CONSIDERATIONS FOR A

NATIONAL DRINKING WATER QUALITY COMPLIANCE ASSESSMENT

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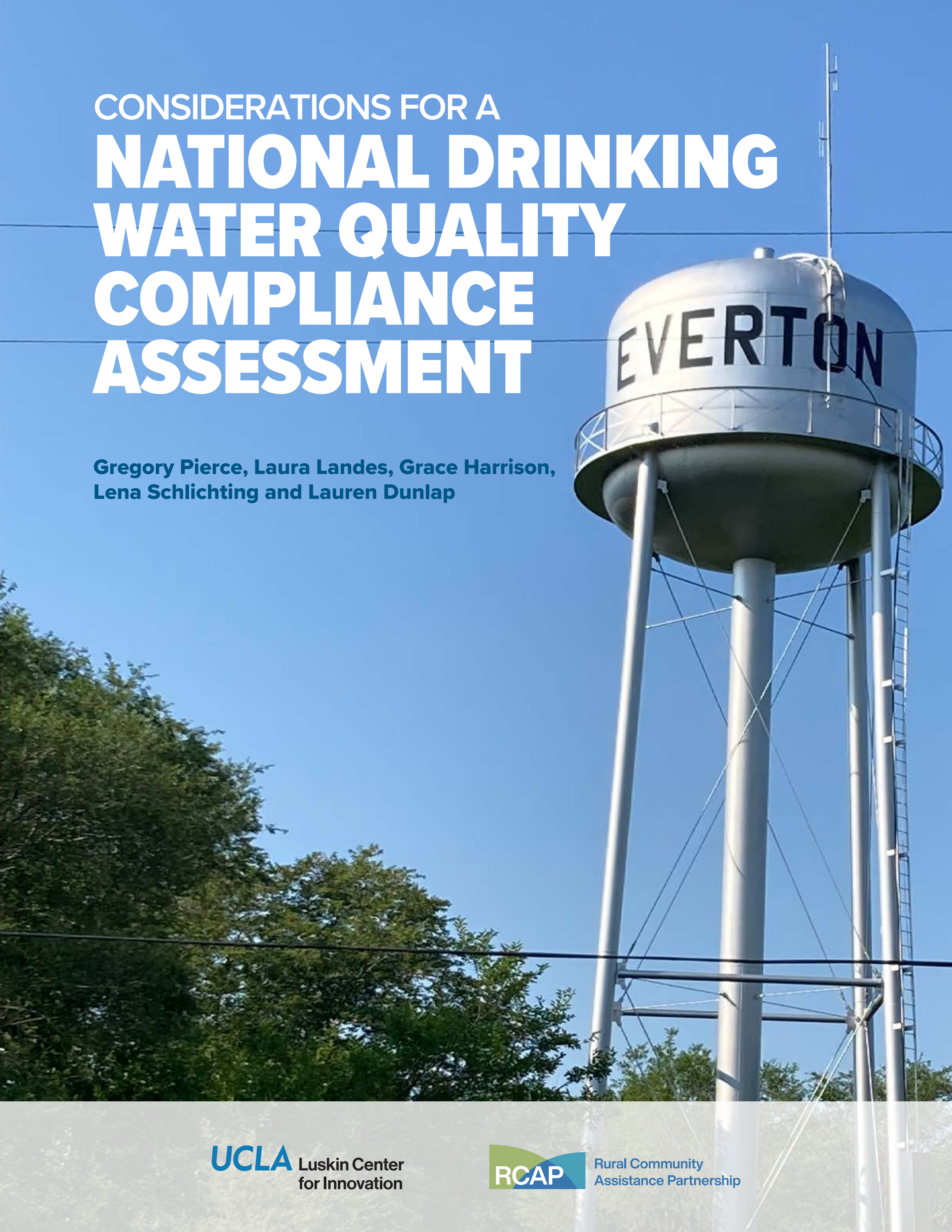

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As a land grant institution, the UCLA Luskin Center for Innovation acknowledges the Gabrielino and Tongva peoples as the traditional land caretakers of Tovaangar (Los Angeles basin, Southern Channel Islands) and that their displacement has enabled the flourishing of UCLA.

DISCLAIMER

The views expressed in this paper are those of the authors alone. They do not necessarily reflect the views of the Luskin Center for Innovation or the Rural Community Assistance Partnership Incorporated.

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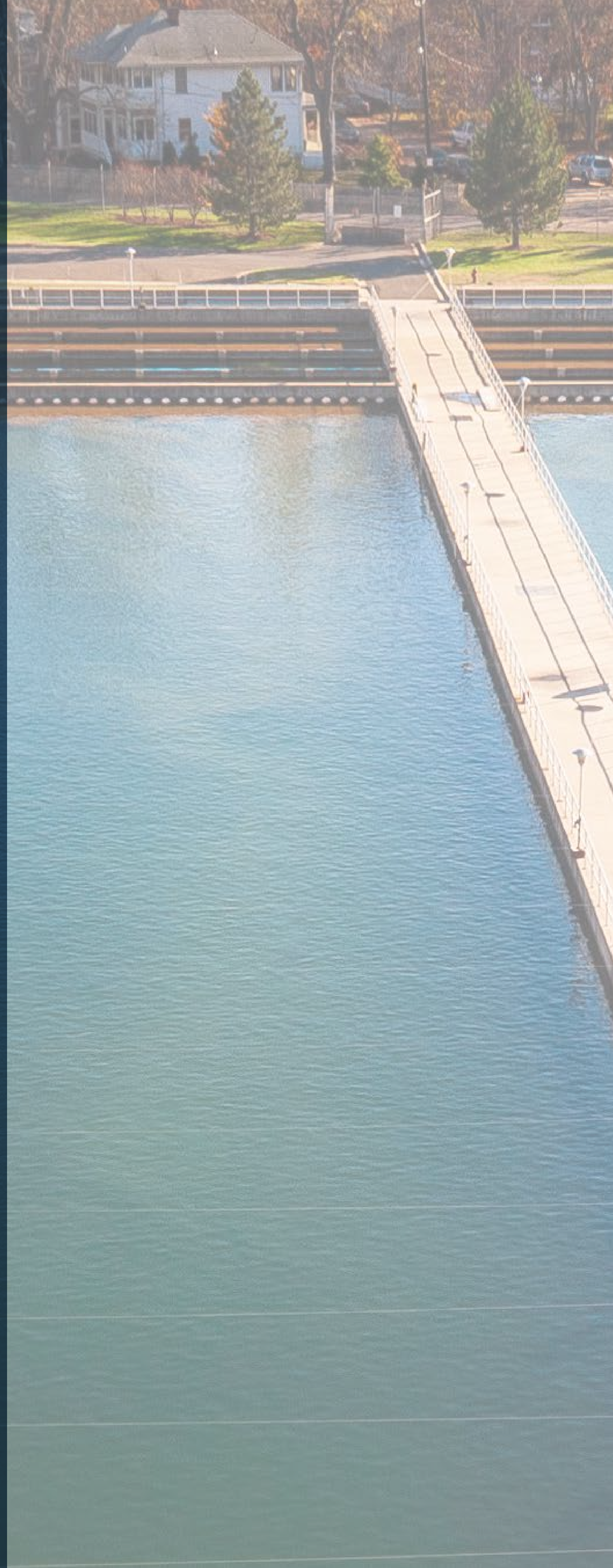

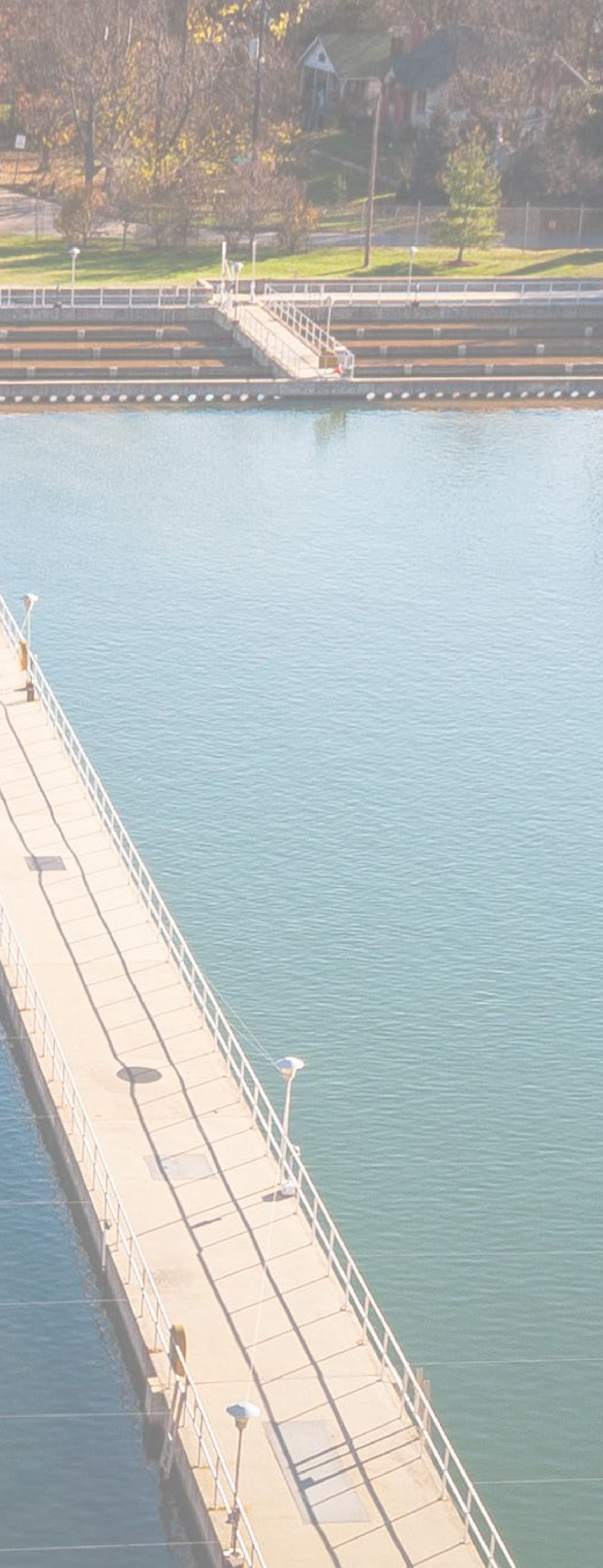

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LIST OF ABBREVIATIONS

ASCE	American Society of Civil Engineers
ASDWA	Association of State Drinking Water Administrators
BIL	Bipartisan Infrastructure Law
BIPOC	Black, Indigenous, People of Color
CA NA	California Drinking Water Needs Assessment
CDP	Census-designated place
CWS	Community water system
CWSRF	Clean Water State Revolving Fund
DAC	Disadvantaged community
DACIP	Disadvantaged Community Involvement Program
DWINSA	Drinking Water Infrastructure Needs Survey and Assessment
DWSRF	Drinking Water State Revolving Fund
ECHO	U.S. EPA's Enforcement and Compliance History Online
EFC	Environmental Finance Center
EPA	United States Environmental Protection Agency
EPIC	Environmental Policy Innovation Center
FRS	Federal Registry Service
GAO	Government Accountability Office
GIS	Geospatial information system
HR2W	Human Right to Water
HUD CDBG	Department of Housing and Development's Community Development Block Grant
IHS	Indian Health Services
IIJA	Infrastructure and Jobs Act
MCL	Maximum contaminant level
MHI	Median household income
NRWA	National Rural Water Association
O&M	Operation and maintenance
POE	Point of entry
POU	Point of use
RCAC	Rural Community Assistance Corporation
RCAP	Rural Community Assistance Partnership Incorporated
SAFER	Safe and Affordable Funding for Equity and Resilience
SDWA	Safe Drinking Water Act
SDWIS	Safe Drinking Water Information System
TMF	Technical, Managerial, and Financial Capacity
UCMR	Unregulated Contaminant Monitoring Rule
UNC EFC	University of North Carolina Environmental Finance Center
USDA	United States Department of Agriculture
USDA RUS WEP	USDA Rural Utilities Service Water and Environment Programs
WBT	Water Boundary Tool
WIFIA	Water Infrastructure Finance and Innovation
WIIN	Water Infrastructure Improvements for the Nation

EXECUTIVE SUMMARY

A national assessment of compliance and related solutions is a necessary next step in increasing access to safe drinking water across the United States. This report represents a first step in outlining what an assessment of that scale can and should look like in the next decade. It identifies and describes four key phases such an assessment would need to undertake; existing and emerging efforts to build on; as well as data, analytical and policy challenges and gaps such an effort would face.

▶ Problem Statement

Community water systems (CWSs) throughout the United States continue to face challenges in delivering high quality drinking-water, with approximately one in ten people in the United States served by systems exposed to any health-based violation over the three-year period from 2018 through 2020. Longstanding infrastructure challenges, water quality concerns and overdue attention to broader environmental justice shortcomings have motivated additional state and federal investments, including from the Bipartisan Infrastructure Law (BIL) (2021).

Through the BIL, historic investments are being made in water infrastructure and environmental justice. These funds aim to implement water infrastructure improvements needed to bring water systems into compliance and ensure safe drinking water for all. A national assessment of drinking water compliance is imperative to inform what types of issues, solutions and communities should be prioritized to make the greatest positive impact with this available funding and beyond.

However, there is currently no comprehensive national assessment of community water systems' compliance with drinking water quality standards, and very few statewide or regional assessments of drinking water quality compliance exist. This type of national assessment is increasingly needed as regulatory standards increase, concerns with aging drinking water infrastructure grow and climate change exacerbates existing water quality concerns.

▶ Methodology

This report serves as a building block towards assessing drinking water quality compliance in the United States and highlights where existing studies and efforts have laid the foundation, and where gaps need to be filled. This study does not conduct a full empirical assessment of drinking water quality compliance in the United States.

The research underpinning the findings and recommendations of this report was based on a mixed methods approach which included a review of the California Drinking Water Needs Assessment and national Drinking Water Infrastructure Needs Survey and Assessment processes, a snowball sample expert interview process, a landscape analysis of published efforts by leaders in the drinking water equity space nationally, as well as original exploratory data analysis. The project was also guided by an advisory committee of regulatory and advocacy representatives.

▶ Key Considerations

The key next steps stemming from our work, which comprise both findings and associated recommendations for each of the four phases of a full compliance assessment, detailed further in the body of this report, are summarized at a high level as:

Quality Compliance Definition and Identification

» More clearly define a label for the systems of concern based on underlying violation data

» Work toward a more transparent, accessible, and consistent set of national drinking water quality data which can better inform a regular assessment process

» Balance regional (contaminant-specific) trends with national compliance standards
» Incorporate community-identified concerns that contextualize violation data

Spatial Location Considerations

» Employ emerging boundary estimate tools, while continuing to refine small water systems geospatial data
» Select the most replicable methods to minimize bias and errors when matching demographic data to water system boundaries

Compliance Solutions and their Costs

» Evaluate if regional assessments are more appropriate and feasible than a single national assessment
» Develop more robust cost estimation methods and underlying datasets to support compliance solution planning
» Establish if different forms of consolidation can be modeled as solutions at the national scale

Solution Funding and Gaps

» Increase no-cost technical assistance to ensure available funding reaches communities with highest need
» Give priority to disadvantaged communities by dividing funding streams to allow for principal forgiveness and grants in addition to loans
» Decide in the near term if an additional tool is needed to characterize water system disadvantage for funding eligibility

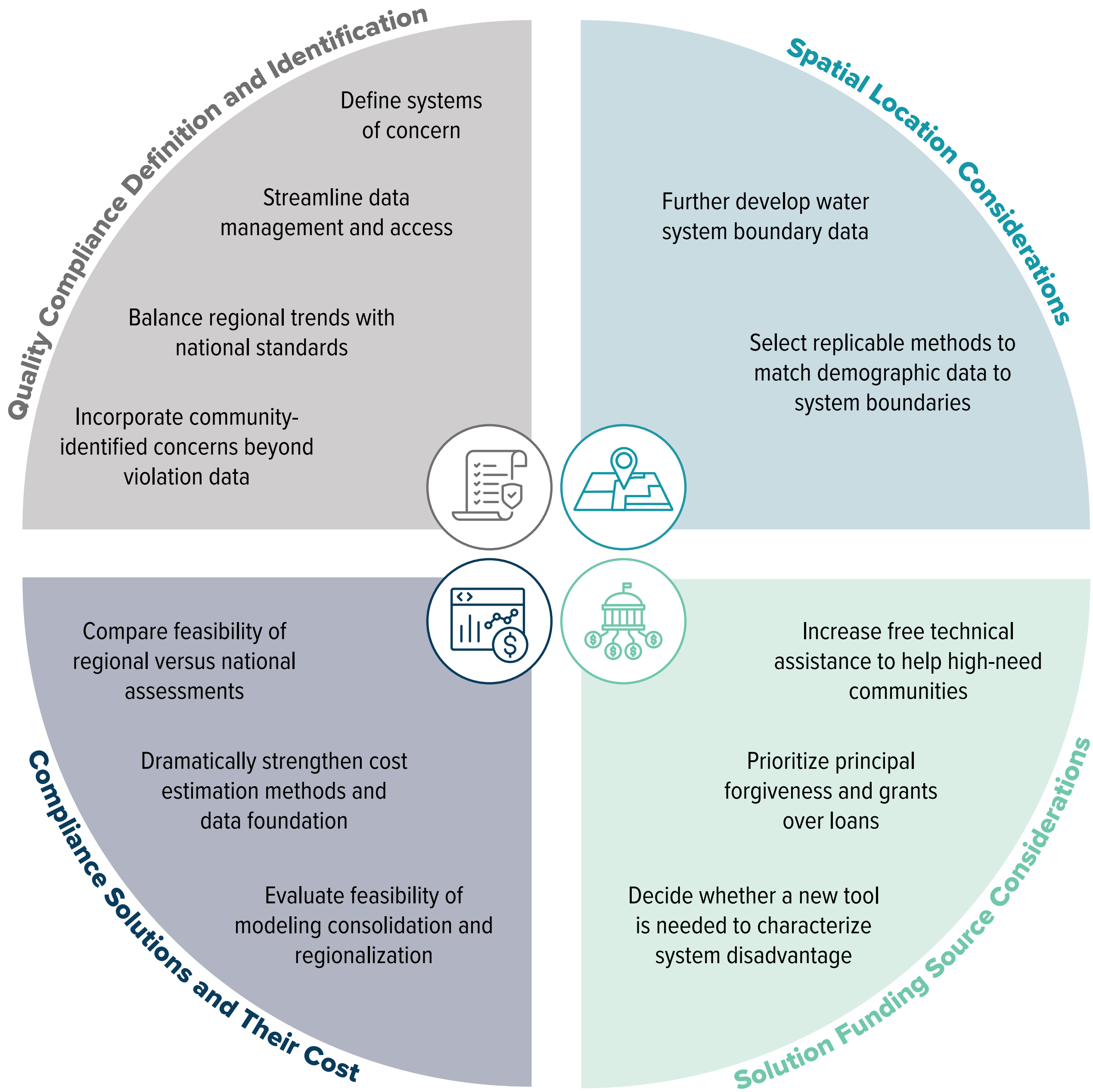
▶ Next Steps

A national assessment of compliance and related solutions is a necessary next step in increasing access to safe drinking water across the United States. This report represents a first step in laying out what an assessment of that scale can and should look like in the next decade. Our recommendations, while layered and complex, are feasible to incorporate over the next 10 years with a continued commitment to and funding for community water systems across the United States.

Over the next five years, Rural Community Assistance Partnership Incorporated (RCAP) and the UCLA Luskin Center for Innovation will be taking the “roadmap,” or methodology, described here and implementing it in select states, also building on the results of EPA’s 2023 Drinking Water Infrastructure Needs Survey and Assessment (DWINSA). This work will be made possible by the expansion of EPA’s Environmental Finance Center (EFC) program, which seeks to help connect communities in need with federal funding opportunities; specifically, the historic investment in water infrastructure by the Bipartisan Infrastructure Law. A major component of RCAP’s EFC program, in partnership with the UCLA Luskin Center for Innovation, involves operationalizing and expanding upon this methodology (with assistance from the University of Illinois to incorporate analysis of communities reliant on private wells and septic systems) to pinpoint communities with the greatest need for technical assistance to access federal funds.

FIGURE 1

Summary of Key Recommendations



BACKGROUND AND MOTIVATION

There are over 50,000 regulated community water systems in the United States[1] (U.S. EPA, 2022). These systems are the building blocks of the nation's drinking water supply network. They provide drinking water to communities across the country while helping communities adapt to drought and climate change. They also face a chronic challenge of aging infrastructure due to underinvestment.

Each CWS is evaluated on the health-related standards established by the national Safe Drinking Water Act (SDWA). This report presents considerations and guidance to support a national assessment of CWSs' compliance with drinking water quality standards, how to define and measure compliance failures and solutions to address those failures. We do not discuss non-community water systems for the sake of scope and clarity.

This report builds on the 2021 California Drinking Water Needs Assessment (CA NA), a comprehensive analysis of what is needed to provide safe drinking water throughout California (State Water Resources Control Board, 2021). The UCLA Luskin Center for Innovation collaborated with the California State Water Board, which serves as the primacy agency for the SDWA in California, to produce the 2021 CA NA. This effort identified where water systems are not in compliance with quality standards and where they are at risk of being out of compliance. It then proposes solutions to bring the systems into compliance and estimates how much it would cost to implement those solutions and successfully deliver safe water to every resident — especially to those living in small, disadvantaged communities. It also identifies the funding sources for solutions and gaps in those sources in meeting the full scope of needs.

The 2021 CA NA universe of analysis included the following:

- 2,779 regulated public water systems (2,241 of which are community drinking water systems)
- 1,236 state small systems[2]
- 240,949 domestic wells

The CA NA was the first comprehensive effort by any state to evaluate what resources are needed to bring systems into compliance with drinking water standards and prevent at-risk water systems from falling out of compliance. This effort enabled the state to make a case for an additional allocation of $800 million from the 2021 California budget surplus to address drinking water quality needs.

Additionally, the CA NA will inform how the state spends funds from the Bipartisan Infrastructure Law (BIL). Signed into law in November 2021, the BIL provides approximately $38.5 billion in funding for drinking water, $30.7 billion of which will go to the Drinking Water State Revolving Fund (DWSRF) program (Brookings, 2022). To receive this funding, states must develop detailed Intended Use Plans describing how they will use the DWSRF funds (Henshaw & Cavalier, 2022).

Other states have similar, and in many cases greater, magnitudes of drinking water quality problems and funding needs as California. In fact, California has a below-average proportion of

1 A community water system (CWS) is the type of "public water system" (PWS) that supplies water to the same population year-round. The "public" means publicly-regulated, and subject to the federal Safe Drinking Water Act as well as other state and local regulations, not necessarily that all systems are publicly-owned. There are approximately 150,000 public water systems in the United States.

2 A California water system providing drinking water to at least five, but not more than 14, service connections and does not regularly serve drinking water to more than an average of 25 individuals daily for more than 60 days out of the year.

public water systems that are in violation of the SDWA.[3] However, many states lack the data and analysis capacity to fully motivate or map out the investments needed to address these problems.

The CA NA was motivated by over 10 years of advocacy, coalition building and Human Right to Water (HR2W) policy development and legislation — namely, the passage of Assembly Bill 685 in 2012, declaring the Human Right to Water in California, and the passage of the Safe and Affordable Drinking Water Fund (Senate Bill 200) in 2019. Moving forward, a new, focused staff group within the State Water Board will conduct this needs assessment annually with the most recent CA NA released in April of 2022.

This report is an initial step toward expanding the CA NA to a national scale. It aims to determine effective methods for conducting a national drinking water quality compliance assessment.[4] Our scoping report, informed by an advisory committee and interviews, presents an initial roadmap for individual states and the federal government to carry out a similar, albeit not identical, drinking water quality needs assessment as conducted in California.

DATA, METHODS AND SCOPE

This year-long effort included a snowball sample expert interview process, a landscape analysis of efforts by national leaders in the drinking water equity space, as well as some original exploratory data analysis. Though we set the groundwork for such a future effort, this study did not set out to conduct an empirical assessment of drinking water systems' quality standard compliance failures and solutions nationally, as this represents a longer and larger undertaking than feasible here. Instead, in this report, we aimed to identify and outline the opportunities and challenges in completing a full compliance assessment. Critically, we highlighted where existing studies and efforts are already laying the foundation for this work. We also examined the rapidly changing and improving landscape of data availability in several key areas of empirical analysis.

The outset of the CA NA took a similar approach: a series of workshops were held in the year before the formal effort launched, and the final product was adapted considerably compared to the initial vision of the effort. The aim of our scope is national, but to the extent possible, we highlighted regional and state examples and trends in capability, especially in comparison to California. The scope included four core analytical components, which reflect some but not all the CA NA components (Figure 2).

3 In 2021, CA had 1091 PWSs with violations, which was 14.5% of the state's 7,539 PWSs. Nationally, 38,853 PWSs had violations — 25.3% of the 153,611 PWSs total. See https://echo.epa.gov/trends/comparative-maps-dashboards/drinking-water-dashboard

4 We do not call this national effort a "needs assessment" to avoid conflation with the EPA's 6th Drinking Water Infrastructure Needs Survey and Assessment process, as well as other water and environmental justice efforts now being called "needs assessments."

FIGURE 2

Core Analytical Components of this Study

There are two components of the CA NA that we did not include in our scoping analysis due to data infeasibility in the near and perhaps even the long term:

» **Unregulated, private drinking water well data:** The private well quality data included in the CA NA was developed over multiple years in a dedicated effort by the CA State Water Board's Groundwater Ambient Monitoring and Assessment Program (GAMA) and was also informed by a parallel effort led by UC Berkeley's Water Equity Science Shop (WESS). EPA has begun private well location estimation efforts (Murray, 2021), but based on public information, these efforts do not yet come close to the precision needed to inform inclusion in a compliance assessment.

» **A standalone affordability assessment:** A national standalone affordability assessment is not feasible simply because valid rate data are still not publicly aggregated for more than half of the states in the United States. Even among states that do have rate data, it rarely includes very small regulated systems (Pierce et al., 2023).[5]

Moreover, there were several elements suggested to us for potential inclusion which we had to ultimately exclude from consideration. These decisions were made in part due to severe data constraints and in part to avoid distracting the focus of the analysis and defining a problem too large for actionable near-term policy. The report does not include wastewater system compliance,[6] which is a related but also distinct and comparatively data-poor outcome of interest. It also does not include a broader assessment of climate change impacts on drinking water system performance (beyond the risk of impacts on water quality compliance as included in the CA NA) due to data limitations and concerns regarding scope drift.

5 We do not consider any assessment of the economic status of water system populations, such as can be undertaken solely by matching Census data on population and income and poverty levels to water system boundaries, to be an "affordability" assessment, especially one to be compared to the CA NA affordability assessment.

6 We note that very targeted wastewater needs assessments have been conducted in the U.S., including an Indian Health Services (IHS) 2019 report on sanitation deficiency levels for Indigenous homes and communities. IHS field staff collaborates with federally recognized tribes to both identify and address sanitation deficiencies, with identification methods ranging from field visits to sanitary surveys, community environmental health profiles, master plans to feasibility studies. After identifying deficiencies, project planning to correct these issues follows to find the deficiency level based on existing or lack of sanitation facilities (IHS, 2019).

▶ Engagement and Consultation: Core Advisory Committee Members and Expert Interviews

The research team convened both a formalized advisory group meeting and conducted expert interviews among folks outside of the committee.

The advisory committee worked to refine the following:

- » The goals and end uses of what was originally called a "Roadmap for a National Drinking Water Quality Needs Assessment" but was renamed "Considerations for a National Drinking Water Quality Compliance Assessment" to avoid confusion with other efforts
- » The list of experts to invite for interviews
- » The key analytical questions that needed answering
- » A working understanding of opportunities to shape how federal, state and other partners conduct drinking water quality needs assessments in an ongoing way

The committee primarily comprised of representatives of advocacy groups and agencies with national-level expertise met as a group two times virtually, reviewed a draft version of the report and provided input by email on an ad-hoc basis to the research team.

Core Advisory Committee

- » Nora Nelson, DigDeep
- » Sean Jackson, Clean Water Action
- » Jacqueline Shirley, Rural Community Assistance Corporation (RCAC)
- » Anthony DeRosa, Association of State Drinking Water Administrators (ASDWA)
- » Jim Barham and Kasey Martin, U.S. Department of Agriculture Rural Development Innovation Center
- » Ron Bergman, U.S. EPA Office of Water

During spring and summer of 2022, we also conducted one-hour informational interviews with experts from across the United States and in different institutions (public, private, non-profit, academic) within the drinking water research sub-sector.

Expert Interview List

We also conducted 10 expert interviews with 13 individuals:

- » Heather Himmelberger, Southwest Environmental Finance Center
- » Chad Seidel and Carleigh Samson, Corona Environmental Consulting
- » Katy Hansen and Walker Grimshaw, Environmental Policy Innovation Center
- » Julia Cavalier, Environmental Finance Center at University of North Carolina, Chapel Hill
- » Michelle Frederick and Kristyn Abhold, California State Water Resources Control Board
- » Yolanda McDonald, Vanderbilt University
- » Jordon Hoang, FlowWest
- » Kyle Onda, Internet of Water initiative at the Lincoln Institute's Center for Geospatial Solutions
- » Jessica Goddard, SimpleLab
- » Sarah Hughes, University of Michigan

The insights of expert interviewees are intentionally cited anonymously in the below analysis, except as explicitly preferred by the interviewees, and in cases where the interviewees provided us with citable publications.

1) QUALITY COMPLIANCE DEFINITION AND IDENTIFICATION

A national drinking water quality compliance assessment must have a clear focus. In this chapter, we explore the challenges and possibilities of defining what systems and problems a national assessment should focus on, how to customize risk assessment for the diverse regional challenges systems face while acknowledging there are significant data limitations and inconsistencies. We organize our discussion of these topics as follows:

» Defining and labeling the problem

» Customizing risk assessment and regional trends

» National data limitations and consistency

» Next steps

▶ Defining and Labeling the Problem

The need to define "problem" systems to set the study scope

To set the scope of a national drinking water quality compliance assessment, we must first define the problem. As one interviewee said, "A national needs assessment should focus on the degree to which current systems fail to meet regulatory conditions and what would it take to address those failures. The greatest public health step we can take is to fully achieve 100% compliance with regulated systems."

The benefit of establishing a threshold for noncompliance to narrow the scope of a national assessment is illustrated by EPA's "serious violator" definition. EPA does not use the term "failing" as used in the CA NA. Instead, it categorizes systems as "serious violators" when they pass specific thresholds of serious, unresolved violations; continuing violations; or multiple violations that, in combination, surpass a defined threshold.[7] The prioritizing function of this classification is clear: in the three-year period from 2008 through 2010, 44% of active water systems had at least one violation. But only about 4% of systems met the criteria for "serious violator" in January 2011. While this number represents a moment in time, not quite comparable to the three-year 2008–2010 period, it illustrates that prioritizing a narrower bracket of noncompliance can help to focus limited resources on the systems that struggle the most to remain in compliance. However, limiting analyses to an even narrower bracket of noncompliance, such as only to intractable[8] water systems, is too restrictive as only 334 systems were included in this definition over the span of 2016, 2017 and 2018. (See Figure 3 for examples of the many terms used for systems of concern.)

A shared definition of "systems of concern" is necessary to inform and motivate action. If there is not widespread buy-in on which systems should be included on a list of concern, discussions about the definition of "failure" and what systems should be prioritized for assistance will continue, rather than moving forward with assistance. Our interviewees made it clear that further discussion is necessary to develop a more customized compliance benchmark for a national assessment. Depending on resources and political will, a national or multi-state assessment could additionally be limited in scope by water system size or analyte type, or by taking a hotspot rather than comprehensive analysis approach.[9]

7 U.S. EPA. (n.d.). Safe Drinking Water Act (SDWA) Resources and FAQs. https://echo.epa.gov/help/sdwa-faqs#Q14

8 A community or noncommunity water system that serves fewer than 1,000 individuals, that is in significant non-compliance with the SDWA National Primary Drinking Water Regulations or listed as having a history of significant non-compliance.

9 A hotspot analysis is a spatial analysis interested in identifying clusters of water systems of concern.

FIGURE 3

Defining and Identifying Systems of Concern

	Noncompliant / In Violation	Chronic Violator	Distressed Utility	Serious Violator	Failing	Intractable
Definition	Common term used generally to refer to systems that have any violations	Term used by Missouri to indicate that a system has repeated monitoring violations	Utility that continually fails to meet standards and provide required service to customers and/or has financial problems (exact definition varies)	Systems with one severe violation, multiple less severe violations, and/or continuing violations	Systems on the "Human Right to Water (HR2W) List," which consistently fail to meet primary drinking water standards	Narrowly-defined term for significantly noncompliant systems serving <1000 customers, abandoned or neglected by the owner/operator*
Used by...	Many entities without a more specific term	Missouri (possibly others but none found in this search)	North Carolina, West Virginia	EPA	California Needs Assessment	EPA
Violations included	Any	Monitoring violations only	Varies	Health-based	All	All
Pros	Captures all types of violations, including monitoring/reporting violations	Captures repeated violations	Used by multiple states; potentially less provocative language	Captures repeated violations and narrows focus to smaller subset of systems	Captures all types of violations, including monitoring/reporting violations	Focuses in on most critical issues of noncompliance
Cons	Too broad and general to be useful for identifying priority systems	Only includes monitoring violations, so may exclude systems with other violations	Operationalized differently in different states	None identified except subjectivity in the "serious" descriptor	Less applicable nationally, given lack of established HR2W	Too narrow to capture harms sufficiently

*See SDWA section 1459C for full definition.

Using the term "failing" systems or an equivalent term

Establishing an exact definition of "failing" requires choosing between countless parameters for the definition, even considering violation data alone. Violation data, which states collect and report into the federal Safe Drinking Water Information System (SDWIS), includes several types of violations, including health-based violations and non–health-based violations, which consist of monitoring and reporting violations.

There are several options for defining "failing" systems, including total violation counts, violation counts for certain types of violations, different time-periods of noncompliance or frequencies of violation(s). Definitions could also vary based on water system size, water source or other system demographics (U.S. EPA, 2022).

One basic way to define "failing" systems at a national level would be to select systems with recent violations of the SDWA, potentially focusing on health-based violations. Health-based violations are, in many ways, the most important violations to resolve to achieve the Human Right to Water, and focusing on these violations may be the best way to narrow the scope of a national assessment toward a feasible effort.

However, while monitoring and reporting violations do not directly contribute to public health problems, they make it difficult or impossible to evaluate whether systems are providing safe drinking water to their customers. Therefore, limiting the scope to health-based violations may miss systems that should be included (U.S. EPA, 2022).

The most fundamental question is what type and length of noncompliance merits inclusion on a list of water systems of concern. For a national assessment, the method used to define and categorize systems of concern must be designed to avoid bias toward any specific state or region, as discussed below.

The CA NA prioritized systems of concern by organizing all systems with fewer than 3,300 connections into one of four categories: "failing," "at risk" of failing, "potentially at risk" of failing or "not at risk."[10] The CA NA identified the systems that were "failing" as those that did not meet the Human Right to Water criteria by providing their customers with safe, clean, affordable, accessible drinking water. Because California recognizes the Human Right to Water as a legal right, this definition had broad buy-in from stakeholders, and the State Water Board already maintained a list of these failing systems.

Defining what it means for a system to "fail" is more complex on the national scale. States that have not legally recognized a Human Right to Water may not be willing to use this type of definition and may not already maintain such a list. However, multiple interviewees raised questions about whether a binary of "failing" versus "not failing" is even helpful when there are so many different evaluation parameters and nuances. Additionally, as discussed later in this section, inconsistencies in how states report violations can also lead to perceived differences between state violation rates.

10 In the CA NA, "failing" water systems are also called water systems on the Human Right to Water list (HR2W list). These are public water systems that are out of compliance or consistently fail to meet primary drinking water standards. Community Water Systems and Non-Community Water Systems that serve K-12 schools and daycares are assessed for meeting HR2W list criteria.
"At-Risk" public water systems are community water systems with 3,300 service connections or less and K-12 schools at risk of failing to meet one or more key Human Right to Water goals.
"Potentially At-Risk" are community water systems with 3,300 service connections or less and K-12 schools potentially at risk of failing to meet one or more key Human Right to Water goals.
"Not At-Risk" are community water systems with 3,300 service connections or less and K-12 schools not at risk of failing to meet one or more key Human Right to Water goals.

Determining the period of compliance

Another key question to consider when defining the scope of the assessment is the period of performance for defining a "failing" system. Given that new violation data feed into the federal database each day, with varying degrees of lag time among different systems and states, this decision will significantly affect the outcome of any analysis. This is a decision point that needs to be considered carefully with sensitivity analyses to understand the implications for the assessment results.

One consideration in deciding an evaluation period is the difficulty of obtaining data for each year. It may be more feasible to obtain data for a shorter time period rather than a longer one, particularly at the outset of this effort. Additionally, a shorter period may be more useful to identify compliance issues proactively rather than reactively.

While there is no clear precedent to determine the period, and no one right length of time to choose, examples of other periods of reference can inform the decision:

- All relevant assessments and regulatory processes use periods longer than one year;
- The CA NA uses a period of three years to assess compliance: each system's violations from the past three years are taken into consideration to determine whether they meet the HR2W criteria;
- EPA's Drinking Water Infrastructure Needs Survey and Assessment (DWINSA, discussed in more detail in section 3) is intended to be conducted every four years, and it assesses the funds needed to implement all the projects needed to address drinking water quality compliance over the following 20 years;
- Primacy agencies must conduct sanitary surveys once every three years for all community water systems in their jurisdiction; and
- EPA's Unregulated Contaminant Monitoring Rule (UCMR) program monitors unregulated drinking water contaminants every five years.[11]

▶ Permutations and Prediction: Regional Differences and Risk Assessment

Drinking water quality compliance issues are found in every U.S. state but vary widely in breadth and depth across regions and in individual states. For example, while CWSs in California struggle with relatively high incidences of arsenic violations, the state has fewer people impacted by lead and copper violations compared to the Northeast, Great Lakes, East Texas and Louisiana regions. Meanwhile, the Southcentral and mid-Atlantic states have the highest number of Disinfectant and Disinfection Byproduct Rule violations (Scanlon et al., 2022).

Communities historically excluded from infrastructure investments are regionally clustered, including California's Central Valley, the Navajo Nation, Colonias, Appalachia, Puerto Rico and rural areas in the South (Roller et al., 2019, Mueller & Gasteyer, 2021). Meanwhile, Alaska, New Mexico, Arizona and Maine have perhaps experienced the most acute, basic indoor water access challenges (Roller et al., 2019).

While the systems of concern should be well defined, a national assessment of drinking water would ideally also be customizable and relevant to specific EPA regions and individual states' needs and concerns. Finding the balance between a common definition of systems of concern and flexibility to address the diverse issues states face will be a key challenge in developing a national

11 https://www.epa.gov/dwucmr/learn-about-unregulated-contaminant-monitoring-rule

water quality compliance assessment. Data inconsistencies across states will be an additional challenge as data type, quality and availability vary widely. These inconsistencies are discussed further in Section 3.

In some cases, states facing issues with specific contaminants may conduct their own drinking water quality needs assessments. State-run assessments focused on specific contaminants could provide a foundation for a regionally differentiated national compliance assessment. There are several examples of such state-level efforts:

- One example of a recent contaminant-specific assessment comes from the Jersey Water Works, a collaborative effort of organizations which completed an assessment of lead in drinking water, providing recommendations and an overview of the issues New Jersey is facing. The report emphasized the need to remove lead service lines and improve water quality testing in schools and childcare centers. This focused resource provides guidance on next steps and recommendations for state level leadership which could also be useful for states facing similar issues (Jersey Water Works, 2019).
- As another example of contaminant-specific reporting, the Michigan PFAS Action Response Team (MPART) completed a survey of per- and polyfluoroalkyl substances (PFAS) in CWSs, schools and childcare services reliant on their own private well, and noncommunity public water supplies serving sensitive populations. Approximately 80 public water supplies returned results greater than 10 parts per trillion (ppt) total tested PFAS and three systems were found to have perfluorooctanoic acid (PFOA) and perfluorooctanesulfonic acid (PFOS) over U.S. EPA's lifetime health advisory (LHA) level of 70 ppt[12] (MPART, 2019).
- Taking a more similar route to the CA NA, South Carolina completed a statewide assessment in 2022 that identified 15 indicators that can provide early warning for utility viability concerns. Both the CA NA and South Carolina's assessment identify risk indicators that address and measure water quality, access and affordability concerns without focusing on a specific contaminant of concern. South Carolina's report is limited to public community drinking water and wastewater systems and uses data provided by the South Carolina Department of Health & Environmental Control, infrastructure funding agencies and organizations that provide technical assistance. The data represents a snapshot in time but provides a proactive evaluation of utilities that can help them seek assistance before a critical situation arises (South Carolina Rural Infrastructure Authority, 2022).
- North Carolina also sought to identify patterns in vulnerabilities across water systems to inform policy-making relevant to multiple water systems. This goal of proactive identification of areas of concern, and concerns shared by multiple water systems is shared by the CA NA and should be central to a national needs assessment of drinking water quality (Mullin & Pickle, 2022).

Assessing Risk of Noncompliance

The 2021 CA NA was conducted for 2,779 public water systems and evaluated their performance across 19 risk indicators within the following four categories: water quality; accessibility; affordability; and technical, managerial and financial (TMF) capacity. The CA NA was designed to predict which systems are likely

12 Total PFAS tests aim to quantify large groups of PFAS in environmental samples. EPA has set a LHA of 70 ppt for PFOS and PFOA, two specific types of PFAS persistent in drinking water.

to fall out of compliance and provide solutions to those issues using a quantitative scoring methodology and labeling system.[13]

However, replicating the CA NA risk assessment methodology at the national level is infeasible. With current data availability, only four of the 19 indicators from the initial CA NA are likely to be immediately available to use in a national assessment (number of water sources, source types, number of service connections, and monitoring and reporting violations). The other variables are not easily available through the national SDWIS or joinable databases. However, we note that an additional six indicators appear feasible to use at the national level in the near future if they are prioritized in targeted efforts to increase data collection, tracking and maintenance.[14] A major shortcoming in available risk data matched to water system boundaries at a national level is that none are climate-focused. A risk prediction tool is necessary to evaluate which water systems are most at risk of not providing safe drinking water, and any risk prediction model should be reviewed over time to see whether the model accurately predicts water systems falling out of compliance, as has been done in the CA NA process.

Beyond a quantitative risk assessment, proxies for water system risk of noncompliance can be used. Recent research by Scanlon and colleagues shows that violations occur disproportionately in socio-economically disadvantaged communities and communities served by very small water systems. In particular, persistent violations are more likely to affect socially vulnerable populations than others, suggesting that these populations face longer periods of contaminated water (Scanlon et al., 2022).

There are also growing numbers of definitions of "vulnerable", or "disadvantaged" communities used by states and across different federal agencies that may help identify communities at risk of water system noncompliance as shown in the DWSRF Disadvantaged Community Definitions handbook from EPA and the Association of State Drinking Water Administrators's (ASDWA's) white paper defining disadvantaged communities in DWSRF (U.S. EPA, 2022(3); ASDWA, 2022). EPA's environmental justice mapping and screening tool, EJScreen, has its own set of environmental and socioeconomic indicators to identify "environmental justice communities." However, EJScreen is not adapted to CWS boundaries and only contains one indicator directly focused on water: wastewater discharge. Although EJScreen includes race, along with socioeconomic indicators, the omission of more water-focused indicators such as drinking water quality limits its usefulness in predicting what communities and water systems may be most at-risk of lacking access to safe drinking water.

▶ National Data Consistency and Depth Limitations

A uniform theme across interviews and advisory committee meetings was that a lack of consistency in violation and water quality testing data across states poses barriers to a nationwide

13 The risk assessment methodology consists of:

1) Risk indicators set as quantifiable measurements of key data points to assess the potential for a water system to uphold the human right to water.
2) Thresholds set to delineate when a water system is more at-risk of failing, typically based on regulatory requirements or industry standards.
3) Scores & weights applied to indicators as certain indicators and categories deemed more critical than others and/or may be out of control of the water system.

14 History of E. coli presence, increasing presence of water quality trends towards MCL, duration of high potential exposure, percentage of sources exceeding a MCL, operator certifier violations, and Median Household Income for the water system may be possible variable to use in the future.

water quality compliance assessment. As a result, additional federal and state data may need to be developed.

The two main sources of violation and compliance data at the federal level are EPA's SDWIS and the Enforcement and Compliance History Online (ECHO) system. The federal SDWIS database contains basic location, type and size information about public water systems and registers their violations of primary drinking water regulations. However, most states maintain their own drinking water data in a state-level SDWIS database, sometimes with much more detail, which is then shared with the federal SDWIS database to create a national database of public water systems and their violations. ECHO is a dashboard that incorporates public water system data from SDWIS such as the number of quarters a system has been in violation, whether the system is a serious violator and enforcement actions taken against each system. However, the drinking water displayed on ECHO are not real-time data and rather are updated quarterly. Some states may have more recent data available on their websites.

EPA has acknowledged there may be underreporting of violation and compliance data into the federal SDWIS. It cautions users that a list of systems with no violations represents the best data available but may not be a complete representation of current compliance (U.S. EPA, n.d.).

SDWIS and ECHO can both be difficult to navigate and extract data from without prior knowledge or training. Extracting detailed violation data from SDWIS requires using its advanced search option which contains many columns, some of which are not intuitive to an untrained user. Extracting large amounts of data from SDWIS can be time consuming and not easily automated without using an API, which requires additional technical knowledge. One interviewee noted that complete water quality data for states within the federal SDWIS is often behind Drinking Water Watch websites, state-specific public web portals with public water system data, are not easily exportable or in some cases may not even be available online. To access this raw data, one must submit a Freedom of Information Act request or Public Record Request which in many states costs money because time and labor are required to source and provide the requested data. Despite these limitations, SDWIS allows users to answer specific research questions by filtering the data to examine specific contaminants of interest, types of violations (health-based vs. monitoring and reporting), or subset results for only small or very small systems.

ECHO is less frequently used because of the time-lagged data but contains many of the same limitations and assets as SDWIS. Though often difficult to use for specific research questions or applications, ECHO can be useful for obtaining quick snapshots of information with the built-in graphics and data export options.

Data Consistency Problems

The quality and frequency of data reporting are very inconsistent from state to state — and even sometimes among water systems in the same state. While states must report violations of the SDWA, some states appear to record data in a manner that is inconsistent with other states.[15] Multiple interviewees discussed issues with state-to-state differences in data reporting that make it difficult to get a full picture of the

15 In a study by Pierce, Rachid-El Khatabbi, and Gmoser-Daskalakis, 2023, Arizona was found to have a high number of monitoring and reporting violations compared to three other states included in the study. It was unclear if these disparate monitoring and reporting trends were caused by system or regulatory enforcement behavior, or if Arizona truly had a significantly larger number of violations.

problems and draw comparisons across states.

There are a few primary reasons for the inconsistencies. First, violation data are manually entered by individuals — often by dozens of separate district engineers within each state. When there is ambiguity in the reporting process, these individuals may make different choices about what data to include and how to organize it. Second, states may report data differently depending on the specific problems they face. For instance, they may report on different water contaminants with varying degrees of granularity depending on the specific contaminant challenges they face.[16] Additionally, both expert interviews and our own observation show that some states enter repeat violations multiple times, causing the list of violations to be much longer, while others only report a repeated violation once, causing these two states' violation histories to look vastly different despite their being the same underlying water quality issue.

The inconsistencies between states can be difficult to interpret without a full understanding of each state's idiosyncratic reporting style. Differences in water quality compliance data across states may in part reflect actual compliance variation while also reflecting inconsistencies in how violation data were coded and entered between states. For example, if one state has fewer violations than another, it may be that the PWSs within the state are more compliant, but it also might mean that state allows minor violations to continue without being reported and is therefore less compliant than it appears.

While understanding how violations are recorded in each state can help researchers interpret the data, the inconsistencies make it infeasible to compare violations uniformly across states. Additionally, the U.S. Government Accountability Office (GAO) found gaps in the data that states reported to EPA for SDWA monitoring compliance. Among 14 states audited by EPA in 2009, 26% of health-based violations and 84% of monitoring violations that should have been reported were either inaccurately reported or not reported at all. States also underreported the percentage of water systems with enforcement actions for compliance. These reporting issues were attributed to errors in reported data, lack of training, staffing and guidance as well as a lack of funding for reporting activities (GAO, 2011).

To complicate matters further, our interviewees reported that intergovernmental data exchange between states and the federal government is often constrained by regulations and procedural differences. EPA is not able to easily request data from states as there may be legal limitations on what data it can request, and this data is not readily available depending on the state.

Underlying Constituent-Level Data Problems

One interviewee highlighted the importance of continuous water quality contamination levels, rather than binary violation, data in identifying at-risk water systems. Continuous contamination level data may be the best indicator of risk of noncompliance; however, this data can be extremely difficult to obtain. Binary violation data are available showing a violation has occurred or a maximum contaminant level (MCL) has been surpassed, but information beyond that — such as the actual measured contaminant level (above or below a standard) — if often unavailable, limiting deeper understanding and analyses of these violations.

The same interviewee further highlighted the fact that EPA uses the Unregulated Contaminant Monitoring Rule (UCMR) to collect data for contaminants suspected to be present in drinking water but does not have a set regulatory

16 One interviewee reported that although states are required to report all the contaminants listed in SDWA, some states have reported data on a few as two contaminants. It is unclear if these states are receiving violations for this lack of data reporting.

standard under the SDWA. Some private firms have extracted this unregulated data from UCMR to create a working database, but these efforts data are not publicly linked to the federal SDWIS, limiting its accessibility and ease of applicability. UCMR data also varies in its relevance to a compliance focus, depending on whether the contaminants being measured in the current round are selected for regulation in the future. Not being selected does not necessarily mean the contaminants do not pose any risk to public health, but their inclusion in any analysis is unlikely to be within scope of any state or national assessment.

▶ Next Steps: Limitations, ongoing questions and recommendations

Setting the Scope

The first step in developing a national assessment of drinking water quality in the United States is setting the scope of what systems, violations and populations should (and can) be included in the assessment.

Based on our research, we believe the following steps are necessary and feasible to set the scope:

» Determine how to define systems of concern/failing systems

A national assessment must establish what type of noncompliance merits a water system's inclusion on a list of systems of concern. Inclusion criteria must balance between a broad definition of systems of concern and enough specificity and flexibility to address the diversity of issues which systems and broader regions are facing.

» Set the appropriate timeframe for assessing compliance

Questions remain about what length of time is appropriate to assess water systems' compliance and identify concerns proactively.

» Create and evaluate a risk prediction tool to identify which water systems are most at risk of being unable to provide water that complies with public health standards

This risk prediction tool will likely not be a completely new resource, but rather will pull from already established tools and resources to create a prediction model appropriate for the national level. This risk prediction model will need be reviewed over time to see if the model accurately predicts when water systems fall out of compliance.

Solving Data Problems

It is critical to create a more transparent, accessible and consistent national drinking water quality data management solution. Several of our interviewees emphasized the need for such a system. One key question discussed in the interview process was who should host and manage this system. Ultimately it was decided that EPA would be the only correct fit, rather than a university, private organization or other government agency. Water systems need to feel they have ownership over this reporting system and be able to easily access and update data. Having the data hosted by a central agency such as EPA will hopefully foster this feeling and participation.

Questions remain about how to incorporate regional, often contaminant-specific, trends such arsenic contamination in the West and lead and copper violations in the Great Lakes region into a national assessment of compliance standards. Finding a balance between state- or region-specific problems and solutions and national compliance standards will continue to be an evolving discussion.

While the systems of concern should be well defined, a national assessment of drinking water would ideally also be customizable and relevant to specific EPA regions and individual states' needs and concerns. Finding the balance between a common definition of systems of concern and flexibility to address the diverse issues states face will be a key challenge in developing a national water quality compliance assessment.

A key consideration that must be at the center of this work is how to incorporate community-identified concerns that go beyond violation data. Quantitative data is one resource a national assessment will rely on, but qualitative resources highlighting key concerns potentially not in the data (including community-identified concerns) are also critical to the success and reliability of a national assessment of drinking water quality.

2) SPATIAL LOCATION CONSIDERATIONS

With so many individual water systems within each county, it is essential to understand where CWSs are located within counties[17] to evaluate the feasibility of solutions. Knowing where systems are located with precision is especially important for considering physical consolidation, as well as characterizing the socioeconomic status of communities served. However, states vary dramatically in how and whether they collect and make public spatial data on system location.

We looked at the availability of numerous types of spatial location and demographic data to characterize systems' geographic and population profiles. We organize our discussion as follows:

- Availability of statewide geospatial information system (GIS) data
- Workarounds to unavailable geospatial data
- Matching Census data to system location
- Next steps

▸ The Gold Standard: System-Specific Geospatial Information

While still imperfect, water system geospatial polygon data[18] allow for the best joining of Census data to water system boundaries to approximate the sociodemographic characteristics of each water system's residential customer base. However, as recently catalogued by Vanderbilt University's Drinking Water Justice Lab, geospatial data representative of water systems' boundaries is only publicly available

17 Counties are often used as a base unit of measurement for geospatial analyses, including of CWS, but are not sufficiently granular to identify where CWSs are located and their demographic characteristics.

18 Polygon data is used to represent areas such as the boundary of a city, park, water system boundary etc. Polygon data is a type of vector data, and vector data can also come in the form of point or line data. ESRI's Shapefile format is the most frequently used file format to store geospatial vector data, but other file formats such as GeoPackage or GeoJSON are preferred by some users.

for 26 states and the District of Columbia.[19] Of these 26 states, 24 and the District of Columbia have geospatial data which are polygons, one state has point data, and one state has line data. Five more states have geospatial data that are currently only available for internal agency use[20] (McDonald et al., 2022).

Among states, California has been a leader in the creation and maintenance of CWS service boundary geospatial data. The Tracking California Water Boundary Tool (WBT), first launched in 2012, compiled information on over 4,800 water systems that serve about 90% of the state's population. The Water Boundary Tool was retired in 2020 when the CA Waterboards developed their own data collection and system boundary tracking system inspired by the WBT. Today, about 97% of CWS service boundary areas are available as geospatial data (McDonald et al., 2022; Tracking California, 2020)2020.

Other notable state-level GIS efforts include those in North Carolina and Texas. In October 2020, Duke University created a set of more than 500 digital maps of publicly owned CWSs across North Carolina; about a quarter of the ~2,000 CWSs in North Carolina. The North Carolina Department of Environmental Quality's Division of Water Resources provided the Duke team with maps of the water systems which were then digitized and combined into a statewide map (Gonsenhauser et al., 2020).

In January 2019, the Texas Water Development Board and the U.S. Geological Survey (USGS) partnered to develop a statewide public water system service area mapping tool called the Texas Water Service Boundary Viewer. This tool provides the most up-to-date geospatial boundaries and data available for all 4,500+ community public water systems within Texas. These data help estimate which public water system serves which population and help locate rural populations not served by any public water system, which likely rely solely on private wells (Texas Water Development Board, 2019).

Other states have created digitized maps of their states' water system service area boundaries, and some have also created public dashboards for users to view maps and easily download data. Despite differences in data collection, quality and availability, the interviews we conducted suggested that many states are working to improve access to spatial water system data, and we expect further improvements in the quantity and quality of this data in the future.

▶ Workarounds to missing locations: Approximated polygons and points

When water system boundary data are not available, similar but less precise geographies such as approximated system boundary data (polygons) or simple point data are often used to conduct analyses. Remarkably, the goal of a public repository of a single, valid address for every system remains elusive, despite regular, mandated site visits by regulatory staff to every system.

There are also several ongoing efforts to improve and democratize water system service boundary data across the United States, which we identified through our expert interviews and landscape analysis. Most promisingly, the Environmental Policy Innovation Center (EPIC) is collaborating with SimpleLab and the Internet of Water Coalition to create a national dataset of drinking water service boundaries from a mix of state-provided geospatial polygon data, town or

19 Alaska, Arizona, Arkansas, California, Colorado, Connecticut, Delaware, District of Columbia, Florida, Idaho, Illinois, Kansas, Massachusetts, Mississippi, Missouri, Nevada, New Jersey, New Mexico, North Carolina, Oklahoma, Pennsylvania, Rhode Island, Tennessee, Texas, Utah, Washington, West Virginia

20 Kentucky, Louisiana, New Hampshire, New York, South Dakota

city geospatial data algorithm-matched to water systems, and statically modeled water service boundary data. This project maps water service boundaries for 49,442 CWSs, or about 91% of active CWSs (SimpleLab Tap Scope, 2022). The data have limitations, such as errors in the algorithm matching, over- and under-estimation of water system boundaries for very small and very large systems, and missing or incomplete data, but the project represents an enormous step in the right direction.[21]

When actual or approximate water system boundaries are not available, the backup for spatial location is a single address for the system. However, as of now, even using a single valid address for each system is not a reliable strategy given that the public facing SDWIS database is missing addresses for some systems. Moreover — and more problematically — some of the addresses are for administrative contacts for the system, and thus are out of county, out of state, or P.O. Box addresses that do not represent the water system's service boundary area. While the Federal Registry Service (FRS) of EPA may have access to more geolocation data for water systems than is publicly available through SWDIS and the publicly available portion of the FRS, it is still not comprehensive (Berahzer, 2022).

Matching demographic data to boundaries: Census options and new opportunities

Income,[22] poverty level, race/ethnicity, homeownership rates, education, unemployment and other socioeconomic variables are key indicators of water quality in CWSs (Balazs et al., 2012; OEHHA, 2015). However, these demographic variables are not included in the water system–level data available through SDWIS. Therefore, these socioeconomic variables can only be estimated for CWSs through imperfect methodologies such as areal interpolation[23] or matching city demographic data to water system data.

When geospatial polygon data is available, block group or Census tract data is conventionally used to match demographic data to water system boundaries. Census tracts are subdivisions of counties and contain approximately 1,200–8,000 people; block groups are smaller subdivisions within Census tracts and contain approximately 600–3,000 people.

When geospatial polygon data is not available, or in some cases even when they are, previous studies have used ZIP Code data to analyze water equity outcomes (Marcillo, C. et al., 2021; Allaire and Acquah, 2022). However, our findings from a recent study demonstrated there may be inaccuracies caused by matching Census data to water systems using ZIP Code data (Pierce, El-Khattabi, Daskalakis, 2023). The study explored which administrative boundaries best fit water system boundary data stored in shapefiles and therefore should be used to estimate water system demographics and found Census-designated places (CDPs) to be the most

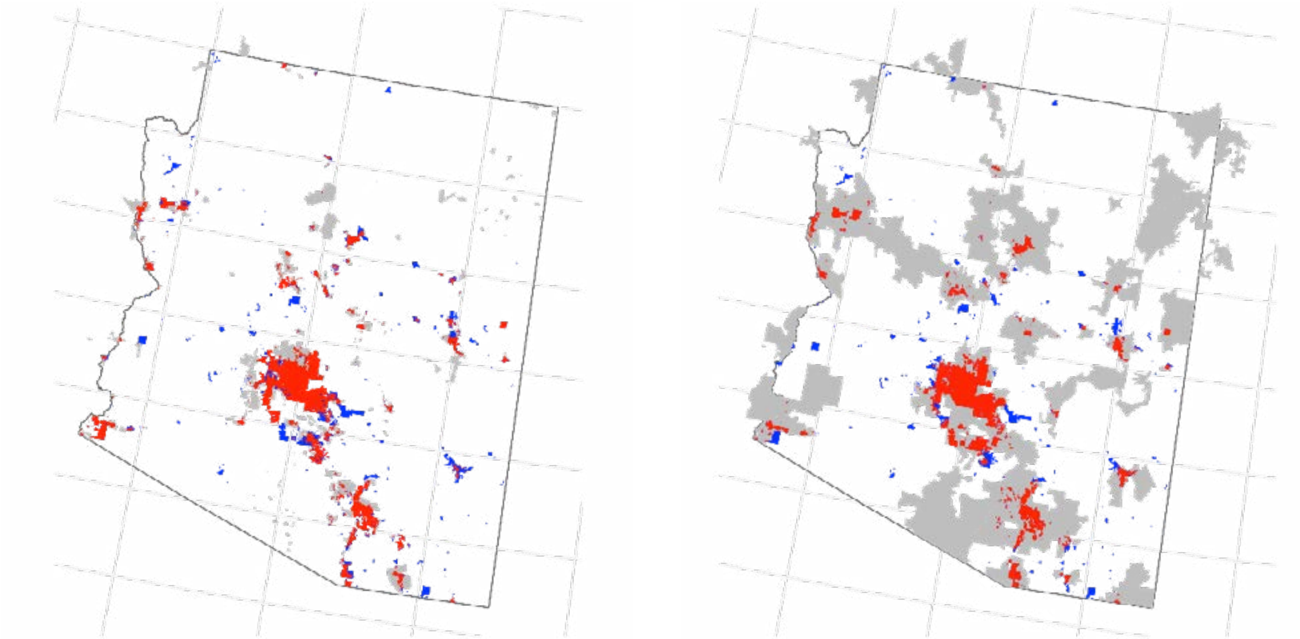
21 Additionally, EPA is working on estimating well locations at the block group scale, but this exercise is in its early stages and has to be validated (Murray et al., 2021).

22 One of the most important demographic variables to characterize for systems is median household income (MHI), which is used to determine eligibility for funding in CA (and increasingly nationally) connected to whether a community is deemed "disadvantaged." The CA NA set margin of error limits and then applies them to population adjusted MHI figures, resulting in slightly different community water MHI calculations than the methodology used by the CA State Water Board's Division of Financial Assistance.

23 Areal interpolation is the process of making estimates from a source set of polygon data to an overlapping but incongruent set of target polygons. In this case Census demographic data at the Census Tract, Census Block, or CDP level are the source polygons and the water system boundary data are the target polygons.

FIGURE 4

Comparison of System Shapefile, CDP (left hand panel) and ZIP (right hand panel) boundary layers in Arizona



In the figure above, the left-hand panel compares CDPs to shapefile boundary areas, whereas the right-hand panel compares ZIP codes to shapefile boundary areas. Gray indicates that the area of a CDP or ZIP code does not overlay with a formal utility area, i.e., the areas that would incorrectly attribute to a water system if using CDP/ZIP (error of inclusion). Blue means a utility area does not overlay with CDP or ZIP code, i.e., the areas that would be missed by CDP or Zip (error of exclusion). Red means represented the area of intersection, i.e., what areas would be correctly predicted by CDP or Zip

Source: *Reproduced with permission from Pierce, Rachid-El Khattabi, and Gmoser-Daskalakis (2023)*

appropriate geography. Figure 4 demonstrates our findings.

The relative reliability of CDPs is also consistent with efforts performed by the Environmental Finance Center at the University of North Carolina, Chapel Hill (UNC EFC) for some of its state dashboards, as well as other recent studies which evaluated similar alternatives (Berahzer, 2022; UNC EFC, 2021). When CDPs are not available, data can be supplemented with the primary county served, which is available from SDWIS codes. Census demographic data can be collected at the CDP and county levels from the National Historical Geographic Information System database (Manson et al., 2021) and matched to systems based on the primary location served.

In the figure above, the left-hand panel compares CDPs to shapefile boundary areas, whereas the right-hand panel compares ZIP codes to shapefile boundary areas. Gray indicates that the area of a CDP or ZIP code does not overlay with a formal utility area, i.e., the areas that would incorrectly attribute to a water system if using CDP/Zip (error of inclusion). Blue means a utility area does not overlay with CDP or ZIP code, i.e., the areas that would be missed by CDP or Zip (error of exclusion). Red means represented the area of intersection, i.e., what areas would be correctly predicted by CDP or Zip.

As discussed in Section 1, there are environmental justice screening tools such as EPA's EJScreen or California's CalEnviroScreen that seek to identify communities vulnerable to environmental injustices. However, these tools are not at the water system level, and in the case of EJScreen, contain no data about drinking water. It may be best not to use these tools to identify vulnerable water systems because they do not have the geographic granularity and data needed to have an accurate demographic description of a water system. Despite limitations, methods such as areal interpolation of demographic data to the water system level may be preferable.[24] There is no one right answer to the question of how to best identify communities and water systems vulnerable to drinking water problems, and new tools and methodologies continue to be developed.

Next Steps: Limitations, ongoing questions and recommendations

Based on our research, we suggest the following are necessary and feasible in the near term:

» Continuing the effort to find and develop small water systems' geospatial data, as these systems make up the majority of CWSs and often serve communities that are disproportionately vulnerable to drinking water challenges

» Solidifying the best methods to minimize bias and errors when applying demographic data to water system data

» Determining whether an additional tool is needed to evaluate water system disadvantage or if an existing tool is sufficient

While water system boundary polygon data is generally considered the best option for data analyses, there are continual challenges with spatial data. Two key issues in joining demographic data to water system boundary data likely remain in the context of a national drinking water quality compliance assessment.

First, any method of attribution of population characteristics from Census data to small and very small CWSs is likely to have a high degree of inaccuracy. This is important because approximately 55% of systems serve 500 people or fewer[25] (U.S. EPA, n.d.).

By contrast, the smallest Census geography at which population characteristic data is available is the block group, which contains 600–3,000 people. Even this geography is larger — often much larger — than a very small water system. Therefore, for very small (and some small) water systems, only manually collected socioeconomic characteristic survey data will be sufficient to truly characterize the population. Some income and broader demographic data, collected for system upgrades or other purposes, is housed in very fragmented fashion on various platforms by different institutions, such as technical assistance service providers including RCAP, different states, and EPA regions. Most very small systems do not have the resources to conduct this type of survey or study to accurately characterize the socioeconomic data of the population they serve, and technical assistance providers or government staff do not have the resources to do this for every, or even most, systems.

Second, physical water system consolidation, one of the key potential solutions for water quality compliance (see box below), requires

24 Areal interpolation is an imperfect method of applying demographic data to water systems. Areal interpolation assumes demographic values are the same for an entire block group or CDP which is often untrue. Additionally, large water systems may contain multiple block groups or CDPs; however, after interpolation to the water system level these disadvantaged areas may become invisible at the water system. Finally, areal interpolation uses the means-of-medians, meaning demographic data is a simplified version of the true data which may obscure demographic details (Reibel, 2018).

25 Number from the most recent Advanced SDWIS search results.

more precise spatial information on the route of pipelines and administrative rights of way than even the most accurate geospatial data. High-resolution spatial data is not consistently available for all states, limiting the feasibility of reliable physical consolidation analyses in the context of a national compliance needs assessment.

As states continue to develop spatial water system boundary data, a central, durable home will be needed to host this location data for accessible use. Similar to the discussion of the recommended location for a federal drinking water quality database that states can easily access and update, something similar hosted by EPA is needed for spatial location and boundary data for water systems.

CONSOLIDATION AND REGIONALIZATION

Regionalization is another term often used to describe the range of collaborative activities, ranging from informal to formal partnerships between communities used to overcome water system compliance challenges. The terms consolidation and regionalization are often used interchangeably. This report primarily uses the term consolidation, but recognizes that the more informal partnerships or agreements often associated with regionalization are also important tools to address water system compliance challenges, especially in small rural communities. See RCAP's 2021 report about regionalization to learn more.

3) COMPLIANCE SOLUTIONS AND THEIR COST

The objective of a compliance needs assessment is not just to point out problems, but rather to identify them alongside feasible solutions and ways to pay for those solutions. Just as the drinking water quality *problems* facing water systems throughout the United States are diverse, the range of *solutions* to address them also are diverse and often contrast with solutions most relevant in California.

Differences in data availability, regulations, funding and other factors between California and the nation as a whole make it important for a national assessment to consider a different set of solutions and cost estimation methodology than the CA NA. As confirmed by our expert interviews, there is generally little to go off: regulatory mandates do more to identify problems than to address them, and there are few transparent methodologies for solution identification from either public or private sectors.

In this section, we examine at a high level the different sets of problems and solutions that are relevant across the country, explore the problems associated with data and policy inconsistencies across states, and compare existing methodologies for estimating how much it will cost to bring all water systems into compliance with drinking water quality requirements.

The primary way we explore how a national analysis of solutions and costs will differ from that in the CA NA is comparing the CA NA to the current best analogue for a national drinking water needs assessment: EPA's Drinking Water Infrastructure Needs Survey and Assessment (DWINSA). The DWINSA takes place every four years and is broader than the type of compliance assessment discussed in this report. The most recent DWINSA is representative of 2021 data and a fact sheet and FAQ was released in April 2023; however, the full-length report has not yet been released.[26] We explore the different solution sets considered in the CA NA and the DWINSA, identify the differences between the DWINSA and a more targeted national compliance assessment, and compare the cost estimation methodologies of the two studies to determine what problems will need to be addressed to conduct a national assessment.

The rest of our discussion is organized as follows:

» Core differences between the DWINSA and CA NA

» Solutions for a national assessment

» Cost estimation methodologies

» Next steps

▶ Core Differences between the DWINSA and CA NA

While we focus on similarities and paths forward, we first note core differences between the DWINSA and the CA NA which are useful to identify potential challenges and barriers to a future national water quality compliance assessment. There may be an opportunity for such a national assessment to bridge the gap between the types of information the CA NA provides and the types of information the DWINSA provides (on their respective geographic scales). Given that the DWINSA is the best current example of a national assessment, any identified knowledge gaps will be difficult to fill.

The scope of projects included in the DWINSA is focused on capital improvement projects that are eligible for DWSRF funding and either explicitly further public health or accessibility goals. The projects included in the DWINSA generally consist of replacing, rehabilitating or expanding existing infrastructure or building new infrastructure. Non-capital needs such as operation and maintenance (O&M) costs, projects not the responsibility of the public water system, projects needed to serve future population growth and anything ineligible for DWSRF funding are excluded from the DWINSA.

The DWINSA and CA NA also differ in the data they use. The CA NA risk assessments contain near contemporary data (although state small water systems and domestic well data is limited).[27] In comparison, the 2015 DWINSA, the most recent full-length DWINSA report, states that small systems were not surveyed in the 2015 DWINSA and rather the report extrapolated data from the 2007 DWINSA to estimate the costs for 2015.

Additionally, the DWINSA is a survey of a sample of U.S. public water systems rather than a Census of nearly all systems like the CA NA. Meaning, the DWINSA aims to be representative

26 Our report research team contacted folks at EPA and CADMUS working on the 2023 DWINSA, but the EPA was not able to provide more details preceding a full public release of the DWINSA. Regarding full report release timing, the 2023 FAQ sheet states that "Section 1452(h) of the Safe Drinking Water Act requires EPA to provide a report to Congress with the results of the DWINSA. When the report is complete and transmitted to Congress, EPA will post the report on its website." See more details at https://www.epa.gov/system/files/documents/2023-04/Final_FAQ_DWINSA_4.4.23.v1.pdf

27 California defines state small water systems, the smallest water systems, as systems which serve at least five, but not more than 14, service connections and do not regularly serve drinking water to more than an average of 25 individuals daily for more than 60 days out of the year.

of all public water systems but does not actually include data from all public water systems. In comparison, the CA NA aims to include data from all water systems in California, and although data are missing or incomplete for some systems, comes closer to a complete census. A national assessment of drinking water in the United States would be unable to take the census approach as data availability would be infeasible.

▶ Solutions for a National Assessment

Relevant solutions: California vs. Nationwide

As noted in many of our expert interviews, solutions relevant to California water systems will likely be different from those relevant to water systems across the United States. Water systems outside of California struggle in different ways than California water systems because of differences in water sources, environmental challenges, local geographic location, population, funding and more. A national assessment must address these varied challenges and propose solutions to a diverse range of state and local situations.

One example of a difference between problems and solutions relevant to California compared to other states is the breakdown of groundwater versus surface water use. California derives about 40% of its drinking water from groundwater in a typical year, and about 60% in a dry year. Some communities in California rely on groundwater for 100% of their water supply regardless of whether it is a wet or dry year (CA SWRCB, n.d. -a). Therefore, the CA NA focused primarily on groundwater solutions. However, groundwater solutions may not be relevant to states primarily relying on surface water. A national water quality assessment must focus on an array of solutions reflective of states' diverse water sources.

Data limitations will also affect which solutions a national assessment should consider. The availability of vendor data and geographic specificity, as well as system size, will need to be further considered. Moreover, as Section 2 of this analysis notes, physical consolidation as a solution could only be considered in any fashion where enough spatial data was available to identify the rough location of systems.

Understanding the most common violations causing systems to fall out of compliance, or likely most common, given data quality challenges, may be helpful in focusing efforts to develop solutions. Though SDWIS has data quality challenges as described, it is relatively simple to pull data on what kinds of violations are most prevalent in an estimated time frame (which National Primary Drinking Water Regulation is being violated, which specific contaminant is in violation, whether it is a health-based or monitoring/reporting violation, etc.). This analysis can be subset to small or very small systems as well, and can be looked at from a framework of "how many instances of violations" or "how many PWSs or CWSs had a violation" depending on the research question.

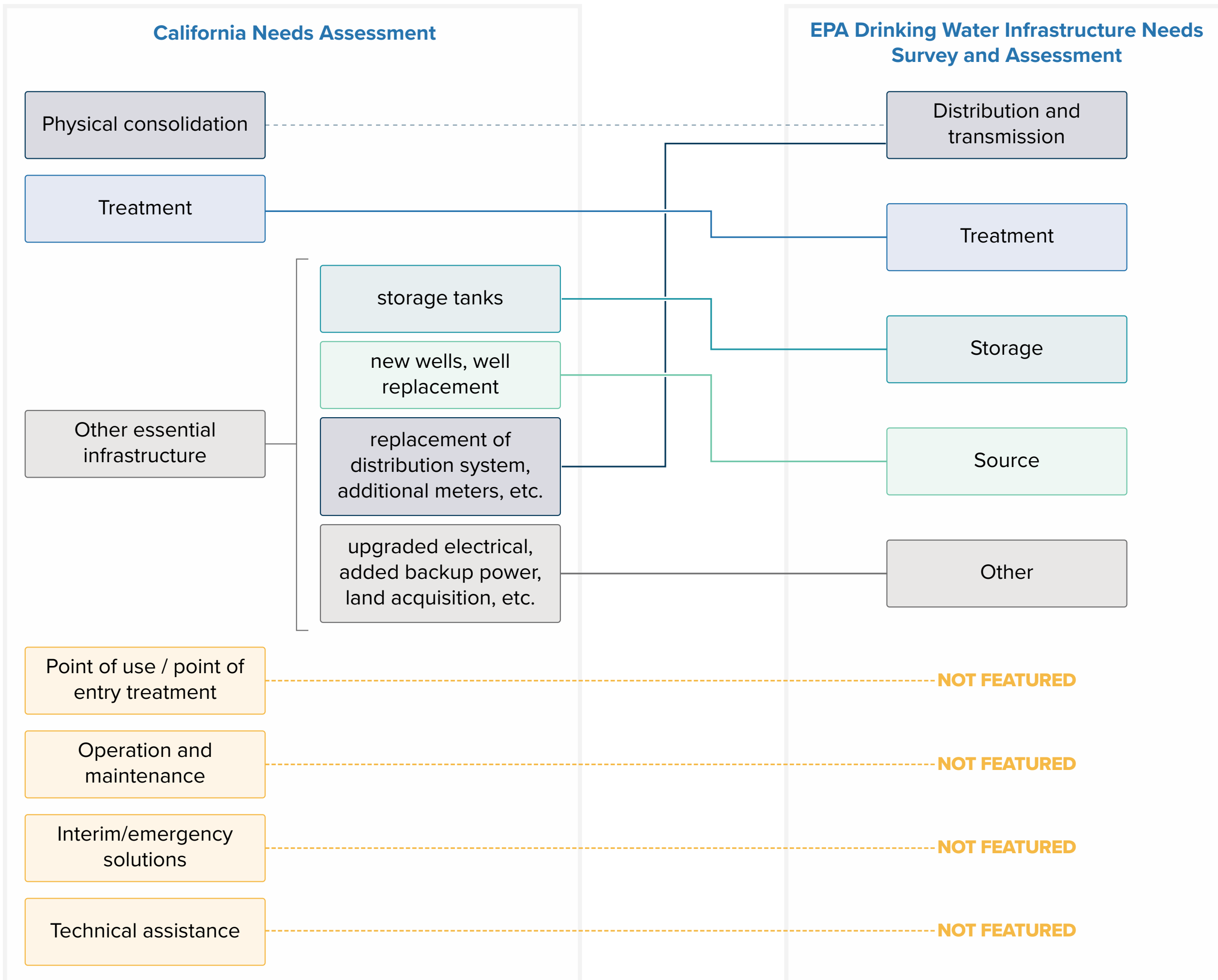
Solutions: CA NA vs. DWINSA

The solutions included in the CA NA and the DWINSA overlap, but there are several differences (see Figure 5).

Treatment: Both the CA NA and the DWINSA include centralized treatment as one of the primary solution categories. The CA NA considered treatment solutions only for water systems on the Human Right to Water list — water systems that "consistently fail" to meet primary drinking water standards. These treatment solutions are infrastructure solutions used to lower the concentration of contaminants that exceed water quality standards to ensure compliance. The DWINSA acknowledges that treatment solutions are diverse and can and should address more than just contaminants negatively impacting

FIGURE 5

Comparing Solutions Included in the CA NA and EPA DWINSA



human health. Treatment solutions can also remove contaminants addressed under, non-mandatory "secondary" water quality standards that adversely affect the taste, odor, and color of drinking water, but have not been judged to impact human health, as much as "primary standards." These secondary contaminants also often negatively impact preference for or trust in tap water, leading customers to seek out more appealing but less safe and affordable sources of water (Pierce and Lai, 2019).

Technical Assistance and Operations and Maintenance (O&M): The CA NA also includes technical assistance and O&M, while the DWINSA is explicitly limited to capital costs and infrastructure projects that are eligible for DWSRF funding. Both technical assistance and O&M costs will be critical to include in a national assessment. Each of these categories was emphasized as vital to include throughout our interview process. These two categories will also be critical to explore from a funding point of view, as they still do not receive sufficient funding from the DWSRF compared to need, especially for disadvantaged communities. This gap was the explicit motivation for the passage of California's Safe and Affordable Funding for Equity and Resilience (SAFER) fund.

Other Infrastructure Categories: The differences between the CA NA and the DWINSA are less discrete within some other solution categories. While the DWINSA treats distribution and transmission, storage, and source solutions each as distinct categories, the CA NA combines most of the projects in these categories as "other essential infrastructure." This category also includes some things that may not be eligible for inclusion in DWINSA, such as upgraded electrical, added backup power and land acquisition.

Physical Consolidation: Whereas the CA NA had a major emphasis on physical consolidation of water systems, it is not clear where this category of solutions fits into the DWINSA. Physical consolidations are eligible for DWSRF funding, but while most of the other major DWSRF categories seem to be included as categories in the DWINSA, consolidation is not directly mentioned. As noted earlier, any analysis of consolidation requires high-resolution spatial data, which is not consistently available for all states. States that have sufficient data could consider analyzing consolidation, but the lack of data means that a national assessment of physical consolidation is likely not feasible.

Point of Use (POU)/Point of Entry (POE) Treatment: Finally, in conducting a national drinking water quality compliance assessment, it will be particularly important to explore the role of POU and POE treatment, not featured in the DWINSA. State regulations vary in terms of how these treatment methods can be used, as illustrated in these examples:

» In California, POE/POU treatment can be used by public water systems with fewer than 200 service connections for up to three years, or until funds are available for centralized treatment.

» In New Jersey, no additional regulations appear to be in place on top of Federal restrictions.[28]

» In Massachusetts the Department of Environmental Protection will review each water system's application to use a POU/POE program on a case-by-case basis considering the number of service connections, population serviced, contaminant of concern, proposed treatment processes, and ability to carry out such a program (CA SWRCB, n.d. -b; MassDEP, n.d.; United States EPA, 2006).

Depending on states' regulations, size of systems of concern, and contaminants causing systems to fall out of compliance, POU/POE treatment may not be a reasonable solution for all states or systems.

Interim Solutions: The CA NA includes analysis of interim solutions (bottled water, vended water, POU or POE treatment units) to be used until permanent solutions are implemented. As noted above, this level of detail is likely too granular for a national assessment.

▶ Cost Estimation Methodologies, Data and Limitations

The CA NA and the DWINSA also vary in the methodologies used to identify problems and solutions for water systems and estimate the costs of the identified solutions. The models used to estimate the costs of solutions in the two assessments have varying degrees of accuracy.

28 EPA is prohibited from listing any POU treatment units as an affordable technology to achieve compliance with an MCL or treatment technique for a microbial contaminant or an indicator of a microbial contaminant. POU and POE units must be owned, controlled, and maintained by the PWS or by a contractor hired by the PWS to ensure proper operation and maintenance of the devices and compliance with MCLs. POU and POE units must have mechanical warnings to automatically notify customers of operational problems. If the American National Standards Institute (ANSI) has issued product standards for a specific type of POU or POE treatment unit, then only those units that have been independently certified according to these standards may be used as part of a compliance strategy.

FIGURE 6

Comparing Methodologies of the California Needs Assessment and the EPA Drinking Water Infrastructure Needs Survey and Assessment

		California Needs Assessment (2021)	EPA Drinking Water Infrastructure Needs Survey and Assessment (2016)	Key Differences
IDENTIFYING NEED	**Which water systems were included?**	All public systems, state small water systems and domestic wells	Sample of public water systems **(not a census)**	CA NA included more types of water systems
	How was need identified?	State HR2W* list → failing systems Risk assessment → at-risk systems	Surveyed systems self-report capital improvement projects they need to fund	DWINSA = water systems self-identify need CA NA = need identified by state or risk assessment
	Why are solutions needed?	Identify why each system was on the HR2W list or at risk of being added to the list	No identification of reason for need	CA NA explored need; DWINSA took systems' project needs at face value
IDENTIFYING SOLUTIONS	**What solutions were considered?**	Physical consolidation; Treatment; Interim solutions; Technical assistance (TA); Operation & maintenance; Other solutions	Treatment; Storage; Source; Distribution & transmission; Other solutions	DWINSA = long-term solutions only CA NA = interim and long-term CA NA included O&M and TA; DWINSA limited eligibility to capital improvement
	How were solutions selected?	Model all relevant solutions and select based on cost and sustainability For at-risk systems, prioritize consolidation	Systems self-identified solutions based on their own analysis	DWINSA = 20-year timeframe CA NA = 5-year timeframe DWINSA = self-identified solutions CA NA = select from solution set
ESTIMATING COSTS	**Where did cost estimates come from?**	Many external sources (literature, industry, US EPA, water systems, and more)	*Systems submitted two types of data:* • Project cost estimates (when available) • Project design parameters to use in models (when estimates not available)	CA NA = external data sources, e.g., literature and industry sources DWINSA = data from water systems' internal analysis as well as external data
	How were costs modeled?	Estimated costs of all potential solutions using normalized cost estimate data Selected best solution for each project based on cost estimates and other factors, prioritizing physical consolidation	Used system cost estimates and other data to build statistical models of solution costs Used statistical models to predict costs where systems did not already have estimates Summed predicted costs and generalize across nation, based on sample surveyed	CA NA used industry and regulatory data to estimate cost of bringing all systems into compliance DWINSA used sample of systems to predict cost of bringing all systems nationwide into compliance

*HR2W = Human Right to Water

Figure 6 outlines a comparison of need and solution identification, as well as cost estimation between the CA NA and the DWINSA.

Differences in whether and how solutions are identified

One of the significant differences between the cost methodology for the CA NA and the DWINSA is how the problems and solutions alike are identified. The CA NA identifies problems and then selects solutions for each problem based on the cost and a sustainability analysis. In many cases, multiple solutions are modeled to find the lowest-cost, most feasible options.

In contrast, for the DWINSA, the solutions are identified by the water systems surveyed. The systems proposed solutions for the problems they identified within their systems, and these solutions are used as a proxy for need. The problems systems face are not directly assessed by the federal government, but rather through the solutions that the systems report they require.

Differences in cost estimate data[29]

The key difference between the CA NA and the DWINSA is the CA NA cost assessment estimates are derived from external data sources such as literature, engineering firms, vendor supplied quotes, EPA Work Breakdown Structure (EDW Treatment Tech Unit Cost Models), and fees from water systems in California while DWINSA relies on internal reported costs from water systems.

For the DWINSA, a portion of the initial cost estimates come from the survey respondents themselves. In 2011, 16% of the improvement projects fit into this category (U.S. EPA, 2014). The water systems provided different types of documentation (capital improvement plans, master plans, preliminary engineering reports, facility plans, bid tabulations and engineers' estimates) which project the estimated cost of each project they report needing. The cost estimates submitted by the water systems are included in the final need.

To estimate the costs of the remaining projects, the DWINSA employs statistical models. The models are generated using the documented cost estimates provided in the survey, along with design parameters, such as size and capacity, that the systems report. In some cases, cost data from RSMeans catalog, product manufacturers, distributors were used to supplement cost data provided by water systems. In 2011, the costs of 84% of the projects were estimated using models built in part with submitted project parameters and cost estimates (U.S. EPA, 2011).

The CA NA developed a cost assessment methodology to estimate the cost of interim and long-term solutions for HR2W list and At-Risk public water systems, tribal water systems, state small water systems and domestic wells. The cost assessment considered physical consolidation, treatment solutions, POU/POE technologies, other essential infrastructure, O&M costs, interim or emergency solutions

29 In the DWINSA, surveyed systems provide cost estimates for identified solutions. The DWINSA uses linear regression to develop the cost models from the cost estimates provided by the water systems in the survey. Cost estimates are provided by surveyed water systems and then normalized for time using the Construction Cost Index (CCI) and location, using the RSMeans Location Factor Index. These estimates are used to create the statistical models used to generate estimates for the projects without cost estimates. The model parameters used to describe the relationship between the inputs, for example: the capacity of the system being modeled and how much the system is projected to cost, are estimated using ordinary least squares regression.

In the CA NA, cost estimates are developed from past research and case studies. The CA NA also normalizes cost data for time using the CCI and location using the RSMeans Location Factor Index. Each county is classified as rural, suburban, or urban, and then each region type is assigned a value based on the CCI. Cost estimates for solutions are only high-level statewide estimates.

and technical assistance costs. These costs were modeled only for specific HR2W list water systems, at-risk water public water systems, and some for domestic wells.

Accuracy of models

The CA NA Cost Assessment corresponds with a Class 5 cost estimate as defined by Association for the Advancement of Cost Engineering International. Therefore, the CA NA Cost Assessment is appropriate for screening level efforts and has a level of accuracy ranging from –50% to –20% on the low end and +30% to +100% on the high end (–50% to +100% overall). For example, if a cost of $100 is estimated, the range of anticipated costs is $50 to $200.

In comparison, the DWINSA states EPA's goal is to be 95% confident that the margin of error for the survey is ± 10% of the total need for systems serving more than 3,300 people for each fully surveyed state and for all American Indian and Alaska Native Village public water systems, assuming the data provided are unbiased. It is likely water systems underestimate their needs because much of water systems' infrastructure is underground (making need difficult to assess), and because the needs survey assesses systems' 20-year need, which many systems have not evaluated or do not understand well.

▸ Next Steps: Limitations, ongoing questions and recommendations

Based on our research, we believe the following are necessary and feasible in the near future:

» Evaluate whether the diversity of problems and solutions calls for smaller regional assessments in addition to a national assessment

Compliance solutions highlighted in a national assessment of drinking water quality compliance must be relevant to the diverse problems facing water systems in the United States. The problems and solutions may be so diverse that they require regional analyses and reports. Future work will determine whether it is feasible to complete a nationwide assessment of compliance solutions and whether it is necessary to complete multiple regional solutions in conjunction with a national assessment.

» Establish the degree to which different forms of consolidation can be considered as solutions at the national scale

It is uncertain how consolidation will fit into a national assessment of water quality as a solution to compliance problems. Consolidation is an important solution; however, it requires high-resolution spatial data which is not currently available for all systems. It must be decided whether it is best to include consolidation as a solution only for states with data available, or to exclude it from a nation assessment if data is not available for all states.

» Acknowledge the possibility of higher-than-expected costs

Finally, it must be acknowledged that the total cost needed by water systems across the United States to update infrastructure and improve compliance is likely largely underestimated. Drinking water infrastructure is often underground and unobserved. Water systems may not have an accurate understanding of the status and quality of their drinking water infrastructure due to a lack of asset management capacities, and therefore are unable to provide a reliable and accurate estimate of their financial needs to update and upkeep infrastructure. This limitation must be considered in cost estimation of water systems' financial needs.

4) COMPLIANCE SOLUTION FINANCING AND FUNDING CONSIDERATIONS

Finally, we present an analysis of public funding sources to meet the assessed compliance needs, including gaps in existing sources. The core areas we discuss are as follows:

- National and state level funding programs and eligibility criteria
- Matching solutions with funding sources
- Historical funding in disinvested and disadvantaged communities
- The gap between available funding and the cost of safe drinking water
- Next steps: Limitations, ongoing questions and recommendations

National and state-level funding programs and eligibility criteria

To understand how to fund projects, we map the federal and state-level funding sources and their associated eligibility criteria in Table 1. For example, the University of North Carolina Environmental Finance Center network maintains a relatively up-to-date state-by-state list of funding, and EPA hosts a database of available financial assistance sources, commonly called a clearinghouse, for water financing (Environmental Finance Center Network, n.d.; U.S. EPA, n.d.). Both sites are expansive in their coverage of funding programs but can be difficult to parse through. We recommend a crosswalk, outlined below, for identifying which funding sources can be included in a national assessment, given the estimated cost and types of solutions identified.

Notable federal funding programs that address drinking water quality in some capacity include DWSRF, U.S. Department of Agriculture (USDA) Rural Utilities Service Water and Environment Programs (RUS WEP), U.S. Department of Housing and Urban Development's Community Development Block Grant (CDBG) Program, EPA-administered Water Infrastructure Finance and Innovation Act (WIFIA), Indian Health Services, and U.S. Department of Health and Human Services. Close attention should be paid to changing criteria and new funding programs as the result of recent legislation, such as the BIL, as well as the eligibility of proposed solutions for major sources of funding. While

FEDERAL INFRASTRUCTURE SPENDING IN FY21*

- $1.126 billion for capitalization grants to states under the EPA's DWSRF
- $59.5 million for subsidy costs for EPA's WIFIA program, allowing the agency to provide credit assistance for drinking water and wastewater infrastructure projects, not to exceed $12.5 billion;
- $463.4 million for grants, approximately $1.4 billion in direct loan authority, and $50 million for guaranteed loan authority for USDA's rural water and waste disposal program;
- $3.45 billion for HUD's CDBG program (water and wastewater projects are among many eligible uses);
- $157 million for EDA's Public Works and Economic Adjustment Assistance programs (water and wastewater projects are among many eligible uses);
- $100 million for United States Army Corps of Engineers environmental infrastructure projects; and
- $64 million for Reclamation's Title XVI reclamation/recycling projects.

* (Ramseur et al., 2020)

TABLE 1

Crosswalk of funding eligibility considerations

	DWSRF	EPA WIFIA	USDA Rural Utilities Service Water and Environmental Programs (RUS WEP)	USDA RUS WEP Decentralized Water Systems Grant Program	USDA RUS WEP SEARCH (Special Evaluation Assistance for Rural Communities and Households)	CDBG (via states)
Eligible Governance Type	Publicly and privately owned community and nonprofit, non-community drinking water systems (varies by state)	Public or private entities, SRF programs	Public entities, non-profits, tribes	Non-profits, tribes	Most state and local governmental entities, non-profits, tribes	Public (or in some states also private) entities
Eligible System Size	N/A	N/A	Under 10,000 people	Up to 50,000. Tribal lands in rural areas, Colonias	Rural areas with a population of 2,500 or less	N/A
Eligible Projects	Physical upgrades/ replacements of drinking water source, treatment, storage, transmission, and distribution	Drinking water SRF eligible projects, energy efficiency improvements, desalination, drought mitigation, property acquisition in certain cases, combination of projects	Physical infrastructure, legal and engineering fees, land acquisition/permits	create a revolving loan fund for eligible individuals. Construct, refurbish, or service individually-owned household water well and septic systems.	Feasibility studies to support applications for funding water or waste disposal projects. Preliminary design and engineering analysis. Technical assistance for the development of an application for financial assistance.	Various needs such as construction or renovation of infrastructure projects such as water, wastewater, solid waste facilities, streets, flood control projects. Different states have other grants, e.g. microenterprises
Ineligible projects	Dams, reservoirs (unless for finished water), water rights (unless purchase through consolidation), O&M	Projects with no cost share	Projects that are not creditworthy	N/A		Acquisition, construction, or reconstruction of buildings for the general conduct of government, political activities, certain income payments, construction of new housing (with some exceptions)
Disadvantaged Community Assistance	Yes; up to 30% of grant (principal forgiveness), 30-year repayment	N/A	DACs are rated higher in scoring	Only available for eligible rural areas, tribal lands in rural areas and Colonias.	Only available for financially distressed communities: median household income below the poverty line or less than 80% of the statewide non-metropolitan median household income based on latest Census data.	Funds must be used to benefit at least 51% low- and moderate-income persons or address urgent community development needs
Grants or Loans	Loans with principal forgiveness	Loans	Long-term (40-yr repayment), low-interest loans. Grants if available.	At least 10% match.	Grants.	Single-purpose project grants

many of the federal funding programs focus on construction and physical infrastructure improvements, many (especially small) systems need assistance with O&M to prevent and address water quality violations. For example, funds may cover building a new treatment plant, but without sufficient funding to pay for an operator to operate the new plant, the system may still have water quality violations.

The BIL, also known as the Infrastructure and Jobs Act (IIJA), was enacted on November 15, 2021, and appropriates over $50 billion to EPA to improve America's drinking water, wastewater and stormwater infrastructure, making it the largest investment in water that the federal government has ever made (U.S. EPA, 2022(1)).

▶ Matching solutions with funding sources

As most federal funding sources only allow funds to be spent on infrastructure, and not on O&M, federal funding opportunities must be matched primarily with solutions involving infrastructure upgrades that help systems access clean water. In the CA NA, federal and other state-specific grants made up less than one-third of eligible funding — only $3.25 billion was attributed to financing necessary solutions through grants in California. Another $7 billion will likely need to be funded through loans repaid with earnings from customer bills.

Table 2 is based on the solutions modeled in the CA NA and lists possible funding resources.

▶ The gap between available funding and the cost of providing safe drinking water

This section assesses the gap between available funding, estimated costs of solutions and related analyses that have been conducted by organizations and institutions in recent years. Generally, all references reviewed found a significant gap between higher needs and available funding — a gap that is predicted to increase in the near future. America's drinking water infrastructure is both aging and underfunded as funding has not kept up with water systems' increased needs (e.g., American Society of Civil Engineers (ASCE), 2021).[30] This is reflected in a 27% increase in the rate of water main breaks between 2021 and 2018, totaling an estimated 300,000 breaks annually and equaling a loss of $7.6 billion in 2019. A lack of federal investment has been increasing pressure on local and state governments, while new challenges and growth of demand are increasing infrastructure needs (ASCE and VWC, 2020).

30 There are numerous other industry estimates of water system and broader infrastructure need. For instance, the ASCE publishes a Report Card for Infrastructure every four years examining the performance and condition of the United States' infrastructure. Even with a growing need for drinking water infrastructure, the federal government's spending on drinking water infrastructure fell from 63% in 1977 to 9% of total capital spending in 2017. Through the DWRSF, the EPA provides low-interest loans to state and local drinking water infrastructure projects, with increased federal appropriations since the federal fiscal year 2017. The allotment for each state is based on the DWINSA results and states provide a 20% funding match. However, the main funding source for water systems remains user fees/rates. Although water rates have increased, utilities still have funding gaps. ASCE's findings are alarming, with only 10% of small utilities and only 20% of very large utilities estimating that they can provide full cost service in five years, main issues being replacement of aging infrastructure and financing for capital improvements. An estimated 36% of households will not be able to afford drinking water by 2024 (ASCE, 2021). ASCE and the Value of Water Campaign published a report in 2020 and found that the cost of water and wastewater failures will increase by seven times in the next 20 years for American households. O&M costs are growing with a deteriorating infrastructure as well, causing a growing gap between O&M needs and funding, hence a sustainable way to fund these expenses becomes more critical (ASCE and VWC, 2020).

TABLE 2

Solutions, descriptions, and possible resources

Solution	Description	Possible Resources
Technical Assistance	A broad category of support to assist water system operators, managers, and community leaders with planning, construction projects, financial management, and O&M tasks.	Often federally funded and at no-cost to system. Planning grants may be state-funded (small set-asides). Technical assistance providers at a national scale include RCAP, NRWA, and the EFC Network. There may be additional providers of low- and no-cost assistance at regional or state levels, other non-profits, or faith-based organizations.
Regionalization/ partnerships/ regional collaboration	Spectrum of collaborative activities, can range from informal mutual aid agreement to physical/managerial consolidation	Various grants from federal, state, and local agencies (for planning opportunities). TA can help/ educate/facilitate. Informal types of regionalization may be possible without high costs, though they require time and effort of local leaders/waster system staff. See https://www.rcap.org/resources/regionalizationresearch/ for information on implementing regionalization. Also see Appendix A linked to at https://www.rcap.org/resources/regionalizationresearchtwo/ for a list of policies by state that encourage/facilitate regionalization, which sometimes include funding opportunities (commonly including SRFs, but vary by state and may include additional resources).
Physical Consolidation (a formal type of regionalization)	The joining of infrastructure of two or more water systems that are geographically close.	SRFs. Some states, e.g. Kentucky, offer financial incentives. TA can facilitate. See Regionalization resources above as well.
Treatment	Treatment solutions are used to address contaminants that exceed water quality standards.	Any change in process must be approved by the primacy agency. SRF and USDA RD also fund treatment upgrades. A SEARCH grant for preliminary engineering report and environmental study would fund at 100% if the community meets guidelines (e.g. South Dakota covers $6,000 for small systems engineering report development).
POU/POE	Point-of-use (POU) or point-of-entry (POE) treatment are used to address contaminants that exceed water quality standards when other solutions are infeasible.	Often used for disaster recovery situations, usually not as a long term solution as proper maintenance is required. Would need a regular O&M plan in place. Suitable only for very small systems. Funding could be provided if it is an accepted solution (e.g. for Arsenic in some areas). Some states have specific POU/POE grants in place for systems in noncompliance.
Other Essential Infrastructure (OEI)	A broad category that includes storage tanks, new wells, well replacement, upgrade electrical, add backup power, replace distribution system, add meters, and land acquisition.	SRF funding, federal and state funding, RD funding. **Backup power**: FEMA generator grants, WARN system. **Meters**: WIIN, primacy agency funds. **Electrical**: grants and incentives available from electric power providers if replacing poor efficiency to high efficiency motors to reduce monthly charges.
Operations & Maintenance (O&M)	Ongoing, day-to-day operations and maintenance of a water system.	Usually covered by user rates. Challenging to get funding for O&M. Technical assistance allows for O&M capacity building, but will not fund the O&M expenses to the utility. FEMA may be able to help in an emergency, and USDA Rural Development started an emergency fund under WEP's Emergency Community Water Assistance Grants.
Interim Solutions	POU/POE and bottled water, including O&M costs for maintaining a temporary installment of POU/POE systems.	In disaster recovery situations, FEMA can help with emergency response. Some communities could get an emergency interconnection through a WARN.
Business plan/model	New systems need to have this in place. States require it when asking for permits. Existing systems that were not on the radar or recently sold may have no revenue stream in place to operate/maintain themselves.	Technical assistance can be helpful for this. Many primacy agencies have a template for the plan. A system would still need funding for capital investments but would have O&M covered and planned.

Source: Table modified from the California Drinking Needs Assessment [2021] Table D2, page 283).

Existing gap analysis

As noted above, the U.S. Congress requires an assessment every four years of the 20-year modeled capital improvement needs for public water systems. As discussed above, EPA conducts the EPA Drinking Water Infrastructure Needs Assessment (DWINSA) to meet this requirement, and the DWINSA in part informs DWSRF allocations to states. The 7th assessment published in 2023 found a total national need of $625 billion for the next 20 years of DWSRF projects to maintain and improve drinking water infrastructure — a 32% increase from the 6th DWINSA in 2018 ($472.6). For this assessment, individual state needs, regulatory needs, small system needs, and the needs of American Indian and Alaska Native Village water systems were considered (U.S. EPA, 2018).

At the state level, the 2021 Drinking Water Cost Needs Assessment and Gap Analysis developed a cost assessment methodology to estimate the cost of short-and long-term solutions, determined funding needs and potential sources, and determined the gap between needs and available funding. While a national assessment could work with this same structure, it would need to focus on both national and potential funding options at the specific state level.

The impacts of climate change are already increasing costs for drinking water, so the 2022 California Needs Assessment also includes a Drought Cost Assessment to estimate the cost for small CWSs in California. The range of costs for drought requirements was estimated to be between $1,202–$4,809 million in California alone (CA SWRCB, 2022).

To understand where additional federal funding is needed, a gap assessment could match ongoing federal grants and loans with systems identified as out of compliance. This has the added benefit of providing a high-level national picture of the scale of assistance federal dollars are currently providing. A national assessment must consider how to fund solutions to meet assessed needs, and on what priority and timeline these funds should flow. Compared to California, other states will likely have fewer funds specific to water infrastructure available, but consideration of the DWSRF, stimulus/infrastructure package and recurring USDA and other federal funds must be considered as funding sources. The CA NA also considered community contributions (via user rates, charges and fees), but including this data in a national gap analysis appears infeasible given the lack of consistent rate or billing data at the national scale.

▸ Historical funding in disinvested and disadvantaged communities

A national assessment should also include steps to ensure an equitable distribution of funding and locate the communities and systems with the most pressing needs. This section motivates how historical funding has not sufficiently benefited disadvantaged communities (DACs) and challenges in access and distribution of funding.

Equitable access to water means all people have access to safe, affordable and non-discriminatory water and wastewater services. Research has shown that majority Black, Indigenous and people of color (BIPOC) communities are more likely to have drinking water standard violations, water shutoffs and affordability struggles, often due to underinvestment in water infrastructure (Hansen et al., 2021). Systems serving DACs often have lower revenue and less capital to finance projects, leading to a lack of maintenance investments and deteriorating infrastructure with reduced water quality and negative impacts on public health (Hansen et al., 2021). As poverty is a key obstacle to water access in the United States, and water access is a result of historical investment, water access often mirrors common social inequalities and affects entire communities (Roller et al., 2019). It is critical to examine how funding has been distributed in the past to decrease inequity and inequality.

Under SDWA, each state has broad jurisdiction to define DACs with its own criteria to assist water systems experiencing greater challenges financing and implementing crucial drinking water infrastructure improvements. It is important to have a clear and accessible definition of DACs to understand which communities qualify for additional assistance and ensure eligible communities are aware of these opportunities (U.S. EPA, 2022(3)). As states have flexibility in the definition of DACs, the assistance directed to DACs and the communities that qualify for this assistance significantly vary from state to state. The different indicators states use can be categorized into socioeconomic, demographic, financial, public health, environmental justice, and other. In January 2023, ASDWA published an updated web tool listing all state definitions based on their Intended Use Plans (ASDWA, 2023).

Intergovernmental financial assistance can address disparities in access to safe and affordable drinking water, as well as resulting health consequences. The DWSRF is the largest source of funding and provides low-interest loans and other subsidized assistance to help drinking water systems finance capital projects. Since 1997, the DWSRF has financed over 16,000 projects. EPIC conducted an analysis using state-level data from 2011 to 2020 and found that communities with three or more health-related violations of the SDWA are more likely to receive assistance, highlighting the focus of the DWSRF on improving drinking water compliance. Communities with lower median household incomes are slightly more likely to receive assistance, and larger communities are also disproportionately more likely to receive more awards. Finally, communities with a larger percentage of white residents are more likely to receive DWSRF funding, despite the fact that these communities often have better access to safe and affordable water services (Hansen et al., 2021).

Other funding programs suffer from similar issues with equitable funding allocations. The Community Water Center researched the funding distribution from the USDA Rural Utilities Service Water and Environmental Programs, which encompassed $3.4 billion dollars in grants and $6.2 billion in loans for water projects between the Department's 2010 and 2021 fiscal years and focuses solely on rural water access in small communities. However, only 15% of these projects served majority BIPOC communities, with 85% in communities with over half of residents identifying as non-Hispanic white. This is especially problematic as the USDA Rural Development is a key player in federal government resources and opportunities to close the water gap in rural communities.

Systems might not apply for DWSRF funding because of a lack of capital to fund projects, lack of awareness of DWSRF opportunities, a general lack of TMF capacity to apply, or availability of other financing options with fewer requirements. Smaller systems have less capacity to take on the debt incurred by these DWSRF loans or do not have the TMF capacity to initially develop the project (Hansen et al., 2021). Lastly, some states allocate DWSRF loans only to municipalities, making some small systems, such as homeowner associations, ineligible (ASDWA, 2022).

Generally, progress on water access has been slowing and the number of people without basic plumbing in their homes has increased in recent years. Many communities lacking water access are determined to solve these challenges with dedicated resources, cross-sectoral partnerships, public awareness, and policy advocacy (Roller et al., 2019). The next section describes how targeted use of funding can support systems that historically have not been able to access funds.

▶ Next Steps: Limitations, ongoing questions and recommendations

Although not fully covered here, initial consideration could be given to community co-design and identification of funding priorities and solution types in a national assessment. These approaches were not emphasized in the research phase of the CA NA but are being considered as spending rolls out. Other efforts like CA Department of Water Resources' Disadvantaged Community Involvement Program (DACIP) Needs Assessment process and Justice40 tenets (White House, 2022) may be incorporated and considered with respect to disadvantaged community involvement principles and best practices in procedural equity in infrastructure investments.

The importance of technical assistance and funding access

While it is important to analyze the gap between available funding and existing needs, it is critical to ensure funding goes to the communities that need it the most, and technical assistance plays a crucial role in this.

Technical assistance during the grant application process helps many small systems identify their TMF needs and apply for related funding. Systems without on-staff grant writers often do not have the capacity to apply for complex federal grants and loans. Funding for technical assistance is essential because it helps small communities match their needs with appropriate funding programs and access funding that they would otherwise be unable to reach. Technical assistance is also a way of ensuring that funding will be effectively invested into water infrastructure and the long-term proper maintenance of facilities (WIN 2004).

The Rural Community Assistance Corporation (RCAC), the National Rural Water Association (NRWA), and EPA's Environmental Finance Center network are the largest technical assistance providers at the national scale that connect rural communities and water systems to federal funding programs. EPA recently expanded the EFC program due to a need for more technical assistance to help connect communities in need to the influx of federal infrastructure funding opportunities from the BIL. In November 2022, EPA announced RCAP as a Category 3 National Environmental Finance Center, one of 29 EFCs total across all three categories.[31]

Providing more assistance to systems with limited capacity to apply for funding and increased outreach to systems improves equitable access to funding. Improving technical assistance can reduce the burden on DACs (Hansen et al., 2019; ASDWA, 2022). To improve access to technical assistance, states could set more funding aside to help with applications, and Congress could appropriate additional funding for technical assistance. However, funding must reach the communities with the highest need in order to improve equity in water access and public health (Hansen et al., 2021).

To assure that historically under-invested communities benefit from federal funding, improving technical assistance to systems with restricted financial capacity is critical, as well as increasing the additional subsidies distributed by states and prioritizing projects in communities with high poverty that have been historically under-invested in (Hansen et al., 2021).

31 Category 3 is a new EFC category for National Water Infrastructure EFCs, made possible through BIL funding.

▶ Strategies to fill the gap between funding and needs and to improve equitable funding access

This section summarizes strategies that improve equity in funding distribution, can ensure that funding goes to communities that need it the most and have not received funding in the past, and other strategies to at least partially fill the gaps between funding and need. Such strategies can cover improved funding allocation to disadvantaged communities, source water protection, innovative funding mechanisms and considering climate change impacts.

Equitable allocation of and access to funding for communities in need

Several studies have discussed approaches to increase equity in the distribution of funding to ensure that the communities with the largest needs are able to improve their water access. Strategies cover improving funding allocation and access to communities in need, improving technical assistance and the tracking and reporting of characteristics of funded communities. Policies must not only highlight and address inequities but be enforceable to be effective. (Mueller and Gasteyer, 2021).

Decrease access hurdles for DACs, increase subsidies, diversify distribution methods

Small systems often lack resources to access DWSRF funding and are not able to pay the costs associated with meeting federal funding requirements (ASDWA, 2022). As the DWSRF is one of the main opportunities to access needed funding for disadvantaged communities, it is crucial to make this funding source more easily accessible.

Hansen et al. (2021) suggest that states can improve equity in drinking water access through the DWSRF by distributing financial assistance to a greater number of eligible systems, providing grants instead of loans to disadvantaged communities, and by distributing the assistance in an equitable way across demographics. States can use DWSRF funding to finance a greater number of small projects as opposed to fewer large projects. Other ways DWSRF funding can prioritize support to underinvested communities are through multi-year support and principal forgiveness/grants that benefit financially restricted communities or are specifically used for project development. Another approach to reducing the water access gap is to increase subsidies allocated to very low-income and high-poverty communities. The reach of funding can be expanded to more eligible systems with higher subsidies, and research shows that states often spend less than the federal ceiling. Raising or removing the federal ceiling on additional subsidies for DACs and increasing funding for DWSRF in general would improve equity in funding and water access (Hansen et al., 2021).

Engaging third parties to advocate for communities, negotiate agreements, help with the application process, financing option evaluations, and connecting communities with resources are additional ways to address the disparity in water access (Hansen et al., 2021). States can work with partners to use all possible funding and assistance from various sources, and states can use funding from other federal programs such as the Federal Emergency Management Agency, Water Infrastructure Improvements for the Nation (WIIN), or Additional Supplemental Appropriations for Disaster Relief Act (ASADRA)) (ASDWA, 2022). Another issue is whether small and disadvantaged systems can show they have the required TMF capacity for DWSRF loans, or if states are willing to add a requirement to develop this capacity to the loan. Finding alternative solutions to fund small, simple costs such as equipment or services, or increased assistance under more flexible federal requirements and a wider eligibility for different projects and assistance would also be helpful (ASDWA, 2022). As small communities and communities with a larger percentage of people of color are less likely to receive assistance, improved diversity in recipients is critical (Hansen et al., 2021).

It is useful to consider what new funding opportunities the BIL presents. While there will be significantly more funding over the next five years, it is crucial to have flexibility and alternative funding solutions and assistance for small and underinvested systems. Most states need more flexibility, funding, and increased eligibilities to improve access for DACs to DWSRF and other federal funding sources (ASDWA, 2022).

Track and report community characteristics

To evaluate and improve equity in DWSRF allocations and other funding, it is critical to measure and report the characteristics of communities that received assistance. Recording community characteristics can help to give priority to historically underinvested communities with high poverty rates, which are the least able to increase water rates to pay for infrastructure funding. The best type of assistance varies for each community, so it is important to target the assistance to their specific needs. This can be improved by states including poverty rates in addition to the median household income to identify disadvantaged communities. Both indicators refer to the resources that households and communities have to fund their water system, but the percentage of a community living below the federal poverty line indicates specifically the ability of households to pay, while median household income indicates the financial capacity of the water system. While most states only use median household income or population size as the main identification for disadvantaged communities, this may fail to identify the communities with the highest needs. By recording community characteristics, more points can be allocated to underinvested in communities in application ranking to prioritize these projects (Hansen et al., 2021). To assess and improve equity in allocation of DWSRF funds, setting a threshold to direct federal investments, such as the Justice40 initiative, is critical (Hansen et al., 2021).

Rempel et al. (2022) recommend that USDA, together with local providers, should create a public list of communities that may need assistance or may be at risk of not having access to safe drinking water (Rempel et al., 2022). Similar suggestions to improve equitable water infrastructure improvements through the CWSRF, such as incorporating other demographic factors when tracking funding distribution, were made by Hansen and Hammer (2022). They recommend updating policies to assign higher priority to projects in disadvantaged communities and increase additional subsidies and design better loan terms for them. Increased proactive outreach and targeted technical assistance to help underrepresented communities with all phases of the process would be helpful as well (Hansen and Hammer, 2022).

5) DISCUSSION AND NEXT STEPS

A national assessment of compliance and related solutions is a necessary next step in increasing access to safe drinking water across the United States. This report represents a first step in laying out what an assessment of that scale can and should look like and what solutions are possible at a national scale. Our recommendations, while layered and complex, are feasible to incorporate in the near future with a continued commitment to and funding for community water systems across the United States.

This effort will be advanced and clarified by the 2023 DWINSA, as well as EPA's Interim Learning Agenda for Drinking Water Compliance, which will be released by 2026. However, RCAP and the UCLA Luskin Center for Innovation have also begun working on next steps for empirical assessment and implementation of the recommendations from this report in pilot needs assessments in feasible states. This work will be made possible by the expansion of EPA's Environmental Finance Center program, which seeks to connect communities in need with federal funding opportunities, specifically, the historic investment in water infrastructure by the Bipartisan Infrastructure Law. A major component of RCAP's EFC program, in partnership with the UCLA Luskin Center for Innovation, involves operationalizing and expanding upon this methodology to pinpoint communities with the greatest need for technical assistance to access federal funds. This work will also be supplemented by analysis from the University of Illinois to incorporate communities reliant on private wells and septic systems.

In addition to clear next steps, we identify and describe below two key frontiers and promising models for future research. While we were not able to incorporate them fully in this analysis, they will inform a more holistic and inclusive national compliance needs assessment process.

▸ Factoring in the impacts of climate change and rural capacity

First, climate change–related impacts will lead to significant cost increases and compliance challenges for the drinking water sector. The impacts seen from climate change, ranging from severe storms to increasing drought severity and frequency to flooding and more show the urgency of building water systems that are resilient and adaptable (e.g., Hara et al., 2022). Considering the inevitable and increasing impacts of climate change on water systems, it is critical to create capacity for water systems to plan for adaptation and resilience, and to factor climate change into federal funding decisions and cost estimates for future infrastructure improvements. To promote a clear understanding of local climate change impacts and to help with adaptation planning, EPA has developed several tools for communities and the water sector under the Creating Resilient Water Utilities (CRWU) initiative.

An example of an actionable model to increasing system resilience to the impacts of climate change and advancing environmental justice in federal funding is the way USDA Rural Development incorporates priority points into scoring and funding for proposed projects and programs. They consider economic risk, the CDC Social Vulnerability Index, and proposals addressing the climate crisis (Rural Development USDA, 2021). Similarly, Headwaters Economics designed a Rural Capacity Map to help identify communities that need support but may not be able to compete for federal funding without assistance (Headwaters Economics, 2022).

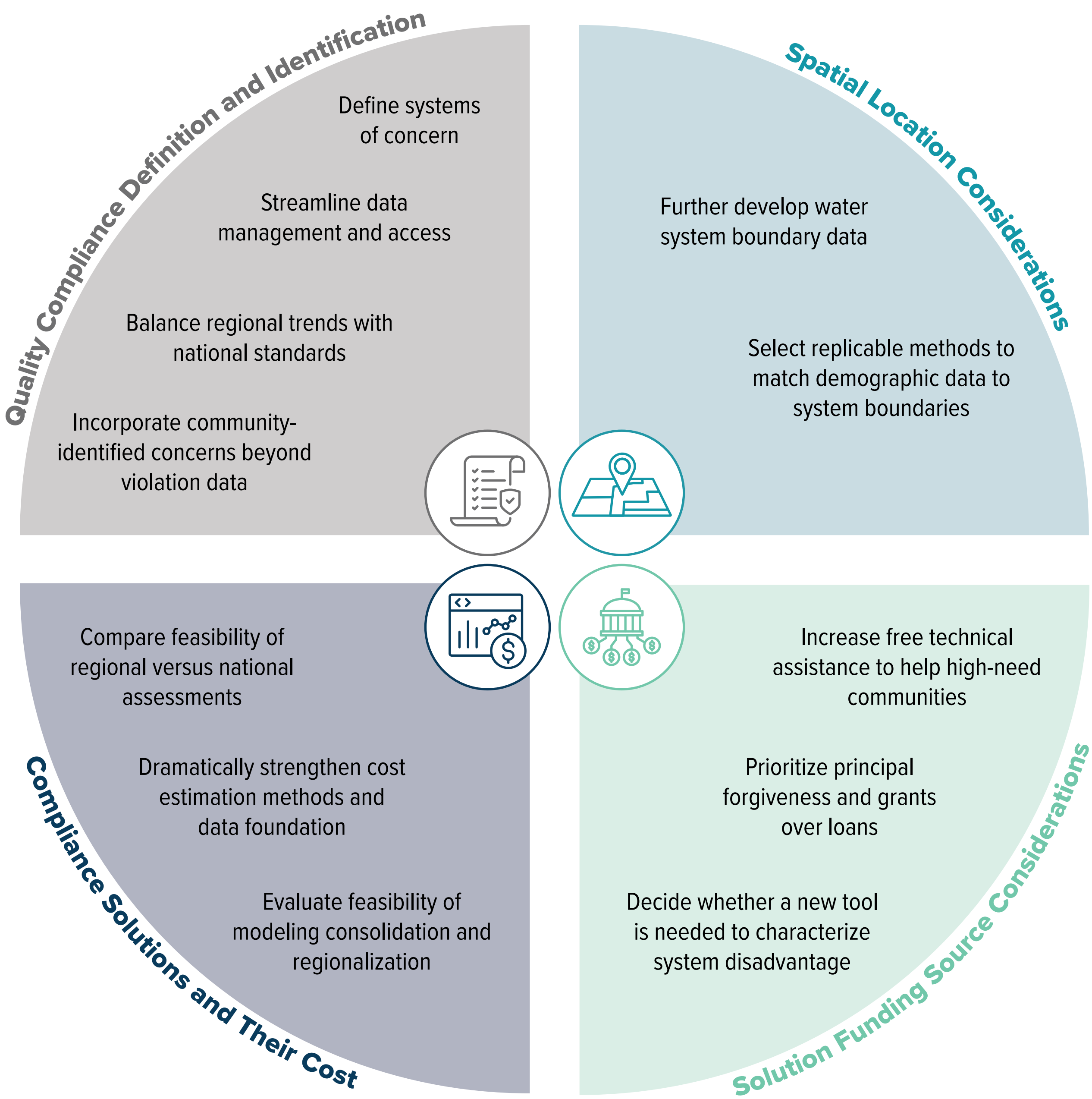
▸ Community-Defined Methods

Second, it is critical to include community-identified concerns and priorities for drinking water quality compliance, rather than only identifying problems in a top-down way. This represents an inherent challenge for an effort with a national geographic scope involving thousands of individual water systems.

At the same time, ways to supplement quantitative, administrative data-driven needs assessments include applying formal qualitative methods, such as community-based organization convenings, compiling community conversations, storytelling, and other "ways of knowing" that paint a more robust and compelling picture of needs. We will consider this carefully starting at the beginning of our next phase of work and develop a method that incorporates local knowledge sources in meaningful ways.

FIGURE 7

Key Recommendations



The CA Department of Water Resources' Disadvantaged Community Involvement Program (DACIP) Needs Assessment process can serve as a model for such community knowledge gathering. This process was undertaken regionally, with priorities and investment decisions informed first and foremost by survey results from households in disadvantaged communities within each region. The Oregon Water Futures Collaborative can serve as a second example; it focuses more broadly on water equity issues than a quality compliance assessment, but it includes a State of Water Justice report highlighting compliance gaps as well as specific reporting on community engagement processes informing their work.

6) REFERENCES

Allaire, M., & Acquah, S. (2022). Disparities in drinking water compliance: Implications for incorporating equity into regulatory practices. *AWWA Water Science*, *4*(2), e1274.

Allaire, M., Wu, H., & Lall, U. (2018). National trends in drinking water quality violations. *Proceedings of the National Academy of Sciences*, *115*(9), 2078–2083.

American Society of Civil Engineers (ASCE) & Value of Water Campaign (VWC). (2020). *The Economic Benefits of Investing in Water Infrastructure: How a Failure to Act Would Affect the U.S. Economic Recovery*.

ASDWA. (2022). *State Drinking Water Program Challenges and Best Practices: Small and Disadvantaged Water System Funding and Assistance*.

Balazs, C. L., Morello-Frosch, R., Hubbard, A. E., & Ray, I. (2012). Environmental justice implications of arsenic contamination in California's San Joaquin Valley: A cross-sectional, cluster-design examining exposure and compliance in community drinking water systems. *Environmental Health*, *11*(1), 84.

Berahzer, et al. (2022). *Demonstrating Affordability Metrics in Relation to Rulemaking*. 74.

Brookings. (2022, February). Brookings Federal Infrastructure Hub. *Brookings*. https://www.brookings.edu/interactives/brookings-federal-infrastructure-hub/

California State Water Resources Control Board (CA SWRCB). (n.d.-a). *Groundwater Issue: Groundwater Quality | California State Water Resources Control Board*. https://www.waterboards.ca.gov/water_issues/programs/groundwater/issue_gq.html

California State Water Resources Control Board (CA SWRCB). (n.d.-b). *Point-of-Use (POU) and Point-of-Entry (POE) Treatment—Permanent Regulations*. https://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/regulations/

California State Water Resources Control Board. (2021). *2021 Drinking Water Needs Assessment*. 332.

California State Water Resources Control Board. (2022). *2022 Drinking Water Needs Assessment*.

Environmental Finance Center Network. (n.d.). Funding Tables. *Environmental Finance Center Network*. Retrieved January 6, 2023, from https://efcnetwork.org/resources/funding-tables/

Environmental Justice. (2023). ASDWA. https://www.asdwa.org/environmental-justice/

EPIC. (2022). *Water Utility Service Area Boundaries*. Environmental Policy Innovation Center. https://www.policyinnovation.org/technology/water-utility-service-area-boundaries

Gonsenhauser, R., Hansen, K., Grimshaw, W., Morris, J., Albertin, K., & Mullin, M. (2020). Digitizing a Statewide Map of Community Water System Service Areas. *Journal AWWA*, *112*(10), 56–61.

Hansen, K., & Hammer, B. (2022). *A Fairer Funding Stream – How Reforming the Clean Water State Revolving Fund Can Equitably Improve Water Infrastructure Across the Country.* NRDC, EPIC.

Hansen, K., Hughes, S., Paine, A., & Polidori, J. (2021). *Drinking Water Equity: Analysis and Recommendations for the Allocation of the State Revolving Funds*. EPIC.

Hara, M., Willette, R., Simonson, E., & U.S. Water Alliance. (2022). *Making Water a Public Good: The Bigger Picture of Water Affordability*.

Headwaters Economics. (2022, January). *A Rural Capacity Map*. Headwaters Economics. https://headwaterseconomics.org/equity/rural-capacity-map/

Henshaw, S., Cavalier, J., & UNC Environmental Finance Center. (2022, July). *A Once-in-a-Generation Investment – How the Bipartisan Infrastructure Law is Reaching Disadvantaged Communities*. https://efc.sog.unc.edu/a-once-in-a-generation-investment-how-the-bipartisan-infrastructure-law-is-reaching-disadvantaged-communities/

IPCC, 2014: Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151 pp.

Jersey Water Works. (2019). *Lead in Drinking Water: A Permanent Solution for New Jersey.* 48.

Jersey Water Works. (2019). *Lead in Drinking Water: A Permanent Solution for New Jersey* (p. 48).

Manson, S., Schroeder, Jonathan, Van Riper, David, Kugler, Tracy, & Ruggles, Steven. (2021). *National Historical Geographic Information System: Version 16.0* (16.0) [Data set]. Minneapolis, MN: IPUMS.

Marcillo, C., Krometis, L.-A., & Krometis, J. (2021). Approximating Community Water System Service Areas to Explore the Demographics of SDWA Compliance in Virginia. *International Journal of Environmental Research and Public Health*, *18*.

MassDEP. (n.d.). *Public Water System—Self Guide for Point-of-Use (POU) and Point of Entry (POE) Treatment Devices Permitting and Approval Process*.

McDonald, Y. J., Anderson, K. M., Caballero, M. D., Ding, K. J., Fisher, D. H., Morkel, C. P., & Hill, E. L. (2022). A systematic review of geospatial representation of United States community water systems. *AWWA Water Science*, *4*(1), e1266.

McDonald, Y. J., & Jones, N. E. (2018). Drinking Water Violations and Environmental Justice in the United States, 2011-2015. *American Journal of Public Health*, *108*(10), 1401–1407.

MPART. (2019). *Statewide Sampling Initiative*. https://www.michigan.gov/pfasresponse/drinking-water/statewide-survey

Mueller, J. T., & Gasteyer, S. (2021). The widespread and unjust drinking water and clean water crisis in the United States. *Nature Communications*, *12*(1), Article 1.

Mullin, M., & Pickle, A. (2022). *Multidimensional Assessment of North Carolina Community Water System Vulnerabilities*.

Murray, A., Hall, A., Weaver, J., & Kremer, F. (2021). Methods for Estimating Locations of Housing Units Served by Private Domestic Wells in the United States Applied to 2010. *JAWRA Journal of the American Water Resources Association*, *57*(5), 828–843.

OEHHA. (2015, November 20). *SB 535 Disadvantaged Communities*. OEHHA. https://oehha.ca.gov/calenviroscreen/sb535

Patterson, L. A., & Doyle, M. W. (2021). Measuring water affordability and the financial capability of utilities. *AWWA Water Science*, *3*(6), e1260.

Pierce, G., & Lai, L. (2019). Toward a comprehensive explanatory model of reliance on alternatives to the tap: Evidence from California's retail water stores. *Journal of Water and Health*, *17*(3), 455–462.

Pierce, Rachid-El Khattabi, and Gmoser-Daskalakis (2023). Comparing with Caution: Commonalities, Correlates and Variation in Household Water and Sewer Bill Levels in 4 U.S. States. Report prepared for the Natural Resources Defense Council.

Ramseur, J., Normand, A., Cowan, T., Humphreys, E., Stubbs, M., & Lawhorn, J. (2020, July). Federally Supported Projects and Programs for Wastewater, Drinking Water, and Water Supply Infrastructure. LIBRARY OF CONGRESS WASHINGTON DC.

Reibel, M. (2018). *Estimating Median Household Income for Community Water Agencies: A Case Study of Los Angeles County*. 17.

Rempel, J., Fencl, A. and CWC (2022). Justice40 and USDA Investment in the Rural Water Gap: A Retrospective Equity Analysis of USDA Rural Development's Water and Environmental Program Awards and Recommendations for Justice40. Community Water Center and Water Foundation. Sacramento, CA.

Roller, Z., Gasteyer, S., Nelson, N., Lai, W., & Shingne, M. C. (2019). *Closing the Water Access Gap in the United States*. DIGDEEP, U.S. Water Alliance.

Rural Development USDA. (2021, August). *Rural Development: Key Priorities*. Rural Development. https://www.rd.usda.gov/priority-points

Scanlon, B. R., Fakhreddine, S., Reedy, R. C., Yang, Q., & Malito, J. G. (2022). Drivers of Spatiotemporal Variability in Drinking Water Quality in the United States. *Environmental Science & Technology*, *56*(18), 12965–12974

SimpleLab Tap Score. (2022, May). *How to Access the First Map of U.S. Water Utilities*. SimpleLab Tap Score.

State Water Resources Control Board. (2021). *2021 Drinking Water Needs Assessment*. 332.

State Water Resources Control Board. (2022). *2022 Drinking Water Needs Assessment*. 241.

South Carolina Rural Infrastructure Authority. (2022). *Working Together: A Path to Water Viability*.

Texas Water Development Board. (2019). *TWSB Viewer*. TWSB Viewer. https://www3.twdb.texas.gov/apps/WaterServiceBoundaries/Home/Overview

Tracking California. (2020). *Water Boundary Tool—Tracking California*. https://trackingcalifornia.org/water-boundary-tool/water-boundary-tool-landing

UNC EFC. (2021). *Affordability Assessment Tool*. Tableau Software. https://public.tableau.com/app/profile/efcatunc/viz/AffordabilityAssessmentTool/Input

U.S. EPA. (n.d.-a). *Analyze Trends: EPA/State Drinking Water Dashboard | ECHO | U.S. EPA*. https://echo.epa.gov/trends/comparative-maps-dashboards/drinking-water-dashboard

U.S. EPA. (n.d. -b). *SDWIS Federal Reports Advanced Search*. https://ordspub.epa.gov/ords/sfdw/f?p=108:1:::NO:1

U.S. EPA. (n.d.). *Water Finance Clearinghouse*. WFC Home. https://ordspub.epa.gov/ords/wfc/f?p=WFC:12

U.S. EPA. (2002). *The Clean Water and Drinking Water Infrastructure Gap Analysis*. *EPA-816-R-02-020.*

U.S. EPA. (2006). *Point-of-Use or Point-of Entry Treatment Options for Small Drinking Water Systems*.

U.S. EPA. (2011). *2007 Drinking Water Infrastructure Needs Survey and Assessment.*

U.S. EPA. (2014). *2011 Drinking Water Infrastructure Needs Survey and Assessment.*

U.S. EPA. (2018). *2015 Drinking Water Infrastructure Needs Survey and Assessment*. *EPA 816-K-17-002.*

U.S. EPA. (2019, November). *Source Water Protection Funding* [Overviews and Factsheets]. https://www.epa.gov/sourcewaterprotection/source-water-protection-funding

U.S. EPA. (2021). *Bipartisan Infrastructure Law: A Historic Investment in Water Fact Sheet*.

U.S. EPA. (2022a). *Fact Sheet: Bipartisan Infrastructure Law: State Revolving Funds Implementation Memorandum*.

U.S. EPA. (2022b). *FY 2022-2026 EPA Strategic Plan—EPA Learning Agenda*. 18.

U.S. EPA. (2022c). *DWSRF Disadvantaged Community Definitions: A Reference for States*. *EPA 810-R-22-00.*

US Government Accountability. (2021). *Private Water Utilities: Actions Needed to Enhance Ownership Data*.

Water Infrastructure Network. (n.d.). *Recommendations for Clean and Safe Water for the 21st Century*.

White House (2022). Justice40. https://www.whitehouse.gov/environmentaljustice/justice40/

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