inorganic and organic chemicals have both the greatest total number of releases and release amounts. Acids and fertilizers are the next two categories released most frequently and in the greatest masses. Petroleum products included in the TRI dataset are naphthalene, polychlorinated biphenyls, and polychlorinated alkanes; diesel and gasoline products are excluded from reporting. Several of the chemical categories are likely to contain regulated substances, such as Cyanide Compounds, Pesticides or Herbicides, Organic Chemicals, etc. In the next phase of work, we will investigate whether these releases are primarily to air, which may have a more diffuse impact on drinking water sources, or other pathways that might affect drinking water sources more directly (e.g., land or water).

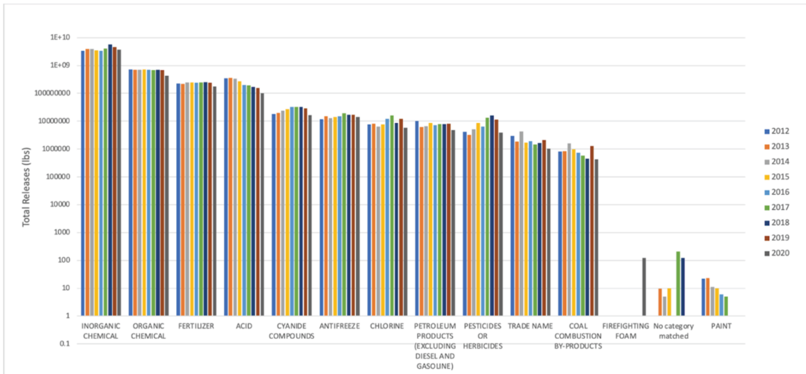
Figure 25 Number and cumulative quantity of releases by chemical category in the TRI dataset (2012-2020)



The trend in releases of toxic substances over the study period is variable by category (Figure 26). Organic, inorganic, fertilizer, non-diesel or gasoline petroleum products and antifreeze chemical releases have not significantly changed since 2012. However, acids, coal combustion by-products, and trade name chemical releases appear to be decreasing in total released mass since 2012. Other categories, such as chlorine, cyanide compounds, and pesticides/herbicides do not have obvious trends. Firefighting foam was introduced as a reportable chemical category in 2020 with the introduction of certain per- and polyfluoroalkyl substances (PFAS) to the list of reportable substances under the TRI program. Some of the firefighting foams contain PFAS that are likely to be regulated at the federal level soon and are already regulated in some states. Paint was last reported as released in 2017 when a single paint product with a unique chemical fingerprint was reported.

A small but noticeable decrease in releases was observed for reporting year 2020 across all of the chemical categories. Fertilizer and organic chemicals demonstrate this trend most obviously. Our hypothesis is that this consistent decrease in 2020 is likely due to supply chain challenges during the Coronavirus-19 pandemic. It would be interesting to compare this trend against 2020 TSCA CDR chemical production and import data when it becomes available.

Figure 26 Annual release totals for all chemical categories 2012-2020

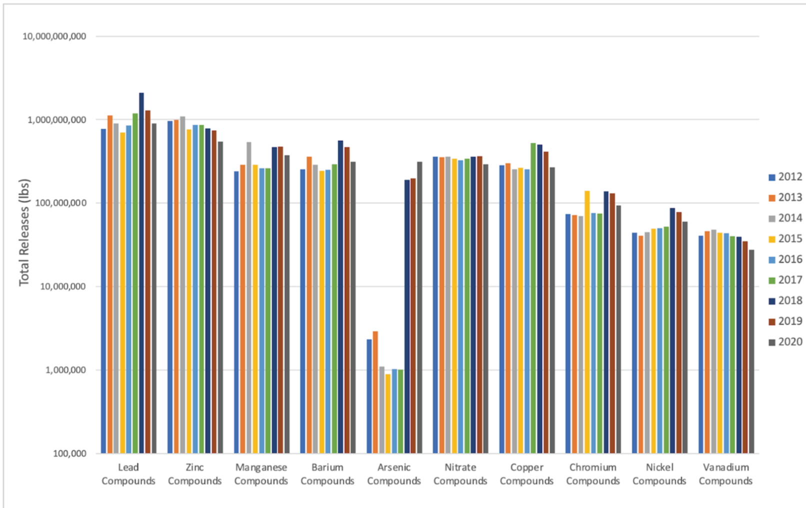


In the category with the greatest released mass, inorganic chemicals, six have federal MCLs chemicals (arsenic, barium, chromium, copper, nickel, and nitrate compounds) (Figure 27). Except for arsenic compounds, each of the top ten inorganic chemicals displayed the same decrease in releases in 2020 that was seen in the category as a whole.

Despite the 2020 decrease and overall variable releases, seven of the most commonly released substances had increasing releases overall from 2012 to 2020. Barium, lead, copper, manganese, nickel, and chromium had modest increases in 2017/2018 and are still above former levels despite the 2020 drop. Arsenic compound releases increased significantly in 2018, and this is the only category for which releases increased in 2020. Vanadium and zinc releases were the only two among the top 10 inorganic chemicals to decrease. Nitrate releases were stable over the study period, except for the 2020 drop. Certain chemicals on the list of top 10 released inorganics have federal drinking water standards: arsenic, barium, chromium, copper, nickel, and nitrate all have federal MCLs, and manganese has an SMCL.

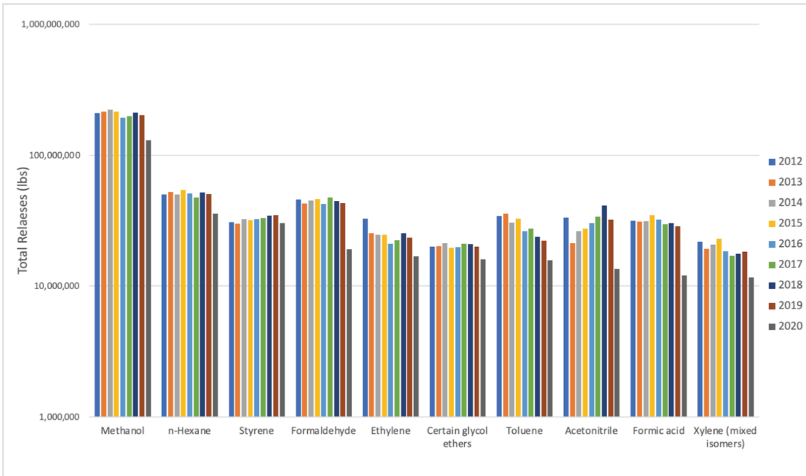
The inorganic chemicals with the top 10 greatest released masses were also the top 10 releases overall, with the exception of methanol and sulfuric acid which replaced nickel and vanadium compounds.

Figure 27 Total releases for the top chemicals in the inorganic category



The category with the second highest total releases was organic chemicals. Figure 28 displays release totals for the top ten chemicals in the organic chemical category. Three of these organic chemicals have federal MCLs (styrene, toluene, and xylene). Unlike the inorganic chemicals, releases of organic chemicals remained relatively stable for six of the ten chemicals (certain glycol ethers, formaldehyde, methanol, formic acid, n-Hexane, and styrene), with the exception of the 2020 drop. Toluene, xylene, and ethylene are generally decreasing, while acetonitrile has increased. A decrease in 2020 is again evident across all chemicals. Two of the three inorganic chemicals with federal MCLs have noticeably decreasing releases across the time period (toluene and xylene), while styrene has remained stable.

Figure 28 Release totals for the top ten chemicals in the organic chemicals category



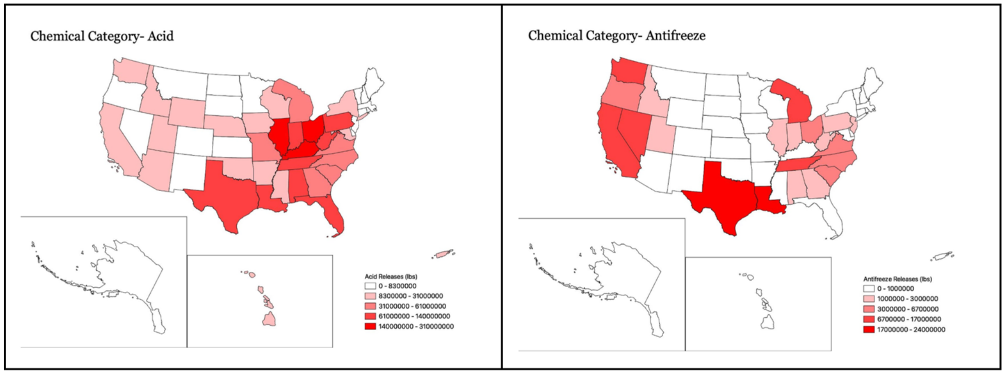
Releases to Air

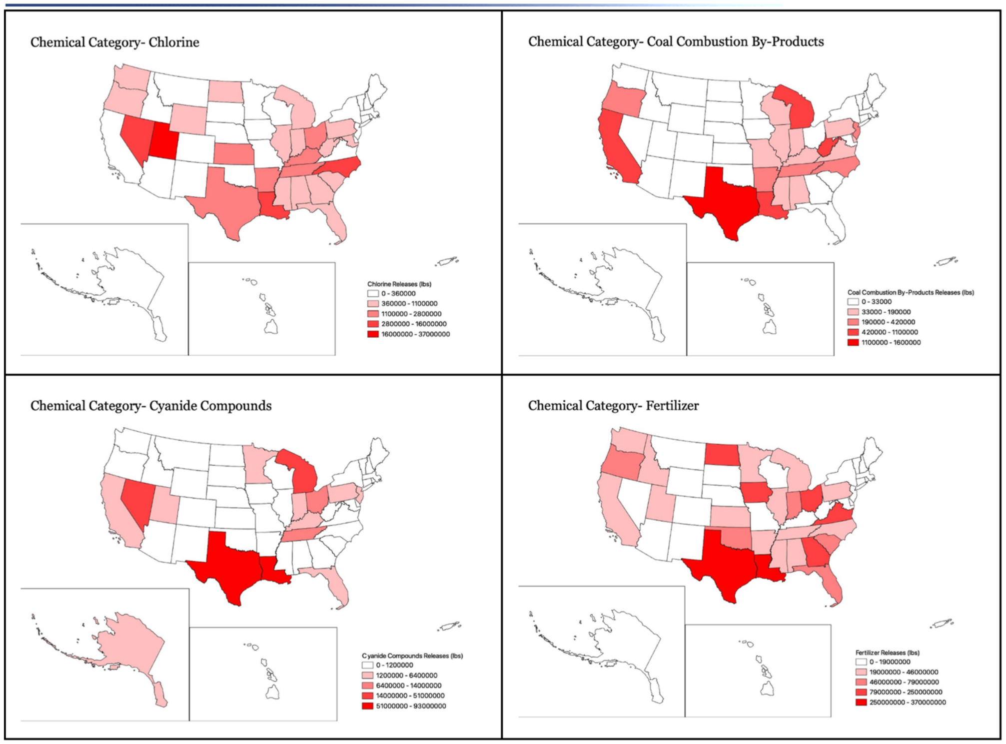
Releases to air in 2020, as defined previously, constituted 14% of the total volume of reported releases. Among facilities with no releases to air, asbestos, sodium nitrite and nitric acid moved up into the list of top 10 chemicals released by volume, pushing lead, arsenic and methanol farther down the list but still within the top 30 releases by volume. Only sulfuric acid was pushed significantly farther down the list, since this chemical was further defined as 'acid aerosols including mists, vapors, gas, fog, and other airborne forms of any particle size' in the TRI dataset. The rest of the list of top 10 released chemicals by volume was unchanged by the inclusion of releases to air.

Regional Release Maps

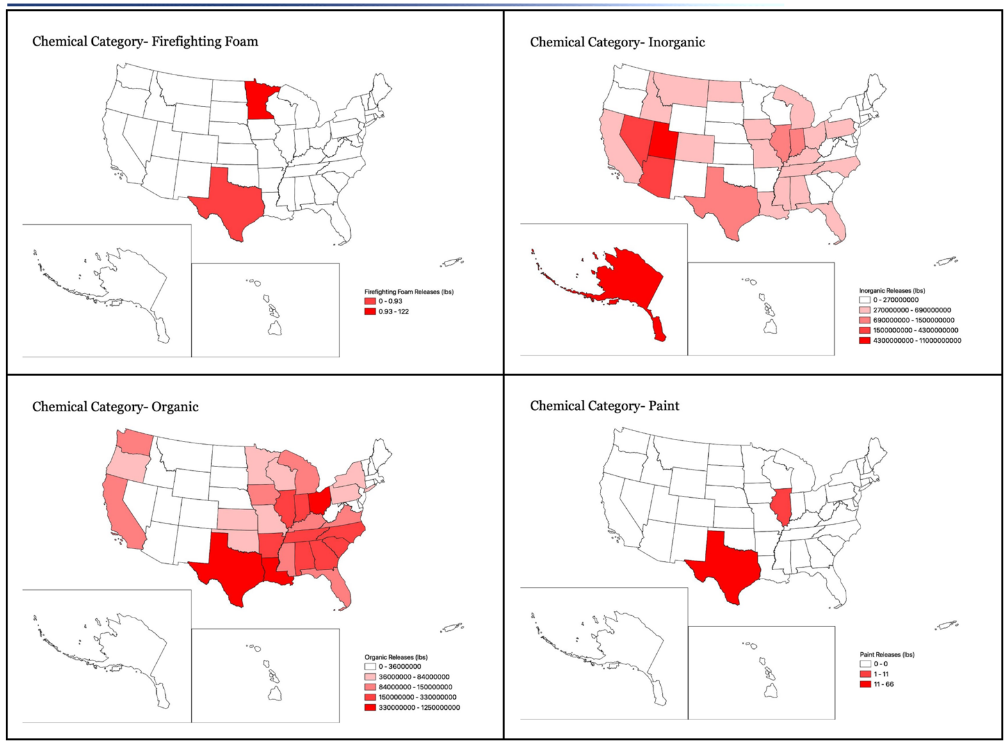
The release of chemicals varies by state due to different levels of production and usage [Fig. 30]. Overall, releases are greatest in the southeastern and southwestern states. Many southern states have large total reported releases in multiple categories due to high levels of production and industry. Texas in particular has significant releases in nearly all chemical categories. By contrast, the northeast has very few and/or small releases across all categories. Releases are typically widespread across the country and are very rarely concentrated in a few states. The two exceptions are firefighting foam and paint, which are only reported in two states. This possibly reflects a niche industry where production of products with reportable substances is concentrated among few companies or factories or confusion over reporting requirements for categories where requirements have changed, as for PFAS in firefighting foams. Interestingly, Alaska had the highest total releases despite only having releases in two categories, inorganic chemicals and cyanide compounds. This result may be due to extensive mining activities, as evidenced by similar patterns for Texas and Nevada, two other states with significant mining activities.

Figure 29 Cumulative releases by category for all states for the study period (2012-2020)





Chemical Category- Chlorine
Chlorine Releases (lbs)
0 - 360000
360000 - 1100000
1100000 - 2800000
2800000 - 16000000
16000000 - 37000000
Chemical Category- Coal Combustion By-Products
Coal Combustion By-Products Releases (lbs)
0 - 33000
33000 - 190000
190000 - 420000
420000 - 1100000
1100000 - 1600000
Chemical Category- Cyanide Compounds
Cyanide Compounds Releases (lbs)
0 - 1200000
1200000 - 6400000
6400000 - 14000000
14000000 - 51000000
51000000 - 93000000
Chemical Category- Fertilizer
Fertilizer Releases (lbs)
0 - 19000000
19000000 - 46000000
46000000 - 79000000
79000000 - 250000000
250000000 - 370000000


Chemical Category- Firefighting Foam
Firefighting Foam Releases (lbs)
0 - 0.93
0.93 - 122
Chemical Category- Inorganic
Inorganic Releases (lbs)
0 - 270000000
270000000 - 690000000
690000000 - 1500000000
1500000000 - 4300000000
4300000000 - 11000000000
Chemical Category- Organic
Organic Releases (lbs)
0 - 36000000
36000000 - 84000000
84000000 - 150000000
150000000 - 330000000
330000000 - 1250000000
Chemical Category- Paint
Paint Releases (lbs)
0 - 0
1 - 11
11 - 66

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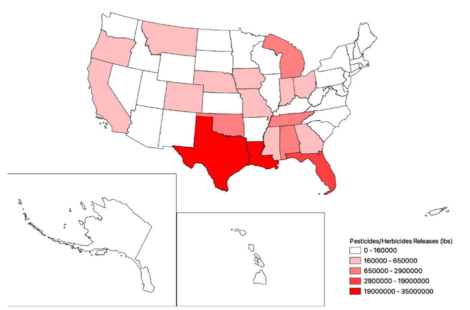
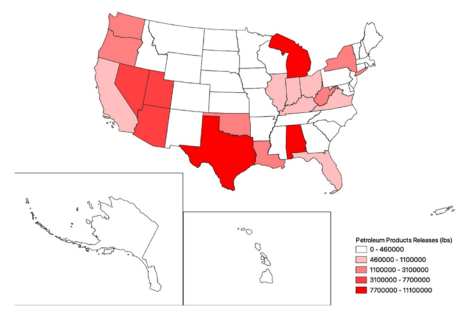
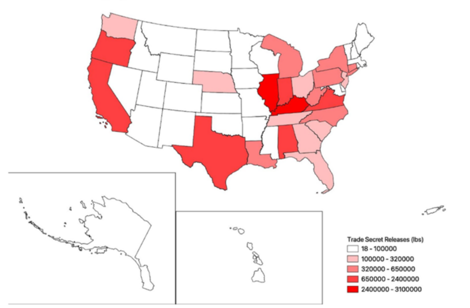
Chemical Category- Pesticides or Herbicides



Chemical Category- Petroleum Products (non-diesel or gasoline)



Chemical Category- Trade Secret



Total Releases

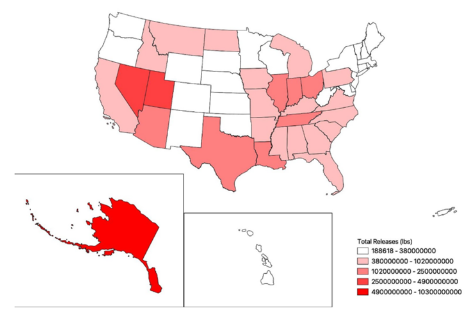


Table 22 presents a summary of the chemicals with the largest production volumes and largest total release masses from the analysis. Sulfuric acid was the only chemical common to both lists, although Leach Solutions, with the second largest production volume, may include some of the top 10 chemicals by release mass (e.g., copper, lead or zinc compounds).

Table 22 Chemicals with the top 10 production volumes and release masses

Release Data (2020)	Production Data (2016)
Lead Compounds	Leach solutions
Zinc Compounds	Sulfite/Cooking liquors
Manganese Compounds	Fuels, diesel No. 2
Barium Compounds	Ethanol
Arsenic Compounds	Calcium oxide silicate
Nitrate Compounds	Fly ash
Copper Compounds	Sulfuric acid
Chromium Compounds	Calcium hydroxide
Methanol	Butane
Sulfuric Acid	Ethane

5 Evaluate POU/POE Treatment Options

In Task 5, the outcomes of Tasks 1-4 were reviewed to develop a list of the contaminants of highest concern identified by each analysis. The development of the list of contaminants of the highest concern considered the analyses conducted in each task and the corresponding outcomes, as well as the authors' best professional judgment on those contaminants that were appropriate for consideration. The chemicals identified from Task 4 were reported as the top produced and/or released chemicals by the EPA. These chemicals were included on the list of contaminants of highest concern, even in cases of little to no data available for drinking water occurrence, as they could represent potential future challenges.

Once the list of the contaminants of the highest concern was compiled, the contaminants were evaluated based on the reasons they were selected, their priority as a drinking water contaminant of concern, and the POU and/or POE treatment options currently available for each contaminant. The evaluations were made through conducting research of available publications as well as the authors' best professional judgment gained from knowledge and experience working in the drinking water community.

Table 23 provides an abbreviated version of the Task 5 deliverable spreadsheet, submitted with this final report. The abbreviated table includes the full list of contaminants, the priority ranking as a drinking water contaminant, the reason for inclusion on the list, the POU/POE treatment category, and the POE and POU treatment options currently available. Contaminants for which POU/POE treatment is not applicable or dependent on the chemical composition of the contaminant that is not specified are listed and described separately in Table 24. The full Task 5 deliverable spreadsheet also includes references and additional information for the contaminants on the list. There are two types of rankings provided in the table: priority for drinking water and POU/POE treatment category. *These are qualitative and subjective rankings assigned by the authors based on the best information available and expert knowledge*. Below is an explanation for the rankings shown in the table:

- Priority for drinking water:
  1. High – contaminants have understood health risks, relatively high occurrence in drinking water at levels of concern based on their health risks in all or most states across the US, and are high priority for the drinking water community (i.e., utilities, treatment providers, researchers, consumers, etc.)
  2. Medium – contaminants that have understood health risks, aesthetic effects, or are emerging contaminants of interest for the drinking water community, occurrence in drinking water at levels of concern may be nationwide or limited to certain regions with contaminated source water
  3. Low – contaminants that have aesthetic effects and are not high priority for the drinking water community at large
- POU/POE treatment category:
  1. Established – Established POU/POE treatment evidenced by NSF/ANSI certified products based on removal claims for contaminant of interest (NSF 2022); available technologies are relatively efficient at removing the contaminant of interest
  2. Available – POU/POE treatment available, needs further research, testing, and/or validation; there may be NSF/ANSI certified products available but there is no verified removal claim for the contaminant of interest, only one technology type is certified while other technologies exist but are not certified for removing the contaminant, or available treatment technologies are not relatively effective or efficient at removing the contaminant of interest
  3. Not Available – POU/POE treatment not well established, not available, or not applicable; no NSF/ANSI certified products with verified removal claims for the contaminant of interest

The results shown in Table 23 provide a summary of the POU/POE treatment options currently available for top priority contaminants, as well as the gaps that may exist in treatment options. *The results provided in the table do not consider aspects such as the initial cost, operational and/or maintenance costs (i.e., filter replacements, energy costs), operational challenges, site-specific considerations, or any unintended consequences associated with the POU/POE treatment options.* It is recommended that these aspects be explored deeper to truly assess the opportunities available for improving POU/POE treatment options for top priority contaminants.

Table 23 POE and POU treatment options for highest priority contaminants

Contaminant	Priority for Drinking Water	Reason for Inclusion	POU/POE Treatment Category	Point of Entry (POE) Treatment Options	Point of Use (POU) Treatment Options
Arsenic	1	*Top 10 list based on number of health based SDWA violations *Top 10 list based on PWSs w/ occurrence over federal MCL *Top 10 list for 2020 chemical release data ("arsenic compounds")	Established	Iron oxide/hydroxides Activated alumina Anion exchange resin in a fixed bed (requires regeneration) Manganese greensand (requires regeneration) Titanium oxy/hydroxide Iron-doped anion resin and activated alumina	Iron oxide/hydroxides Activated alumina with or without iron oxide coating Anion exchange Titanium oxy/hydroxide Reverse osmosis (RO) Carbon block filters
Copper	1	*Top 10 list based on number of health based SDWA violations *Top 10 list based on PWSs w/ occurrence over federal MCL *Top 10 list for 2020 chemical release data ("copper compounds")	Established	Reverse osmosis Cation exchange resin pH neutralizing filter (if copper source is in-home corrosion)	Reverse osmosis (RO) Cation exchange resin
Lead	1	*Top 10 list based on number of health based SDWA violations *Top 10 list based on PWSs w/ occurrence over federal MCL *Top 10 list for 2020 chemical release data ("lead compounds") *Recent revisions to Lead & Copper Rule *Identified in web search for recent new articles and publications	Established	Fine filtration + adsorption	Reverse osmosis Fine filtration + adsorption

Contaminant	Priority for Drinking Water	Reason for Inclusion	POU/POE Treatment Category	Point of Entry (POE) Treatment Options	Point of Use (POU) Treatment Options
Nitrate	1	*Top 10 list based on number of health based SDWA violations *Top 10 list based on PWSs w/ occurrence over federal MCL *Top 10 list for 2020 chemical release data ("nitrate compounds") *Identified in web search for recent new articles and publications	Established	Reverse osmosis (RO) Anion exchange resin (subject to sulfates competitive ion exchange) Nitrate "selective" anion exchange resins	Reverse osmosis (RO) Anion exchange resin (subject to sulfates competitive ion exchange) Nitrate "selective" anion exchange resins
DBPs (TTHM)	1	*Top 10 list based on number of health based SDWA violations *Top 10 list based on PWSs w/ occurrence over federal MCL *Identified in web search for recent new articles and publications *Potential future changes to M/DBP Rules in next 5-10 years	Established	Reverse osmosis (RO) Granular activated carbon (GAC)	Reverse osmosis (RO) Granular activated carbon (GAC), powdered activated carbon (PAC), and carbon block filters
Total Coliform	1	*Top 10 list based on number of health based SDWA violations	Available[1]	Ultraviolet (UV) Reverse osmosis (RO) Ozonation	Ultraviolet (UV) Reverse osmosis (RO) Ozonation P231 rated filters

[1] The NSF site (NSF 2022) indicates that there are NSF/ANSI certified POU and POE treatment options for ultraviolet (UV) microbiological water treatment systems with claims for Class A and Class B disinfection performance. The are no certified products utilizing the other technologies listed for microbiological treatment (i.e., reverse osmosis, ozonation, P231 filters)

Contaminant	Priority for Drinking Water	Reason for Inclusion	POU/POE Treatment Category	Point of Entry (POE) Treatment Options	Point of Use (POU) Treatment Options
Legionella	1	*Potential future regulatory changes to M/DBP Rule *Identified in web search for recent news articles and publications *Included in EPA's CCL5 list	Available [2]	Ultraviolet (UV) Reverse osmosis (RO) Ozonation	Ultraviolet (UV) Ozonation 0.2 micron biological filter P231 rated filters
DBPs (HAA5/HAA9)	1	*Top 10 list based on number of health based SDWA violations *Top 10 list based on PWSs w/ occurrence over federal MCL *Identified in web search for recent new articles and publications *Regulated (HAA5) and unregulated (HAA6Br, HAA9) included in EPA's UCMR4 *Potential future changes to M/DBP Rules in next 5-10 years	Available	Reverse osmosis (RO) Granular activated carbon (GAC)	Reverse osmosis (RO) Granular activated carbon (GAC), powdered activated carbon (PAC), and carbon block filters
PFAS (PFOA + PFOS)	1	*Included in EPA's UCMR3 and upcoming UCMR5 *Top finding in web search for recent news articles and publications *Upcoming regulations planned by EPA	Established	Granular activated carbon (GAC) Anion exchange resin	Reverse osmosis (RO) Granular activated carbon (GAC), powdered activated carbon (PAC), and carbon block filters Anion exchange resin

[2] The NSF site (NSF 2022) indicates that there are NSF/ANSI certified POU and POE treatment options for ultraviolet (UV) microbiological water treatment systems with claims for Class A and Class B disinfection performance. The are no certified products utilizing the other technologies listed for microbiological treatment (i.e., reverse osmosis, ozonation, P231 filters)

Contaminant	Priority for Drinking Water	Reason for Inclusion	POU/POE Treatment Category	Point of Entry (POE) Treatment Options	Point of Use (POU) Treatment Options
PFAS (other PFAS)	1	*Included in EPA's CCL5 *Included in EPA's UCMR3 and upcoming UCMR5 *Top finding in web search for recent news articles and publications *Upcoming regulations planned by EPA	Available	Granular activated carbon (GAC) Anion exchange resin	Reverse osmosis (RO) Granular activated carbon (GAC), powdered activated carbon (PAC), and carbon block filters Anion exchange resin
DBPs (unregulated, i.e., haloacetonitriles, halonitromethanes, iodinated THMs, nitrosamines, chlorate)	1	*Identified in web search for recent new articles and publications *Unregulated DBPs included in EPA's CCL5 *Potential future changes to M/DBP Rules in next 5-10 years	Available	Reverse osmosis (RO) Granular activated carbon (GAC) *Above treatment options are not effective for removal of nitrosamines	Reverse osmosis (RO) Granular activated carbon (GAC) *Above treatment options are not effective for removal of nitrosamines
Manganese	2	*Top 10 list based on PWSs w/ occurrence over state MCL *Included on EPA's CCL5 list *Included in EPA's UCMR4, most detected UCMR4 contaminant after DBPs (HAAs)	Established	Ion exchange Greensand filter/ manganese dioxide	Ion exchange resin Greensand filter/ manganese dioxide Reverse osmosis
Barium	2	*Top 10 list for 2020 chemical release data ("barium compounds")	Established	Cation exchange resin Reverse osmosis (RO)	Cation exchange resin Reverse osmosis (RO)
Fluoride	2	*Top 10 list based on number of health based SDWA violations *Top 10 list based on PWSs w/ occurrence over federal MCL *Identified in web search for recent news articles and publications	Established	Activated alumina (requires regeneration or tank exchange) Anion exchange (requires regeneration or tank exchange) Reverse osmosis (RO)	Activated alumina Anion exchange Reverse osmosis (RO)
Iron	2	*Top 10 list based on PWSs w/ occurrence over state MCL	Established	Ion exchange resin Greensand filter Oxidation / filtration	Ion exchange resin Greensand filter Reverse osmosis (RO)

Contaminant	Priority for Drinking Water	Reason for Inclusion	POU/POE Treatment Category	Point of Entry (POE) Treatment Options	Point of Use (POU) Treatment Options
Radium	2	*Top 10 list based on number of health based SDWA violations *Top 10 list based on PWSs w/ occurrence over federal MCL *Identified in web search for recent new articles and publications	Established	Cation exchange softening Reverse osmosis (RO)	Cation exchange softening Reverse osmosis
Uranium/ Gross Alpha	2	*Top 10 list based on number of health based SDWA violations *Top 10 list based on PWSs w/ occurrence over federal MCL	Established	Strong base anion exchange resins (chloride form) Reverse osmosis (RO)	Strong base anion exchange resins (chloride form) Reverse osmosis (RO)
Chromium Compounds/ Chromium-6, Total chromium	2	*Top 10 list for 2020 chemical release data ("chromium compounds") *CA's draft hexavalent chromium regulations released in March 2022	Established	Reverse osmosis (RO) Ion exchange resin	Reverse osmosis (RO) Ion exchange resin
Perchlorate	2	*Emerging contaminant of concern	Available	Anion exchange resin (regenerable and non-regenerable) Reverse osmosis (RO)	Anion exchange resin (regenerable and non-regenerable) Reverse osmosis
1,2,3-trichloropropane (TCP)	2	*Included in EPA's CCL5 *Included in EPA's UCMR3	Available	Granular activated carbon (GAC)	Granular activated carbon (GAC), powdered activated carbon (PAC), and carbon block filters
Cyanotoxins	2	*Included in EPA's CCL5 *Included in EPA's UCMR4 *Identified in web search for recent new articles and publications	Available [3]	Reverse osmosis (RO) Granular activated carbon (GAC)	Reverse osmosis (RO) Granular activated carbon (GAC), powdered activated carbon (PAC), and carbon block filters

[3] While there are POU/POE treatment options with NSF/ANSI certified microcystin removal claims, there are no certified removal claims for other cyanotoxins

Contaminant	Priority for Drinking Water	Reason for Inclusion	POU/POE Treatment Category	Point of Entry (POE) Treatment Options	Point of Use (POU) Treatment Options
Microplastics	2	*Identified in web search for recent news articles and publications *Emerging contaminant of concern	Available	Reverse osmosis (RO)	Carbon block filter Reverse osmosis (RO)
1,4-dioxane	2	*Included on EPA's CCL5 *Identified as emerging contaminant of concern	Not Available	Granular activated carbon (GAC) Reverse osmosis (RO)	Reverse osmosis (RO) Granular activated carbon (GAC)
Calcium hydroxide	3	*Top 10 list for 2016 chemical production data	Established	Cation exchange water softener (treatment for calcium/hardness)	Cation exchange water softener (treatment for calcium/hardness) Reverse osmosis (RO)
Calcium oxide silicate	3	*Top 10 list for 2016 chemical production data	Established	Cation exchange water softener (treatment for calcium/hardness)	Cation exchange water softener (treatment for calcium/hardness) Reverse osmosis (RO)
Chloride	3	*Top 10 list based on PWSs w/ occurrence over state MCL, increasing concentrations over time in CT	Available	Reverse osmosis (RO) Ion exchange resin	Reverse osmosis (RO) Ion exchange resin
Sulfuric Acid (Sulfate considered for POU/POE treatment options)	3	*Top 10 list for 2016 chemical production data	Available	pH neutralizing filter	Reverse osmosis (RO) Anion exchange resin Adsorptive media filtration pH neutralizing filter
Zinc	3	*Top 10 list for 2020 chemical release data ("zinc compounds")	Established	Ion exchange resin Reverse osmosis (RO)	Ion exchange resin Reverse osmosis (RO)

Table 24 Identified contaminants for which POU/POE treatment options cannot be determined or may not be applicable

Contaminant	Priority for Drinking Water	Reason for Inclusion	POU/POE Treatment Category	Reasons for Why POU/POE Treatment Options Cannot Be Determined or May Not Be Applicable
Butane	3	*Top 10 list for 2016 chemical production data	Not Available	Under atmospheric temperature and pressure, butane occurs as a gas, not a liquid
Ethane	3	*Top 10 list for 2016 chemical production data	Not Available	Under atmospheric temperature and pressure, ethane occurs as a gas, not a liquid
Ethanol	3	*Top 10 list for 2016 chemical production data	Not Available	Volatile and biodegradable organic, likely not amenable to POE/POU treatment
Methanol	3	*Top 10 list for 2016 chemical production data	Not Available	Volatile and biodegradable organic, likely not amenable to POE/POU treatment
Sulfite/ Cooking liquors	3	*Top 10 list for 2016 chemical production data	Not Available	May not be a concern for drinking water
Fly Ash	Dependent on chemical composition	*Top 10 list for 2016 chemical production data	Not Available	Treatment depends on chemical composition
Fuels, diesel #2	Dependent on chemical composition	*Top 10 list for 2016 chemical production data	Not Available	Treatment depends on chemical composition
Leach solutions	Dependent on chemical composition	*Top 10 list for 2016 chemical production data	Not Available	Treatment depends on chemical composition

6 Develop Future Expectations for the POU/POE Industry

The objective of Task 6 is to synthesize the information collected through Tasks 1-5 to develop future expectations for the POU/POE industry for the next 5- to 10-year horizon. The top priority contaminants that were identified in Tasks 1-5 are grouped by federally regulated contaminants, state regulated contaminants, and unregulated/emerging contaminants. The future expectations for these contaminants and for the POU/POE industry with respect to each contaminant are described below.

Task 5 results for POU/POE treatment options are included in the summaries below for each contaminant or group of contaminants. *The Task 5 effort did not consider aspects such as the initial cost, operational and/or maintenance costs (i.e., filter replacements, energy costs), operational challenges, site-specific considerations, or any unintended consequences associated with the POU/POE treatment options.* There is a wide array of potential unintended consequences for POU/POE treatment that should be considered by the POU/POE treatment industry and by consumers before treatment options are implemented. These unintended consequences may be related to water quality and co-occurring contaminants (i.e., some NSF/ANSI certifications specify a reference concentration and valency of arsenic in the water), the impact of the treatment on water quality (i.e., removing the disinfectant residual and risk for microbiological growth), or site-specific conditions. Any future research and development related to POU/POE treatment options for the contaminants identified in this study or any other drinking water concerns should always consider and attempt to mitigate all potential unintended consequences.

Federally Regulated Contaminants

There are several federally regulated contaminants on the list of top priority contaminants, including lead, copper, fluoride, regulated DBPs (TTHMs and HAA5), arsenic, nitrate, total coliform (inclusive of *E.coli*), radium, uranium, and barium. While not currently federally regulated, PFAS was included in this group because EPA has announced plans to propose a PFAS drinking water regulation in the fall of 2022. The future expectations for the POU/POE industry regarding these contaminants are described below.

Lead and Copper

Lead and copper are high priority contaminants of concern and present a major opportunity for the POU/POE industry over the next 5-10 years in terms of health risk reduction. Lead has been a hot topic among the EPA, the broader drinking water community, and the public, due to the health risks associated with lead and the prevalence of lead in distribution system service lines and in home plumbing fixtures. December 16, 2021 was the effective date for EPA's Revised Lead and Copper Rule, and the initial compliance date is set to October 16, 2024. Also on December 16, 2021, EPA also announced their developments of a new regulation, Lead and Copper Rule Improvements.

Over the next 5-10 years, we anticipate many drinking water systems will be working on meeting compliance with the lead and copper rule (LCR) through replacing lead service lines and implementing optimal corrosion control treatment. The outcomes of Task 5 (see Table 23) indicate that there are established POU and POE options for lead, including reverse osmosis (RO) and fine filtration and adsorption, and for copper, including RO, cation exchange, and pH neutralizing filters. In some cases, drinking water utilities may implement the use of POU treatment as a compliance strategy. Denver Water in Denver, Colorado is an example of a drinking water utility that is currently implement POU treatment as one aspect of its Lead Reduction Program (https://www.denverwater.org/your-water/water-quality/lead/filter-program). The City of Newark in Newark, New Jersey and the Newark

Department of Water & Sewer Utilities have also implemented the use of POU filters for reducing consumers' lead exposure (https://www.newarkleadserviceline.com/filters). Beyond drinking water utilities, consumers that may have concerns about lead levels in their own drinking water may also look toward POU or POE treatment to reduce their exposure. Lead exposure at any level is understood to present a health risk, and therefore, even consumers served by a drinking water system that is in compliance with the LCR may look for additional treatment for lead.

We anticipate lead and copper to remain primary contaminants of concern in the next 5-10 years and for the POU/POE industry to be an important aspect of meaningful health risk reduction through the removal of lead and copper in drinking water.

Total Coliform and E.coli

One fundamental goal of drinking water treatment is to prevent pathogen growth and the risks associated with a pathogen outbreak in drinking water through appropriate disinfection practices. Total Coliform Rule (TCR) violations related to total coliform positive data were found to be the greatest number of violations of MCL violations of the period of data analyzed in Task 1. Boil water alerts that may be issued with these violations can be very disruptive and alarming to consumers. While the data available for analysis were all from public water systems, it is expected that private well owners experience similar or even greater exposure to drinking water contamination. The POU/POE industry provides consumers with the opportunity for an additional and final barrier against microbial contamination. The outcomes of Task 5 indicate established POU and POE options, including ultraviolet (UV) light, RO, ozonation, and P231 rated filters. Based on currently available data, total coliform and *E.coli* are expected to remain major contaminants of concern for the next 5-10 years. It is possible that EPA could propose revisions to the microbial, disinfectant, and disinfection byproduct (M/DBP) by 2024 that may strengthen disinfection requirements and subsequently reduce the occurrence of total coliform and *E.coli*, but the time period for such revisions to be implemented and affect meaningful change would be beyond the five year horizon.

DBPs

Regulated DBPs, including TTHM and HAA5, have been leading contaminants in terms of the number of health based MCL violations in drinking water. Unlike most other contaminants, DBPs are formed in the treatment process when disinfectants are added to the water. To properly protect consumers against risks associated with pathogens, a disinfectant residual should be maintained through the distribution system. This also leads to continued formation of DBPs as long as DBP precursor materials (i.e., total organic carbon (TOC), bromide, etc.) are present. DBPs issues tend to be a bigger challenge for drinking water utilities using surface water sources, which are often the larger utilities, as surface water tends to have higher levels of organic matter, but some groundwater systems have also had DBP challenges. Many drinking water utilities with surface water treatment plants have optimized their enhanced coagulation, sedimentation, and filtration processes, and some utilities have implemented advanced strategies, i.e., GAC filters, aeration in clearwells or storage tanks, switching from free chlorine to chloramines for their distribution system disinfectant residual. Despite these efforts, DBP reduction strategies will always be part of a balancing act between meeting the necessary disinfection to protect against acute risks associated with pathogens while reducing DBP levels to protect against health risks associated with long term exposure to DBPs. Due to this balancing act, it is not expected that a drinking water utility that applies disinfection would ever completely remove DBPs from the drinking water provide to its consumers. It is also important to note that EPA is currently working to revise the microbial, disinfectant, and disinfection byproduct (M/DBP) Rules. Any potential change to the disinfectant residual requirements could temporarily cause further DBP challenges for drinking water systems that are currently struggling to meet compliance.

Due to the nature of DBPs, the POU/POE industry will always have an opportunity to further protect the public against potential health risks from DBP exposure. The outcomes of Task 5 indicate POU and POE options for removing DBPs, including RO, granular activated carbon (GAC), powdered activated carbon (PAC), and carbon block filters. Depending on the application of the POU/POE treatment, e.g., for compliance, further testing and validation may be necessary. For example, the treatment technologies available are generally far more effective at removing TTHM as opposed to HAAs. The analysis conducted as part of this study suggests that DBPs will continue to be major contaminants of concern for the next 5-10 years, and POU/POE treatment options provide the public with a means to reduce their DBP exposure.

PFAS

Over the last 5 years, PFAS have been a major topic in drinking water communities, conferences, publications, and news articles. In 2013-2015, six PFAS analytes were included in the UCMR3 sampling effort, but due to relatively high reporting limits, there were few detections nationally as compared with other contaminants included in UCMR3. Since that time, analytical methods have improved, and reporting and detection limits have lowered. Many drinking water systems that did not detect PFAS in UCMR3 have since detected PFAS, and various states have set their own regulations for several PFAS analytes. Currently the EPA plans to propose the first federal PFAS drinking water regulation in fall of 2022, following by a final regulation in fall of 2023, starting with two PFAS analytes, PFOA and PFAS. Additionally, UCMR5 sampling will including 29 PFAS analytes, and it is expected that many more drinking water systems across the country will discover detectable PFAS. PFAS currently represents an important opportunity for the POU/POE industry to support consumers and potentially drinking water utilities, depending on the state and state approvals for compliance by POU/POE treatment, in effectively removing PFAS to protect public health. The Task 5 outcomes indicate that POU/POE treatment options include RO, GAC, PAC, carbon block filters, and anion exchange resin, although further testing and validation will be important based on the application of the POU/POE treatment and based on the specific PFAS contaminants. For example, there are NSF/ANSI certified POU/POE treatment options for the PFOS and PFOA removal claims, but not for other types of PFAS which may not be removed as effectively due their chemical composition.

Arsenic

The current arsenic MCL was set by the Arsenic Rule in 2001, which public drinking water systems were required to meet by 2006. Today, sixteen years later, the Arsenic Rule is still responsible for significant number of health based MCL violations, particularly for smaller drinking water systems. Arsenic was also found to be one of the top contaminants based on occurrence over the MCL. The outcomes of Task 5 indicate several established POU/POE treatment options, including iron oxide/hydroxides, activated alumina, anion exchange resin, manganese greensand, titanium oxy/hydroxide, and iron-doped anion resin and activated alumina. There is a meaningful opportunity for the POU/POE industry to help protect consumers against exposure to arsenic in the next 5-10 years, and in some states, there may be opportunities to work with drinking water utilities and state regulators to employ or enable POU/POE options for compliance purposes.

Nitrate

Similar to arsenic, nitrate has been regulated for many years. It is not an emerging contaminant or a new concern, but it is one of the top priority contaminants in terms of the number of health based MCL violations and occurrence over the MCL. Nitrate has an acute MCL due to the dangers of methemoglobinemia, also known as blue baby syndrome, from a single exposure over 10 mg/L for vulnerable populations, particularly infants. Nitrate is expected to remain a top concern over the next 5-10 years based on the analysis conducted in this study. While nitrate levels in drinking water served to consumers has remained relatively consistent, the analysis showed that levels in raw water samples have shown an increasing trend over time. This suggests that nitrate may become a bigger problem in the future for drinking water systems. The Task 5 outcomes indicate there are established POU/POE treatment options, including RO, anion exchange resin, and nitrate selective anion exchange resins. As with arsenic, there is an opportunity for the POU/POE industry to help protect consumers against exposure to nitrate above the MCL. Additionally, in some states, there could be an opportunity to work with drinking water utilities and state regulators to employ or enable POU/POE options for compliance purposes.

Radionuclides (Radium, Uranium)

Two radionuclides, radium and uranium, were found to be at the top of the list of contaminants based on number of violations and drinking water occurrences over the respective MCLs. These fall into a similar category as arsenic and uranium such that the Radionuclide Rule has been in place for years, no upcoming changes to the rule are anticipated, but the contaminants remain a concern for many public drinking water utilities. The Task 5 outcomes indicate that for radium, established cation exchange softening and RO POU and POE treatment options are available, and for uranium, established strong base anion exchange resins and RO POU and POE treatment options are available. Based on the analysis conducted, these contaminants are expected to still be a concern in the next 5-10 years, and they present an opportunity for the POU/POE industry through helping consumers protect themselves and potentially, for some states, could provide an opportunity to work with drinking water utilities and state regulators for compliance purposes.

Fluoride

Fluoride is often used in drinking water treatment for dental purposes, but also regulated due to health issues at higher concentrations. Fluoride was found to be one of the top ten contaminants based on the number of health based MCL violations and based on the occurrence above the MCL. In Task 2 analyses showing trends over time, fluoride was found to be decreasing over time. In the next 5-10 years, thought, it is expected that fluoride will continue to be a concern in areas with high naturally occurring levels. Based on state MCLs and available data, this study found the greatest number of PWSs with fluoride occurrence over the state MCL in New York, although further analysis would be warranted to determine areas of concern. The Task 5 outcomes indicate that established POU/POE treatment options for fluoride include activated alumina, anion exchange, and RO. The POU/POE industry has the opportunity to provide these treatment options to consumers, especially in areas with high naturally occurring fluoride.

Barium

Barium has not been a contaminant of concern based on violations and occurrence over the MCL, but barium compounds were found to be in the top 10 of chemicals released based on EPA's TRI dataset. While it is not clear whether these releases will result in any increased barium levels in source waters for drinking water systems, it is important to be aware that this is a possibility. While there's no clear indication that barium represents a significant opportunity for the POU/POE industry to protect public health, it important to identify this contaminant as a potential future contaminant of concern. Established POU/POE treatment options for barium include cation exchange resin and RO.

State Regulated Contaminants

There are also a group of contaminants on the list of top priority contaminants that are regulated by one or more states, chromium-6, manganese, iron, chloride, perchlorate, 1,4-dioxide, and 1,2,3-trichloropropane. Chromium-6 is particularly noteworthy at the time of this report because the California Department of Drinking Water released a new draft MCL for chromium-6. The reinstatement of a chromium-6 MCL could have implications for hundreds of drinking water systems in California. The new regulation could result in more consumers looking for additional home treatment options, such as POU or POE devices, or it is possible that systems could investigate POU/POE treatment options for compliance.

Contaminants such as manganese, 1,4-dioxane, and 1,2,3-trichloropropane are currently on EPA's CCL5, and while they are not currently federally regulated, there is the potential that they could be in the future. Perchlorate is another contaminant that has been considered for federal regulation by the EPA. In a decision published in 2020, the EPA chose not to regulate perchlorate, stating that it did not meet the requirements as a drinking water contaminant under the SDWA. EPA did release a plan to address perchlorate contamination on March 31, 2022 (USEPA 2022). In the case of manganese, 1,4-dioxane, 1,2,3-trichloropropane, and perchlorate, there are understood health risks from exposure, and the reduction or removal of their occurrence could be beneficial to consumer health. Therefore, the POU/POE industry has an opportunity to provide consumers with a treatment option for these contaminants. Task 5 evaluated current POU/POE treatment for manganese, including ion exchange, greensand filters, and RO, and for perchlorate, including anion exchange resin and RO, as established treatment options, while POU/POE treatment options for 1,2,3-trichloropropane, including GAC, need further validation and testing, and for 1,4-dioxane, including GAC and RO, are not well established.

Iron, chloride, zinc, and sulfate are three contaminants that are regulated in some states and have a secondary standard set by the EPA based on aesthetic impacts. Concerns with iron, chloride, zinc, and sulfate are expected to be focused on aesthetic issues, as opposed to health risks. While sulfate was not directly identified in Tasks 1-4, Task 4 found sulfuric acid to be one of the most produced chemicals in the most recent TSCA dataset. In terms of potential impacts on drinking water quality, sulfate was evaluated as a potential drinking water contaminant of concern. The established POU/POE treatment options for iron include ion exchange resin, greensand filter, oxidation/filtration, and RO, for chloride and zinc, include RO and ion exchange resin, and for sulfate, include pH neutralizing filters, RO, anion exchange resin, and adsorptive media filtration. Based on occurrence above state MCLs, iron, chloride, zinc, and sulfate are a challenge for some drinking water systems and provide an opportunity for the POU/POE industry, particularly in those states and systems where they are a concern.

Unregulated/ Emerging Contaminants

There are several unregulated or emerging contaminants that are expected to be primary contaminants of concern for at least the next 5-10 years.

Cyanotoxins

Harmful algal blooms (HABs) and cyanotoxins are a health risk in natural water bodies, including source waters for drinking water, and cyanotoxins are a concern for public drinking water. Currently, the EPA has health advisories for two cyanotoxins, cylindrospermopsin and microcystins, set in 2015. More recently, nine cyanotoxins and one cyanotoxin group (total microcystins) were included in the UCMR4 sampling that occurred in 2018-2020, although there were a relatively low number of detections. Cyanotoxins were included in the CCL5 draft and have been a major topic in recent drinking water focused conferences and publications. Conventional drinking water treatment processes can generally remove cyanobacteria and low levels of cyanotoxins, there is an opportunity for the POU/POE industry particularly for communities where source waters have been experiencing seasonal blooms and high levels of cyanotoxins. In these communities, consumers may have interest in further protection against these toxins. POU/POE treatment options include RO, GAC, PAC, and carbon block filters, although depending on the application of the treatment, further testing and validation may be needed. While there are POU/POE treatment options with NSF/ANSI certification for microcystin removal claims, there are no certified options for the removal of other cyanotoxins.

Unregulated DBPs

Several unregulated DBPs were identified in Tasks 1-4 and are expected to remain primary contaminants of interest over the next 5-10 years. The EPA's draft CCL 5 includes brominated HAAs, which were also included in the UCMR4 sampling, haloacetonitriles (HANs), iodinated trihalomethanes, nitrosamines (including NDMA), chlorate, and formaldehyde. Currently, EPA is tasked with proposing revisions to the M/DBP rules, and recent stakeholder meetings have suggested that the brominated HAAs, in the form of HAA9, are the most likely group of unregulated DBPs that may be regulated in the near future. Several unregulated DBPs were also included in UCMR2, and it is noteworthy that NDMA had the highest number of detections of the UCMR2 contaminants. Unregulated DBPs also remain a major topic for drinking water related research and publications. For consumers that may want to ensure further removal of DBPs, the POU/POE industry provides important treatment options, such as RO and GAC although these treatment options may not be well established depending on the intended application. For example, while there are POU/POE treatment options with NSF/ANSI certification based on haloacetonitriles removal claims, the available treatment options are ineffective at removing nitrosamines, i.e., NDMA. Further testing and validation, as well as gaining further understand of the public's concern with unregulated DBPs presents an important opportunity for the POU/POE industry.

Legionella

Legionella, especially *Legionella pneumophila*, was found to be the unregulated microbial contaminant of the greatest concern based on the efforts in Tasks 1-4. Currently, *Legionella* has been a major topic in stakeholder meetings related to EPA's efforts to propose revisions to the M/DBP rules. Controlling *Legionella* presents challenges for drinking water utilities because these efforts also rely on the management of building water systems and premise plumbing, which are not under the control of drinking water utilities. Due to the nature of *Legionella* and the reliance on building water system management, the POU/POE industry has an opportunity to provide options for building water managers and consumers to treat drinking water for *Legionella* at locations where it can be problematic. POU/POE treatment options for *Legionella* include UV light, RO, ozonation, and P231 rated filters.

Microplastics

Microplastics have been become a contaminant of concern over the last several years, and they have been at the center of drinking water related news articles, publications, and conference talks. Due to consumer concerns, the POU/POE industry has an opportunity to provide treatment options for microplastics. The Task 5 outcomes found that POU/POE treatment options for microplastics include RO and carbon block filters, and there are certified POU/POE treatment options for microplastics removal. Microplastics remain an emerging contaminant with far more research required to fully understand the impact on drinking water quality and human health, and similarly, further research is recommended to provide the best POU/POE treatment options.

Calcium/hardness

The Task 4 analysis found that calcium hydroxide and calcium oxide silicate were two of the most produced chemicals based on the EPA's most recent TSCA dataset. In drinking water, calcium increases the hardness of water. While hardness is not regulated or found to be a health concern, hard water can be a concern for various reasons. Hardness can interfere with the action of soaps and detergents, leave solid deposits that can clog pipes, lead to galvanic corrosion of metal pipes, etc. Any increase in hardness as a result of increased production of calcium hydroxide and calcium oxide silicate could present more need for POU/POE treatment options. The Task 5 outcomes identified established POU/POE options such as cation exchange water softeners and RO for treatment of calcium in drinking water.

Summary

The Predictive Modeling Study presented a methodology to evaluate all relevant data available to identify the top priority drinking water contaminants that will remain a concern for the next 5-10 years. The methodology evaluated violation data available from EPA's SDWIS, the occurrence of unregulated contaminants from EPA's UCMRs, the occurrence of regulated contaminants above their MCLs and trends in occurrence over time, upcoming or recent regulatory changes, contaminants that may be considered for future regulations based on inclusion on the CCL, recent drinking water related news articles, publications, and conferences, and EPA's TSCA and TRI data sets of the most produced and released chemicals. The methodology then evaluated the identified top contaminants of concern based on their priority as a drinking water contaminant, which took into account the authors' expert judgment based on understood health risks, occurrence, and priority from the drinking water community. Next the methodology included a review of available POU and POE treatment options and an evaluation of how well established the treatment options are currently for the removal of the contaminant.

The methodology resulted in a list of 28 top priority drinking water contaminants for the next 5-10 years. The future expectations for each of the contaminants are discussed in Task 6 of the methodology, which synthesizes the information gathered through Tasks 1-5. The methodology developed in the Predictive Modeling Study can be repeated at any time to evaluate future years of interest.

References

California Water Boards, 2022. Chromium-6 Drinking Water MCL. Last accessed April 11, 2022. https://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/Chromium6.html.

NSF 2022. Water Treatment Products Testing and Certification Services. Las Accessed April 26, 20222. https://www.nsf.org/testing/water/water-treatment.

USEPA, 2019. National Primary Drinking Water Regulations: Lead and Copper Rule Revisions. Federal Register, 82 FR 61684, 40 CFR Parts 141 and 142. https://www.regulations.gov/document/EPA-HQ-OW-2017-0300-0001.

USEPA, 2021a. Drinking Water Contaminant Candidate List 5 – Draft. Federal Register, 86 FR 37948, 40 CFR 141. https://www.federalregister.gov/documents/2021/07/19/2021-15121/drinking-water-contaminant-candidate-list-5-draft.

USEPA, 2021b. National Primary Drinking Water Regulations: Lead and Copper Rule Revisions. Federal Register, 86 FR 4198, 40 CFR 141, 40 CFR 142. https://www.federalregister.gov/documents/2021/01/15/2020-28691/national-primary-drinking-water-regulations-lead-and-copper-rule-revisions.

USEPA, 2021c. Review of the National Primary Drinking Water Regulations: Lead and Copper Rule Revisions (LCRR), Federal Register, 86 FR 71574, 40 CFR 141. https://www.federalregister.gov/documents/2021/12/17/2021-27457/review-of-the-national-primary-drinking-water-regulation-lead-and-copper-rule-revisions-lcrr.

USEPA, 2021d. Announcement of Final Regulatory Determinations for Contaminants on the Fourth Drinking Water Contaminant Candidate List. Federal Register, 86 FR 12272, 40 CFR 141. https://www.federalregister.gov/documents/2021/03/03/2021-04184/announcement-of-final-regulatory-determinations-for-contaminants-on-the-fourth-drinking-water.

USEPA, 2022. EPA's Plan to Address Perchlorate Contamination. Last accessed April 11, 2022. https://www.epa.gov/system/files/documents/2022-03/epa-plan-to-address-perchlorate.final_.pdf.

Wang, Y. and Chen, J., 2020. *Drinking Water Crises in the United States, 2009-2019*. Unpublished data. University of Wisconsin-Milwaukee.

Water Quality Association (WQA), 2022. EPA Lead and Copper Rule Changes. Last accessed June 9, 2022. https://www.wqa.org/programs-services/government-affairs/federal-affairs/regulatory/epa-lead-and-copper-rule.

* Additional references included in the Task 3 and Task 5 datasets submitted with the final report as spreadsheets

Sustainability Comparison Study: Assessing Centralized Treatment Upgrades and POU/POE Treatment for Small System Compliance to the SDWA

Final Report
April 29th, 2022

Dr. Emily Kumpel
Dr. Kaycie Lane
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List of Abbreviations

ADD	Average daily dose
AM	Adsorptive media
ANSI	American National Standards Institute
CDI	Chronic daily intake
CSA	Canadian Standards Association
CWS	Community water system*
DWUR	Drinking water unit risk
GAC	Granular activated carbon
GFH	Granular ferric hydroxide
HQ	Hazard quotient
IAPMO	International Association of Plumbing and Mechanical Officials
IRIS	Integrated Risk Information System
IX	Ion exchange
LCA	Life cycle analysis
LCC	Life cycle costing
LOAEL	Lowest observable adverse effect level
MCL	Maximum contaminant level
MLE	Maximum likelihood estimate
NOAEL	No observable adverse effect level
NSF	NSF International
PFAS	Perfluoroalkyl substances
PID	Performance indicator device
POE	Point-of-entry
POU	Point-of-use
RO	Reverse osmosis
SDWA	Safe Drinking Water Act
SDWIS	Safe Drinking Water Information System
TCR	Total carcinogenic risk
USEPA	United States Environmental Protection Agency
WBS	Work-based structure
WQA	Water Quality Association

*Note: in this report, CWS and "Community" are used interchangeably to refer to community water systems

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Executive Summary

This study examined point-of-use (POU) and point-of-entry (POE) devices in comparison to improvements to existing centralized systems for Safe Drinking Water Act compliance using a triple bottom line analysis. The study was conducted using data from four very small community water systems (serving less than 500 people) from four different USEPA regions in the United States to ground the analysis in the community specific considerations necessary to complete a triple bottom line analysis. An exposure assessment was conducted to evaluate human health impacts of each alternative (POU/POE versus centralized treatment), a life cycle analysis to examine environmental impacts and a life cycle costing analysis to examine economic impacts over a thirty-year study period. The analysis was specifically targeted to examine the considerations necessary to implement POU/POE devices as a compliance solution for either arsenic or nitrate contamination for community water systems. The purpose of the study was to holistically examine the tradeoffs a very small water system may face when choosing an additional treatment solution to remove a specific drinking water contaminant of concern.

The triple bottom line analysis conducted in this study was informed by state-specific and community-specific assumptions in order to ensure the analysis was as complete and realistic as possible. As such, the assumptions we documented for each state are presented in the full report to frame the analysis results in detail. In each community water system, we consulted with state administrators, community water system operators and other important water system stakeholders to understand the existing water treatment system and to identify a realistic improvement that the community was interested in exploring. We then identified two POU/POE devices for each community water system that are certified to the relevant NSF/ANSI standards for the removal of either arsenic or nitrate specifically. We consulted state specific guidance on POU/POE devices to determine (1) whether to select a POU or POE solutions and (2) how the state approves and implements POU/POE devices to determine the necessary steps to implement a POU/POE device as a compliance strategy.

Human Health Exposure
Exposure assessment was used to examine the health impacts associated with the implementation of a technology. Exposure assessment results revealed the importance of the relationship between the removal efficiency of a treatment solution and the number of years until a solution could feasibly be expected to be implemented in a community water system. While the installation time of POU/POE devices is expected to be quicker than a centralized improvement in many cases, the planning time (including state approvals, device selection, etc.) is expected to contribute a significant amount to how rapidly POU/POE devices can be implemented as a compliance solution.

Even though POU/POE device removal efficiencies tend to be higher than centralized technologies, the requirement for 100% participation prior to implementation extends the implementation timeline such that the benefits of removal efficiencies tend to be minimized. Our results show that in systems with high concentrations of contaminants such as arsenic and nitrate, it is critical to implement a technology in a timely manner to reduce lifetime exposure in the most vulnerable populations.

Environmental Sustainability

The life cycle analysis (LCA) performed in this study utilized the SimaPro software (version 8.2.1), the ecoinvent inventory database, the TRACI 2.0 method for impact assessment and a functional unit of the water consumer in one household. LCA results indicate that POU/POE devices contribute less per kilogram of material to environmental impacts than improvements to centralized systems in general as a result of a smaller amount of material used in 30 years. Where POU units were compared to adsorptive media and ion exchange centralized technologies, we observed that the cost to process, transport and dispose of these medias contributed the most to the overall impact of these solutions. Similarly, the POE adsorptive media devices examined in Region 5 specifically had larger impacts than the relatively small centralized improvement of optimizing pre-oxidation because of the high impact of the adsorptive media. In Region 1, 7 and 9, POU devices proved to have the lowest overall impacts, with POU RO Device D having the lowest total environmental impact overall.

Economic Cost

The life cycle cost (LCC) analysis utilized the replacement frequencies from manufacturers, the EPA Cost Models and state specific assumptions to create a detailed inventory of the costs associated with each technological alternative. We extracted unit costs and useful life from the EPA cost models for the centralized cost alternatives and informed these same cost components through conversations with manufacturers and state stakeholders for the POU/POE devices.

Our results indicate that POU devices were a viable alternative from an economic perspective in Region 1, which is the smallest size community with 24 connections and a state-enabling environment that removes many of the barriers to POU/POE implementation. The replacement frequency of POU/POE components in each household coupled with the regulatory sampling requirements for POU/POE compliance generate large O&M costs for these devices which exceeded the cost of the centralized's upgrade O&M in Regions 5,7, and 9 over the 30 year study period.

Considerations for POU/POE as a compliance strategy

Through our analysis, we identified several critical factors that influence whether a POU/POE device may be used as a compliance solution in very small community water systems. We separated these factors into three categories: systemic barriers to timely and effective POU/POE implementation, technical barriers to long-term sustainability and viability of POU/POE devices and model specific assumptions that need to be considered when applying the triple bottom line analysis to other community water systems. Systemic barriers included whether a state allowed POU or POE devices for compliance purposes, the requirement of 100% community participation prior to piloting and implementation, difficulties identifying certified POU/POE options suitable to a specific community and SDWA sampling compliance requirements. Technical barriers included the high replacement frequency of POU/POE components over the 30-year study period, the number of households where POU/POE units needed to be installed and maintained, and the piloting requirements specific to state guidance on POU/POE devices. Finally, assumptions that need to be changed based on the specific community water system include disposal options for specific technology types and contaminants of concern, long-term sampling frequencies for compliance, the number of O&M activities (labor and frequency of maintenance) and the source water characteristics of the community water supply.

Based on the three different factors above, we present recommendations both to state compliance agencies and POU/POE device manufacturers to aid in the implementation and viability of POU/POE devices in very small water systems. Through conversations with state administrators and POU/POE manufacturers, we learned there are barriers to implementing and installing POU/POE devices in a reasonable timeframe that can be removed with greater communication between these two groups of stakeholders. We present recommendations to aid community water systems to readily find information about POU/POE devices, to aid state administrators in obtaining information about device performance and to aid manufacturers in communicating performance of POU/POE devices.

1 - Introduction

Small community water systems (CWS) are faced with many challenges in delivering water that meets regulatory standards (Allaire et al., 2018; Oxenford and Barrett, 2016). The USEPA defines small water systems as those that serve at least 25 people (or at least 15 service connections) but fewer than 10,000 people (USEPA,2017a). While previous research has found that small systems are no more likely to violate health related requirements as compared to large systems, these results are likely confounded by lack of adequate monitoring and reporting among smaller systems (Allaire et al., 2018; Rubin, 2013). Safe Drinking Water Act (SDWA) health-based violations are issued to small water systems that have maximum contaminant levels (MCLs) exceedances, do not meet required treatment techniques, or exceed the maximum residual disinfectant levels. In the recent study by Allaire et al (2018), 9% of all CWS in the United States experienced a health-based violation in 2015, including total coliform, surface water treatment rule (SWTR) or groundwater rule (GWR), nitrate, arsenic, lead and copper, disinfection byproducts, and radionuclides. These exceedances may result from unprotected or contaminated source waters, inadequate or poorly maintained treatment systems, and/or conditions within distribution systems. Small systems are often constrained by limited financial, technical, and personnel resources, which may lead to their inability to address any of these issues (Oxenford and Barrett, 2016).

For small and, particularly, very small systems (serving fewer than 500 people), there may be a point at which installing point-of use or point-of-entry (POU/POE) devices at individual households or buildings are a feasible option that provides equal benefits at less economic, human, and/or environment costs compared to investments in the centralized water system that would be needed for the CWS to be compliant with the Safe Drinking Water Act (SDWA). This triple bottom line approach involves the analysis of three key impacts: human health impacts (People), environmental impacts (Planet) and economic impacts (Profit). While estimations of each of these three costs for individual POU/POE systems or centralized water systems have been conducted individually, to our knowledge, no study has addressed and compared their tradeoffs in economic, human, and environmental costs. Furthermore, previous cost estimates have been system-specific and focused on determining the feasibility of alternatives for a given water system rather than developing a framework for decision-making. Community water systems often need to weigh the human, environmental, and economic costs prior to choosing an alternative form of treatment; a holistic model that provides a water system with this information is currently missing when examining the tradeoffs between centralized treatment upgrades and POU/POE devices.

The objective of this study was to use a triple bottom line approach to examine improvements to water treatment systems. We specifically examine and compare installing POU/POE systems in individual households to adjusting the centralized water treatment system to meet SDWA standards for an existing small CWS. We gathered case study data from four CWS, each in different regions of the US, to assess human health exposure due to time to implement (human exposure to a contaminant in drinking water), the environmental sustainability using a life cycle assessment (environmental cost), and the life cycle costs (economic costs) to install and maintain each type of treatment improvement. In addition to the rich case study approach we take in this analysis, we use these four CWS systems to develop generalizable frameworks for collecting data and comparing options for meeting regulatory compliance, including examining which parameters need to be system specific. We present the results from each individual case study as well as recommendations, generalizable methods, and adaptations for application to future water system analysis.

This study examines improvements to water treatment systems in *existing* CWS that are not currently in compliance with (or are close to noncompliance with) SDWA regulations for a *single* chemical contaminant. The boundaries of our analysis are drawn around the specific improvement needed to bring an existing CWS system into compliance for one specific contaminant. Our analysis is notably different than other studies which compare whether to install POU/POEs in self-supply households as opposed to creation of a new CWS where one does not exist. Additionally, we focus on only the treatment upgrade needed to bring a system into compliance for a single contaminant; while treatment is designed to treat a suite of contaminants, we assume the existing treatment at the CWS stays intact to treat the other contaminants (including to meet Total Coliform Rule compliance, for which POUs/POEs cannot be used for SDWA compliance). To that end, we present process flow diagrams of each centralized improvement and POU/POE device to delineate the system boundaries defined for each CWS. We have used this detailed process to explicitly identify the components of each improvement (centralized or POU/POE) to demonstrate how these are additions to an existing system as opposed to standalone technological solutions. The intention is to provide information to inform CWS deciding between improvements to water treatment systems based on information about cost, sustainability and protection of human health; small systems often have to balance these three factors when making changes to an existing piece of infrastructure.

The seven primary requirements to use a POU/POE device as a compliance strategy are presented in the following text box (USEPA, 2006b). These requirements are used throughout the report to guide modeling assumptions and conversations with state administrators and CWS stakeholders.

USEPA POU/POE Guidance for SDWA Compliance

1. It is the responsibility of the water system to operate and maintain the POU or POE treatment system
2. The water system must submit and receive approval for a monitoring plan that provides equivalent health protection as centralized treatment prior to installing any POU/POE devices
3. The water system must apply effective technology as approved by the state
4. The device must consider the potential for an increase in heterotrophic bacteria and microbiological safety must be preserved
5. The state must require adequate certification of performance, field-testing or a rigorous design review of the POU/POE devices
6. The water system must ensure all buildings connected to the system has sufficient POU/POE coverage
7. If using POE, the device must not increase the likelihood of the release of corrosive materials such as lead and copper.

We examine POU/POE devices as a compliance strategy to meet the requirements of the SDWA; this is a different context than a homeowner installing a POU/POE device by choice. To use a POU/POE device as part of a CWS compliance strategy, the CWS must meet several requirements: 100% community participation (a device installed at every connection), piloting of devices prior to device selection and installation and state level approval to use these devices. These requirements are discussed in detail in this report. Past studies have examined POU/POE devices outside of the regulatory context of a CWS, which can underestimate the amount of time necessary to implement POU/POE devices in community water systems and the cost associated with conducting compliance monitoring and maintenance activities (Table 1). We focus our analyses on the steps and activities necessary to use POU/POE devices for compliance to the SDWA and highlight how this lens impacts our results.

Table 1: Summary of cost comparison studies

	Sustainability Comparison Study: Assessing Centralized Treatment Upgrades and POU/POE Treatment for Small System Compliance to the SDWA (Kumpel et. al.)	Feasibility of an Economically Sustainable POU/POE Decentralized Public Water System (NSF International)	Comparing centralized and point-of-use treatments of per- and polyfluoroalkyl substances (Bixler et. al.)	Cost of POU vs Centralized Treatment (Speth et.al.)
Year of study completion	**2022**	2003	2021	2020
Objective of study	**Holistically examine the tradeoffs between human health, environmental and economic impacts (triple bottom line) that very small systems may face when choosing a treatment upgrade to remove a specific drinking water contaminant**	Evaluate methods for day-to-day management and operation of a centrally-managed POU strategy for small system compliance	Evaluate and compare the triple bottom line of centralized treatment upgrades versus POU devices specifically for the removal of PFAS	Show how the EPA Cost Models can be specifically for POU/POE device using the examples of nitrate, PFAS and perchlorate contamination
Outcome of study	**Developed a framework for comparing the triple bottom line of central treatment upgrades needed for SDWA compliance to the triple bottom line of using POU/POE devices as a compliance solution**	Demonstrated feasibility of POU as a compliance solution for arsenic treatment in small systems	Demonstrated tradeoffs associated with using centralized versus POU for PFAS removal	Showed the results of the nitrate and perchlorate treatment options for different categories of small systems

Intended end use of study	**Provide recommendations to state compliance agencies and POU/POE device manufacturers to aid in the implementation and viability of POU/POE devices as compliance solutions for very small water systems**	Encourage decision makers to apply the methods identified in the study when utilizing POU for compliance	Provide decision makers with data and information to aid in future decisions about centralized and POU systems for the treatment of PFAS chemicals	Demonstrate how to use the EPA Cost Models and provide information that compares central to POU/POE cost for nitrate, PFAS and perchlorate treatment
Number of case studies	**4**	1	1	4 treatment technologies overall, which evaluated POU RO, no case studies, only a desktop study
Physical POU/POE device install or literature review?	**Literature review/data collection**	Physical install	Literature review/data collection	Literature review
Contaminant(s)	**Variable (Arsenic or nitrate)**	Arsenic	PFAS	Nitrate, perchlorate, PFAS
Number of connections in CWS	**Variable (24-221)**	122	6800	Variable, depends upon model being run
Population served by CWS	**Variable (50-450)**	400	25500	Variable, depends upon model being run
POU/POE technology	**POU Carbon, POU RO, POE GFH Media**	POU activated alumina followed by GAC	3 POU scenarios - GAC&IX prefilters followed by RO, combined GAC&IX filter, and GAC filter & RO & IX filter	RO
NSF/ANSI certification?	**NSF/ANSI 53, 58, and/or 61 respectively**	NSF/ANSI 61[1]	NSF P473 for reduction of PFOA and PFOS	NSF/ANSI 58
POU/POE same technology type as central treatment?	**No, POU/POE upgrade is specific to each case study**	Yes, looks at new activated alumina	No	No

Costs include all aspects for central system, or upgrade only?	**Only includes costs for upgrade, which excludes any existing centralized infrastructure and components**	Includes all aspects of the central system, including construction of a new building	Only includes costs for upgrade, which involves development of three new central GAC treatment facilities	Includes all aspects of the central system
Were POU/POE devices discounted for bulk purchase in the cost analysis?	**No**	Yes - reported as "substantially less than retail" [no % given for the discount]	Yes - 5% discount applied	Unclear[2]
Costs take into consideration regulations/practices necessary for Safe Drinking Water Act (SDWA) Compliance?	**Yes, comprehensive approach including federal and state-specific regulations**	Yes, however the EPA was still drafting federal requirements for POU maintenance and sampling at the time of this study	No, does not consider costs associated with SDWA sampling requirements	Not directly. The EPA Cost models make some assumptions about cost of compliance, however, the results of this study are not state specific
Unit for cost analysis	**Total cost per household over 30 years**	Monthly cost per household (or connection)[3]	Annual net present value per average volume of water used per household per year[4]	Annualized cost for a volume of water treated

[1]Arsenic reduction was not included in NSF/ANSI 53 at the time of this study, but the POU devices were tested against the draft NSF/ANSI 53 protocol prior to installation

[2]The EPA models use a default discount rate of 7%, which users can adjust directly on the output sheet. However it is unclear if this discount rate is being applied for bulk POU/POE device purchases.

[3]Assumes a cost recovery of 7% over seven years

[4]Only considered volume of water used directly for cooking and drinking in the POU scenario, while the centralized scenario considers all water used in the household

2 – Selection of Case Studies and Technology Alternatives

2.1 Methods

We began this study by identifying four community water systems (CWSs) as the case studies, and then identified an improvement to the centralized water system and to POU/POE system options appropriate to treat the contaminant of concern for each CWS. We selected four very small water systems (serving a population of fewer than 500 people) for this study in four different USEPA regions to enable examination of the real-world conditions very small systems face in different regional contexts when examining POU/POE devices as a strategy to meet the SDWA regulations. We compared treatment alternatives in the selected communities, including one centralized treatment improvement and two different POU/POE devices in each CWS.

2.1.1 Community Water System Selection

We selected four CWSs from EPA Regions 1, 5, 7, and 9 (Figure 2.1). Initially, Regions 1, 5, 6 and 9 were selected to represent different regions across the United States. Region 7 was substituted for Region 6 after a review of data and reasons explained below; initial results from the CWS identification process include Region 6 and not Region 7 since Region 7 was not initially included in the CWS selection process.

We retrieved violation reports from the Safe Drinking Water Information System (SDWIS) database for each of the selected EPA regions (USEPA, 2017) from 2013-2019. Using these reports, we reviewed the data for maximum contaminant level (MCL) violations and found the top six contaminants most often in violation of an MCL were arsenic, combined radium (226 and 228), fluoride, gross alpha (excluding uranium and radon), nitrate, and total trihalomethanes. From this list of contaminants, we selected arsenic and nitrate as contaminants to focus on in this study. Next, we selected a state within each region with the greatest number of violations for either contaminant, or a state with a high number of violations and of systems in violation of the MCL for the contaminant to narrow our search.

For each state, we then identified a list of eligible CWSs meeting the following criteria:

1. A groundwater supply
2. Violations of either arsenic or nitrate in the past five years
3. Violations of either arsenic or nitrate in more than one year
4. A population served less than or equal to 500 people

Groundwater supplies were included to ensure comparability between water systems and because there are additional treatment requirements for surface water systems that are state specific. Populations less than or equal to 500 people were selected as very small systems per the USEPA's definitions of small systems (USEPA, 2017a). Arsenic and nitrate were selected as focus contaminants due to the large number of systems that have experienced at least one violation of either parameter between 2010-2019. To find systems with potential long-standing problems with either arsenic or nitrate, we selected communities with more than one violation in the past five years. This allowed us to locate communities with chronic concerns with either arsenic or nitrate that were potentially still experiencing these concerns at the time of our study.

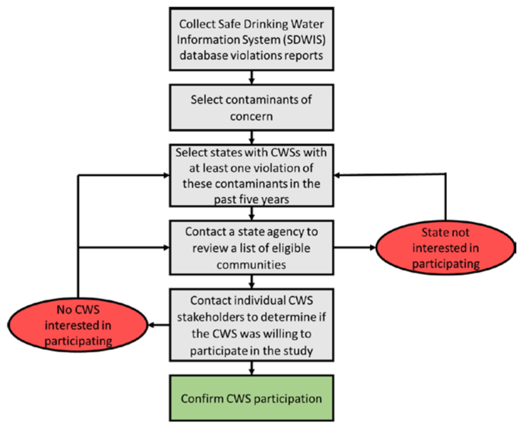


Figure 2.11: Methodology for finding and selecting CWSs for participation in this study

Using these criteria, we identified 12 eligible systems in Region 1 for arsenic contamination, 15 eligible systems in Region 5 for arsenic contamination, 63 eligible systems in Region 6 for nitrate contamination, and, in Region 9, 132 eligible systems for arsenic and 55 for nitrate contamination (Table 2.1). Initially, we decided to pursue arsenic contamination in Region 1 and 5, and nitrate contamination in Region 6 and 9.

After generating a list of eligible CWSs, we then contacted state-level administrators in the corresponding states to introduce the purpose of the project. If a state declined to participate, we returned to the SDWIS data and iterated through the steps outlined in Figure 2.1 to locate another state in the target Region meeting our criteria and generated a new list of eligible CWSs. States declined to participate for several reasons: POU/POE devices cannot be used for regulatory compliance purposes in the state, the systems identified through SDWIS were not ideal communities to work with due to ongoing water quality concerns or projects, or because the state was not interested in "promoting" POU/POE devices as a solution for very small water systems. If a state-level administrator was willing to assist in reviewing and contacting the eligible CWSs, we selected three communities to contact in each state. The state-level administrator provided an initial introductory email to the CWS. In the event that a CWS within a given state declined to participate, we collaborated with state-level administrators to continue working through the list of eligible communities until a CWS interested in participating was found. If no CWS was found with the help of the state-level administrator, we identified another state within the region and iterated through the methodology in Figure 2.1. Using the methodology presented in Figure 2.1, we were able to successfully select communities in Region 1, 5 and 9. A CWS with arsenic contamination meeting the eligibility criteria and willing to provide data for the study was found in each of Region 1 and Region 5. In Region 9, CWSs with nitrate contamination were identified, however, the majority of these CWSs did not have centralized treatment and distribution in place. As a result, we worked with state administrators in Region 9 to locate a CWS with arsenic contamination and existing centralized treatment and distribution.

Table 2.1: Number of eligible CWSs by region and contaminant

Region	Contaminant	Number of Eligible CWSs
1	Arsenic	12
5	Arsenic	15
6	Nitrate	63
9	Arsenic	77
	Nitrate	55

Region 6 was initially selected as the fourth EPA region, with a focus on nitrate contamination. However, after working with three different states within the region, we were unable to identify an interested CWS. Subsequently, we connected with researchers at the University of Lincoln Nebraska to determine whether a community in Nebraska (Region 7) would be interested in participating in this study. We confirmed participation in a Nebraska CWS in place of a CWS from Region 6. Region 7 is not included in Table 2.1, as we did not use the SDWIS data set to identify eligible CWS in the initial months of this project. The CWS in Region 7 meets the initial criteria used in the analysis of the SDWIS data: a groundwater source, a population less than 500 people and chronic concerns with nitrate contamination in the system. While the CWS selected in Region 7 has not yet had an MCL violation of nitrate, nitrate levels in multiple groundwater wells have been increasing for the past 5 years and the CWS was already considering treatment alternatives at the time of this study.

2.1.2 Selection of Alternatives for Comparison

2.1.2.1 Centralized Treatment Improvements

We next worked with each CWS to select a centralized treatment improvement for each system to model. We first contacted the relevant CWS stakeholders to discuss the current centralized system structure, and obtained prior system assessment reports, sanitary surveys, water quality data, and other relevant reports such as engineering consultant reports. Using this information, we consulted the CWS operators and state administrators to determine an appropriate improvement to the existing centralized treatment system. Centralized system improvements focused specifically on feasible options for removing the contaminant of concern chosen for each CWS; we did not consider additional components in the triple bottom line approach related to overall treatment system performance or improvements. We chose treatment improvements that could be easily added to the current centralized infrastructure where possible and focused on technologies designed to specifically remove either arsenic or nitrate.

2.1.2.2 POU and POE Devices

According to the EPA Guidance on POU/POE devices for small water systems (USEPA, 2006b), if a certified POU or POE device is available for a given contaminant, the certified devices must be considered first. If a certified device is unavailable, other devices tested for performance may be considered for use for compliance purposes. Certified devices can be found from the following certifying organizations: NSF International (NSF), the Water Quality Association (WQA), the Underwriters Laboratory, the Canadian Standards Association (CSA International) (USEPA, 2006) and through listings provided by the International Association of Plumbing and Mechanical Officials (IAPMO). We determined two standards were applicable to our study: NSF/ANSI 53 (Health Effects) for arsenic contamination and NSF/ANSI 58 (Reverse Osmosis systems) for both arsenic and nitrate contamination. While NSF/ANSI testing protocols allow for both trivalent and pentavalent arsenic reduction claims, we found no devices certified to the trivalent arsenic reduction claim at the time of the initial device search in January 2021. We compiled lists of POU and POE devices certified to NSF/ANSI 53 and NSF/ANSI 58 from NSF International, WQA, and IAPMO listings for review. A list of the number of records found from NSF listings is presented in Appendix B.

To select two POU or POE devices for each CWS, we used state level regulations to determine which type of device is allowable at a state level for compliance purposes in small CWSs (Figure 2). We considered at least 2 different devices per CWS to ensure our methodology can be translated in the future to other devices and removal claims. In Region 1, we selected a community in New Hampshire, in Region 5 a CWS in Illinois, in Region 7 a CWS in Nebraska and in Region 9 a CWS in California. In the states selected for both Regions 1, 7, and 9, POU devices are allowed as a solution for compliance with the SDWA, with Region 9 specifying POUs are only allowed if no alternative centralized treatment or consecutive connection is a viable solution. In Illinois, only POE devices are allowed as a solution to comply with the SDWA; POU devices may only be used as an emergency measure and must be removed from use once the emergency has passed. Through a conversation with Illinois state administrator, POU devices have been previously implemented for inorganic contaminant remediation, but no systems currently employ POE devices.

Next, we identified the relevant NSF/ANSI standards applicable to the selected contaminants in each CWS as described in Table 2.2 to narrow down the number of devices to consider. Through discussions with stakeholders in each CWS, we chose one POU device certified to NSF/ANSI 53 (an adsorptive media technology) and one POU device to NSF/ANSI 58 (reverse osmosis) each for arsenic contamination in Region 1 and Region 9. In Region 7, we selected two different POU devices certified to NSF/ANSI 58 for nitrate reduction and in Region 5, we selected two POE devices certified to

NSF/ANSI 53. Figure 2.2 presents the selection criteria used to find two devices applicable to each CWS.

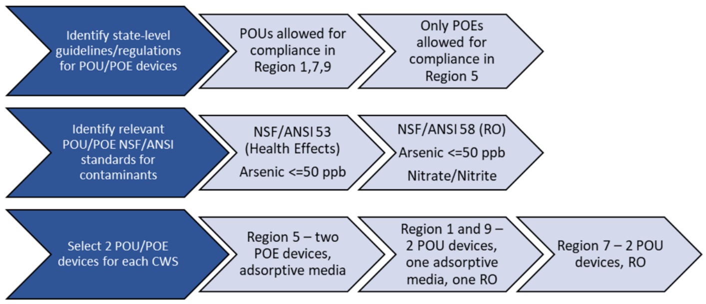


Figure 2.2: Criteria used to select 2 POU/POE devices for each CWS.

The complete list of eligible POU and POE devices identified for consideration in this study are shown in Appendix B with anonymized company names and model numbers. Table B1 presents the eligible POU devices certified to NSF/ANSI 53, Table B2 presents the eligible POU devices certified to NSF/ANSI 58 and Table B3 presents the POE devices available through multiple listings. Due to the high cost associated with POE RO units and the absence of an NSF/ANSI 58 testing protocol for POE RO devices, we limited our focus to POE devices certified to NSF/ANSI 53. After reviewing the NSF/ANSI POE listings, we expanded our search to CSA B483.1 listings and devices with certified NSF/ANSI 61 media to find additional POE devices.

2.1.3 Data collection for selected treatment alternatives

After selecting each alternative, we then gathered relevant information from the CWS stakeholders and POU/POE manufacturers to begin the triple bottom line analysis. For centralized treatment we requested the following types of information: (1) historical water quality data, (2) cost information (e.g., utility bills and inventory sheets), (3) the removal rate of either arsenic or nitrate for each centralized treatment option and (4) other relevant information necessary to create an inventory of system components. For POU/POE devices, we requested information from device manufacturers and distributors, including: (1) device manuals, (2) component listings, (3) performance data including certified contaminant removal rates and efficiencies, and (4) the useful life of device components. If data could not be obtained from either CWS stakeholders or device manufacturers, we consulted literature to locate relevant values for removal rates and the cost of components. This included the EPA Arsenic Demo Reports generated by the National Risk Management Laboratory for information on useful life, removal rates by specific technology types, and cost information. We also examined the documentation of the EPA work-breakdown structure (WBS) cost models for specific technologies to fill data gaps. When literature values were used to fill data gaps, we included both best-case and worst-case values to include in our data analysis.

Using the data obtained from CWS stakeholders, literature, and POU/POE manufacturers, we next constructed process flow diagrams for each improvement to document the components of each system alternative. This study focuses on improvements to a water system above and beyond the current treatment and distribution processes; as a result, we documented the current system components and the new necessary improvement components to show where the improvement integrates with the existing infrastructure where appropriate. Flow diagrams from EPA design manuals for arsenic and nitrate removal (USEPA, 1978, USEPA, 2003a, USEPA, 2003b, USEPA 2006a) were used to generate a basic flow diagram for each improvement. Then we indicated CWS specific alterations to capture the components to include in the triple bottom line analysis. Flow diagrams for POU/POE devices were built from figures presented in the EPA POU/POE Guidance document (USEPA, 2006b) and then altered where necessary to reflect the specific devices selected for this study.

2.2 Selection process results

2.2.1 Selected Communities

After iterating through the CWS selection methodology (Figure 2.1), we identified a CWS in both Region 1 and Region 5 meeting our criteria with arsenic as the contaminant of concern. In Region 9, we initially investigated communities with nitrate concerns, however, there were few CWSs in California with nitrate contamination that have either a centralized treatment facility or centralized distribution systems. As a result, we identified a CWS in Region 9 with arsenic contamination (in addition to uranium contamination) that met our criteria. Initially, we contacted state administrators in three different states in Region 6 to identify a CWS with nitrate contamination willing to participate in this study. However, as descried earlier, we could not identify a candidate CWS and instead identified an eligible system in Region 7 (Nebraska). Through conversations with our contact in Nebraska, we identified a CWS with known nitrate issues interested in examining POU/POE devices as a solution. The participating CWSs are presented in Table 2.2.

Table 2.2: Selected community water systems (CWSs) for study.

Region	State	Contaminant	Population	Connections	Source Water Type	Current Treatment Method	Average contaminant concentration	
							Well	Treated
1	New Hampshire	Arsenic (As)	50	24	Ground water	Adsorptive Media Filtration	10.8 μg/L[1]	8.3 μg/L[1]
5	Illinois	Arsenic	450	221	Ground water	Pressure Sand Filtration and Aeration	21.6μg/L[2]	9.2 μg/L[2]
7	Nebraska	Nitrate	128	75	Ground water	Distribution from wellheads	8.6 mg/L[1]	9.4 mg/L[3]
9	California	Arsenic and Uranium (U)	41	29	Ground water	Adsorptive Media Filtration	Well #1: As = 55 μg/L[4] U = 22 PCi/L[4] Well #2: As = 4.4 μg/L[4] U = 24.2 PCi/L[4]	As = 19.6 μg/L[4] U = 24.9 PCi/L[4]

[1]Represents data from 2013-2020

[2]Represents data from 2002-2020

[3]Data point represents the concentration at the CWS wellhead distribution sampling location as there is no treatment currently present.

[4] Represents data from 2016-2020

In Region 1, we selected a CWS in New Hampshire serving approximately 50 people through 24 service connections. The current treatment system uses adsorptive media filtration to treat 50% of the water volume from two combined wells. The remaining 50% of well water is untreated and blended with the treated water prior to distribution. System data revealed an average arsenic concentration in the combined groundwater wells of 10.8 μg/L with a treated water average of 8.34 μg/L based on data between 2013 and 2020. The system has experienced several past violations for arsenic contamination, with values exceeding the MCL for arsenic (10 μg/L) more frequently prior to 2013, but with consistent arsenic concentrations between 8-11 μg/L between 2013 and 2020. In New Hampshire, the MCL for arsenic is 5 μg/L and thus the state administrators identified this CWS as a system that would benefit from increased treatment to remove arsenic below the state MCL.

In Region 5, we selected a CWS in Illinois serving approximately 450 people with 221 service connections. The system serves both households connections and a large industrial connection within the area. The current treatment system utilizes an aeration tower to treat water from a groundwater well, followed by chlorine injection and subsequent pressure sand filtration. The aeration process removes particulate iron from the well prior to filtration. Filter media consists of a sand media marketed as a greensand filtration media designed to remove both iron and arsenic from water. The total arsenic concentration in the active well averaged 21.6 µg/L with an average treated water concentration of 9.2 µg/L. Iron concentrations in the wells exceed 3000 µg/L, with an average iron to arsenic ratio of approximately 55:1.

In Region 7, we selected a CWS in Nebraska serving approximately 150 people with 71 services connections. The CWS consists of three groundwater wells, only one which is active and distributes from the wellhead with no current treatment or water storage prior to distribution. The wellhead is contained in a small shed prior to pumping wellhead water directly from the wellhead into the distribution system. Nitrate levels in the groundwater wells in this system have been increasing over time and the CWS has been considering applying for permits to drill an additional well in the town. However, there are concerns with rising nitrate levels in nearby wells and cross-contamination of new wells as a result of the aquifer structure. Nitrate levels in the active well averaged 8.6 mg/L as N between 2013 and 2020, with a nitrate level of 9.34 mg/L recorded at the wellhead distribution sampling location.

In Region 9, we selected a CWS in California serving approximately 29 connections and an average of 41 people. The CWS has both permanent and transient residents; therefore, the population presented in Table 3 represents the average number of people present in the system year-round. This water system has both arsenic and uranium contamination in two different groundwater wells and has primarily focused on removing arsenic from the wellheads. Well #1 has an average arsenic concentration of 55 µg/L and an average uranium concentration of 22 PCi/L. Prior to 2020, Well #1 was the primary active well and was treated via two adsorptive media filters. After 2020, the CWS switched to using Well #2 after the adsorptive media filters failed before the manufacturer's indicated useful life of the media. Well #2 has an average arsenic concentration of 4.4 µg/L and an average uranium concentration of 24.2 PCi/L. The smaller arsenic concentration in Well #2 has helped to reduce arsenic MCL violations but uranium remains a concern. Arsenic and uranium levels measured in the distribution system measure 19.6 µg/L and 24.9 µg/L respectively. Arsenic levels in 2016 were recorded at 37, 41 and 48 µg/L in the distribution system in 2016. The water system is not currently using the adsorptive media system due to its early failure and the switch to Well #2 and has been considering water treatment solutions to remove both arsenic and uranium. Due to water quantity concerns, CWS stakeholders indicated they were interested in blending the two wells to ensure daily water demands are met over time.

We addressed both arsenic and uranium contamination in Region 9 as separate sources of contamination when examining results for comparisons between CWSs in different regions. When providing a comparison between other regions (notably Region 1), we examined arsenic alone for an accurate comparison. When completing our analyses in Region 9, we focus on arsenic alone for comparison to other CWSs, and the combined contamination from both arsenic and uranium when making a recommendation specifically for Region 9. For example, when comparing centralized treatment to POU/POE devices within Region 9, we examined removal of both arsenic and uranium, but when we compare the final results between Region 1 and Region 9, we examined only arsenic removal.

2.2.2 Selected technology alternatives

2.2.2.1 Centralized treatment improvements

In Region 1, arsenic is currently removed from two groundwater wells using an adsorptive media (granular ferric hydroxide media) filtration system. Only half of the flow produced from the two wells is currently treated at the central facility, with the remaining half of the flow bypassing treatment and then blended with treated water before distribution to customers. Through conversations with CWS stakeholders, we determined the current system has functioned well over the past ten years and the CWS is satisfied with the adsorptive media performance. Furthermore, there is sufficient space available in the current treatment facility to house an additional filtration unit and thereby treat the full flow from the two wells. The cost of the media, the size of the current filter and the amount of water to be treated by this improvement are well known and documented, making the addition of a second filter in series a viable improvement for the Region 1 CWS.

In Region 5, arsenic is currently co-precipitated with iron via aeration and pressure sand filtration. The current system consists of the following components: two wells providing water with an iron to arsenic ratio of 55:1, an aeration column, pre-chlorination, followed by filtration with pressure sand filters with a silica sand filtration media nominally able to remove iron. The media in this system was replaced recently, in 2018, which helped to lower the mean treated arsenic concentration below the MCL of 10 µg/L, but there are still concerns arsenic will not be effectively removed long-term. There is no current data available detailing the fraction of arsenic in the trivalent (As (III)) form compared to the pentavalent (As (V)) form. After conversations with stakeholders in this system, we decided to focus on improving pre-oxidation of As (III) to As (V) for this study, postulating the sand filters were only removing As (V) effectively. Therefore, in the Illinois system, the centralized improvement will consist of altering the order of pre-oxidation steps by placing pre-chlorination ahead of aeration to oxidize As (III) to As (V).

In Region 7, water is blended from two wells high in nitrate and then distributed to the community. No current treatment processes exist in this system. After consulting with the CWS, we determined the CWS has been exploring drilling new wells to alleviate nitrate contamination. However, groundwater studies in this community have shown increasing nitrate levels in both the community and neighboring wells, raising the concern that any new well could suffer from surface and subsurface contamination. A consulting company working closely with this community recommended the following alternative choices: ion exchange, nanofiltration or reverse osmosis, or a consecutive connection to a neighboring system. Using the EPA cost models for ion exchange, membrane filtration, and consecutive connection (interconnection), we screened these different options to determine which may be more reasonable in the CWS based on initial capital cost. We determined interconnection was at least four times more costly than centralized ion exchange, and reverse osmosis and nanofiltration were expensive alternatives due to maintenance, operation and brine disposal concerns. We therefore selected centralized anion exchange using a nitrate selective resin as the centralized improvement alternative in Region 7. With the addition of centralized treatment, the system in Region 7 will also require chlorine disinfection to comply with treatment requirements in Nebraska. As a result, the cost and components of a chlorine disinfection system are included as part of the centralized treatment solution in subsequent analyses. We also include post-treatment water storage in our centralized improvement analysis since there is currently no water storage in the community.

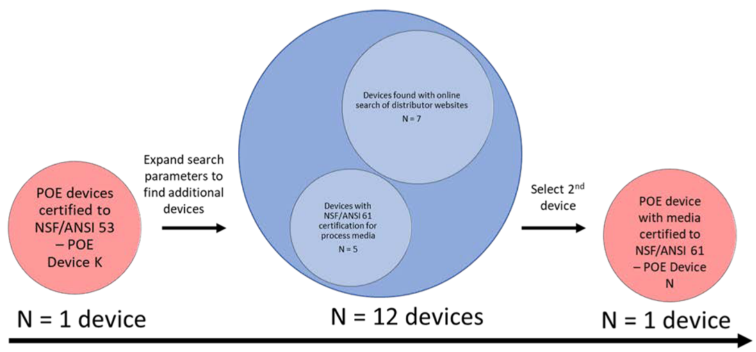
In Region 9, the current treatment facility is designed to remove arsenic from groundwater wells using an adsorptive media (granular ferric hydroxide media) filtration system. The current treatment facility was designed to remove arsenic from Well #1, but the community switched to Well #2 as the primary source in the past five years. As a result, the CWS is currently dealing with uranium levels in exceedance of the 30 PCi/L MCL and has lingering arsenic contamination. The current treatment facility is not in operation, but the infrastructure is relatively new, and the community stakeholders are interested in optimizing the current system to remove arsenic. Through conversations with stakeholders from this community, the following options were considered:

1) Blending Well #1 and Well #2 and removing arsenic centrally via the current adsorptive media;
2) Removing arsenic from Well #1 centrally with the current infrastructure and removing Uranium with a POU device;
3)Removing uranium centrally with a POE RO device.

We selected a centralized alternative based on the liquid waste disposal and spent media disposal options best suited to the community. We consulted the regional Water Board to determine the permitting requirements for the disposal of brine from either RO or ion exchange systems and assessed the current waste disposal methods available in the community. The community currently relies on nine septic tanks that would be unlikely to be able to handle the brine from a centralized RO system without extensive additional piping. As a result, we decided to examine ion exchange with an option to dispose spent media to a landfill or an evaporative pond on site.

2.2.2.2 POU/POE devices

The decision making process to select POU/POE devices is presented in Figure 2.3 to show the criteria used to refine and improve our list of eligible POE adsorptive media devices for Region 5 and POU RO devices for Region 1, 7 and 9. Initially, we only identified one POE device currently certified to NSF/ANSI 53. We expanded our search to include device listings from IAPMO, resulting in the identification of additional devices certified to CSA B483.1, a Canadian standard for devices installed in plumbed systems (IAPMO, 2021) which had a device with NSF 53 listed. We also performed a search of the NSF/ANSI 61 listings to identify adsorptive media with an NSF/ANSI 61 certification (NSF, 2021c). Using this information, we then searched through both manufacturer websites and water filtration distributor websites offering "whole house" water filtration systems. We compiled a list of POE devices with media certified to NSF/ANSI 61 and included only devices where we could verify the presence of a performance indicator device (PID) and a filter housing also certified to NSF/ANSI 61 in our final list of POE devices to consider for Region 5. This yielded a total of 7 devices to examine for Region 5 (Appendix B, Table B3). Figure 2.3, Panel 1, shows the process of expanding the search parameters for POE devices to find the second POE device to use in this study.



Methodology to select 2 POE adsorptive media units from device listings (Region 5)

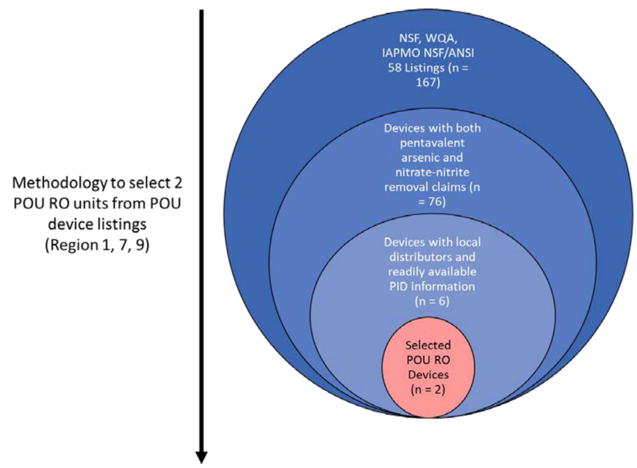


Figure 2.3: We expanded our search for POE devices from the one device we located using device listing search tools to include a total of 12 devices found through online searches and then narrowed the list of 12 devices to find the second POE device for Region 5 (Panel 1). We narrowed the list of POU RO devices for Regions 1, 7, and 9 from 167 total devices to 2 RO devices by selecting devices certified for both arsenic and nitrate removal, and devices available from local distributors and had performance indicator device (PID) information readily available (Panel 2).

After searching for NSF/ANSI 58 listings, we identified 167 devices from the combined listings from NSF, WQA and IAPMO. First, we selected only devices certified for both pentavalent arsenic removal and nitrate-nitrite removal claims for NSF/ANSI 58 to ensure that we can compare device performance across communities (i.e., Region 1 versus Region 9) and across contaminants (arsenic vs. nitrate). We used the guidance from the EPA (USEPA, 2006b) to identify components necessary for POU/POE to be used for regulatory compliance, including the presence of performance indicator devices (PIDs). While most devices certified to NSF/ANSI 58 listed on either the NSF, WQA or IAPMO websites will have PIDs as a result of certification requirements, we decided to approach the search from the lens of a CWS operator or manager. We therefore searched for device manuals and product listings that were readily available to customers and have easily accessible information on the presence of PIDs. We further refined our search by identifying devices available through local distributors and whether replacement components or media were readily available in the EPA Region or state where the CWS is located. This criterion was based on feedback from state administrators who stressed the importance of finding devices locally to ensure that maintenance and repair activities can be completed in a timely manner to ensure compliance. Six devices were identified using these criteria for consideration (Appendix B, Table B2) (Figure 2.3, Panel 2). From these devices, we selected the same RO unit (Company D, Device D1) for Region 1, 7 and 9, listed as Device D, to enable a comparison of context in costing and exposure analyses. We selected a second RO device (Company G, Device G1) for Region 7 for nitrate removal to complete our selection of POU/POE devices.

In Regions 1 and 9, POU devices are allowed at a state level for compliance with the SDWA. POU devices have been previously piloted and installed in CWS in the Region 1 state; through conversations with state level administrators, we learned how the state approves selected POU devices in addition to other state level requirements for use of POUs. In Region 1, we selected a carbon fiber adsorptive media POU certified to NSF/ANSI 53 and an RO POU certified to NSF/ANSI 58. The same guidelines hold for California in Region 9, where POUs are allowed for compliance, and we also selected the same NSF/ANSI 53 and NSF/ANSI 58 devices for the Region 9 system to allow for comparisons between the context in each CWS as opposed to comparisons of devices. Devices were selected based on local availability, cost (one low cost and one high-cost option) and evidence from manufacturers that a PID was present (Table 2.3).

In Region 5, only POE devices are allowed for long term compliance to the SDWA. Using the IAPMO device listings presented in Table B3 in Appendix B, we determined only Company K produced devices certified to NSF/ANSI 53 that could be used in this study. We therefore identified a list of 7 POE devices by searching for NSF/ANSI 61 certified adsorptive medias, and through online searches of manufacturer websites. From this list of 7 devices, we identified a device from Company N with a media certified to NSF/ANSI 61, as well as readily available filter housings certified to NSF/ANSI 61 as the second POE option in Region 5 (Table 2.3).

In Region 7, we selected two POU RO devices certified to NSF/ANSI 58 for nitrate/nitrite removal. From a list of 6 eligible devices (presence of a PID, availability of the device, NSF/ANSI 58 certification for both arsenic and nitrate removal), we identified two RO POU devices. The first device from Company D was chosen to be consistent with that selected in Regions 1 and 9 to enable comparison. The second device is from Company G and was selected for both its availability in Region 7 and because it is approximately twice the capital cost as Device D1, providing for a comparison of low and high-cost devices (Table 2.3). Capital costs for each device are listed in Appendix B and E.

Table 2.3: Selected water treatment system improvements for each community

Region	Current Centralized Treatment	Centralized Upgrade	POU/POE Device #1			POU/POE Device #2		
			Company and Model	Type of Device	Certification	Company and Model	Type of Device	Certification
1	Treatment of 50% of the flow rate from the GW via adsorptive media filtration	Treatment of 100% of the flow rate by adding an additional filtration module	Company B Device B2	POU adsorptive media	NSF/ ANSI 53	Company D, Device D1	POU reverse osmosis	NSF/ ANSI 58
5	Aeration and Pressure Sand Filtration for co-precipitation of arsenic with iron	Enhance pre-oxidation by moving pre-chlorination step ahead of aeration	Company K Device K1	POE adsorptive media	NSF/ ANSI 53 and CSA B483.1	Company N, Device N2	POE adsorpti ve media	NSF 61
7	Wellhead and Distribution System	Centralized anion exchange with a nitrate selective resin	Company G Device G1	POU reverse osmosis	NSF/ ANSI 58	Company D, Device D1	POU reverse osmosis	NSF/ ANSI 58
9	Adsorption Media for Arsenic removal + hypochlorite disinfection	Centralized anion exchange with a strong base anion resin	Company B Device B2	POU adsorptive media	NSF/ ANSI 53	Company D, Device D1	POU reverse osmosis	NSF/ ANSI 58

2.2.2.3 Initial data collection results and water treatment system improvement diagrams

After selecting centralized treatment improvements and POU/POE devices, we constructed process flow diagrams for each alternative to highlight the components included in the triple bottom line analysis. Figure 2.4 shows the centralized treatment improvement for Region 1, highlighting additional components needed to install and operate a second GFH adsorptive media filter. Components in grey represent components of the system already in place that will not be included in our analysis as they do not constitute an "improvement" to the system.

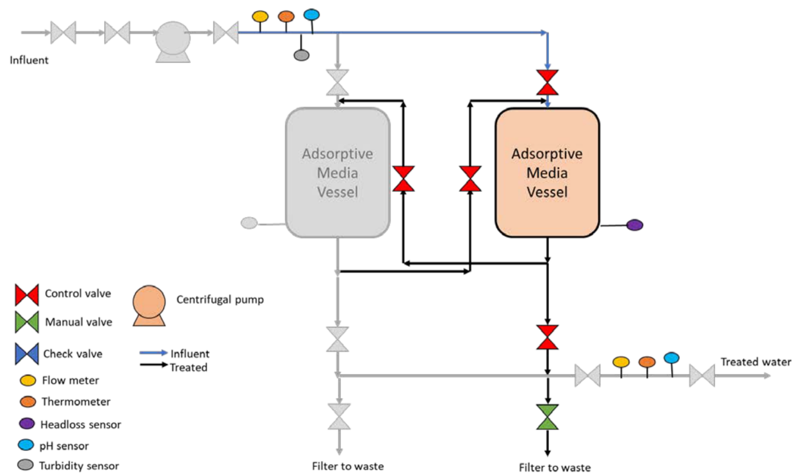


Figure 2.4: Components of the centralized treatment improvement for Region 1. Note that components in grey already exist that and will not be included in the analysis but are shown for illustrative purposes only.

Similarly, Figure 2.5 shows a generalized diagram of a POU RO unit based on documentation from the EPA POU/POE Guidance document (USEPA, 2006b). Components include pre-filters (both granular activated carbon (GAC) and sediment removal), the RO membrane, flow meters and additional piping. The components listed in these diagrams provide a starting point for both the LCA and LCC analyses explained in detail in Sections 4 and 5 respectively. Appendix A provides additional process flow diagrams of each CWS centralized improvement and additional POU/POE devices to document the components considered in the triple bottom line analysis.

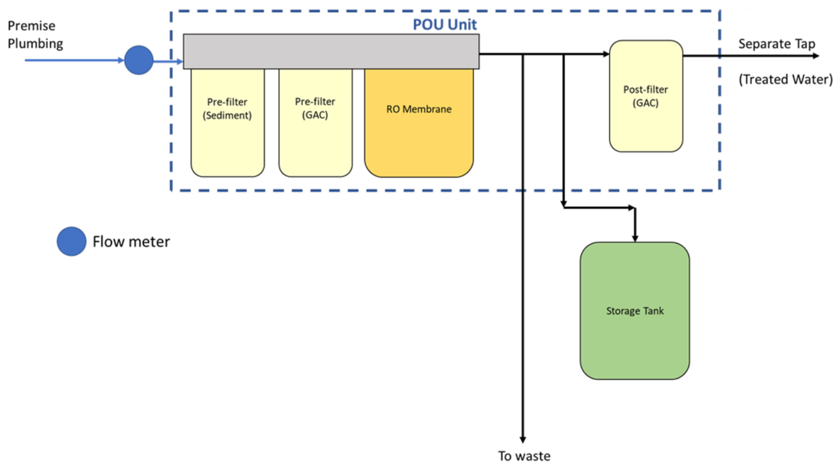


Figure 2.5: Components of a POU RO device selected for Region 1.

Specific design considerations for each improvement such as contaminant removal rates, sizing of centralized treatment vessels and operational parameters such as empty bed contact time (EBCT) were recorded for each improvement. Removal rate information is presented in the exposure assessment component of this report in Section 3.

The process flow diagrams presented in Figure 2.4 and Figure 2.5 were used to calculate the amount of material needed for each alternative for the life cycle analysis component of the triple bottom line analysis. The process flow diagrams were also used to evaluate the material and number of components for the life cycle costing analysis (Chapter 4) and life cycle assessment (Chapter 5).

3 – Exposure Assessment

3.1 Methods

To quantify exposure, we calculated both the estimated chronic daily intake (CDI) and the average daily dose (ADD) associated with each water treatment system improvement. CDI was used to quantify potential lifetime health impacts using both a deterministic approach and a probabilistic approach. Deterministic exposure provides only a single point estimate of exposure, while probabilistic exposure was used to generate a range of values to capture best- and worst-case exposure scenarios. ADD was used to examine exposure duration to quantify the time available to implement an alternative over an averaging time of 30 years. CDI and ADD values were calculated for both *pre-* and *post-intervention* concentrations: *pre-intervention* refers to the exposure in the CWS in its current state, while *post-intervention* refers to the exposure associated with water in the CWS after either installing a centralized improvement or a POU/POE device. We examined exposure from three routes: oral during consumption of drinking water, inhalation of aerosolized water during showering, and dermal contact with water during showering or bathing. Ultimately, we estimated oral and dermal exposure only due to data gaps in the literature surrounding inhalation exposure reference values and a lack of equations available to accurately quantify the concentration of contaminants in aerosolized water droplets.

In Regions 1 and 5 we examined exposure to arsenic contamination via the oral and dermal exposure routes. In Region 7, we examined exposure to nitrate through the oral exposure route only. In Region 9, we addressed both arsenic and uranium in our exposure assessment. Arsenic contamination via oral and dermal routes is included in our analysis while only the oral exposure route for uranium is considered. Detailed calculations and methods for each analysis are explained in detail in the following paragraphs.

3.1.1 Estimating contaminant exposure

Contaminant exposure was calculated for the oral and dermal exposure routes using EPA guidance for exposure assessments (USEPA, 1992). We have provided a discussion of the calculations for CDI, hazard quotient, total carcinogenic risk, and maximum likelihood estimates for each exposure route separately. Difference in deterministic and probabilistic calculations are presented once for oral exposure; the same procedures apply to the dermal exposure route. Input values to each set of equations are provided for each exposure route for clarity. Reference values such as no observable adverse effect level (NOAEL), lowest observable adverse effect level (LOAEL), reference dose, and oral slope factors are provided specific to exposure routes when applicable and by specific contaminant. A discussion of the challenges associated with calculating exposure via inhalation is also provided for completeness.

Oral exposure.

Deterministic Calculations. For each CWS, the pre-intervention exposure was calculated using CDI (units of mg/kg-day) and the historical concentrations of a given contaminant in a CWS (Equation 3.1) (USEPA, 1992). CDI is the product of the concentration (*C*), intake rate (*IR)*, exposure frequency (*EF*), exposure duration (*ED)*, divided by the product of the average lifetime (*LT*), and bodyweight (*BW*). The average contaminant concentration in both groundwater wells and treated water was used to calculate CDI values. Only treated water concentration calculations are shown in the subsequent results.

$$CDI = \frac{C*IR*ED*EF}{BW*LT} \quad (3.1)$$

Total carcinogenic risk (TCR) is the product of the CDI and the oral slope factor (units of kg-day/mg), which is then subsequently used to produce an estimate hazard quotient (HQ) (Equation 3.2). The oral slope factor (SF) is a contaminant-specific value determined through epidemiological studies and used as a conversion factor to express exposure risk in unitless terms (USEPA IRIS, 1991). Hazard quotient (HQ) is found by multiplying the TCR value by the oral slope factor. HQ values are then added for each contaminant of concern to provide an overall estimate of exposure risk (Equation 3.3). For the purposes of this study, the HQ in each community is the sum of the HQ for individual contaminants. The HQ is equal to the exposure only from the contaminant of concern: arsenic in Region 1 and Region 5, and nitrate in Region 7. In Region 9, the HQ for arsenic only was calculated for comparison purposes with Region 1. We also planned to calculate the HQ for both arsenic and uranium in Region 9 by adding the HQ values to arsenic to uranium. In all scenarios, if the HQ is greater than one, then adverse effects from a contaminant that are potentially carcinogenic in nature exist in the system.

Carcinogenic risk was not calculated for nitrate (the contaminant in Region 7), as there are no data supporting carcinogenic effects of nitrate and no documented oral slope factor to calculate a HQ (USEPA IRIS, 2021b). In Region 9, the HQ for arsenic equals the total carcinogenic risk; a complete evaluation of carcinogenic potential for uranium has not been conducted by the US EPA IRIS program (US EPA IRIS, 1989) and there is currently no oral slope factor available for uranium in literature. Currently there have been no studies have been entered into the IRIS database that confirm uranium is a carcinogen. We calculate the total exposure using CDI for both arsenic and uranium, however, calculations for total carcinogenic risk in Region 9 only represent the carcinogenic risk from arsenic.

$$HQ = TCR * \text{ Oral Slope Factor} \quad (3.2)$$

$$\text{Carcinogenic Risk} = \sum_{i=1}^{n} HQ_{i} \quad (3.3)$$

Where a HQ could be calculated, carcinogenic risk was then used to find the maximum likelihood estimate (MLE) for arsenic (Equation 3.4):

$$MLE = TCR * DWUR * BWadjusted \quad (3.4)$$

The MLE value provides an estimate of the number of people in a population of 10,000 people who are impacted by carcinogenic risk from a given contaminant. For example, an MLE value of 4.0×10^{-5}, translates to 4 people impacted by arsenic contamination per 10,000 people. In Equation 3.4, the drinking water unit risk (DWUR) is a value specific to a given contaminant. A DWUR of 5×10^{-5} per µg/L is available for arsenic through the USEPA IRIS database (USEPA IRIS, 1991); no DWUR value for nitrate or uranium has yet been calculated due to a comparatively small body of epidemiological literature evidence for these contaminants (USEPA IRIS, 2021b, USEPA IRIS, 1989). Reference values from the World Health Organization for acceptable MLE values for cancers caused by arsenic contamination are in Appendix C, Table C1.

Probabilistic exposure. CDI was calculated as a range of values based on probabilistic modeling (Table 3) using the same equations described above. A deterministic analysis was used to provide a baseline average and median CDI and is a point estimate only. The probabilistic analysis provides a range of exposure values to estimate the best- and worst-case exposures for specific percentiles in a given population.

Probabilistic estimates were calculated by randomly generating a normal or lognormal distribution of 1000 data points, centered at a mean equal to the deterministic values in Table 3.1. For example, for intake rate, a normal distribution with 1000 data points was centered on 2 L/day intake which generated intake values ranging from 0 to 4 L/day to simulate both lower and higher than average water intake by individual members of the community water system population. Using the distributions for each variable, we then calculated a distribution of CDI values and extracted representative percentiles per the USEPA's exposure assessment method guidance (USEPA, 1992).

The 50^{th}, 90^{th}, 95^{th}, 98^{th}, 99^{th} and 99.9^{th} percentiles were selected as representative metrics for our analysis. The 50^{th} percentile represents the Central Tendency of the distribution, the 90^{th}-98^{th} percentile represents the Reasonable Worst-Case Exposure, the 98^{th} percentile represents the Maximum Exposure, the 90^{th} -99^{th} percentile represents the reasonable maximum exposure (RME), the 99.9^{th} percentile represents the Bounding Estimate; any value greater than the 90^{th} percentile represents a high-end estimate of exposure (Figure 3.1) (USEPA, 1992). Once each percentile was calculated, these exposure values were compared to literature values for the NOAEL and LOAEL of each contaminant to determine an approximate percentile of the population exposed to a contaminant. Probabilistic exposure estimates expand upon the point estimates from the deterministic exposure assessment, providing worst case exposure assessments for a conservative estimate of exposure.

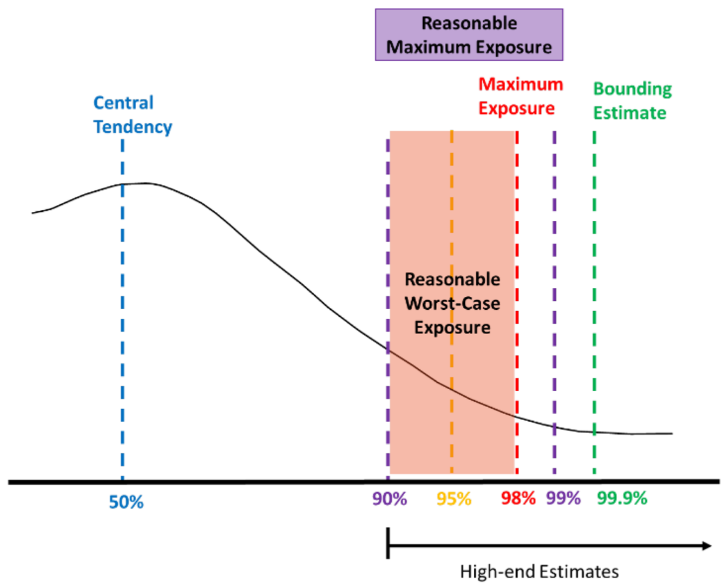


Figure 3.1: Estimated probabilistic chronic daily intake scenarios.

Input and Reference Values. We made the following assumptions for oral exposure to calculate CDI: IR of 2 L/day for an adult, EF is 365 days/year, ED of 70 years, LT of 70 years, male BW of 70 kg, female BW of 55 kg, child bodyweight of 15 kg and infant bodyweight of 5 kg (USEPA, 1992) (Table 3.1). The pre-implementation concentration of arsenic (C) was obtained from data from the CWS and the average concentration in treated water was used in CDI calculations.

Table 3.1: Assumptions for CDI calculation (USEPA, 1992).

Parameter	Deterministic Value	Probabilistic Values
Concentration (C)	Based on water quality data from each community water system	Lognormal distribution of concentrations from the water quality data from each community water system
Intake Rate (IR)	2 L/day	Normal distribution of 1000 randomly generated values with a mean at the deterministic values
Exposure Frequency (EF)	365 days/year	
Exposure Duration (ED)	Time to implement: CDI calculation: 70 years ADD calculation: variable	
Average Lifetime (AT)	70 years	
Bodyweight (BW)	Male = 70 kg Female = 55 kg Child = 15 kg Infant = 5 kg	

To determine post-intervention concentrations, we multiplied the pre-implementation concentration by the removal rate associated with a specific alternative. For example, if a POU manufacturer's manual or guide specified the POU device is certified to reliably remove 80% of arsenic up to 40,000 bed volumes (and under specific source water pH conditions), we found the post-implementation concentration by multiplying 0.2 (1-0.80) by the pre-implementation concentration. Table 3.2 presents the identified removal rates associated with both centralized treatment improvements and POU/POE devices. Removal rates for centralized treatment technologies were identified by examining the EPA Arsenic Demo Reports and EPA Design Manuals for removal of arsenic or nitrate (USEPA, n.d., USEPA, 1978, USEPA, 2003a, USEPA, 2003b, USEPA, 2006a). Removal rates for POU/POE devices were found by consulting their performance data or contacting device manufacturers or distributors to verify removal rates.

Table 3.2: Contaminant removal rates for selected alternatives (USEPA, n.d., USEPA, 1978, USEPA, 2003a, USEPA, 2003b, USEPA, 2006a)

Region	Contaminant	Alternative	Technology	Removal Rate	Source of Information
1	Arsenic	Centralized upgrade	GFH Adsorptive Media Filtration	95%	Literature: USEPA (n.d.). Arsenic Mitigation Strategies.
		POU – Company B, Device B2	Adsorptive Media (Carbon fiber)	96% at pH = 8.5 99% at pH = 6.5	Device performance specifications
		POU Device D	Reverse Osmosis	97% as pentavalent Arsenic	Device performance specifications
5	Arsenic	Centralized	Pre-oxidation/ Filtration	80%	Literature: USEPA (n.d.). Arsenic Mitigation Strategies
		POE Device N	Adsorptive Media (GFH)	95% at pH = 7.5	Conversation with device distributor[1]
		POE Device K	Adsorptive Media (GFH)	97% removal of total arsenic	Conversation with device distributor[2]
7	Nitrate	Centralized	Anion Exchange	90% removal of nitrate	Literature: DeSilva, 2003
		POU Device D	Reverse Osmosis	70% as N, 86% removal of nitrate-nitrite	Device performance specifications
		POU Device G	Reverse Osmosis	80%	Conversation with device distributor[1]
9	Arsenic	Centralized	Anion Exchange	95% removal of total arsenic	Literature: USEPA (n.d.). Arsenic Mitigation Strategies.
		POU Device B	Adsorptive Media (Carbon fiber)	96% at pH = 8.5 99% at pH = 6.5	Device performance specifications
		POU Device D	Reverse Osmosis	97% as pentavalent Arsenic	Device performance specifications

[1]Information made available upon request, but not publicly available

[2]The company is currently redoing their website information on this product as it has been updated and no written information is currently available

Previous studies of POU/POE devices have shown the nominal removal rate associated with devices may not accurately represent the actual performance of a POU/POE device in operation over time (AWWARF, 2005). To incorporate suboptimal operational removal rates, we identified the following studies (Table 3.3) through a literature review of studies or projects that examined POU/POE devices for the removal of arsenic or nitrate from drinking water (AWWARF, 2005). Additional removal rates from literature can be found in Appendix C, Table C2, C3 and C4 from several different studies (AWWARF, 2005, Yang et.al., 2020). We used the removal rates in Appendix C to generate a "best case" contaminant removal scenario (high removal rate) and a "worst case" contaminant removal scenario (low removal rate). We then calculated post-treatment implementation values using both the best-and worst-case removal rates to provide a range of expected exposure for each exposure route.

Best-case, worst-case and actual removal rates for both centralized treatment upgrades and POU/POE devices are in Table 3.3. Notably, the best-case and worst-case scenarios are derived only from literature values and represent removal rates from field testing of POU/POE devices. Our selected POU/POE devices have removal rates from manufacturers that may be greater or less than the values provided in literature based on manufacturer and third-party testing and certification claims. For example, in Region 1, Device B has an arsenic removal rate claim of 99%, which is higher than the best-case removal rate found from literature (96%). Since we did not test POU/POE devices in field, we used the manufacturer's removal rate to calculate the "actual" removal rate of a contaminant under ideal conditions. The best-case and worst-case scenarios from literature are used to provide a model for understanding the impact of potential variations in performance in field settings. As a result, we include best-case scenarios (those where the device performed at or close to manufacturer removal claims) and worst-case scenarios (those where the device underperformed compared to the manufacturer's claims) to ensure our analysis does not under- or overestimate exposure.

Table 3.3: Selected centralized and POU/POE alternative removal rates and best-case and worst-case scenarios based on removal rates from literature used to model exposure in each CWS.

Region	Mean Contaminant Concentration in treated water pre-implementation	Scenario (Centralized Upgrade (C) or POU/POE Device (D))	Contaminant Removal Rate	Mean Contaminant Concentration in treated water post-implementation	Source of Information
1	8.3 μg/L of arsenic	C, selected	95%	0.42 μg/L	Literature: USEPA (n.d.). Arsenic Mitigation Strategies
		C, best-case	95%	0.42 μg/L	Literature: USEPA (n.d.). Arsenic Mitigation Strategies
		C, worst-case	74%	2.2 μg/L	Arsenic Demo Reports
		POU Device B, selected	99%	0.08 μg/L	Manufacturer specifications
		POU Device D, selected	97%	0.27 μg/L	Manufacturer specifications
		POU, best-case (Carbon fiber adsorptive media and RO)	96%	0.33 μg/L	AWWARF Report 2005
		POU, worst-case (Carbon fiber adsorptive media)	68%	6.6 μg/L	Powers et.al., 2019
		POU, worst-case, (Reverse osmosis)	46%	4.5 μg/L	AWWARF Report 2005
5	9.1 μg/L of arsenic	C, selected	80%	1.8 μg/L	Literature: USEPA (n.d.). Arsenic Mitigation Strategies
		C, best-case	80%	1.8 μg/L	Literature: USEPA (n.d.). Arsenic Mitigation Strategies
		C, worst-case	79%	1.9 μg/L	Arsenic Demo Reports
		POE Device N, selected	95%	0.46 μg/L	Manufacturer specifications
		POE Device K, selected	98%	0.18 μg/L	Manufacturer specifications
		POE, best-case	96%	0.37 μg/L	AWWARF Report 2005
		POE, worst-case	42%	5.3 μg/L	AWWARF Report 2005
7	9.3 mg/L of nitrate as N	C, selected	90%	0.94 mg/L	Literature: DeSilva, 2003
		C, best-case	90%	0.94 mg/L	Literature: DeSilva, 2003
		C, worst-case	65%	3.3 mg/L	Arsenic Demo Reports

		POU Device D, selected	80%	1.9 mg/L	Manufacturer specifications
		POU Device G, selected	70%	2.8 mg/L	Manufacturer specifications
		POU, best-case	97%	0.28 mg/L	Arsenic Demo Reports
		POU, worst-case	57%	4.0 mg/L	Arsenic Demo Reports
9	19.6 µg/L of arsenic	C, selected	95%	0.98 µg/L	Literature: USEPA (n.d.). Arsenic Mitigation Strategies
		C, best-case	95%	0.98 µg/L	Literature: USEPA (n.d.). Arsenic Mitigation Strategies
		C, worst-case	40%	11.8 µg/L	Arsenic Demo Reports
		POU Device B, selected	99%	0.2 µg/L	Manufacturer specifications
		POU Device D, selected	97%	0.59 µg/L	Manufacturer specifications
		POU, best-case (Carbon fiber adsorptive media and RO)	96%	0.78 µg/L	AWWARF Report 2005
		POU, worst-case (carbon fiber adsorptive media)	68%	15.7 µg/L	Powers et.al., 2019
		POU, worst-case (reverse osmosis)	46%	10.6 µg/L	AWWARF Report 2005

After completing calculations, we compared the CDI, carcinogenic risk, and MLE for both pre- and post-implementation values for each water system to the corresponding contaminant NOAEL and LOAEL values to determine if exposure to the contaminant is expected to result in observable adverse effects in the customer population. The CDI values for nitrate and uranium were compared only to the respective NOAEL and LOAEL values from literature as TCR and HQ cannot be calculated for these contaminants. Reference values from US EPA literature are in Table 3.4 (USEPA IRIS, 1989, USEPA IRIS, 1991, USEPA IRIS, 2021b). We adjusted the NOAEL and LOAEL values for arsenic for an intake of 2L/day and both a male bodyweight of 75 kg and a female bodyweight of 55 kg to align with the input values selected above.

Table 3.4: Reference literature values for each contaminant considered in the oral exposure route (USEPA IRIS, 1989, USEPA IRIS, 1991, USEPA IRIS, 2021b).

Contaminant	Reference Dose (RfD)	NOAEL	Adjusted NOAEL†					LOAEL	Oral Slope Factor
			Units	Male (75 kg)	Female (55 kg)	Child (15 kg)	Infant (5 kg)		
Arsenic*	0.3 µg/kg/ day	0.8 ug/kg/ day (0.009 mg/L)*	µg/kg/ day	0.27	0.36	1.33	4.0	14.0 µg/kg/ day (0.17 mg/L)*	1.5 per mg/kg/ day
Nitrate	1.6 L/kg/ day	1.6 mg/kg/ day	mg/kg/ day	0.27	0.36	1.33	4.0	1.8-3.2 mg/kg/ day	NA
Uranium	3.0×10^{-3} mg/kg/ day	NA	NA	NA	NA	NA	NA	2.8 mg/kg/ day from food	NA

† Adjusted NOAEL values were calculated for an intake rate of 2L/day and the corresponding bodyweight

*NOAEL and LOAEL values are based on an intake rate of 4.5 L/day and a bodyweight of 75 kg

^based on 0.64 L/day for a 4 kg infant

Dermal exposure.

Calculations. Chronic daily intake for dermal exposure can be calculated using the following equation:

$$CDI = \frac{DA*SA*ED*EF}{BW*LT} \quad (3.6)$$

$$DA = Kp * C * t \quad (3.7)$$

In Equations 3.6 and 3.7, *DA* (mg/cm^2-event) represents the dermal absorption dose, which is the product of the permeability coefficient K_p (cm/hr.), the concentration of the chemical contacting the skin *C* (mg/cm^3) and the time per contact event *t* (hours/event). The variable *SA* (cm^2) represents the skin area available for contact with the chemical (US EPA, 2020b).

Input values. Using the EPA Exposure Factors Handbook (US EPA, Chapter 7, 2011), we selected a surface area for the entire body (assuming dermal contact occurs during showering or bathing) of 210 cm^2 for an adult male, 180 cm^2 for an adult female, 160 cm^2 for a teenager and 50 cm^2 for an infant. A contact time per dose of 15 minutes was selected to calculate the dermal dose absorbed. Literature values for the permeability coefficient of arsenic were identified and a permeability coefficient of 2.7×10^{-3} was used for arsenite (As (III)) and a coefficient of 9.2×10^{-5} was used for arsenate (As (V)). No data detailing the ratio of As (III) to As (V) was available from Region 1, 5 or 9; therefore, we calculated exposure using both coefficients and reported the worst-case scenario estimates.

3.1.2 Estimating time to implement by modeling exposure duration

Calculations and inputs. Average daily dose (ADD) was used to model different exposure scenarios over an averaging time (AT) of 30 years (USEPA, 1992). ADD uses the same variables as the CDI calculation, but with an averaging time instead of a lifetime in the denominator. Using the same assumptions for CDI in Table 3.1, we modeled several exposure durations (ED) and concentrations (C) post-implementation. The following equations show the ADD calculation (Equation 3.8) and the relationships between pre- and post-implementation values (Equation 3.9 and 3.10)

$$ADD = \frac{C*IR*ED*EF}{BW*AT} \tag{3.8}$$

$$ADDtotal = ADDpre + ADD\ post \tag{3.9}$$

$$EDpre = 30\ [years] - EDpost \tag{3.10}$$

Using an averaging time of 30 years, we modeled ADD for pre-intervention and post-intervention doses, modeling ED values between 0-30 years for pre-implementation exposure. The ADD_{total} value was calculated as the sum of the ADD_{pre} value using an ED_{pre} value equal to 30 [years] – ED_{post} and the ADD_{post} value equal to ED_{post} (Equation 3.10). Pre- and post-implementation concentrations were calculated as described above for CDI calculations. The pre- and post-intervention doses were then summed to determine the average daily dose over the averaging time of 30 years and compared to literature values to determine when the ADD exceeded the NOAEL or LOAEL for a given contaminant. If ADD_{total} exceeded the adjusted NOAEL value for the specific contaminant, we located the first ED_{pre} value where $ADD_{total} > NOAEL_{adjusted}$. This ED_{pre} value represents the maximum amount of time a CWS would have to implement the post-implementation solution (with a specific removal rate) before adverse effects are observable in a population. For example, if an intervention takes five years to implement, the pre-intervention dose is calculated using the pre-implementation concentration of the given contaminant over a five-year exposure duration, while the post-implementation dose was calculated using the post-implementation concentration (pre-implementation concentration multiplied by the removal rate) and a 25-year exposure duration. The aim of this analysis is to identify the first ED_{pre} value associated with each contaminant removal rate that exceeds the adjusted NOAEL to provide a maximum number of years a CWS will have to implement the specific alternative (Figure 3.2). Notably, this analysis is specific to a given removal rate and the initial contaminant concentration; the number of years to implement in practice depends on other water quality characteristics and contaminants in the system. For the purposes of this study, we focus specifically on each contaminant of concern in isolation when finding the ED_{pre} values for implementation timelines.

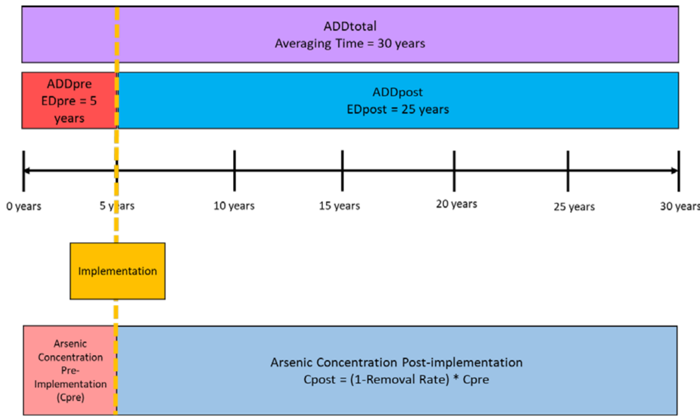


Figure 3.2: Method describing use of ADD over 30 years to determine the time to implement an alternative based on removal rate and exposure duration.

Comparing ADD values to timelines to implement

To put ADD_{total} values into context in each CWS, we consulted with CWS stakeholders and state administrators to construct timelines to realistically implement either a centralized treatment improvement or a POU/POE device. Activities included time to:

1. Obtain permits or state approval
2. Select and evaluate technologies
3. Secure funding for a system upgrade
4. Install a device or treatment improvement
5. Pilot studies prior to installation

Timelines were constructed for both a best-case (fastest time to implement) and worst-case scenarios (longer time to implement) to capture variations present in specific CWSs. We then compared the implementation timeline to the ED_{pre} values to determine whether an alternative can feasibly be implemented to reduce exposure. From these comparisons, it is then possible to make a judgement between the exposure associated with a POU/POE device and a centralized treatment improvement. It is important to note this analysis focuses primarily on the time necessary to implement a technology and the removal of a contaminant achieved by a technology. Operation and maintenance, including device replacement, is necessary to continue to assume the nominal removal rate remains the same over time; our analysis assumes consistent performance over time.

In addition, to use POU/POE units for compliance purposes, there must be a unit at each connection in a water system, meeting the “100% participation” requirement from the USEPA (USEPA, 2006b). CWS stakeholders interviewed for this project and information documented in literature have highlighted difficulties with obtaining 100% participation when considering POU/POE solutions which often can significantly delay POU/POE implementation in a CWS. In Region 9, California requirements have leniency wherein pilot testing may begin before 100% participation has been achieved, however, the requirement for 100% participation still has a significant impact on overall implementation timelines. As a result, when comparing the results of the ADD analysis described above to actual implementation, we compare two scenarios for POU/POE devices: (1) ideal implementation time as described by CWS stakeholders (best-case) and (2) worst-case implementation that includes an additional 3-5 years to achieve 100% participation before implementation can occur.

Estimating lifetime exposure

Finally, we adjusted our calculations of ADD and CDI to reflect lifetime exposure. While the study period is 30 years, calculating the average daily dose for an infant over a 30-year period does not represent the reality that an infant is considered a 0–2-year-old by USEPA exposure documentation (USEPA, 1992). Calculating 30 years of exposure for only an adult bodyweight does not account for the higher doses of a contaminant ingested by smaller bodyweight infants and children at the same contaminant concentration in water as adults consume. As a result, we examined exposure from 0-30 years using the following age ranges: 0-2 years old represents an infant, 2-10 years represents a child, and 10-30 years represents an adult (either female or male). We calculated both the ADD as described previously and the cumulative ADD to estimate 30 years of exposure from birth to 30 years old. We calculated lifetime exposure for a scenario where no improvement was implemented, where one of the two POU/POE devices was implemented, and where a centralized treatment improvement was implemented, and compared these values to the estimated implementation timelines. Dose was calculated per year to determine a cumulative dose from 0-30 years, representing the worst-case scenario of exposure in the CWSs.

3.2 Results

Results from individual calculations (including CDI, TCR and MLE) are presented in detail for only one case study CWS in the report as an example. Results from the three additional CWSs are presented in Appendix C.

3.2.1.1 Estimating intake of contaminants

3.2.1.1 Deterministic exposure

Oral exposure.
Table 3.6 shows the pre- and post-implementation exposure calculations for Region 1 using the identified removal rates (Table 3.2) to determine the final concentration of a contaminant in a water

system (similar tables for Regions 5, 7, and 9 are in Appendix C). Pre-implementation exposure to a mean arsenic concentration of 8.1 µg/L results in a carcinogenic risk greater than the NOAEL for all bodyweights evaluated if no treatment technology is implemented within the AT of 30 years. Pre-implementation, the HQ exceeds one for all bodyweights, indicating there is carcinogenic risk associated with exposure to arsenic.

Post-implementation, we found that for all treatment scenarios (best-case performance, actual device performance, etc.) evaluated in Region 1, the total carcinogenic risk values were less than the NOAEL (TCR< NOAEL) and HQ values were less than one (HQ < 1), except for the worst-case POU removal efficiency (20%). For this scenario, 20% removal would not adequately remove arsenic in the drinking water system to a level where there is no carcinogenic risk to the population (TCR > NOAEL or HQ >1) over a 30-year exposure duration. Both the centralized treatment system improvement (95% removal) and the POU device alternatives (99% and 97% removal respectively) sufficiently reduce the total carcinogenic risk values below NOAEL values for arsenic, indicating that there is no evidence of carcinogenic risk. Table 3.5 presents these results, showing the mean arsenic concentration post-implementation (C_{post}), the CDI, TCR, HQ, and MLE values, including the MLE value translated into the number of people impacted per 10,000 people. CDI and TCR >NOAEL are highlighted in yellow and HQ >1 is highlighted in red.

Table 3.5: Oral chronic daily intake exposure from arsenic in Region 1. Total carcinogenic risk values exceeding the adjusted NOAEL are highlighted in yellow and hazard quotient values greater than one are highlighted in red.

Scenario			Mean Arsenic Concentration (µg/L)	Bodyweight	CDI (ug/kg/day)	Carcinogenic Risk (ug/kg/day)	Hazard Quotient	MLE	# of People per 10,000 people
Pre-Implementation	Centralized	Treatment of 50% of the flow rate from the GW via adsorptive media filtration	8.3	Male = 75 kg	0.22	0.33	1.1	1.7E-05	1.7
				Female = 55 kg	0.30	0.45	1.5	2.3E-05	2.3
				Child = 15 kg	1.11	1.66	5.5	8.3E-05	8.3
				Infant = 5 kg	3.32	4.98	16.6	2.5E-04	24.9
Post-Implementation	Centralized Upgrade	Treatment of 100% of the flow rate by adding an additional filtration module (95% Removal)	0.42	Male = 75 kg	0.01	0.02	0.06	8.3E-07	0.1
				Female = 55 kg	0.02	0.02	0.08	1.1E-06	0.1
				Child = 15 kg	0.06	0.08	0.28	4.2E-06	0.4
				Infant = 5 kg	0.17	0.25	0.83	1.2E-05	1.2
	POU	POU Device B, Adsorptive Media (99% Removal)	0.08	Male = 75 kg	0.0022	0.00	0.01	1.7E-07	0.0
				Female = 55 kg	0.0030	0.00	0.02	2.3E-07	0.0
				Child = 15 kg	0.011	0.02	0.06	8.3E-07	0.1
				Infant = 5 kg	0.033	0.05	0.17	2.5E-06	0.2
	POU	POU Device D, Reverse Osmosis (97% Removal)	0.25	Male = 75 kg	0.0066	0.01	0.03	5.0E-07	0.0
				Female = 55 kg	0.0091	0.01	0.05	6.8E-07	0.1
				Child = 15 kg	0.0332	0.05	0.17	2.5E-06	0.2
				Infant = 5 kg	0.0996	0.15	0.50	7.5E-06	0.7

In Region 5, due to a higher pre-implementation arsenic concentration of 9.1 µg/L and a lower centralized treatment removal efficiency of 80% of arsenic (compared to Region 1), the calculated HQ values were >1 for specific bodyweights, indicating a risk of carcinogenic effects from arsenic in children and infants. The removal efficiency from POE Device N (95% of arsenic) and POE Device K (97% removal of total arsenic) produced TCR values less than the NOAEL and HQ < 1, indicating no carcinogenic risk from arsenic to the customers in the Region 5 CWS after a 30- year exposure duration. Deterministic results in Region 5 indicate higher removal efficiencies are preferrable, with the POE devices adequately reducing exposure so that HQ < 1, minimizing carcinogenic risk.

In Region 7, we did not calculate TCR, HQ and MLE since nitrate is non-carcinogenic according to the USEPA IRIS database (USEPA, 2021b). Instead, we compared the CDI values to the NOAEL and LOAEL values for nitrate via oral exposure to determine any expected observable effects. Pre-implementation, no CDI values exceeded the NOAEL or LOAEL for nitrate, with the same result post-implementation as well. Deterministic results indicate that there was no difference in exposure from centralized or POU treatment since the pre-implementation concentration of nitrate was already below the NOAEL threshold.

In Region 9, due to a high mean pre-implementation arsenic concentration of 19.6 µg/L, our results indicated carcinogenic risk associated with all currently identified removal efficiencies, with the exception of 99% removal of arsenic by POU Device B. All but one upgrade option resulted in a HQ >1; however, POU Device B resulted in HQ<1 with a total carcinogenic risk < NOAEL. Carcinogenic risk associated with arsenic was calculated to be a concern particularly for infants, due to the smaller bodyweight of 5 kg. Deterministic results indicate that a high removal efficiency is necessary in Region 9 to sufficiently reduce exposure; the only option able to meet this requirement was POU Device B with a removal efficiency of 99%.

In Region 9, we also evaluated the risk associated with uranium exposure and the combined exposure to uranium and arsenic. There are no current NOAEL and LOAEL values for uranium associated in water, therefore, we compared CDI and TCR values to the reference dose for uranium. Deterministic results for uranium alone indicate the CDI value exceeds the reference dose for uranium pre-implementation. Pre-implementation, the TCR values exceed the reference dose for all bodyweights, with a HQ > 1 for infant bodyweights. Post-implementation, 50% removal of uranium would be sufficient so that a male person in a community will not have a CDI value greater than the reference dose, but the TCR and CDI values for a woman, child, and teen remain greater that the reference dose. When the removal rate is increased to 90-99% based on literature removal values for uranium, the CDI and TCR values would then be less than the reference dose and no HQ>1, indicating sufficient reduction in uranium exposure. These results indicate that POU/POE devices with higher removal efficiencies may be preferential in Region 9, particularly when reducing both arsenic and uranium concentrations to levels where adverse impacts are not seen in the population.

Initial results provide evidence that the higher removal efficiencies associated with POU/POE devices under best case circumstances may reduce total carcinogenic risk to the small CWSs considered in this study (Table 3.6). In the Regions 5 and 9 cases, the higher initial arsenic concentration corresponds with higher TCR and HQ values with resulting potential carcinogenic risk for these communities. In Region 7, because neither pre- nor post-implementation concentrations of nitrate resulted in CDI greater than the NOAEL for nitrate, there was no advantage of centralized or POU/POE treatment alternative based on lifetime oral exposure alone.

Table 3.6: Overall initial results indicating where carcinogenic risk is expected in at least one bodyweight category for arsenic contamination or where no observable adverse effects are present for nitrate contamination.

Scenario		Region 1	Region 5	Region 7	Region 9
Pre-Implementation	Centralized	Carcinogenic Risk	Carcinogenic Risk	No Observable Adverse Effects	Carcinogenic Risk
Post-Implementation	Centralized Upgrade	No Carcinogenic Risk	Carcinogenic Risk	No Observable Adverse Effects	Carcinogenic Risk
	POU/POE Device(Larger Removal Rate)	No Carcinogenic Risk	No Carcinogenic Risk	No Observable Adverse Effects	No Carcinogenic Risk
	POU/POE Device (Smaller Removal Rate)	Carcinogenic Risk	No Carcinogenic Risk	No Observable Adverse Effects	Carcinogenic Risk

Inhalation and Dermal Exposure.

After reviewing literature and completing initial calculations for both inhalation and dermal exposure, we determined the oral exposure route was the most significant source of exposure based on our selected contaminants. We considered the inhalation and dermal exposure routes due to the possibility of inhalation of contaminated water at shower heads, a scenario that could occur if a POU device were installed, since a POU device only treats water at the tap where installed. Therefore, exposure risks would exist at pre-implementation contaminant concentrations (arsenic, nitrate or uranium) in Regions 1, 7 and 9. In contrast, a POE device, which treats all water prior to entering premise plumbing, Would reduce inhalation and dermal exposure; in Region 5, POE devices were selected, and therefore dermal and inhalation exposure would rely on the post-implementation concentrations of a contaminant. Therefore, we considered exposure to pre-implementation concentrations via inhalation and dermal routes for all selected POU devices and exposure to post-implementation concentration via inhalation and dermal exposure for selected POE devices (Region 5) and centralized treatment improvements.

Inhalation and dermal exposure pathways for uranium are not in the EPA IRIS database, showing that exposure to these have not yet been evaluated through epidemiological studies and thus there is no reference data available to determine a NOAEL, LOAEL, reference dose, or potential carcinogenic risk of uranium via these exposure routes (USEPA IRIS, 1989). Exposure to nitrate via the inhalation and dermal route is not considered significant compared to nitrate exposure via food consumption and through the oral exposure to drinking water (USEA IRIS, 2021b). Arsenic can cause potential carcinogenic and non-carcinogenic effects in humans via the dermal and inhalation routes (USEPA IRIS, 1991). Based on this information, we conducted an exploratory analysis of exposure via dermal and inhalation routes to assess the magnitude of exposure in comparison to the oral exposure route.
Inhalation exposure. While studies have shown inhalation of arsenic to be detrimental to human health, exposure to arsenic through inhalation is primarily through air as a media (dust particles), rather than water (USEPA, 1991). Few, if any studies have examined exposure to inorganic contaminants such as arsenic via inhalation of aerosolized water droplets. Studies examining exposure to contaminants in aerosolized water droplets in household showers have largely focused on microbial contamination (e.g., *Legionella*) or from volatile organic contaminants (Azuma et.al., 2013, Zhou et.al., 2011). To estimate arsenic exposure via aerosolized water droplets, we first attempted to determine the concentration of arsenic in water droplets using the equations in Davis et.al. 2016. However, these calculations rely on knowledge of the fraction volume of water droplets inhaled, the water volume aerosolization rate per shower fixture, the flow rate of water at a shower fixture, the breathing rate of a person, and the arsenic specific fraction aerosolized. While several of these values can be estimated via literature, no studies have been conducted to determine how much arsenic in water is aerosolized in a shower, leading to a large degree of uncertainty in the concentration of arsenic inhaled by an average person during a bathing event.

Furthermore, even if the arsenic concentration in aerosolized water particles could be estimated, USEPA IRIS studies have only investigated the risk of exposure to arsenic via the inhalation in air (not in aerosolized water droplets). Therefore, any reference values provided by the IRIS database are not applicable to our scenario (USEPA, 1989). In addition, once arsenic in aerosolized droplets is inhaled, only a fraction of the arsenic concentration is absorbed by lung tissue and has the potential to cause carcinogenic or non-carcinogenic effects (USEPA, 2020a). While the inhalation pathway is important for microbial and volatile organic contaminants, we did not find sufficient guidance to perform a reasonable calculation of inhalation exposure for the inorganic contaminants such as arsenic, nitrate and uranium, nor evidence to suggest that these are important routes of exposure to these contaminants relative to ingestion of drinking water.

Dermal exposure. We did, however, find evidence from literature that dermal exposure to arsenic is an important exposure route to include in our analysis (Boffetta et.al., 2020). For dermal exposure, we determined it would be necessary to calculate exposure to arsenite (As(III)) and arsenate (As(V)) separately as each compound has a different permeability coefficient. Since we lack arsenic speciation from Region 1, 5, or 9, we assumed a worst-case scenario for each species, using the total arsenic pre-implementation concentration to calculate the dermal concentration absorbed in $\mu g/cm^2$. Initial calculations indicate the exposure to arsenic via the dermal route is 2 orders of magnitude smaller than through the oral exposure route for Region 1 and does not pose a carcinogenic risk.

An example of dermal exposure to arsenite (As (III)) and arsenate (As (V)) are in Appendix C. Dermal exposure values (CDI, TCR and HQ) were calculated separately for arsenite and arsenate because each compound has a different permeability coefficient. We calculated exposure parameters assuming that 100% of arsenic in Region 1 was either arsenite or arsenate to generate worst-case exposure scenarios. Dermal exposure results are not discussed in detail in the results of this report, but calculated values are provided in Appendix C for completeness.

3.2.1.2 Probabilistic exposure

Oral exposure.

Table 3.7 provides the results of probabilistic modeling of chronic daily intake for Region 1. For all considered removal efficiencies, the central tendency estimate (median) does not exceed the NOAEL. However, reasonable worst case exposure values (90^{th}-98^{th} percentiles) indicate the CDI values exceed the NOAEL values both in the pre-implementation scenario and when using the worst-case exposure POU scenario (68% removal of arsenic). For removal efficiencies of 95% (centralized treatment), 96% (best-case POU treatment from literature) and 99% (POU Device B), the 90^{th} percentile values for CDI do not exceed the NOAEL, indicating any of these removal efficiencies are sufficient to reduce arsenic exposure below the NOAEL. The probabilistic modeling results verify the conclusions made from the deterministic analysis presented previously for Region 1, indicating higher removal rates are preferrable for reducing contaminant exposure.

Table 3.7: Probabilistic chronic daily intake results for Region 1 exposure showing percentiles of interest related to exposure

Pre-implementation							
	Bodyweight*	Central Tendency	Reasonable Worst- Case Exposure (Lower Bound)	95th Percentile	Maximum Exposure	Maximum Exposure (Upper Bound)	Bounding Estimate
	Male	0.120	0.233	0.277	0.291	0.294	0.301
	Female	0.150	0.289	0.347	0.351	0.360	0.377
Post-implementation							
Removal Rate							
95% Removal	Male	0.011	0.015	0.016	0.017	0.017	0.019
	Female	0.015	0.020	0.021	0.023	0.024	0.027
	Child	0.056	0.074	0.079	0.084	0.087	0.096
	Infant	0.169	0.229	0.248	0.269	0.287	0.319
96% Removal	Male	0.009	0.012	0.013	0.014	0.014	0.015
	Female	0.012	0.016	0.017	0.018	0.019	0.021
	Child	0.045	0.059	0.063	0.067	0.070	0.077
	Infant	0.135	0.183	0.198	0.215	0.230	0.256
99% Removal	Male	0.002	0.003	0.003	0.003	0.003	0.004
	Female	0.003	0.004	0.004	0.005	0.005	0.005
	Child	0.011	0.015	0.016	0.017	0.017	0.019
	Infant	0.034	0.046	0.050	0.054	0.057	0.064

*Male bodyweight = 75 kg, Female bodyweight = 55 kg, Child bodyweight – 15 kg, and infant bodyweight = 5kg

Probabilistic results for Regions 5, 7 and 9 are presented in Appendix C. Results from the probabilistic modeling verify the results obtained via deterministic calculations.

3.2.2 Estimating time to implement by modeling exposure duration

Table 3.8 provides a summary of both the total carcinogenic risk and HQ values for a number of years (0-30 years) to implement an alternative in Region 1. The table compares the TCR and HQ values for a male bodyweight and an infant bodyweight to highlight the importance of both bodyweight and removal efficiency. The number of years to implement represents the ED pre-implementation value used to calculate ADD during modeling.

In Region 1, TCR values for a worst-case 68% arsenic removal efficiency and a male bodyweight does exceed the NOAEL for arsenic. This indicates that if a POU device with a low removal efficiency was implemented today, the male population in Region 1 would not be at risk for carcinogenic effects. With actual device removal efficiencies between 95-99%, TCR values do not exceed the NOAEL until 24 years of pre-implementation exposure. This indicates a male population in Region 1 would not expect to see carcinogenic effects from the combined pre-implementation concentrations of arsenic (8.3 µg/L) and post-implementation concentrations of arsenic (0.08-0.42 µg/L) until year 24. Recall TCR is evaluated using the total average daily dose values over 30 years multiplied by the reference dose for arsenic. This means the male population in Region 1 will cross the threshold from non-carcinogenic risk to carcinogenic risk (TCR > NOAEL) when the maximum pre-implementation concentration is 8.3 µg/L for 24 years, and a post-implementation concentration is 0.08-0.42 µg/L for 6 years. From an implementation standpoint, if the removal is 95-99%, the system has 24 years in which to implement the technologies with a 95-99% removal efficiency before carcinogenic risk is present in the male population. If an alternative is implemented after 24 years, the average daily dose experienced by the male population yields a TCR value > NOAEL because the population has been exposed to the pre-implementation concentration for too long compared to exposure to post-implementation concentrations. If we examine the TCR values for an infant, a child, and a female bodyweight, we see similar results.

However, if we examine HQ instead of TCR, we discover that for an infant bodyweight, the number of years available to implement a treatment technology decreased. In Table 3.8, scenarios where the HQ>1 are highlighted in red, representing scenarios with carcinogenic risk present to a given population. For removal rates of 95% (centralized treatment) and 97% (POU Device D), only one year can pass pre-implementation before reaching HQ>1 for an infant bodyweight. POU Device B with a removal efficiency of 99% has HQ >1 after two years of pre-implementation exposure. Either the centralized treatment upgrade or POU Device D would need to be implemented within one year to prevent total exposure over a 30-year period from causing carcinogenic effects. POU Device D, having a higher removal rate, needs to be implemented within 2 years to minimize carcinogenic risk for infants.

Table 3.8: Region 1 ADD values for POU AM technologies (Device B) and centralized improvements with several different removal rates for arsenic for male and infant bodyweights.

Number of years to implement	Male										Infant									
	Total Carcinogenic Risk (ug/kg/day)					Hazard Quotient					Total Carcinogenic Risk (ug/kg/day)					Hazard Quotient				
	Removal Rate					Removal Rate					Removal Rate					Removal Rate				
	Centralized (95%)	POU Device B (99%)	POU Device D (97%)	Best Case POU (96%)	Worst Case POU (68%)	Centralized (95%)	POU Device B (99%)	POU Device D (97%)	Best Case POU (96%)	Worst Case POU (268%)	Centralized (95%)	POU Device B (99%)	POU Device D (97%)	Best Case POU (96%)	Worst Case POU (68%)	Centralized (95%)	POU Device B (99%)	POU Device D (97%)	Best Case POU (96%)	Worst Case POU (68%)
0	0.02	0.00	0.01	0.01	**0.25**	0.1	0.0	0.0	0.0	**0.4**	0.25	0.05	0.15	0.20	**1.59**	0.8	0.2	0.5	0.7	**5.3**
1	0.03	0.01	0.02	0.02	**0.27**	0.1	0.0	0.1	0.1	**0.4**	0.41	0.21	0.31	0.36	**1.71**	1.4	0.7	1.0	1.2	**5.7**
2	0.04	0.03	0.03	0.03	**0.29**	0.1	0.1	0.1	0.1	**0.4**	0.56	0.38	0.47	0.52	**1.82**	1.9	1.3	1.6	1.7	**6.1**
3	0.05	0.04	0.04	0.05	**0.30**	0.2	0.1	0.1	0.2	**0.4**	0.72	0.54	0.63	0.68	**1.93**	2.4	1.8	2.1	2.3	**6.4**
4	0.06	0.05	0.05	0.06	**0.32**	0.2	0.2	0.2	0.2	**0.5**	0.88	0.71	0.79	0.84	**2.05**	2.9	2.4	2.6	2.8	**6.8**
5	0.07	0.06	0.06	0.07	**0.34**	0.2	0.2	0.2	0.2	**0.5**	1.04	0.87	0.95	1.00	**2.16**	3.5	2.9	3.2	3.3	**7.2**
6	0.08	0.07	0.07	0.08	**0.36**	0.3	0.2	0.2	0.3	**0.5**	1.20	1.04	1.12	1.16	**2.27**	4.0	3.5	3.7	3.9	**7.6**
7	0.09	0.08	0.09	0.09	**0.38**	0.3	0.3	0.3	0.3	**0.5**	1.35	1.20	1.28	1.31	**2.38**	4.5	4.0	4.3	4.4	**7.9**
8	0.10	0.09	0.10	0.10	**0.39**	0.3	0.3	0.3	0.3	**0.6**	1.51	1.36	1.44	1.47	**2.50**	5.0	4.5	4.8	4.9	**8.3**
9	0.11	0.10	0.11	0.11	**0.41**	0.4	0.3	0.4	0.4	**0.6**	1.67	1.53	1.60	1.63	**2.61**	5.6	5.1	5.3	5.4	**8.7**
10	0.12	0.11	0.12	0.12	**0.43**	0.4	0.4	0.4	0.4	**0.6**	1.83	1.69	1.76	1.79	**2.72**	6.1	5.6	5.9	6.0	**9.1**
11	0.13	0.12	0.13	0.13	**0.45**	0.4	0.4	0.4	0.4	**0.6**	1.98	1.86	1.92	1.95	**2.84**	6.6	6.2	6.4	6.5	**9.5**
12	0.14	0.13	0.14	0.14	**0.46**	0.5	0.4	0.5	0.5	**0.7**	2.14	2.02	2.08	2.11	**2.95**	7.1	6.7	6.9	7.0	**9.8**
13	0.15	0.15	0.15	0.15	**0.48**	0.5	0.5	0.5	0.5	**0.7**	2.30	2.19	2.24	2.27	**3.06**	7.7	7.3	7.5	7.6	**10.2**
14	0.16	0.16	0.16	0.16	**0.50**	0.5	0.5	0.5	0.5	**0.7**	2.46	2.35	2.40	2.43	**3.17**	8.2	7.8	8.0	8.1	**10.6**
15	0.17	0.17	0.17	0.17	**0.52**	0.6	0.6	0.6	0.6	**0.7**	2.61	2.51	2.56	2.59	**3.29**	8.7	8.4	8.5	8.6	**11.0**
16	0.18	0.18	0.18	0.18	**0.54**	0.6	0.6	0.6	0.6	**0.8**	2.77	2.68	2.73	2.75	**3.40**	9.2	8.9	9.1	9.2	**11.3**

17	0.20	0.19	0.19	0.19	**0.55**	0.7	0.6	0.6	0.6	**0.8**	2.93	2.84	2.89	2.91	**3.51**	9.8	9.5	9.6	9.7	**11.7**
18	0.21	0.20	0.20	0.20	**0.57**	0.7	0.7	0.7	0.7	**0.8**	3.09	3.01	3.05	3.07	**3.63**	10.3	10.0	10.2	10.2	**12.1**
19	0.22	0.21	0.21	0.22	**0.59**	0.7	0.7	0.7	0.7	**0.8**	3.25	3.17	3.21	3.23	**3.74**	10.8	10.6	10.7	10.8	**12.5**
20	0.23	0.22	0.22	0.23	**0.61**	0.8	0.7	0.7	0.8	**0.9**	3.40	3.34	3.37	3.39	**3.85**	11.3	11.1	11.2	11.3	**12.8**
21	0.24	0.23	0.24	0.24	**0.62**	0.8	0.8	0.8	0.8	**0.9**	3.56	3.50	3.53	3.55	**3.96**	11.9	11.7	11.8	11.8	**13.2**
22	0.25	0.24	0.25	0.25	**0.64**	0.8	0.8	0.8	0.8	**0.9**	3.72	3.67	3.69	3.71	**4.08**	12.4	12.2	12.3	12.4	**13.6**
23	0.26	0.26	0.26	0.26	**0.66**	0.9	0.9	0.9	0.9	**0.9**	3.88	3.83	3.85	3.86	**4.19**	12.9	12.8	12.8	12.9	**14.0**
24	0.27	0.27	0.27	0.27	**0.68**	0.9	0.9	0.9	0.9	**1.0**	4.03	3.99	4.01	4.02	**4.30**	13.4	13.3	13.4	13.4	**14.3**
25	0.28	0.28	0.28	0.28	**0.70**	0.9	0.9	0.9	0.9	**1.0**	4.19	4.16	4.17	4.18	**4.42**	14.0	13.9	13.9	13.9	**14.7**
26	0.29	0.29	0.29	0.29	**0.71**	1.0	1.0	1.0	1.0	**1.0**	4.35	4.32	4.34	4.34	**4.53**	14.5	14.4	14.5	14.5	**15.1**
27	0.30	0.30	0.30	0.30	**0.73**	1.0	1.0	1.0	1.0	**1.0**	4.51	4.49	4.50	4.50	**4.64**	15.0	15.0	15.0	15.0	**15.5**
28	0.31	0.31	0.31	0.31	**0.75**	1.0	1.0	1.0	1.0	**1.1**	4.66	4.65	4.66	4.66	**4.75**	15.5	15.5	15.5	15.5	**15.8**
29	0.32	0.32	0.32	0.32	**0.77**	1.1	1.1	1.1	1.1	**1.1**	4.82	4.82	4.82	4.82	**4.87**	16.1	16.1	16.1	16.1	**16.2**
30	0.33	0.33	0.33	0.33	**0.78**	1.1	1.1	1.1	1.1	**1.1**	4.98	4.98	4.98	4.98	**4.98**	16.6	16.6	16.6	16.6	**16.6**

The results from Table 3.8 reveal the importance of incorporating the removal efficiencies. As the removal efficiency increases, a population can be exposed to a pre-implementation concentration for longer without either the TCR>NOAEL or the HQ >1. Technologies offering higher removal efficiencies will have longer possible implementation timelines before carcinogenic risk from arsenic is a concern in the water system.

The pre-implementation contaminant concentration is also critical. Results from Region 5 (pre-implementation mean arsenic concentration of 9.1 μg/L) and Region 9 (pre-implementation mean arsenic concentration of 19.6 μg/L) would need to implement technologies sooner to minimize potential health effects even if the technologies offered the same removal rates as Region 1. In Region 5, centralized treatment with an arsenic removal rate of 80% would need to be implemented within 20 years for male and female populations (Table 3.8), but because the pre-implementation concentration is higher than Region 1 and the removal efficiency is smaller, even if the centralized treatment system were implemented today (0 years) there would still be a carcinogenic risk associated with arsenic exposure. However, if POE Device N (arsenic removal rate of 95%) were implemented, there would be 1 year for infants and 4 years for children before we expect carcinogenic effects.

Table 3.9 provides a summary of the number of years to implement an alternative in each Region.

Table 3.9: Summary of the of the time to implement alternatives for different removal rates. The time to implement was estimated using both the total carcinogenic risk and the hazard quotient for systems with arsenic contamination (EPA Regions 1, 5 and 9). In Region 7, we present the total ADD values in the TCR column for completeness.

EPA Region	Removal Rate	Male		Female		Child		Infant	
		Time to Implement (years)		Time to Implement (years)		Time to Implement (years)		Time to Implement (years)	
		Based on Total Carcinogenic Risk > NOAEL	Based on Hazard Quotient > 1	Based on Total Carcinogenic Risk > NOAEL	Based on Hazard Quotient > 1	Based on Total Carcinogenic Risk > NOAEL	Based on Hazard Quotient > 1	Based on Total Carcinogenic Risk > NOAEL	Based on Hazard Quotient > 1
1	Centralized Treatment Upgrade (95%)	24	26	24	20	24	5	24	1
	POU, Device B, Adsorptive Media (99%)	24	26	24	20	24	6	25	2
	POU, Device D, RO (97%)	24	26	24	20	24	5	24	1
5	Centralized Treatment Upgrade (80%)	20	22	20	15	20	0	20	0
	POE, Device K, Adsorptive Media (98%)	22	24	22	18	22	5	1	2
	POE, Device N, Adsorptive Media (95%)	22	23	22	18	22	4	22	1
7	Centralized Treatment Upgrade (90%)	20	23	20	16	20	2	20	0
	POU, Device D, RO (70%)	18	21	18	12	17	0	17	0

	POU, Device G, RO (80%)	19	22	19	14	19	0	19	0
9	Centralized Treatment Upgrade (95%)	10	11	10	8	10	1	10	0
	POU, Device B, Adsorptive Media (99%)	11	12	10	9	10	3	11	1
	POU, Device D, RO (97%)	10	11	10	8	10	2	10	0

***Values represent the total ADD over 30 years for nitrate as nitrate is currently classified as non-carcinogenic**

We gathered data from CWS stakeholders to determine time to implement the new treatment (centralized or POU/POE) to compare with the exposure assessment results. Stakeholders included state drinking water department administrators, community water system operators and managers, and engineering consultants who had worked with CWS on system improvements. Figure 3.3 below presents data from Region 1 comparing the necessary time expected to implement either a centralized improvement or a POU/POE. Improvements to the centralized system were estimated to take 3-5 years to implement (including obtaining permits, applying for funding, selecting the improvement, piloting the improvement and installing the improvement). In comparison, POU/POE devices would be expected to have a shorter implementation time of 2-4 years, provided there is 100% participation in the POU/POE program (a concern noted earlier). However, the time to approve adoption of a POU/POE compliance strategy by securing 100% participation can extend the time it takes to approve and install a POU/POE option. Overall, we estimated the worst-case scenarios of as 5.25 years to install a centralized treatment option and 4.25 years to install POUs/POEs.

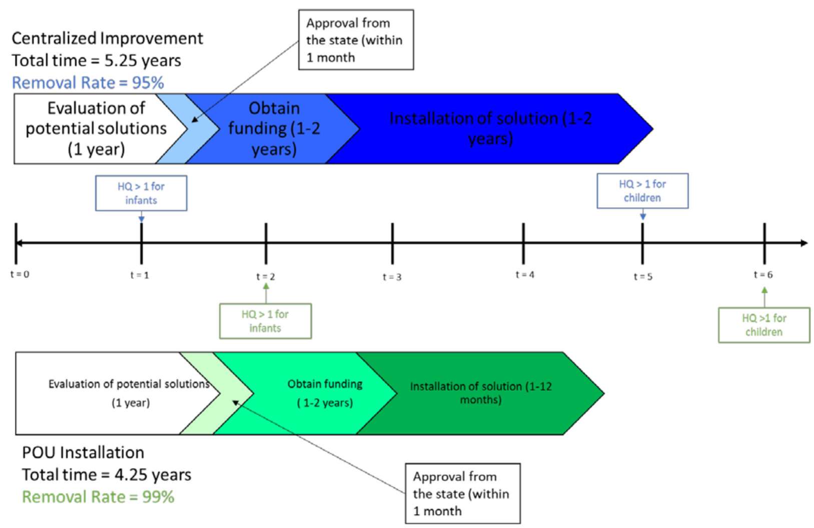


Figure 3.3: Timeline of worst-case installation estimates for alternatives including the time at which the ADD values exceed the NOAEL values for a given removal efficiency in Region 1 based on feedback from Region 1 stakeholders.

We then superimposed our results from evaluating TCR and HQ onto the timelines (Figure 3.3). In Region 1, we determined that after one year, the HQ >1 for infants with a centralized treatment removal rate of 95%, and the HQ >1 after two years for POU Device B with a removal rate of 99%. We found HQ >1 for children at 5 years for the centralized treatment removal rate of 95% and the HQ >1 at 6 years for POU Device B with a removal rate of 99%. This analysis suggests that installation of POU Device B can take several years and still be protective of human health when compared to centralized treatment. While a carcinogenic risk in the infant population would be observed before POU Device B is completely implemented, the HQ <1 for children within the 4-5 years it would take for POUs to be implemented while for centralized treatment, the timeline to implement is longer and the HQ >1 for children within this timeline. Provided POU Device B truly does achieved 99% removal of arsenic, this device would allow the CWS in Region 1 more time to complete the necessary treatment upgrade installation timeline while minimizing carcinogenic risk to younger and more vulnerable populations.

The centralized upgrade and POU/POE implementation timelines for Regions 5, 7 and 9 are in Appendix C, Figures C1-3. In Region 9, sampling activities are included in the implementation timeline because California allows a pilot to be completed prior to 100% participation. Table 3.10 provides a summary of the results of modeling time to implement each alternative in all four regions. Entries in the table are marked "before" if the combination of removal rate and bodyweight resulted in HQ>1 prior to completing the full implementation timeline of the alternative. Entries in the table are marked "after" if the combination of removal efficiency and bodyweight result in HQ>1 after an alternative has been fully implemented.

Table 3.10: Summary of time to implement for each alternative. Entries in the table are marked "before" if the combination of removal rate and bodyweight result in HQ>1 prior to full implementation of the alternative and "after" if the combination of removal efficiency and bodyweight result in a HQ>1 after an alternative has been fully implemented.

Region	Bodyweight	Centralized Treatment Upgrade			POU/POE Devices			
		Actual	Best-case	Worst-case	Device (Higher removal)	Device (Smaller Removal	Best-case	Worst-case
1	Infant	Before	Before	Before	Before	Before	Before	Before
	Child	Before	Before	Before	After	After	Before	Before
	Female	After	After	After	After	After	After	Before
	Male	After	After	After	After	After	After	After
5	Infant	Before	Before	Before	Before	Before	Before	Before
	Child	Before	Before	Before	Before	Before	Before	Before
	Female	After	After	After	After	After	After	Before
	Male	After	After	After	After	After	After	After
7	Infant	Before	Before	Before	Before	Before	Before	Before
	Child	Before	Before	Before	Before	Before	Before	Before
	Female	After	After	After	After	After	After	After
	Male	After	After	After	After	After	After	After
9	Infant	Before	Before	Before	Before	Before	Before	Before
	Child	Before	Before	Before	Before	Before	Before	Before
	Female	After	After	Before	After	After	After	Before
	Male	After	After	Before	After	After	After	Before

The following figure presents each centralized or POU/POE alternative selected for each CWS and compares the worst-case implementation timeline (shown in orange in each panel) to the number of years (from Table 3.10) before the HQ>1. The numeric values presented on the graph represent the number of years when the HQ first exceeds 1, indicating the new treatment system is no longer reducing human exposure below an acceptable threshold for the given contaminant. The HQ values are shown as vertical lines based on the ADD calculations. The values are then compared to the number of years (worst-case scenario) to implement each treatment type in each CWS (explained earlier). If the number of years to implement any treatment upgrade is greater than the first year where the HQ value exceeds one, then the alternative falls in a region shaded blue to represent the fact that this scenario does not adequately reduce exposure to a given contaminant within the worst-case timeline. We have included both the ideal implementation timeline (solid blue) and a worst-case scenario (dotted blue line) to represent an additional 5 years of time to give time to achieve 100% community participation (dotted blue line). If the blue bar passes any of the vertical lines moving from left to right, then we expect to see adverse effects in the community population because an alternative has not been implemented early enough to reduce arsenic or nitrate exposure.

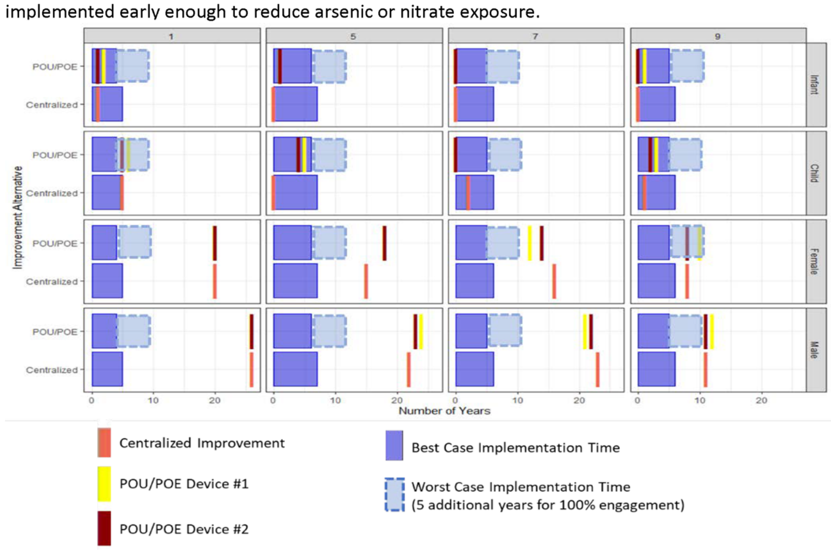


Figure 3.4: Summary of the number of years before the HQ>1 compared to the worst-case implementation timeline as identified by CWS stakeholders.

3.2.3 Lifetime exposure

In this section, we present lifetime exposure assessment calculations and use these to make conclusions about the suitability of each alternative based on human health impact. For each region, a table is presented detailing the average daily dose (ADD) over 30 years from birth to age 30. The ADD is compared to the NOAEL over 30 years (calculated by adding the NOAEL values over 30 years for each phase of life (infant, child, adult). In addition, a figure comparing lifetime exposure to the implementation timeline for each CWS is presented to show how each intervention changes the exposure experience from birth to 30 years. In these figures, the red dotted line represents the NOAEL value at 30 years, the black trend represents lifetime exposure if no intervention is implemented, and the remaining curves represent the best case (shortest estimated time to implement) and worst case (longest estimated time to implement) in each CWS. In each figure, the estimated implementation timeline for each CWS is shown, as well as the number of years before exposure is expected to exceed the NOAEL value if no intervention is implemented (shown in black).

3.2.3.1 Region 1 Lifetime exposure results

In Region 1, all of the selected treatment systems' removal efficiencies and implementation timelines resulted in an ADD <NOAEL, sufficiently reducing exposure to arsenic to no observable adverse effect levels. If no intervention is implemented in Region 1, the total ADD over 30 years will exceed the NOAEL by 4.68 ug/kg/day (Table 3.11). If centralized treatment is implemented within 3 years, the total ADD over 30 years will be 4.18 ug/kg/day below the NOAEL. The largest decrease in exposure is seen when the POU carbon fiber adsorptive media device is implemented within 2 years (a decrease of 5.19 ug/kg/day), which is intuitive given the POU AM device has a removal efficiency of 99%.

Table 3.11: Region 1 lifetime exposure results over 30 years compared to an exposure to the NOAEL level of arsenic.

Improvement	Time to Implement (Years)	ADD over 30 years (ug/kg/day)	Compared to NOAEL (ug/kg/day)
No Intervention	-	12.78	+ 4.68
Central	3	3.92	- 4.18
	6	5.74	- 2.36
POU AM Device B	2	2.91	- 5.19
	5	4.81	- 3.29
POU RO Device D	2	3.12	- 4.98
	5	4.97	- 3.13

Table 3.11 presents results specific to the treatment options selected for each system. Figure 3.5 shows the best-and worst-case removal efficiencies and best-case/worst-case implementation timelines for each in Region 1 (the red dotted line represents the NOAEL value of 8.1 ug/kg/day over 30 years, the black trend line represents total exposure (ug/kg/day) assuming no intervention is implemented). In Region 1, assuming no intervention is implemented, the total dose a person will be exposed to exceeds the NOAEL value at 17.5 years based on an average pre-intervention total arsenic concentration of 8.1 ug/L.

According to CWS stakeholders in Region 1, a POU device can feasibly be implemented in 2-5 years while a centralized treatment improvement can be feasibly implemented in 3-6 years. While POU devices can be installed in households in a short amount of time in general, implementation can take as long as 5 years due to the requirement of 100% community buy-in prior to initiating piloting and permitting activities, which take additional time. In Region 1, Figure 3.5 shows that any alternative implemented in the timelines described by stakeholders will be implemented quickly enough to reduce 3-year exposure. Similarly, all best-case scenario removal efficiencies also remove enough arsenic from the system to reduce arsenic exposure below the cumulative 30-year NOAEL.

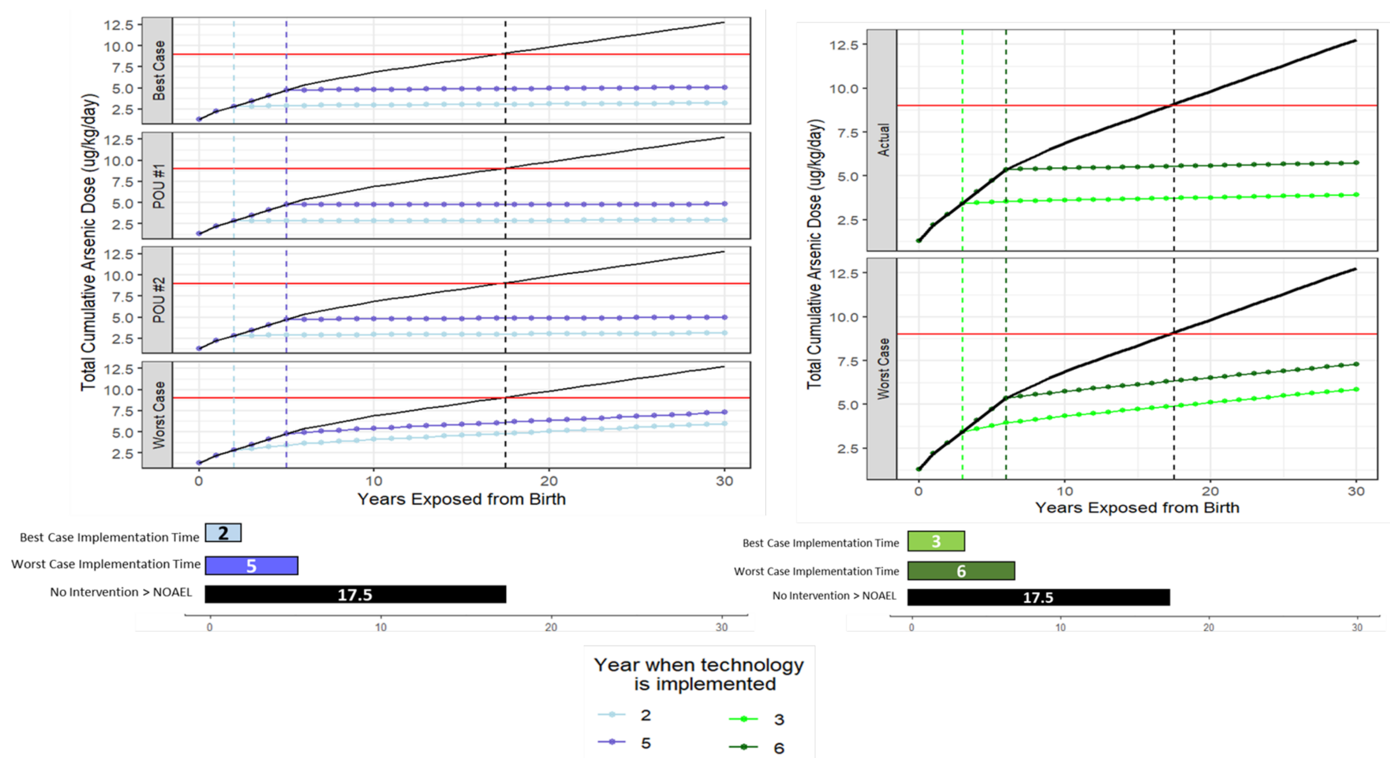


Figure 3.5: Lifetime exposure results for Region 1 based on specific CWS timelines for implementation.

3.2.3.2 Region 5 Lifetime exposure results

In Region 5, all of the selected treatment alternatives reduce 30-year exposure below the NOAEL. Table 3.12 indicates that without intervention, the ADD over 30 years is 14.36 ug/kg/day, which exceeds the 30-year cumulative NOAEL by 6.5 ug/kg/day. The largest decrease in exposure is achieved by POE Device K within a 3-year implementation best-case scenario, followed by POE Device N within 3 years. Centralized treatment, if implemented by 7 years, results in a cumulative exposure that is only 0.07 ug/kg/day below the cumulative 30-year NOAEL, indicating this option is still able to reduce exposure, but that beyond 30 years, there may be observable adverse effects in the community population.

Table 3.12: Region 5 lifetime exposure results over 30 years compared to an exposure to the NOAEL level of arsenic.

Improvement	Time to Implement (Years)	ADD over 30 years (ug/kg/day)	Compared to NOAEL (ug/kg/day)
No Intervention	-	14.36	+6.5
Central	4	6.55	-1.55
	7	8.04	-0.07
POE AM Device N	3	4.40	-3.70
	6	6.45	-1.65
POE AM Device K	3	4.08	-4.02
	6	6.30	-1.80

According to stakeholders in Region 5, POE could feasibly be implemented in 3-6 years while a centralized improvement is likely to take 4-7 years. The difference between these stems from differences in approval (piloting and permitting) and installation time. Because there are 221 homes in the Region 5 community, it is likely that installation of POE devices would require significant organizational effort, likely increasing implementation time. Notably, the centralized improvement we selected to address the contaminant concern is relatively simple to install. Assuming that the POE takes longer to implement because of the number of households, and centralized takes less time to install, both POE devices still provide a larger arsenic removal over 30-years, indicating the importance of removal efficiencies.

In Figure 3.6, we observed that if no intervention is implemented in Region 5, exposure will exceed the cumulative 30-year NOAEL value at 13.5 years. Any of the alternatives selected for Region 5 are likely to be implemented at this time according to the estimated timelines.

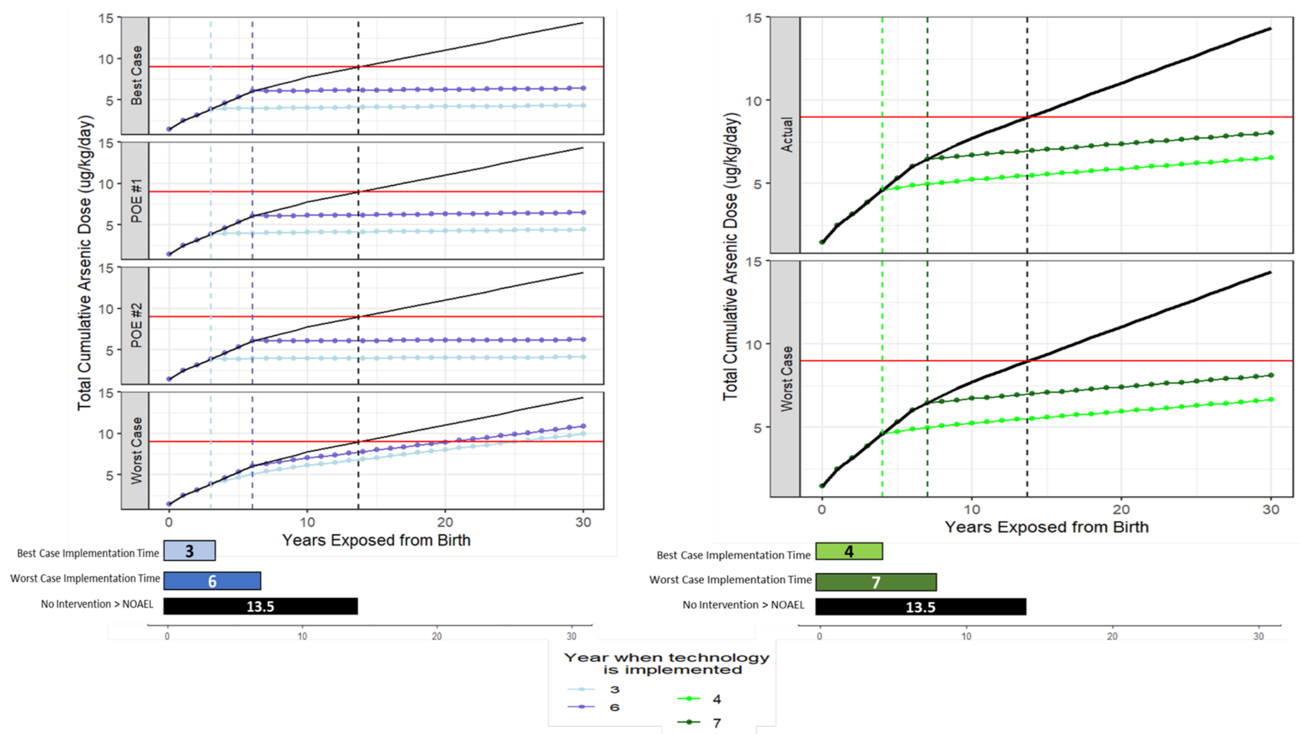


Figure 3.6: Lifetime exposure results for Region 5 based on specific CWS timelines for implementation.

3.2.3.3 Region 7 Lifetime exposure results

In Region 7, if no intervention is implemented, the total exposure dose over 30 years is 14.75 ug/kg/day, which exceeds the cumulative 30-year NOAEL by 6.65 ug/kg/day. In Region 7, the centralized treatment upgrade would have a better removal efficiency of nitrate than the POU RO device. As a result, using POU RO Device G (70% removal efficiency) generates a total exposure dose over 30 years of 8.25 ug/kg/day, which exceeds the cumulative 30-year NOAEL by 0.15 ug/kg/day if the device is implemented with a worst-case scenario of 5 years. All other alternatives can successfully decrease total exposure below the cumulative 30-year NOAEL.

Table 3.13: Region 7 lifetime exposure results over 30 years compared to an exposure to the NOAEL level of arsenic.

Improvement	Time to Implement (Years)	ADD over 30 years (ug/kg/day)	Compared to NOAEL (ug/kg/day)
No Intervention	-	14.75	+6.65
Central	4	5.72	-2.38
	6	7.05	-1.05
POU RO Device D	3	6.14	-1.96
	5	7.32	-0.78
POU RO Device G	3	7.21	-0.89
	5	8.25	+0.15

If a treatment upgrade is not implemented in Region 7, nitrate exposure will exceed the NOAEL in 13 years (according to Figure 3.7). In this region, centralized treatment was estimated to take 4-6 years and POU/POEs 3-5 years. The selected centralized treatment improvement requires a new facility rather than just an improvement to an existing facility and therefore, implementation is likely on the high end of the estimate. For POUs, it is difficult to estimate implementation time as there are few POU installations used for compliance in Nebraska and the community does need to have all have 75 households agree prior to implementation.

In Region 7, the worst-case scenarios for both centralized and POU removal efficiencies would both exceed the cumulative NOAEL after year 25.

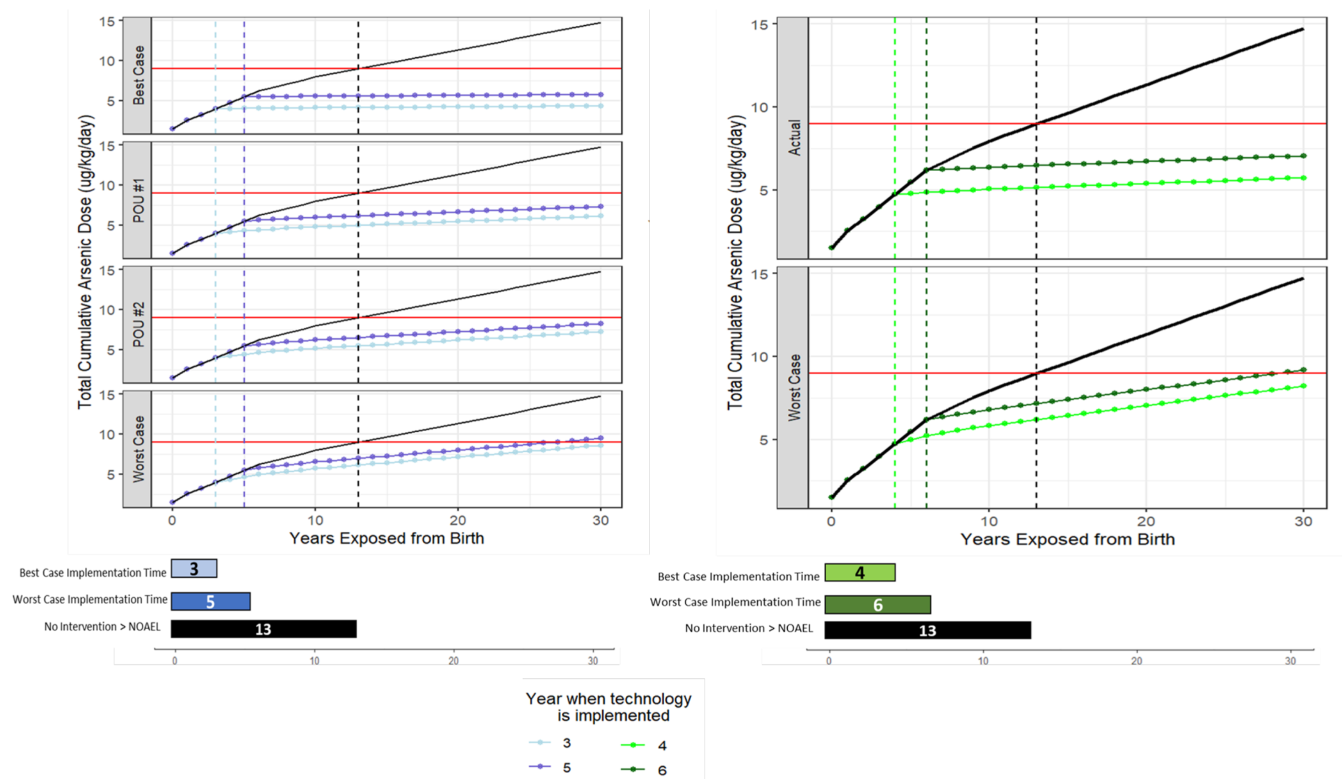


Figure 3.7: Lifetime exposure results for Region 7 based on specific CWS timelines for implementation.

3.2.3.4 Region 9 Lifetime exposure results

In Region 9, there was no combination of removal efficiency and implementation timeline among the selected alternatives that sufficiently reduces 30-year exposure below the cumulative 30-year NOAEL. The initial concentration of total arsenic in this water system exceeded 20 ug/L, and if no intervention is implemented, would result in a 30-year exposure dose of 34.08 ug/kg/day, exceeding the cumulative 30-year NOAEL by 25.98 ug/kg/day (Table 3.14) (and would exceed the cumulative 30-year NOAEL of 8.1 ug/kg/day within 3 years). Our results indicate that, given their higher removal efficiencies and faster timelines, only a POU unit could be implemented fast enough to decrease exposure to below acceptable limits. If the POU carbon fiber adsorptive media device with a 99% removal efficiency was implemented as fast as possible (3 years or potentially less), the total dose over 30 years decreases to 9.45 ug/kg/day which exceeds the 30-year cumulative NOAEL by 1.35 ug/kg/day.

Table 3.14: Region 9 lifetime exposure results over 30 years compared to an exposure to the NOAEL level of arsenic.

Improvement	Time to Implement (Years)	ADD over 30 years (ug/kg/day)	Compared to NOAEL (ug/kg/day)
No Intervention	-	34.08	+25.98
Central	4	12.06	+3.96
	6	15.03	+6.93
POU AM Device B	3	9.45	+1.35
	5	12.83	+4.73
POU RO Device D	3	9.95	+1.85
	5	13.26	+5.16

Figure 3.8 reveals that no selected alternatives, nor the best-case/worst-case scenarios, could sufficiently decrease arsenic exposure in Region 9 within the estimated implementation timelines given the high concentration of arsenic. In Region 9, an alternative solution that had been explored by the CWS previously was using a new well with lower arsenic concentration. If a switch to a well with lower arsenic concentrations were made and POU devices were installed within the estimated timelines, human exposure to arsenic could be sufficiently decreased below the cumulative 30-year NOAEL threshold in Region 9.

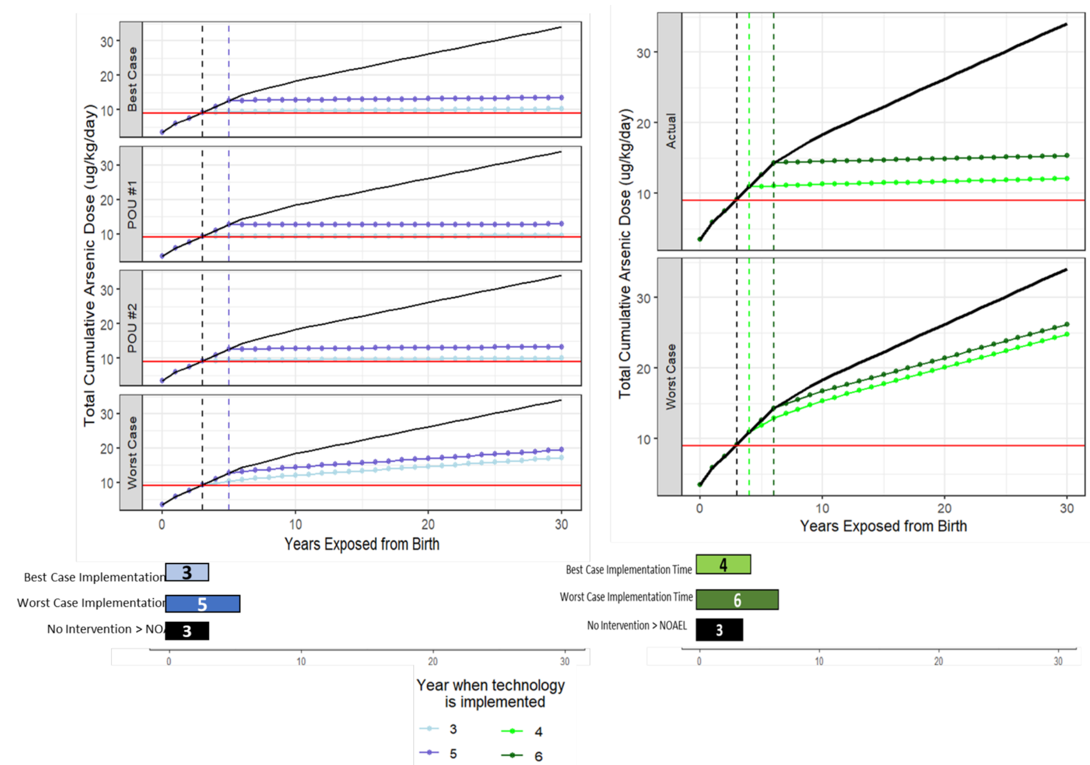


Figure 3.8: Lifetime exposure results for Region 9 based on specific CWS timelines for implementation

3.2.3.5 Summary of lifetime exposure results

In the Regions 1 and 5 cases, all potential alternatives sufficiently removed arsenic within the timelines outlined by the CWS stakeholders. In Region 7, due to a smaller removal efficiency of nitrate, POU RO Device G would not reduce nitrate exposure below the cumulative 30-year NOAEL, while centralized treatment would achieve sufficient reduced nitrate exposure. In Region 9, no combination of selected upgrades, removal efficiencies, and timelines available decreases arsenic contamination below the cumulative NOAEL, but a faster implementation timeline for the POU AM device or an additional improvement of changing the source water well could provide the additional steps necessary to sufficiently reduce arsenic exposure.

Table 3.15: Summary of lifetime exposure modeling. The NOAEL value used for comparison is 8.1 ug/kg/day over 30 years (calculated by multiplying the 0.27 ug/kg/day adjusted NOAEL by 30 years). The total ADD over 30 years is compared to the NOAEL; a positive value indicates the calculated ADD >NOAEL, negative values indicate calculated ADD < NOAEL.

Region	Improvement	Time to Implement (Years)	ADD over 30 years (ug/kg/day)	Compared to NOAEL (ug/kg/day)
Region 1	No Intervention	-	12.78	+ 4.68
	Central Upgrade	3	3.92	- 4.18
		6	5.74	- 2.36
	POU AM Device B	2	2.91	- 5.19
		5	4.81	- 3.29
	POU RO Device D	2	3.12	- 4.98
		5	4.97	- 3.13
Region 5	No Intervention	-	14.36	+6.5
	Central Upgrade	4	6.55	-1.55
		7	8.04	-0.07
	POE AM Device N	3	4.40	-3.70
		6	6.45	-1.65

	POE AM Device K	3	4.08	4.02
		6	6.30	-1.80
Region 7	No Intervention	-	14.75	+6.65
	Central Upgrade	4	5.72	-2.38
		6	7.05	-1.05
	POU RO Device D	3	6.14	-1.96
		5	7.32	-0.78
	POU Device G	3	7.21	-0.89
		5	8.25	+0.15
Region 9	No Intervention	-	34.08	+25.98
	Central Upgrade	4	12.06	+3.96
		6	15.03	+6.93
	POU AM Device B	3	9.45	+1.35
		5	12.83	+4.73
	POU RO Device D	3	9.95	+1.85
		5	13.26	+5.16

Based on the exposure assessment results, we ranked each treatment upgrade in each region (Table 3.16) (ranked as 3, 2, 1, with 3 as the option that most effectively decreased contaminant exposure, and subsequently 2 and 1). The highest-ranked options based on exposure assessment are:
Region 1) POU AM device B implemented in a 2–5-year time frame
Region 5) POE Device N implemented in a 3–6-year timeframe;
Region 7) Centralized IX implemented in a 4–6-year timeframe;
Region 9) POU AM device implemented as soon as feasibly possible.

Table 3.16: Rankings for each option in all regions based on the lifetime exposure assessment results.

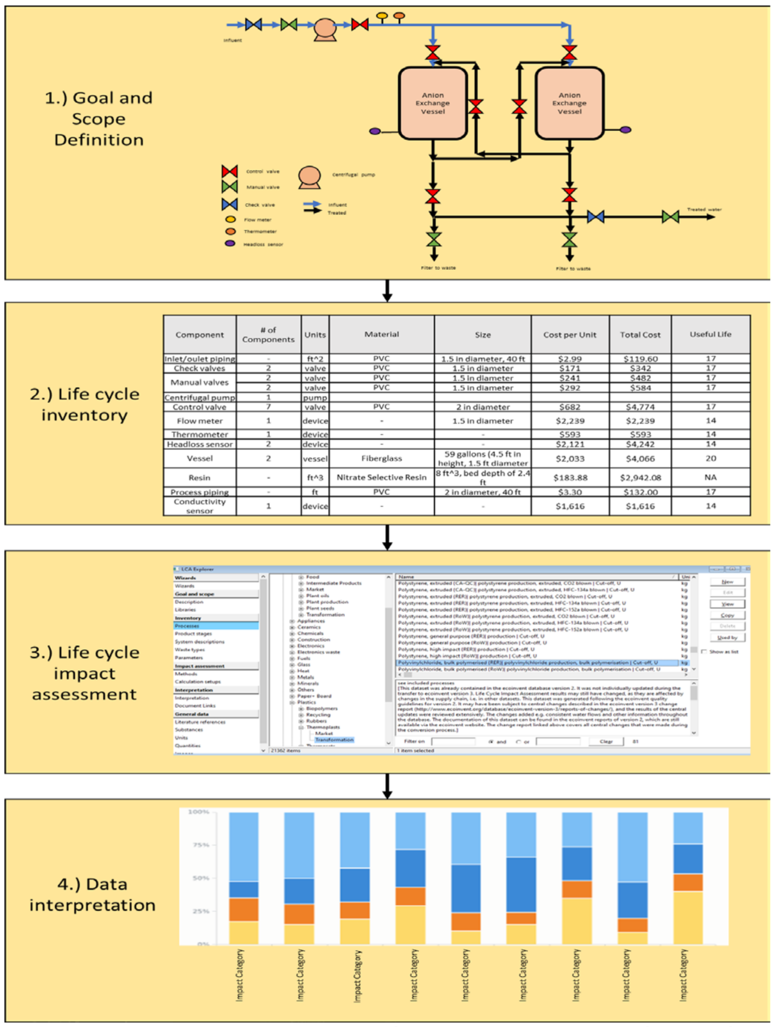
Region	Technology	Metric Decrease in contaminant exposure (ug/kg/day) 3 = Best Option, 2 = 2nd Best Option, 1 = 3rd Best Option
1	Centralized Upgrade	1
	POU AM Device B	3
	POU RO Device D	2
5	Centralized Upgrade	1
	POE AM Device N	2
	POE AM Device K	3
7	Centralized Upgrade	3
	POU RO Device D	2
	POU RO Device G	1
9	Centralized Upgrade	1
	POU AM Device B	3
	POU RO Device D	2

4 – Life Cycle Analysis (LCA)

4.1 Methods

To understand the environmental sustainability of the alternatives selected, we used a life cycle analysis (LCA). LCAs can be process-based and economic input-output (EIO) models. Process-based LCAs connect the inputs to a product or system (including the materials and energy) to outputs of those specific inputs (emissions, wastes). However, this approach can be limited by insufficient data and intensive time and cost requirements (Bilec et al., 2006). The EIO-LCA approach uses US industrial sector input-output tables to map interdependencies between sectors, which includes supply chains into each sector. While the advantages of this method include examining the entire US economy and its role in environmental impacts and the data are publicly available, the ability to draw conclusions is limited by its aggregation of results. We therefore elected to use the process based LCA methodology, as it provides greater resolution in results when comparing the complex details of centralized treatment improvements to POU/POE devices.

LCAs consist of four phases: (1) definition of the goal and scope, (2) life cycle inventory, (3) life cycle impact assessment and (4) data interpretation (ISO, 2006) (Figure 4.1). The definition of goal and scope involves setting the system boundaries and defining a functional unit. The functional unit serves to standardize material flows, enabling generation of accurate comparisons of alternative products. The life cycle inventory component involves generating a database of the system or process components, including the material, size, and other relevant information for calculating the total amounts of a component used. LCAs connect the life cycle inventory to a database of process flow information and estimate the environmental impact (measured by greenhouse gas emission, ecotoxicity, etc.) of each defined process (ISO, 2006). Based on the inventory inputs and method used, the LCA practitioner then analyzes and interprets the data, often using sensitivity analyses.



Component	# of Components	Units	Material	Size	Cost per Unit	Total Cost	Useful Life
Inlet/oulet piping	-	ft^2	PVC	1.5 in diameter, 40 ft	$2.99	$119.60	17
Check valves	2	valve	PVC	1.5 in diameter	$171	$342	17
Manual valves	2	valve	PVC	1.5 in diameter	$241	$482	17
	2	valve	PVC	1.5 in diameter	$292	$584	17
Centrifugal pump	1	pump					
Control valve	7	valve	PVC	2 in diameter	$682	$4,774	17
Flow meter	1	device	-	1.5 in diameter	$2,239	$2,239	14
Thermometer	1	device	-	-	$593	$593	14
Headloss sensor	2	device	-	-	$2,121	$4,242	14
Vessel	2	vessel	Fiberglass	59 gallons (4.5 ft in height, 1.5 ft diameter	$2,033	$4,066	20
Resin	-	ft^3	Nitrate Selective Resin	8 ft^3, bed depth of 2.4 ft	$183.88	$2,942.08	NA
Process piping	-	ft	PVC	2 in diameter, 40 ft	$3.30	$132.00	17
Conductivity sensor	1	device	-	-	$1,616	$1,616	14

Figure 4.1: LCA methodology components adapted from the ISO, 14040 standard (ISO, 2006).

4.1.1 Functional Unit

We originally proposed to use a functional unit of 1 m^3 (1000 L) of water produced; however, after a more extensive literature review, we selected a functional unit of one household. We decided not to use a volume of water because the volume of water consumed per household per day is variable across each household and community, and the flow rate for each community also differs. Normalizing by the flow rate may obscure the importance of the number of households in a community. Furthermore, POU/POE devices commonly rely on volume as an indicator of when service or device replacement is needed; because water use is variable per household, devices will fail at different rates. For central treatment, the water volume produced is not expected to change significantly as a result of the selected improvements in each community. We therefore normalized the amount of material in a device or centralized upgrade per household over the total 30-year study period to compare the impact assessment. We used the useful life of each component to extrapolate the number of replacements of each component over a 30-year time frame and calculated the total mass of material (in kg) for each treatment option. This allowed us to compare options at a household level and find the breakpoint number of homes per community at which one option becomes more or less environmentally sustainable than the other. By calculating the amount of material per household, we can also account for an increase or decrease in the number of customers served by the CWS if the population of the community changes over time.

4.1.2 Software and Databases

The SimaPro software contains several databases from which the life cycle inventory can be completed. For this study, we used the ecoinvent 3 database, which provides information about the process flows for specific materials and processes needed to generate the materials present in each of the selected treatment options. Using this database, we generated process flows for each centralized improvement and each POU/POE device based on an inventory (described below). We then selected the TRACI 2.1 analysis method to translate the process flows into environmental impacts. TRACI 2.1 iscommonly used in North America to conduct data analysis in LCAs with supporting documentation from the USEPA (USEPA, 2020c).

4.1.3 System boundaries and data collection

The system boundaries for this analysis encompassed only the upgrades made to the centralized system, or the entire POU/POE device installed. Using SimaPro, we traced raw inputs, material processing, transportation, and disposal of each of treatment options for each CWS. We considered the following impacts: conventional air pollutants (e.g., Sox, NOx, PM, VOCs, CO), greenhouse gases, energy use (GJ/functional unit), toxic chemical releases, water withdrawals, ecotoxicity, acidification, eutrophication, global warming potential and others.

The system boundaries, existing system, and additional components needed for the centralized water treatment system in Region 1 is shown in Figure 4.2 (the pre-implementation components shown in gray and additional components needed to complete the improvement shown in color). While pre-existing system components will likely need to be replaced within the 30-year period, we focused our analysis only on the upgrades to the system necessary for meeting the isolated treatment objective also addressed by the contaminant of concern, for adequate comparison to the POU/POE systems.

In Region 1, we consulted stakeholders to determine which components were already in place in this CWS since the selected improvement involves adding an additional filtration unit. In Region 1, backwashing equipment for the absorptive media system are already in place; as a result, no piping or storage tanks for backwash water were included in the LCA inventory. The current treatment facility is fed by a submersible pump in the well and has sufficient capacity to continue to pump to an additional adsorptive media filter (the centralized upgrade). We therefore excluded a pump from the inventory. We included several sensors, including headloss sensors, turbidity meters, and high/low alarms for the second adsorptive media filter. As a result, Region 1 centralized materials primarily consist of the new filter housing (fiberglass), the filter media (granular ferric hydroxide), and additional piping and valve components to feed the second filtration unit (PVC).

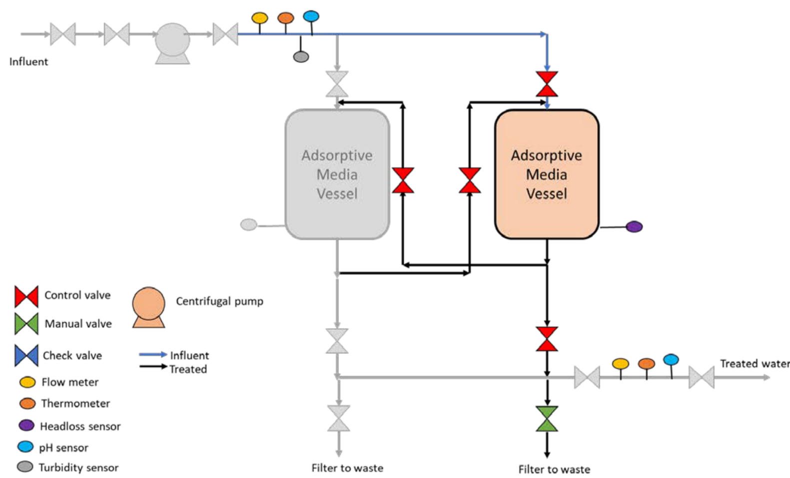


Figure 4.2: Components included within the system boundaries for Region 1's LCA are shown in color while pre-existing components are shown in grey.

In Region 5, we worked with stakeholders to determine which pre-oxidation components were already in place to identify whether components could be repurposed or should be newly installed (illustrations and details of system boundaries in Appendix A). After several conversations, we decided to model a worst-case scenario and install a new chemical feedline, calibration cylinder, and chemical feed pump to the system. The chlorine disinfection unit is located within the pump house and configured to provide chlorine gas for both pre-oxidation after aeration and a disinfectant residual after sand filtration. The aeration tower is located outside the treatment facility, and it remained unclear whether the current system could be adapted to locate a chlorine supply ahead of aeration. As a result, we modeled the full inventory of components necessary to install pre-chlorination, using the EPA Design Manual for Iron Removal which contains pre-treatment options (USEPA, 2006a).

Region 7 does not have a treatment system, although there is space for installing new treatment components (illustrations and details of system boundaries in Appendix A). As a result, we inventoried all components necessary to install a new anion exchange system, including 2 vessels, backwashing equipment, all sensors, piping, valves, and redundant components. Per Nebraska regulations, we also included the materials and cost associated with installing basic chlorine disinfection, as chlorine disinfection would then be required once any type of treatment system is implemented. After conversations with stakeholders, it remained unclear if there was water storage prior to distribution; we therefore included a storage tank in the inventory to reflect the worst-case scenario.

In Region 9, we included all components necessary to install a new anion exchange system and the additional components necessary for handling waste disposal (illustrations and details of system boundaries in Appendix A). We did not include the cost and material to build a treatment facility as there is an already existing treatment plant. To handle waste disposal, we included an evaporation pond based on recommendations from state-level stakeholders consisting of two filtration vessels, the piping and pumping required for regenerating the ion exchange resin onsite, and an evaporative pond sized for 30 household connections (USEPA, 2006a).

For POU/POE devices, the system boundary includes the device itself (including pre-filters, post-filters and sensors included in the device), the separate faucet installed at each connection, and any process piping to connect the POU/POE device to the separate faucet (Appendix D). For some of the selected devices, these components would be included in the overall device cost and package and were could easily be identified through device manuals and manufacturers. For POE devices in particular, the piping necessary may not be included in the cost of the device depending upon the distributor, necessitating additional piping.

4.1.3 Inventory generation

To perform an LCA, an inventory of the material and size of each component in the selected upgrades was needed.

For centralized treatment system upgrades, the process flow schematics for each water system were used to create a component list for each CWS, which we then used along with used the EPA Work-based Structure (WBS) cost models to construct an inventory for each improvement (USEPA, 2021a) (Table 4.1). The EPA WBS models were created to allow water systems to explore the cost of installing specific treatment solutions based on the system size (based on the average daily flow). For Region 1, we used the US EPA Adsorptive Media Cost Model with a granular ferric hydroxide (GFH) media and the EPA standard design for small systems (average daily flow rate = 0.03 MGD) (USEPA, 2021c). In

Regions 7 and 9, we used the Anion Exchange cost model, with a nitrate selective resin for Region 7 and a strong base polyacrylic resin for Region 9 (USEPA, 2017b). In Region 5, we were unable to access a cost model specifically for pre-oxidation; we instead consulted other chemical addition models under development by the EPA to generate a list of components to create an inventory for Region 5.

Table 4.1: A cost model and set of model assumptions were selected for each CWS to generate an inventory of components for each centralized treatment upgrade (USEPA, 2017b, USEPA, 2021c).

EPA Region	Centralized Improvement	EPA WBS Cost Model	Input assumptions
1	Treatment of 100% of the flow rate by adding an additional filtration module	Adsorptive Media (granular ferric hydroxide media)	Average daily flow rate = 0.03 MGD Media is thrown away after 45,000 Bed Volumes (BVs) 1 additional vessel, EBCT = 3.6 minutes
5	Enhance pre-oxidation by moving pre-chlorination step ahead of aeration	Not applicable Generated a list of potential components using chemical addition models	Average daily flow rate = 0.03 MGD
7	Centralized anion exchange with a nitrate selective resin	Anion Exchange – Nitrate selective resin	Average daily flow rate = 0.03 MGD Throwaway media after 22,000 BVs 2 vessels in series Residuals disposed of at a wastewater facility Bed depth of 2.4 ft EBCT = 3 minutes (1.5 min per vessel)
9	Centralized anion exchange with a strong base anion resin	Anion Exchange – Strong Base Polyacrylic resin	Average daily flow rate = 0.03 MGD Throwaway media after 40,000 BVs 2 vessels in series Disposal of residuals to an evaporative pond EBCT = 12 minutes

For POU/POE devices, we contacted manufacturers to locate device manuals and generated component lists based on these materials. Manuals were located for four (all 3 POU devices and 1 POE device) of the five devices from manufacturer's websites, with the fifth POE device manual obtained via email with the manufacturer. From the manuals, we generated a list of components for each device separately and then cross-referenced the lists to determine missing components for any one device. For example, some device manuals include schematics of the process piping necessary to install a POU device with a separate faucet under the sink while other manuals only include the POU device itself. In this scenario, we included process piping for POU device in the inventory when device manuals indicate process piping would be necessary. We also consulted with manufacturers to determine what process piping needs to be included to install POU devices if no information was provided in the manuals.

For each technology option, we calculated the amount of material needed per household over 30 years in kilograms. First, we calculated the amount of material for each component: for example, if a both a process valve and a length of piping are made of polyvinylchloride, we calculated the amount of each component separately. This allowed us to examine whether specific components contributed more to the impact assessment in initial analysis to determine how granular of detail was necessary. From this initial analysis, we concluded we could combine components to obtain a total amount of material for each material type (e.g., PVC, GAC, polypropylene) when calculating the raw material and processing components of the LCA.

Prior to conducting the impact assessment, we calculated individual components of the life cycle separately (i.e., raw material extraction and processing were calculated in one step and waste disposal was calculated in a separate step) for the following reasons: (1) the SimaPro software requires a specific "waste type" when inputting waste disposal scenarios and not all materials used in the technology options are represented in the preloaded waste types, and (2) materials such as granular ferric hydroxide media (used in the Region 1 centralized improvement and POE devices in Region 5) are difficult to represent with preset processes. As a result, it became difficult to link raw material inputs and processes to waste disposal scenarios using the preloaded structures in SimaPro. To ensure we did not over- or under-estimate the impact of materials such as adsorptive medias, we ran a basic analysis to determine the impact of 1 kg of material and then exported the SimaPro results for further analysis, allowing us to adjust these components to the desired functional unit without unintentionally introducing errors.

To calculate transportation impacts, we searched for processing facilities and municipal landfills located close to each CWS using Google Maps. We searched for plastics processing locations, iron and steel processing facilities, local manufacturers of ion exchange resin and adsorptive media, and locations where raw materials are extracted. We then took the average of the distance from each raw material extraction location to the processing facility to the community to obtain a distance in kilometers necessary to transport raw materials to a processing facility and then to the community. Using the amount of material, we translated this distance into units of tonne-kilometers to calculate transportation impacts in SimaPro. We also located at least two municipal landfills close to each CWS and averaged the distance from the CWS to the landfill to calculate the transportation distance in tonne-kilometers (Table 4.2).

Table 4.2: Distances used to calculate transportation impacts in each CWS.

Community water system	Transport of processed materials to CWS (km)	Transport of materials from CWS to landfill (km)
New Hampshire (Region 1)	56.3	16.1
Illinois (Region 5)	24.1	24.1
Nebraska (Region 7)	24.1	24.1
California (Region 9)	96.6	193.1

Finally, SimaPro had a built-in material for anionic exchange resins and granular activated carbon medias, but not for specific adsorptive medias such as granular ferric hydroxide (GFH). We explored using the base material of GFH medias (commonly pumice or sand) and creating a new process in SimaPro to represent the coating of GFH media. However, of the built-in coating processes in SimaPro are specific to metal working and not appropriate for coating adsorptive medias. Little literature exists detailing how adsorptive media was accounted for in water treatment LCAs; we therefore modeled the GFH media as similar to GAC. While it is possible to define a new process in SimaPro, it requires known environmental impacts of the process. However, we were unable to locate information on the processing and disposal of GFH media through either literature or manufacturer website search. Therefore, we modeled GFH as GAC for simplicity, however, since there was a lack of information on specific GFH media, the impacts associated with the GFH media may constitute an underestimation or overestimation of the total impact. Notably, the extraction of coal and other base materials to generate activated carbon have high ecotoxicity impacts as analyzed using the TRACI 2.1.

4.1.4 Impact Assessment

Using the TRACI 2.1 database in SimaPro, we calculated the impact of each treatment option. In SimaPro, we created assemblies for each using the identified components. For example, for the POU AM device in Region 1 and 9, we created an assembly that included piping materials, filter cartridges, stainless steel faucets, and other additional components. We then set up a calculation for each assembly using the "Analyze" function in SimaPro. We selected "inventory by sub-component" to better pinpoint which materials contribute the most to the environmental impacts. We then created "Life Cycles" in SimaPro using the material assemblies described above and included the waste disposal scenario and transportation. The results from each analysis were exported to Excel for further analysis and interpretation.

4.1.5 Data Interpretation

To compare data across technologies, we normalized the impact assessment results to the largest impact category for each material. We compiled the data from each alternative for a given CWS and identified the largest impact category for each material. We then divided each entry by the largest impact to obtain normalized results. For each scenario, this generates a number from 0 to 1, with the largest impact as 1.

4.2 Results

4.2.1 Inventory generation

We generated inventories for the following centralized improvements: adsorptive media filtration in Region 1 and anion exchange for both Regions 7 and 9. We worked with community stakeholders in Region 5 to delineate the system boundaries of the centralized pre-oxidation upgrade. In Region 5, we modeled changing the order of the current pre-oxidation system by moving pre-chlorination ahead of the current aeration unit. Because the CWS in Region 5 has many of the components necessary to implement this upgrade already in place, we conducted phone calls with stakeholders to determine which to include in the inventory. Examples of inventories are provided below with additional details in Appendix D.

4.2.1.1 Centralized improvement inventories

Table 4.3 provides an example of an inventory generated for centralized anion exchange with a nitrate selective resin in Region 7. Using the assumptions provided in Table 4.1, we consulted the Output tab of the EPA WBS Anion Exchange Cost Model (USEPA, 2017b) and selected the relevant components from the detailed output that matched the components we identified as necessary for Region 7 (Appendix A, Figure A3). We identified the component, the corresponding entry in the cost model output (not shown), the material where available, the size of the component, the unit cost of a component, the total cost of the component (as calculated by the EPA cost model algorithms), and the useful life. Since this study examines a 30-year timeframe, we calculated the number of replacements necessary in this timeframe based on each component's useful life. This number of replacements was used to adjust the total amount of material calculated by the equations in the EPA cost models to accurately account for replacements over 30 years. The example inventory in Table 4.3 does not include the addition of a chlorine disinfection system or water storage for the CWS (these details are included in the Appendix); each of these, including the IX system, the backwashing components, and the chlorine disinfection components, are inventoried separately with a process in line with the above (not shown in Table 4.3). Table 4.3 presents the amount of material per centralized anion exchange system component, representing the amount of material per home. The amount of material in Region 7 is found by multiplying the amount of material per device by the 75 connections in the community to show how the number of homes impacts the amount of material entered into the impact assessment of the LCA.

Table 4.3: Example inventory for centralized anion exchange with a nitrate selective resin in Region 7

Component	# of Components	Units	Material	Useful Life [years]	Amount of material [kg]	Amount Region 7 (75 homes) [kg]	Amount of material over 30 years [kg]
IX System							
Inlet/outlet piping	-	ft^2ft^2	PVC	17	36.89	2,767.06	73.79
Check valves	2	valve	PVC	17	0.23	17.29	0.46
Manual valves	2	valve	PVC	17	0.23	17.29	0.46
	2	valve	PVC	17	0.23	17.29	0.46
Centrifugal pump	1	pump	Cast iron	17	203.88	15,291.07	407.76
Control valve	7	valve	PVC	17	0.24	18.04	0.48
Vessel	2	vessel	Fiberglass	20	0.90	67.16	1.79
Resin (polyacrylic beads)	16	ft^3ft^3/yr.	Nitrate Selective Resin	1	435.84	32,688.00	13,511.04
Process piping	-	ft	PVC	17	38.48	2,885.99	76.96

Backwashing							
Tank	1	vessel	Fiberglass	20	0.46	34.15	0.91
Piping	50	ft	PVC	17	28.24	2,118.02	56.48
motor/ air-operated valves	8	valves	PVC	20	0.14	10.59	0.28
check valves	2	valves	PVC	20	0.14	10.59	0.28
rinse pumps	2	pumps	Cast iron	17	815.53	61,164.39	1,631.05
Chlorine disinfection							
Storage tank	1	vessel	fiberglass	20	0.46	34.15	0.91
chemical metering pump	2	pump	PVC	15	0.29	64.66	0.59
check valves	4	valves	PVC	20	0.29	64.66	0.29
pressure relief valves	4	valves	PVC	20	0.29	64.66	0.29
suction tubing	4	ft	PVC	5	1.17	258.65	7.02
discharge tubing	4	ft	PVC	5	1.17	258.65	7.02
chemical mixer	1	unit	PVC	22	10.22	2,258.08	10.22
process piping	110	ft	PVC	17	0.29	64.66	0.29
Dosing pump	1	pump	Cast iron	17	203.88	45,057.77	203.88

4.2.1.2 POU/POE Device Inventories

We created inventories for the five POU/POE devices based on information obtained from a variety of sources (Table 4.4).

Table 4.4: For each region, we obtained a device manual by searching manufacturer websites or by contacting manufacturers and called manufacturers to obtain additional data where necessary to identify device removal rates for specific contaminants and identify all device components.

EPA Region	Device	Manual	Conversation with Manufacturer
1	POU Device B, Adsorptive Media (Carbon fiber)	Obtained from manufacturer website	July 2021
	POU Device D, RO	Obtained from manufacturer website	August 2021
5	POE Device K, Adsorptive Media (GFH)	Obtained from conversation with manufacturer	January 2022
	POE Device N, Adsorptive Media (GFH)	Obtained from manufacturer website	July 2021
7	POU Device D, RO	Obtained from manufacturer website	August 2021

	POU Device G, RO	Obtained via email with manufacturer and distributor	September 2021
9	POU Device B, Adsorptive Media (Carbon fiber)	Obtained from manufacturer website	July 2021
	POU Device D, RO	Obtained from manufacturer website	August 2021

To complete the LCA in SimaPro, we calculated the amount of material per device and per community over a 30-year period. Table 4.5 shows two RO devices selected in this study and the amount of material both per device and per community (scaled to per community by multiplying by the number of homes in the community). Both RO devices contain the same materials in differing amounts by size and configuration. We found the amount of material over 30 years by calculating the number of replacements of each component and then using the number of replacements to calculate the total amount of material over 30 years. The amount of material for the communities in Regions 1, 7, and 9 are shown to demonstrate how the number of households impacts the amount of raw material entered into the LCA impact assessment. Details for each POU/POE device are in Appendix D in Tables D1-5.

Table 4.5: Inventory of material for two POU RO devices

		Material (kg)											
		Fiberglass		Polypropylene		Polysulfone		Stainless Steel		PVC		GAC	
		POU RO Device D	POU RO Device G	POU RO Device D	POU RO Device G	POU RO Device D	POU RO Device G	POU RO Device D	POU RO Device G	POU RO Device D	POU RO Device G	POU RO Device D	POU RO Device G
Amount of Material (kg) per Device		0.01	0.01	0.001	0.001	0.004	0.004	0.86	0.01	0.04	0.00	0.57	0.57
Initial Installation	Amount of Material for Region 1 (24 homes)	0.33	0.33	0.02	0.02	0.10	0.10	20.63	0.18	0.96	0.00	13.77	13.77
	Amount of Material for Region 7 (75 homes)	1.02	1.02	0.06	0.06	0.31	0.31	64.47	0.57	3.01	0.00	43.03	43.03
	Amount of Material for Region 9 (29 homes)	0.40	0.40	0.02	0.02	0.12	0.12	24.93	0.22	1.16	0.00	16.64	16.64

Over 30 years	Amount of Material for Region 1 (24 homes)	0.33	0.33	0.55	0.55	0.60	0.60	20.63	0.18	1.70	0.00	413.13	413.13
	Amount of Material for Region 7 (75 homes)	1.02	1.02	1.71	1.71	1.86	1.86	64.47	0.57	5.31	0.01	1291.03	1291.03
	Amount of Material for Region 9 (29 homes)	0.40	0.40	0.66	0.66	0.72	0.72	24.93	0.22	2.05	0.00	499.20	499.20

The amount of material in each POU RO device is similar for filter components such as the fiberglass housing, the size and amount of polysulfone in an RO membrane, the amount of polypropylene in sediment filter cartridges, the amount of PVC piping needed to connect the devices, and the amount of GAC in pre- and post-filters. However, RO Device D has more stainless-steel components due the additional faucet components and filter housing materials. Over 30 years, components such as fiberglass filter housings and stainless-steel faucet components and housings did not need replacement based on their useful life. However, components such as RO membranes (polysulfone), sediment prefilters (polypropylene), and GAC filters need to be replaced every 3-5 years for RO membranes and every year for pre- and post-filters; the -year material amount for these components therefore noticeably increases from the initial installation.

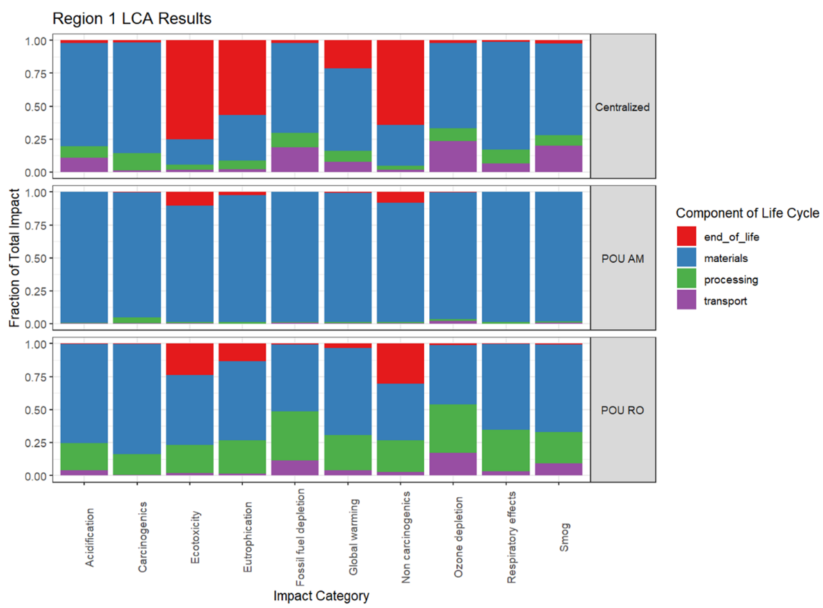
Similarly, for the POU adsorptive media device used in Region 1 and Region 9, carbon fiber filters constitute a large amount of the materials due to frequent replacement within 30 years The stainless-steel housing used in the POU AM device also contributes a large amount of material to the overall inventory. For the POE devices selected for Region 5, filter media (gravel under-bedding and granular ferric hydroxide media) generate a larger amount of material to the overall device inventory compared to the POU devices. Because POE filtration devices are larger than POU filters, they also require more material for filter housings (fiberglass) and piping (PVC) in Region 5 than the POUs for Regions 1 and 9.

4.2.2 Impact Assessment

Impact assessment results are presented in detail in this section for each region, each as two panels: Panel A presents the normalized results to show the relative portion of each component of the life cycle (raw materials, transport, processing and end of life) and Panel B which presents a comparison of each treatment option, normalized to the highest value for impact in each impact category among all three alternatives.

4.2.2.1 Region 1 Impact Assessment Results

In Region 1, processing and waste disposal facilities are located relatively close to the CWS, resulting in a small transportation component to all three alternatives (Figure 4.3A). For the centralized improvement, the end-of-life had a larger fraction of the total impact for the ecotoxicity, eutrophication, and non-carcinogenics, driven in part by the disposal of the adsorptive media material to a landfill. While the POU AM device also has adsorptive media, the stainless-steel housing and plumbing generated a higher material contribution to the total impact for the POU AM device. For the POU RO device, the processing of polysulfone to create a membrane for use in the unit contributes to the processing phase (Figure 4.3A).



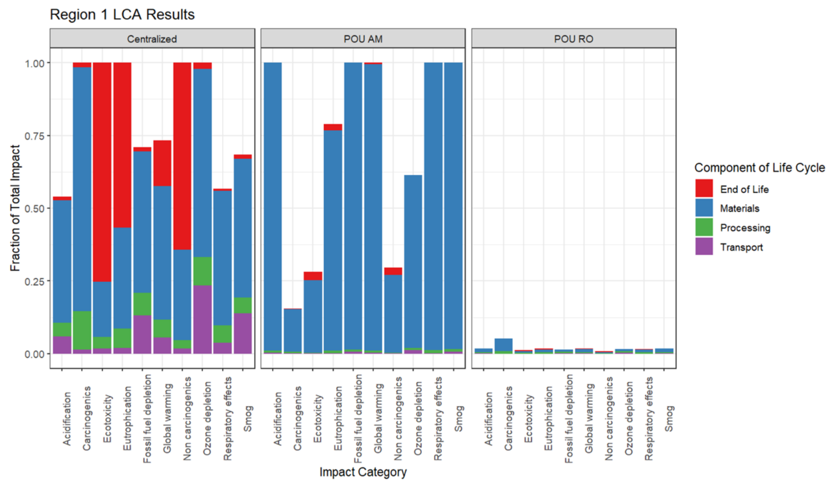


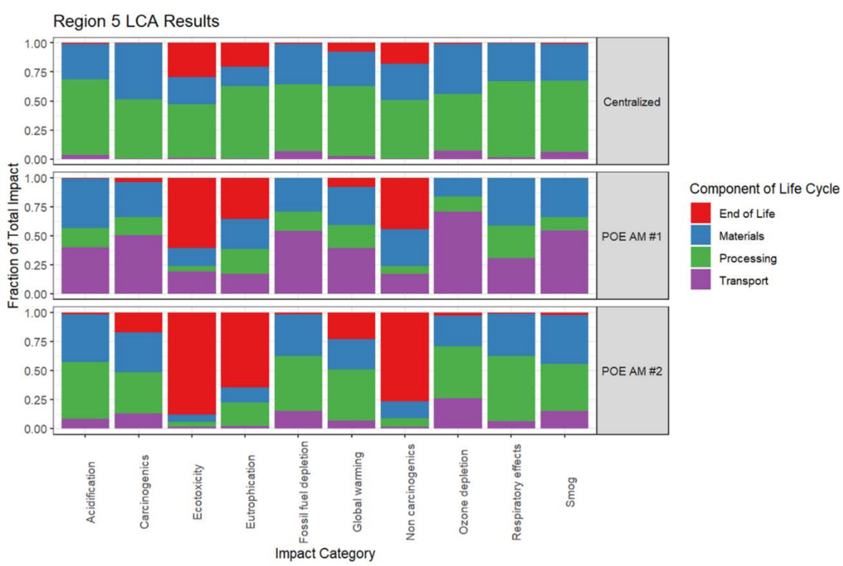
Figure 4.3: LCA Impact assessment results for Region 1. A) Relative contribution of each stage of the life cycle of a product to the overall impact; B) Comparison of the treatment options normalizing the data to the highest impact across all three alternatives.

In Figure 4.3B, we observed that the largest relative impact is associated with the ecotoxicity impact category for centralized treatment, due in part to the disposal of the adsorptive media over time. In comparison, the total relative impacts associated with ecotoxicity for both POU devices are less than half the magnitude of centralized treatment. Both the centralized treatment improvement and the POU AM Device B have 5 categories of impact where the alternative is highest. However, the relative impacts of the POU AM Device B are smaller than for the centralized improvement in the categories where POU AM Device B is not the highest impact alternative. In Region 1, the POU RO Device D has the lowest total overall impact across all impact categories. As a result, we rated the POU RO Device D with the highest score and the centralized alternative with the lowest score.

4.2.2.2 Region 5 Impact Assessment Results

In Region 5, the modeled centralized treatment improvement consisted primarily of PVC and cast-iron pump components; the fraction of the life cycle corresponding to processing is primarily driven by the processing and molding of PVC pipes and the casting of iron components (Figure 4.4A). The relative contribution from transportation is highest for POE Device N, in part due to additional components such as PVC piping, rubber spacers, etc. that need to be included in the device installation that are not present in POE Device K. The end of life of spent adsorptive media for both POE devices contribute the most to the total impact from these devices, particularly to the ecotoxicity category. Centralized treatment has the highest impact for the carcinogenics category only, driven by the cast iron components.

POE Device K has the largest total impact overall, predominantly due to the end-of-life disposal of the adsorptive media (Figure 4.4B). POE Device K has a higher frequency of replacement that POE Device N due to a shorter useful life of the media, accounting for the difference in impact between the two devices. The centralized improvement has the lowest impact of the three alternatives; this is a result of relatively little material being needed over a 30-year period. The centralized improvement consists largely of installing additional PVC piping and a new chlorine dosing pump, both of which have an estimated useful life of 17 years (derived from the EPA Cost Models). As a result, only one replacement is necessary in the 30-year period for the components in the centralized improvement. In contrast, media within the POE devices has a useful like of 7-10 years (depending on the specific device), resulting in 3-4 full replacements within the 30-year period.



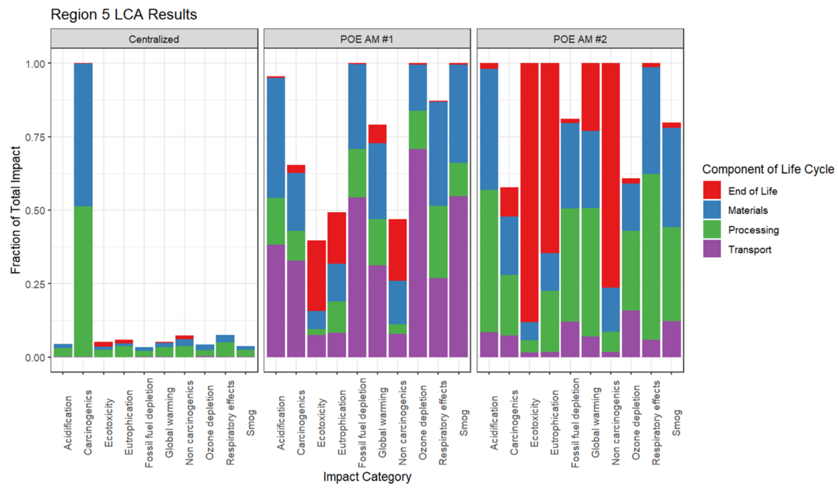
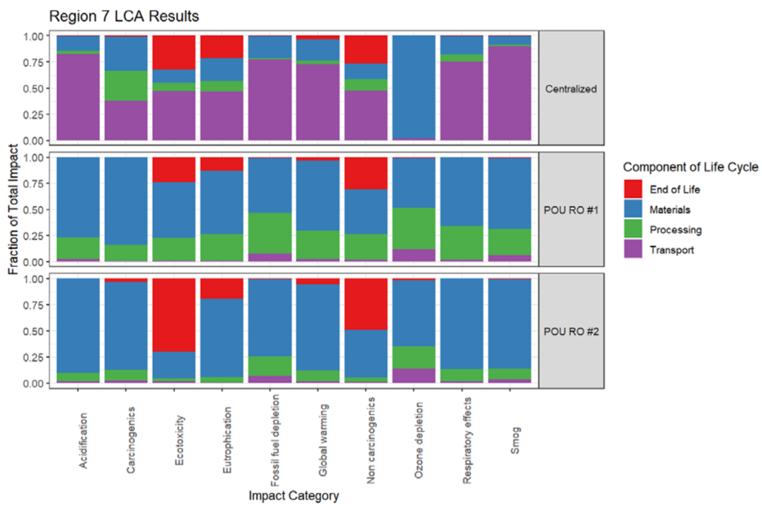


Figure 4.4: LCA Impact assessment results for Region 5. Panel (A) shows the relative contribution of each stage of the life cycle of a product to the overall impact. Panel (B) compares the alternative technologies, normalizing the data to the highest impact across all three alternatives.

4.2.2.3 Region 7 Impact Assessment Results

In Region 7, Figure 4.5A shows which phases of the life cycle the largest fraction to the total impact. For centralized treatment, transportation has a large impact on all categories with the exception of ozone depletion, driven largely by the distance needed to obtain the ion exchange resin from a manufacturer and the number of times the resin is transported to a waste disposal facility over the 30-year period. For both POU RO units, the materials phase of the life cycle is a larger fraction of the total impact, in part due to the multiple components (each RO device contains two prefilters (GAC and polyethylene pre-sediment filters), one post filter (GAC), and a polysulfone membrane). Obtaining these raw materials contributes to all impact categories, particularly to acidification, carcinogenics, global warming, respiratory effects, and smog. We hypothesize that part of the reason these raw materials contribute to these categories specifically is due to the extraction and activation of the GAC pre- and post- filters, as the carbon component can come from the extraction of coal. We also observed that the disposal of GAC increases the end-of-life fraction of the total impact for both POU RO devices, particularly in the ecotoxicity and non-carcinogenics impact categories.


Region 7 LCA Results
Fraction of Total Impact
Centralized
POU RO #1
POU RO #2
Component of Life Cycle
End of Life
Materials
Processing
Transport
Acidification
Carcinogenics
Ecotoxicity
Eutrophication
Fossil fuel depletion
Global warming
Non carcinogenics
Ozone depletion
Respiratory effects
Smog
Impact Category

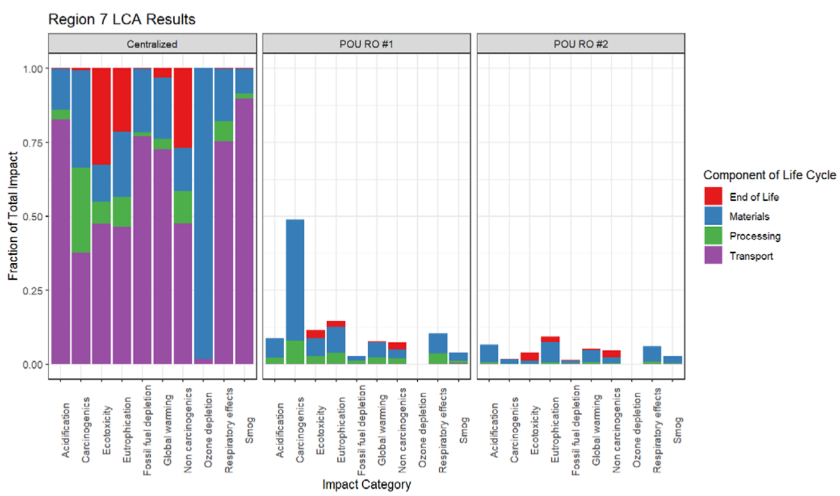
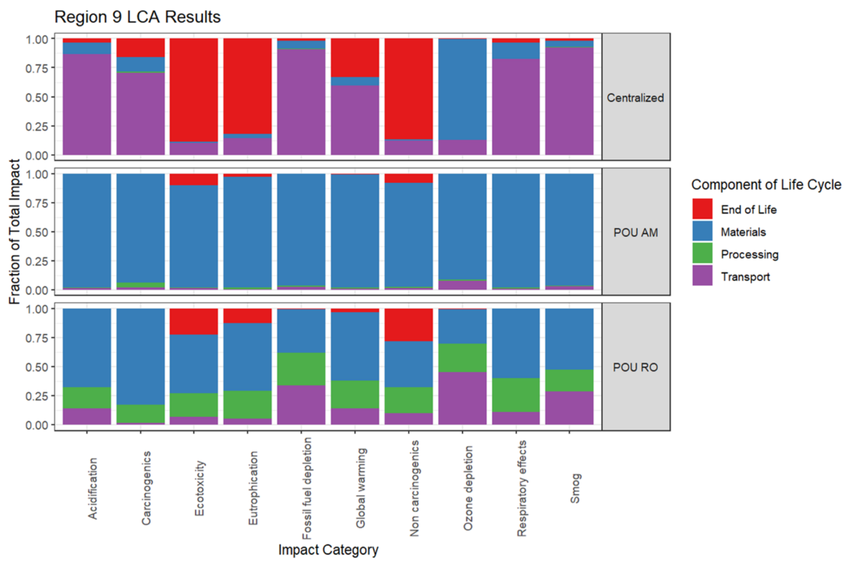

Region 7 LCA Results
Fraction of Total Impact
Centralized
POU RO #1
POU RO #2
Component of Life Cycle
End of Life
Materials
Processing
Transport
Impact Category

Figure 4.5: LCA Impact assessment results for Region 7. Panel (A) shows the relative contribution of each stage of the life cycle of a product to the overall impact. Panel (B) compares the alternative technologies, normalizing the data to the highest impact across all three alternatives.

Figure 4.5B shows that the centralized improvement was the largest relative impact in each impact category. The largest total impact was observed for the centralized treatment improvement in all impact categories, largely due to obtaining, processing, transporting and disposing of the ion exchange resin over time. Similarly, to the adsorptive media results obtained in Region 1 and 5, we observed that the higher frequency of replacement of the media over time contributes to the transportation and end of life phases of the life cycle. In contrast, the ecotoxicity impact category for the POU RO units is primarily due to the material and end of life components of the life cycle, due primarily to the frequent disposal of GAC pre- and post-filters. POU RO Device G has the lowest impact overall in Region 7, preferred over POU RO Device D because it contains smaller components and therefore less material.

4.2.2.4 Region 9 Impact Assessment Results

In Region 9, the materials phase of the life cycle constituted the largest fraction of the total impact for POU AM Device B (Figure 4.6A). For POU RO Device D, the total impact is a balance between all four life cycle phases, driven by the presence of several different materials. In POU AM Device B, the primary component driving the material impact is stainless steel, present in both the device housing and valve components. For centralized treatment, the transportation phase of the LCA makes up a large component of the total impact largely due to the remoteness of the CWS, which is on average 60 miles from manufacturing and processing facilities and 120 miles from the nearest municipal solid waste disposal location, approximately 2-4 times the distance to a processing facility in the other three regions and 8-12 times the distance to a solid waste disposal facility in the other three regions. As a result, disposal, including transportation to disposal facilities drives the total impact along with the 7–10-year useful life of ion exchange resin.


Region 9 LCA Results
Fraction of Total Impact
1.00
0.75
0.50
0.25
0.00
Centralized
POU AM
POU RO
Component of Life Cycle
End of Life
Materials
Processing
Transport
Acidification
Carcinogenics
Ecotoxicity
Eutrophication
Fossil fuel depletion
Global warming
Non carcinogenics
Ozone depletion
Respiratory effects
Smog
Impact Category

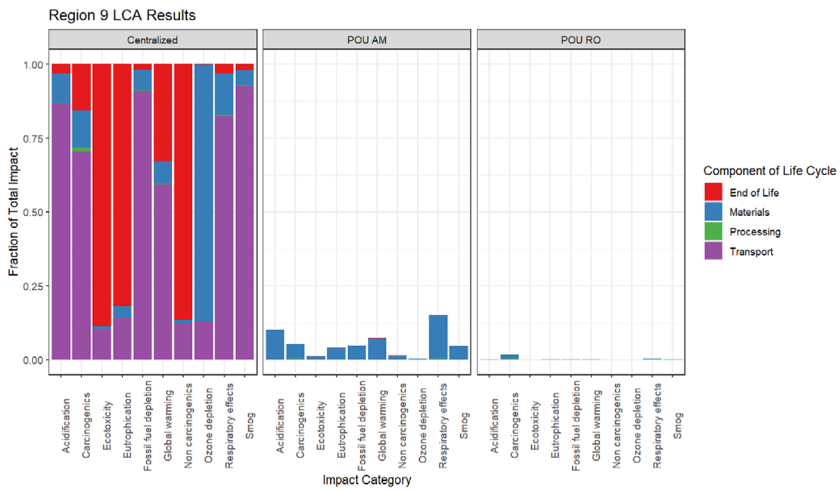
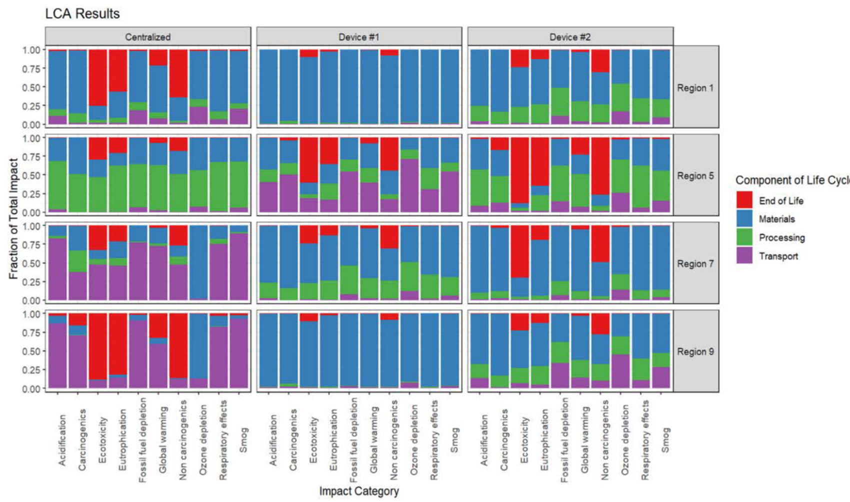


Figure 4.6: LCA Impact assessment results for Region 9. Panel (A) shows the relative contribution of each stage of the life cycle of a product to the overall impact. Panel (B) compares the alternative technologies, normalizing the data to the highest impact across all three alternatives.

Figure 4.6B revealed the centralized treatment improvement has the largest total relative impact, across all impact categories. Compared to the total impact from the centralized treatment facility, the impact from both POU devices is very small, less than 25% of the total impact from centralized treatment in each impact category. The POU RO device has the lowest total impact of the three alternatives. The POU AM device, as was found in Region 1, has a higher overall impact than the RO device due to the disposal and raw materials associated with the adsorptive media.

4.2.2.5 Summary of LCA impact assessment results

Figure 4.7 provides a summary of each treatment option in each of the four regions, including comparing life cycle phases across phases regions and treatment options (panel A) and the total relative impact normalized within each region (Panel B).


LCA Results
Centralized
Device #1
Device #2
Region 1
Region 5
Region 7
Region 9
Fraction of Total Impact
1.00
0.75
0.50
0.25
0.00
Component of Life Cycle
End of Life
Materials
Processing
Transport
Acidification
Carcinogenics
Ecotoxicity
Eutrophication
Fossil fuel depletion
Global warming
Non carcinogenics
Ozone depletion
Respiratory effects
Smog
Impact Category

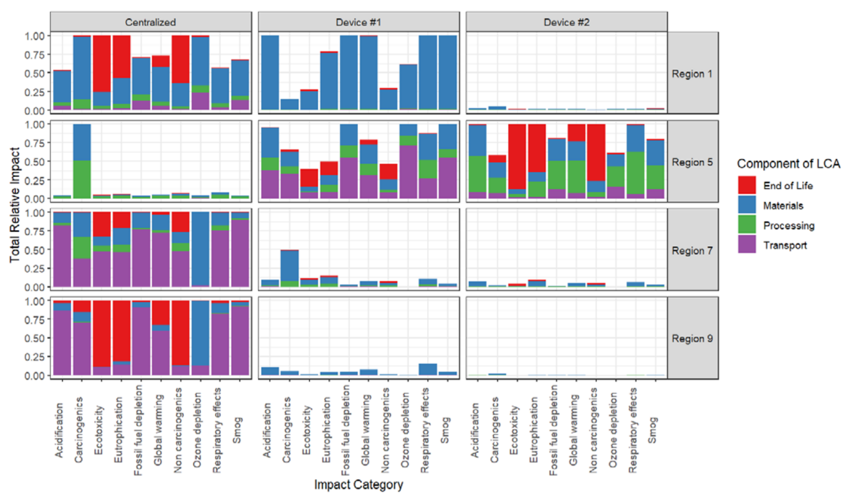

Centralized
Device #1
Device #2
Region 1
Region 5
Region 7
Region 9
Total Relative Impact
1.00
0.75
0.50
0.25
0.00
Component of LCA
End of Life
Materials
Processing
Transport
Acidification
Carcinogenics
Ecotoxicity
Eutrophication
Fossil fuel depletion
Global warming
Non carcinogenics
Ozone depletion
Respiratory effects
Smog
Impact Category

Figure 4.7: Comparison of LCA impact assessments across all four case studies. Panel (A) shows the relative contribution of each stage of the life cycle of a product to the overall impact. Panel (B) compares the alternative technologies, normalizing the data to the highest impact across all three alternatives.

The impact assessment revealed the following conclusions in each Region: the POU RO unit (Device D) selected in both Regions 1 and 9 had the lowest total relative impact compared to the POU AM device and the individual centralized improvements, the centralized alternative had the lowest total relative impact in Region 5, and POU RO Device G had the lowest total relative impact in Region 7. Conversely, centralized treatment alternatives had the highest total relative impact in Regions 1, 7 and 9. In Region 5, POE Device K had the highest total relative impact, driven by the frequency of replacement of the adsorptive media. Table 4.6 summarizes these results, scoring the alternative with the lowest impact with three points and the alternative with the highest impact with one point.

Table 4.6: Summary and ranking of the LCA impact assessment results in each CWS.

Region	Technology	Metric LCA (Smallest Impact) 3 = Best Option, 2 = 2nd Best Option, 1 = 3rd Best Option
1	Centralized Upgrade	1
	POU AM Device B	2
	POU RO Device D	3
5	Centralized Upgrade	3
	POE AM Device N	2
	POE AM Device K	1
7	Centralized Upgrade	1
	POU RO Device D	2
	POU RO Device G	3
9	Centralized Upgrade	1
	POU AM Device B	2
	POU RO Device D	3

5 – Life Cycle Costing (LCC)

5.1 Methods

The cost of each treatment improvement was quantified using the EPA WBS Cost Model equations and unit costs for individual technologies over 30 years (USEPA, 2021a). EPA cost model assumptions were modified to accurately reflect the components present in each selected treatment option, with both one-time costs (capital costs such as installation) and ongoing costs (such as filter cartridge replacement) accounted for. Results are presented both as total costs and costs per household, similar to the functional unit used in the LCA. A comparison of the cost methodology presented in this study in comparison to past studies in presented in Appendix E for reference.

5.1.1 EPA Cost Models

We used components of the EPA work-based structure cost models for centralized treatment technologies and for POU/POE devices for cost modeling for small systems (USE EPA, 2021a) (Figure 5.1). Using components from each model, we estimated the life cycle cost (LCC) over 30 years using data from: (1) the default assumptions in each model to size the system design (flow rate), (2) values determined through conversations with CWS stakeholders where existing infrastructure was already in place (Region 1 and Region 5), (3) replacement frequencies and component costs of POU/POE devices, and (4) values from literature and previous case studies where the CWS stakeholders could not provide a specific value or where the improvement involved the installation of a new centralized treatment technology (Region 7 and 9).To accurately estimate costs for each CWS, we made the assumptions and decisions described below when using the models.

In the POU/POE cost model, we determined the capital cost of a unit by consulting manufacturers for hardware costs, replacement frequencies, and replacement component costs for each device. We used the number of connections in a CWS as the input for the number of households and estimated both the average daily flow and max daily flow where possible from data provided from the community. In the centralized cost models for the upgrade, each CWS had a treatment facility building already built in the community with adequate footprint to house a treatment improvement; therefore, we excluded the cost of construction of a facility from the centralized cost models.

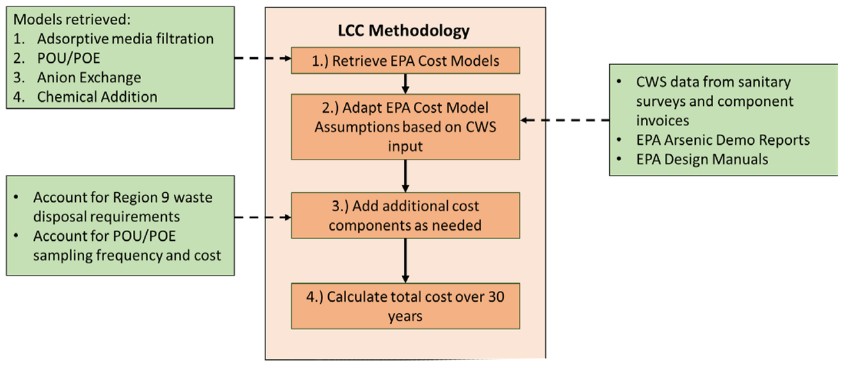


Figure 5.1: Methodology (shown in orange) and data inputs (shown in green) to calculate life cycle cost over a 30-year period.

Using estimates from stakeholder engagement and literature, we generated results for centralized treatment upgrades for each CWS. Cost information was extracted from the Output sheet of each EPA Cost model after running the model with a set of data. We extracted the following information from each model: (1) the component material, (2) the size of the component, (3) the number of components, (4) the unit cost of each component and (5) the useful life of the component. The process flow schematics (Appendix A) were used to extract the relevant information from the EPA cost model output to populate a cost inventory (similar to the procedure in Section 5 for LCA). From this inventory, we calculated the total capital cost (including both direct, indirect, and add-on costs), and annual operation and maintenance costs (O&M) for each set of design assumptions.

We used the useful life information provided in the EPA Cost Models to determine the number of replacements necessary over 30 years by dividing the useful life by thirty years and rounding down to the nearest whole number. For POU/POE devices, we relied upon communication with manufacturers to determine the useful life of POU/POE device components since replacement of specific components such as filter cartridges is more frequent (1-3 years) compared to centralized treatment components lifetimes (10-20 years). Based on the number of replacements, we then adjusted the total cost of each component prior to calculating total capital and O&M costs. For yearly costs such as labor and chemical costs, we multiplied the yearly cost by 30 years to obtain the total cost over 30 years to avoid double counting the first year of labor.

Table 5.1 shows which values were extracted from the EPA cost models and which values we calculated to find the total cost over 30 years. These calculations do not consider interest over time and provide example calculations only, not actual values used to estimate cost in subsequent figures (full details are provided in the Appendix).

Table 5.1: Values extracted from EPA cost models were used to calculate the number of replacements over a 30-year period. Values extracted from the EPA cost model are shown on the left in yellow and calculated values are shown in green on the right of the table.

Values extracted from EPA Cost Model					Calculated values		
Cost Compone nt	Number of Units [unitless]	Unit Cost [$]	Compone nt Cost [$]	Usefu l Life [years]	Number of full replacements in 30 years [replacement s]	Number of multiples to include [unitless]	Cost over 30 years [$]
Example Compone nt	*a*	*B*	*C* = *a* * *B*	*x*	*r* = 30/*x*	*R* = 1 [initial installation] + ROUNDDOWN(*r*)	*R***C*
Process Valve	2 units	$45.00	= 2 units * $45 = $90	17 years	30/17 years [useful life] = 1.76	= 1 + ROUNDDOWN(1.7 6) = 2	=2 * 90 = $180
Operator Labor	60 hours/yea r	$30/hou r	$1800/yea r	1 year	30/1 year = 30 years	= 30 years (this was manually adjusted to avoid double counting the first year)	= 30* $1800 = $54,00 0

5.1.2 Data inputs

5.1.2.1 Community data

We consulted stakeholders from each CWS to adjust the assumptions made in the EPA cost models to more accurately reflect state policies, community characteristics, and additional factors influencing costs. We presented the current list of model assumptions from the EPA cost models to each CWS's stakeholders and discussed how each assumption could be modified if necessary. Then, the assumptions from each CWS were used to iterate through the EPA cost model under different scenarios: POU RO device, POU adsorptive media device, model by number of households, model by flow rate, etc.

5.1.2.2 Literature data

To fill any gaps in the EPA cost models, we consulted previously conducted LCC studies from literature, previous EPA studies such as the Arsenic Treatment Demonstration project, and the EPA design manuals for specific treatment technologies. Data and assumption sources have been noted where applicable.

5.1.3 Modeling best and worst-case cost

Through conversations with POU/POE manufacturers and CWS stakeholders, we determined that including a range of cost estimates in our analysis was important. For example, we learned that, often, POU/POE devices were observed to need frequent component replacement and that replacing components in private households can be challenging, especially in light of social distancing during the COVID-19 pandemic. In addition, we learned from manufacturers the quality of water entering the POU/POE device has a large impact on device performance. For example, while a POU device may remove 95% of pentavalent arsenic at a pH of 7.5, this can be influenced by sulfate, iron, and total solids content of the influent water. As a result, we determined a set of best- and worst-case assumptions to model both low and high-cost estimates respectively.

First, where possible, we used CWS-specific information for best- and worst-case scenario values. Best-case scenarios used manufacturer and design standards for both POU/POE and centralized treatment upgrades and represent the ideal scenario (water quality in source water, operational practices, technology performance) for technology installation and operation. Worst-case scenarios integrated evidence from previous POU/POE and centralized treatment installation case studies and feedback from CWS stakeholders. For example, we learned from a conversation with a stakeholder in Region 7 that travel time in rural areas of Nebraska can significantly increase the labor costs of maintenance activities for POU/POE and centralized systems, and the time to sample POU/POE units for compliance purposes. CWS stakeholders in Region 9 also highlighted the importance of waste disposal per California state regulations; therefore, specific cost considerations related to residuals management were adjusted based on these requirements recommendations from Region 9 stakeholders.

For input data generated from literature, the best-case scenario was constructed by selecting the smallest values from literature or from each community water system assumptions as the assumptions for each of the cost component from the EPA Cost Model. The best-case represents the scenario where labor requirements are minimized, lab analysis is reduced after the first year as a result of adequate contaminant removal, operation and maintenance times are limited to only necessary activities and replacement frequencies are decreased by increasing the useful life of the components. The worst-case scenario was constructed by selecting the largest values from literature or from each community water system assumptions. The worst-case scenario represents an increase in the labor costs, an increase in the number of hours per year spent on operations and maintenance activities, no reduced compliance sampling after the first year and replacement frequencies are increased by decreasing the useful life of components. Because many of these best-case and worst-case values were primarily generated from literature, the assumptions may be smaller or larger than the CWS-specific assumptions which leads to a non-intuitive decrease in cost in the worst-case assumptions.

5.2 Results

5.2.1 Cost Assumptions

5.2.1.1 Centralized treatment improvements

We estimated the cost of centralized improvements using the EPA Cost Models for adsorptive media (for Region 1), chemical addition (Region 5), and anion exchange (for Region 7, Region 9) as a baseline to inventory components necessary to life cycle costing. In Region 1, we used the EPA Adsorptive media cost model default assumptions to generate a baseline inventory for an adsorptive media system including 2 filtration vessels and a backwash system (USEPA, 2021c).

In Region 5, we reviewed an inventory report provided by the CWS to create an inventory of current system components. In addition, we reviewed other EPA cost models specific to chemical addition (such as phosphate addition), since a pre-chlorination cost model is not yet publicly available and used these to generate a list of potential components to include in the centralized upgrade. In addition, since no EPA cost model was available, we relied on literature from the EPA Arsenic Demo Reports, manufacturer websites, and past project invoices where possible to collect cost information.

In Regions 7 and 9, we relied primarily on the EPA Anion Exchange cost model since there is little existing centralized infrastructure in place in either CWSs. In Region 7 we chose a nitrate selective resin and based the design parameters on the EPA Design Manual for Nitrate Removal by ion Exchange (USEPA, 1978) and the WBS documentation for the anion exchange cost model (USEPA, 2017b). We selected a residuals management strategy of piping liquid waste streams to a centralized wastewater facility and a fully automated system in Region 7. We calculated the number of bed volumes using the sulfate concentration in the groundwater in Region 7 and the following relationship from the EPA WBS Cost model:

$$BV = -606 * \ln x + 3150$$

Where BV represents the number of bed volumes before regeneration, and x represents the sulfate concentration in the groundwater source (USEPA, 2017b). This yielded a BV value of 1052 BVs for Region 7 and a value of 1366 BVs for Region 9. In Region 9, we selected a strong base polyacrylic resin, a fully automated system and residuals discharge to an evaporative pond based on feedback from CWS stakeholders.

3.4.2 POU/POE Devices

As with the centralized treatment improvement, we adjusted the EPA Cost Model assumptions for POU/POE devices to be specific to each case study's context. The EPA POU/POE cost model consists of both standardized models (with assumptions about flow rates based on household size), and user defined models wherein assumptions can be adjusted to suite a specific community.

In Region 1, state-level stakeholders suggested the following adjustments to the EPA POU Cost model assumptions: decreased printing and distribution of public education materials to reflect virtual means of communication, increased labor costs corresponding to state specific wage requirements, increased monitoring frequency for initial monitoring, increased cost per arsenic sample analysis, and consolidated maintenance and operational activities. These changes resulted in higher costs for lab analysis, materials and initial monitoring costs than the standard EPA model, but lower labor costs. In Region 5, CWS stakeholders indicated the EPA standard model assumptions were likely the best assumptions for the community. Few POE or POU installations have been completed in Illinois and thus there is relatively little evidence from past experiences with POE and POU devices. In Region 7, CWS stakeholders did indicate the time to complete both sampling and maintenance needed to be increased to reflect the amount of travel time necessary to reach rural communities with POU/POE installations; they also noted that the cost of POU devices in the past has been highly variable and specific to each community. In Region 9, we consulted previous POU studies and state level administrators and learned California has a very intensive initial public education program to encourage 100% participation in POU/POE installations. In addition, depending on the system, the California sampling requirements for compliance are higher than other states, in part because California allows systems to begin piloting prior to 100% installation. Previous case studies from California have sampled in each house 2-4 times a year compared to once a year specifically due to the nature of the contaminant in the system (for example, acute exposure to elevated levels of nitrate). The assumptions in Table 5.2 reflect these higher public education costs, including more public meetings, flyers, and outreach materials and labor from clerical staff to prepare materials. These assumptions are summarized in Table 5.1 from each CWS in comparison to the standard EPA Cost Model assumptions. Where appropriate, we also included values from a 2020 California white paper based on previously installed POU/POE devices (California Water Boards, 2020).

Table 5.2: Assumptions used to model cost using the EPA POU/POE Cost Model. The assumptions presented in this table do not include individual POU/POE device components as these components are device specific.

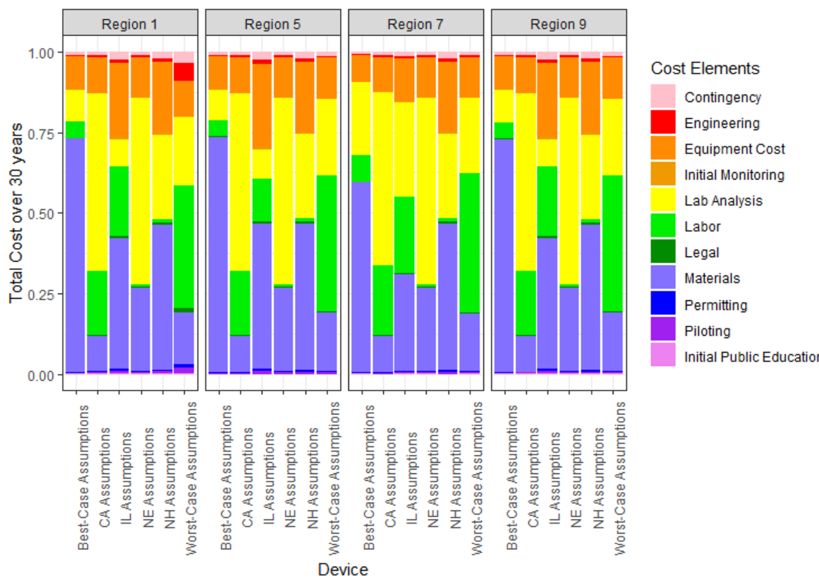
Category	Sub-Category	Parameter	Units	Default Value in EPA Model	CA 2020 Paper Assumptions	NH Assumptions (Region 1)	IL Assumptions (Region 5)	NE Assumptions (Region 7)	CA Assumptions (Region 9)
Initial Equipment Costs	Initial Equipment Costs	Wage rate for installation specialist (plumber/electrician)	$/hour	$33.12	$33.12*	$24.49	$33.12*	$33.12*	$100
		Wage rate for system technical and maintenance labor	$/hour	$25.07	$25.07*	$21.01	$25.07*	$25.07*	$57
		Wage rate for scheduling and administrative labor	$/hour	$17.89	$17.89*	$10.95	$17.89*	$17.89*	$37
		POU/POE installation time	Hours/household	2	4	2*	2*	4	5

		POU/POE installation scheduling time	Hours/household	0.5	2	0.5	0.5*	2	2
Initial Educational Costs	Technical Labor to Support Educational Program	Develop technical education materials	Total hours	10	10*	0	10*	10*	0.25
		Prepare for and attend public meetings	Total hours	2	2*	2*	2*	2*	7.2
		Post-meeting stakeholder communication	Total hours	2	2*	2*	2*	2*	2.75
	Clerical Labor to Support Educational Program	Prepare educational materials for distribution	Total hours	6	6*	0	6*	6*	6*
		Prepare for and attend public meetings	Total hours	2	2*	2*	2*	2*	2*
		Prepare post-meeting materials for distribution	Total hours	2	2*	0	2*	2*	2*
	Communication for Materials for Educational Program	Print flyers announcing public meetings	Flyers	10	10*	0	10*	10*	3
		Cost per flyer for printing	$/flyer	$2.00	$2.00*	0	$2.00*	$2*	$2*
		Buy ads to announce public meetings	Ads	0	0*	0*	0*	0*	$10
		Cost per meeting ad	$/ad	$40	$40*	0	$40*	$40*	$40*
		Print handouts for meetings	Pages/household	3/house	3/house*	0	3/house*	3/house*	3*
		Print inserts for billing mailers	Pages/household	1/house	1/house*	0	1/house*	1/house*	2
		Cost to print handouts and mailers	$/page	$0.08	$0.08*	0	$0.08*	$0.08*	$1.50
Initial Monitoring Costs	Initial Monitoring Costs (First year only)	Time to take sample during first year	Hours/sample	0.25	0.25*	0.25*	0.25*	0.25*	1
		Time to schedule sample event at household	Hours/sample	1	0*	0	1*	1*	2
		Number of samples per household during the first year	Samples/household	1	1*	1*	1*	1*	4
		Fraction of households sampled during the first year	% households	100	100*	100*	100*	100*	100*

		Laboratory analysis fee	$/sample	$25.75 (arsenic) / $24.25 (nitrate)	$25.75 (arsenic) / $24.25 (nitrate)*	$30 (arsenic)	$25.75 (arsenic)*	$16-19 per nitrate	$30 per sample
		Sample shipping cost (bulk)	$/bulk shipment	$9 for 15 samples	$9 for 15 samples*	0	$9 for 15 samples*	$9 for 15 samples*	$9 for 15 samples*
Indirect Capital Costs	Indirect Capital Costs	Cost to obtain operating permit	$/% of installed equipment cost	3	3*	0	3*	3*	3*
		Cost to conduct pilot study	$/% of installed equipment cost	3	3*	0	3*	3*	3*
		Cost for legal activities	$/% of installed equipment cost	3	3*	3*	3*	3*	3*
		Cost for engineering activities (device selection)	$/% of installed equipment cost	15	15*	0	15*	15*	15*
		Contingency cost (unknown factors)	$/% of installed equipment cost	10	10*	10*	10*	10*	10*

*Assumption from the state stakeholder is the same as the EPA Cost Model

We then calculated the total cost per household over 30 years for each POU/POE device using the corresponding assumptions (Table 5.2, Figure 5.2). In Figure 5.2, we present the results from running the EPA cost model for a generic NSF/ANSI 53 certified device removing arsenic under different assumptions, including A) the total cost over 30 years as a portion of the total cost to highlight which elements contribute most to the total cost under different cost assumptions; 2) the total cost over 30 years for each set of assumptions. The results highlight the importance of understanding the true time commitment and cost to operate and maintain POU/POE devices in each CWS. For example, using the California cost assumptions, labor costs are higher as a result of a higher operator wage and increased time to complete O&M activities in California due to the geographically remote location of the community.


Region 1
Region 5
Region 7
Region 9
Total Cost over 30 years
1.00
0.75
0.50
0.25
0.00
Best-Case Assumptions
CA Assumptions
IL Assumptions
NE Assumptions
NH Assumptions
Worst-Case Assumptions
Device
Cost Elements
Contingency
Engineering
Equipment Cost
Initial Monitoring
Lab Analysis
Labor
Legal
Materials
Permitting
Piloting
Initial Public Education

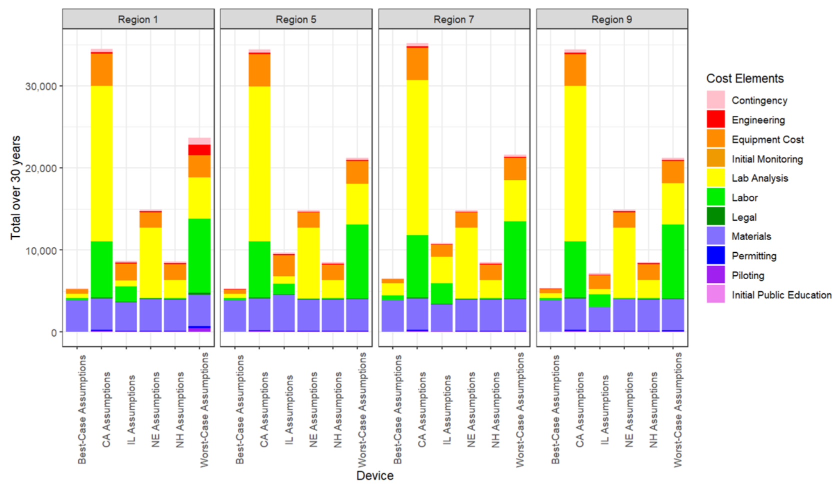


Figure 5.2: A) Total cost over 30 years normalized per household for each set of assumptions used in the POU/POE Cost Models; B) Total cost over 30 years in USD. The results represent a generic POU AM device certified to NSF/ANSI 53 found in the EPA Cost models to show how the difference in assumptions impact cost based on the population served.

Labor and lab analysis are particularly important elements contributing to overall cost when installing POU/POE devices in a CWS (Figure 5.2). California and worst-case assumptions had higher wages for staff, more required samples to be tested, more expensive lab analysis costs, and more staff hours than the other set of assumptions, accounting in part for the large lab analysis cost. In New Hampshire or with best-case assumptions, materials such as POU filter replacement components make up a large portion of the total cost, reflecting a higher replacement frequency of components but lower costs of labor and lab analysis components, while engineering, contingency, initial public education, legal, permitting, piloting and initial monitoring costs are minimal for all the sets of assumptions. The largest portions of costs across all systems are labor, materials, equipment cost and lab analysis. Because these elements constitute O&M costs, we see that O&M costs make up the largest portion of the costs associated with POU/POE devices over 30 years, as anticipated.

5.2.2 Cost Results

The following cost results represent the total cost over 30-years per household in each CWS. A table and figure for each CWS shows the total direct, indirect, and O&M costs over 30 –years per household. Total direct costs consist of equipment costs, initial monitoring costs and initial public education costs.

Total indirect costs consist of permitting, piloting, contingency, engineering and legal and administrative costs. Total O&M costs consist of lab analysis costs, materials costs (replacement components) and labor costs.

5.2.2.1 Region 1 Cost Results

In Region 1, the centralized treatment improvement had the highest per household total direct and total indirect cost over 30 years. The POU carbon fiber adsorptive media had the lowest overall cost; the total direct cost of the adsorptive media device is larger than the RO device, however, the replacement frequency and number of components in the RO system make the O&M costs of the RO device larger over time. The total cost per household of the POU devices are within $900 of each other over 30 years within O&M costs being the differentiating cost component. Indirect costs over 30 years are smaller for both POU devices compared to centralized treatment.

Table 5.3: Summary of primary costs per household over 30 years in Region 1

Total cost ($) per household over 30 years			
Improvement	Total Direct	Total Indirect	Total O&M
Central Upgrade	1,953	1,398	8,880
POU AM Device B	2,550	277	4,817
POU RO Device D	1,962	215	5,568

Equipment and material costs make up more of the total per household cost for both POU options (Figure 5.3). This is due in part to the high frequency of replacement components needed for the POUs compared to replacement needs for the centralized treatment upgrade. In addition, lab analysis accounts for much of the total POU cost over 30 years, resulting from monitoring requirements for compliance when using POUs for regulatory compliance in CWSs. For example, in Region 1, in the first year, a sample must be taken at least once in each home for compliance purposes (24 samples in year one). While in some states, after the first year, sampling frequency can be reduced to a fraction of the total houses if contaminant removal is satisfactory in the first year; however, in Region 1, sampling frequency must remain at 100% of the homes over time. Conversations with state administrators revealed that approval for reducing sampling frequency would not likely be reduced because the contaminant is arsenic and because the community only consists of 24 households.

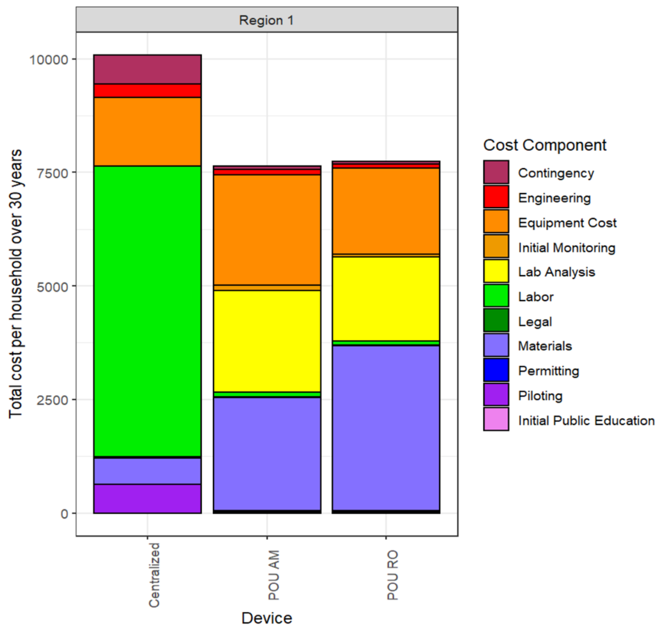


Figure 5.3: Total cost per household over 30 years for each alternative in Region 1 with a breakdown to show the cost elements.

5.2.2.2 Region 5 Cost Results

In Region 5, the total cost per household over 30 years is lowest for the centralized treatment improvement. The treatment improvement is small, therefore, the total direct cost per household over 30 years is $36, the total indirect cost is $35, and the total O&M cost is $298, which consists primarily of labor for the operation of the treatment facility. The total direct cost for POE AM Device N was $3,774 per household over 30 years, the total indirect cost was $905, and the total O&M cost was $16.467. The larger total O&M cost per household is driven by the equipment cost for the POE unit, the cost to replace the adsorptive media over time, and the cost of lab sampling for compliance in all 221 homes in the first year of operation. For POE AM Device K, the total direct cost is $3,559, the total indirect cost is $1,202, and the total O&M cost is $10,496 per household over 30 years (Table 5.4).

Table 5.4: Summary of primary costs per household over 30 years in Region 5

Total cost ($) per household over 30 years			
Improvement	Total Direct	Total Indirect	Total O&M
Central Upgrade	26	35	298
POE AM Device N	137	602	14,584
POE AM Device K	533	1,096	28,945

In Region 5, because there are many connections (221 homes), the cost to replace adsorptive media filter components in POEs and to conduct lab sampling for compliance is larger than in Region 1. In addition, the POE units are more expensive than the POU AM unit examined in Region 1; replacements are less frequent for the POE unit, but more expensive since the media needs full replacement which can be an intensive process. In addition, even as the portion of houses that must be monitoring yearly for SDWA compliance decreases, since the community consists of 221 homes, the total lab analysis cost is approximately $10,000 for both POE devices per household over 30 years.

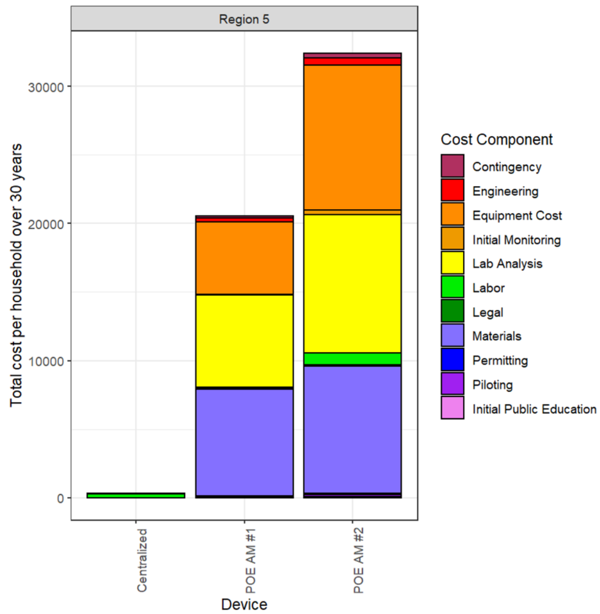


Figure 5.4: Total cost per household over 30 years for each alternative in Region 5 with a breakdown to show the cost elements.

5.2.2.3 Region 7 Cost Results

In Region 7, the centralized ion exchange treatment facility has the lowest per household cost over 30 years out of the three treatment options examined. POU RO Device D was the highest cost alternative, followed by POU RO Device G (Table 5.5) per household over 30 years. The centralized treatment option has a total direct cost per household over 30 years of $914, a total indirect cost of $296, and a total O&M cost of $2,974. POU RO Device D has a total direct cost per household over 30 years of $7,526, a total indirect cost of $1,802, and a total O&M cost of $13,498. POU RO Device G has a total direct cost per household over 30 years of $5,626, a total indirect cost of $1,346, and a total O&M cost of $12,808, making it marginally cheaper than POU RO D. For both POU RO devices, the total O&M cost is higher than the centralized cost in part because 75 devices must be maintained across the community and because both RO devices require pre-filters and post-filters be replaced yearly and the RO membrane be replaced every 3-5 years.

Table 5.5: Summary of primary costs per household over 30 years in Region 7

Total cost ($) per household over 30 years			
Improvement	Total Direct	Total Indirect	Total O&M
Central Upgrade	914	296	2,974
POU RO Device D	2,414	258	13,498
POU RO Device G	1,834	194	12,808

The higher total costs over 30 years per household associated with the POU RO devices are a result of the lab analysis, equipment, and materials costs associated with each device. Higher lab analysis costs are largely driven by monitoring requirements for nitrate, which cannot be reduced over time; samples must be taken yearly in each home for nitrate (USEPA, 2006) in all 75 households as a precautionary measure. Nitrate contamination is associated with methemoglobinemia which impacts infants predominantly, and therefore samples are required at all locations yearly. There is also a higher public education and labor cost for the POU RO devices than seen in Region 1 due to the increased requirements to provide public notification surrounding the impacts of nitrate (as opposed to arsenic).

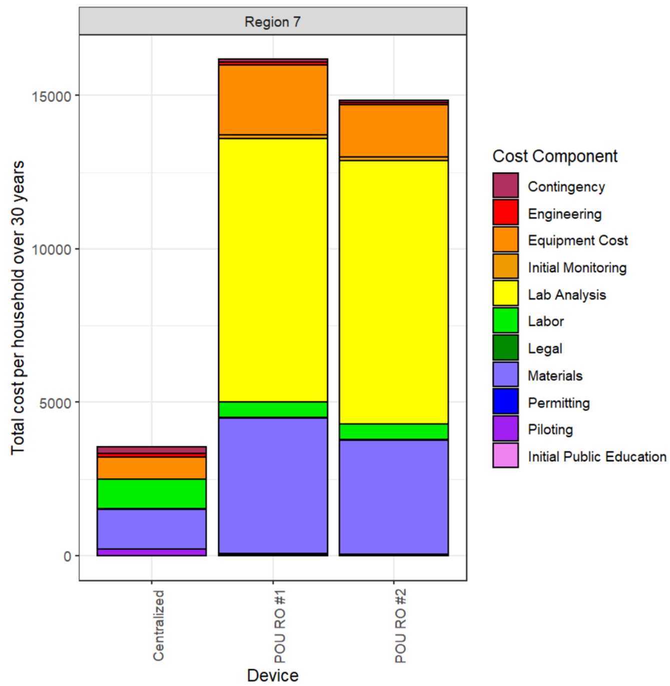


Figure 5.5: Total cost per household over 30 years for each alternative in Region 7 with a breakdown to show the cost elements.

5.2.2.4 Region 9 Cost Results

In Region 9, the centralized treatment improvement is the lowest cost alternative per household over the 30-year period. The centralized improvement has a total direct cost per household over 30 years of $5,461, a total indirect cost of $1,881, and a total O&M cost of $7,307. Of the two POU devices selected for this CWS, POU AM Device B has a higher total direct and indirect cost per household over 30 years, but a lower O&M cost compared to POU RO Device D. The higher total O&M cost of the RO device is largely due to needing to replace multiple components over time, while the AM device has only one primary component to replace every 3-5 years.

Table 5.6: Summary of primary costs per household over 30 years in Region 9

Total cost ($) per household over 30 years			
Improvement	Total Direct	Total Indirect	Total O&M
Central Upgrade	5,461	1,881	7,307
POU AM Device B	3,634	388	28,246
POU RO Device D	3,484	371	30,157

In Region 9, the labor cost associated with the POU devices results from a higher wage rate in California and an increase in the number of hours spent on POU maintenance compared to other regions. As observed with the other three regions, the lab analysis and equipment costs associated with the POU devices were a larger portion of the total cost per household over 30 years. For both the POU devices, the equipment cost is approximately $10,000 per household over 30 years and the lab analysis is approximately $20,000 per household. In Region 9, we assumed multiple samples were necessary in the initial year of monitoring and more samples were taken for compliance over time based on a report of a case study conducted in California (Corona Environmental Engineering, 2021). State sampling requirements for parameters such as nitrate and perchlorate match the recommendations from the Corona case study and other previous case studies conducted in systems using POU devices for arsenic and uranium contamination. Because there were several known case studies in California suggesting higher sampling frequency, we elected to use a higher initial monitoring requirement of 4 samples in the first year only as a result. Conversations with state administrators revealed that this is likely an overestimation of lab analysis costs over time as the frequency of sampling is expected to decrease if the POU devices are performing as intended.

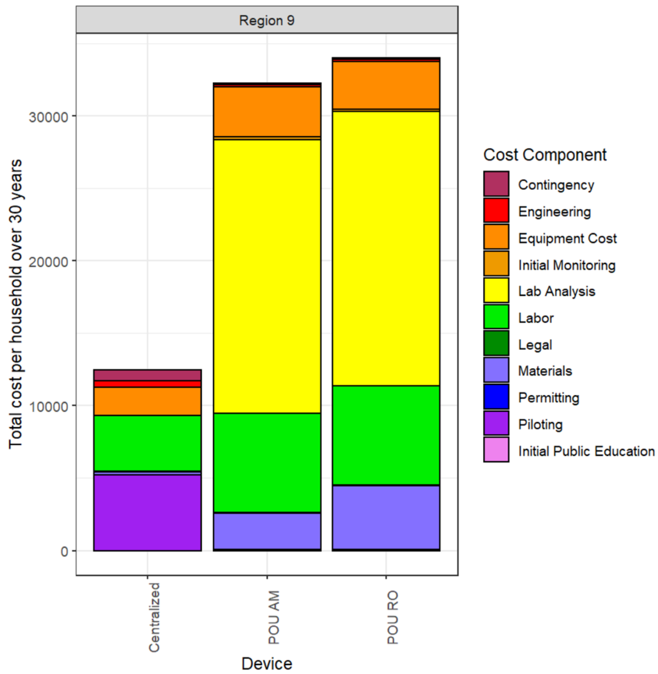


Figure 5.6: Total cost per household over 30 years for each alternative in Region 9 with a breakdown to show the cost elements.

5.2.3 Cost comparisons between centralized and POU/POE

When comparing the cost of POU/POE devices to centralized treatment costs using the EPA models, we made the following assumptions to align the cost element categories (Figure 5.5). The total cost is the total of the total direct, the total indirect and the total O&M costs over the 30-year period. Centralized treatment upgrade costs included the costs of fittings, valves, pumps, and instrumentation, aligning with the components included in the POU/POE equipment cost element. Centralized legal costs were calculated using the "Administration" line from the centralized cost models to align with the "Legal and Administrative" costs from the POU/POE models. Centralized material costs were calculated as the sum of media, resin and chemical costs, aligning with POU/POE materials costs. Finally, "Miscellaneous" cost for centralized treatment is the sum of miscellaneous costs for both equipment and O&M.

Table 5.7: Cost comparison ($) by category of cost for each CWS over 30 years per household

Type of Cost	Region 1 (New Hampshire)			Region 5 (Illinois)			Region 7 (Nebraska)			Region 9 (California)		
	POU AM Device B	POU RO Device D	Centralized Upgrade	POE AM Device N	POE AM Device K	Centralized Upgrade	POU RO Device D	POU RO Device G	Centralized Upgrade	POU AM Device B	POU RO Device D	Centralized Upgrade
Total Direct	8,157	7,657	1,953	3,774	3,559	26	7,526	5,626	914	11,420	10,920	5,461
Total Indirect	1,942	1,822	761	905	1,202	35	1,802	1,346	296	2,736	2,616	1,881
Total O&M	4,817	6,728	8,880	16,467	10,496	298	13,498	12,808	2,974	28,246	30,157	7,307

Type of Cost	Region 1 (New Hampshire)			Region 5 (Illinois)			Region 7 (Nebraska)			Region 9 (California)		
	POU AM Device B	POU RO Device D	Centralized Upgrade	POE AM Device N	POE AM Device K	Centralized Upgrade	POU RO Device D	POU RO Device G	Centralized Upgrade	POU AM Device B	POU RO Device D	Centralized Upgrade
Equipment Cost	8,090	7,590	1,509	3,770	3535	26	7,510	5,610	716	11,400	10,900	1,949
Initial Public Education	9	9	NA	4	4	NA	16	16	NA	20	20	NA
Initial Monitoring	59	59	NA	0	19	NA	0	0	NA	0	0	NA
Permitting	243	228	11	113	106	NA	225	168	0	342	327	1
Piloting	243	228	626	113	106	NA	225	168	208	342	327	5,227
Legal and Administrative	243	228	30	113	106	NA	225	168	12	342	327	52
Engineering	404	379	299	189	530	NA	376	281	120	570	545	446
Contingency	809	759	637	377	353	NA	751	561	221	1,140	1,090	728
Labor	101	101	6,405	83	574	298	508	508	970	6,840	6,840	3,835
Materials	2,479	4,390	570	7,800	9286	0	4,398	3,708	1,305	2,479	4,390	209
Lab Analysis	2,236	2,236	NA	8,585	10113	NA	8,591	8,591	NA	18,927	18,927	NA
Residuals	NA	NA	268	NA	NA	NA	NA	NA	172	NA	NA	877

Total O&M costs made up the largest portion of the costs over 30 years for both centralized upgrades and POU/POE treatment options; however, these results can vary by system. In Region 1, the total O&M cost of the centralized upgrade is higher than either POU option per household over the 30-year timeframe, while the opposite is true for Regions 5, 7 and 9 where the total O&M cost of centralized upgrade is less than POU/POE alternatives. In addition, for all four systems, the total direct capital cost and the total indirect capital cost were higher for POU/POE devices than for centralized systems. One possible explanation for larger capital costs for POU/POE units is that their equipment costs are based on the number of homes in each community. In smaller communities such as in New Hampshire and California, the equipment cost per household is larger than in Nebraska and Illinois, where there are few houses to spread the capital cost of centralized treatment. Notably, in Region 5, the centralized treatment improvement is also a small improvement requiring only additional dosing equipment to improve pre-oxidation practices.

Figure 5.7 summarizes Table 5.7, showing the total cost over 30 years for each alternative by the cost component. The total cost to implement and maintain POU/POE systems is larger than the centralized treatment option. In New Hampshire, this is primarily because of material and equipment costs associated with frequently replacing POU/POE units. In California, lab analysis and labor costs drive the total costs of the POU/POE system. In Nebraska and Illinois (which have similar assumptions in Table 5.3), the larger cost of POU/POE devices is primarily driven by lab analysis and equipment and material costs.

Figure 5.7: shows the cost elements that constitute the total cost of each alternative in each water system.

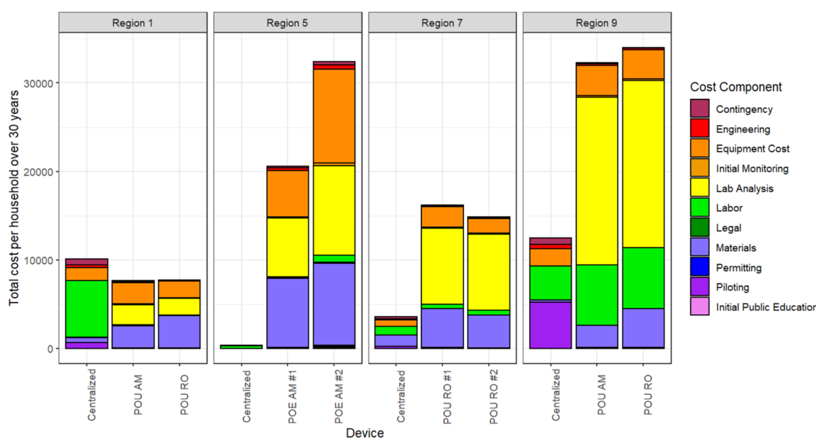


Figure 5.7: Total cost over 30 years for each alternative in each community water system.

Figure 5.8 presents the total cost over 30 years in the first year and in increments of 5 years to capture how cost increases over time for each alternative. In the first year of implementation, the total cost per household of a centralized upgrade is within the same order of magnitude as the installation of a POU/POE device. However, over time, the lab analysis costs, material costs and equipment costs of POU/POE devices increase at a faster rate than centralized treatment upgrades. Centralized treatment upgrade components only need to be replaced on average once in the thirty year time frame, or not at all. However, POU/POE components need to be replaced on average every five years, resulting in a higher equipment and materials cost compared to centralized upgrades. Region 1 and Region 9 have current systems serving approximately the same population and the POU devices considered in our analysis were the same. However, the labor and lab analysis cost model assumptions for Region 9 are such that the cost of ensuring SDWA compliance for the same devices as Region 1 are higher in Region 9, which results in the higher total cost per household over 30 years.

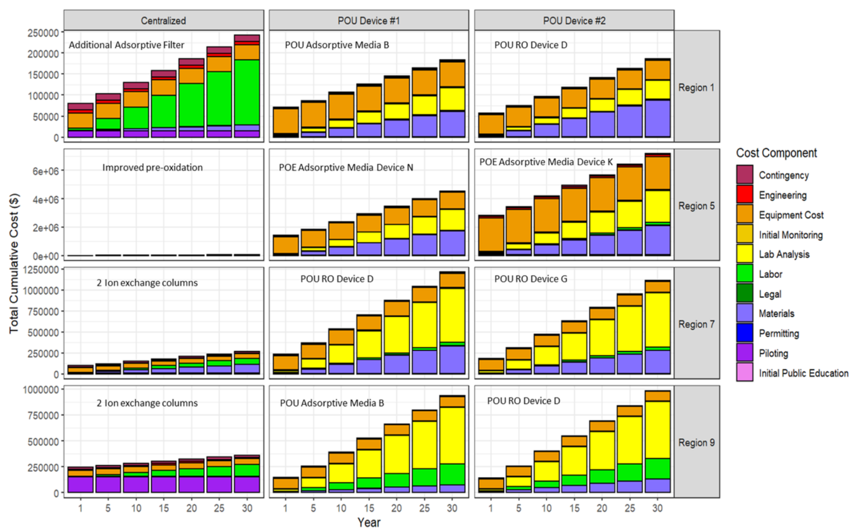


Figure 5.8: Summary of cumulative cost over time for each selected alternative to highlight differences in initial costs to a CWS compared to long term costs.

5.2.3 Cost Sensitivity Results

We conducted a cost sensitivity analysis for each technology option. For illustrative purposes, we present the individual analyses as well as a comparison figure to show the relative increase in cost in total dollars over 30 years for Region 1. For Regions 5, 7 and 9, only the comparison figure is shown in the text for Regions 5, 7 and 9, with full analyses in Appendix E. The cost sensitivity analysis focused on planning costs, the frequency of component replacements, labor costs, and specifically for POU/POE devices, the laboratory sampling costs. The y-axis of the following graphs shows an increase in a specific cost as a percent (either 25% or 50% increase). Because equations for cost are linear, an increase of 25% or 50% results in a change in total dollars of the same magnitude as a decrease by the same percentage. As a result, results are presented as an increase in cost; however, the cost savings for each scenario are the same if a decrease in cost where applied.

5.2.3.1 Region 1 cost sensitivity analysis results

In Region 1, centralized cost estimates were most susceptible to changes in labor costs. If the labor costs were increased by 50% (more hours worked), over 30 years, this can increase the total cost to the community water system by more than $100,000 (Figure 5.8). In the centralized treatment option assumptions retrieved from the EPA Cost Models, the number of hours worked per year was used to analyze sensitivity while keeping the wage the same. Because centralized treatment requires more hours per year of maintenance and labor, the total cost increases when the time to complete operational and maintenance activities increases.

If the frequency of replacements is increased (decreasing the useful life of a component) by 50%, in Region 1 over 30-years, the total cost can increase by as much as $60,000 for the community. A combination of increasing labor costs by 25% and replacement costs by 25% can increase the total cost by as much as $75,000 for centralized treatment. The assumptions made about the time to complete maintenance (labor) and the frequency of replacement components can have a large impact on the total cost to a community over a 30-year period (Figure 5.8). In Region 1, replacing the centralized GFH adsorptive filter media every 7-10 years generated a total cost per household over 30 years less than the total cost for either POU. However, if the filter media needed to be replaced more frequently, requiring more labor, the total cost would increase to $75,000 over 30 years, which is approximately $3,125 additional for each home over 30 years.

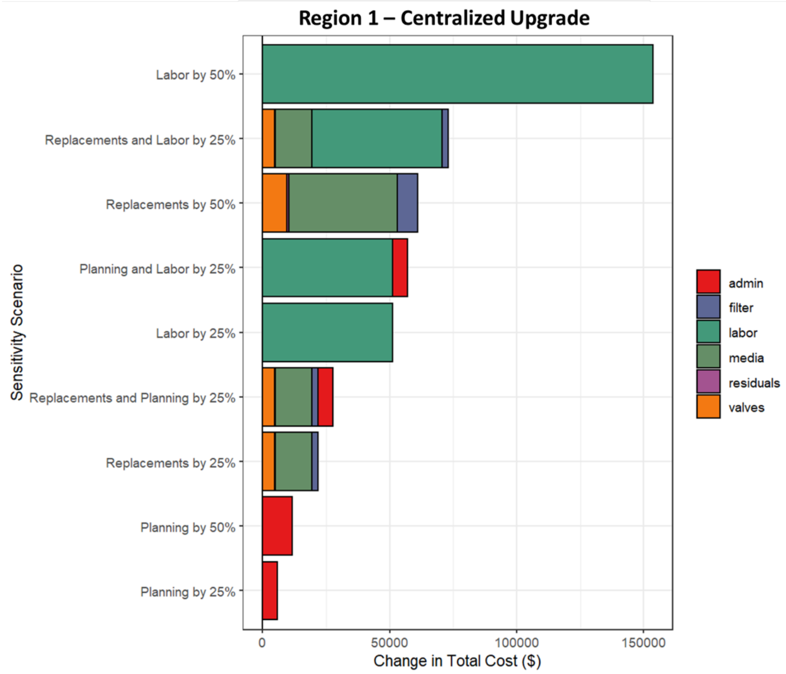


Figure 5.9: Cost sensitivity analysis results for centralized treatment in Region 1

In contrast, the cost sensitivity analysis results for the POU AM device and POU RO device show that for both POU devices, a change in the total planning costs (contingency, permitting, piloting, engineering and legal costs) generates the largest increase in the total cost over 30 years (Figures 5.10 and 5.11). For the POU AM device, an increase in the planning costs of 50% results in a total cost increase of approximately $3,300, which equates to an additional cost per household of $138 over 30 years. For the POU RO device, an increase in the planning costs of 50% results in a total cost increase of approximately $3,100 dollars which equates to an additional $129 per household over 30 years.

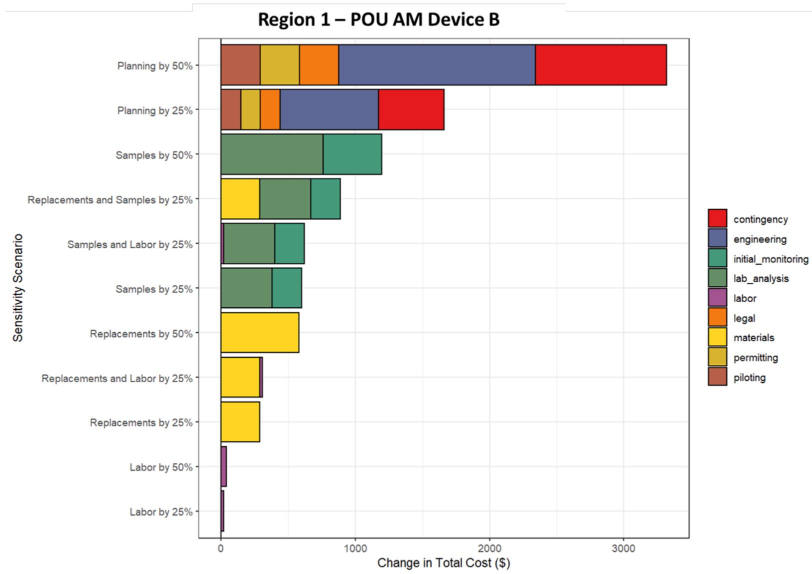


Figure 5.10: Cost sensitivity results for POU AM Device B in Region 1

For the POU AM device, an increase in the sampling cost by 50% results in an increase in the total cost of $1,200 (or $50 per household) over 30 years, largely driven by both lab analysis costs and additional initial monitoring costs. Similarly, an increase in the frequency of replacement by 50% results in an increase in the total cost of approximately $600 (or $25 per household) over 30 years (Figure 5.10). For the POU RO device, a 50% increase in the sampling cost increases the total cost by $1,200 (or $50 per household) over 30 years. A 50% increase in the replacement frequency results in an increase in the total cost of $1,400 (or $58 dollars per home) over 30 years (Figure 5.11). For the POU RO, the total cost is more sensitive to the change in replacement frequency because there are more components needing replacement. While the POU AM is designed to only need replacement of the adsorptive media component itself, the POU RO requires replacement of pre-filters, post-filters and the membrane itself. We hypothesize this is one reason the total cost for the RO device is more sensitive to an increase in the replacement frequency compared to the AM device.

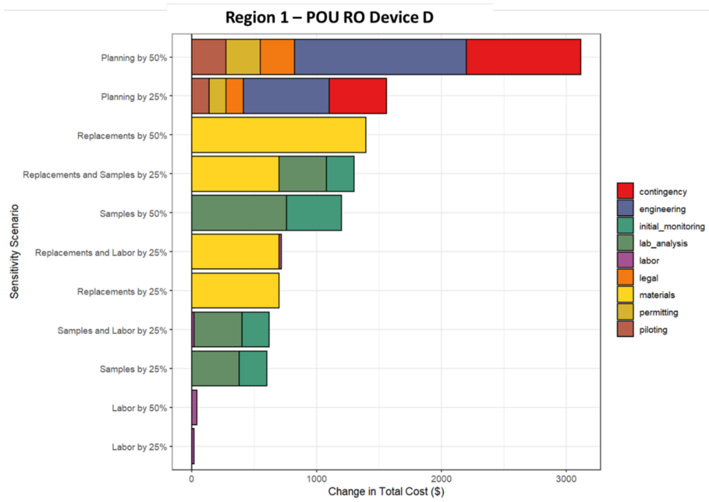


Figure 5.11: Cost sensitivity analysis for POU RO Device D in Region 1.

The increase in total cost in the centralized treatment is at least one order of magnitude greater than the increase in cost in the POU devices (Figure 5.12). POU device components are less expensive than centralized treatment components and, while these components need to be replaced at several locations, the cost is still an order of magnitude smaller than replacing components in the centralized system. In addition, the centralized treatment system cost is highly sensitive to changes in labor costs; POU devices do not experience this sensitivity due to the small number of hours allotted to O&M per year in our modeling assumptions (1-5 hours per year per home). The labor variable was changed by increasing the number of hours spent on operational activities. As a result, in the POU model, the number of hours spent on O&M increased to 1.5-7.5 hours with a 50% increase. Conversely, in the central systems, 127 hours of operator labor were allotted from the EPA Cost model; an increase of 50% resulted in 191 hours of labor at the same rate, causing the substantial increase in the total cost. Therefore, one possible advantage of POU devices may be the decrease in total labor costs over time compared to central treatment.

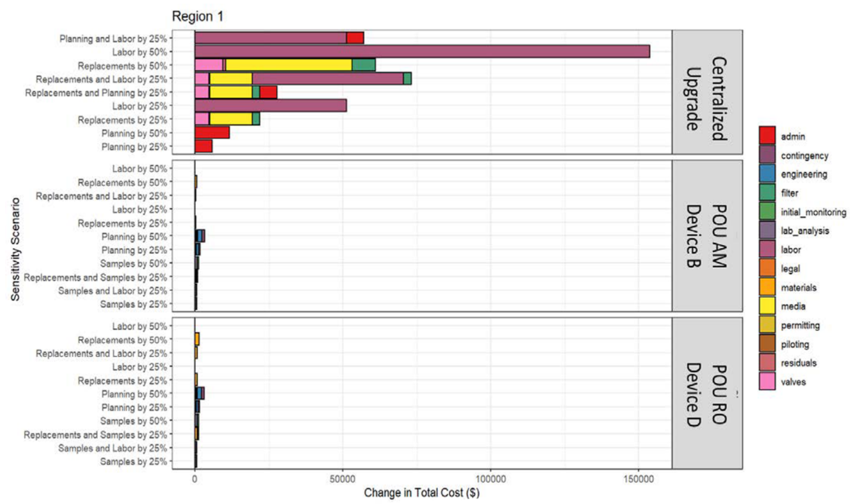


Figure 5.12: Full comparison of cost sensitivity analysis for Region 1.

5.2.3.2 Region 5 cost sensitivity analysis results

In Region 5, centralized treatment costs were most susceptible to changes in labor, similar to the findings in Region 1. In Region 5, centralized treatment costs consisted primarily of PVC piping and a cast iron pump; therefore, the total cost was not sensitive to increases in replacement frequency, as most of the components have a 17-year useful life. An increase in labor costs by 50% increases the total cost of centralized treatment by as much as $2,000,000 over 30 years, corresponding to an additional $9,050 per household. Even with this increase in per household cost, the total cost per household over 30 years of centralized treatment is still less than the total cost associated with either POE unit (a total cost of O&M $9,348 for centralized compared to $10,496-$16,467 for the POE units).

In comparison, for both POE units, the total cost is most sensitive to changes in planning costs, partly because planning costs are a percentage of the total direct cost. For POE Device N, an increase in planning costs of 50% resulted in an increase in the total cost of approximately $65,000 over 30 years (or $294 per household), while this was $140,000 for POE Device K. For both POE devices, the total cost was also sensitive to an increase in replacement cost but less so to changes in sampling cost and labor costs. For POE Device N, an increase in the replacement frequency and cost by 50% would result in an increase in the total cost of approximately $30,000 over 30 years (or $136 per household), while the same increase for POE Device K, would result in an increase in the total cost of approximately $35,000 over 30 years (or $158 per household).

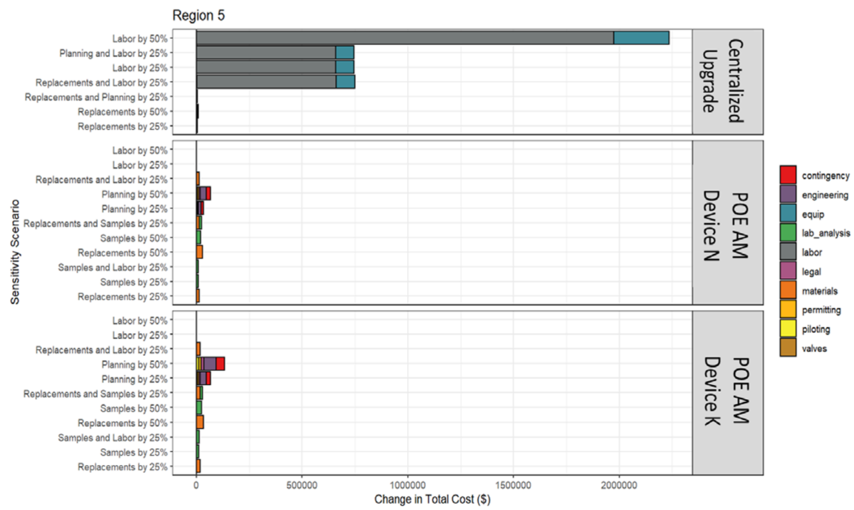


Figure 5.13: Summary of the cost sensitivity results from Region 5.

As in Region 1, the centralized improvement was most sensitive to increases in labor costs, resulting in an increase in the total cost two orders of magnitude greater than the increases in total cost for both POE devices (Figure 5.13). While the centralized improvement is most sensitive to changes in labor costs, the POEs were most sensitive to changes in both planning and replacement costs (see Appendix E for detailed cost sensitivity results).

5.2.3.3 Region 7 cost sensitivity analysis results

In Region 7, centralized costs were most sensitive to changes in the replacement of the ion exchange resin (Figure 5.13). Increasing the replacement frequency by 50% would increase the total cost over 30 years by approximately $100,000 (or $1,300 per household). An increase in the centralized system planning costs by 50% results in an increase in cost of approximately $50,000 (or $667 per household). Centralized system costs were least sensitive to changes in labor costs, which notably differs from Region 1 and 5. In Region 7, the centralized treatment system is a full new facility, whereas in Region 1 and 5, the improvement is a small addition to the existing system. As a result, in Region 7, we see the replacements of not only the ion exchange resin, but also from chlorination disinfection chemicals as well, has a larger impact on the total cost over time.

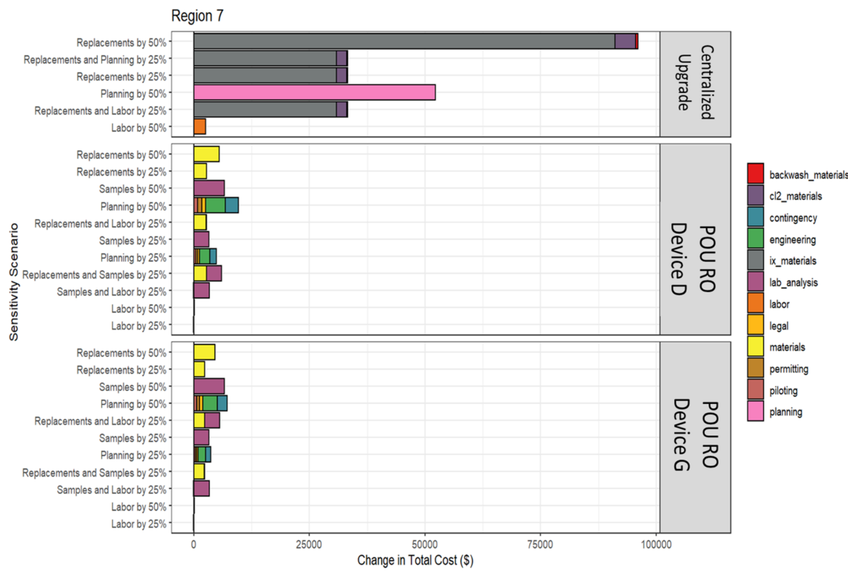


Figure 5.14: Summary of the cost sensitivity results from Region 7.

For both POU RO devices, each device is most sensitive to changes in the total planning costs, which are driven in part by the equipment cost. For POU RO Device D, a 50% increase in the total planning costs would result in an increase of approximately $10,000 over 30 years (or $133 per household), while for the same increase, for POU RO Device G, would be an additional $7,000 over 30 years (or $93 per household). Both RO devices are also susceptible to changes in sampling frequency as well. In Region 7, because the contaminant of concern is nitrate, the sampling frequency for compliance cannot be reduced over time since nitrate has acute health impacts on infants. As a result, an increase in sampling frequency of 25% would lead to an increase of approximately $6,500 for both POUs ($87 per household). Neither RO device was sensitive to changes in labor costs. Increasing the frequency of replacements resulted in an increase of approximately $5,500 for POU RO Device D ($73 per household) and approximately $4,500 for POU RO Device K ($60 per household).

5.2.3.4 Region 9 cost sensitivity analysis results

In Region 9, centralized cost was most sensitive to the frequency of replacement (Figure 5.15). If replacement frequency were to experience a 50% increase, the centralized costs would increase by approximately $170,000 (or $5,862 per household). Similar to Region 7, the centralized treatment improvement is a new ion exchange facility, including an evaporative pond. Full replacement of the ion exchange media must occur more frequently than replacement of the adsorptive media in Region 1, and two vessels with resin are required in the basic ion exchange system (USEPA, 2017b). The centralized treatment improvement is also sensitive to changes in labor. An increase of 50% to the total hours of labor worked in Region 9 results in an increase of approximately $120,000 (or $4,138 per household).

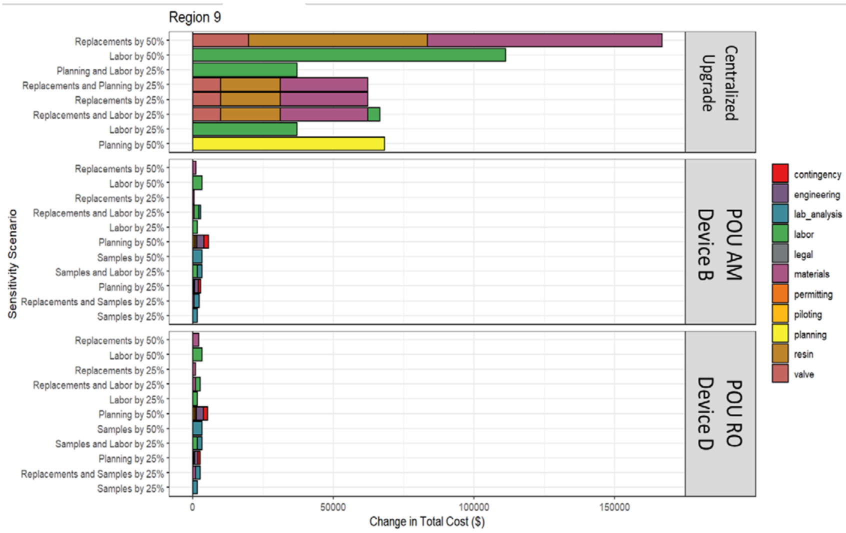


Figure 5.15: Summary of the cost sensitivity results from Region 9.

Both POU devices in Region 9 were most sensitive to changes in planning costs: an increase in the total planning costs for the POU AM or in the POU RO would increase costs by approximately $5,500 over 30 years (or $190 per household). Both devices are approximately equally sensitive to changes in sampling and labor; notably, in this region, both the number of hours spent on O&M activities and the labor age were the highest of all four regions, accounting in part for the greater sensitivity to changes in labor costs. A 50% increase in either the sampling costs or the sampling frequency yielded an increase in total cost of approximately $3,000 for either device ($103 per household). The POU costs were more sensitive to costs related to POU operation and compliance than to the specific device, as the total cost was least sensitive to changes in the replacement cost over 30 years.

5.2.4 Best- and Worst-Case Cost Scenarios

The assumptions found through a literature search are presents in Table 5.8. Where values could not be found in literature, we selected the lowest value across the CWS assumptions found through stakeholder conversations to represent the best-case scenario. Similarly, we selected the highest value across all four case study CWSs for the worst-case scenario. Using this method, the best-case scenario may increase costs of some elements while decreasing costs of others compared to the specific CWS assumptions since values were derived primarily from literature. For example, sampling frequency after the first year may be reduced to a fraction of the total number of households in a community depending upon the state: we found that some states allow the community water system to reduce sampling frequency to a third of the total homes over time (best-case scenario). However, some states require the CWS to continue to sample 100% of the households after the first year (worst-case scenario), such as in New Hampshire. Therefore, when modeled with the best-case assumptions, the cost of sampling decreases, while the worst-case model in New Hampshire shows results similar to the model run with the NH assumptions, with the only increases resulting from increases in the wages paid to operators.

Table 5.8: Assumptions for best-case and worst-case cost modeling. Assumptions are primarily based on values found in past literature studies.

Sub-Section	Parameter	Units	Default Value in EPA Model	Best Case	Worst Case
Equipment Costs	Unit cost of POU/POE without installation	$/unit	$560.92	$150	$700
	Unit cost of UV system	$/unit		$0	
	Wage rate for installation specialist (plumber/electrician)	$/hour	$33.12	$25	$40
	Wage rate for system technical and maintenance labor	$/hour	$25.07	$25	$30
	Wage rate for scheduling and administrative labor	$/hour	$17.89	$10	$20
	POU/POE installation time	Hours/household	2	1	5
	POU/POE installation scheduling time	Hours/household	0.5	0.5	1
	UV installation time	Hours/household		0	
Technical Labor to Support Educational Program	Develop technical education materials	Total hours	10	0.5	10
	Develop nitrate health impact information	Total hours			

	Prepare for and attend public meetings	Total hours	2	1	2
	Post-meeting stakeholder communication	Total hours	2	0.5	2
Clerical Labor to Support Educational Program	Prepare educational materials for distribution	Total hours	6	0.5	6
	Prepare nitrate health impact information for distribution	Total hours			
	Prepare for and attend public meetings	Total hours	2	1	2
	Prepare post-meeting materials for distribution	Total hours	2	0.5	2
Communication for Materials for Educational Program	Print flyers announcing public meetings	Flyers	10	0	10
	Cost per flyer for printing	$/flyer	$2.00	0	$2.00
	Buy ads to announce public meetings	Ads		0	
	Cost per meeting ad	$/ad	$40	0	$40
	Print nitrate health impact flyers	Flyers		0	
	Print handouts for meetings	Pages/household	3/house	0	3/house
	Print inserts for billing mailers	Pages/household	1/house	0	1/house
	Cost to print handouts and mailers	$/page	$0.08	0	$0.08
Initial Monitoring Costs	Time to take sample during first year	Hours/sample	0.25	0.25	0.5
	Time to schedule sample event at household	Hours/sample	0	0.25	3
	Number of samples per household during the first year	Samples/household	1	1	2
	Fraction of households sampled during the first year	% households	100	100%	100%
	Laboratory analysis fee	$/sample	$25.75 (arsenic) / $24.25 (nitrate)	$15	$30
	Sample shipping cost (bulk)	$/bulk shipment	$9 for 15 samples	$15	$15
Indirect Capital Costs	Cost to obtain operating permit	$/% of installed equipment cost	3	3%	3%
	Cost to conduct pilot study	$/% of installed equipment cost	3	3%	5%
	Cost for legal activities	$/% of installed equipment cost	3	3%	3%
	Cost for engineering activities (device selection)	$/% of installed equipment cost	15	15%	15%
	Contingency cost (unknown factors)	$/% of installed equipment cost	10	10%	10%

Equipment Maintenance Labor Costs	POU/POE maintenance	Hours/visit	0.5	0.25	2
	POU/POE replacement frequency	Visits/household/year	1	1	4
	*UV maintenance	Hours/visit	0	0	
	*UV maintenance frequency	Visits/household/year	0	0	
	Scheduling time	Hours/visit	0.5	0.25	0.75
Annual Monitoring Costs	Sampling time (including travel)	Hrs./sample		0.25	1.5
	Sampling scheduling time	Hrs./sample		0	0.25
	Analysis frequency (samples)	Samples/household/year		1	2
	Analysis frequency (Percent)	% households/year		33.3%	100%

Overall, for all of the POU/POE devices modeled, the total cost calculated with the best-case scenario assumptions was smaller than the total cost calculated with the CWS specific assumptions (Figure 5.16). Lab analysis shows the greatest decrease in cost over 30 years with the best-case scenario resulting from decreasing the fraction of houses sampled after year one. In Region 1, lab analysis cost would decrease by $1,000 over 30 years ($42 per household) compared to the New Hampshire cost model assumptions, while in Region 5, lab analysis costs would decrease by over $50,000 ($226 per household over 30 years).

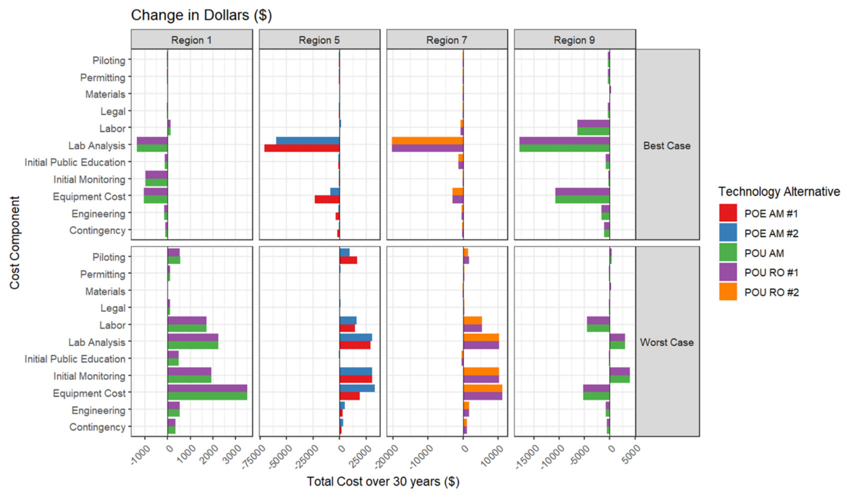


Figure 5.16: Summary of best-case and worst-case cost sensitivity results in all four CWSs. The x-axis represents the change in the total cost over 30 years: a positive number indicates an increase in total cost and a negative number indicates a decrease in total cost.

Modeling total cost with the worst-case assumptions generates notable differences between each CWS. In New Hampshire (Region 1), all of the cost components with the exception of materials would increase under the worst-case assumptions found in literature compared to the CWS-specific assumptions for New Hampshire. Materials costs do not increase or decrease because these are device specific, and the results presented in Figure 5.16 assume the devices and component costs are dependent on the manufacturer-specified cost for a specific device. The same increase in cost compared to the CWS specific assumptions occurs in Region 5 and 9, although the increase in cost varies and decreases for some cost components in Region 7. For example, the equipment cost increases based on the number of households: in Region 1, the total cost over 30 years increases by approximately $3,500, in Region 5 by approximately $25,000, in Region 7 by approximately $10,000. In Region 9, the equipment cost decreases by approximately $5,000 in the worst-case scenario because the worst-case scenario assumptions are smaller than in Region 9.

In addition to the best/worst-case analysis, we also specifically examined a longer useful life for the RO membrane component of POU Device D. Through conversations with additional device manufacturers, we learned that newer RO devices have a membrane that last up to 10 years compared to the 3–5-year lifetime identified for the specific devices selected in this study. If the useful life of an RO membrane is increased to 10 years (3 full replacements over 30 years), then for POU Device D, the total materials cost decreases in Regions 1, 7 and 9 compared to the materials cost found with a useful life of 3 years. The materials costs decreased by $392 ($16 per household) in Region 1, by $1,225 ($16 per household) in Region 7, and by $617 ($21 per household) in Region 9 over 30 years.

5.2.5 Summary of cost analysis results

Table 5.8 summarizes the alternative technologies by categorizing the lowest cost per household over 30 years as the best option for a CWS (3 for the lowest cost option, 1 for the highest cost). In three of four CWSs, the total cost per household over 30 years is the lowest for the centralized treatment improvement. Of the POU RO units, in Regions 1 and 9, the RO unit has a higher cost over time than the adsorptive media units, driven in part by more components needing frequent replacement in all households in the community. In Region 5, POE Device K is more expensive, driven by a shorter useful life of the media and a higher equipment cost in comparison to POE Device K. In Region 7, POU RO device G is less expensive than POU RO Device D, most likely from a slightly lower equipment cost; the frequency of replacement components was the same for both devices.

Table 5.8: Summary of best cost options for each CWS.

Region	Technology	Total Cost per household over 30 years ($) **3 = Best Option, 2 = 2nd Best Option, 1 = 3rd Best Option**
1	Centralized Upgrade	1
	POU AM Device B	3
	POU RO Device	2
5	Centralized Upgrade	3
	POEAM Device N	2
	POE AM Device K	1
7	Centralized Upgrade	3
	POU RO Device D	1
	POU RO Device G	2
9	Centralized Upgrade	3
	POU AM Device B	2
	POU RO Device D	1

6 – Triple Bottom Line Approach Summary

6.1 CWS and Device Selection

Four CWS were selected as case studies using data from both the SDWIS database and information from state-level stakeholders in each EPA region selected. In Region 1, we selected a CWS serving 50 people in New Hampshire currently using adsorptive media filtration to treat arsenic, with a mean arsenic concentration of 8.3 µg/L in groundwater. In Region 5, we selected a CWS serving 450 people in Illinois currently using aeration and pressure sand filtration to co-precipitate iron and arsenic with a mean arsenic concentration of 21.6 µg/L in a series of ground water wells. In Region 7 we selected a CWS serving 150 people in Nebraska, currently distributing water from a wellhead with a mean nitrate concentration of 9.3 mg/L in groundwater wells. Finally, in Region 9, we selected a CWS serving approximately 50 people in California, with an inactive adsorptive media filtration treatment facility and both arsenic and uranium contamination in two groundwater wells.

In Region 1, we chose two POU devices, one certified to NSF/ANSI 53 (adsorptive media) and one certified to NSF/ANSI 58 (reverse osmosis) for arsenic removal. We identified a potentially viable centralized treatment upgrade as installation of a second adsorptive media filter unit to treat the full flow from both groundwater well heads with a specific arsenic removal filter media. In Region 5, we chose two POE devices (since only POE devices may be used for long-term compliance in Illinois), one certified to NSF/ANSI 53 and one with a media designed to remove arsenic and certified to NSF/ANSI 61. For the centralized alternative, we elected to optimize pre-oxidation of arsenic from As (III) to As (V) using pre-chlorination prior to pressure sand filtration. In Region 7, we selected two devices certified to NSF/ANSI 58 (reverse osmosis) for nitrate-nitrite removal. We chose ion exchange with a nitrate selective resin as the centralized treatment improvement in Region 7. Finally, In Region 9, we selected the same two POU devices as in Region 1 for arsenic removal and, for the centralized treatment system improvement, we chose anion exchange with a strong base polyacrylic resin as the CWS improvement.

6.2 Triple Bottom Line Approach results

Table 6.1 presents the summary results for the triple bottom line approach for each of the three treatment options in each CWS. We scored each option from 1-3, with 3 as the 'best' for each analysis. For exposure assessment, the best score was given to the option that minimized lifetime exposure to a person within each community, measured as the decrease in average daily contaminant dose from the expected exposure with no intervention. For the LCA, the best score was given to the option with the smallest relative overall impact in comparison to the other options. For the LCC, the best score was given to the option with the lowest total per household cost over the 30-year study period. The scores were then added up to generate an aggregate score for each alternative considered for the CWS.

While an aggregate score was used to make a judgement about the "best" alternative for each CWS, each analysis should be considered separately to avoid obscuring important results. For example, while a centralized treatment improvement device may score highly for cost, the contaminant exposure a

CWS population is exposed to may be deemed unacceptable by a CWS and therefore, regardless of the sustainability or cost of the alternative, be unacceptable. Similarly, if the cost of an alternative is so high that a community cannot finance the treatment option, the alternative may be unacceptable even if the sustainability of the device is preferred and exposure is reduced to an acceptable level. In the following discussion of each CWS, we use this aggregate score as a starting point only to examine which alternative may be the best option for a CWS.

Table 6.1: Summary of the triple bottom line results for each CWS

Region	Technology	Metric			TOTAL
		Decrease in contaminant exposure (ug/kg/day)	LCA	Total Cost per household over 30 years ($)	
		3 = Best Option, 2 = 2nd Best Option, 1 = 3rd Best Option			
1	Centralized Upgrade	1	1	1	3
	POU AM Device B	3	2	3	8
	POU RO Device D	2	3	2	7
5	Centralized Upgrade	1	3	3	7
	POE AM Device N	2	2	2	6
	POE AM Device K	3	1	1	5
7	Centralized Upgrade	3	1	3	7
	POU RO Device D	2	2	1	5
	POU RO Device G	1	3	2	6

9	Centralized Upgrade	1	1	3	5
	POU AM Device B	3	2	2	7
	POU RO Device D	2	3	1	6

6.2.1 Region 1

In Region 1, no treatment option scored highest across all analyses, but centralized treatment scored lowest across all analyses. The POU Device B (AM) provided the largest reduction in contaminant exposure over the 30-year period due to its high removal efficiency of 99%, however, it had a larger relative environmental impact than POU Device D (RO device) due to the disposal and processing of both the adsorptive media and the stainless-steel housing. While POU Device D was considered the most sustainable alternative, it was also the most costly, driven by the frequent replacement of RO membranes, pre-filters and post-filters. The POU AM Device B treatment option had the lowest per household cost over the 30-year period because of its low material and equipment costs compared to the RO device and an enabling environment in New Hampshire that optimizes the labor cost for maintenance of devices in a CWS. The centralized treatment improvement, was the least sustainable, resulting from the mass of adsorptive media necessary in the system. Because the LCA impact assessment is based on the amount (in kg) of material needed in each device, both of the POU devices would have a lower impact. The centralized treatment alternative is also the least effective at removing arsenic based on a literature removal efficiency of 80%, resulting in a decrease in exposure that is below the 30-year cumulative NOAEL value but does not meet the same reduction in exposure as the POU devices. Despite the cost benefits of the centralized treatment upgrade, the alternative is ranked lowest among the three alternatives. POU Device B (AM) provides the best removal of the contaminant and is a compromise between the two POU options in terms of sustainability and cost.

In Region 1, the smaller population in the community is one factor that makes it easier to justify the selection of a POU device over centralized treatment. There are only 24 households in this CWS, so the O&M costs for the POU devices is not much lower than for the centralized treatment upgrade, particularly because the centralized treatment improvement also contains an adsorptive media component which increases the cost along with the environmental impact. The lab analysis costs with POUs also contributes to the overall costs of POUs: as a reminder, in this state, 100% of the homes must be sampled for compliance in the first year and in subsequent years.

6.2.2 Region 5

In Region 5, the nature of the centralized improvement and the use of POE devices as opposed to POU devices drives the results (Table 6.1). Similar to Region 1 results, both POE devices have a higher removal efficiency for pentavalent arsenic than the centralized treatment upgrade. POE Device N has a removal rate of 97%, leading to the largest reduction in contaminant exposure, resulting in the highest ranking. However, this device is the most expensive over the 30-year study period and has the largest environmental impact, resulting in the lowest ranking among the three alternatives. Both POE devices have a larger environmental impact than the centralized system because of the large amount of adsorptive media to frequently replace compared to the relatively small amount of piping and pumping components necessary for the centralized pre-oxidation system.

Of the three options, the centralized is both the lowest cost alternative and lowest environmental impact. The centralized improvement consisted primarily of PVC piping and cast-iron pumping components, both which have 15–25-year lifetimes and do not need frequent replacements within the 30-year period. The larger useful life of centralized components compared to POU/POE devices results in a lower overall O&M cost. In addition, the centralized improvement did not contain components that have a large environmental impact in any phase of the life cycle (materials, processing, etc.) compared to the adsorptive media found in the POE devices.

The large difference in cost and environmental impact between the centralized treatment system and the POE devices stems from community-specific characteristics. In Illinois, only POE devices are allowed for SDWA compliance, and few examples of successful POE installations were available for reference. POE units are generally more expensive than POU units, require more maintenance and more frequent component replacement. Also, the larger population size of the community (221 people) means the cost of supplying and maintaining POE units in Region 5 is much higher than altering the existing treatment system. In addition, the centralized treatment system already had capacity to remove arsenic; the primary concern was bringing the arsenic levels below the MCL consistently. Based on conversations with the operators and managers, no past speciation of arsenic had been completed so there was no data to determine whether the current treatment system was only removing As (V) and not As (III); we assumed that the centralized system in place pre-intervention was only effectively removing As (V) and therefore pre-oxidation was a logical improvement for the system.

6.2.3 Region 7

In Region 7, the centralized treatment improvement provided the largest decrease in nitrate exposure over 30 years, since the centralized ion exchange system had a literature value removal efficiency of 90% which was larger than the removal efficiency for either of the POU RO devices. Choosing an option that removes as much nitrate as possible is a benefit since it is well documented that nitrate can have deleterious health effects on infants. The centralized treatment improvement also had the lowest cost over the 30-year study period when compared to either POU RO Device. Despite the need to replace the ion exchange resin in the centralized improvement, the useful life of the resin column is estimated at 10 years, longer than any of the POU RO components identified for the two devices in this study. Furthermore, the ion exchange resin only has to be replaced at one location whereas the RO devices would need to be replaced in 75 households over time.

However, the centralized treatment upgrade had the worst environmental impact when the impacts were normalized amongst the three alternatives, resulting from the ion resin, including obtaining and processing the material and disposing the material to a landfill. In comparison, POU RO Device G has the lowest environmental impact of the three alternatives, driven by fewer components to replace over time compared to POU RO Device D. Device G was also more affordable. In Region 7, the centralized treatment improvement therefore provided the lowest cost option and the largest reduction in contaminant exposure, with a tradeoff associated with the centralized improvement in its larger environmental impact compared to the POU RO devices.

6.2.4 Region 9

In Region 9, POU Device B (AM) removed 99% of the arsenic in the system, resulting in the largest contaminant exposure decrease. However, due to arsenic concentrations above 30 ug/L in the source water, the 99% removal efficiency is not removing as much arsenic in California as was seen in Region 1. Even with the highest removal efficiency from POU Device B (99%), the cumulative average daily dose of arsenic would exceed the cumulative 30-year NOAEL within the 30-year timeframe because of the implementation timeframe. As a result, none of the options considered adequately remove sufficient arsenic, although we assigned ranking for consistency. It is likely that an additional improvement to the system will need to be made to ensure that arsenic is removed from the drinking water.

While POU Device B provided the largest decrease in contaminant exposure compared to no intervention, it was ranked second in both environmental impact and cost. The centralized treatment cost over 30 years is smallest compared to either POU device, despite the addition of a new treatment facility and an evaporative pond onsite for brine disposal. While the initial capital cost of the centralized treatment facility is more than the POU devices, the total cost over time is less because the O&J costs of the POU devices are influenced by the replacement frequency of device components in multiple households over time. Therefore, in Region 9, the POU AM ranks the highest. While the centralized improvement is the least cost option over 30 years, it lacks the ability to adequately remove arsenic and decrease exposure as well as having a large environmental impact due to the ion exchange resin transportation and disposal. Compared to the POU RO device D, POU AM Device B has a higher contaminant removal efficiency but a higher environmental impact. While POU Device B is ranked highest among all three options, aggregating the results into a single metric obscure some of the nuances of each alternative. In Region 9, the decision between which alternative to select will depend on CWS finances and preferences. If the sampling cost could be reduced over time, this could reduce the POU device cost further and make either device more comparable to the cost of centralized treatment.

POU Device G has the smallest environmental impact of the three alternatives, followed by POU Device B. The centralized treatment improvement has the largest overall environmental impact due to the large amount of anionic resin that needs to be processed, transported, and disposed of. In addition, in Region 9, the community is geographically remote, located more than 100 km from the nearest landfill, resulting in a higher environmental impact associated with both disposal of the centralized system components and the transportation impacts of moving components from the centralized treatment facility to the landfill.

7 – Considerations and Recommendations for POU/POE devices as a SDWA compliance strategy

Through this study, we identified several important considerations and assumptions related to the use of POU/POE devices as a compliance strategy in small CWSs. These include system and policy barriers, which constitute challenges to POU/POE implementation found at a regulatory or state level, and technical barriers, which constitute challenges to the long-term health, environmental, and cost impacts of POU/POE devices. Finally, we discuss specific assumptions used in our model that are subject to change based on CWS characteristics. We present these categories below in detail, as well as recommendations for different stakeholder groups involved in the process (state administrators, CWS stakeholders, and device manufacturers).

7.1 Systemic and Policy-Level Barriers

Our case study revealed several systemic or policy-level barriers that influence the feasibility and advantages of implementing POU/POE devices as a compliance strategy. First, using POU/POE devices as a SDWA compliance strategy is governed by what types of devices are allowed for treating specific contaminants in each state. For example, in Illinois, only POE devices are allowed for long-term SDWA compliance and have only been applied previously for radionuclides in specific conditions; had had POUs been an option as a compliance strategy, the total cost per household over 30 years would have likely been much smaller than our case study findings for the two POE devices. According the USEPA guidance document on POU/POE devices, a survey of states by the Association of State Drinking Water Administrators showed that there are states where POU/POE devices are not allowed as a compliance strategy and other states where no guidance currently exists on POU/POE for compliance (USEPA, 2006b). Over the course of this study, we shifted our focus from Region 6 to Region 7 to select a case study community in part because we could not locate a state where POU/POE devices would be allowed as a compliance strategy.

Among the model assumptions we explored, we found that the frequency and number of samples necessary to ensure POU/POE performance for compliance can be a driving factor in the cost to implement POU/POE units long-term. While all states we worked with required sampling of 100% of the samples in the first year of POU/POE device operation per USEPA guidance (USEPA, 2006b), whether a state can reduce sampling requirements (and therefore lab analysis costs) is state- and contaminant-specific. A decrease in sampling frequency may be advantageous where POU/POE devices are performing to manufacturer specifications. However, water use in each home depends on the household water consumption patterns and decreasing the sampling frequency could obscure breakthrough of a contaminant in a specific location due to early failure of the device. As a result, state and CWS discretion and input is critical to determining if the additional cost of sampling outweighs the benefit of ensuring public health is protected.

Another potential barrier to POU/POE implementation is the time and energy required to ensure that all households have an equitable access to safe drinking water by ensuring 100% household participation. The USEPA requirement of 100% CWS participation is critical to protecting consumers from contaminated water; one homeowner with a POU/POE device cannot receive water with lower concentrations of arsenic than a homeowner with no POU/POE device. However, from conversations with state administrators, it can take 2-10 years to come to a legal agreement across 100% of households in a CWS to implement POU/POE devices. In Illinois, the only past POE installation our state contacts knew of was in a small community where it took 7 years to organize the community prior to pilot testing. In New Hampshire, we conversed with a water systems where expensive legal agreements had to be put in place, including a clause in the homeowner's agreement to allow an operator to access POU/POE units inside of people's homes. In California, some communities have considered installing POU under-sink units on the outside of the homes for ease of maintenance but also to assuage homeowner concerns with having an operator inside their home when the homeowner is not present. While in many places, the majority community homeowners may be open to the idea of a POU/POE device, they have concerns about the logistics of maintaining the POU/POE device over time. As a result, we see a need to continue exploring options to ensure homeowners understand POU/POE device benefits and to streamline the community engagement component to gain 100% participation through a systematic approach that acknowledges community concerns while continuing to move the implementation timeline forward.

Part of the difficulty implementing POU/POE devices as a CWS stems from the challenge of finding certified POU/POE devices that can be sourced locally and have readily available replacement components, particularly for rural communities. Over the course of this study, we encountered the challenge both of narrowing down a list of over 150 POU RO devices and locating a second POE device certified to NSF 53. Certification can be costly to a company – including running water quality testing and maintaining certification – so we were only able to initially locate one POE device certified to NSF 53. We did find several POE devices with media certified to NSF 61 and individual manufacturer performance testing, but not a complete NSF/ANSI or WQA certification. As a result, we spent considerable time locating and verifying a second POE device that fit the certification criteria used in this study. A small CWS water system will also encounter these concerns when searching for devices and do not have the benefit of a guiding taskforce to help them locate devices. In addition, if a CWS wants to use a POU RO unit, the problem the CWS will face is narrowing down the list of potential devices to those that can be found at a reasonable price locally. Furthermore, when we examined the list of potential POU RO devices available for pentavalent arsenic removal, we found it difficult to translate the information present on WQA, NSF International, and IAPMO listings to a device on the manufacturer and distributor websites. While it was easy to locate device information for some products, other product websites listed device model numbers different than the NSF International or WQA website; if we found the product on the website, sometimes it was unavailable through the local distributor and had to be sourced from another distribution or a location across the country.

Furthermore, POU/POE devices are certified for removal of specific contaminants while CWSs are responsible for providing water with acceptably low concentrations of all contaminants regulated by the SDWA. A POU/POE device may be certified to remove more than one contaminant; however, using a POU/POE device for SDWA compliance typically focuses on one contaminant at a time. For example, in Region 5, past MCL violations of the arsenic MCL necessitate a solution to specifically remove arsenic from the system. While the POE may in practice remove multiple contaminants, the context around its implementation and monitoring was focused only on removal of and compliance with the specific contaminant. Therefore, it cannot be used to replace centralized treatment because of the need to meet MCLs for other contaminants.; the designed compliance strategy is designed so centralized treatment and the POE device work in tandem to ensure SDWA compliance. In this case, centralized treatment is allowing the system to meet all other relevant SDWA water quality regulations and the POE device focuses specifically on arsenic. However, implementation of POUs/POEs to meet multiple SDWA compliance objectives is an interesting, but unexplored, option.

7.2 Technical Barriers

Our case study results revealed the importance of the number of households served by a CWS when considering POU/POE implementations. In the two larger CWSs in Region 7 and Region 9, the centralized treatment option was favorable overall partly because replacing POU/POE components at multiple households over time generated a higher cost O&M than the centralized option. Because POU/POE components such a RO membranes, pre-filters, and post-filters, and POE adsorptive media every 3-10 years, there is a large cost associated with replacing components in every household over the 30-year study period. For example, in Region 5 we observed that the replacement of the adsorptive GFH media in either POE unit was a significant component of the overall per household cost because the media needed to be replaced every 7-10 years in 221 households. In contrast, in Region 1, the difference in total cost between the centralized improvement and the POU devices was approximately $5,000-6,000 over 30 years, compared to a difference in total cost of $21,000-24,000 in Region 5 between centralized and POE devices. Because Region 1 only has 24 households, the cost of replacement materials is smaller than in the other three regions, narrowing the total cost difference between the centralized option and the POU devices. While Region 9 has a similar number of homes to Region 1, the difference in cost is larger due to the larger labor and lab analysis costs. The disposal and replacement of multiple components in POU/POE units are therefore a key driver of the total O&M cost over time and impact CWSs differently. Making devices more durable by increasing the useful life and decreasing replacement cost is one potential solution to ensuring POU/POE device longevity and acceptability over time.

In addition to systemic concerns with POU/POE device piloting, there are technical barriers that can make piloting a lengthy and costly process, particularly for very small CWSs. Many of the small CWSs included in this study run a water treatment plant intermittently, with no continuous 24-hour water supply. Supply and operational hours of the treatment facility are governed by demand and storage availability. As a result, piloting POU/POE devices in each specific CWS with water use patterns is critical to understanding how POU/POE devices will function in the CWS. In addition, the water quality of each CWS varies. When consulting with POU/POE device manufacturers, we asked questions about CWS specific water quality to determine whether additional components would be necessary to ensure the POU/POE device functions according to performance claims. For example, for the POE AM Device N in Region 5, the manufacturer recommended an additional iron prefilter because the iron to arsenic ratio is 55:1. Piloting is therefore necessary to ensure that the POU/POE devices are properly configured to both the water demand and water quality present in each CWS.

7.3 Model Assumptions specific to CWSs

During this study, we conversed with four different states that each take a different approach to adopting and implementing POU/POE devices for small CWS SDWA compliance. We presented the assumptions we made for each of our analyses for both POU/POE and centralized treatment improvements and summarize the critical parameters that vary across states for future use of the triple bottom line approach.

For centralized treatment, we focused on components above and beyond current CWS operation to emphasize how the improvement would impact the system. For the four states we worked with, only Region 7 required additional water quality sampling for the centralized improvement. Because arsenic and nitrate sampling are already required by the SDWA, the frequency and number of samples taken would not increase with the centralized improvement. However, in Region 7, the addition of a chlorine disinfection system necessitated additional chlorine residual sampling in the distribution system that the CWS would have to pay for if the improvement was implemented. We identified these additional sampling requirements by consulting state specific treatment guidelines and monitoring programs. Additional sampling requirements for centralized treatment will be state specific; we therefore recommend CWSs work with state administrators to identify additional sampling costs.

In addition, centralized disposal of liquid waste streams such as brine from an ion exchange system, may be subject to state specific guidelines. We worked with state administrators in California to identify possible waste disposal scenarios for brine in the Region 9 CWS. The Region 9 CWS had a series of septic tanks onsite which are not considered an appropriate waste treatment method for ion exchange brine in California. As a result, state administrators suggested we add the construction and maintenance of an evaporative pond to the system as an evaporative pond would be the solution the state would ask the system to install if the centralized ion exchange facility was implemented. In addition, we also learned that some states allow POU RO reject water to be disposed of in a septic system in small communities where others do not. Therefore, waste disposal solutions for both centralized and POU/POE should be carefully considered to ensure appropriateness and to ensure that all system components are included in the alternative prior to analysis.

For POU/POE devices specifically, we noted several state specific guidelines or requirements that influence both the LCA and LCC analyses. First, while most states require sampling in 100% of the households in the first year of POU/POE operation, some states allow a CWS to reduce the percent of homes sampled per year based on the contaminant. For nitrate, no decrease in sampling frequency is recommended because nitrate is an acute contaminant for infants, but for arsenic, states such as California and Illinois have programs to reduce the number of samples over time. The percent of households sampled over time is critical to the overall lab analysis cost, which we noted was a large component of POU/POE total costs over 30 years.

In addition, the labor component of O&M activities for POU/POE devices varied between states. Labor costs changed based on both the wage paid to an operator and the amount of time spent on O&M activities. In Region 1, less than one hour was allotted for maintenance activities, while in Region 9, up to 4 hours was spent on device maintenance. As a result, the O&M costs between these two regions was noticeably different even though the CWSs had a similar number of households served. Since labor assumptions are state specific, we recommend CWSs consult with state administrators to develop O&M plans to ensure labor and maintenance costs are not underestimated.

Finally, for both centralized and POU/POE alternatives, the source water quality and specific contaminant of concern are both critical to the selection of an appropriate device or technology. USEPA guidance on POU/POE devices provides a list of the best available technologies that are considered appropriate for specific contaminants (USEPA, 2006b). POU/POE devices are listed by contaminant on the NSF International and WQA websites and, while there are multiple devices, we noted that not every technology type (ion exchange, RO, etc.) is certified to NSF/ANSI standards for a specific contaminant. As a result, choosing the technology type for a POU/POE application largely depends on the types of devices currently certified to NSF/ANSI standards, especially because USEPA guidance requires devices to be certified if they are being used for SDWA compliance (USEPA, 2006b).

For centralized treatment improvement options, we analyzed past water quality data and discussed operational concerns with state administrators and CWS stakeholders to identify appropriate technologies to evaluate. For example, in Region 5, our decision to examine pre-oxidation was driven by the water chemistry in the system: the iron to arsenic ratio is 55:1 and the amount of iron present in the groundwater makes technologies such as pre-oxidation preferable to adsorptive media technologies due to concerns of preferential removal of iron. Similarly, in Region 7, we identified ion exchange as an appropriate technology to remove nitrate because there were few competing ions such as sulfates in the ground water source. Furthermore, specific contaminant chemistry is also important to technology selection. For example, arsenic has two forms in water, and different technologies preferentially remove As (V) over As (III). Identifying the relevant water quality parameters to make an informed decision is key to selecting appropriate technologies.

7.4 Recommendations

In this section, we present specific recommendations for the different stakeholders involved in POU/POE implementation for SDWA compliance. We then provide recommendations and considerations for the use of the triple bottom line approach by water systems.

7.4.1. For CWS managers and stakeholders

For CWS stakeholders including managers, operators and homeowners interested in implementing POU/POEs for compliance, we recommend:

- Initiating the community household consultation process early when considering POU/POE devices as a compliance strategy to ensure 100% participation in a timely manner. Provide structure and support when creating legal agreements to facilitate 100% participation.

- Understanding the CWS financing situation to best forecast upfront capital costs and examine long-term O&M costs of using POU/POE devices as a compliance strategy.
- Understanding changes in operator certification requirements, legal administrative costs, etc. that would occur when implementing a centralized or POU/POE device. Consider hiring an engineering firm to establish these costs prior to making a commitment to either a centralized improvement or a POU/POE device.
- Streamlining and coordinating maintenance and sampling activities to limit the burden on households during O&M activities.

7.4.2 For POU/POE device manufacturers and distributors

For POU/POE device manufacturers and distributors, we recommend:

- Aligning the information available to CWSs across the certifier, manufacturer, and distributors websites and media platforms to ensure that CWSs have easy access to device cost and performance information.
- Collaborating with state agencies and administrators to pilot and test device performance with CWS specific water quality to decrease the time required to pilot and implement POU/POE devices.
- Increasing the durability and useful life of POU/POE components to decrease the frequency of replacing components to ultimately decrease the total overall O&M costs of POU/POE devices over the long-term.
- Include clear information on manufacturer or trade association websites that can be used not only by homeowners, but also by CWS managers to understand the appropriateness of POU/POE devices as a CWS SDWA compliance solution.

7.4.3 For State administrators

For state administrators and agencies, we recommend:

- Establishing clear guidance for both POU and POE devices within the state to allow small CWSs greater flexibility to meet SDWA compliance regulations.
- Continually review the sampling requirements for POU/POE device compliance over time to verify whether the sampling program is both cost effective for the community and whether the POU/Poe device is adequately removing the contaminant of concern at a representative number of households within the CWS.
- Helping CWS stakeholders to adequately characterize the water quality in both the source and treated water to enable informed decisions about appropriate technologies. For example, speciating arsenic to understand whether additional pre-oxidation is needed for the removal of As(III) in addition to As (V0.
- Establishing clear procedures to permit and approve POU/POE devices to minimize a case-by-case approach. The state should document the steps taken to approve the POU/POE solution to aide future CWSs interested in using POU/POE devices as a solution and promote knowledge sharing.
- Providing support and structure for constructing legal agreements in CWSs that facilitate 100% household participation in a timely manner.

7.4.4 Future use of the triple bottom line approach

To obtain accurate results from the triple bottom line approach, we have compiled the following recommendations for CWSs or state administrators looking to leverage this approach for very small water systems.

Exposure Assessment

1. Exposure assessment calculations should account for lifetime exposure to ensure that exposure over time is not an underestimation. We recommend evaluating exposure to an infant, child and adult over the study period to examine a worst-case exposure scenario using the average daily dose equations.
2. Exposure routes should be specific to the contaminant being evaluated. While this study examined contaminants where inhalation and dermal exposure was negligible, the inhalation and dermal exposure routes should be accounted for when examining volatile inorganic contaminants and other contaminants with inhalation and dermal information available from the EPA IRIS database.
3. In general, additional studies are needed to model inhalation of aerosolized water particles, including the concentration of a contaminant that is aerosolized and the lung absorption rates of different individuals to understand if inhalation risk is truly negligible from water.

Life Cycle Assessment

1. Disposal of waste media and materials from both centralized and POU/POE devices needs to be examined to determine if the concentration of contaminants in device components are non-hazardous or hazardous waste. For the purposes of this study, we assumed the concentration of arsenic in disposed media would not be large enough to constitute a hazardous waste; however, for other contaminants this may not be the case. CWSs and state administrators need to work with device manufacturers to understand how much of a contaminant is present in spent media prior to landfill disposal.
2. A CWS may consider recycling or media regeneration as potential waste scenarios within the life cycle analysis. In this study, we assumed that materials would be disposed in a landfill; however, specific adsorptive medias can be regenerated or recycled, providing a more environmentally sustainable alternative.

Life Cycle Costing

1. Cost modeling needs to include the useful life and replacement frequency of all components of either a centralized improvement or a POU/POE device to capture the total cost over time of operating and maintaining the improvement. Other studies (Bixler et.al., 2021) have examined net present value or worth using an average useful life and a functional unit based on volume of water treated which may not accurately account for the total cost over time to a community.
2. State and CWS-specific cost assumptions need to be clearly documented and reported so that future studies can accurately compare results and make informed decisions. When reviewing literature to conduct this study, we identified several different cost models and assumptions that needed careful evaluation to determine their applicability to our study. We recommend states and CWSs keep a very clear record of the assumptions used to model cost.

References

Allaire, M., Wu, H., Lall, U., 2018. National trends in drinking water quality violations. Proceedings of the National Academy of Sciences 115, 2078–2083. https://doi.org/10.1073/pnas.1719805115
AWWA Research Foundation (AWWARF). (2005). POU/POE Implementation Feasibility Study for Arsenic Treatment. Retrieved from: https://www.waterrf.org/research/projects/poupoe-implementation-feasibility-study-arsenic-treatment

Azuma, K., Uchiyama, I., & Okumura, J. (2013). Assessing the risk of Legionnaires' disease: The inhalation exposure model and the estimated risk in residential bathrooms. *Regulatory Toxicology and Pharmacology*, *65*(1), 1–6. https://doi.org/10.1016/j.yrtph.2012.11.003

Bilec, M., Ries, R., Matthews, H.S., Sharrard, A.L., 2006. Example of a Hybrid Life-Cycle Assessment of Construction Processes. J. Infrastruct. Syst. 12, 207–215. https://doi.org/10.1061/(ASCE)1076-0342(2006) 12:4(207)

Bixler, T.S., Song, C. and Mo, W. (2021). Comparing centralized and point-of-use treatments of per- and polyfluoroalkyl substance. AWWA Water Science. DOI: 10.1002/aws2.1265

Boffetta, P., Zunarelli, C., & Borron, C. (2020). Dose-Response Analysis of Exposure to Arsenic in Drinking Water and Risk of Skin Lesions: A Systematic Review of the Literature. *Dose-Response*, *18*(4), 155932582095782. https://doi.org/10.1177/1559325820957823

California Water Boards. (2020). Draft White Paper Discussion on: Long Term Solutions Cost Methodology for Public Water Systems and Domestic Wells. Retrieved from: https://www.waterboards.ca.gov/safer/docs/draft_whitepaper_lt_solutions_cost_meth_pws_dom_wells_updated.pdf

Corona Environmental Engineering. (2021). Developing Equitable and Effective Early Action Plans: The Cost of Interim Drinking Water Solutions and Public Outreach for Nitrate Contaminated Drinking Water. Retrieved from: https://www.communitywatercenter.org/coronareport

Davis, M. J., Janke, R., & Taxon, T. N. (2016). Assessing Inhalation Exposures Associated with Contamination Events in Water Distribution Systems. *PLOS ONE*, *11*(12), e0168051. https://doi.org/10.1371/journal.pone.0168051

International Association of Plumbing and Mechanical Officials [IAPMO]. (2021). Product Listing Directory. Retrieved from: https://pld.iapmo.org/. [3 February 2021]

International Standards Organization [ISO] (2006). ISO 14040: Environmental Management – Life cycle assessment – principles and framework. Retrieved from: https://www.iso.org/standard/37456.html

National Sanitation Foundation [NSF]. (2021a). NSF Product and Service Listing: NSF/ANSI 53. Drinking Water Treatment Units – Health Effects. Retrieved from: https://info.nsf.org/Certified/DWTU/Listings.asp?ProductFunction=053%7CArsenic+%28Pentavalent%29%3C%3D50+ppb+Reduction&ProductType=&submit2=Searchhttps://info.nsf.org/Certified/DWTU/Listings.asp?ProductFunction=053%7CArsenic+%28Pentavalent%29%3C%3D50+ppb+Reduction&ProductType=&submit2=Search [15 March 2021].

National Sanitation Foundation [NSF]. (2021b). NSF Product and Service Listing: NSF/ANSI 58. Reverse Osmosis Drinking Water Treatment Units. Retrieved from: https://info.nsf.org/Certified/DWTU/Listings.asp?ProductFunction=058%7CArsenic+%28Pentavalent%29%3C%3D300+ppb+Reduction&ProductType=&submit2=Search [15 March 2021].

National Sanitation Foundation [NSF]. (2021c). Search for NSF Certified Drinking Water System Components. Retrieved from: http://info.nsf.org/certified/pwscomponents/index.asp?standard=061

Oxenford, J. L., & Barrett, J. M. (2016). Understanding Small Water System Violations and Deficiencies. *Journal - American Water Works Association*, *108*, 31–37. https://doi.org/10.5942/jawwa.2016.108.0040

Powers, M., Yracheta,J., Harvey, D., O'Leary,M., Best, L. G., Bear, A.B., MacDonald, L., Hasan, J. S. K., Thomas, E., Morgan,C., Olmedo, P., Chen, R., Rule, A., Schwab, K., Navas-Acien, A. , George, C.M. (2019). Arsenic in groundwater in private wells in rural North Dakota and South Dakota: Water quality assessment for an intervention trial. *Environmental Research*. Vol. 168. Pp. 41-47. Doi: https://doi.org/10.1016/j.envres.2018.09.016.

Rubin, S.J., 2013. Evaluating violations of drinking water regulations. Journal - American Water Works Association 105, E137–E147. https://doi.org/10.5942/jawwa.2013.105.0024

Speth, T., R. Khera, C. Patterson, AND P. Ransom. Cost of POU vs Centralized Treatment. 2020 WQA Virtual Annual, NA Virtual Meeting,OH, April 16 - 21, 2020. Retrieved from: https://cfpub.epa.gov/si/si_public_record_report.cfm?Lab=CESER&dirEntryId=348941

USEPA (n.d.). Arsenic Mitigation Strategies. Retrieved from: https://www.epa.gov/sites/default/files/2015-09/documents/train5-mitigation.pdf

US EPA. (2007). COST EVALUATION OF POINT-OF-USE AND POINT-OF-ENTRY TREATMENT UNITS FOR SMALL SYSTEMS: COST ESTIMATING TOOL AND USER GUIDE. Retrieved from: https://www.epa.gov/sites/production/files/2015-04/documents/epa815b07001.pdf

USEPA. (2006a). Design Manual: Removal of Arsenic from Drinking Water supplies by Iron Removal Process. Retrieved from: https://nepis.epa.gov/Exe/ZyNET.exe/2000D2G2.TXT

US EPA. (2021a). Drinking Water Treatment Technology Unit Cost Models. Retrieved from: https://www.epa.gov/sdwa/drinking-water-treatment-technology-unit-cost-models

USEPA (2011). Exposure Factors Handbook. Retrieved from: https://cfpub.epa.gov/ncea/risk/recordisplay.cfm?deid=236252

US EPA. (2020a). Exposure Assessment Tools by Routes – Inhalation. Retrieved from: https://www.epa.gov/expobox/exposure-assessment-tools-routes-inhalation

US EPA. (2020b). Exposure Assessment Tools by Routes – Dermal. Retrieved from: https://www.epa.gov/expobox/exposure-assessment-tools-routes-dermal

US EPA. (1992). Guidelines for Exposure Assessment. Retrieved from: https://www.epa.gov/sites/production/files/2014-11/documents/guidelines_exp_assessment.pdf

US EPA Integrated Risk Information System [IRIS]. (1991). Arsenic, inorganic; CASRN 7440-38-2. Retrieved from: https://iris.epa.gov/static/pdfs/0278_summary.pdf

US EPA Integrated Risk Information System [IRIS]. (2021b). Nitrate: CASRN 14797-55-8 | DTXSID5024217. Retrieved from: https://cfpub.epa.gov/ncea/iris2/chemicalLanding.cfm?substance_nmbr=76.

US EPA Integrated Risk Information System [IRIS]. (1989). Uranium, soluble salts; no CASRN. Retrieved from: https://cfpub.epa.gov/ncea/iris/iris_documents/documents/subst/0421_summary.pdf

USEPA (1978). Nitrate Removal from Water Supplies by Ion Exchange. Retrieved from: https://nepis.epa.gov/Exe/ZyNET.exe/9101MNNX.TXT

USEPA. (2006b) Point-of-Use or Point-of-Entry Treatment Options for Small Drinking Water Systems Retrieved from: https://www.epa.gov/sites/production/files/2015-09/documents/guide_smallsystems_pou-poe_june6-2006.pdf

USEPA (2003a). Removal of Arsenic from Drinking Water by Adsorptive Media. Retrieved from: https://nepis.epa.gov/Exe/ZyNET.exe/30002K50.TXT

USEPA (2003b). Removal of Arsenic from Drinking Water by Ion Exchange. Retrieved from: https://nepis.epa.gov/Exe/ZyNET.exe/30002KZR.TXT

USEPA (2017a). Safe Drinking Water Information System [SDWIS] Federal Reporting Services. Retrieved from: https://www.epa.gov/ground-water-and-drinking-water/safe-drinking-water-information-system-sdwis-federal-reporting

USEPA. (2020c). Tool for Reduction and Assessment of Chemicals and Other Environmental Impacts (TRACI). Retrieved from: https://www.epa.gov/chemical-research/tool-reduction-and-assessment-chemicals-and-other-environmental-impacts-traci

US EPA. (2021c). Work Breakdown Structure-Based Cost Model for Adsorptive Media Drinking Water Treatment. *Personal communication*.

US EPA. (2017b). Work Breakdown Structure-Based Cost Model for Anion Exchange Drinking Water Treatment. Retrieved from: https://www.epa.gov/sdwa/drinking-water-treatment-technology-unit-cost-models

Water Quality Association. (2021). *Find WQA-Certified Water Treatment Products.* Retrieved from: https://www.wqa.org/find-products#/keyword/?claims=121. [26 January 2021]

Zhou, J., You, Y., Bai, Z., Hu, Y., Zhang, J., & Zhang, N. (2011). Health risk assessment of personal inhalation exposure to volatile organic compounds in Tianjin, China. *Science of The Total Environment*, *409*(3), 452–459. https://doi.org/10.1016/j.scitotenv.2010.10.022

Zhou, Y., Benson, J. M., Irvin, C., Irshad, H., & Cheng, Y.-S. (2007). Particle Size Distribution and Inhalation Dose of Shower Water Under Selected Operating Conditions. Inhalation Toxicology, 19(4), 333–342. https://doi.org/10.1080/08958370601144241

Appendix A: Selected technology process flow diagrams

Figure A1: Centralized adsorptive media for Region 1

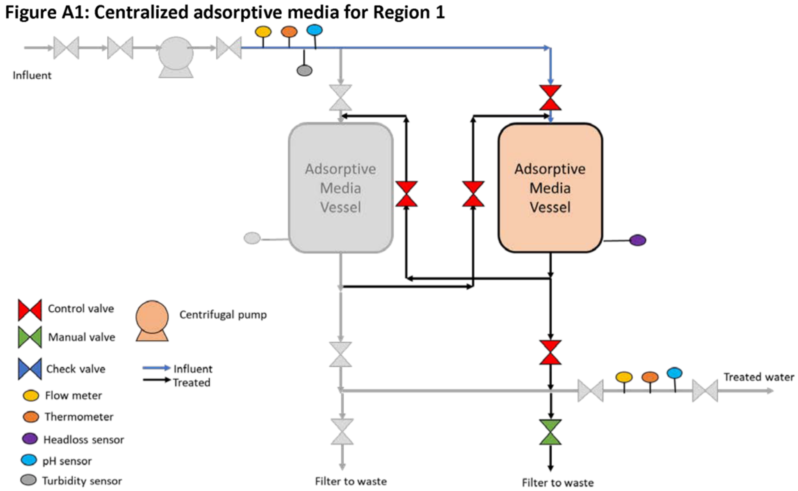


Figure A2: Centralized pre-oxidation modifications for Region 5

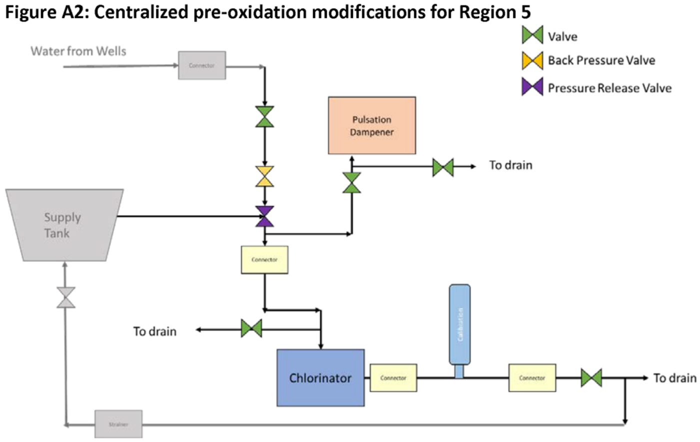


Figure A3: Centralized anion exchange process for Region 7 and Region 9

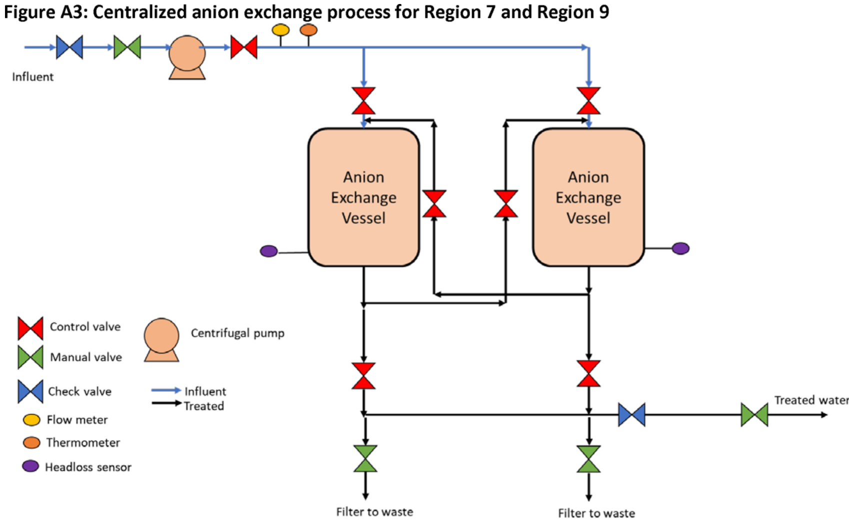


Figure A4: POE Adsorptive Media process flow (Region 5)

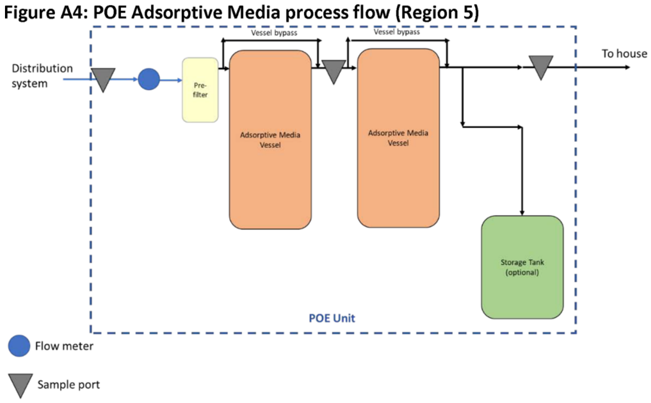


Figure A5: POU Adsorptive media device (Region 1 and Region 9)

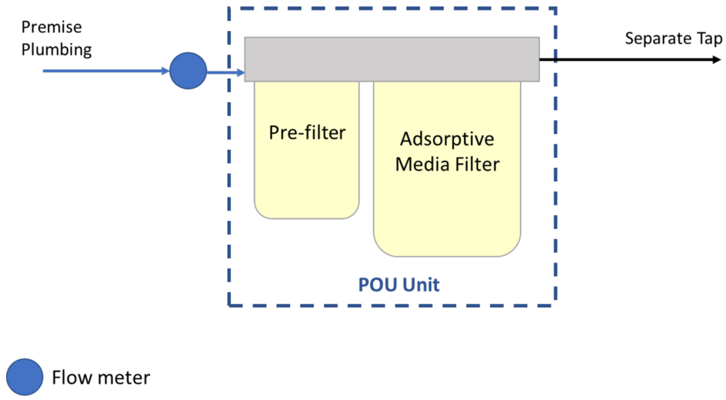
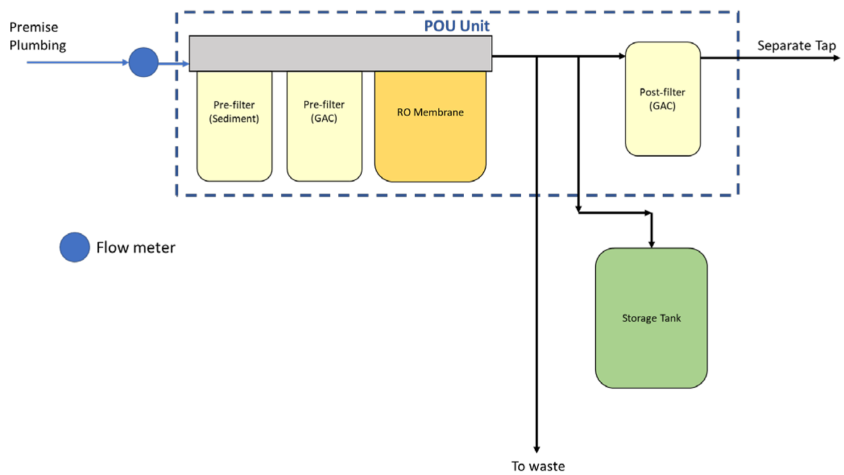


Figure A6: Process flow diagram of POU RO devices (Region 1, Region 7 and Region 9)



Appendix B: POU and POE Device Listings

Table B1: Eligible POU devices certified to NSF/ANSI 53

Company Name	Device	Device Type	Service Cycle (gallons)	Cost Information
Company A	Device A1	Plumbed-In	600	Retail is $550, cost of replacements is approximately $125
	Device A2	Plumbed-In	600	
Company B	Device B1	Plumbed-In	500	Unit = $1035, with no additional kits (additional kits are $45 for the countertop kit and $45 for the below the sink kit US Continental Shipping = $15.50 Replacement filter = $150, $10 shipping
	Device B2	Plumbed-In	600	Model XXXX Device = $740, shipping = $13.00 Replacement filter = $150, $10 shipping
Company C	Device C1	Plumbed-In to Separate Tap	600	Three different models

Table B2: Eligible POU devices certified to NSF /ANSI 58

Company	Model Number	Type of Device	Daily Production Rate (gpd)	Claim	Certification
Company D	Device D1	Plumbed-In to Separate Tap	11	Nitrate/Nitrite Reduction, Arsenic Pentavalent <= 300 ppb Reduction	NSF/ANSI 58
Company E	Device E1	Plumbed-In to Separate Tap	15.75	Nitrate/Nitrite Reduction, Arsenic Pentavalent <= 300 ppb Reduction	NSF/ANSI 58

Company F	Device F1	Plumbed-In to Separate Tap	11	Nitrate/Nitrite Reduction, Arsenic Pentavalent <= 300 ppb Reduction	NSF/ANSI 58
Company G	Device G1	Plumbed-In to Separate Tap	11	Nitrate/Nitrite Reduction, Arsenic Pentavalent <= 300 ppb Reduction	NSF/ANSI 58
Company H	Device H1	Plumbed-In to Separate Tap	11	Nitrate/Nitrite Reduction, Arsenic Pentavalent <= 300 ppb Reduction	NSF/ANSI 58
Company I	Device I1	Plumbed-In to Separate Tap	11	Nitrate/Nitrite Reduction, Arsenic Pentavalent <= 300 ppb Reduction	NSF/ANSI 58

Table B3: Eligible certified POE devices

Company Name	Device	Technology Type	Certifications
Company J	Device J1	RO	CSA B483.1 – 2007
Company K	Device K1	Adsorptive Media (GFH)	CSA B483.1 – 2007 NSF/ANSI 53
	Device K2	Adsorptive Media (GFH)	CSA B483.1 – 2007 NSF/ANSI 53
	Device K3	Adsorptive Media (GFH)	CSA B483.1 – 2007 NSF/ANSI 53
Company L	Device L1	RO	CSA B483.1 – 2007
	Device L2	RO	CSA B483.1 – 2007
Company M	Device M1	RO	CSA B483.1 – 2007

Company N	Device N1	Adsorptive Media (GFH)	NSF/ANSI 61
	Device N2	Adsorptive Media (GFH)	NSF/ANSI 61
	Device N3	Adsorptive Media (GFH)	NSF/ANSI 61
	Device N4	Adsorptive Media (GFH)	NSF/ANSI 61

Table B4: NSF Listings as of January 2021

NSF/ANSI Standard	Performance Claim	# of Companies	# of Products
NSF/ANSI 58 (RO)	Pentavalent Arsenic <= 50 ppb*	5	19
NSF/ANSI 58 (RO)	Pentavalent Arsenic <= 300 ppb	30	135
NSF/ANSI 53 (Health Effects)	Pentavalent Arsenic <= 50 ppb*	4	6
NSF/ANSI 58 (RO)	Nitrate/Nitrite	23	104

Appendix C: Exposure Assessment

Methods for Inhalation Exposure

Inhalation.

Calculations. Chronic daily intake for the inhalation exposure route can be calculated using the following equation (US EPA, 2020a):

$$CDI = \frac{Cair * InhR * ED * EF}{BW * LT} \quad (3.5)$$

In Equation 3.5, *InhR* represents the inhalation rate in m^3/hour, C_{air} represents the concentration of the contaminant in air in mg/m^3. The remaining variables are the same as Equation 3.1, and we used the same deterministic values to calculate chronic daily intake (Table 3.1).

Input values. An inhalation rate *(InhR)* of 16 m^3/day was used for adults (both male and female) from the US EPA Exposure Factors Handbook, *InhR* of 15 m^3/day for teenagers, and *InhR* 5 m^3/day for infants (US EPA, Chapter 6, 2011). The C_{air} was calculated by finding the total volume of water inhaled during a 15-minute bathing event. Zhou et.al. calculated the total volume of water inhaled during a ten- minute shower to be 0.5 m^3. From this value, we calculated the total volume inhaled during a 15- minute bathing event as 0.75 m^3. Using a total showering volume of 90 L (based on a flow rate of 6 L/min and exposure time of 15 minutes), we determined an equation to relate the concentration and volume of water from the shower to the volume inhaled and then solved for the concentration in air.

Table C1: Literature values for health effects from the contaminants of concern considered in this study.

Contaminant	Intake Values (mg/kg/day)	Health Effects
Arsenic*	0.01 – 0.1	Hyperpigmentation, Hyperkeratosis
	>0.01	GI concerns, Liver damage
	>0.05	Hematological
	0.01-0.03	Neurological (peripheral neuropathy)
	0.014 – 0.065	Cardiovascular
	0.02-0.06	Increase in Raynaud's disease, cyanosis of fingers and toes

*Source: USEPA Integrated Risk Information System [IRIS]. (2020). Arsenic, inorganic; CASRN 7440-38-2

Table C2: Literature values for the removal of arsenic via POU or POE devices

Study	Location (s)	POU or POE	Technology	Sample Size	Arsenic Removal
Yang et. al. 2020	New Jersey Maine	POE (NJ) POU (ME)	RO POU Dual Tank Adsorption (NJ)		ME: mean reduction from 105 to 14.3 µg/L NJ: mean reduction from 15.8 to 2.1 µg/L
Walker et.al. 2005	Nevada	POU	47% of homes had RO or distillation	134 homes	50% of homes still had As > 13 µg/L
George et.al. 2006	Nevada	POU	RO	19 homes	10 homes still had As > 10 µg/L at end of study period
Walker et.al. 2008	Nevada	POU	RO	59 homes	Average As removal = 80%, 18 homes still had As > 10 µg/L
Slotnick et.al., 2006	Michigan	POU	RO	5 homes	85.5% removal of As, all homes below 10 µg/L

Lothrop et.al., 2015	Arizona		RO Activated Carbon	5 homes for each technology (10 homes total)	81-99% removal with RO, 24-45% removal with AC
Spayd et.al. 2015	New Jersey	8 POE, 4 POU			As removal to below 3 µg/L POE worked better
Rockafellow-Baldoni et.al., 2018	New Jersey	POE		55 homes	51 homes (93 %) treated below NJ MCL of 5 µg/L
Powers et.al. 2019	North Dakota South Dakota	POU	Adsorption (Carbon fiber)	6 homes	As removal to 1 µg/L for at least 9 months
EPA Demo POU Devices		POU	Adsorptive Media (GFH) RO	8 buildings (AM) 9 homes (RO)	For Media: Kinetico units could remove to 6 µg/L As over 1000 gal and AdEdge units could remove to 8 µg/L over 3000 gal

Table C3: AWWARF Project Arsenic removal efficiencies (AWWARF, 2005)

Location	Technology type	Influent arsenic (mg/L)	Influent iron (mg/L)	Influent pH	Effluent arsenic (mg/L)	Effluent pH	Gallons treated to 10 ppb arsenic breakthrough	Removal efficiency
		Arsenic: Iron ratio						
Metrowater, Tuscon, AZ	POU RO	0.011	< 0.05	7.8	<0.002	6.7-8.8	>780	82%
	POU AA	4.5:1			<0.002	7.4-8.8	2660	82%
	POE Fe-AA				<0.001 – 0.01	7.0-7.7	356,400	91%
	POE GFH				<0.001 – 0.025	7.2-7.7	343,400	91%
Sun City West, AZ	POU RO	0.023	0.04	8.4	<0.002	7.1-8.7	>1300	91%
	POU AA	1.74:1			<0.001 – 0.025	7.7-8.4	1780	96%
	POU Mn-AA				<0.001 – 0.026	7.9-8.5	1780	96%
	POE Fe-AA				<0.001 – 0.022	7.2-8.5	63,400	96%
	POE GFH				<0.001 – 0.014	7.2-8.5	368,600	96%

Stagecoach, NV	POE Fe-AA	0.024	0.73	8.2	<0.001 – 0.014	8.0-8.3	34600	42-96%
	POE GFH	30.4:1			<0.001 – 0.009	8.0-8.3	110,000	63-96%
Unity, ME	POU RO	0.098	0.06	8.1	0.053 – 0.1	8.2	NA	46%
	POU Mn-AA	0.61:1			<0.001 – 0.11	8.0 – 8.1	640	99%
Carson City, NV	POU GFH	0.015	< 0.05	8.3	<0.002-0.012	7.7-8.3	15200	20-87%
	POU Mn-AA	3.3:1			<0.002-0.016	8.0-9.0	7700	87%
Houston, TX	POE GFH	0.002	0.16	7.6	<0.001-0.008	6.2-7.8	>328900	64-95%
	POE Fe-AA	7.3:1			<0.001 – 0.014	5.2-7.0	201,450	36-95%

Table C4: Literature values for removal rates for arsenic achieved by POU/POE devices (AWWARF, 2005).

Location	Influent As (mg/L)	Influent Fe (mg/L)	As: Fe Ratio	Influent pH	Gallons treated before 10 ppb breakthrough	POU/ POE	Technology	Effluent pH	Removal Rate (%)
Arizona	0.011	<0.05	4.5: 1	7.8	> 780	POU	RO	6.7-8.8	82%
					2660	POU	Activated Alumina	7.4-8.6	82%
					356,400	POE	Iron based adsorptive media	7-7.7	91%
					343,400	POE	Granular ferric hydroxide media	7.2-7.7	91%
Arizona	0.023	0.04	1.74:1	8.4	>1300	POU	RO	7.1-8.7	91%
					1780	POU	Activated Alumina	7.7-8.4	96%
					1780	POU	Manganese based adsorptive media	7.9-8.5	96%
					63,400	POE	Iron based adsorptive media	7.2-8.5	96%
					368,600	POE	Granular ferric	7.2-8.5	96%

							hydroxide media		
Nevada	0.024	0.73	30.4:1	8.2	34,600	POE	Iron based adsorptive media	8-8.3	42-96%
					110000	POE	Granular ferric hydroxide media	8-8.3	63-96%
Maine	0.098	0.06	0.61:1	8.1	NA	POU	RO	8.2	46%
					640	POU	Manganese based adsorptive media	8-8.1	99%
Nevada	0.015	<0.05	3.3:1	8.3	15,200	POU	Granular ferric hydroxide media	7.7-8.3	20-87%
					7,700	POU	Manganese based adsorptive media	8-9	87%
Texas	0.022	0.16	7.3:1	7.6	> 328,900	POE	Iron based adsorptive media	6.2-7.8	64-95%
					201,450	POE	Granular ferric	5.2-7	36-95%

							hydroxide media		

Table C5: Arsenic removal efficiencies from Yang et.al., 2020

State	Study	POU/POE	Technology	Sample size	Removal efficiency
NV	Walker et.al., 2005	POU	47% of homes on RO, 53% using distillation	134 homes	50% of homes still had arsenic > 13 ug/L
NV	George et.al., 2006	POU	RO	19 homes	10 homes till had arsenic > 10 ug/L
NV	Walker et.al. 2008	POU	RO	59 homes	Average removal = 80%, 18 homes still had arsenic> 10 ug/L
MI	Slotnick et.al. 2006	POU	RO	5 homes	85.5% removal of arsenic All homes met MCL (10 ug/L)
AZ	Lothrop et.al., 2015	POU	RO	5 homes	81-99% removal of arsenic
			Activated carbon	5 homes	24-45% removal of arsenic
NJ	Spayd et.al., 2015	8 POE 4 POU	Mixture	Not specified	POE devices performed better and removed arsenic below 3 ug/L
NJ	Rockafellow-Baldoni et.al., 2018	POE	Not specified	55 homes	51 homes treated below NJ MCL of 5 ug/L for arsenic
ND and SD	Powers et.al., 2019	POU	Adsorption	6 homes	Arsenic removed to 1 ug/L for at least 9 months before breakthrough
ME	Yang et.al. 2020	POU	RO	Not specified	86 - 99% removal of arsenic on average from 105 ug/L to 14.3 ug/L

NJ	Yang et.al. 2020	POE	Dual tank filtration	Not specified	86-98% removal of arsenic on average from 15.8 ug/L to 2.1 ug/L

Table C6: Deterministic CDI values for Region 5

Scenario			Mean Arsenic Concentration (µg/L)	Bodyweight	CDI (ug/kg/day)	Carcinogenic Risk (ug/kg/day)	Hazard Quotient	MLE	# of People per 10,000 people
Pre-Implementation	Centralized	Aeration, pre-chlorination and pressure sand filtration	9.2	Male = 75 kg	0.25	0.37	0.82	1.8E-05	2
				Female = 55 kg	0.33	0.50	1.12	2.5E-05	3
				Child = 15 kg	1.23	1.84	4.09	9.2E-05	9
				Infant = 5 kg	3.68	5.52	12.27	2.8E-04	28
Post-Implementation	Centralized	Pre-chlorination, aeration, filtration (80% Removal)	1.8	Male = 75 kg	0.0491	0.07	0.25	3.7E-06	0.4
				Female = 55 kg	0.0669	0.10	0.33	5.0E-06	0.5
				Child = 15 kg	0.2453	0.37	1.23	1.8E-05	1.8
				Infant = 5 kg	0.7360	1.10	3.68	5.5E-05	5.5
	POE	POE Device K, Adsorptive Media (98%)	0.37	Male = 75 kg	0.0049	0.01	0.02	3.7E-07	0.0
				Female = 55 kg	0.0067	0.01	0.03	5.0E-07	0.1
				Child = 15 kg	0.0245	0.04	0.12	1.8E-06	0.2
				Infant = 5 kg	0.0736	0.11	0.37	5.5E-06	0.6

	POE	POE Device N, Adsorptive Media (95% Removal)	0.46	Male = 75 kg	0.012	0.02	0.06	9.2E-07	0.1
				Female = 55 kg	0.017	0.03	0.08	1.3E-06	0.1
				Child = 15 kg	0.061	0.09	0.31	4.6E-06	0.5
				Infant = 5 kg	0.18	0.28	0.92	1.4E-05	1.4
Best-Case	Centralized	80% Removal	1.8	Male = 75 kg	0.049	0.07	0.25	3.7E-06	0.4
				Female = 55 kg	0.067	0.10	0.33	5.0E-06	0.5
				Child = 15 kg	0.25	0.37	1.23	1.8E-05	1.8
				Infant = 5 kg	0.74	1.10	3.68	5.5E-05	5.5
	POE	96% Removal	0.37	Male = 75 kg	0.0098	0.01	0.05	7.4E-07	0.1
				Female = 55 kg	0.013	0.02	0.07	1.0E-06	0.1
				Child = 15 kg	0.049	0.07	0.25	3.7E-06	0.4
				Infant = 5 kg	0.15	0.22	0.74	1.1E-05	1.1
Worst-Case	Centralized	79% Removal	1.9	Male = 75 kg	0.0515	0.08	0.26	3.9E-06	0.4
				Female = 55 kg	0.0703	0.11	0.35	5.3E-06	0.5
				Child = 15 kg	0.2576	0.39	1.29	1.9E-05	1.9
				Infant = 5 kg	0.7728	1.16	3.86	5.8E-05	5.8
	POE	42% Removal	5.3	Male = 75 kg	0.14	0.21	0.71	1.1E-05	1.1
				Female = 55 kg	0.19	0.29	0.97	1.5E-05	1.5
				Child = 15 kg	0.71	1.07	3.56	5.3E-05	5.3
				Infant = 5 kg	2.13	3.20	10.7	1.6E-04	16.0

Table C7: Deterministic CDI values for Region 7

Scenario			Mean Nitrate Concentration (mg/L)	Bodyweight	CDI (mg/kg/day)
Pre-Implementation	Centralized	Distribution from Wellhead	9.4	Male = 75 kg	0.25
				Female = 55 kg	0.34
				Child = 15 kg	1.25
				Infant = 5 kg	3.76
Post-Implementation	Centralized	Anion exchange with nitrate selective resin (95% removal)	0.47	Male = 75 kg	0.013
				Female = 55 kg	0.017
				Child = 15 kg	0.063
				Infant = 5 kg	0.19
	POU	POU Device D, Reverse Osmosis (70% Removal)	2.8	Male = 75 kg	0.075
				Female = 55 kg	0.1
				Child = 15 kg	0.38
				Infant = 5 kg	1.13
	POU	POU Device G, Reverse Osmosis (80% removal)	1.9	Male = 75 kg	0.05
				Female = 55 kg	0.068

				Child = 15 kg	0.25
				Infant = 5 kg	0.75
Best-Case	Centralized	95% Removal	0.47	Male = 75 kg	0.013
				Female = 55 kg	0.017
				Child = 15 kg	0.063
				Infant = 5 kg	0.19
	POU	97% Removal	0.28	Male = 75 kg	0.0075
				Female = 55 kg	0.0103
				Child = 15 kg	0.0376
				Infant = 5 kg	0.1128
Worst-Case	Centralized	65% Removal	3.3	Male = 75 kg	0.0877
				Female = 55 kg	0.1196
				Child = 15 kg	0.4387
				Infant = 5 kg	1.3160
	POU	57% Removal	4.0	Male = 75 kg	0.1078
				Female = 55 kg	0.1470
				Child = 15 kg	0.5389
				Infant = 5 kg	1.6168

Table C8: Deterministic CDI for Region 9

Scenario			Mean Arsenic Concentration (µgµg/L)	Bodyweight	CDI (ug/kg/day)	Carcinogenic Risk (ug/kg/day)	Hazard Quotient	MLE	# of People per 10,000 people
Pre-Implementation	Centralized	Adsorptive Media Filtration (inactive)	19.6	Male = 75 kg	0.52	0.78	2.61	3.9E-05	3.9
				Female = 55 kg	0.71	1.1	3.56	5.3E-05	5.3
				Child = 15 kg	2.61	3.9	13.07	2.0E-04	19.6
				Infant = 5 kg	7.84	11.8	39.20	5.9E-04	58.8
Post-Implementation	Centralized	Anion Exchange with strong base resin (95% removal)	0.98	Male = 75 kg	0.026	0.04	0.13	2.0E-06	0.2
				Female = 55 kg	0.036	0.05	0.18	2.7E-06	0.3
				Child = 15 kg	0.13	0.20	0.65	9.8E-06	1.0
				Infant = 5 kg	0.39	0.59	1.96	2.9E-05	2.9
	POU	POU Device B,	0.2	Male = 75 kg	0.0052	0.01	0.03	3.9E-07	0.0

		Adsorptive Media (99% Removal)		Female = 55 kg	0.0071	0.01	0.04	5.3E-07	0.1
				Child = 15 kg	0.026	0.04	0.13	2.0E-06	0.2
				Infant = 5 kg	0.078	0.12	0.39	5.9E-06	0.6
	POU	POU Device D, Reverse Osmosis (97% Removal)	0.59	Male = 75 kg	0.016	0.02	0.08	1.2E-06	0.1
				Female = 55 kg	0.021	0.03	0.11	1.6E-06	0.2
				Child = 15 kg	0.078	0.12	0.39	5.9E-06	0.6
				Infant = 5 kg	0.24	0.35	1.18	1.8E-05	1.8
Best-Case	Centralized	95% Removal	0.98	Male = 75 kg	0.026	0.04	0.13	2.0E-06	0.2
				Female = 55 kg	0.036	0.05	0.18	2.7E-06	0.3
				Child = 15 kg	0.13	0.20	0.65	9.8E-06	1.0
				Infant = 5 kg	0.39	0.59	1.96	2.9E-05	2.9
	POU	96% Removal	0.78	Male = 75 kg	0.021	0.03	0.10	1.6E-06	0.2

				Female = 55 kg	0.029	0.04	0.14	2.1E-06	0.2
				Child = 15 kg	0.105	0.16	0.52	7.8E-06	0.8
				Infant = 5 kg	0.31	0.47	1.57	2.4E-05	2.4
Worst-Case	Centralized	40% Removal	11.8	Male = 75 kg	0.3136	0.47	1.57	2.4E-05	2.4
				Female = 55 kg	0.4276	0.64	2.14	3.2E-05	3.2
				Child = 15 kg	1.5680	2.35	7.84	1.2E-04	11.8
				Infant = 5 kg	4.7040	7.06	23.52	3.5E-04	35.3
	POU AM	68% Removal	14.7	Male = 75 kg	0.42	0.63	2.09	3.1E-05	3.1
				Female = 55 kg	0.57	0.86	2.9	4.3E-05	4.3
				Child = 15 kg	2.09	3.14	10.5	1.6E-04	15.7
				Infant = 5 kg	6.27	9.41	31.4	4.7E-04	47.0

Table C9: Uranium deterministic exposure for Region 9

Scenario			Mean Uranium Concentration (µg/L)	Bodyweight	CDI (ug/kg/day)	Carcinogenic Risk (ug/kg/day)	Hazard Quotient	MLE	# of People per 10,000 people
Pre-Implementation	Centralized	Adsorptive Media Filtration (inactive)	21.5	Male = 75 kg	0.5733	0.57	0.19	2.9E-05	2.9
				Female = 55 kg	0.7818	0.78	0.26	3.9E-05	3.9
				Child = 15 kg	2.8667	2.87	0.96	1.4E-04	14.3
				Infant = 5 kg	8.6000	8.60	2.87	4.3E-04	43.0
Post-Implementation	Centralized	Anion Exchange with strong base resin (95% removal)	1.075	Male = 75 kg	0.0287	0.03	0.01	1.4E-06	0.1
				Female = 55 kg	0.0391	0.04	0.01	2.0E-06	0.2
				Child = 15 kg	0.1433	0.14	0.05	7.2E-06	0.7
				Infant = 5 kg	0.4300	0.43	0.14	2.2E-05	2.2
Best-Case	Centralized	99% Removal	0.215	Male = 75 kg	0.0057	0.01	0.00	2.9E-07	0.0
				Female = 55 kg	0.0078	0.01	0.00	3.9E-07	0.0

				Child = 15 kg	0.0287	0.03	0.01	1.4E-06	0.1
				Infant = 5 kg	0.0860	0.09	0.03	4.3E-06	0.4
	POU	50% Removal	10.75	Male = 75 kg	0.2867	0.29	0.10	1.4E-05	1.4
				Female = 55 kg	0.3909	0.39	0.13	2.0E-05	2.0
				Child = 15 kg	1.4333	1.43	0.48	7.2E-05	7.2
				Infant = 5 kg	4.3000	4.30	1.43	2.2E-04	21.5
Worst-Case	Centralized	99% Removal	0.215	Male = 75 kg	0.0057	0.01	0.00	2.9E-07	0.0
				Female = 55 kg	0.0078	0.01	0.00	3.9E-07	0.0
				Child = 15 kg	0.0287	0.03	0.01	1.4E-06	0.1
				Infant = 5 kg	0.0860	0.09	0.03	4.3E-06	0.4
	POU	90% Removal	2.15	Male = 75 kg	0.0573	0.06	0.02	2.9E-06	0.3
				Female = 55 kg	0.0782	0.08	0.03	3.9E-06	0.4
				Child = 15 kg	0.2867	0.29	0.10	1.4E-05	1.4

				Infant = 5 kg	0.8600	0.86	0.29	4.3E-05	4.3

Table C10: Probabilistic CDI values for Region 5

Pre-implementation							
	Bodyweight	Central Tendency	Reasonable Worst-Case Exposure (Lower Bound)	95th Percentile	Maximum Exposure	Maximum Exposure (Upper Bound)	Bounding Estimate
	Male	0.068	0.290	0.412	0.608	0.772	1.722
	Female	0.092	0.397	0.561	0.813	1.058	2.368
Post-implementation							
Removal Rate							
42% Removal	Male	0.143	0.189	0.201	0.212	0.222	0.264
	Female	0.195	0.258	0.276	0.290	0.311	0.364
	Child	0.711	0.947	1.017	1.086	1.126	1.280
	Infant	2.151	2.951	3.177	3.436	3.668	4.390
79% Removal	Male	0.052	0.068	0.073	0.077	0.081	0.096
	Female	0.071	0.093	0.100	0.105	0.113	0.132
	Child	0.257	0.343	0.368	0.393	0.408	0.463
	Infant	0.779	1.068	1.150	1.244	1.328	1.589
80% Removal	Male	0.049	0.065	0.069	0.073	0.077	0.091
	Female	0.067	0.089	0.095	0.100	0.107	0.125
	Child	0.245	0.327	0.351	0.375	0.388	0.441
	Infant	0.742	1.018	1.095	1.185	1.265	1.514
95% Removal	Male	0.012	0.016	0.017	0.018	0.019	0.023

	Female	0.017	0.022	0.024	0.025	0.027	0.031
	Child	0.061	0.082	0.088	0.094	0.097	0.110
	Infant	0.185	0.254	0.274	0.296	0.316	0.378
96% Removal	Male	0.010	0.013	0.014	0.015	0.015	0.018
	Female	0.013	0.018	0.019	0.020	0.021	0.025
	Child	0.049	0.065	0.070	0.075	0.078	0.088
	Infant	0.148	0.204	0.219	0.237	0.253	0.303
98% Removal	Male	0.195	0.258	0.276	0.290	0.311	0.364
	Female	0.007	0.009	0.010	0.010	0.011	0.013
	Child	0.025	0.033	0.035	0.037	0.039	0.044
	Infant	0.074	0.102	0.110	0.118	0.126	0.151

Table C11: Probabilistic CDI values for Region 7

Pre-implementation							
	Bodyweight	Central Tendency	Reasonable Worst-Case Exposure (Lower Bound)	95th Percentile	Maximum Exposure	Maximum Exposure (Upper Bound)	Bounding Estimate
	Male	0.248	0.330	0.356	0.375	0.391	0.425
	Female	0.336	0.452	0.483	0.515	0.525	0.587
Post-implementation							
Removal Rate							
10% Removal	Male	0.223	0.297	0.321	0.338	0.352	0.382
	Female	0.302	0.407	0.435	0.463	0.473	0.529
	Child	1.112	1.480	1.604	1.720	1.778	1.951
	Infant	3.358	4.648	4.975	5.460	5.728	6.973
65% Removal	Male	0.087	0.116	0.125	0.131	0.137	0.149

	Female	0.118	0.158	0.169	0.180	0.184	0.206
	Child	0.432	0.576	0.624	0.669	0.692	0.759
	Infant	1.306	1.807	1.935	2.123	2.228	2.712
70% Removal	Male	0.074	0.099	0.107	0.113	0.117	0.127
	Female	0.101	0.136	0.145	0.154	0.158	0.176
	Child	0.371	0.493	0.535	0.573	0.593	0.650
	Infant	1.119	1.549	1.658	1.820	1.909	2.324
80% Removal	Male	0.050	0.066	0.071	0.075	0.078	0.085
	Female	0.067	0.090	0.097	0.103	0.105	0.117
	Child	0.247	0.329	0.356	0.382	0.395	0.434
	Infant	0.746	1.033	1.106	1.213	1.273	1.549
90% Removal	Male	0.025	0.033	0.036	0.038	0.039	0.042
	Female	0.034	0.045	0.048	0.051	0.053	0.059
	Child	0.124	0.164	0.178	0.191	0.198	0.217
	Infant	0.373	0.516	0.553	0.607	0.636	0.775
97% Removal	Male	0.007	0.010	0.011	0.011	0.012	0.013
	Female	0.010	0.014	0.014	0.015	0.016	0.018
	Child	0.037	0.049	0.053	0.057	0.059	0.065
	Infant	0.112	0.155	0.166	0.182	0.191	0.232

Table C12: Probabilistic CDI values for Region 9

Pre-implementation							
	Bodyweight	Central Tendency	Reasonable Worst-Case Exposure (Lower Bound)	95th Percentile	Maximum Exposure	Maximum Exposure (Upper Bound)	Bounding Estimate
	Male	0.14	0.52	0.74	1.53	2.15	3.00
	Female	0.17	0.65	0.93	1.90	2.71	3.71
Post-implementation							
Removal Rate							
45% Removal	Male	0.315	0.414	0.437	0.466	0.481	0.523
	Female	0.431	0.562	0.603	0.637	0.653	0.743
	Child	1.589	2.075	2.207	2.356	2.439	2.682
	Infant	4.704	6.416	6.950	7.618	8.111	9.161
95% Removal	Male	0.026	0.035	0.036	0.039	0.040	0.044
	Female	0.036	0.047	0.050	0.053	0.054	0.062
	Child	0.132	0.173	0.184	0.196	0.203	0.224
	Infant	0.392	0.535	0.579	0.635	0.676	0.763
96% Removal	Male	0.021	0.028	0.029	0.031	0.032	0.035
	Female	0.029	0.037	0.040	0.042	0.044	0.050
	Child	0.106	0.138	0.147	0.157	0.163	0.179
	Infant	0.235	0.321	0.348	0.381	0.406	0.458
97% Removal	Male	0.016	0.021	0.022	0.023	0.024	0.026
	Female	0.022	0.028	0.030	0.032	0.033	0.037
	Child	0.079	0.104	0.110	0.118	0.122	0.134
	Infant	0.235	0.321	0.348	0.381	0.406	0.458
99% Removal	Male	0.005	0.007	0.007	0.008	0.008	0.009
	Female	0.007	0.009	0.010	0.011	0.011	0.012
	Child	0.026	0.035	0.037	0.039	0.041	0.045

	Infant	0.078	0.107	0.116	0.127	0.135	0.153

Table C13: Probabilistic uranium removal in Region 9

Pre-implementation							
	Bodyweight	Central Tendency	Reasonable Worst-Case Exposure (Lower Bound)	95th Percentile	Maximum Exposure	Maximum Exposure (Upper Bound)	Bounding Estimate
	Male	0.67	0.90	0.95	1.00	1.03	1.18
	Female	0.91	1.22	1.31	1.37	1.43	1.64
Post-implementation							
Removal Rate							
50% Removal	Male	0.33	0.45	0.47	0.50	0.52	0.59
	Female	0.46	0.61	0.65	0.69	0.71	0.82
	Child	1.68	2.23	2.38	2.53	2.64	2.94
	Infant	5.03	6.93	7.43	8.15	8.60	10.20
90% Removal	Male	0.07	0.09	0.09	0.10	0.10	0.12
	Female	0.09	0.12	0.13	0.14	0.14	0.16
	Child	0.34	0.45	0.48	0.51	0.53	0.59
	Infant	1.01	1.39	1.49	1.63	1.72	2.04
95% Removal	Male	0.03	0.04	0.05	0.05	0.05	0.06
	Female	0.05	0.06	0.07	0.07	0.07	0.08
	Child	0.17	0.22	0.24	0.25	0.26	0.29
	Infant	0.50	0.69	0.74	0.81	0.86	1.02
99% Removal	Male	0.01	0.01	0.01	0.01	0.01	0.01
	Female	0.01	0.01	0.01	0.01	0.01	0.02
	Child	0.03	0.04	0.05	0.05	0.05	0.06
	Infant	0.10	0.14	0.15	0.16	0.17	0.20

Table C14: Number of years to implement an alternative for Region 5 removal rates for a male bodyweight of 75 kg. TCR values > NOAEL and Hazard quotient values > 1 are highlighted in red.

Number of years to implement	Total Carcinogenic Risk (ug/kg/day)				Hazard Quotient			
	Removal Rate				Removal Rate			
	96%	95%	80%	42%	96%	95%	80%	42%
0	0.01	0.02	0.07	0.21	0.0	0.1	0.2	0.7
1	0.03	0.03	0.08	0.22	0.1	0.1	0.3	0.7
2	0.04	0.04	0.09	0.22	0.1	0.1	0.3	0.7
3	0.05	0.05	0.10	0.23	0.2	0.2	0.3	0.8
4	0.06	0.07	0.11	0.23	0.2	0.2	0.4	0.8
5	0.07	0.08	0.12	0.24	0.2	0.3	0.4	0.8
6	0.09	0.09	0.13	0.24	0.3	0.3	0.4	0.8
7	0.10	0.10	0.14	0.25	0.3	0.3	0.5	0.8
8	0.11	0.11	0.15	0.25	0.4	0.4	0.5	0.8
9	0.12	0.12	0.16	0.26	0.4	0.4	0.5	0.9
10	0.13	0.13	0.17	0.26	0.4	0.4	0.6	0.9
11	0.14	0.15	0.18	0.27	0.5	0.5	0.6	0.9
12	0.16	0.16	0.19	0.28	0.5	0.5	0.6	0.9
13	0.17	0.17	0.20	0.28	0.6	0.6	0.7	0.9
14	0.18	0.18	0.21	0.29	0.6	0.6	0.7	1.0
15	0.19	0.19	0.22	0.29	0.6	0.6	0.7	1.0
16	0.20	0.20	0.23	0.30	0.7	0.7	0.8	1.0
17	0.21	0.22	0.24	0.30	0.7	0.7	0.8	1.0
18	0.23	0.23	0.25	0.31	0.8	0.8	0.8	1.0
19	0.24	0.24	0.26	0.31	0.8	0.8	0.9	1.0
20	0.25	0.25	0.27	0.32	0.8	0.8	0.9	1.1
21	0.26	0.26	0.28	0.32	0.9	0.9	0.9	1.1

22	0.27	0.27	0.29	0.33	0.9	0.9	1.0	1.1
23	0.29	0.29	0.30	0.33	1.0	1.0	1.0	1.1
24	0.30	0.30	0.31	0.34	1.0	1.0	1.0	1.1
25	0.31	0.31	0.32	0.34	1.0	1.0	1.1	1.1
26	0.32	0.32	0.33	0.35	1.1	1.1	1.1	1.2
27	0.33	0.33	0.34	0.35	1.1	1.1	1.1	1.2
28	0.34	0.34	0.35	0.36	1.1	1.1	1.2	1.2
29	0.36	0.36	0.36	0.36	1.2	1.2	1.2	1.2
30	0.37	0.37	0.37	0.37	1.2	1.2	1.2	1.2

Table C15: Number of years to implement an alternative for Region 7 removal rates for a male bodyweight of 75 kg

Number of years to implement	Average Daily Dose (ug/kg/day)		
	Removal Rate		
	90%	80%	70%
0	0.03	0.05	0.08
1	0.03	0.06	0.08
2	0.04	0.06	0.09
3	0.05	0.07	0.09
4	0.06	0.08	0.10
5	0.06	0.08	0.10
6	0.07	0.09	0.11
7	0.08	0.10	0.12
8	0.09	0.10	0.12
9	0.09	0.11	0.13
10	0.10	0.12	0.13
11	0.11	0.12	0.14

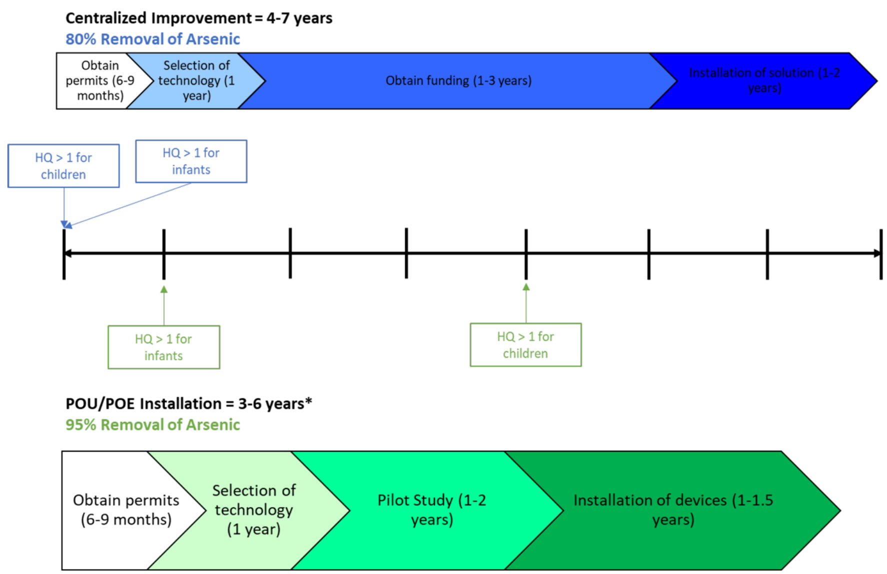
12	0.12	0.13	0.15
13	0.12	0.14	0.15
14	0.13	0.14	0.16
15	0.14	0.15	0.16
16	0.15	0.16	0.17
17	0.15	0.16	0.17
18	0.16	0.17	0.18
19	0.17	0.18	0.19
20	0.18	0.18	0.19
21	0.18	0.19	0.20
22	0.19	0.20	0.20
23	0.20	0.20	0.21
24	0.21	0.21	0.22
25	0.21	0.22	0.22
26	0.22	0.22	0.23
27	0.23	0.23	0.23
28	0.24	0.24	0.24
29	0.24	0.24	0.24
30	0.25	0.25	0.25

Table C16: Number of years to implement an alternative for Region 9removal rates for a male bodyweight of 75 kg. TCR values > NOAEL and Hazard quotient values > 1 are highlighted in red.

Number of years to implement	Total Carcinogenic Risk (ug/kg/day)				Hazard Quotient			
	Removal Rate				Removal Rate			
	95%	99%	97%	96%	95%	99%	97%	96%
0	0.04	0.01	0.02	0.03	0.1	0.0	0.1	0.1
1	0.06	0.03	0.05	0.06	0.2	0.1	0.2	0.2
2	0.09	0.06	0.07	0.08	0.3	0.2	0.2	0.3

3	0.11	0.09	0.10	0.11	0.4	0.3	0.3	0.4
4	0.14	0.11	0.12	0.13	0.5	0.4	0.4	0.4
5	0.16	0.14	0.15	0.16	0.5	0.5	0.5	0.5
6	0.19	0.16	0.18	0.18	0.6	0.5	0.6	0.6
7	0.21	0.19	0.20	0.21	0.7	0.6	0.7	0.7
8	0.24	0.21	0.23	0.23	0.8	0.7	0.8	0.8
9	0.26	0.24	0.25	0.26	0.9	0.8	0.8	0.9
10	0.29	0.27	0.28	0.28	1.0	0.9	0.9	0.9
11	0.31	0.29	0.30	0.31	1.0	1.0	1.0	1.0
12	0.34	0.32	0.33	0.33	1.1	1.1	1.1	1.1
13	0.36	0.34	0.35	0.36	1.2	1.1	1.2	1.2
14	0.39	0.37	0.38	0.38	1.3	1.2	1.3	1.3
15	0.41	0.40	0.40	0.41	1.4	1.3	1.3	1.4
16	0.44	0.42	0.43	0.43	1.5	1.4	1.4	1.4
17	0.46	0.45	0.45	0.46	1.5	1.5	1.5	1.5
18	0.49	0.47	0.48	0.48	1.6	1.6	1.6	1.6
19	0.51	0.50	0.51	0.51	1.7	1.7	1.7	1.7
20	0.54	0.53	0.53	0.53	1.8	1.8	1.8	1.8
21	0.56	0.55	0.56	0.56	1.9	1.8	1.9	1.9
22	0.59	0.58	0.58	0.58	2.0	1.9	1.9	1.9
23	0.61	0.60	0.61	0.61	2.0	2.0	2.0	2.0
24	0.64	0.63	0.63	0.63	2.1	2.1	2.1	2.1
25	0.66	0.65	0.66	0.66	2.2	2.2	2.2	2.2
26	0.68	0.68	0.68	0.68	2.3	2.3	2.3	2.3
27	0.71	0.71	0.71	0.71	2.4	2.4	2.4	2.4
28	0.73	0.73	0.73	0.73	2.4	2.4	2.4	2.4
29	0.76	0.76	0.76	0.76	2.5	2.5	2.5	2.5
30	0.78	0.78	0.78	0.78	2.6	2.6	2.6	2.6

Figure C1: Implementation timeline for Region 5

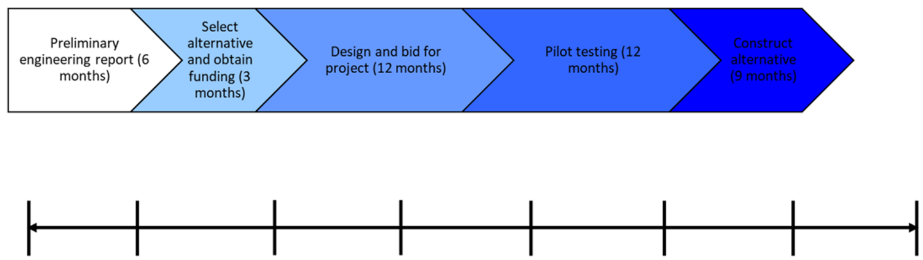


*Reliant upon 100% community participation

Figure C2: Implementation timeline for Region 7

Centralized Improvement = 4-6 years

90% Removal of Nitrate as N



POU/POE Installation = 3-5 years*

70% Removal of Nitrate as N

Figure C3: Implementation timeline for Region 9

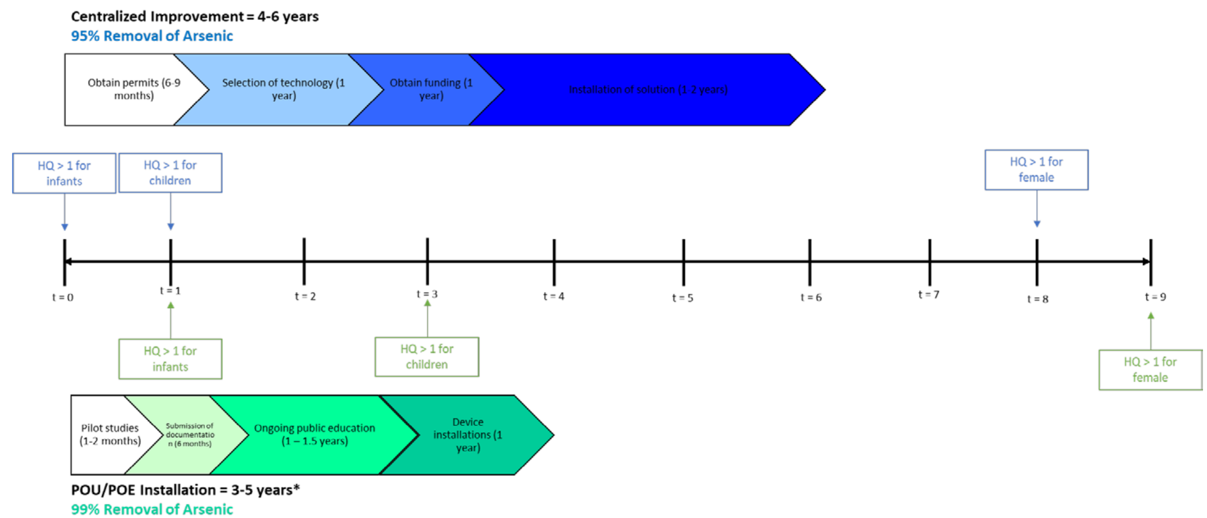

Centralized Improvement = 4-6 years
95% Removal of Arsenic
Obtain permits (6-9 months)
Selection of technology (1 year)
Obtain funding (1 year)
Installation of solution (1-2 years)
HQ > 1 for infants
HQ > 1 for children
HQ > 1 for female
t = 0
t = 1
t = 2
t = 3
t = 4
t = 5
t = 6
t = 7
t = 8
t = 9
HQ > 1 for infants
HQ > 1 for children
HQ > 1 for female
Pilot studies (1-2 months)
Submission of documentation (6 months)
Ongoing public education (1 – 1.5 years)
Device installations (1 year)
POU/POE Installation = 3-5 years*
99% Removal of Arsenic

Table C17: Dermal exposure calculations for Region 1 are shown for the current concentration of arsenic in the water system. Dermal exposure is quantified separately for arsenite and arsenate because each compound has a different permeability coefficient. We have calculated ADD< CDI, TCR and HQ values as if 100% of the arsenic is in each form. Therefore, the values presented are worst-case estimates of arsenite and arsenate exposure in Region 1.

Bodyweight	Exposure Duration	ARSENITE				ARSENATE			
		ADD (mg/kg/day)	CDI (mg/kg/day)	TCR (mg/kg/day)	HQ	ADD (mg/kg/day)	CDI (mg/kg/day)	TCR (mg/kg/day)	HQ
Male (75 kg)	30	1.18E-03	5.07E-04	3.38E-04	1.13E+00	4.03E-05	1.73E-05	1.15E-05	3.84E-02
Female (55 kg)	30	1.01E-03	4.34E-04	2.90E-04	9.65E-01	3.45E-05	1.48E-05	9.87E-06	3.29E-02
Child (15 kg)	30	9.01E-04	3.86E-04	2.57E-04	8.58E-01	3.07E-05	1.32E-05	8.77E-06	2.92E-02
Infant (5 kg)	30	2.81E-04	1.21E-04	8.04E-05	2.68E-01	9.59E-06	4.11E-06	2.74E-06	9.13E-03

Appendix D: Life Cycle Assessment

Table D1: Inventory of material for POU AM device used in Region 1 and Region 9

Material	Amount of Material (kg) per Device	Initial		30 years	
		Amount of Material for Region 1 (24 homes)	Amount of Material for Region 9 (29 homes)	Amount of Material for Region 1 (24 homes)	Amount of Material for Region 9 (29 homes)
Stainless steel	0.582	13.973	16.884	13.973	16.884
Carbon Fiber	6.012	144.288	174.348	865.729	1046.089
PVC	0.000	0.001	0.001	0.002	0.002

Table D2: Inventory of material for POU RO Device D used in Regions 1, 7 and 9

Material	Amount of Material (kg) per Device	Initial Installation			Over 30 years		
		Amount of Material for Region 1 (24 homes)	Amount of Material for Region 7 (75 homes)	Amount of Material for Region 9 (29 homes)	Amount of Material for Region 1 (24 homes)	Amount of Material for Region 7 (75 homes)	Amount of Material for Region 9 (29 homes)
Fiberglass	0.01	0.33	1.02	0.40	0.33	1.02	0.40
Polypropylene	0.00	0.02	0.06	0.02	0.55	1.71	0.66
Polysulfone	0.00	0.10	0.31	0.12	0.60	1.86	0.72
Stainless Steel	0.86	20.63	64.47	24.93	20.63	64.47	24.93
PVC	0.04	0.96	3.01	1.16	1.70	5.31	2.05
GAC	0.57	13.77	43.03	16.64	413.13	1291.03	499.20

Table D3: Inventory of material for POU RO Device G used in Region 7

Material	Amount of Material (kg) per Device	Initial Installation			Over 30 years		
		Amount of Material for Region 1 (24 homes)	Amount of Material for Region 7 (75 homes)	Amount of Material for Region 9 (29 homes)	Amount of Material for Region 1 (24 homes)	Amount of Material for Region 7 (75 homes)	Amount of Material for Region 9 (29 homes)
Fiberglass	0.01	0.33	1.02	0.40	0.33	1.02	0.40
Polypropylene	0.00	0.02	0.06	0.02	0.55	1.71	0.66
Polysulfone	0.00	0.10	0.31	0.12	0.60	1.86	0.72
Stainless Steel	0.01	0.18	0.57	0.22	0.18	0.57	0.22
PVC	0.00	0.00	0.00	0.00	0.00	0.01	0.00
GAC	0.57	13.77	43.03	16.64	413.13	1291.03	499.20

Table D4: Inventory of material for POE AM Device N used in Region 5

Material	Amount per device (kg)	Initial Amount in Region 5 (221 homes)	Amount over 30 years in Region 5 (221 homes)
granular ferric hydroxide	74.05	16365.47	49096.41
GAC	0.29	63.40	951.06
fiberglass	3268.91	722428.91	722428.91
PVC	0.05	10.90	19.23
rubber	4.67	1031.08	30932.34
gravel	20148.01	4452709.36	13358128.09

Table D5: Inventory of material for POE AM Device K used in Region 5

Material	Amount per device	Initial Amount in Region 5 (221 homes)	Amount over 30 years in Region 5 (221 homes)
PVC	0.05	10.90	19.23
Fiberglass	3268.91	722428.91	722428.91
GFO	3111.42	687624.79	2062874.36
Gravel	570.87	126161.75	378485.24

Table D6: Inventory of raw material for centralized alternative in Region 1

Component	# of Components	Units	Material	Amount of material (kg)	Amount in Region 1 (24 homes)	Amount of material over 30 years (per household)	Amount of material for 24 homes over 30 years
Inlet/outlet piping	20	ft	PVC	18.45	442.73	36.89	885.46
Check valves	2	valve	PVC	0.07	1.67	0.14	3.35
	1	valve	PVC	0.04	0.98	0.08	1.97
Manual valves	2	valve	PVC	0.08	1.97	0.16	3.93
	6	valve	PVC	0.25	5.90	0.49	11.80
	5	valve	PVC	0.23	5.50	0.46	11.01
	3	valve	PVC	0.10	2.51	0.21	5.02
Centrifugal pump	1	pump	Cast iron	203.88	4893.14	407.76	9786.29
Vessel	1	vessel	Fiberglass	7.13	171.10	14.26	342.21
Media	7.6	ft^3	GFH	138.02	3312.38	4278.50	102683.90
Process piping	20	ft	PVC	18.45	442.73	36.89	885.46
residuals piping	50	ft	PVC	28.58	685.83	57.15	1371.66

Table D7: Inventory of raw material for centralized alternative in Region 5

Component	# of Components	Units	Material	Amount of material (kg)	Amount for Region 5 (221 homes)	Amount of material over 30 years (per household)
chemical metering pump	2	pump	PVC	0.29	64.66	0.59
check valves	4	valves	PVC	0.29	64.66	0.29
pressure relief valves	4	valves	PVC	0.29	64.66	0.29
suction tubing	4	ft	PVC	1.17	258.65	7.02
discharge tubing	4	ft	PVC	1.17	258.65	7.02
chemical mixer	1	unit	PVC	10.22	2258.08	10.22
process piping	110	ft	PVC	0.29	64.66	0.29
Dosing pump	1	pump	Cast iron	203.88	45057.77	203.88
eductor	1	eductor	Cast iron	40.78	9011.55	40.78

Table D8: Inventory of raw material for centralized alternative in Region 9

Item	Quantity	Material	Amount of material (kg)	Useful Life (years)	Amount of material per household (29 homes) [kg]	Amount of material per household over 30 years [kg]
Fiber glass pressure vessel	2	Fiberglass	83.28	20	2.87	5.74
Polyacrylic Strong basin resin	34 ft^3	Polyacrylic beads	926.16	1	31.94	31.94
Cartridge filters	2	Carbon fibers	337.30	3	11.63	127.94
PVC process piping	40 ft	PVC	4.80E-08	17	1.65E-09	3.31E-09
PVC Backwash piping	50 ft	PVC	3.52E-08	17	1.21E-09	2.43E-09
PVC inlet + outlet piping	40 ft	PVC	4.60E-08	17	1.59E-09	3.17E-09

PVC process valve (air-powered)	6	PVC	2.88E-10	17	9.92E-12	1.98E-11
PVC inlet + outlet valve (manual)	2	PVC	2.88E-10	17	9.92E-12	1.98E-11
PVC process valve (manual)	2	PVC	2.88E-10	17	9.92E-12	1.98E-11
PVC Backwash valve (air-powered)	7	PVC	1.76E-10	17	6.07E-12	1.21E-11
PVC Residual check vale	1	PVC	2.88E-10	17	9.92E-12	1.98E-11
PVC inlet/outlet valve (check)	2	PVC	2.88E-10	17	9.92E-12	1.98E-11
Stainless steel sample port	5	Stainless steel	1667.09	30	57.49	114.97
Backfill	2 cells	Gravel	1143724.34	30	39438.77	78877.54
Liner	2 cells	Polyethylene	101.42	30	3.50	6.99
Dike Construction	2 cells	Sand	541854.12	15	18684.62	56053.87
solids drying pad	1 unit	Concrete	196.19	30	6.77	13.53
Cartridge filters replacements	2.4	Carbon fibers	0.34	0.42	0.01	0.85
Sodium chloride	4879.679144	Sodium chloride	2215.37	1	76.39	2368.16
Complete bed replacement	5 ft3/yr.	Polyacrylic beads	136.20	1	4.70	140.90
Backwash tank	1 vessel	Fiberglass	0.04	20	0.00	0.00
Backwash rinse pumps	2 pumps	Cast iron	3.27	17	0.11	0.23

Appendix E: Life Cycle Cost

Table E1: Cost Components of the centralized improvement in Region 1

Category of Cost	Subcategory of Cost	Item	Quantity	unit	Unit Cost	Total Cost	Useful Life	Number of Replacements over 30 years	Replacements Rounded	Total cost over 30 years
Direct Capital Cost	Piping	Inlet/outlet piping	20	ft	3	60	17	1.8	1	60
Direct Capital Cost	Valves	Check valves	2	valve	118	236	20	1.5	1	236
Direct Capital Cost	Valves	Check valves	1	valve	178	178	20	1.5	1	178
Direct Capital Cost	Valves	Manual valves	2	valve	265	530	20	1.5	1	530
Direct Capital Cost	Valves	Manual valves	6	valve	265	1590	20	1.5	1	1590
Direct Capital Cost	Valves	Manual valves	5	valve	323.77	1618.85	20	1.5	1	1618.85
Direct Capital Cost	Valves	Manual valves	3	valve	195.93	587.79	20	1.5	1	587.79
Direct Capital Cost	Instrumentation	Flow meter	1	meter	1865	1865	14	2.1	2	3730
Direct Capital Cost	Instrumentation		1	device	2339	2339	14	2.1	2	4678
Direct Capital Cost	Instrumentation	Thermometer	1	device	621	621	14	2.1	2	1242
Direct Capital Cost	Instrumentation	Headloss sensor	1	device	1966	1966	14	2.1	2	3932
Direct Capital Cost	Filter	Vessel	1	vessel	2790	2790	20	1.5	1	2790
Direct Capital Cost	Filter	Media	14	ft^3	187.36	2623.04	10	3.0	3	7869.12
Direct Capital Cost	Piping	Process piping	20	ft	3	60	17	1.8	1	60
Direct Capital Cost	Instrumentation	pH sensor	1	device	2755	2755	14	2.1	2	5510
Direct Capital Cost	Instrumentation	Turbidity sensor	1	device	5466	5466	14	2.1	2	10932

Direct Capital Cost	Piping	residuals piping	50	ft	2	100	17	1.8	1	100
Direct Capital Cost	Instrumentation	high/low alarm	1	unit	620	620	14	2.1	2	1240
Add-on Cost	Administration	Permits				$253	30	1.0	1	$253
Add-on Cost	Administration	Pilot Study				$15,030	30	1.0	1	$15,030
Indirect Capital Cost	Administration	Site Work				$ 1,349	30	1.0	1	$1,349
Indirect Capital Cost	Administration	Yard Piping				$ 1,263	30	1.0	1	$1,263
Indirect Capital Cost	Administration	Electrical (including yard wiring)				3172.35 67	30	1.0	1	$3,172
Indirect Capital Cost	Administration	Process Engineering				7166.17 34	30	1.0	1	$7,166
Indirect Capital Cost	Administration	Miscellaneous Allowance				3583.08 67	30	1.0	1	$3,583
Indirect Capital Cost	Administration	Legal, Fiscal, and Administrative				716.617 34	30	1.0	1	$717
Indirect Capital Cost	Administration	Construction Management and GC Overhead				1017.59 66	30	1.0	1	$1,018
Annual O&M Cost	Labor	Manager	12.66323	hrs./yr.	48.2	$610	1	30.0	30	$18,311.03
Annual O&M Cost	Labor	Administrative	12.66323	hrs./yr.	31.31	$396	1	30.0	30	$11,894.57
Annual O&M Cost	Labor	Operator	126.6323	hrs./yr.	32.51	$4,117	1	30.0	30	$123,504.50
Annual O&M Cost	Materials	Building and HVAC maintenance (materials and labor)	80	sf	6.16579 306	$493	1	30.0	30	$14,797.90
Annual O&M Cost	Media and Chemicals	Granular Ferric Hydroxide	7.600481	cf/yr.	187.361 579	$1,424	1	30.0	30	$42,721.15
Annual O&M Cost	Energy	Energy for residuals pumps	0.001561	Mwh/yr.	0.1066	$0	1	30.0	30	$4.99
Annual O&M Cost	Energy	Energy for lighting	0.010131	Mwh/yr.	0.1066	$1	1	30.0	30	$32.40
Annual O&M Cost	Energy	Energy for ventilation	0.054444	Mwh/yr.	0.1066	$6	1	30.0	30	$174.11
Annual O&M Cost	Residuals disposal	Spent media disposal	30%	ton/yr.	$107	$32	1	30.0	30	$958.50
Annual O&M Cost	Residuals disposal	Holding tanks solids disposal	0.003998	ton/yr.	107.1	0.42813 83	1	30.0	30	$12.84

Annual O&M Cost	Miscellaneous	Miscellaneous Allowance	0.1		715.7426128	715.74261	1	30.0	30	715.7426128

Table E2: Cost Components of the centralized improvement in Region 5

Component	# of Components	Units	Material	Size	Analogous component in model	Cost per Unit	Total Cost	Useful Life	Number of replacements	Replacements rounded	Total cost over 30 years
chemical metering pump	2	pump	PVC	0.13 gph	4.1.1 PVC Electric pump	467.7490579	935.4981	15	2.0	2.0	1871.0
check valves	4	valves	PVC	0.5 inch diameter pipe	3.3.1 Check valves for chemical feed	70.65770016	282.6308	20	1.5	1.0	282.6
pressure relief valves	4	valves	PVC	0.5 inch diameter pipe	3.1.1 Motor valves for chemical feed	495.6549745	1982.62	20	1.5	1.0	1982.6
suction tubing	4	ft	PVC	Assume 0.5 in diam pipe	Piping from amazon ($45.99/50ft)	0.92	3.68	5	6.0	6.0	22.1
discharge tubing	4	ft	PVC	Assume 0.5 in diam pipe	Piping from amazon ($45.99/50ft)	0.92	3.68	5	6.0	6.0	22.1
chemical mixer	1	unit	PVC	3 inch diameter	5.1.1 Plastic mixer	993.6378806	993.6379	22	1.4	1.0	993.6
process piping	110	ft	PVC	0.5 inch diameter pipe	2.1.1 CPVC Process Chemical feed piping	2.708213782	297.9035	17	1.8	1.0	297.9

Table E3: Cost Components of the centralized improvement in Region 7

Component	# of Components	Units	Material	Size	Analogous component in model	Cost per Unit	Total Cost	Useful Life	Number of replacements per 30 years	Num_round	Quantity needed over 30 years
Inlet/outlet piping	-	ft^2	PVC	1.5 in diameter, 40 ft	5.5.1 Inlet/Outlet Piping - PVC	$2.99	$119.60	17	1.764705882	1	2
Check valves	2	valve	PVC	1.5 in diameter	6.3.2 Inlet/Outlet Check valve	$171	$342	17	1.764705882	1	2
Manual valves	2	valve	PVC	1.5 in diameter	6.2.1 Inlet/Outlet Manual Valves	$241	$482	17	1.764705882	1	2
	2	valve	PVC	1.5 in diameter	6.2.2 Process Manual Valve	$292	$584	17	1.764705882	1	2

Centrifugal pump	1	pump	Cast iron	1 cu ft	7.1 Booster pump			17	1.764705882	1	2
Control valve	7	valve	PVC	2 in diameter	6.1.1 Process Air Valves	$682	$4,774	17	1.764705882	1	2
Vessel	2	vessel	Fiberglass	59 gallons (4.5 ft in height, 1.5 ft diameter	1.1 Fiber glass pressure vessel	$2,033	$4,066	20	1.5	1	2
Resin (polyacrylic beads)	16	ft^3/yr.	Nitrate Selective Resin	8 ft^3, bed depth of 2.4 ft	2.1 Nitrate selective resin	$183.88	$2,942.08	1	30	30	31
Process piping	-	ft	PVC	2 in diameter, 40 ft	5.3.1 Process Piping - PVC	$3.30	$132.00	17	1.764705882	1	2
Backwashing											
Tank	1	vessel	Fiberglass	60 gallons	3.1.1 Fiberglass backwash tank	$5,489	$5,489	20	1.5	1	2
Piping	50	ft	PVC	1 inch diameter	5.1.1 Backwash piping (PVC)	$2.74	$137.00	17	1.764705882	1	2
motor/ air-operated valves	8	valves	PVC	1 inch diameter	6.1.2 Backwash valves (PVC) - process valves	$551	$4,408	20	1.5	1	2
check valves	2	valves	PVC	1 inch diameter	6.3.1 Backwash valves (PVC) - check valves	$113	$226	20	1.5	1	2
rinse pumps	2	pumps	Cast iron	6 gpm	7.2 Backwash rinse pumps	$6,879	$13,758	17	1.764705882	1	2
Chlorine disinfection											
Storage tank	1	vessel	fiberglass	60 gallons	3.1.1 Fiberglass backwash tank	$5,489	$5,489	20	1.5	1	2
chemical metering pump	2	pump	PVC	0.13 gph	4.1.1 PVC Electric pump	467.7490579	935.4981157	15	2.0	2.0	1871.0
check valves	4	valves	PVC	0.5 inch diameter pipe	3.3.1 Check valves for chemical feed	70.65770016	282.6308006	20	1.5	1.0	282.6
pressure relief valves	4	valves	PVC	0.5 inch diameter pipe	3.1.1 Motor valves for chemical feed	495.6549745	1982.619898	20	1.5	1.0	1982.6
suction tubing	4	ft	PVC	Assume 0.5 in diam pipe	Piping from amazon ($45.99/50ft)	0.92	3.68	5	6.0	6.0	22.1
discharge tubing	4	ft	PVC	Assume 0.5 in diam pipe	Piping from amazon ($45.99/50ft)	0.92	3.68	5	6.0	6.0	22.1
chemical mixer	1	unit	PVC	3 inch diameter	5.1.1 Plastic mixer	993.6378806	993.6378806	22	1.4	1.0	993.6
process piping	110	ft	PVC	0.5 inch diameter pipe	2.1.1 CPVC Process Chemical feed piping	2.708213782	297.903516	17	1.8	1.0	297.9
Dosing pump	1	pump	Cast iron	1 ft^3	NA	NA	NA	17	1.764705882	1	

Storage											
Small low cost shed	150	ft2	Wood	$46/ft2		46	6900	20	1.5	1	6900.0
Fiberglass storage tank	1036	gal	Fiberglass	1036 gal			6491	7	4.285714286	4	25964.0
Lab Costs											
Nitrate Samples	4	per year		1 sample location		30.08	120.32	1	30	30	3609.6
Chlorine residual samples	12	per year		2 samples locations		16	384	1	30	30	11520.0

Table E4: Cost Components of the centralized improvement in Region 9

Category of Cost	Subcategory of Cost	Item	Quantity	Size	Unit Cost	Total Cost	Useful Life	Number of Replacements over 30 years	Replacements Rounded	Replacement multiplier	Total Cost over 30 years
Direct Capital Cost	Pressure Vessels	Fiber glass pressure vessel	2	220 gal	$4,931	$9,861	20	1.5	1	2	$4,930.64
Direct Capital Cost	Ion exchange resin	Polyacrylic Strong basin resin	34 ft^3	34 ft^3	$260.56	$8,953	10	3	3	4	$781.68
Direct Capital Cost	Cartridge filters	Cartridge filters	2	0.03 MGD	$998	$1,995	30	1	1	2	$997.58
Direct Capital Cost	Piping	PVC process piping	40 ft	2 in diam	$3.30	$132	17	1.764706	1	2	$3.30
Direct Capital Cost	Piping	PVC Backwash piping	50 ft	1.5 in diam	$2.99	$150	17	1.764706	1	2	$2.99
Direct Capital Cost	Piping	PVC inlet + outlet piping	40 ft	1.5 in diam	$2.99	$120	17	1.764706	1	2	$2.99
Direct Capital Cost	Valves and Fittings	PVC process valve (air-powered)	6	2 in diam	$682	$4,091	20	1.5	1	2	$681.91
Direct Capital Cost	Valves and Fittings	PVC inlet + outlet valve (manual)	2	1.5 in diam	$241	$482	20	1.5	1	2	$240.95

Direct Capital Cost	Valves and Fittings	PVC process valve (manual)	2	2 in diam	$292	$584	20	1.5	1	2	$292.21
Direct Capital Cost	Valves and Fittings	PVC Backwash valve (air-powered)	7	2 in diam	$613	$4,2 92	20	1.5	1	2	$613.12
Direct Capital Cost	Valves and Fittings	PVC Residual check vale	1	1.5 in diam	$171	$171	20	1.5	1	2	$170.94
Direct Capital Cost	Valves and Fittings	PVC inlet/outlet valve (check)	2	1.5 in diam	$171	$342	20	1.5	1	2	$170.94
Direct Capital Cost	Controls and Instrumentation	Flow meter propeller (input + output)	1	1.5 in diam	$2,239	$2,2 39	14	2.142857	2	3	$4,477.52
Direct Capital Cost	Controls and Instrumentation	Flow meter propeller (backwash)	1	1.5 in diam	$2,239	$2,2 39	14	2.142857	2	3	$4,477.52
Direct Capital Cost	Controls and Instrumentation	Flow meter propeller (residuals)	1	1.5 in diam	$2,239	$2,2 39	14	2.142857	2	3	$4,477.52
Direct Capital Cost	Controls and Instrumentation	High/low alarm	1	NA	$593	$593	14	2.142857	2	3	$1,185.14
Direct Capital Cost	Controls and Instrumentation	Headloss sensors	2	NA	$2,121	$4,2 42	14	2.142857	2	3	$4,242.19
Direct Capital Cost	Controls and Instrumentation	Stainless steel sample port	5	NA	$50	$250	30	1	1	2	$50.00
Direct Capital Cost	Controls and Instrumentation	PLC racks and power supplies	2	NA	$340	$680	8	3.75	3	4	$1,020.48
Direct Capital Cost	Controls and Instrumentation	CPUs	2	NA	$628	$1,2 56	8	3.75	3	4	$1,884.61
Direct Capital Cost	Controls and Instrumentation	I/O discrete input modules	1	NA	$307	$307	8	3.75	3	4	$920.62
Direct Capital Cost	Controls and Instrumentation	I/O discrete output modules	1	NA	$375	$375	8	3.75	3	4	$1,124.83

Direct Capital Cost	Controls and Instrumentation	I/O combination analog modules	4	NA	$653	$2,611	8	3.75	3	4	$1,958.03
Direct Capital Cost	Controls and Instrumentation	Ethernet modules	2	NA	$865	$1,730	8	3.75	3	4	$2,595.67
Direct Capital Cost	Controls and Instrumentation	UPSs	1	NA	$563	$563	8	3.75	3	4	$1,689.46
Direct Capital Cost	Controls and Instrumentation	Drive controllers	2	NA	$1,072	$2,145	14	2.142857	2	3	$2,144.87
Direct Capital Cost	Controls and Instrumentation	Operator interface units	2	NA	$1,956	$3,911	8	3.75	3	4	$5,867.19
Direct Capital Cost	Evaporative Ponds	Excavation	2 cells	640 cy	$19,887.71	$39,775	10	3	3	4	$59,663.13
Direct Capital Cost	Evaporative Ponds	Backfill	2 cells	520.5 cy	$9,220.01	$18,440	10	3	3	4	$27,660.02
Direct Capital Cost	Evaporative Ponds	Liner	2 cells	3055.3 ft2	$5,678.83	$11,358	10	3	3	4	$17,036.50
Direct Capital Cost	Evaporative Ponds	Dike Construction	2 cells	258.6 cy	$2,116.94	$547,416	10	3	3	4	$6,350.83
Direct Capital Cost	Evaporative Ponds	solids drying pad	1 unit	1 cy	$647.97	$648	37	0.810811	0	1	$647.97
Add-on Costs	Permits	Permits	NA	NA	23.5	23.5	NA	NA	NA	NA	$23.50
Add-on Costs	Pilot Study	Pilot Study	NA	NA	15572.82396	15572.82	NA	NA	NA	NA	$15,572.82
Add-on Costs	Land Cost	Land Cost	NA	NA	5522.818468	5522.818	NA	NA	NA	NA	$5,522.82
Indirect Capital Costs	Site Work	Site Work	NA	NA	2563.076923	2563.077	NA	NA	NA	NA	$2,563.08
Indirect Capital Costs	Yard Piping	Yard Piping	NA	NA	1313.646683	1313.647	NA	NA	NA	NA	$1,313.65

Indirect Capital Costs	Geotechnical	Geotechnical	Na	NA	17870.63266	17870.63	NA	NA	NA	NA	$17,870.63
Indirect Capital Costs	Electrical Wiring	Electrical Wiring	NA	NA	6716.761125	6716.761	NA	NA	NA	NA	$6,716.76
Indirect Capital Costs	Process Engineering	Process Engineering	NA	NA	14980.78065	14980.78	NA	NA	NA	NA	$14,980.78
Indirect Capital Costs	Miscellaneous Allowance	Miscellaneous Allowance	NA	NA	7490.390323	7490.39	NA	NA	NA	NA	$7,490.39
Indirect Capital Costs	Legal, Fiscal and Administrative	Legal, Fiscal and Administrative	NA	NA	1498.078065	1498.078	NA	NA	NA	NA	$1,498.08
Indirect Capital Costs	Construction Management + Overhead	Construction Management + Overhead	NA	NA	2127.270852	$2,127	NA	NA	NA	NA	$2,127.27
Annual O&M	Labor	Manager	9.389324	hr./yr.	45.23962688	$425	1	30	30	31	$12,743.09
Annual O&M	Labor	Clerical	9.389324	hr./yr.	30.4776465	$286	1	30	30	31	$8,584.94
Annual O&M	Labor	Operator	93.89324	hr./yr.	31.91489117	$2,997	1	30	30	31	$89,897.78
Annual O&M	Materials	Cartridge filters replacements	2.4	filter/year	169.5708886	$407	1	30	30	31	$12,209.10
Annual O&M	Materials	Building maintenance	140 ft2	sf	5.786613273	$810	1	30	30	31	$24,303.78
Annual O&M	Chemicals	Sodium chloride	4879.679	lb./yr.	0.147537698	$720	1	30	30	31	$21,598.10
Annual O&M	Resin replacement	Complete bed replacement	5 ft3/yr.		260.5605391	$1,221	1	30	30	31	$36,644.02
Annual O&M	Energy	Lighting	0	Mwh/yr.	0.121218321	$2	1	30	30	31	$60.00
Annual O&M	Energy	Ventilation	0	Mwh/yr.	0.121218321	$2	1	30	30	31	$60.00
Annual O&M	Energy	Cooling	0	Mwh/yr.	0.121218321	$2	1	30	30	31	$60.00
Annual O&M	Residuals	Spent resin disposal	0.100789	ton/yr.	697.6744186	$70	1	30	30	31	$2,109.53

Annual O&M	Residuals	Evaporation pond solids disposal	1.26 9198	ton/y r.	$75	$95	1	30	30	31	$2,852.47
Annual O&M	Residuals	Spent cartridge filter disposal	0%	ton/y r.	74.915 23843	1.43 8373	1	30	30	31	$43.15
Annual O&M	Miscellaneous Allowance	Miscellaneous Allowance	10%			743. 9783	1	30	30	31	$743.98

Table E5: Cost Components of the POU AM Device B in Region 1 and 9

Component	Material	Size	Useful life (years)	Cost per unit ($)
Filter housing	stainless steel	500 gallon capacity, 13" high, 8" wide	30	740
Filter cartridge	carbon fibers		1	145
Inlet pipe	PVC	3/8 inch diameter	17	Included in filter housing cost
Outlet pipe	PVC	1/4 inch diameter	17	Included in filter housing cost
Connector valve	PVC	1/4 inch diameter	1	25
Faucet	stainless steel	0.75 ft high, 10 mm diameter	5	12

Table E6: Cost Components of the POU RO Device D in Region 1, 7 and 9

Component	Material	Size/Amount	Useful Life (years)	Cost per unit ($)
Holding Tank	Fiberglass	50 gallons	20	Included in $599 unit cost
Holding tank shutoff valve	PVC	3/8 inch	20	25
Dispensing faucet	Stainless steel	1 ft of steel, 1mm thick	5	12
in-line activated carbon post filter	GAC	1.5 ft high, 0.5 ft diameter, 0.25 ft radius	1	34
Drain clamp	Stainless steel	3/8 inch	30	Included in unit cost
feed water saddle valve	PVC	3/8 inch	1	25
activated carbon pre-filter	GAC	1.5 ft high, 0.5 ft diameter, 0.25 ft radius	1	34

sediment removal pre-filter	Polypropylene	1.5 ft high, 0.5 ft diameter, 0.25 ft radius	1	17
RO membrane	Polysulfone	1.5 ft high, 1 ft diameter, 0.5 ft radius	3	70
Polytube tee	PVC	3/8 inch	30	Included in unit cost
piping from holding tank to RO unit	PVC	3/8 inch	30	Included in unit cost
drain piping	PVC	3/8 inch	30	Included in unit cost
inlet piping	PVC	3/8 inch	30	Included in unit cost

Table E7: Cost Components of the POE AM Device N in Region 5

Component	Material	Size	Useful Life (years)	Unit Cost ($)
Filter media	granular ferric hydroxide	1 cu. Ft. (1.0 CF model)	5	$650
Iron pre-filter	GAC	1.5 ft high, 0.5 ft diameter, 0.25 ft radius	1	$40
Filter vessel	fiberglass	DIAMETER: 9" HEIGHT: 55" (1.0 CF unit)	30	$2394
5900 system valves	PVC	1/4 inch	1	$50
O-rings and spacers	rubber	1 inch diameter, 0.8 inner diameter	1	$40 (replacing all o-rings and spacers)
Filter gravel	gravel	12 cu.ft.	30	Initial gravel included with POE unit

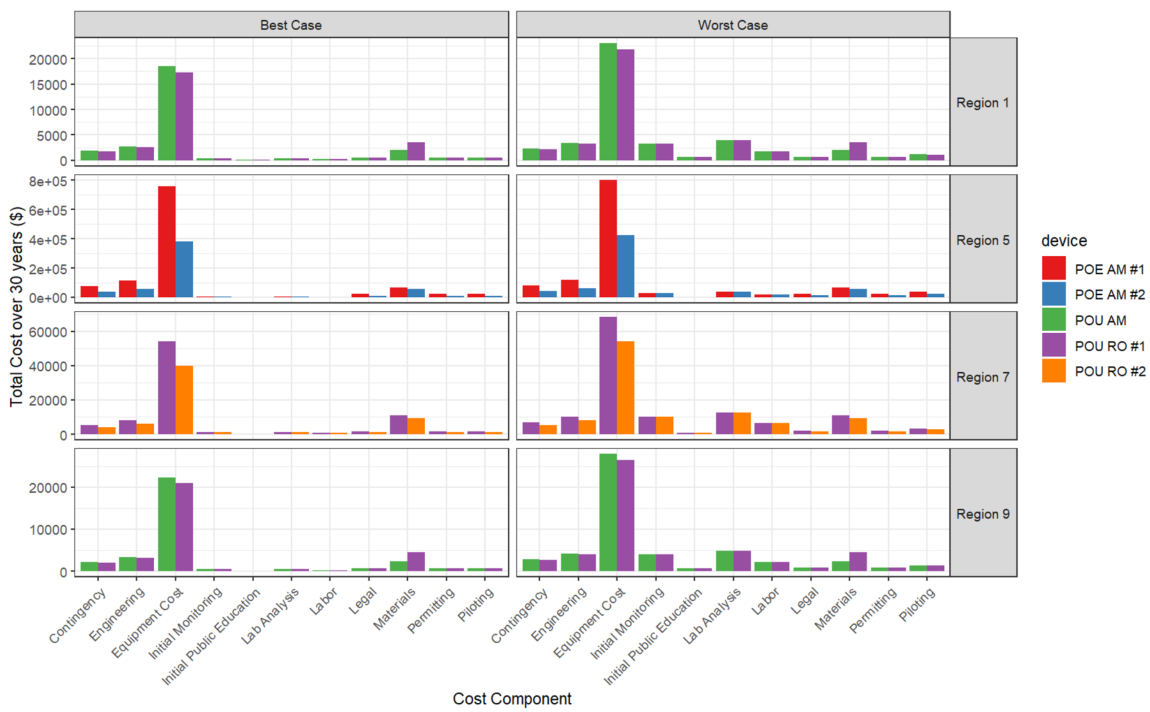
Table E8: Cost Components of the POE AM Device K in Region 5

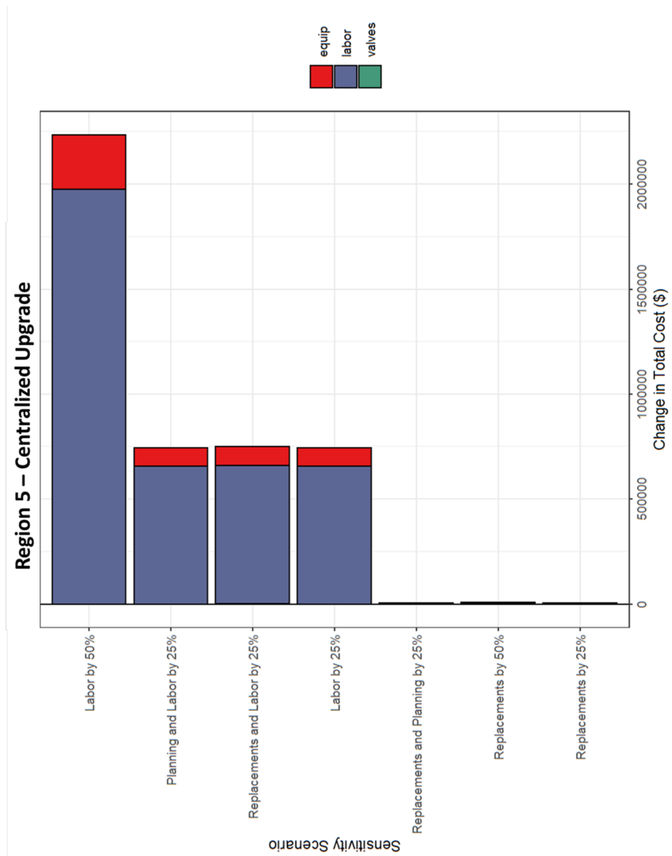
Component	Material	Size	Useful Life (years)	Unit cost ($)
Control Valve	reinforced thermoplastic	1" thick	4	$150
Media tank	Quadra-Hull tank (fiberglass)	10 x 54 in	30	$3400 (includes initial underbedding)
filter media	GFH	1.5 cu ft	3	$815
underbedding	Gravel	15 lb.	30	Initial underbedding included in unit cost of POE device

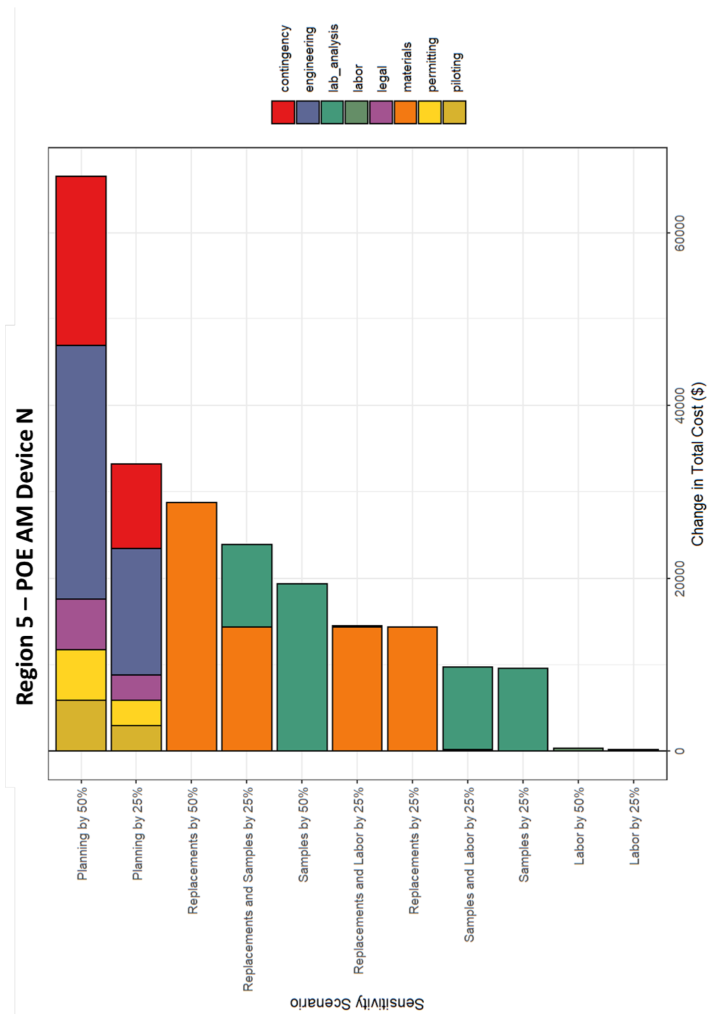
Table E9: Cost Components of the POU RO Device G in Region 7

Component	Material	Size	Useful Life (years)	Unit Cost ($)
Storage Tank	Fiberglass	1.7 gallons	20	Included in initial unit cost of $500
Pre-filter (carbon)	GAC	1.5 ft high, 0.5 ft diameter, 0.25 ft radius	1	$30
Pre-filter (sediment)	Polypropylene	1.5 ft high, 0.5 ft diameter, 0.25 ft radius	1	$25
post-filter (carbon)	GAC	1.5 ft high, 0.5 ft diameter, 0.25 ft radius	1	$30
Faucet	Stainless steel		5	$12
RO membrane	Polysulfone	1.5 ft high, 1 ft diameter, 0.5 ft radius	3	$70
inlet piping	PVC	1/4 inch	30	Included in initial unit cost
drain piping	PVC	1/4 inch	30	Included in initial unit cost
piping to tank	PVC	1/4 inch	30	Included in initial unit cost

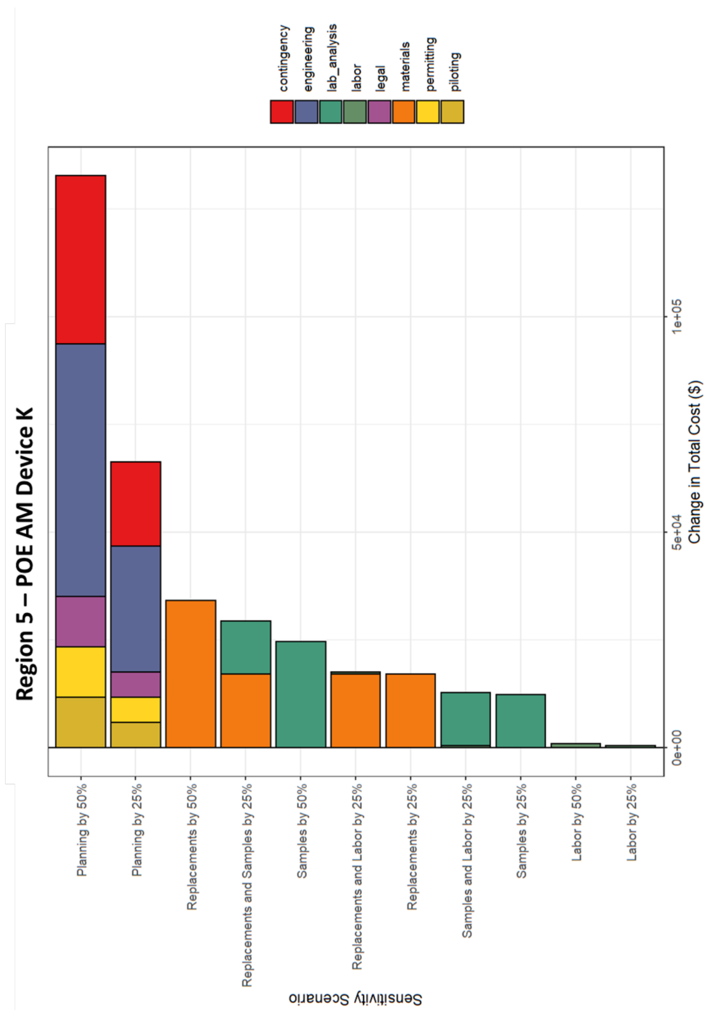
Figure E1: Best case and worst-case cost estimates for POU/POE devices across all four regions



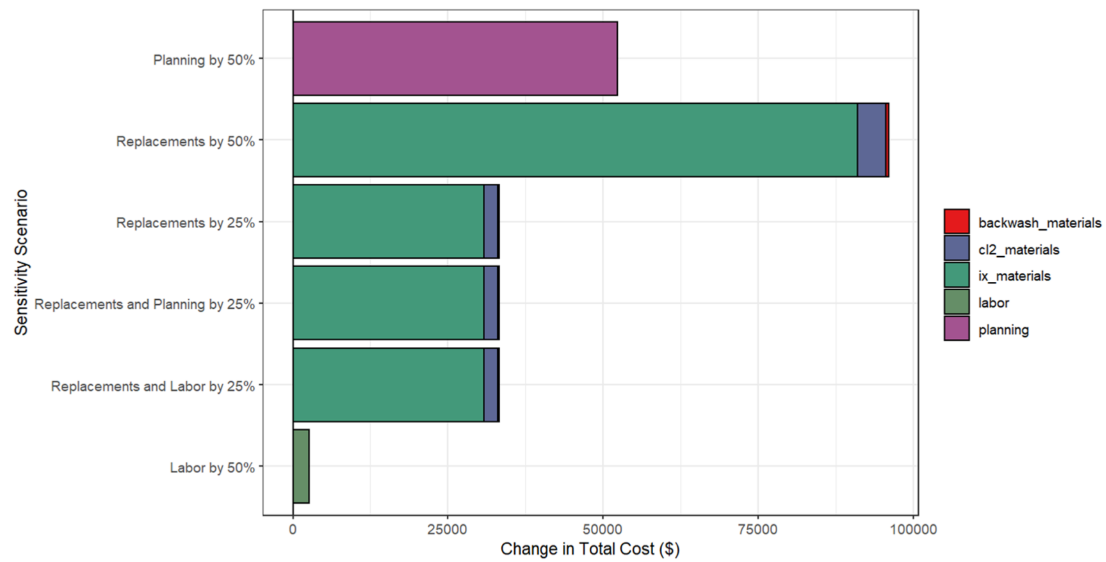

Region 5 – Centralized Upgrade
equip
labor
valves
Sensitivity Scenario
Labor by 50%
Planning and Labor by 25%
Replacements and Labor by 25%
Labor by 25%
Replacements and Planning by 25%
Replacements by 50%
Replacements by 25%
0
500000
1000000
1500000
2000000
Change in Total Cost ($)

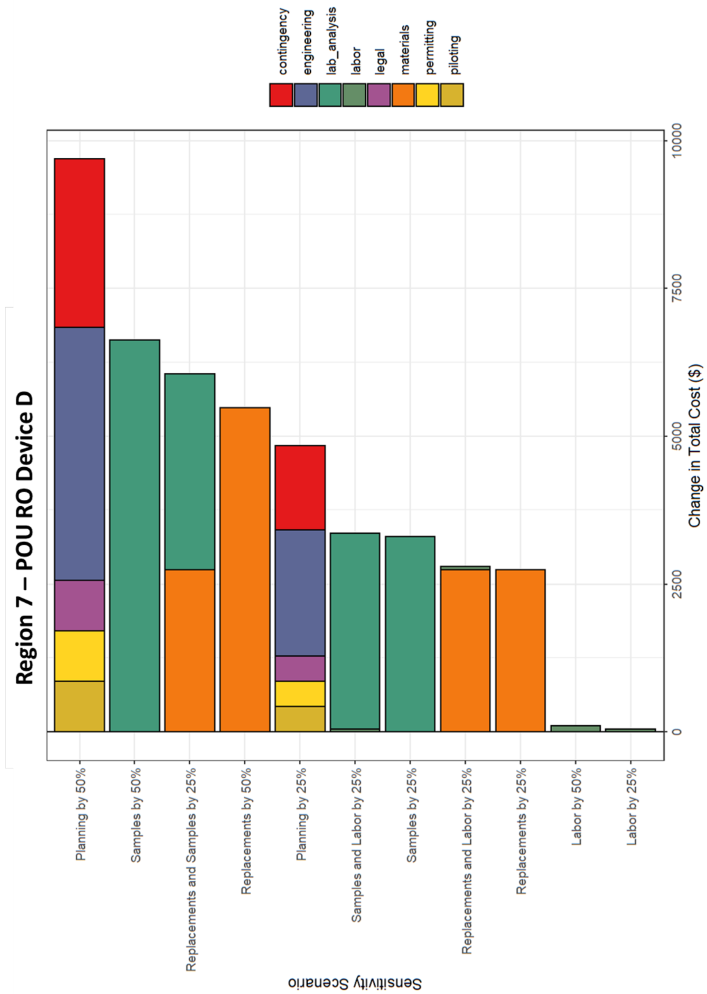


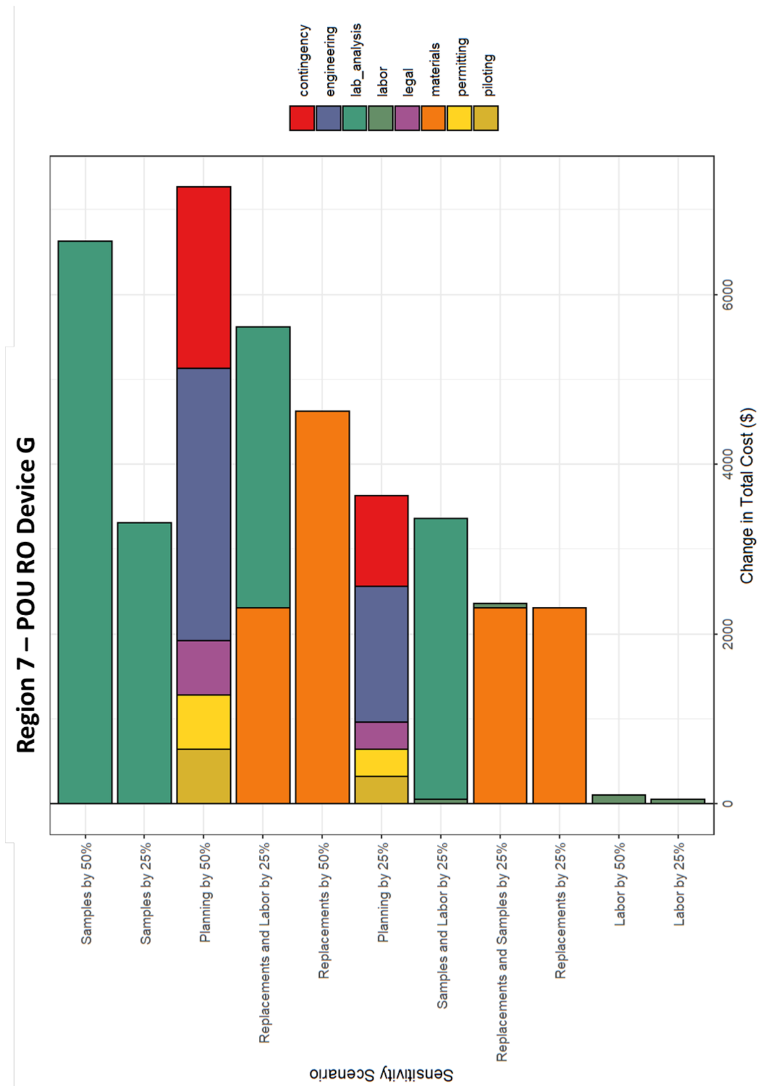
Region 5 – POE AM Device N
Sensitivity Scenario
Change in Total Cost ($)
Planning by 50%
Planning by 25%
Replacements by 50%
Replacements and Samples by 25%
Samples by 50%
Replacements and Labor by 25%
Replacements by 25%
Samples and Labor by 25%
Samples by 25%
Labor by 50%
Labor by 25%
0
20000
40000
60000
contingency
engineering
lab_analysis
labor
legal
materials
permitting
piloting

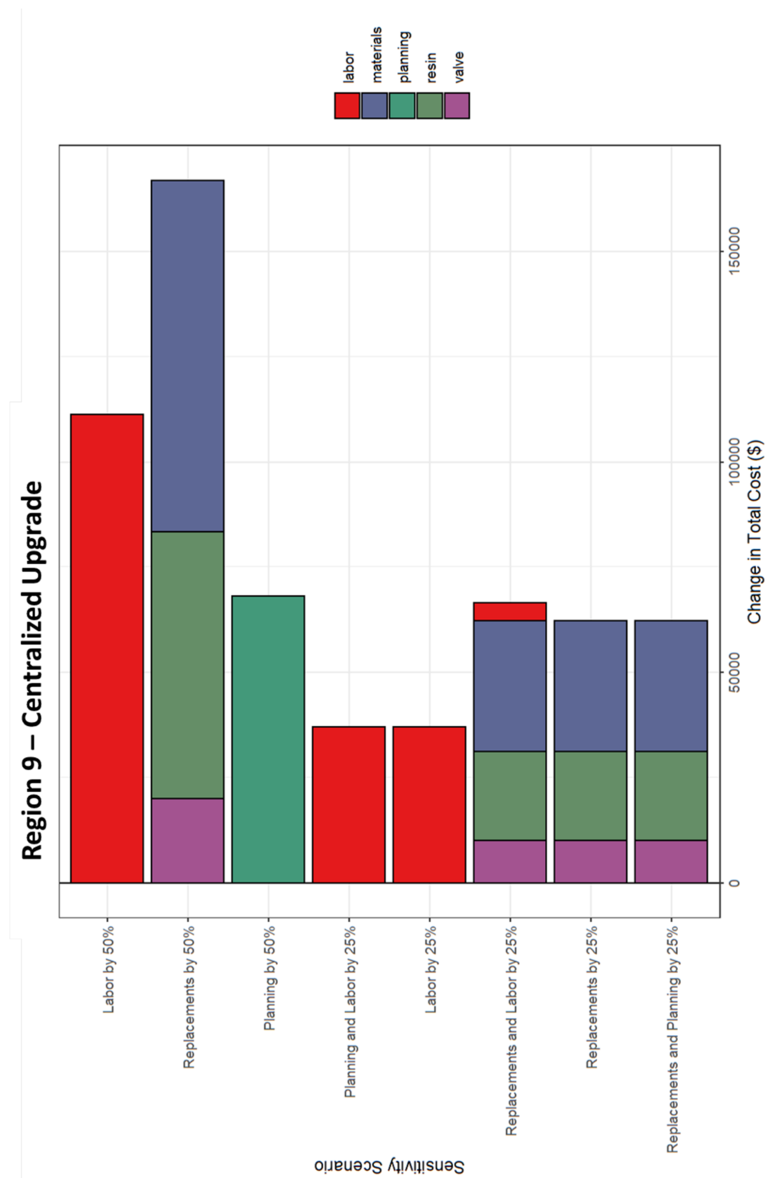

Region 5 – POE AM Device K
Sensitivity Scenario
Change in Total Cost ($)
0e+00
5e+04
1e+05
Planning by 50%
Planning by 25%
Replacements by 50%
Replacements and Samples by 25%
Samples by 50%
Replacements and Labor by 25%
Replacements by 25%
Samples and Labor by 25%
Samples by 25%
Labor by 50%
Labor by 25%
contingency
engineering
lab_analysis
labor
legal
materials
permitting
piloting

Region 7 – Centralized Upgrade

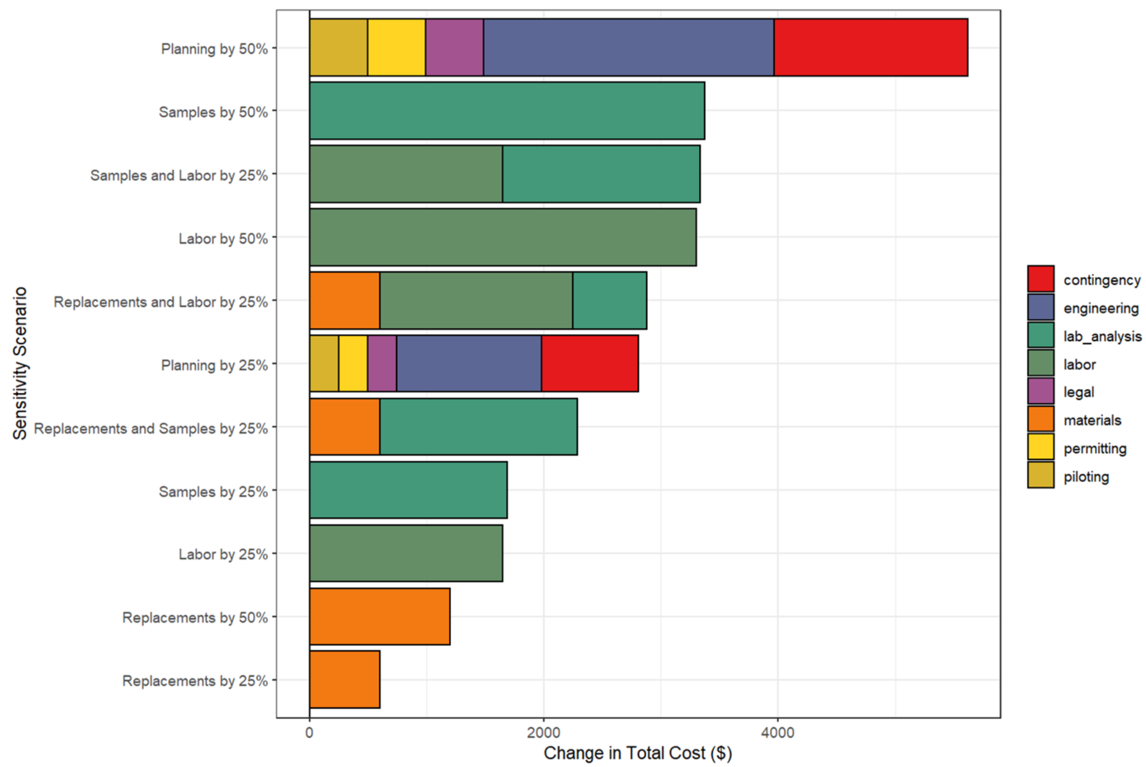


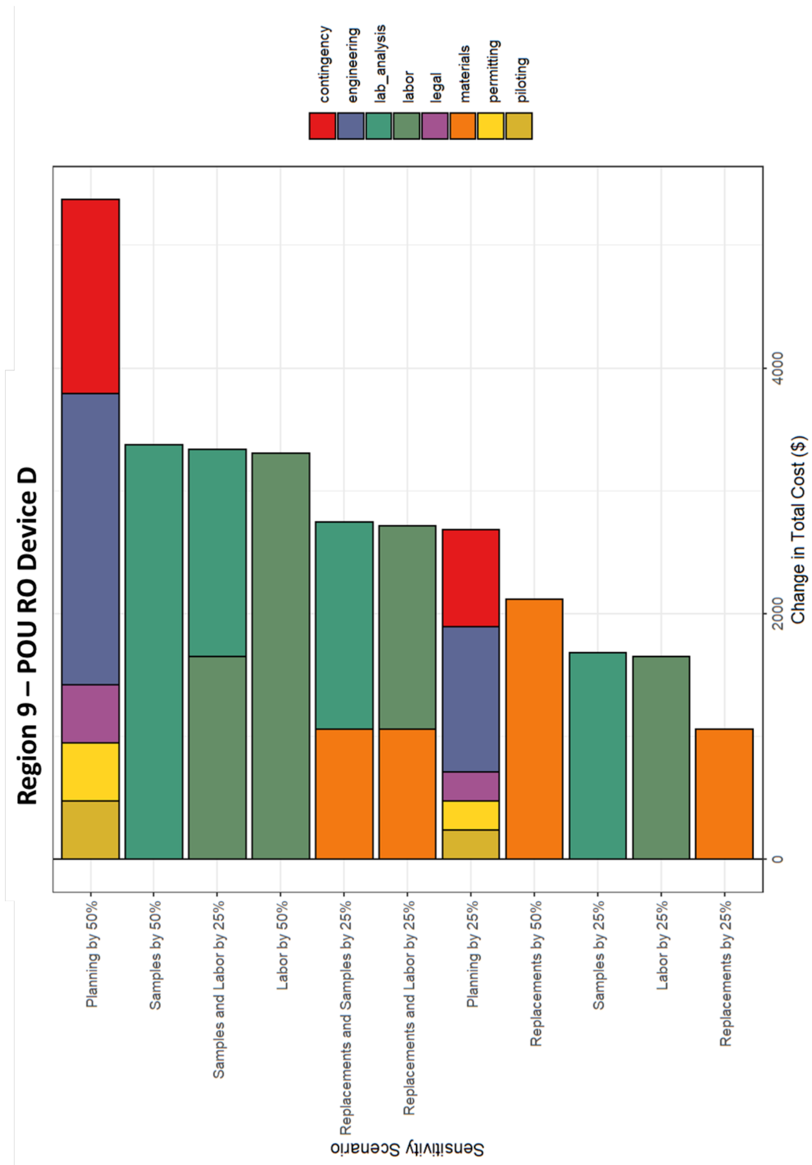

Region 7 – POU RO Device D
Sensitivity Scenario
Change in Total Cost ($)
0
2500
5000
7500
10000
Planning by 50%
Samples by 50%
Replacements and Samples by 25%
Replacements by 50%
Planning by 25%
Samples and Labor by 25%
Samples by 25%
Replacements and Labor by 25%
Replacements by 25%
Labor by 50%
Labor by 25%
contingency
engineering
lab_analysis
labor
legal
materials
permitting
piloting


Region 7 – POU RO Device G
contingency
engineering
lab_analysis
labor
legal
materials
permitting
piloting
Samples by 50%
Samples by 25%
Planning by 50%
Replacements and Labor by 25%
Replacements by 50%
Planning by 25%
Samples and Labor by 25%
Replacements and Samples by 25%
Replacements by 25%
Labor by 50%
Labor by 25%
Sensitivity Scenario
0
2000
4000
6000
Change in Total Cost ($)


Region 9 – Centralized Upgrade
Sensitivity Scenario
Labor by 50%
Replacements by 50%
Planning by 50%
Planning and Labor by 25%
Labor by 25%
Replacements and Labor by 25%
Replacements by 25%
Replacements and Planning by 25%
Change in Total Cost ($)
0
50000
100000
150000
labor
materials
planning
resin
valve

Region 9 – POU AM Device B





Region 9 – POU RO Device D
Sensitivity Scenario
Planning by 50%
Samples by 50%
Samples and Labor by 25%
Labor by 50%
Replacements and Samples by 25%
Replacements and Labor by 25%
Planning by 25%
Replacements by 50%
Samples by 25%
Labor by 25%
Replacements by 25%
0
2000
4000
Change in Total Cost ($)
contingency
engineering
lab_analysis
labor
legal
materials
permitting
piloting

NRWA

ARWA ALABAMA RURAL WATER ASSOCIATION

TESTIMONY OF

ROBERT WHITE, IV
EXECUTIVE DIRECTOR, ALABAMA RURAL WATER ASSOCIATION
AND ON BEHALF OF
THE NATIONAL RURAL WATER ASSOCIATION
BEFORE THE
SENATE COMMITTEE ON AGRICULTURE, NUTRITION, AND FORESTRY
SUBCOMMITTEE ON RURAL DEVELOPMENT AND ENERGY
HEARING ON JULY 19, 2023, ENTITLED
"RURAL WATER: MODERNIZING OUR COMMUNITY WATER SYSTEMS"

Good afternoon, Chairman Welch, Ranking Member Tuberville, and esteemed members of this Committee. I am deeply honored to be here today, offering my insights on the U.S. Department of Agriculture's (USDA) Rural Development Water and Environmental Programs, and their crucial technical assistance initiatives, which are integral to offering affordable and sustainable services to this nation's rural communities.

I would like to extend my personal gratitude to Senator Tuberville for his invitation and, more importantly, his stalwart leadership and advocacy for Alabama's rural water and wastewater sector.

My name is Rob White, and I serve as the Executive Director of the Alabama Rural Water Association (ARWA), a non-profit organization that advocates for small and rural water and wastewater systems across Alabama. I am not only here to represent the interests of ARWA but also to voice the concerns of the National Rural Water Association, which stands for over 31,000 rural systems throughout the country.

Our rural systems have their roots in the 1960s Farmers Home Administration, and they continue to benefit from assistance and support from its successor agency, Rural Development to this day. The aggregate impact of improved health outcomes and bolstered economic prosperity for rural communities resulting from Rural Development's efforts is immeasurable.

If I may, I'd like to express my gratitude to this Committee for its unwavering commitment to the success of these initiatives. These investments have yielded remarkable returns in terms of enhancing the quality of life in rural America. Regrettably, the public often overlooks the tremendous strides made in improving their communities' health and economic landscape over the past six decades. The outcomes, however, speak for themselves, as I have witnessed firsthand in nearly every small and rural community I have visited across Alabama and the nation. On behalf of both the Alabama Rural Water Association and the National Rural Water Association, I extend our heartfelt appreciation for your vision and leadership.

History of the Alabama Rural Water Association

The Alabama Rural Water Association (ARWA) was inaugurated in 1977, offering training workshops for Alabama's water systems. These workshops were designed to navigate the then newly introduced regulations from the 1974 Safe Drinking Water Act and other subjects essential to the effective management and expansion of critical water services throughout Alabama.

Starting from such modest beginnings, the ARWA has evolved into the leading service provider and resource center for rural water and wastewater systems across Alabama. At present, our team consists of nineteen committed employees, and we represent 457 member utilities. This corresponds to an impressive 91% of Alabama's 503 permitted community water systems. Our dedication to service transcends membership status as we extend our support to all communities within Alabama that request our assistance. We provide a wide array of services, including hands-on assistance and training with utilities, covering everything from regulatory compliance and continued professional education to daily operations, to system maintenance, governance, and much more.

We also invest in the future, training the upcoming generation of professionals to succeed in an aging workforce. Our services extend to emergency response and recovery, source water protection, asset management, energy audits, rate studies, and much more. We stand ready to assist communities in need, 24 hours a day, 365 days a year.

Our operations are steered by a volunteer board of ten full-time operators, managers, or directors from rural water and wastewater utilities. A key component of our service success is rooted in the fact that our staff and board members come from within the industry. Their rich experience in operating and managing water utilities provides an unmatched level of trust and confidence, establishing valuable peer-to-peer relationships from a non-regulatory, third-party entity respected in rural communities.

Although we value and invest in academic knowledge, we firmly believe that practical, on-the-ground experience is irreplaceable and central to the future success of the water and wastewater industry in rural America. Despite the industry's growing reliance on technology to enhance efficiencies, the persistent need for experienced professionals to perform on-site duties is undeniable. This tangible experience in the field forms an essential part of our successful strategy.

We are well aware, though, of the emerging challenges in our industry. Existing systems are aging and increasingly burdened by more rigorous regulations designed to shield our customers from newly discovered contaminants like PFAS and renewed initiatives to eradicate lead from our communities.

Simultaneously, we are seeing a wave of retirements in the industry alongside the escalating complexity of operating water and wastewater systems. These factors highlight the importance of a robust, relevant, and dynamic training program. Such a program is crucial in cultivating a new generation of proficient operators and providing existing operators with the necessary knowledge and tools to perform their daily tasks effectively.

The recent pandemic has exposed vulnerabilities in our supply chains, leading to unforeseen challenges in project planning and execution and subsequent cost overruns. These complications hinder any communities' ability to renovate their systems efficiently and effectively.

Despite the progress made so far, significant needs remain, especially in Alabama, with respect to extending sewer services to the remotest rural areas of our state.

ARWA Partnerships

The Alabama Rural Water Association (ARWA) is known for its successful partnerships with a variety of state and federal organizations. Our non-regulatory role serves as an essential aid to these agencies, often being the sole provider of on-site actions to solve immediate issues in Alabama. Among our partnerships, the one with the U.S. Department of Agriculture (USDA) has proven to be especially influential and beneficial. We both share the objective of delivering accessible, safe, and affordable water and wastewater services to smaller, rural communities. Currently, ARWA is partnering with the USDA and the EPA on the Closing America's Wastewater Access Gap Community Initiative to mitigate the wastewater issue in Lowndes and Greene counties in Alabama.

This pilot project was announced in White Hall, Alabama, last August. Its purpose is to help promote the development of programs to expand or introduce a variety of wastewater treatment solutions for communities that lack sufficient sanitary sewer service in 11 areas across the nation, 2 in Alabama. Significantly, Greene and Lowndes County represent just two out of sixteen counties in Alabama's Black Belt region dealing with this need. Latest estimates indicate that roughly $1.4 billion is needed to implement decentralized wastewater treatment technologies and to resolve individual septic tank issues across Alabama's Black Belt.

ARWA works closely with the Alabama Rural Development State Director and his committed team to advance the Agency's mission within the State.

It's worth noting that USDA Rural Development has been specifically designed by Congress to cater to rural America. Considering that 91% of the nation's water systems serve communities with less than 10,000 residents and 54% serve communities with less than 500, the need for their services is immense. The task of providing adequate service and improving the infrastructure in these communities lies at the core of the Rural Development's Water and Environmental Programs portfolio and aligns with our technical assistance efforts. Rural Development is devoted to updating, maintaining, and extending this crucial infrastructure.

ARWA Suggestions for Consideration in the 2023 Farm Bill

I will now provide a few examples of pending issues in Alabama and suggested solutions for your consideration as you draft the 2023 Farm Bill.

Circuit Riders

Established by this Committee in 1980, the Circuit Rider program was our pioneer initiative aimed at offering solutions and hands-on support to rural communities. Initially, it was designed to assist small and rural towns with regulatory compliance following the enactment of the Clean Water Act. Over the years, this Committee and the USDA have broadened the Circuit Rider's roles and activities to tackle emerging issues.

In Alabama, the ARWA employs a robust team, including 3 Water Circuit Riders, 2 Wastewater Specialists, an Energy Efficiency Specialist, a Source Water Protection Specialist, an Apprenticeship and Training Coordinator, along with other training experts and operations consultants. These professionals aid utilities statewide in all aspects of operating, managing, and maintaining any community's water or wastewater system. On a national scale, last year alone, Water Circuit Riders made a direct impact on the health and safety of 24,780,065 individuals, constituting 41% of rural America.

Our Alabama team successfully conducted 47 training events, which consisted of 43 local on-site training sessions, 2 conferences, and 2 online sessions attended by 2,950 industry professionals. Six of these training courses are tailored each year specifically for Board Members and decision-makers, equipping them with the knowledge to fulfill their fiscal and public health obligations effectively. Our objective is to provide a class within a 60-mile radius of every operator in Alabama annually, to reduce the burden of travel and time away from operating their systems. We also hosted nine certification schools with 150 potential new operators participating.

Our technical service providers also carried out 2,271 individual on-site visits across Alabama, providing various forms of technical assistance. Key examples of service included 49 leak surveys, which resulted in annual systems savings of 2.8 billion gallons of water valued at $8.3 million. Circuit Riders completed 151

Consumer Confidence Reports, saving an extra $135,750.00 for those systems. Moreover, our energy program, up until the end of 2022, identified potential annual energy savings of $1,828,279 for the systems that participated.

Water Circuit Riders offer a wide range of services such as hands-on training, certification licensing, financial management, environmental compliance, disaster assistance, governance, and on-site technical aid. These efforts ensure that facilities operate effectively, safeguarding the community and government's investment.

We are available all year to respond to calls for assistance, whether they concern disaster management, sourcing disinfection supplies, design and construction advice, or existing system maintenance. We assure immediate response upon being contacted.

We humbly request this Committee to renew authorization for this program.

E*mergency Preparedness and Response Activities*

For many years, the National Rural Water Association (NRWA) and State Associations have been at the forefront of emergency disaster response. We have not only maintained these services, but we've also broadened them by offering yearly training accessible to all State Associations. This training provides a platform to exchange knowledge, methodologies, and technologies to strengthen recovery initiatives.

In Alabama, we've fostered strong alliances with our Gulf State Associations, establishing a cooperative partnership to facilitate a more effective deployment of resources and immediate responses to significant disasters. For instance, following Hurricane Sally's landfall on September 15, 2020, our Association mobilized staff and resources the day after the event. We stationed our equipment and command center at one member system's office. Assistance came from multiple Rural Water associations, and we were able to maintain essential water and sewage services for about 97,000 individuals, despite power outages.

Last year, in October, we demonstrated the resilience of our emergency response network when the Alabama Rural Water Association dispatched a team to Florida following Hurricane Ian. Other Rural Water Associations also provided substantial support.

During the 2022 Christmas week, Alabama experienced a historic cold front. On Christmas Day, while most families were home opening presents and enjoying other holiday traditions, ARWA Circuit Riders left their families to respond to several locations in Alabama that were either without or nearly without water service due to the freezing conditions. The ARWA worked with system personnel to find and fix leaks, manage extreme consumption due to customers flowing water to prevent frozen pipes, and even had 2,880 cases of bottled water delivered to systems without water, valued at $18,144. These systems had been without water for several days and were able to provide this water to their customers at no cost through a partnership with ARWA, ADEM, and other State Agencies.

In most of these emergencies, State Associations finance their staff, equipment, and expenses with internal non-federal resources. However, statutory and administrative constraints limit the full efficacy of our service in impacted areas.

We propose that this Committee consider extending authorities to enable and enhance preparedness activities. This will allow Alabama and other Rural Water Associations to dedicate more resources to communities during periods of calm, or 'blue-sky days.' These efforts could include assisting utilities in planning and preparing by identifying vulnerabilities, mapping infrastructure, developing disaster protocols, coordinating with statewide emergency networks, and registering utilities on hazard mitigation lists. Additional training could focus on real-world, hands-on disaster response for water and wastewater systems.

Another crucial aspect of emergency response is the administrative requirements during and after a disaster. Adequate documentation and follow-up with agencies are mandatory to access recovery funds. Our small and rural communities often lack the necessary resources to effectively fulfill this function, leaving potential funds unclaimed.

Examples and Images of Emergency Response in Action

Hurricane Ian

ARWA Andrew Crawford and FRWA Ben Lewis set up the Starlink at the National Rural Water Command Center

ARWA Generator being delivered to Englewood

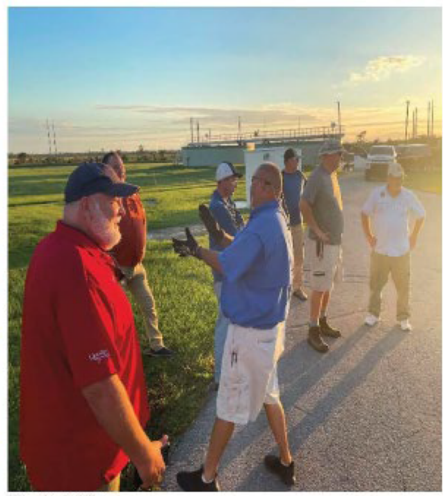
ARWA, Andrew Crawford surveying damage to a well

One of the many night time deliveries of Generators

Checking for Leaks

Georgia Rural Water Association Emergency Response

Some of the response efforts



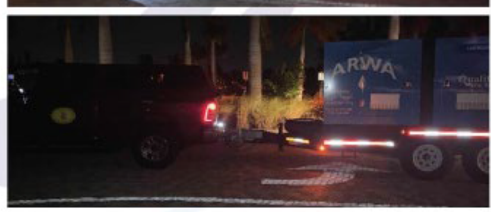
Morning Briefing

National Rural Water Emergency Response Trailer and Truck that was utilized as the Command Center.

FRWA's numerous Emergency Response

Some of the many assets that were used.

ARWA Darrell Brewer, Delivering a Generator.



October 12th the last of our two Man deployments headed back to Alabama with two of our Large Generators.

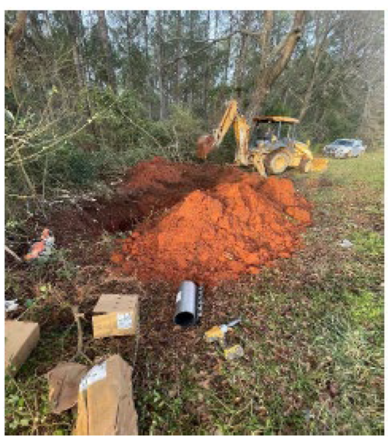
Christmas Deployments

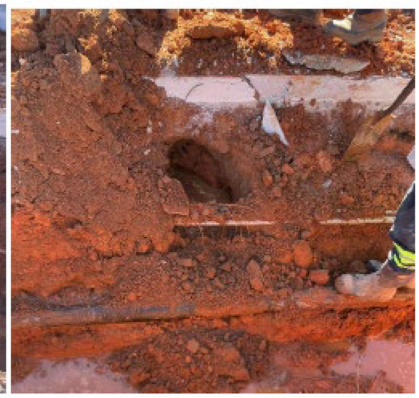
Water Delivery to Old Line Water Authority in Jackson, Alabama, located in Clarke County. They serve approximately 2,475 water customers. Through the Associations' efforts, Old Line Water Authority Received 432 cases of bottled water. (10,368 Bottles)

Water Delivery Wilcox County Water Authority, in Camden, Alabama, located in Wilcox County, Alabama, serves approximately 4050 Customers. Through the Associations' efforts Wilcox County Water Authority, Received 576 cases of bottled water. (13,824 Bottles)

Water Delivery City of Reform Water & Sewer Board, Located in Pickens County, Alabama, serves approximately 754 Customers. Through the Associations' efforts City of Reform Water & Sewer Board, Received 432 cases of bottled water. (10,368 Bottles)

Leaks, Repairs, and Generators






ARWA


ARWA

Rural Water and Wastewater Cyber Security Circuit Rider Program

The cybersecurity of small and rural water systems is a paramount concern for the ARWA and NRWA. However, the multifaceted nature of cyber threats to vital water infrastructure means that many rural utilities are ill-equipped to ward off such attacks, often due to a lack of financial means and technical proficiency. Furthermore, it's commonplace for smaller rural communities in Alabama to be reliant on a single operator who is already overburdened with a multitude of critical duties.

Congress had stipulated that all systems catering to populations over 3,300 complete a cyber/physical evaluation by December 31, 2021. Yet, smaller systems serving populations less than 3,300, with their constrained financial and personnel resources, are in dire need of direct aid to comply. Additionally, federal agencies like the EPA and Rural Development are starting to mandate cybersecurity provisions before authorizing any new financial assistance.

We suggest this Committee consider providing a corps of cybersecurity specialists to help rural water systems protect their utility and the public health of the residents. This program should aim to assist rural utilities that lack the means or knowledge to adhere to these federal mandates. Initiatives could encompass swift evaluation of the utilities' efficacy in safeguarding their cyber infrastructure and public health, creating sensible protocols to bolster protection, and assisting with the enhancement of any deficient cyber protection strategies.

Modernization of Rural Development Water & Environmental Programs

Across Alabama and the nation, numerous small and rural utilities function on slim profit margins, depending largely on customer rates to cover all operation costs like salaries, infrastructure loan repayments, energy costs, materials, maintenance, and more. This financial limitation is particularly felt by utilities serving low-income residents with smaller economies of scale, which urgently need to modernize their aging water infrastructure.

NRWA and ARWA propose the modernization of the Rural Development Water and Environmental Programs to align with current needs, offering affordable financing and servicing options. This mirrors the modernization seen in other infrastructure programs such as the EPA State Revolving Loan Fund programs. Currently, EPA has the authority to offer "additional subsidization", which can include principal forgiveness, zero or negative interest loans, or a mix of these tools. Moreover, loan terms have recently been lengthened.

NRWA supports current and past legislative initiatives that would grant the Rural Development additional affordable financing and servicing instruments. New financing options should empower Rural Development to extend zero and 1% percent loans to disadvantaged or financially struggling communities. This limited authority should be targeted for low-income communities to ensure their access to affordable water and wastewater services.

I want to note that on June 22nd, the FY2024 Senate Agriculture, Rural Development, Food and Drug Administration, and Related Agencies Appropriations bill reported the inclusion of $30 million in loan authority for USDA to provide 1% loans to selected communities.

In Alabama, there are numerous systems that would greatly benefit from these enhanced authorities. Whether the communities face financial constraints due to low-income availability for utility bills or the financial hardship caused by the closure or relocation of commercial entities, these flexible options would shield these communities from excessive, costly, and burdensome utility bills and potential default on community financial commitments.

Concerning servicing options, the Rural Development should be equipped with the means to financially stabilize a utility borrower in communities experiencing economic downturns through no fault of their own. Both the EPA and USDA Rural Housing Service currently have this authority.

As stated earlier, Rural Development is the only federal agency specifically mandated by Congress to cater to rural communities with a population below 10,000. These rural systems, characterized by thin revenue margins over expenses and a lack of economies of scale, can face serious challenges in providing affordable rates for lower-income residents.

NRWA and ARWA appeal to this Committee to consider providing these additional affordable financing and servicing options.

Regionalization and Consolidation for Rural Water Utilities

According to EPA's Safe Drinking Water Information System (SDWIS), in Alabama, 503 community water systems exist currently, out of which 376 (or 75%) serve communities with a population of less than 10,000. Different states and regions have their own interpretations and policies regarding what counts as regionalization or consolidation. Considering the significant number of small community water systems throughout the country, it's only natural that regionalization and consolidation of water and wastewater services occur wherever it is economically viable.

We urge the Committee to include additional measures that will incentivize affordable sustainable services for underserved rural communities. We recommend this language should focus on lower-income communities lacking adequate water or wastewater services. These communities frequently fall short in terms of financial and managerial resources and the ability to independently maintain affordable services. A financial incentive will allow a high-performing local or adjacent system to apply for a grant or loan on behalf of the underprivileged community.

At present, most rural utilities and their boards have the desire to provide service to their neighboring communities but lack the necessary financial support to move forward. Local and adjacent utilities and their boards hesitate to impact their current customers financially by raising rates or taking on the financial burden of inadequate infrastructure for new customers outside their original service area. For example, there is one small struggling community in south-central, AL whose neighboring, higher-performing system already treats the wastewater for the community. The neighboring system has expressed interest in taking over operations for its neighbor-in-need, but the struggling system's existing debt and needed infrastructure upgrades would cause an undue burden for the higher-performing system's existing customers.

NRWA and ARWA believe that a calculated financial incentive could mitigate these concerns and further the objective of providing affordable and financially sustainable services to rural residents in underserved areas.

The authority should be directed to ensure additional subsidy is directed exclusively toward the community in need. The EPA keeps a list of significant non-compliant utilities, and Rural Development tags many of these utilities as high risk. We believe that this initiative will effectively decrease that list and could potentially result in future federal resources being saved.

Workforce Development

As highlighted before, the imminent retirement of a large portion of our workforce remains a major concern, especially given that labor market data predicts half of these workers will exit the water industry within the coming decade. Owners and operators of rural water and wastewater utilities require a steady flow of trained personnel to ensure the public continues to enjoy clean, safe water and to maintain the infrastructure necessary for keeping rural services economically sustainable.

To address this, NRWA, State Rural Water Associations, rural water utilities, USDA, the Department of Labor (DOL), and private stakeholders such as CoBank, have jointly established the first nationally acknowledged Guideline Standards for Registered Apprenticeship for water and wastewater system operators. This successful collaboration has resulted in quality job creation in rural USA.

The vast majority of small community water systems across the country face challenges due to limited staffing, with some systems only employing one part- or full-time operator. The limited economies of scale and technical expertise in rural water utilities are further strained by a lack of qualified operators, which increases the difficulties small and rural communities encounter when trying to comply with complex federal regulations and provide safe, affordable drinking water and sanitation.

The NRWA Apprenticeship Program has seen considerable growth and success over the past five years, creating over 600 water industry jobs in rural America. However, the registered apprenticeship program model is constrained in very small communities where there is insufficient capacity to employ or provide mentorship to an apprentice. This problem is unique to these communities and acts as a significant obstacle to attracting, training, and retaining capable staff.

This harsh reality also inhibits these communities' access to many resources available through the Department of Labor's workforce system.

In Alabama, our Apprenticeship Program standards were finalized with the Alabama Office of Apprenticeship on February 7th, 2020. Despite delays due to the pandemic, we have 14 participating employers and successfully placed 9 apprentices with systems. Our first graduate is projected to complete the program in April 2024. Our unprecedented, growing program in Alabama aims not only to increase public awareness of careers in the water and wastewater sectors through state career centers, but also to support newcomers in the field with a structured program offering incentives and assistance to those starting out in the industry. Furthermore, Alabama's Rural Water Association's training program is listed on the Eligible Training Providers List for Alabama, and we recently received approval from the VA for additional incentives and resources for veterans entering our field.

We urge the Committee to consider incorporating financial resources and policies into the 2023 Farm Bill to provide mentoring and training to address these workforce issues specific to Rural Development borrowers and potential borrowers. A sustainable solution is urgently required to boost participation and retention for the rural water workforce, safeguard the substantial federal investment in rural America's water and wastewater systems, and improve these crucial services and basic civic necessities on which our customers rely.

1926(b)- Curtailment or Limitation of Service

This provision, or what is commonly referred to as the 1926(b) service protection clause, is of the utmost importance to our membership. This provision has protected the service areas for many smaller utilities in Alabama and across the nation. The 1926(b)-protection clause (7 U.S.C. 1926(b)), was designed by Congress with two goals in mind:

> (1) Congress wanted to ensure the USDA federal debt held by borrowers was protected and would be repaid, and
>
> (2) Congress wanted to promote the development of rural water systems for rural residents and ensure they are economical and safe.

There have been previous attempts to modify or eliminate this existing provision, and they were rejected by this Committee. This provision has been litigated for decades since its inception. NRWA is concerned that any modification of the existing statute would have to be relitigated at a potentially tremendous cost to the rural utilities and could potentially reduce their service area and cause negative financial consequences, including repayment ability to Rural Development and long-term sustainability.

Conclusion

In summary, USDA's Rural Development Water and Environmental Programs are critical to keeping water and wastewater service areas economically viable, while also providing the funding and resources to address underserved communities. With a current backlog of approximately $4 billion, demand remains high. The accompanying direct technical assistance is necessary to assist rural utilities and enhance the capacity and experience to protect the community's and federal government's investment. These programs work together to advance the mission to provide safe, sustainable, and affordable water and wastewater services throughout Rural America. ARWA and NRWA are honored to continue and strengthen this successful partnership with USDA Rural Development and this Committee.

Thank you for the opportunity to participate today, and I am happy to take any questions that you may have at this time.

QUESTIONS AND ANSWERS

JULY 19, 2023

U.S. Senate Committee on Agriculture, Nutrition, and Forestry
Subcommittee on Rural Development and Energy
Rural Water: Modernizing our Community Water Systems
July 19, 2023
Questions for the Record
Ms. Jennifer Day

Senator John Boozman

1. Throughout our series of Farm Bill hearings and in my travels around the country talking with stakeholders about what they believe is needed to increase access to federal programs for small and rural communities, one issue has consistently come up. And that is the issue of overburdensome applications processes. What specific challenges do small communities face when navigating the funding application process for water and wastewater projects and then how can we alleviate the administrative burden for communities when participating in these programs?

Thank you, Senator Boozman, for this question. The small systems have volunteer boards, part time clerks, and operators that rely on federally funded predevelopment grants and technical assistance, like the RCAP network provides. They do not have the funds available to pay up front for engineering costs that are required for the Preliminary Engineering Reports that are required as part of the Water and Environment Program (WEP) Loans. In most cases, it takes multiple years of predevelopment planning and multiple funders to successfully implement each project. Big cities have planners and engineers on staff or have access to predevelopment funding to hire consultants to help design projects and estimate costs. Where small community members are available and motivated to contribute to the loan application process on the RD Apply portal, an electronic application intake system for Rural Utilities Services (RUS) Programs launched in 2015, their enthusiasm often turns to frustration. The design of the site requires an intimate working knowledge of the application process, an understanding of how data is displayed and requested under the numerous tabs and sub-tabs, and patience – forms requested after portal submission can be repetitive and confusing. For community members or even technical assistance providers seeking guidance, they may soon realize that the Water & Environmental Customer User Guide available for the RD Apply system was last updated in October of 2018 and has not kept up with changes in the web-based application process. Continued support, increased funding and state office oversight of the SEARCH and Water and Waste Predevelopment grant funds, in addition to more effective and user-friendly technical resources, will support more successful applications to WEP. This should also continue to increase funding in the next five years to leverage the infrastructure dollars set aside by the Environmental Protection Agency (EPA) as part of the Bipartisan Infrastructure Law to make sure that no small and/or rural systems are left behind.

- Reauthorize the **Water & Waste Disposal Loan & Grant Program** (Section 306 of the Consolidated Farm and Rural Development Act).

- Reauthorize the **SEARCH -Special Evaluation Assistance for Rural Communities and Households Program**, include additional matching flexibility under the program to include in-kind or waivers in cases of extreme need.
- Reauthorize the **Water & Waste Disposal Predevelopment Planning Grant Program**, include additional matching flexibility under the program to include in-kind or waivers in cases of extreme need.

2. I often speak with mayors and community leaders across Arkansas and the country who understand the great challenges they face but lack the human and technical infrastructure to determine the steps necessary to address them. Can you please list any recommendations you might have regarding ways in which the Farm Bill can better facilitate capacity building in rural communities?

I appreciate this question, as we build trusted relationships in the rural communities we serve and are often asked if we can continue our work on predevelopment planning activities and application assistance on projects beyond water and wastewater needs. One of RCAP's most recent new initiatives was through a Community Facilities (CF) Technical Assistance Cooperative Agreement with USDA-RD. Community Facilities technical assistance consists of enriching resources and leveraging funding to improve, expand, or build necessary community facilities, such as healthcare facilities, city halls, fire stations, schools, etc. Putting this provision in the Farm Bill to authorize technical assistance to rural communities to assist with their other infrastructure needs would increase their ability to plan for growth that can support community and economic development.

RCAP Community Facilities Programs Farm Bill Recommendations:

- Reauthorize the **Community Facilities Technical Assistance and Training Program** (Section 306(a)(26) of the Consolidated Farm and Rural Development Act), set-aside no less than 10% of funding for national multi-state technical assistance and capacity building, and to create additional flexibility under the program by removing caps on funding.
- Reauthorize the **Community Facilities Direct Loan & Grant Program** (Sec. 306(a)(19) of the Consolidated Farm and Rural Development Act).
- Authorize a **Community Facilities Connect Program** to provide five-year direct community facilities technical assistance in each state and territory, to help underserved rural areas access the Community Facilities Direct Loan and Grant Program, plus other funding sources.

3. While the health impacts to communities without clean drinking water and sanitation systems is clear, can you paint a picture of what the economic development challenges look like in communities without access to high functioning water and wastewater systems?

I live in rural western MA and am surrounded by towns that have not invested in development planning for their downtown areas. Restaurants and small hotels have been forced to close because the water or wastewater infrastructure in the community lacked the ability to support those businesses. Often the business doesn't own enough land to expand and develop their own well or septic solution. They may be too close to a river, a neighboring well or septic system and unable to meet the required setback distances, which also hinders expansion. Then the business closes and the building falls into disrepair and becomes unappealing for new investors. I have visited rural towns across new England that are experiencing the same problem, vacant business or business that are limited by the water and wastewater infrastructure and cannot expand - even when there have business models that are working, the lack of planning by the municipality stymies the growth potential for development. The success stories exist, and they typically involve dedicated volunteers that work on planning and application requirements to leverage support for projects across business, investor, and municipal support. RCAP supports the authorization of a Rural Investment Initiative (RII), which, if enacted would be a locally driven, flexible capacity building and financing program to support all mission areas of Rural Development: rural utilities, rural housing, and rural business. Many USDA-RD programs that help unlock private investment are difficult for rural towns and organizations to access. Local governments and non-profit organizations often lack the staff and technical expertise to apply for grants. It is also exceptionally challenging for part-time local government officials and their limited staff to track and advocate for their community's fair share of funds from states or apply for federal grants directly. The RII would match rural communities and their needs to a cohort of local, regional, and national technical assistance providers, making it easier for communities to access right-sized technical assistance and ensuring better access to <u>all</u> USDA-RD programs, financing, and services. The RII would be designed to provide financial capital directly to communities and strengthen human capital to unlock new investment, including public private partnerships, that would improve the capacity, economic health, and overall well-being of local communities.

RCAP Rural Investment Initiative Farm Bill Recommendations:

- Authorize a **Community Facilities Technical Assistance and Training Program** with dedicated resources in the Rural Development Title to support locally driven capacity building and financing for small towns and rural communities across all mission areas of USDA-RD.

<u>Senator Ben Ray Luján</u>

1. New Mexico has thousands of small communities that depend on rural water programs for safe and reliable drinking water. Ms. Day, you highlight in your testimony the need for increased training investments for, as you state, a "dwindling water workforce."

   It is estimated that 50% of the rural water workforce will leave the industry within the next 10 years. That is why, again this year, I urged Senate Appropriations to support the workforce needs of the water and wastewater industry, particularly in rural and small communities. This letter calls for the establishment of a national water and wastewater operator industry workforce training and apprenticeship program through Department of Labor's Apprenticeship Grant Program.

Ms. Day, in what ways could USDA and DOL better coordinate to train the workforce that is urgently needed to protect the rural water systems that communities in New Mexico and across the nation depend on?

Thank you, Senator Luján, for this question. I observed a wastewater system in Bell Buckle, Tennessee, and was very impressed by the new young operator that the system secured through a state-funded apprenticeship program. Funding salaries and the associated licensing fees for apprentice programs is key to solving the "dwindling workforce problem". I asked the young operator so many questions and he was eager to share his experience. He was working for a contractor at the plant on the air conditioning unit and the current plant operator recruited him for the internship program. Most young people are not aware of water and wastewater careers, even those that attend trade schools. This young man was supported with a salary and the state covered his training and testing costs as he passed his exams. He was excited to be earning a livable wage and staying in his rural community. The systems that have USDA loans and are in DOL priority communities could all take advantage of a similar program that supports existing careers in rural areas.

Administrative professionals are the most overlooked but essential positions at a water utility, especially in small communities. They are often also the most under-trained of any position a utility might possess. Large utilities often employ multiple administrative professionals under a range of job titles including utility clerk, billing clerk, and administrative assistant, who work alongside boards and mangers to help manage the systems. In small communities, there is often a single administrative professional who takes on most of the day-to-day financial, managerial, and occasionally operational work of the system. The work of these administrative professionals directly impacts the utility's ability to comply with the Safe Drinking Water Act (SDWA) and to ensure the financial sustainability of the system. RCAP believes that one of the most effective ways to enhance utility capacity development is to invest in leadership and management training for drinking water administrative professionals. RCAP has taken the first steps to build an innovative program to train and credential drinking water administrative professionals that is based on a job analysis and need-to-know criteria. This program was initially funded by EPA and RCAP continues to look for ways to develop support services for all the water workforce staff.

U.S. Senate Committee on Agriculture, Nutrition, and Forestry
Subcommittee on Rural Development and Energy
Rural Water: Modernizing our Community Water Systems
July 19, 2023
Questions for the Record
Mr. Joseph Duncan

Senator John Boozman

1. I often speak with mayors and community leaders across Arkansas and the country who understand the great challenges they face but lack the human and technical infrastructure to determine the steps necessary to address them. Can you please list any recommendations you might have regarding ways in which the Farm Bill can better facilitate capacity building in rural communities?

Response
Funding planning efforts and the Circuit Rider program are key to helping our rural communities identify paths forward for addressing their infrastructure issues. Most small water systems know they need to do something, but they just do not know how to navigate the financial, technical, and public challenges in advancing a project from an idea to construction.

It is recommended that the Committee consider specifically allocating planning grant funding under the USDA Water & Environmental Programs (WEP) in the upcoming Farm Bill. Planning typically involves retaining a consultant(s) to develop recommended improvements and associated costs. Identifying the technical solution is usually the easiest part of the process. The complicated part of advancing a project is securing funding and getting public support for the project. Typically, consultants assist in that process, ranging from engineers to financing specialists to public relations professionals. Investing in the development of a project from planning through construction is often a stumbling block for small water systems due to financial restrictions. Being able to access funding for planning is critical in getting projects off the ground. The USDA WEP does offer planning funds, but they are in the form of loans. Providing grant funding specifically for planning can play a key role in advancing projects.

It is further recommended to continue funding the Circuit Rider program through the upcoming Farm Bill. The Circuit Rider program includes a nationwide pool of experienced hands-on water experts to provide peer-to-peer direct assistance to help rural systems manage and operate their utility. Circuit Riders are typically known for their boots on the ground efforts with troubleshooting issues and solving problems at water systems. Their technical expertise is critical but their assistance with management, finance, and planning is equally important given the lack of managerial capacity in most water systems. When it comes to projects, Circuit Riders work closely with water staff and municipal leaders to educate them on what planning is required and connecting them with consultants who can move them through the process. They often play a key role in supporting the water system throughout the planning process.

Thank you for the opportunity to provide a response to your question. I am happy to be a resource for any future questions you may have.

U.S. Senate Committee on Agriculture, Nutrition, and Forestry
Subcommittee on Rural Development and Energy
Rural Water: Modernizing our Community Water Systems
July 19, 2023
Questions for the Record
Ms. Catherine Coleman Flowers

Senator John Boozman

1. I often speak with mayors and community leaders across Arkansas and the country who understand the great challenges they face but lack the human and technical infrastructure to determine the steps necessary to address them. Can you please list any recommendations you might have regarding ways in which the Farm Bill can better facilitate capacity building in rural communities?

Getting technical assistance to rural communities is a major problem and it leaves many without access to the help they need. The Farm Bill can facilitate capacity building in rural communities by supporting funding to support deploying or training grant writers for communities that do not have this skill. However, the key to sustaining access is by providing training for community based technical assistance. That also includes hot spots for those areas without stable internet or broadband because applying for grants often involves registering at various government websites.

2. While the health impacts to communities without clean drinking water and sanitation systems is clear, can you paint a picture of what the economic development challenges look like in communities without access to high functioning water and wastewater systems?

It is hard to attract large economic projects that areas that do not have high functioning water and wastewater systems. This will leave many communities out of the clean energy transition and the prosperity that comes with it. Often it is a criterion for industry to locate in an area causing communities not to be able to compete for retail such as pharmacies or grocery stores, or any industry that from other economic segments that needs access to water and sanitation. Without it, there is more economic despair where there are no good paying jobs. leading to hopelessness, population loss, and youth leaving the area to seek employment. High functioning water and wastewater treatment infrastructure can reinvigorate communities that are literally dying without it.

U.S. Senate Committee on Agriculture, Nutrition, and Forestry
Subcommittee on Rural Development and Energy
Rural Water: Modernizing our Community Water Systems
July 19, 2023
Questions for the Record
Ms. Pauli Undesser

Senator John Boozman

1. You mentioned in your testimony the importance of flexibility for the funding programs at USDA. Can you please explain where you see additional flexibility needed and how that could provide better outcomes for small and rural communities?

USDA, through its Rural Utilities Service Water and Environmental Programs (WEP), provides an essential service to rural communities that need technical assistance and/or financing to help overcome water challenges. Numerous programs focus on providing funding through governmental entities to support larger-scale projects, while other programs, mostly loan programs, such as those facilitated through non-profits, also help grant access to running water and septic systems. These programs are essential, but here are three gaps we have identified where flexibility has benefits:

1. **USDA funding is not going directly to the individual and is often trickled down through several agencies (state or local) or requires many applications before it benefits the community. WQA has heard from other non-profits specializing in these types of programs who refrained from applying for USDA funding because of the cost and lengthy process associated with receiving funding.**

2. **Projects often focus on community system upgrades, connecting a community to a centralized system, or digging a new well when other cost-effective immediate solutions could be applied to the existing water source in most circumstances, such as point-of-use (POU) and point-of-entry (POE) technology.**

3. **Many programs that would directly assist a household are loan programs, as opposed to grant programs, which may prevent participation from people who need it most.**

While WQA believes several of these issues could be corrected through existing programs, we believe the current program offerings must be expanded and allow flexibility to cover these gaps. This is why we strongly support the inclusion of the bipartisan, bicameral Healthy H2O Act in the 2023 Farm Bill.

The Healthy H2O Act would help these rural and underserved communities by authorizing a new U.S. Department of Agriculture grant program to cover the costs of water quality testing and the purchase, installation, and maintenance of POU/POE water treatment systems certified to address health-based contaminants found in their drinking water. Funding would go directly to individuals, licensed child-care facilities, and non-profits equipped to help people undergo testing and then find and install a water treatment product to address their situation.

This program would be used to assist the over 43 million people who rely on groundwater delivered from private wells and those dependent on rural community water systems that are struggling with ongoing or recurring issues. This is important since violation incidence in rural areas is more common than in urbanized areas and may take several years to correct,[1] while POU/POE systems can be deployed far more efficiently.

In addition to being a bipartisan effort, the bill is supported by more than 35 organizations, including the Rural Community Assistance Partnership (RCAP) and Water Systems Council (WSC), which currently help administer USDA programs.

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[1] https://www.researchgate.net/publication/368994706_Triple-bottom-line_approach_for_comparing_point-of-use_point-of-entry_to_centralized_water_treatment

2. I often speak with mayors and community leaders across Arkansas and the country who understand the great challenges they face but lack the human and technical infrastructure to determine the steps necessary to address them. Can you please list any recommendations you might have regarding ways in which the Farm Bill can better facilitate capacity building in rural communities?

Capacity building starts with education for both the community and technical professionals. The latest data shows that much more must be done to bring awareness to water quality issues.

The Water Quality Association commissions a national study to gather data on U.S. consumers' evolving attitudes toward water and water treatment. The 2023 study shows that 58% of consumers are concerned about the quality of their household water supply, more than any previous study. However, there is still a lack of education, as illustrated by only about one-third of survey respondents being able to name a specific contaminant. Furthermore, households on municipal water receive an annual Consumer Confidence Report (CCR) on their water quality. Most (55%) claim they didn't receive it or don't know if they received it. Only a third (30%) claimed to have received, read, and understood the CCR. The remainder (14%) state that they didn't read it or did not understand it.[2]

To better help empower our communities, an interagency working group should be established that collaborates with industry to improve water literacy. Communities need to understand not just the issues with their water but the available solutions. WQA's Water Treatment for Dummies booklet and the establishment of our public-facing website, Betterwatertoday.org, are some of the ways we hope to tackle this issue. However, a coordinated effort between USDA, EPA, HHS, and the HUD would help amplify this messaging and better support this initiative.

Additionally, training and providing professionals with the tools to discuss these issues with residents would also go a long way in bridging the gap. The Farm Bill traditionally authorizes loan and grant programs deployed through non-profits, but funding should also be available to expand the workforce for water treatment services and qualified professionals outside of the traditional municipal realms. More people should be encouraged to enter and join the water treatment industry, which has good-paying, localized jobs while upholding the high professional and ethical standards the industry has set for itself.

WQA is doing its part to increase the hiring of water quality professionals. WQA's website includes job postings, operates a mentorship program, and an active rebate to increase participation in training and certification programs. However, it would be helpful if the USDA facilitated additional funding and support by promoting these education programs in rural areas that go beyond municipal water treatment. There are courses already available to start building the workforce these communities need today.

WQA's professional certification programs use industry-approved and recognized goals for knowledge and skills. Training programs are offered on a scheduled or on-demand basis; many are remote instructor-led classes. Allied professionals also take advantage of WQA's training. These include academic researchers, state and local public health professionals, dialysis technicians, and U.S. EPA personnel. WQA training materials are also used as training for state POU/POE water treatment licensing in several states, such as California, Colorado, Connecticut, Minnesota, New York, Oregon, Texas, and Wisconsin.

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[2] https://wqa.org/grow/wqa-consumer-opinion-study/

3. Many households in Arkansas rely on private wells for their drinking water. Can you please expand on the most common challenges these households face when maintaining or upgrading these facilities and where you see gaps in funding to improve drinking water for those that rely on wells for their drinking water?

Private wells are an important source of drinking water for many Americans, particularly in rural areas. However, these wells are not subject to the same regulatory oversight as public water systems, and as a result, many residents may unknowingly consume contaminated drinking water. Testing and monitoring for drinking water are essential first steps, and as of now, there are no federal requirements for these systems. As residents become aware of health-based contaminants, many will then look to identify proper remediation and mitigation options.

Today, most USDA program options focus on transitioning a household or neighborhood currently served by a well to a new water source, including requiring the drilling of an entirely new well, which could have the same contaminants, or a public water system that could be far away. These options are usually costly and time-consuming, thus delaying relief. However, there are other, more immediate options available. "Permanently" remediating a well can be done, but that only applies to microbial contamination. Naturally occurring or man-made contaminants such as Arsenic, Radon, and Nitrates can be treated almost immediately using third-party certified point-of-use (POU) and point-of-entry (POE) water treatment systems.

To address this gap and expand available solutions, we support the passage of the bipartisan Healthy H2O Act that would establish a USDA grant program to increase access to safer and healthier drinking water in rural communities that have often been overlooked when it comes to recent infrastructure investments. The Healthy H2O Act will fill this gap by providing readily deployable, cost-effective, and sustainable final barrier solutions such as POU/POE to reduce contaminants in drinking water.

Senator Ben Ray Luján

4. Like several other states, New Mexico has seen first-hand the devastating impacts a PFAS contamination can have on a community. Just last week, the U.S. Geological Survey released a study that found 45% of tap water in the United States could contain PFAS. Rural communities have historically been overlooked by federal investments when it comes to addressing drinking water challenges, especially those who are dependent on private wells.

   In New Mexico, over 10% of our population relies on private wells for their water supply and do not have access to the same water quality testing programs as public water supplies.

   The Healthy H2O Act, which I cosponsor and I understand the Water Quality Association is supporting, would provide grants to rural communities to purchase water filtration devices to protect private well water supplies.

   Beyond protecting private water supplies, how would the Healthy H2O Act assist people in small, rural communities with testing and evaluation equipment so that these families can trust the water coming out of their tap?

WQA believes strongly in the "3 Ts": Testing, Training, and Taking Action.[3] Testing is always the first step since the contaminants we see in rural areas, especially for people dependent on wells, vary from state to state, county to county, and even home to home. Providing cleaner and safer drinking water requires a tailored solution based on the contaminants identified, whether it's nitrates, arsenic, lead, or even PFAS.

The Healthy H2O Act would support water testing and allow rural residents to submit other documentation that demonstrates the presence of health contaminants in their drinking water in order to receive the grant. When a health contaminant is identified, the grant will help them "take action" by facilitating the purchase, installation, and maintenance of certified water treatment systems such as point-of-use (POU) and point-of-entry (POE)

[3] https://www.epa.gov/ground-water-and-drinking-water/individual-modules-3ts

technologies. The Healthy H2O Act requires certified water treatment technologies for the health contaminants identified, referencing the appropriate NSF/ANSI standard(s). These national standards cover product performance, material safety, structural integrity, and quality control to help ensure the public that these products work as intended.

These technologies are essential to providing cost-effective treatment to the 43 million individuals that rely on groundwater delivered from private wells, but they also play a crucial role for people with centralized treatment. The Healthy H2O Act includes people who are connected to small and very small community water systems, as residents served by these systems are often not afforded the same quality of service that midsize and large systems are able to provide, given their relatively large ratepayer bases and staffing capacities. According to the EPA's Safe Drinking Water Information System (SDWIS) data, between 2008 and 2018, 2,720 small community water systems experienced at least one maximum contaminant level (MCL) violation, with a total of 31,127 MCL violations reported. Of those violations, 68% occurred in very small systems providing water to less than five people, many of which were chronic violations. [4]

The Healthy H2O Act will help provide these communities with POU and POE technologies, which have been utilized for over 75 years and can help improve consumer confidence in the water coming out of the tap. These products are widely used and have been acknowledged in guidance by the U.S. EPA and Centers for Disease Control and Prevention (CDC) for mitigating drinking water contaminants. According to WQA's 2023 Consumer Opinion Study, more than 60% of Americans already have a refrigerator filter, and almost 50% have additional POU or POE water treatment solutions in their homes.[5]

We applaud your support of the Healthy H2O Act, which will help people dependent on private wells and small community water systems utilize these readily deployable and effective solutions. WQA is dedicated to working with you to improve water quality across the country and in New Mexico. We would be happy to meet with you to discuss how these technologies can address PFAS.

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[4] https://doi.org/10.1002/aws2.1320
[5] https://wqa.org/grow/wqa-consumer-opinion-study/

U.S. Senate Committee on Agriculture, Nutrition, and Forestry
Subcommittee on Rural Development and Energy
Rural Water: Modernizing our Community Water Systems
July 19, 2023
Questions for the Record
Mr. Robert N. White IV

Ranking Member Tommy Tuberville

1. Potential cybersecurity threats and natural disasters are constant concerns for water systems across the country. We must ensure systems are prepared to respond to these threats and resilient enough to quickly get back up and running to ensure access to drinking and wastewater services.

   What expanded authority or improvements do you think is necessary to address cybersecurity in the Farm Bill?

   Many small and rural systems, especially in Alabama and throughout the nation, face financial and expertise constraints in defending against cyber threats. It's not uncommon for such utilities to have a single operator, be it full-time or part-time, overseeing the entire operation.

   In line with my testimony and building upon one of the nation's most successful technical assistance model proven over the past 40 years, the NRWA urges this Committee to consider the introduction of Cybersecurity Circuit Riders. It's important to note that while the existing Circuit Riders have been effective in their roles, they don't possess the specialized skills inherent to adept cybersecurity professionals. The realm of cybersecurity is ever-evolving; with each vulnerability patched or defense erected, a new threat emerges. This dynamic is further complicated by the advent of sophisticated AI Learning Language Models, which have already been weaponized to spawn novel attack avenues such as WormGPT, FraudGPT, and others.

   The role of the Cybersecurity Circuit Rider would be to assist these systems in safeguarding their utilities and customers against cyber-attacks. Proposed initiatives include quick evaluations of current cybersecurity response capabilities, crafting realistic protocols for enhanced cyber protection, and reporting on the cyber defense posture of the water supply, Cybersecurity Circuit Riders will bolster the utility's defense capabilities, allowing them to judiciously use their limited financial resources to maintain services and ensure public health.

   Key points:

   - Legislation authorizing Cybersecurity Circuit Riders will significantly aid rural utilities that don't have the financial or technical means to shield themselves from cyber threats.

- Prior to new engagements, USDA RD mandates a cyber evaluation.

- Local administrations in Alabama and nationwide are exposed to potential threats from malicious entities globally.

- In 2021, cyber assailants targeted water treatment facilities in California and Florida. With a more robust and regular cybersecurity assessment, it might have been possible to prevent unauthorized access altogether. Thankfully, those breaches were detected in time to avert significant harm to the public. However, it's crucial to note that beyond mechanical system vulnerabilities, customer and financial data are continually under threat. Such exposures can jeopardize the personal and financial information of utility customers and also lead to malevolent actors demanding ransoms from utilities. In such situations, without robust backups and redundancies, utilities could be compelled to pay ransoms just to access their own systems and data. This is yet another domain where the expertise of a Cybersecurity Circuit Rider would prove invaluable.

- The proposed legislation will deploy a cadre of Circuit Rider cybersecurity experts to aid rural water systems in ensuring the well-being of their communities.

- We thank this Committee for considering our comments and ideas for improvement of this essential legislation, with aims at a more robust, ready, and secure water sector.

2. Our nation is facing an ongoing workforce shortage, and the water industry is no exception. Water systems need trained and experienced personnel to function. Yet, the industry is losing more employees to retirement, creating a knowledge gap. Rural communities are already at a disadvantage in recruiting and retaining qualified employees compared to their urban counterparts, and we must ensure they are not left behind.

   What provisions are needed in this Farm Bill to improve recruitment, training, and retention for rural water operations?

Workforce Transition & Apprenticeship Response

As stated in my written testimony, employment data indicates that 50% of our workforce will be retiring in the next decade. Recognizing this serious gap, the National Rural Water Association (NRWA) launched a Department of Labor-recognized Apprenticeship program. To date, 36 states, including Alabama, have initiated local apprenticeships using the proven Registered Apprenticeship model. These programs not only introduce new talent to our sector but also offer a structured career path, promoting retention and enhancing worker expertise.

To address this workforce challenge, it's crucial to support the NRWA Apprenticeship Program and allocate resources for ongoing recruitment, training, and technical assistance.

NRWA Apprenticeship Program Overview

National Rural Water, State Rural Water Associations, local small and rural community water utilities, and federal agencies including USDA, DOL and EPA are collaborating successfully to establish the first nationally recognized Registered Apprenticeship Program for water and wastewater system operators (O*NET-SOC CODE: 51-8031.00), while creating jobs in rural America. As of August 2023, 36 State Rural Water Associations have established nationally approved apprenticeship programs, with over 600 apprentices either trained or in training. This joint effort between National Rural Water, State Rural Water Associations, local water utilities, and federal agencies aims to fill the workforce void in rural water and wastewater systems. Alabama currently has 14 systems engaged in the program with 9 active apprentices placed and 1 currently pending, with the first Apprentice scheduled to graduate in April of 2024.

The U.S. has over 50,000 community water supplies. With 91% catering to populations under 10,000 and 55% serving fewer than 500 residents, the projected workforce departure is concerning. The challenge for rural water systems is attracting and retaining talent due to unclear career progression and limited compensation. The Farm Bill authorization will enable these systems to embrace modern apprenticeship models and clear career paths.

NRWA's apprenticeship includes 4,000 hands-on training hours, 288 technical instruction hours over two years, and periodic wage increments. Graduates are equipped to ensure their communities have safe water and sanitation around the clock.

The program covers a wide range of skills, from basic tool handling and safety measures to advanced system operations, compliance with federal regulations, and the adoption of new industry technologies.

Program Impact & Funding

In 2018, Rural Development granted NRWA about $10 million over a two-year period to kickstart this initiative. NRWA now estimates $9.45 million in annual funding will:
- Employ Apprenticeship Program Coordinators across the U.S. and Puerto Rico.
- Initiate apprenticeship programs in more states.
- Enroll more apprentices, engage additional employers, offer technical instruction, and provide on-the-job training which will increase wages as skills develop.

Most participants in this program serve communities with populations under 5,500, emphasizing the program's importance to smaller, underserved areas.

3. Under current law, USDA Rural Development has jurisdiction over rural communities and aims to help them economically prosper. However, I've heard from small water system operators across Alabama that current EPA regulations require expensive and advanced filtration technologies to remove contaminants that many systems do not have the technologies, staff, or resources to test for.

Do you believe there is a disconnect between EPA standards and the mission USDA has for rural communities? How do you propose to bridge this gap?

The USDA's Rural Development has maintained a robust partnership with Alabama for an extended period. Since 2012, they have channeled over $411 million into 224 distinct projects within Alabama, with nearly 50% of these initiatives directly benefiting communities that are socially vulnerable. For water and wastewater infrastructure financing needs, Rural Development stands as a tested and reliable ally.

While the EPA's intentions are commendable, its regulations often pose significant challenges, both in terms of implementation and financial costs, particularly for smaller rural areas. It's imperative that the EPA offers the necessary technical support and financial aid to help these communities adhere to these regulations. Additionally, clarification of intent and implementation of the regulations will be necessary for any utility to meet the demands of those regulations. For instance, the lead rule revisions require systems to conduct detailed analysis of not only their distribution systems, but customer owned plumbing in order to comply with the rule. In Alabama, this brings up many concerns over private property issues and a variety of liability concerns for the system. It should be noted that these lead line inventories are required to be conducted and must be robust and thorough if the system will be able to qualify for access to funding in order to fix the lead issues found, including pipes on private property.

Another major concern is PFAS contamination. Health advisories established prior to maximum contamination limits caused great consternation and concern in many communities. Especially since recent health advisories were set at limits below the capabilities of current laboratory technology, making them undetectable, but potentially present, by default.

If you will indulge me, I'd like to share some comments from ARWA Board Member and General Manager of the West Morgan East Lawrence Water and Sewer Authority (WMEL) in North Alabama, Ms. Jeaniece Slater. While WMEL is no longer a truly rural system, they are a success story that started through the vision of 15 folks and has grown to serve 100,000 Alabama Citizens over the past half century. This story describes a system that has gone through the challenges PFAS has raised for water systems to date, and both describes a success in planning and operation, as well as serves as a cautionary tale as to the impact of these types of regulations and how they may, if improperly considered and implemented, destroy the ability of small and rural systems to operate, as well as undermine in general the publics' trust in their water supply.

BEGIN WMEL COMMENTS##

As the General Manager of the West Morgan-East Lawrence Water and Sewer Authority - WMEL for short - I am proud to represent the many hard-working people of our utility who, for nearly a decade, fought the good fight against PFAS contamination of our drinking water supply. It was not easy; there were times when it seemed like all the pressure in the world was being placed on us to sit back and suffer in silence.

To provide you with some background on WMEL, it was founded more than 50 years ago by a group of fifteen concerned citizens who wanted to create a water system to serve and protect the citizens of western Morgan and eastern Lawrence counties in northern Alabama.

Thanks to their vision, approximately 100,000 of your constituents receive clean, safe water and wastewater services from WMEL.

I do not have to tell you about the variety of challenges our nation needs to meet every day. But one of the issues that cuts to the core and is essential to the daily lives of all Alabamans is the need to not only maintain our water systems, but safely expand them to support critical economic development.

Fulfilling these duties relies on our retaining the trust of the people we serve. Unfortunately, this trust is at risk because of numerous water treatment challenges we face today, one of which we have dealt with firsthand since 2016: PFAS contamination.

In 2016, WMEL discovered high levels of PFAS in our drinking water. The findings were so troubling our leadership made what was a difficult decision at the time; we had to tell our customers it was not safe to drink their water.

This protection of public health started years of sometimes extremely uncomfortable work to force those who polluted our drinking water to be held accountable for their actions. That work paid off; our relatively new (2021) reverse osmosis water treatment plant is currently providing safe drinking water to the 100,000 Alabamans I mentioned and at no additional cost on their bills.

Over the course of the last couple of decades, discoveries of PFAS contaminants in our source waters across the country have resulted in changes to state drinking water regulations. Now, the EPA is in the middle of establishing new PFAS-related drinking water standards on the national level. While they are being set with an admirable goal of protecting public health in mind, they also come with several unintended consequences which we would like to ask you to help us address.

We at WMEL were, in a sense, lucky we had to deal with PFAS contamination years ago. Since the day we started our plant at WMEL, we've been able to say the past health advisories that were issued for our contamination have been addressed, our current challenges are being met, and we will almost certainly be compliant with whatever new drinking water regulations the EPA may come up with in the future.

I'm pleased to report to you we've won our share of awards for our work to deal with our PFAS challenges, and I'm especially proud of the work of the people who stood arm in arm with us to make sure that the cleanest water possible was being provided to the people of north Alabama.

But while WMEL is a success story, we are also a cautionary tale, and it is one being repeated with utilities across Alabama and all over the country. Not only are we discovering more and more PFAS contamination of our water sources, but the recently proposed EPA regulations are creating fundamental questions about the safety of drinking water nationwide.

When the EPA's proposed Maximum Contaminant Levels (MCLs) and "Hazard Index" are finalized, we are likely to see significant treatment and financial challenges created for Alabama and the nation's water utilities, and all at once. And based on our experience to date, we will have to address the following issues as well:

- The public will understandably react emotionally and believe their water is unsafe NOW. They are not going to care that water providers will have up to five years to comply with the new standards. They are going to believe they are being made sick now by the utility providing their water.
- Providers will not be able to meet such an immediate demand from the public because determining, evaluating, and choosing the right treatment solutions take time to properly conduct.
- Because hundreds, if not thousands, of providers will need advanced treatment - and quickly- the demand will quickly outstrip the supply. Not only will the needed number of systems be unavailable, but the ones that are ready will cost exponentially more to purchase.
- The cost of the systems to design, build, and implement will be expensive, with the need for nearly immediate funding. The EPA's estimate for funding for PFAS treatment nationwide is woefully inadequate. Customers will be left to pay more for the advanced treatment, and - in some cases - a lot more. Rates will go up at the very time activists are calling drinking water unaffordable for many.
- Of course, like many other industries, we likely will not have the number of employees we need to operate these thousands of systems. We will be able to train our current staff- if they stay after potential attacks on their work - but we will need tens of thousands of new people to join our industry, on top of the employees we need to simply replace our retirees.
- Meanwhile, PFAS is still going to be produced, used in millions of pieces of consumer goods, and spilled into our waterways or put into our wastewater streams through public use.
- Most water providers also will not have the staff or resources to explain all their challenges to the public before or as they occur, placing their reputations at risk. They are simply not ready to discuss PFAS with the press or their customers, nor their elected officials and community leaders who shape public opinion.

And all of this will occur simply as a result of EPA's intent to provide safer drinking water for our country. And only then will we begin to face the fallout of EPA's future decisions related to classifying PFAS as hazardous wastes and the implications that this will have on water and wastewater utilities who are trying to manage these man-made chemicals.

The drinking water world will be forced to change drastically after the EPA announces its final MCLs and Hazard Index. Combining these challenges with new CERCLA regulations that do not provide exemptions for water and wastewater utilities creates an untenable situation for the nation's water providers. Not only is the safety of our water being called into permanent question, but our ability to effectively manage our wastewater services - and keep them affordable - will be stripped away.

Fundamental - and costly - questions about what we will have to do with our waste streams and biosolids will be created; it is hard to imagine scenarios where we will be able to land apply biosolids anymore. And taking them to landfill, if it is even possible, will come at a much higher cost because the landfills will be managing PFAS-containing biosolids as a CERCLA waste.

Not only will we have to spend significantly more money to further protect our employees, but the people needed to oversee our biosolids will become scarcer. Jobs that require handling hazardous substances are naturally harder to fill, especially during tight labor markets. And our market is a non-profit market funded on the backs of ratepayers, which makes our positions even harder to fill.

The designation of PFAS as hazardous wastes under CERCLA will have far-reaching implications and severe unintended consequences on public nonprofit water and wastewater systems like WMEL. We have never profited from the manufacture or use of these chemicals and our customers will be forced to pay for the cleanup. CERCLA's bedrock principal says the profiting polluter shall pay for cleanups; that is not us. The reality is that any method the utility uses to remove this hazardous waste from drinking water or wastewater is expensive and must be passed onto the customer. Therefore, without exemptions the customer will also foot the bill for the cleanup the utility is charged. This is a vicious cycle that always lands on • the customer to pay. The potential is the customer also sues the utility which, since we are customer-funded, is them basically suing themselves. I wish I could state today that things like that, do not happen, but the discovery of PFAS in our drinking water prompted four class action suits against WMEL.

The reality is the strength of CERCLA is "the polluter pays" for the years of profiteering from a substance harmful to human consumption. If water and wastewater utilities are not exempted, this basic principle will be ignored.

We in water and wastewater have always delivered high-quality services and succeeded in the face of difficult challenges. In many ways, PFAS will be no different.

However, we at WMEL saw firsthand how PFAS can push a water and wastewater utility to its breaking point, even though we did not contaminate our source water, we did not add a single drop of these substances into our distribution system, and we have never profited one cent off of their production.

What we experienced is something no other utility should be forced to go through. After all, none of us produce a single drop of PFAS. The Utility is a passthrough for these man-made chemicals. Chemicals that end up in our source water and we are forced to remove through media, filtration, and some even Reverse Osmosis. The utility receives these chemicals from domestic, commercial, and industrial sources but make no mistake they all start from the industrial site. These chemicals have been produced since World War 2 and the Atom Bomb, eighty-one years of profits made by the chemical manufacturer leaving cleanup on the water and wastewater industry. While opening the potential not only for class action suits mentioned above but also other utilities suing each other, landfills suing water and wastewater entities, and vice versa. In the end it will be the communities and customers who will pay for this cleanup without exemptions.

If these chemicals are designated hazard waste, it is imperative the Utilities receive exemptions. However, without CERCLA exemptions, hundreds, if not thousands, of service providers could be forced to confront their own breaking points. And nothing less than public confidence in the safety of our American water supply is at stake.

END WMEL COMMENTS##

NRWA strongly supports S.1430, the Water Systems PFAS Liability Protection Act, introduced by Sen. Lummis (R-WY), which will protect our Water and Wastewater systems, treatment plant operators, municipal stormwater dischargers, and local water agencies (including their contractors) that release PFAS as part of operation. We encourage Members of this Committee to support this effort, as well as continue to work to highlight these issues to EPA leadership and consider impacts of regulatory actions on water and wastewater systems throughout rural America, especially those that rely on assistance made available in the Farm Bill.

Senator John Boozman

1. Throughout our series of Farm Bill hearings and in my travels around the country talking with stakeholders about what they believe is needed to increase access to federal programs for small and rural communities, one issue has consistently come up. And that is the issue of overburdensome applications processes. What specific challenges do small communities face when navigating the funding application process for water and wastewater projects and then how can we alleviate the administrative burden for communities when participating in these programs?

The complexity of applications for funding, such as through the USDA, is inherent, especially for projects like water or wastewater. These require detailed evaluations like environmental studies, financial details, and population data. Such complexity ensures the prudent use of public funds and appropriate project prioritization.

While I agree that the process should be as easy as possible, I would disagree with any change or challenge to the process that would weaken the Department's ability to award public funds efficiently and effectively. I tend to think of this in the same way I do operator training. I want as many folks in my industry as possible, but I do appreciate having a process difficult enough to ensure I only greet capable and responsible colleagues into the ranks.

Securing financing for water and wastewater projects can be daunting for many communities, more so for those with limited resources or expertise to navigate the application process. The USDA's Rural Development is dedicated to simplifying this process and minimizing bureaucratic hurdles. However, there's an undeniable need for additional financial and resource backing to make these funds universally accessible.

In a commendable move in recent times, the USDA launched 'RD Apply', an innovative online platform that has transformed the application process. It synergizes stakeholders under a singular digital umbrella, equipped with features to diminish the exhaustive research previously needed. For instance, by simply outlining the target area for the funds on the platform, it automatically computes population, MHI, and other pertinent data. Before this, such calculations required extensive manual input and were susceptible to human inaccuracies, even by those skilled in data interpretation. The Rural Water Circuit Riders are well-versed with this system, receiving direct training from Rural Development two times each year. However, it's vital to remember that the RD Apply platform will need periodic updates and enhancements. For its continued optimization, it's essential for the USDA to allocate regular funds.

However, a functional IT platform alone isn't enough. Many rural communities still struggle with the application process due to limited capabilities. State employees from the Rural Development office are in a prime position to offer direct assistance, but a staffing shortage has reduced their outreach capabilities. Allocating funds for more staff will allow them to visit these communities and guide them step-by-step.

And technology isn't the only answer. Many rural areas find the application process challenging due to limited expertise. The Rural Development office can be instrumental in guiding them, but they're understaffed. Increasing their workforce would enhance their reach. For places beyond their direct reach, collaboration with technical assistance providers can fill the gap. Allocating more for such grants can enable localized experts to assist communities directly.

In conclusion, the preliminary stages of applying for funding, which include registering on SAMS.GOV, securing necessary codes like CAGE, procuring a Preliminary Engineering Report, confirming accurate financial information, and meeting NEPA standards, can incur significant costs. Providing financial assistance to cover these initial expenses would empower under-resourced communities to meet the criteria for government aid.

2. I often speak with mayors and community leaders across Arkansas and the country who understand the great challenges they face but lack the human and technical infrastructure to determine the steps necessary to address them. Can you please list any recommendations you might have regarding ways in which the Farm Bill can better facilitate capacity building in rural communities?

   As the Committee knows, the Circuit Rider initiative was established in 1980 to bolster capacity in rural communities struggling with Clean Water Act compliance. Since then, these communities have faced many challenges. Increased regulatory burdens, natural disasters, cyber-attacks, and PFAS contamination, to name a few.

   Many of our small, rural communities in Arkansas, Alabama, and across the country often have just one individual handling all operations due to limited financial resources and economies of scale.

   The NRWA proposes five key recommendations for the committee to enhance utility capacity in these rural areas:

   1. **Continue the Circuit Rider Program**: This program is vital for rural communities, safeguarding public health and both community and federal investments. The financial relief provided by this program, such as reducing leaks and energy use, is crucial. Many of these utilities, due to financial constraints, can't afford external consultants, and this program offers many insights into operations at no cost to the utility, often providing amazing results. If you would indulge me, I could provide 40 years of evidence of the efficacy of this program, but I doubt you will, so I'll simply state that Alabama and any other Rural Water Association would be happy to support this initiative with detailed evidence of progress and success if requested.

   2. **Introduce a Cybersecurity Circuit Rider**: This would directly help systems defend against cyber-attacks. This should encompass rapid threat assessment, formulation of cybersecurity protocols, and documentation of cybersecurity measures related to water supplies.

   3. **Enhance Circuit Rider Emergency Response**: This should include pre- and post-disaster activities such as vulnerability assessments, GIS mapping, disaster protocol development, and coordination with state emergency networks. Activities after major disasters should also incorporate support from insurance and FEMA. The NRWA is an agency that leads in water and wastewater emergency response due to the efforts of its individual state leaders cooperating under a unified umbrella. However, these response efforts are executed during disaster events. While we are proficient during these events, efforts could be improved with dedicated staff operating under the emergency response umbrella outside of disasters or on 'blue-sky' days. These efforts would only serve to strengthen the resilience of water and wastewater systems during and after disasters, which is critical to avoiding costly damage where possible and ensuring all resources are utilized by any community that suffers a disaster to be made whole again after any event.

4. **Update the Rural Development Water and Wastewater Programs**: As other infrastructure initiatives have advanced, this program should adapt accordingly. We recommend introducing financial tools like zero and one-percent interest loans tailored for financially limited organizations. Providing options for loan adjustments, refinancing, and potential forgiveness can help maintain utility stability and ensure affordable customer rates. This is particularly crucial for communities unjustly impacted. Numerous organizations in Alabama would benefit immediately from such flexible options. Whether due to key commercial entities leaving them unsupported or the need to refinance existing debts, these changes can be pivotal in sustaining entities in fluctuating economic climates.

5. **Encourage Consolidation and Regionalization Where Feasible and Mutually Desired**: As touched upon in my testimony, this is a viable approach where it makes financial sense and is narrowly scoped. We recommend that the Committee promote this through voluntary policies and incentives, particularly targeting lower-income communities without adequate services. High-performing neighboring systems should be allowed to seek grants/loans for these underserved areas.

3. Through the efforts of organizations like yours, tremendous progress has been made in getting clean and safe drinking water to rural communities across your state and the country. However, too many communities are still unable to provide this necessary service to their residents. Do you see a role for high functioning water systems to utilize USDA funding to assist their neighboring communities who are unable to provide for their own citizens?

High-functioning utilities can play a crucial role in supporting neighboring areas in delivering safe, affordable, and sustainable water and wastewater services. While we fully respect a community's wish to independently manage its water and wastewater utilities when economically viable and they have the managerial expertise, there's a growing trend of regionalization and consolidation nationwide. This is evident given that 91% (44,924) of the nation's water systems cater to populations under 10,000, making consolidation financially practical in many cases.

Different states and regions have varying definitions of what constitutes regionalization or consolidation. We propose that the Committee introduce further incentives to boost sustainable services offered by rural utilities, especially targeting lower-income communities that currently lack sufficient water or wastewater services. Often, these communities don't have the financial and managerial resources, nor the inclination to maintain independent, affordable services. We suggest offering financial incentives to high-performing utilities, either local or adjacent, allowing them to apply for grants/loans on behalf of these underserved communities.

At the moment, many rural utilities and their governing boards are eager to assist their neighbors but are constrained by financial challenges. They are hesitant to expand their service areas if it means compromising the quality of service to their existing clientele, increasing rates, or inheriting subpar infrastructure. The National Rural Water Association (NRWA) asserts that introducing a focused and fair financial incentive can address these concerns, ensuring affordable and sustainable services for rural Americans. It's essential that this support is precisely targeted toward the communities that genuinely require it.

In Alabama's Crenshaw County, there's a telling example of two adjacent utility systems. The larger system already processes the wastewater of its smaller counterpart. With just a few hundred yards of additional piping, it could also supply water to the smaller utility. This smaller utility has been shrinking over the past years, and there appears to be limited local interest in taking the leadership reins to revive its operations.

While the larger utility has shown an inclination and willingness to assist, existing debts and the need for infrastructure upgrades hamper its ability to step in. This is primarily because taking on these responsibilities could adversely affect their current customers, placing the larger utility's board in the unfortunate position where they must prioritize fiscal responsibility for their own customers over the ambition to provide the needed assistance of their neighbor.

However, if narrowly-scoped incentives were provided to utilities like the larger one in this scenario, it would pave the way for potential mergers or collaborations, benefiting both entities in the long run.

To reiterate, we recommend introducing financial incentives for top-performing, local or neighboring systems, enabling them to secure grants/loans for the benefit of communities that are currently underserved.

4. While the health impacts to communities without clean drinking water and sanitation systems is clear, can you paint a picture of what the economic development challenges look like in communities without access to high functioning water and wastewater systems?

To answer this, I'd like to delve into a prime example showcasing the collaborative efforts between USDA, federal, state, local funding partners, local stakeholders, and ARWA's technical team, who united to address a dire situation in a community at the edge of despair.

Uniontown, Alabama, established in 1818 and initially named Woodville, holds a rich historical tapestry. With early infrastructure developments, the town saw growth, especially after the introduction of the Alabama and Mississippi Railroad in 1857. By 1860, Uniontown had educational facilities and bustling main streets. Its economy was anchored by surrounding farms, but by the early 20th century, factors like the boll weevil crisis led to population and economic decline.

By 2010, Uniontown faced an impending disaster with a failing sewer system, resulting in legal ramifications. A significant turning point came in 2012 when USDA funded a $4 million project to rectify the system, but given the magnitude of the problem, it proved insufficient. Consequently, in 2018, a comprehensive $32 million project was embarked upon to address the entirety of the system's issues.

As the community grappled with its deteriorating infrastructure, economic casualties were evident. Key businesses closed (including the community's only grocery store, and most recently its only bank), underscoring the community's vulnerability. However, the USDA's $24 million grant, and an additional $8 million from other funding sources, coupled with stringent oversight measures, breathed hope. Separation of water and sewer management, secondary inspection measures by two independent engineering firms were implemented to guarantee the investment's security.

The Alabama Rural Water Association played a pivotal role in Uniontown's turnaround. We were not just involved superficially, but intricately interwoven into the efforts to revive the town's water infrastructure. Starting with facilitating the grant application process, ARWA ensured that the City of Uniontown secured the vital funding in a swift two-month period. The Association's involvement extended beyond just funding, as they collaborated with local attorneys to draft essential ordinances and resolutions. This laid the groundwork for establishing a legal board to oversee the efforts.

For the newly formed board, ARWA provided specialized training to the members, ensuring they were well-equipped to serve the community's needs. They also played a key role in pivotal public board meetings, from hiring attorneys and electing officers to streamlining administrative tasks like transferring agreements and establishing bank accounts. One of the most crucial interventions by ARWA was in assisting the board and their management company in finding a dedicated building for board operations. This ensured the residents had a singular, dedicated location for all their water-related needs.

By embedding themselves in the process, ARWA made sure that each step was not just taken, but taken with precision, expertise, and with the community's best interests at heart. As this response is being authored, efforts to rejuvenate the sewer lines are ongoing. There is a great deal more work to do, but I am happy to state with optimism, that we anticipate that in a few years, Uniontown's revamped sewer system will be compliant, fostering business growth and providing the community with superior water and wastewater facilities on par with the nation's best for many years to come.

It should be noted that all these efforts are made possible through existing provisions of the Farm Bill.