ACHIEVING THE HUMAN RIGHT TO WATER IN CALIFORNIA

AN ASSESSMENT OF THE STATE'S COMMUNITY WATER SYSTEMS

JANUARY 2021

Office of Environmental Health Hazard Assessment

California Environmental Protection Agency

OEHHA

SCIENCE FOR A HEALTHY CALIFORNIA

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Acknowledgments

We thank Robert Brownwood, Laurel Firestone, Michelle Frederick, Max Gomberg, Liz Haven, Wendy Killou, Karen Mogus, Betsy Lichti, Gilbert Penales, Darrin Polhemus, Dave Spath and Jim Stites at the State Water Resources Control Board. We thank Julie Ekstrom at the Department of Water Resources. We thank Hongtai Huang for analysis which helped inform OEHHA's consideration of how to assess outcomes across components. Ella Belfer, Cynthia Chang, Emilie Fons, Seigi Karasaki, Molly Starke and Anushka Thakkar provided valuable research assistance. This document builds on early work conducted at University of California, Berkeley and the Community Water Center with funding from the University of California Center for Collaborative Research for an Equitable California, in collaboration with professors Rachel Morello-Frosch, Isha Ray, Jim Sadd, and Manuel Pastor. Brandon Lee of Brandon Lee Design designed the report. We acknowledge former OEHHA Director George Alexeeff for his initial support of this work.

Preface

In 2012, California passed Assembly Bill (AB) 685 (Eng, Chapter 524, Statutes of 2012), becoming the first state in the nation to legislatively recognize the human right to water. This landmark bill recognized the variety of water quality, accessibility and affordability challenges that residents in the state had been facing for years and cemented the state's commitment to achieving this right.

Monitoring the state's progress in meeting the human right to water is fundamental to achieving this right. Thus in 2015, the California Environmental Protection Agency (CalEPA) enlisted the Office of Environmental Health Hazard Assessment (OEHHA) to develop a framework and tool to assess the human right to water. In 2016, the State Water Resources Control Board provided funding to OEHHA to develop the first Human Right to Water Framework and Data Tool (CalHRTW 1.0) to quantitatively assess the state's progress in realizing the human right to water for all Californians.

The Human Right to Water Framework and Data Tool (CalHRTW 1.0) provides a consolidated, stand-alone, quantitative assessment of baseline conditions in the quality, accessibility and affordability of California's drinking water. This assessment can help screen for drinking water challenges and analyze changes over time and complements existing cumulative impacts analyses (e.g., CalEnviroScreen (OEHHA, 2021b)) by providing information at a greater level of detail regarding drinking water.

The Human Right to Water Framework and Data Tool 1.0 (CalHRTW 1.0)—comprised of this written report and accompanying web tool—builds on an initial framework presented in January 2019 (OEHHA, 2019a) and draft results that were subsequently released in August 2019 (OEHHA, 2019b). The final framework measures nine indicators, in three main areas: Water Quality, Water Accessibility and Water Affordability. CalHRTW 1.0 incorporates the most recent water quality data (from 2011 to 2019), updates the water accessibility component to include a more refined measure of physical vulnerability and includes three key metrics to assess water affordability challenges. An additional equity and vulnerability chapter explores the relationship between human right to water outcomes and three characteristics of social and institutional vulnerability: disadvantaged community status, water system size and managerial constraints. In addition to summarizing system-level information for the nine indicators and three components, the web tool includes information on critically over-drafted basins and time since the last high potential exposure or non-compliance event. The inclusion of these items reflects the incorporation of extensive public comment received during academic and public workshops, following the release of the 2019 drafts. The framework and tool allow the flexibility to incorporate new indicators over time, including, for example, measurements of sanitation and new affordability challenges that have been highlighted during our current global pandemic. Ultimately, CalHRTW 1.0 represents one of several key state efforts in ensuring the human right to water is met, including the State Water Board's Needs Assessment (Senate Bill No. 862., 2018) and the Department of Water Resource's Drought and Water Shortage Risk Assessment (Assembly Bill No. 1668., 2018).

In its passage of AB 685 in 2012, California declared that clean, safe, accessible and affordable drinking water are a fundamental right for all residents of the state. With the publication of CalHRTW 1.0, California becomes the first state to develop a tool for measuring the progressive realization of this right. The completion of CalHRTW 1.0 alongside other key statewide efforts, such as the passage of Senate Bill 200 (Monning, Chapter 120, Statutes of 2019) and the development of the State Water Resources Control Board's needs assessment and the Department of Water Resource's Drought and Water Shortage risk efforts, signals California's leadership and commitment in providing safe, affordable and accessible water to all. Especially in light of the strains on water supplies due to climate change, and the threats to some of the state's most vulnerable communities posed by the COVID-19 pandemic, this kind of broad, periodic assessment of our realization of the human right to water in California is even more essential. Coordination across state agencies with drinking water related responsibilities is a critical part of the work going forward.

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Abbreviations

AB 685	Assembly Bill No. 685
ACS	American Community Survey
AL	Action Level
AR	Affordability Ratio
CalHRTW	California's Human Right to Water Framework and Data Tool
CCR	Consumer Confidence Report
CPT	County Poverty Threshold
COV	Coefficient of Variation
CWS	Community Water System
DAC	Disadvantaged Communities
DBCP	1,3-Dibromo-3-Chloropropane
DBP	Disinfection By-Products
DP	Deep Poverty
eAR	Electronic Annual Report
FPL	Federal Poverty Level
GC 15	General Comment 15
GW	Ground Water
HCF	Hundred Cubic Feet
HM	Hours Worked at Minimum Wage
IQR	Interquartile Range
JMP	Joint Monitoring Program
LCR	Lead and Copper Rule
LIRA	Low Income Rate Assistance
MCL	Maximum Contaminant Level
MHI	Median Household Income
MOE	Margin of Error
MTBE	Methyl *Tert*-Butyl Ether
OEHHA	Office of Environmental Health Hazard Assessment
PCE	Perchloroethylene
PHG	Public Health Goal
PPIC	Public Policy Institute of California

PUC	Public Utility Commission
rTCR	Revised Total Coliform Rule
SDAC	Severely Disadvantaged Community
SDWA	Safe Drinking Water Act
SDWIS	Safe Drinking Water Information System
SJV	San Joaquin Valley
SW	Surface Water
SWRCB	State Water Resources Control Board, State Water Board
SWTR	Surface Water Treatment Rule
TMF	Technical, Managerial, and Financial Capacity
TCR	Total Coliform Rule
TTHM	Total Trihalomethanes
TCE	Trichloroethylene
1,2,3-TCP	1,2,3-Trichloropropane
UN	United Nations
UNICEF	United Nations Children's Fund
UN CESCR	United Nations Committee on Economic, Social, and Cultural Rights
US EPA	US Environmental Protection Agency
WHO	World Health Organization
WQM	Water Quality Monitoring Database

Executive Summary

In 2012, Assembly Bill (AB) 685 (Statutes of 2012. Eng, Chapter 524) was signed into law, declaring that "it is the established policy of the state that every human being has the right to safe, clean, affordable, and accessible water adequate for human consumption, cooking, and sanitary purposes" (Water Code Section 106.3). The Human Right to Water Framework and Data Tool 1.0 (CalHRTW 1.0)—comprised of this written report and an accompanying web tool—marks a foundational step in the development of a baseline from which to comprehensively track challenges in drinking water quality, accessibility and affordability statewide. The purpose of CalHRTW 1.0 is to provide a comprehensive, stand-alone, quantitative assessment of the human right to water in California that can assess conditions and changes over time.

Overview of Framework

The Human Right to Water Framework and Data Tool 1.0 (CalHRTW 1.0) measures and scores nine indicators across three core components of drinking water: quality, accessibility and affordability. These scores are calculated for the state's 2,839 active community water systems (as of January 2019). These indicators cover compliance with primary drinking water standards, exposure to drinking water contaminants, a system's vulnerability to water outages, and the affordability of the water for median-income and low-income customers. The report lays out methods for scoring individual indicators, with higher scores indicating greater challenges faced by systems. Indicator scores within each of the three components are combined to create three individual composite component scores to illustrate a system's overall status in providing clean, accessible and affordable water to its customers.

Figure ES 1 summarizes the conceptual framework used, highlighting the use of scores, individual indicators and components. Scores range from 0 to 4, with a lower number indicating a better score and outcome.

Figure ES 1. Conceptual framework of the human right to water in California.

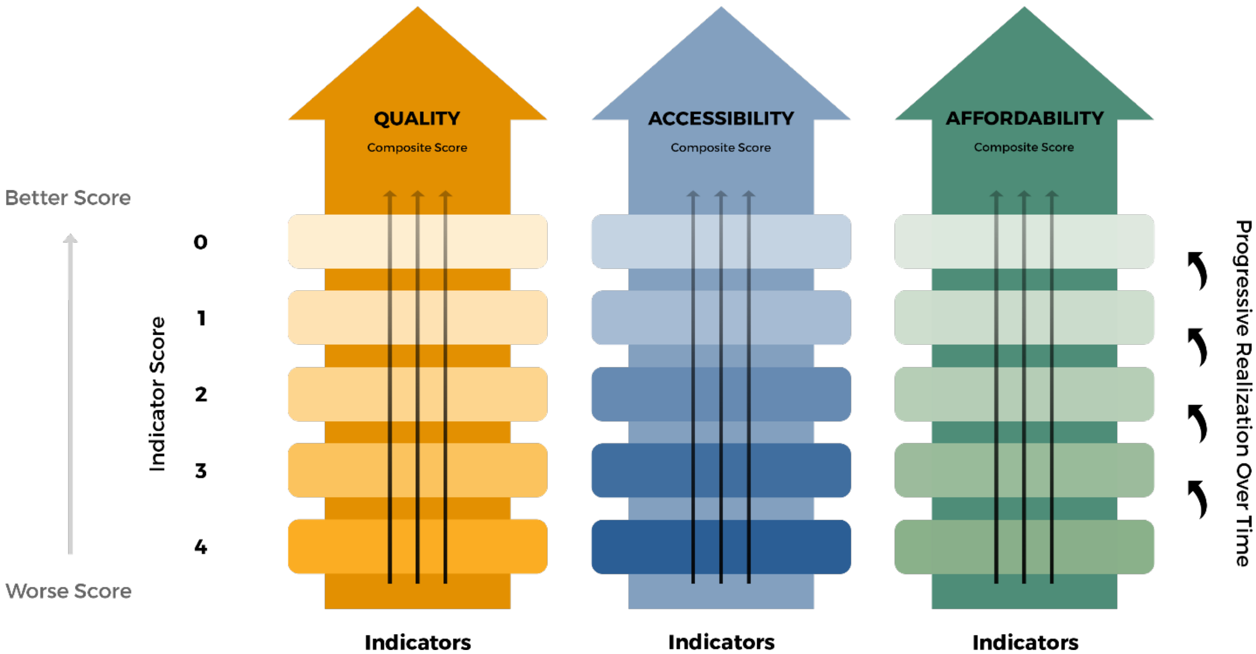
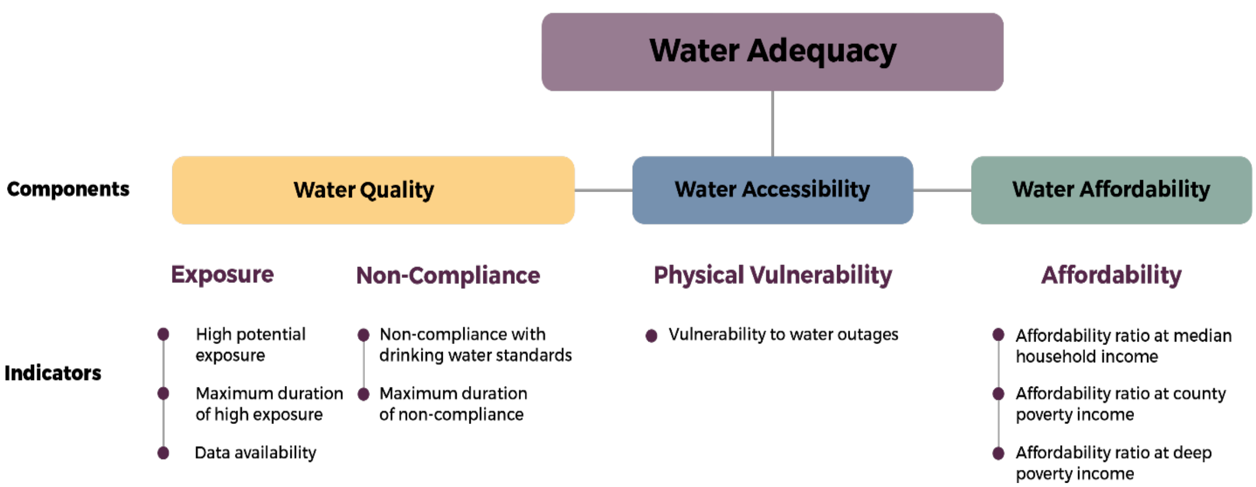


Figure ES 2 summarizes the final framework which includes three components and nine indicators. Here, water quality, water accessibility and water affordability all comprise the broader notion of water adequacy.

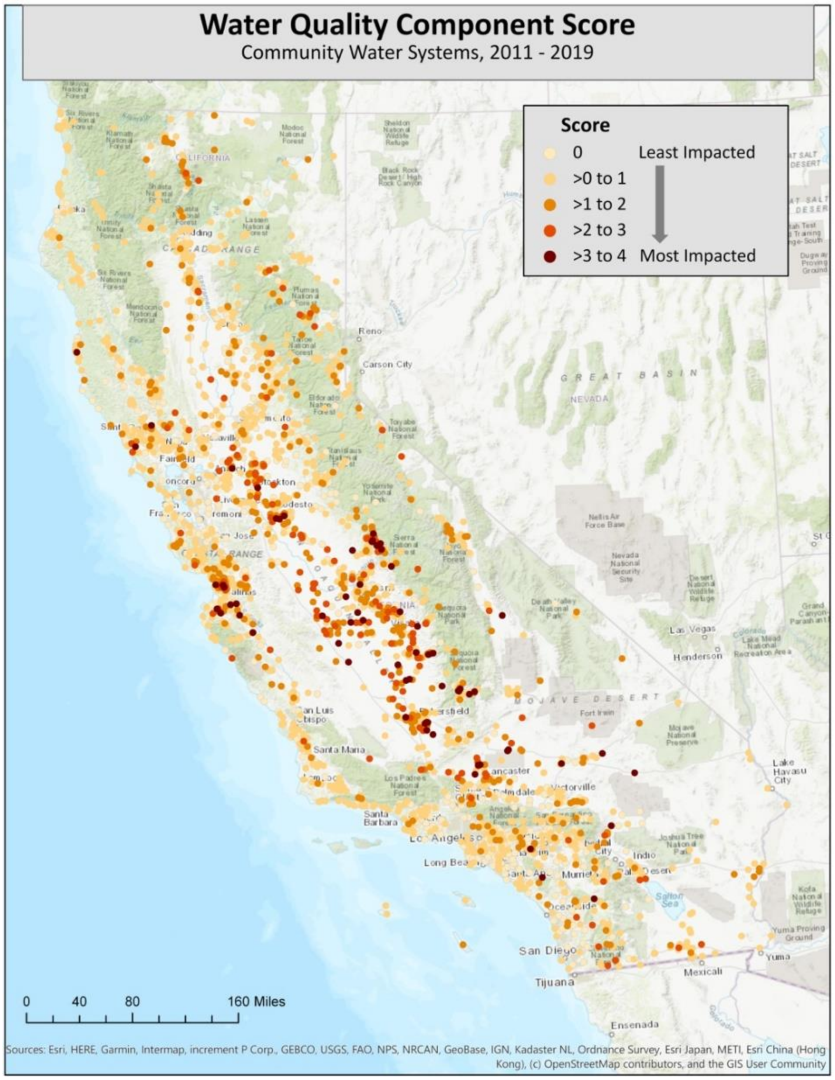
Figure ES 2. Human right to water framework with components and indicators.



Summary of Findings

Among the 2,839 community water systems studied during the time period of 2011 to 2019, this assessment highlights several key findings:

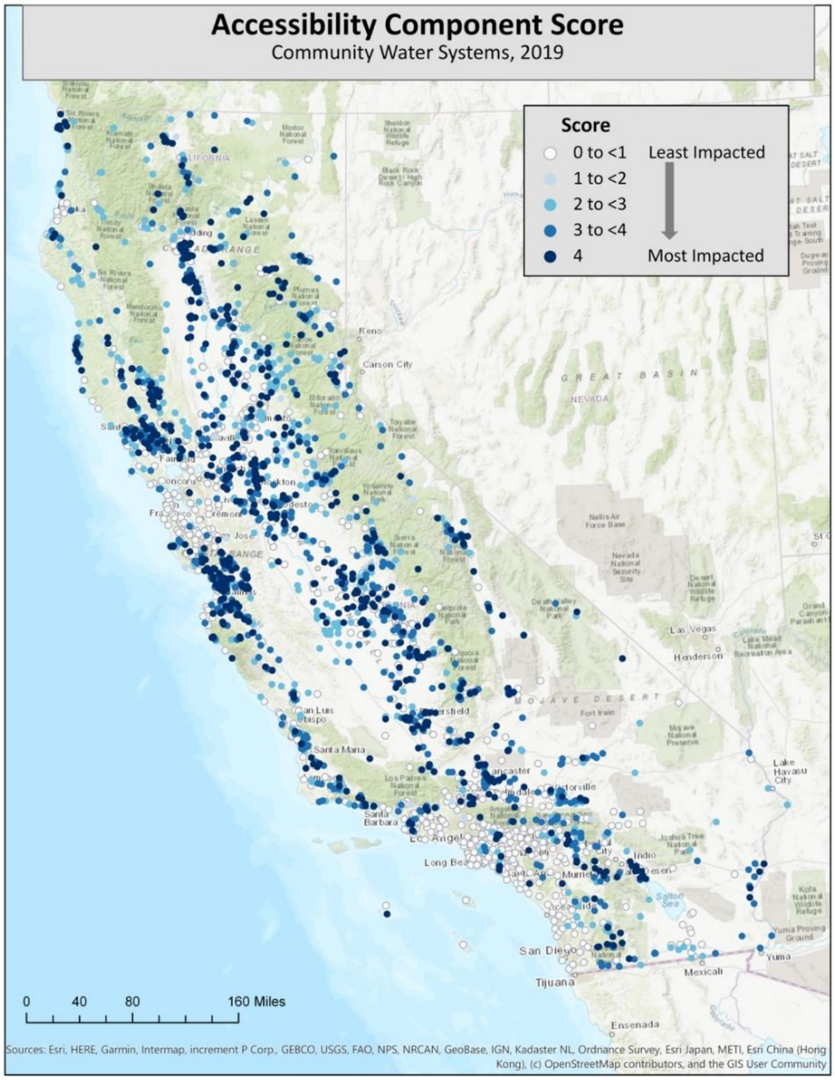
Water Quality



- Nearly three-fourths of the state's community water systems (74%) had water quality scores showing relatively good overall water quality, with nearly one third of these systems showing no water quality issue in terms of the measured indicators.
- Approximately one quarter of systems (26%, or 637 systems) received composite water quality scores greater than 1. Of these, 218 systems received the highest indicator scores, indicating they face the most significant challenges.
- Nearly 60% of systems (1,687 systems) had no high potential exposure (measured as an average annual concentration exceeding the Maximum Contaminant Level [MCL] for that contaminant). However, nearly 32% of systems had one contaminant with high potential exposure. And nearly 9% of systems (252 systems) had high potential exposure for two or more contaminants. The most prevalent contaminants with high potential exposure were: Total coliform/E. coli, arsenic, gross alpha, nitrate, total trihalomethanes (TTHMs), nitrate and Lead.
- 32% of systems had at least one MCL violation during the time period. Of these, approximately 5% had MCL violations for two or more contaminants.

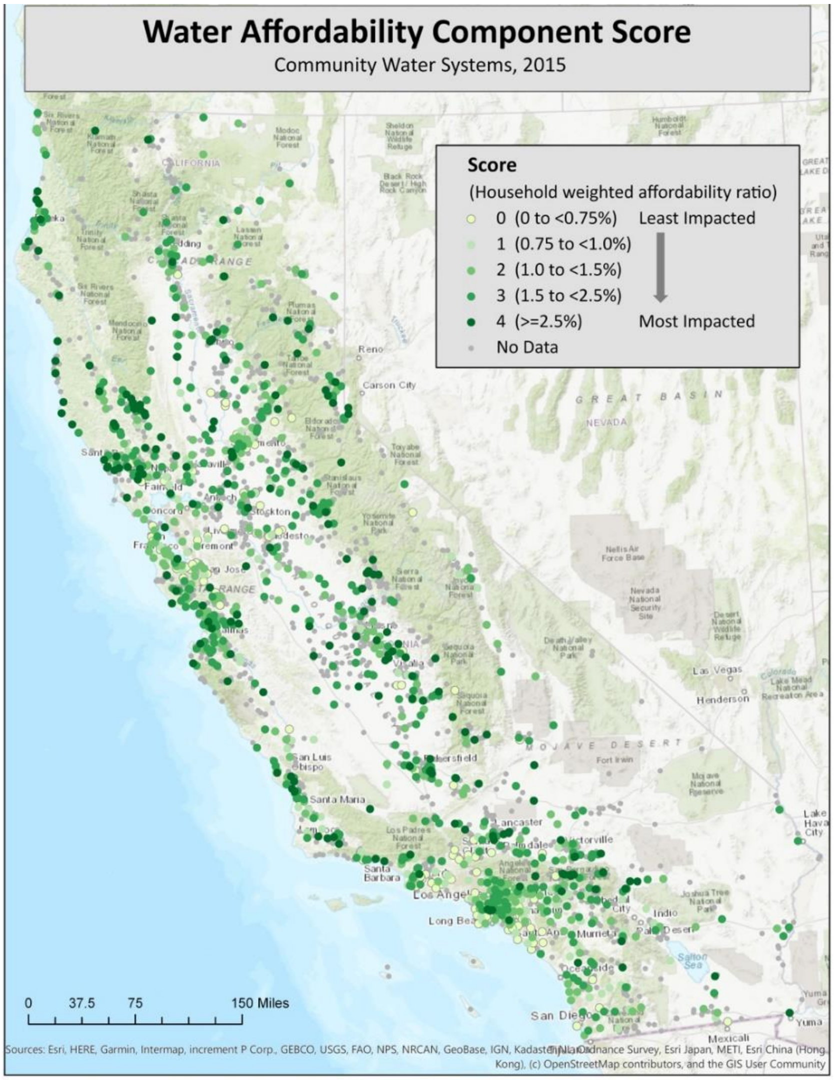
- Nearly 17% of systems had two or more years of MCL violations for any given contaminant, and 52 systems had nine years of recurring non-compliance. Contaminants with the longest duration of non-compliance were arsenic, nitrate and TTHMs.
- Regional trends highlight that some of the highest composite water quality scores occur in the San Joaquin Valley and the Central Coast regions of the state.

Water Accessibility



- Approximately 26% of the 2,839 systems studied have only one water source, no emergency source, and rely solely on groundwater. These systems are particularly vulnerable to water outages.
- Groundwater systems by far comprise the largest fraction of the highest-scoring (most susceptible) systems for physical vulnerability. Nonetheless, a small fraction of the highest-scoring systems (6%) are surface water systems with only 1 source, indicating vulnerability to water outages for these systems as well.
- Systems with only one source are found across the state. However, the regions that, on average, had the highest scores were: Northern California, the Central Coast and the San Joaquin Valley.

Water Affordability



- While there is a significant gap in the available data on water affordability, the analysis shows that at the median household income level, water is relatively affordable across systems. In particular, approximately 62% of water systems have water bills that are less than 1% of median household income in the system's service area. This is a good indicator that the water is affordable for a majority of households in those systems.
- For nearly 23% of water systems, water bills are between 1-1.5% of the area's median household income. For these systems, this indicates potential future challenges if water rates continue to increase.
- In a majority of water systems, water bills exceed 1.5% of poverty-level incomes in the county where the system is based. In these systems, this signifies that households earning at the county poverty level face significant challenges in affording their drinking water.
- In the vast majority of systems (77.6%), water bills exceed 2.5% of "deep poverty level" incomes. Deep poverty is defined as one-half of the poverty-level income in the county where a system is based. In these systems, this signifies that the lowest-income households face significant challenges in affording their drinking water.
- 60% of systems did not have adequate data to evaluate the affordability of their drinking water. The systems with missing or excluded data serve approximately 8.7% of the state's population. A majority of systems missing data are small systems. Data gaps in affordability will need to be addressed in statewide data collection efforts.

Human Right to Water and Social Equity

It is critical to assess human right to water outcomes in terms of social equity. The report considers the relationship between these outcomes and key measures of social and institutional vulnerability. As a starting point, this report explores the connection between disadvantaged community status (i.e., disadvantaged, severely disadvantaged and non-disadvantaged communities), size and managerial constraints (measured by monitoring and reporting violations) of water systems. Results from this assessment highlight that:

- Water quality is worse in disadvantaged and severely disadvantaged communities than non-disadvantaged communities.
- Systems with more monitoring and reporting violations (i.e., greater managerial constraints), have higher (i.e., worse) water quality scores.
- Among systems with data, small and very small systems face greater affordability challenges compared to larger systems.

These findings support the continued exploration of human right to water outcomes by vulnerability measures.

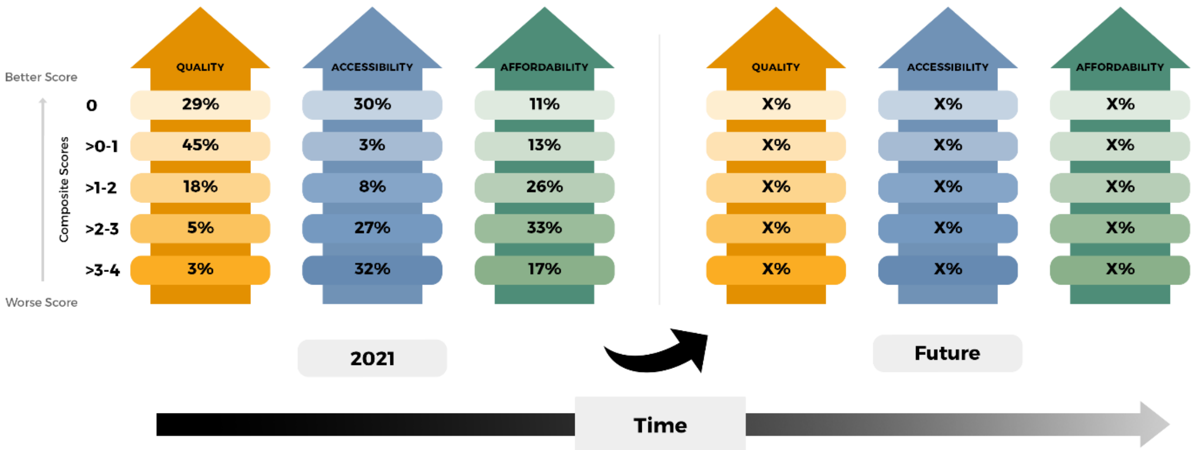
Conclusions and Next Steps

The Human Right to Water Framework and Data Tool 1.0 provides a comprehensive, quantitative stand-alone approach that can be used to evaluate progress in achieving the human right to water in California. It is the first such approach developed by the State of California. OEHHA and the Water Board envision a role for this framework and data tool in providing a baseline of information that can be periodically updated to provide a snapshot of progress towards the human right to water. This can inform efforts to ensure that all households receive clean, safe, accessible and affordable water and help focus the state's attention on water systems facing the greatest challenges over time. When coupled with related efforts, such as the State Water Board's Needs Assessment (Senate Bill No. 862., 2018) and DWR's drought and water shortage risk assessment (DWR, 2021), OEHHA's tool offers a flexible, versatile, and adaptable way for CalEPA and the Board to view and evaluate progress towards achieving the human right to water in California.

OEHHA plans to maintain the tool and conduct periodic updates to evaluate progress toward achieving the human right to water. Such updates may include: 1) updating indicators, as new data become available, 2) evaluating the distribution of each indicator score and how it compared to the previous time period, and 3) incorporating additional drinking water-related metrics (e.g., sanitation needs). Over time, and as new data is developed and/or acquired via related statewide efforts (e.g., the State Water Board's Needs Assessment or Department of Water Resources County Drought Advisory Group), OEHHA will align the tool with ongoing developments.

Figure ES 3 exemplifies how these updates can be used to track changes over time. For example, summary results from CalHRTW 1.0 are shown in the first box on the left. Over time, the same metrics can be measured and the state can gain a perspective on which components or indicators improve over time, thereby capturing progressive realization.

Figure ES 3. Human right to water outcomes tracked over time in California.



As a starting point, CalHRTW 1.0 focuses on households served by community water systems. With time and further data acquisition efforts, additional areas that this framework seeks to incorporate include:

- Sanitation
- State small water systems
- Households reliant on domestic water systems
- Schools
- Transient and homeless populations
- Tribal water systems
- Equity analyses

Introduction

Reliable access to safe and affordable water is fundamental to human health and well-being. While many Californians may take safe and affordable drinking water for granted, some residents receive water of marginal quality, or that they struggle to afford. Still others can lose access to water during periods of drought.

In California, nearly one million Californians are served by water systems that are out of compliance with primary drinking water standards, including arsenic, disinfection by-products and nitrate (State Water Resources Control Board, 2020d). Other Californians depend on small water systems and domestic wells impacted by contaminants like nitrate, which can likewise cause detrimental health outcomes (Bangia *et al.*, 2020). Across the state, contaminated water sources disproportionately burden low-income communities and communities of color, further exacerbating persistent inequities (Balazs *et al.*, 2011; Balazs *et al.*, 2012; Francis and Firestone, 2011; London, 2018). In addition, many low-income households depend on water systems struggling with issues such as aging infrastructure, unreliable supplies, and a cost structure that pushes water rates to unaffordable levels. Climate change is also dramatically affecting water quality, availability, and affordability. In light of these trends, it is increasingly critical for the state to develop methods for identifying drinking water challenges, and to design and implement solutions that improve the quality of water delivered to California households, while also improving supply resiliency and affordability for all Californians.

In 2012, with the enactment of Assembly Bill (AB) 685 (Eng, Chapter 524, Statutes of 2012), California became the first state to declare that every human being in the state has a right to clean, safe, affordable, and accessible water adequate for human consumption and sanitary purposes. The legislation instructed all relevant state agencies, including the State Water Resources Control Board (State Water Board, or Board), to consider the human right to water when revising, adopting, or establishing policies, regulations, and grant criteria pertinent to water uses. More recently, on July 24, 2019, the Governor signed Senate Bill (SB) 200 (Monning, Chapter 120, Statutes of 2019), which directs the state to "bring true environmental justice" to its residents, and to "begin to address the continuing disproportionate environmental burdens in the state by creating a fund to provide safe drinking water in every California community, for every Californian."

OEHHA's Human Right to Water Framework and Data Tool

OEHHA's Human Right to Water Framework and Data Tool (CalHRTW 1.0) —comprised of this written report and an accompanying web platform— is the first statewide effort to provide a comprehensive, quantitative, stand-alone assessment of the quality, accessibility and affordability of California drinking water. This baseline assessment includes an examination of the capacities, deficiencies, and vulnerabilities of the state's community water systems. This report also provides a conceptual framework and approach for quantifying the state's progress in delivering clean, safe, affordable, and accessible water through community water systems. When updated over time, the framework and tool will enable the assessment of changes relating to drinking water and the evaluation of progress toward achieving the human right to water. This would entail: 1) updating and improving indicators; and 2) evaluating the distribution of each indicator and component score and how it compared to the previous time period by assessing the reduction or increase in number of systems receiving each score.

As such, CalHRTW 1.0 offers information that the public and decision makers can view at the statewide or system-level, and across all three principal components of the state's human right to water. The data tool is designed to support state and local government agencies including the State Water Board and regional boards, the Legislature, researchers, and community organizations in quantitative assessments of how California is achieving the human right to water, in policy planning and implementation, and in designing programs to deliver safe and affordable water to households and individuals. The data tool is designed to show how a set of systems (e.g. community water systems) might be assessed and tracked over time.

OEHHA intends to expand the scope of the assessment and refine the data tool over time as additional data on water quality, accessibility and affordability in California becomes available. For example, in future versions OEHHA will seek to include state small water systems, schools, communities reliant on domestic wells, and marginalized populations (e.g., people experiencing homelessness), as well as tribal water systems. Similarly, sanitation is a critical component of the human right to water that OEHHA will seek to include in future versions. As OEHHA adds additional systems and populations to its tool, the data and metrics can continue to support refined and additional policy implementation efforts at the state, regional, and local levels. These efforts will work in concert with the aforementioned state efforts, yielding a robust set of tools and analyses that assess how the state of California is doing with regards to delivering safe, accessible and affordable water.

The report begins with an overview of the assessment and data tool. Next, it introduces each of the three components—water quality, water accessibility and water affordability—along with the indicators that comprise each component. Each section includes results for each indicator and component. The report then explains how the data tool works and walks readers through a series of hypothetical cases with supporting visual information, with a chapter showing how human right to water outcomes can be viewed in the context of social equity. The report also includes several appendices that describe additional data and indicators that could be added into future versions of the assessment and data tool, and provides details on various technical aspects of the methods.

State Agency Efforts to Develop and Implement Policy Solutions

Under the direction of CalEPA and the leadership of its Boards, Departments and Office (BDOs), a number of inter-related efforts showcase the state's commitment and leadership in assessing and achieving the human right to water, and are a testament to the state's evolving and growing drinking water assessment toolkits.

For example, other complementary methods to assess and track water system needs and vulnerabilities include:

- The State Water Board's interactive map of out-of-compliance systems,[1] and its Needs Assessment (Senate Bill No. 862., 2018),[2] which is aimed at prioritizing the Board's funding, assistance and regulatory work in the State's most vulnerable systems;
- The State Water Board's assessment of low-income affordability challenges and a plan for statewide low-income rate assistance (Assembly Bill No. 401., 2015);[3] and
- The Department of Water Resource's statewide evaluation of small water systems and self-supplied households in terms of their vulnerabilities to drought and water shortage risk (Assembly Bill No. 1668., 2018).[4]

Each of these efforts focuses on water system and household issues, and specific policy mechanisms to address them. The diversity of efforts underscores the state's commitment to achieving the human right to water in California, and ensuring sustainable and equitable water for domestic uses. These efforts have already closely informed each other in terms of frameworks, methods and indicators. This collaboration will continue over time, leading to the continual development of a robust, inter-related and diverse toolkit to address human right to water issues that meet the needs of the state and its various stakeholders.

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[1] See: Human Right to Water Portal at https://www.waterboards.ca.gov/water_issues/programs/hr2w/, which provides information about all of the Board's work on implementing the human right to water, including a map of out-of-compliance systems.

[2] The Water Board was directed to conduct a needs assessment pursuant to the Budget Act of 2018; http://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201720180SB862

[3] (Assembly Bill No. 401., 2015) directed the Water Board to develop a plan and recommendations for a statewide low-income rate assistance program.

[4] (Assembly Bill No. 1668., 2018) directed the Department of Water Resources, in consultation with the Water Board and other stakeholders, to evaluate supply vulnerabilities and risk for small water systems and self-supplied households.

Framework and Data Tool: Assessment Approach and Overview

Approach to Building the Framework and Data Tool

In developing the Human Right to Water Framework and Data Tool (CalHRTW), OEHHA drew on existing international approaches that track the human right to water (See Box 1), most importantly those of the World Health Organization and the United Nations' Joint Monitoring Program (WHO and UNICEF, 2017). OEHHA adapted these approaches to develop specific indicators that address the conditions and needs of California (Jensen *et al.*, 2014),[5] and to complement and provide a foundation for the work of the State Water Board and other agencies to ensure the quality, accessibility, and affordability of California's drinking water supply.[6]

This tool provides:

1) A working data set and analytic framework for evaluating trends in the provision of clean, safe, accessible and affordable water to all Californians, and assessing progress over time in achieving the human right to water.
2) A set of indicators of water quality, accessibility and affordability that can be examined individually or in groups to allow for a nuanced understanding of key drinking water issues.
3) An assessment of California-specific objectives for safe, clean, affordable, and accessible water for all state residents, to guide policy development and implementation.

Framework and Assessment Overview

Assessing the overall adequacy of the provision of water means taking into account the following three objectives:

Water Quality: The water supplied to California residents should be safe to use. This means that it should be free from harmful bacteria and other pathogens, and that the levels of chemical contaminants such as solvents and pesticides, nitrates, heavy metals, and radioactivity should not pose significant public health risks.

[5] OEHHA followed Jensen et al.'s (2014) methodology for developing a human right to water framework for the screening tool, while drawing on international tracking efforts such as the United Nations' Joint Monitoring Program (UNICEF 2017).

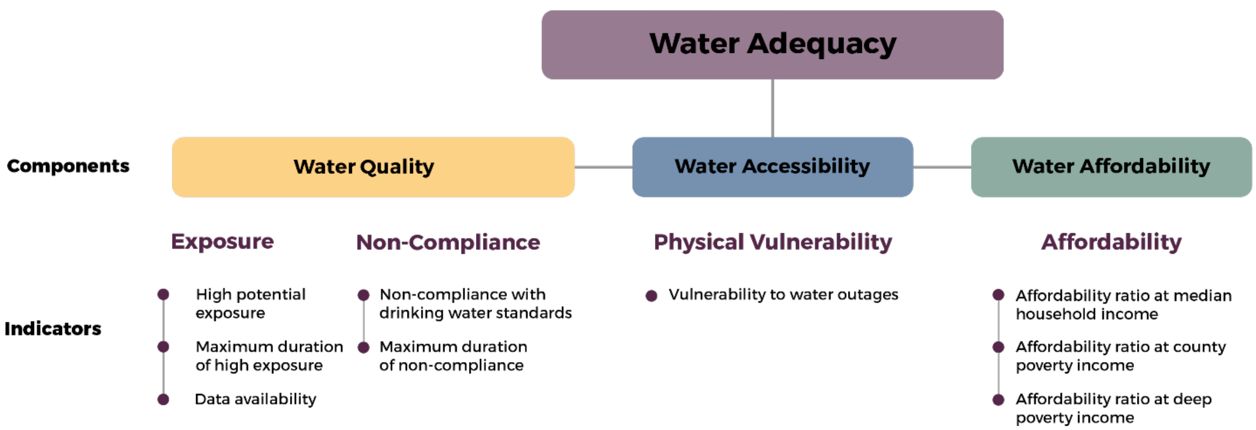
[6] Drinking water supply refers to domestic water supply used for household purposes such as drinking, cooking, bathing, etc.

Water Accessibility: Water should be accessible in sufficient and continuous amounts to meet everyday household needs. For example, it should be available for drinking, preparing food, bathing, clothes washing, household cleaning, and toilet use.

Water Affordability: Water to meet household needs should be affordable, taking into consideration other household living expenses, and the direct and indirect costs associated with obtaining access to the water.

Figure 1 presents the framework used to characterize these three components. A total of nine indicators are used to measure water quality, accessibility, and affordability for households served by community water systems. These are represented in Figure 1. Each indicator was chosen based on data availability, data coverage and data quality. Other indicators that were not been included due to data limitations may be added or refined in future versions, as improvements in data collection permit (see Table 18). For an in-depth review of how OEHHA developed its framework, please see (Balazs *et al.*, 2021).

Figure 1. Human Right to Water Framework. Components are indicated in blue boxes. In each yellow box, subcomponent names are indicated at the top, followed by individual bulleted indicators.



Unit of Analysis

This first assessment and data tool analyzes community water systems. These are defined as public water systems that serve at least 15 year-round service connections, or regularly serve at least 25 yearlong residents (Health and Safety Code Section 116275). Community water systems were included if they were active during the 2011-2019 study period. A total of 2,839 community water systems met this criterion (OEHHA, 2017).[7]

[7] This number includes five service areas comprising the Los Angeles Department of Water & Power, but not the parent system itself. The five service areas were used to better estimate intra-system water quality and affordability variability for this system. This approach is further described in OEHHA's CalEnviroScreen 4.0 report (OEHHA 2020).

Time Period

This assessment focuses on data from the most recent time period available across each dataset. For water quality, the assessment offers a long-term view of water quality, thus the water-quality indicators cover the period from 2011 to 2019 (This is discussed in the section on the Water Quality component.).

Box 1: The Human Right to Water

The Human Right to Water is broadly defined as the right of individuals to safe and acceptable, sufficient, physically accessible and affordable water for drinking and sanitation. Whether this right is met is best assessed for each individual. However, most monitoring efforts typically assess the proportion of a population with access to adequate water. In this current report, OEHHA focuses on households served by community water systems, which provide water to approximately 90% of California's population.

A comprehensive evaluation of the human right to water and sanitation must focus on all points of access, including schools, communities reliant on domestic wells, etc. Accordingly, with time, this assessment would expand to include sanitation and all such populations in order to provide a complete picture of the human right to water in California.

Indicator Selection and Scoring

To create indicators for each component, we:

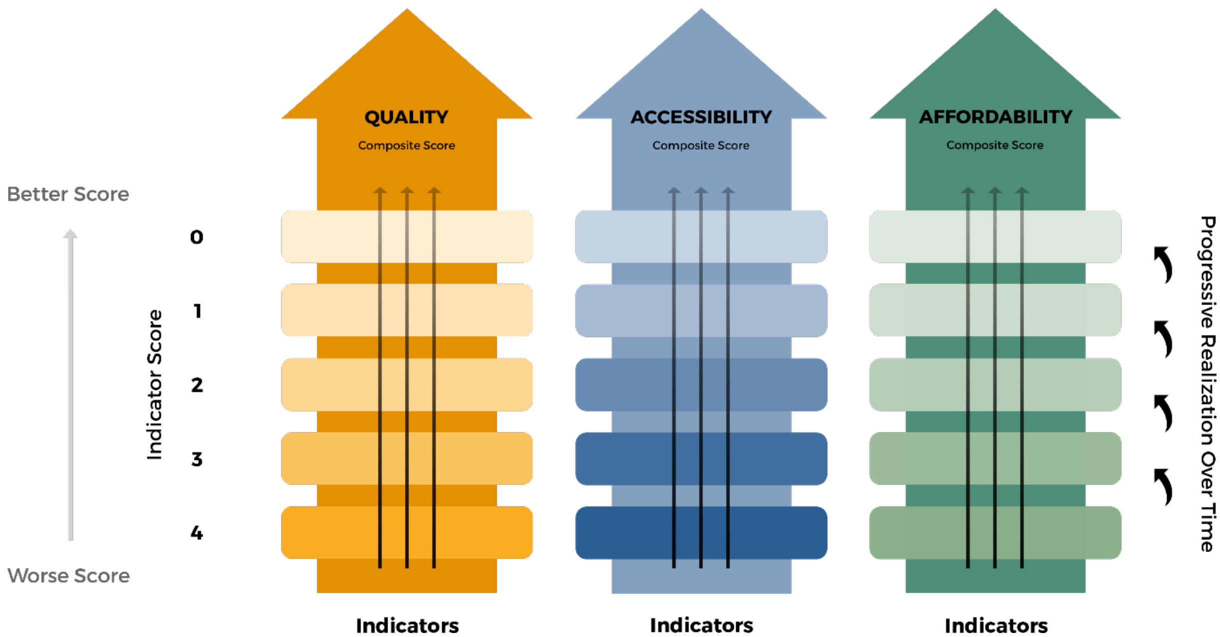
- Assessed sources of data for quality, coverage, and availability.
- Evaluated indicators for human right to water monitoring in academic and policy literature light of data availability in the California context
- Selected data for the relevant time period that is high quality, provides broad coverage, and is publicly available.
- Presented indicators for public and expert feedback during the release of the Conceptual Framework (2019a) and Draft report (2019b).

As shown conceptually in Figure 2, we then:

- Calculated each indicator value.
- Assigned scores to each indicator along a five point scale of 0 to 4, with higher values given to systems that perform less favorably in the area that the indicator represents, and lower values given to systems that perform more favorably. This results, for example, in a low water-quality score for better water quality, and a higher score for poorer water quality.

- Developed a composite scoring approach for each component, so that individual water systems have an overall score for water quality, accessibility and affordability based on the indicators that comprise each component.

Figure 2. Conceptual View of the Proposed Assessment and Tool. The assessment is composed of three core components, with indicators assigned to each component. Higher indicator scores reflect poorer outcomes for water quality, accessibility or affordability. Scores are shown along a spectrum to reflect the notion of improvement. As the framework is implemented over time, improving scores can also capture the notion of progressive realization.



A Holistic View of Water Systems

While individual indicators associated with each of the assessment's three components provide useful information, a holistic view of all components together is necessary for monitoring the human right to water. Decision-makers may wish to assess water systems across components, to better understand the relationship between various water delivery and service characteristics. For this purpose, it is valuable to use the three composite component scores for a given system, to illustrate a system's overall status. Such a cross-component view allows users of the tool to understand how a system's water quality, accessibility and affordability might relate to each other, as demonstrated conceptually in Figure 3, which is further elaborated upon later in the report (see Figure 35). The cross-component view offered by this assessment can identify water systems and regions that may need a more in-depth evaluation of water challenges. A cross-component view can also signal which systems are doing well in one or more of the three components. Periodic updating of the indicators will also illuminate broad trends and progress over time.

Figure 3. Conceptual View of How Multiple Challenges Can Affect Individual Water Systems. The framework and data tool allow users to view overall trends for each human right to water component, while also comparing the overall status of a water system across these three components.

While a cross-component view yields valuable information, each of the three components alone, and its associated indicators, offers important information that is useful for planning and shaping policy solutions to local water system challenges. Of course, a holistic view of an individual or set of water systems should not replace a more tailored view that might facilitate the development of an appropriate solution to a particular system-level challenge. For example, a system with unsafe drinking water needs an immediate remedy to address water quality, regardless of whether the supply is plentiful and the rates are low. In other words, a system's deficiencies in any given component should not be outweighed or downplayed by more favorable performance in the other components.

This first application of the framework and data tool assesses households served by community water systems. With time and further data acquisition efforts, future assessments would seek to incorporate information on sanitation, domestic well users and other key populations. These are further discussed in the "Future Considerations" chapter at the end of the report.

Component 1: Water Quality

Water Quality and Its Subcomponents

Clean water that is safe to drink is essential to human health. However, not everyone in the state experiences the same level of drinking water quality.

Water quality is evaluated here in two basic ways:

- A "contaminant exposure" subcomponent, which measures the extent of exposure of a water system's customers to chemical and microbiological contaminants in the system's drinking water.
- A "non-compliance" subcomponent, which measures the extent to which a water system fails to comply with primary drinking water standards, specifically the Maximum Contaminant Levels (MCLs).[8]

These two subcomponents provide different kinds of critical information in evaluating the quality of the water provided by water systems. Compliance status offers important information about how successfully water systems are meeting regulatory requirements that pertain to public health. However, measuring compliance alone may not fully capture the public health implications of exposure to drinking water contaminants because compliance with most regulatory standards is determined by whether a water system meets federal and state drinking water standards at their individual water sources, such as a well, the site of a surface water intake, or the treatment facility.[9] Assessing contaminant exposure offers additional information by estimating which contaminants people can be exposed to at the tap. **Figure 4** illustrates the various points that each subcomponent focuses on (Balazs *et al.*, 2011; OEHHA, 2017).[10] It highlights how the compliance subcomponent is based on measurements at Points A and C, while the exposure subcomponent is based on measurements at Point D. While existing human right to water frameworks[11] assess compliance with regulatory levels, OEHHA folds in

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[8] Most human right to water efforts, such as the United Nations' Joint Monitoring Program, only evaluate water quality in relation to compliance with regulatory standards.

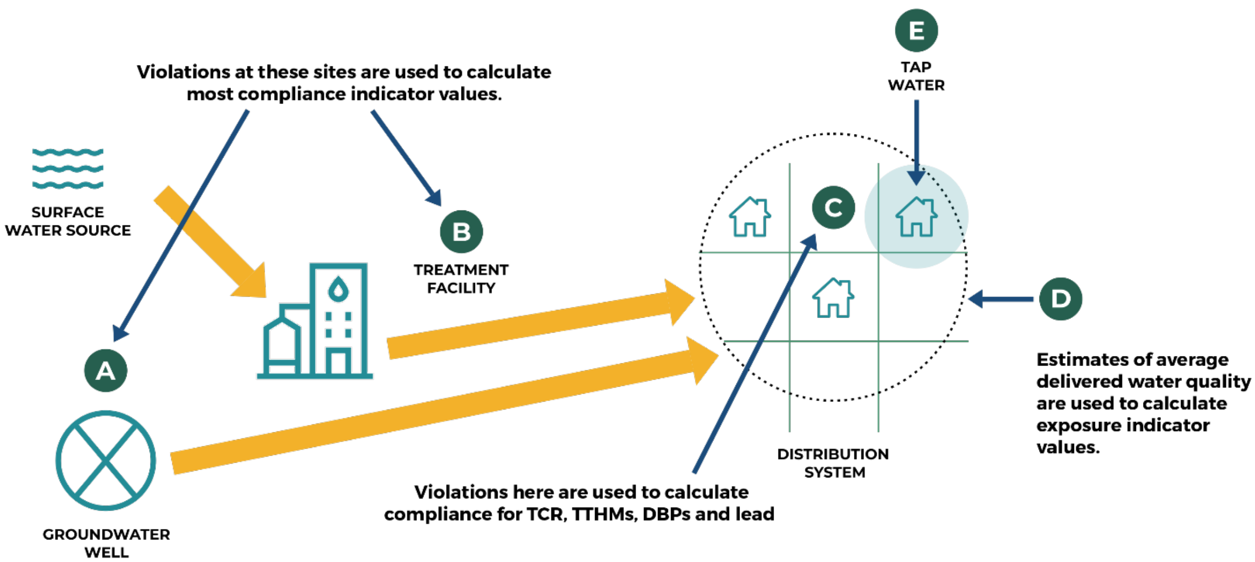
[9] Exceptions include samples for the Total Coliform Rule (TCR), the Lead and Copper Rule (LCR) and the Disinfectants/Disinfection Byproducts Rule (DBPR). For example, compliance for TCR is determined using water samples taken from the distribution system.

[10] Data about water quality at the tap is not widely available, so the average quality of delivered water is used here to represent potential exposure. This is the best way available to accurately capture information about water quality before water enters the household distribution system (Balazs *et al.*, 2011; OEHHA, 2017)

[11] Such as the United Nation's Joint Monitoring Program (JMP)

exposure metrics to give a broader assessment of the types of water quality challenges faced by California's water systems.

Figure 4. A Hypothetical Community Water System. Generally, compliance with regulatory standards is assessed at the "source level" water quality monitoring points, meaning the site of a groundwater well (A) and/or at the treatment facility (B). For lead, disinfection byproducts, total trihalomethanes and the Total Coliform Rule/revised Total Coliform Rule compliance is assessed within the distribution system, at monitoring points represented by Point C. The "non-compliance" subcomponent measures MCL violations detected at points A, B and C to calculate the compliance indicator values. Point D represents OEHHA's estimate of water quality representative of a system's average delivered water quality for a given contaminant. Average water quality calculated within the distribution system (D) is used to represent an estimate of tap water quality at Point E, for which data is not available (except lead).



Time Period of Coverage

Water-quality data was drawn from a nine-year period from 2011 through 2019, the most recent and complete compliance cycle for which data are available (US EPA, 2004).[12] Since not all systems are required to report monitoring data for all contaminants each year, using this nine-year period results in a greater chance of capturing water quality monitoring data for a given system, since all systems would need to sample during a nine-year compliance cycle.

Contaminants Selected

Approximately 107 drinking water contaminants are regulated in California under federal and state law. Of these 94 have primary standards and 16 have secondary standards (three of

[12] US EPA guidelines govern the monitoring and reporting of drinking water quality over three-year compliance periods, within nine-year compliance cycles (US EPA, 2004).

which also have primary standards). From a human-right-to-water perspective, consideration of primary and secondary contaminants is important. However, for this first version of the tool, OEHHA selected a subset of primary contaminants to characterize the water quality component of the tool. Each contaminant was selected based on whether it has a maximum contaminant level, and whether there was significant coverage (i.e. 80%) of water quality sampling data for that contaminant in the Water Quality Monitoring database across water systems in the 9-year time period between 2011 through 2019.

OEHHA started with 19 contaminants that had been considered for use in the CalEnviroScreen 3.0 drinking water quality indicator (OEHHA, 2017). For 17 of these contaminants at least 80% of community water systems in the state reported at least one monitoring sample:[13]

> Arsenic, barium, benzene, cadmium, carbon tetrachloride, Gross Alpha,[14] lead, mercury, methyl tertiary butyl ether (MTBE), nitrate, perchloroethylene (PCE), perchlorate, trichloroethylene (TCE), 1,2,3-trichloropropane (1,2,3-TCP), and total trihalomethanes (TTHM), toluene, and xylene (See Table 1).

Two additional contaminants not meeting this criterion are associated with significant health effects, and had a significant number of MCL violations. 1,2-dibromo-3-chloropropane (DBCP) had less than 80% coverage, but was included because it poses risks for a significant number of water systems and has significant health effects (See Table 1). Total coliform/E.coli was included since it is an important measure of microbiological contamination, though there is no statewide sampling data available of coliform samples (but data is available for compliance status).[15] Future versions of this tool will explore additional contaminants, including those with secondary drinking water standards.

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[13] Regulations require water systems to sample and test for a particular subset of chemicals unless the water system can demonstrate that these chemicals are not used, manufactured, transported, stored, or disposed of within their source watershed or within the zone of influence of their groundwater source(s). Upon a successful demonstration, systems are considered non-vulnerable to the subset of chemicals, and testing for them is not required. This subset of chemicals is not included in this report, since the report relies on chemicals with universal sampling and testing requirements.

[14] Because of the inclusion of Gross Alpha as a test of overall drinking water radioactivity, measurements for specific radionuclides (e.g., radium-226 and uranium) are not included.

[15] Because this assessment period for total coliform/E.coli spans 2016, the year the Total Coliform Rule (TCR) was revised (rTCR) and became effective, information from both periods is included here.

Table 1. Contaminants Used to Characterize the Water Quality Component. The table indicates whether the contaminant was used for the exposure or compliance subcomponents, and the percentage of systems statewide that had at least one water quality monitoring sample in the period from 2011 through 2019.

Contaminant	Used in Exposure Indicators	Used in Compliance Indicators	Percent of Systems with Water Quality Monitoring Data
Arsenic	Yes	Yes	97%
Barium	Yes	Yes	97%
Benzene	Yes	Yes	95%
Cadmium	Yes	Yes	97%
Carbon tetrachloride	Yes	Yes	95%
Dibromochloropropane (DBCP)	Yes	Yes	61%
Gross Alpha	Yes	Yes	95%
Lead	Yes	**No**	99%
Mercury	Yes	Yes	97%
Methyl tertiary butyl ether (MTBE)	Yes	Yes	95%
Nitrate	Yes	Yes	98%
Perchloroethylene (PCE)	Yes	Yes	95%
Perchlorate	Yes	Yes	97%
Trichloroethylene (TCE)	Yes	Yes	95%
1,2,3-Trichloropropane (1,2,3-TCP)	Yes	Yes	96%
Toluene	Yes	Yes	95%
Total coliform/E.coli	Yes	Yes	Not available
Total trihalomethanes (TTHM)	Yes	Yes	96%
Xylene	Yes	Yes	95%

Exposure Subcomponent

Approach

For the exposure subcomponent, OEHHA developed three exposure indicators that measure:

1. The nature of contaminant concentrations ("high potential exposure").
2. The duration of high potential exposure.
3. The availability of monitoring data.

For each of these indicators, average delivered water quality for each contaminant is used to represent exposure to drinking water contaminants at the tap. A contaminant's MCL is used as the benchmark against which to compare measured concentration levels. Potential exposure—measured as the annual average concentration of delivered water quality—is considered high if the annual average water concentration of a contaminant is at or above the MCL. Potential exposure is considered not high if it is below the MCL. Indicating that a potential exposure is not high under this approach is not intended to suggest an absence of health risk for a contaminant. OEHHA's Public Health Goals (PHG) for drinking water are the benchmark used to determine health risks from exposure to contaminants. However, use of PHGs as a benchmark for these indicators is a challenge, as the detection limits for many contaminants are well above their corresponding PHGs. [16]

OEHHA made the following adjustments for specific contaminants:

- For 1,2,3-TCP, the 2017 MCL were used as the benchmark.
- For lead, tap water sampling results for the 90th percentile of samples (as per the Lead and Copper Rule) were used in place of average delivered water quality estimates. Lead levels are then assessed against the lead Action Level Exceedances instead of an MCL, since there is no MCL for lead. Therefore, we compare the average of these 90th percentile results in a given water system to lead's Action Level (Title 17, 2012).[17]
- Total coliform/E.coli counts are monitored regularly.[18] Here, MCL violations of the Total Coliform Rule (TCR) and the Revised Total Coliform Rule (RTCR) were used to represent high potential exposure events, instead of the average contaminant concentration, as is done for other contaminants. MCL violations of the TCR/RTCR are used to calculate

[16] Future versions of this report and tool will explore how to better incorporate the potential toxicity related to drinking water contaminant exposure.

[17] Lead and Copper Rule; Title 17, California Code of Regulations, section 64673. The only system-level information on lead available statewide is from sampling pursuant to the Lead and Copper Rule. While source-level lead sampling data is also available, such data does not approximate lead levels in the home. Instead, following the Lead and Copper Rule, a subset of homes within each system are sampled, and the 90th percentile results are publicly available and can be used to estimate potential exposure levels. As a result, however, estimated lead exposure levels may be under or over-represented for the average lead levels of a water system.

[18] TCR/RTCR results are sent as hardcopies by laboratories directly to the State Water Board District Offices and Local Primacy Agencies. Compliance decisions are made manually by regulators, and entered into the Water Board's Safe Drinking Water Information System database.

both exposure and compliance indicators.

Data Source

Water Quality Monitoring (WQM) Database, 2011 through 2019, Available at URL: http://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/EDTlibrary.shtml

Estimating Potential Exposure

As noted above, *average delivered water quality for each water system* serves as a proxy for average exposure at the tap. For each contaminant of interest, annual average delivered water quality was calculated using the following steps:

- Sources providing delivered water were identified for each water system (OEHHA, 2021a).
- Time-weighted annual averages were calculated for each year within each source.
- A system-level average concentration was calculated for each contaminant, using the annual source-level water quality sampling results (OEHHA, 2017) (e.g., point D in**Figure 4**).[19]

Indicators

Water Quality Indicator 1: High Potential Exposure

This indicator evaluates the number of contaminants with high potential exposure levels. We define *high potential exposure* as a situation in which a system's average annual contaminant concentration is at or above the MCL for the contaminant at least once during the study period.

Method

To create the indicator of "high potential exposure" for each water system we:

- Estimated the average annual concentration of delivered water for each contaminant (except for Total Coliform/E.coli)
- Assessed whether the concentration was greater than the MCL (or the Action Level for lead) at least once in the time period for each contaminant.
- Counted the number of contaminants whose average annual concentration was greater than its MCL (or Action Level for lead)

[19] Here, we used the approach developed in CalEnviroScreen 3.0 where water quality monitoring samples were taken from the State Water Board's Water Quality Monitoring database. Samples for sources that represented delivered water included post-treatment or untreated sources. For systems that had no treated or untreated sources, water quality samples from "raw" sources were used.

- Added a count if the system exceeded the TCR/rTCR MCL at least once during the study period.

The reason for considering whether a system had "at least one" such high exposure instead of counting the exact number of high potential exposures is to account for variation in the amount of water quality monitoring data available by year. Some systems sample more or less frequently based on their monitoring requirements, but would ideally have data for at least one year of data during the 9-year time period. Counting "at least one" high exposure in the 9-year time period accounts for monitoring or reporting bias in which some systems may have fewer years of data (and therefore fewer high potential exposures) due to lack of reporting or monitoring, not because of their prescribed monitoring schedule.

In addition to calculating the above indicator, we also calculated the most recent year of high potential exposure for descriptive purposes. This information allows users to ascertain how recent the high potential exposure event was. This information is included in the on-line data tool that accompanies the written report. See Box 2 (below) for a more detailed discussion of the significance of including the most recent high potential exposure.

Scoring Approach

To score this indicator we assessed the distribution of the data, determined significant break points in the data, and assigned water systems the following scores:

- 0, if the system had 0 contaminants with high potential exposure
- 1, if the system had 1 contaminant with high potential exposure.
- 2, if the system had 2 contaminants with high potential exposure.
- 3, if the system had 3 contaminants with high potential exposure.
- 4, if the system had 4 or more contaminants with high potential exposure.

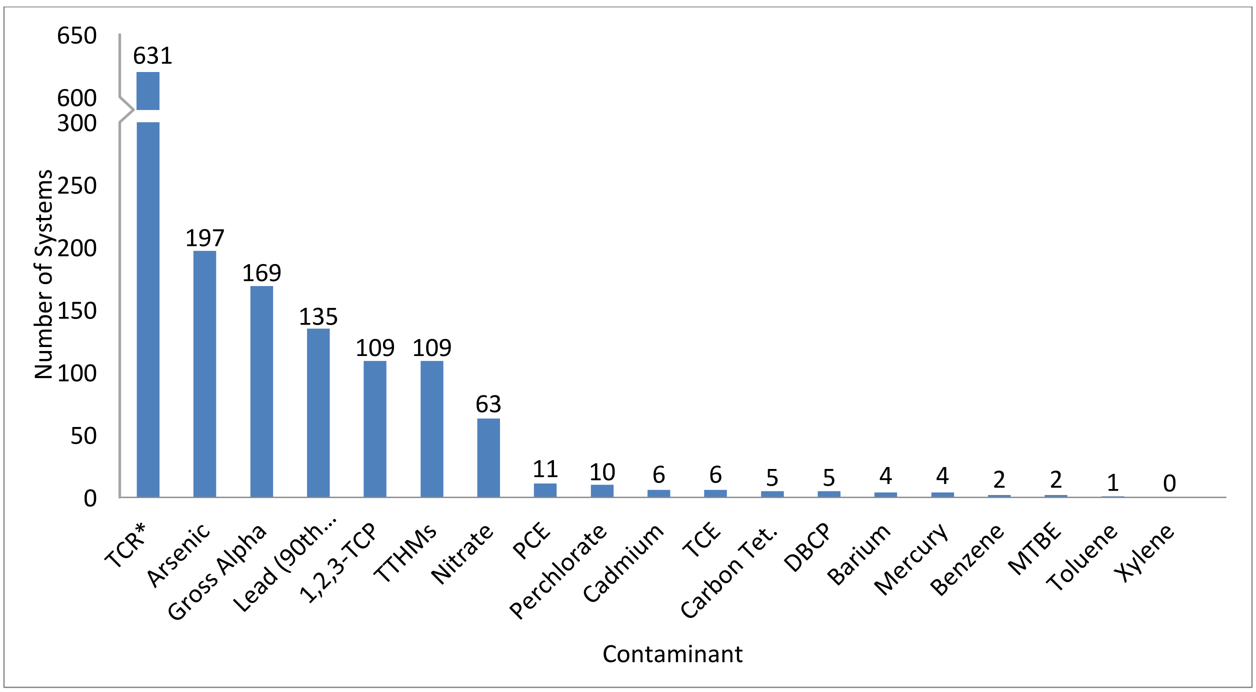
Results

All 2,839 community water systems evaluated had some form of water quality information available for at least one contaminant. As shown in Table 2, most water systems (~59%) did not have any contaminants with high potential exposure. For the majority of those that did, it was due to one contaminant (~32%). As illustrated in Figure 5, the most common high exposure contaminant was Total Coliform, followed by arsenic and gross alpha. Figure 6 plots the scores for each community water system across the state.

Table 2. Water Quality Indicator 1: High Potential Exposure. Number of systems with contaminants whose annual average concentration was greater than the MCL at least once during the nine-year period 2011-19, with associated indicator score.

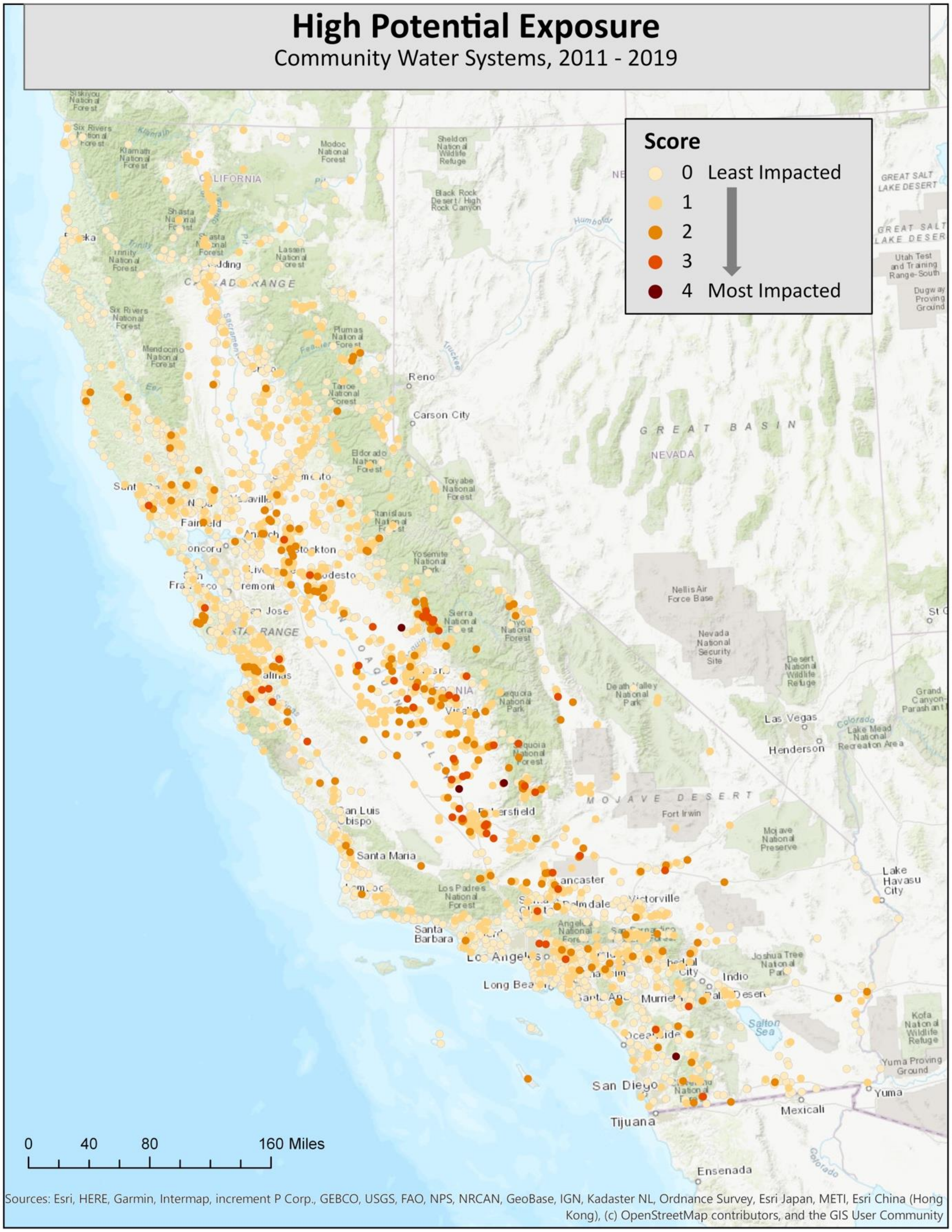
Number of Contaminants	Indicator Score	Number of Systems	Percent
0	0	1,687	59.4
1	1	900	31.7
2	2	192	6.8
3	3	56	2.0
4 to 5	4	4	0.1
Total		2,839	100

Figure 5. Number of Systems with High Potential Exposure. (Annual average concentration exceeds MCL at least once in nine-year period, 2011-19)[†]. N=2,839. Maximum contaminant level (MCL) or relevant threshold used*.



** MCL for all contaminants used, except for lead, in which the Action Level is used. For lead, Lead and Copper Rule monitoring data for samples at the 90th percentile is used to estimate average exposure. For Total Coliform, MCL violation of the Total Coliform and Revised Total Coliform Rule is used as a proxy measure of exposure to total coliform and E.coli.*

Figure 6. Water Quality Indicator 1. High Potential Exposure. Lower scores represent a better outcome for this indicator; higher scores represent poorer outcomes. For a definition of score values, please consult Table 2.



Water Quality Indicator 2: Maximum Duration of High Potential Exposure

This indicator measures the duration of high potential exposure for each of the 19 selected contaminants by summing the number of years for which each contaminant had high potential exposure (from 2011 to 2019). The indicator score is based on the maximum duration of high potential exposure across all contaminants during the nine-year study period (2011-2019). In contrast to Indicator 1, which captures how many systems have had *any* high-contaminant concentrations, this indicator focuses on the recurring nature of contamination. Accordingly, it highlights systems that show an ongoing contamination problem. Capturing this recurring exposure is important, especially when such exposure involves contaminants whose health effects are associated with chronic exposure. A long duration of high potential exposure can also signal that a system may need additional resources or support to remedy contamination.

Method

To create this indicator we:

- Used the estimated average annual concentration for each contaminant (except for Total Coliform/E.coli).
- Summed the number of years (from 2011 through 2019) for which any contaminant's annual average concentrations was greater than the MCL (or Action Level for lead) for each contaminant, and summed the total years of TCR/RTCR MCL violations.
- Selected the maximum duration of high potential exposure across the 19 contaminants.

Scoring Approach

For this indicator we assigned water systems the following scores:

- 0, if the system had 0 years of high potential exposure.
- 1, if the system had 1 year of high potential exposure.
- 2, if the system had 2-3 years of high potential exposure.
- 3, if the system had 4-5 years of high potential exposure.
- 4, if the system had 6 or more years of high potential exposure.

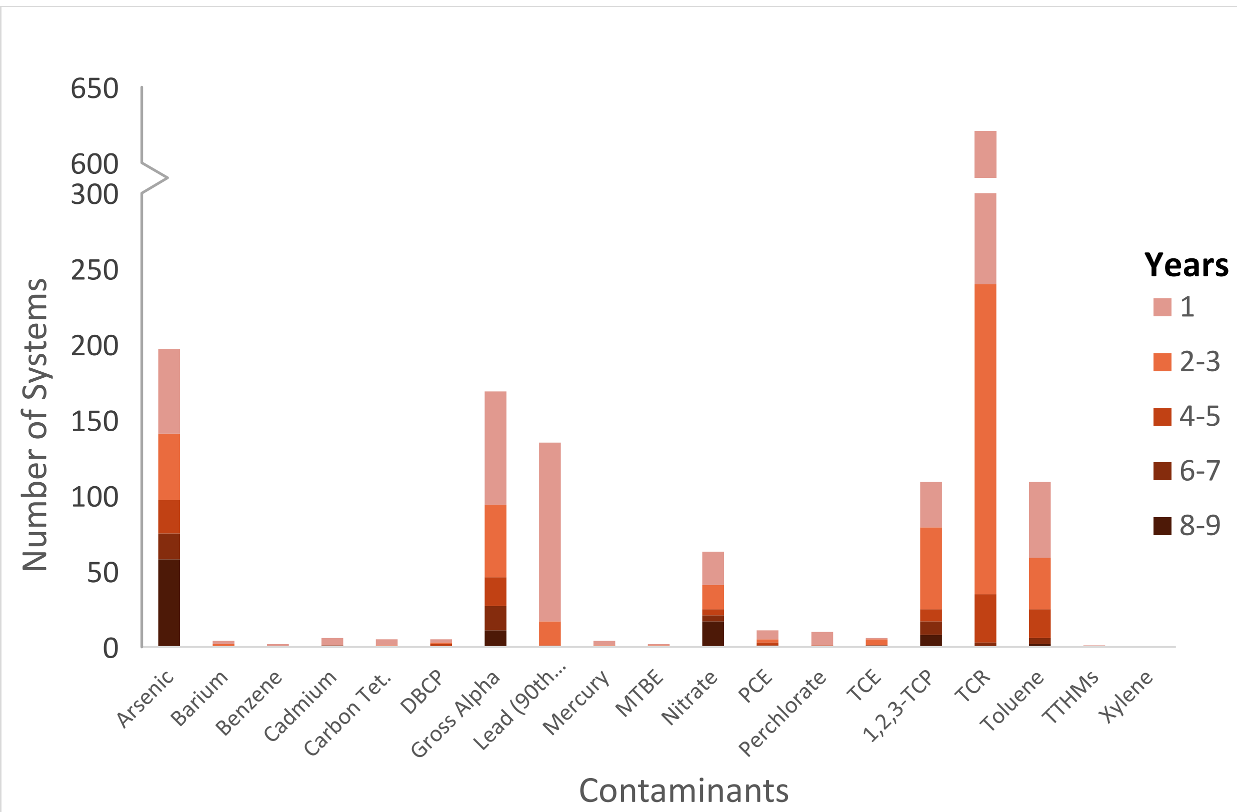
Results

As shown in Table 3, most water systems had zero years or one year of high potential exposure. However, roughly 21 percent of systems had multiple years of high exposure. Figure 7 shows that this was mostly for ongoing arsenic contamination. Also shown in Figure 7, arsenic had the largest number of systems (n=55) with the longest duration of high exposure (8 to 9 years). Only one contaminant—xylene—had no systems with high potential exposure. The map below shows the scores for each community water system across the state (Figure 8).

Table 3. Water Quality Indicator 2: Maximum Duration of High Potential Exposure. Indicator score is applied to systems based on maximum years of high potential exposure across all contaminants, 2011-2019.

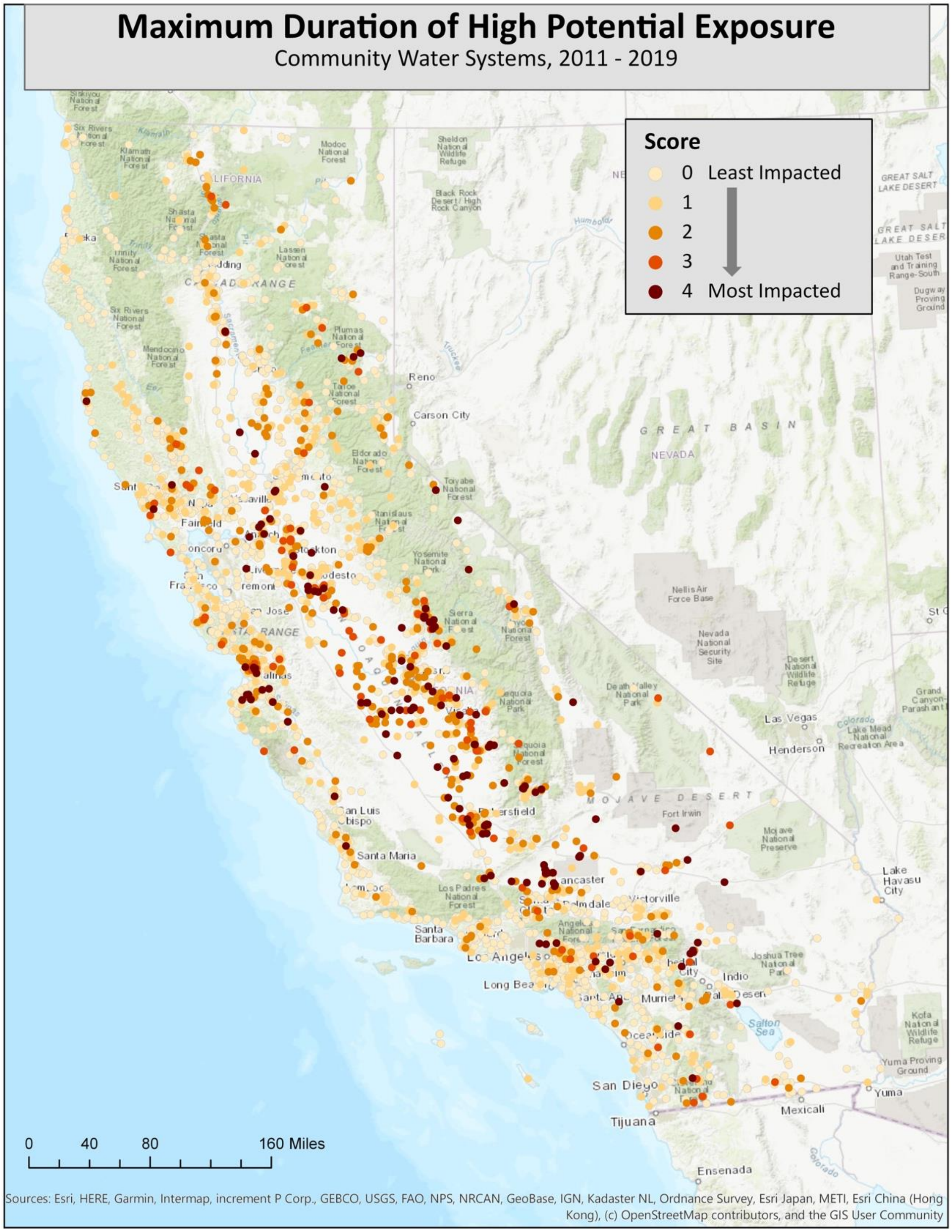
Maximum Duration of High Potential Exposure (Years)	Indicator Score	Number of Systems	Percent
0	0	1,687	59.4
1	1	555	19.6
2 to 3	2	353	12.4
4 to 5	3	98	3.5
6+	4	146	5.1
	Total	2,839	100

Figure 7. Duration of High Potential Exposure, by Contaminant. Maximum contaminant or action level (for lead) used*,† N= 2,839 community water systems.



** Duration of high exposure refers to how many years a given system had an annual average contaminant concentration exceed that contaminants' MCL (or Action Level for lead).*
† The possible range of years of duration for each contaminant is 0 to 9. Inclusion of Total Coliform/E.Coli is based on systems that received at least one TCR/RTCR MCL violation in a given year.

Figure 8. Water Quality Indicator 2: Maximum Duration of High Potential Exposure. Lower scores represent a better outcome for this indicator; higher scores represent poorer outcomes. For a definition of score values, please consult Table 4.



Water Quality Indicator 3: Data Availability

Water quality monitoring is essential to ensure compliance with drinking water standards, and to ensure that water systems and their customers have adequate information. Access to information on water quality is part of the right to water (UN CESCR, 2002, Article 37). Indicator 3 measures how much data is available to evaluate water quality in current water sampling databases (Title 22, California Code of Regulations. Section 60098).[20] It is used to characterize the adequacy of information with respect to a system's water quality. Monitoring and reporting violations are not used to calculate this indicator, instead the presence of water quality monitoring data in the Water Quality Monitoring database is used as a direct measure on whether data is available to assess water quality.

This indicator evaluates the extent of system water quality sampling data for 14 contaminants for which a system must have conducted water quality monitoring. According to US EPA's Standardized Monitoring Framework (US EPA, 2004), the following 11 contaminants should be sampled at least once every nine years: arsenic, barium, cadmium, mercury, benzene, MTBE, carbon tetrachloride, toluene, TCE, PCE, and xylene.[21] Two contaminants—lead and perchlorate—should be sampled at least three times every nine years.[22] Nitrate and Total coliform must be sampled in each of the study period's nine years. Because monitoring results for total coliform are not included in state water quality monitoring databases, total coliform is not included in this indicator.

Method

To create this indicator we:

- Assigned each of the 14 contaminants noted above a value of one or zero, depending on whether the water system had at least the minimum number of samples required. For each contaminant, a 1 means the water system had the minimum number of samples, while a value of 0 means the water system did not have the minimum number of samples.
- Summed the count of this binary value across all fourteen contaminants.

[20] Note that this indicator is different from Monitoring and Reporting violations which capture instances of a water system not adhering to monitoring and reporting requirements (Title 22, California Code of Regulations. Section 60098).

[21] Gross alpha also meets this requirement but is not included.

[22] According to monitoring regulations, sampling for these contaminants must actually occur once in each compliance period. However, for the purposes of this report (and based on guidance we received from the State Water Board), sampling results occurring during any three years of the entire time period of 2011 to 2019 are considered sufficient.

Scoring Approach

To score this indicator, we assessed the distribution of the data and applied a qualitative assessment of what level of data availability was of lesser or greater concern. The final scores were assigned as follows:

- 0, if the system had all 14 contaminants with the minimum required data in the time period.
- 1, if the system had 12 or 13 contaminants with the minimum required data in the time period.
- 2, if the system had 8 to 11 contaminants with the minimum required data in the time period.
- 3, if the system had 1 to 7 contaminants with the minimum required data in the time period.
- 4, if the system had zero contaminants with the minimum required data in the time period.

Results

Table 4 shows that nearly 50% of systems did not have the minimum data required for the 14 contaminants.

Table 4. Water Quality Indicator 3: Data Availability for 14 Contaminants. Indicator scores are shown.†

Number of Contaminants with Required Data	Indicator Score	Number of Systems	Percent
14	0	1,424	50.2
12 to 13	1	1,093	38.5
8 to 11	2	178	6.3
1 to 7	3	116	4.1
0	4	28	1.0
	Total	2,839	100

† Number of systems with contaminants that had available data in the 9-year time period. Rounded values may not sum perfectly to 100%.

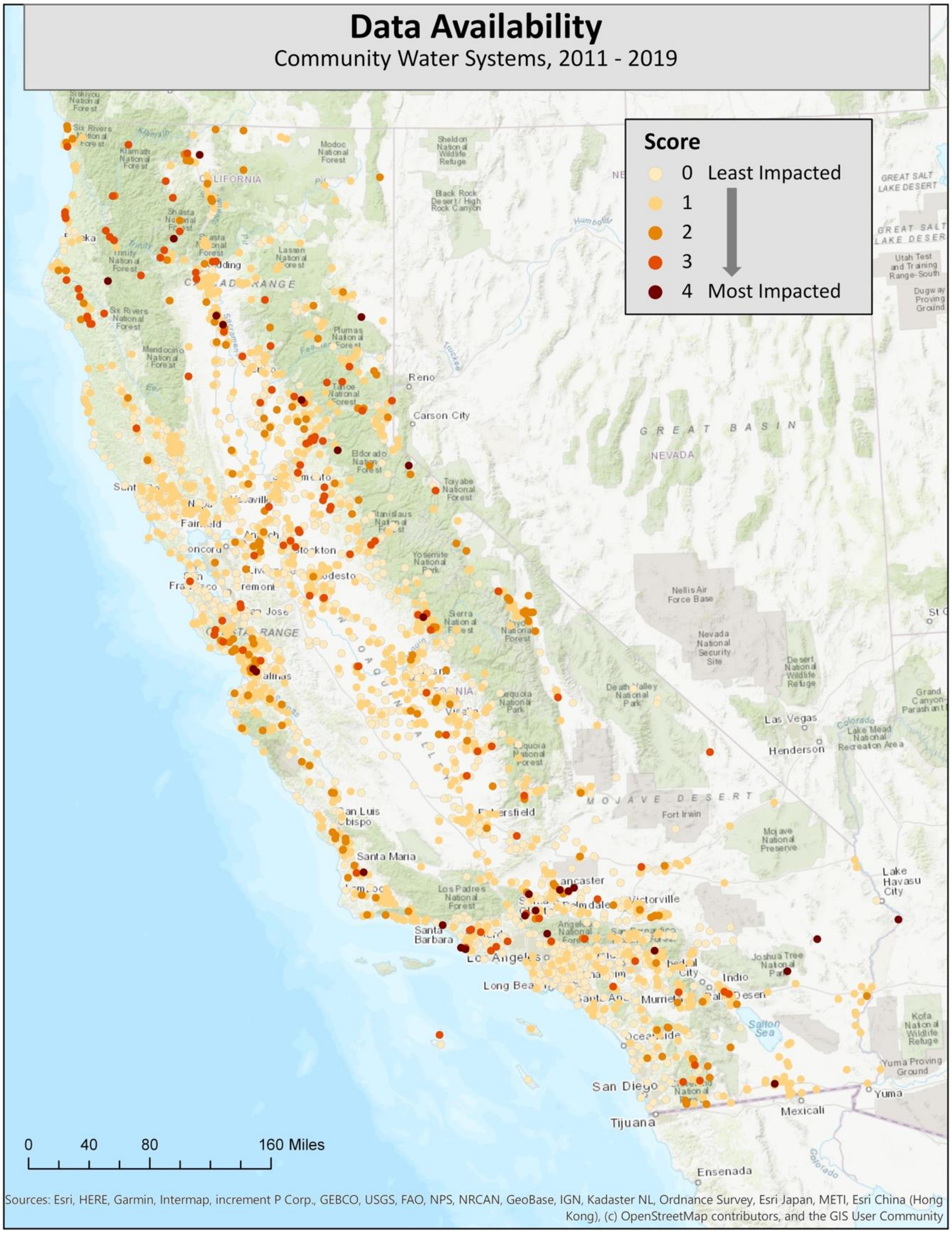
Nearly half of all systems (n=1,415) did not have the minimum data requirements for all 14 contaminants. Table 5 lists, by contaminant, the number of systems that did not have the minimum required data. Across contaminants, the fraction of systems without this data ranged from 1.1% to 4.9%.[23] The locations of systems with missing data were dispersed throughout the state, as shown in Figure 9.

Table 5. Number of Systems without Required Water Quality Data by Contaminant, as per minimum sampling requirements.

Contaminant	Number of systems without required data	Percent of Total (N=2,839)
Arsenic	82	2.9%
Barium	97	3.4%
Benzene	140	4.9%
Cadmium	96	3.4%
Carbon Tetrachloride	140	4.9%
Lead	31	1.1%
Mercury	96	3.4%
MTBE	133	4.7%
Nitrate	54	1.9%
PCE	139	4.9%
Perchlorate	91	3.2%
TCE	139	4.9%
Toluene	138	4.9%
Xylene	139	4.9%

[23] This does not necessarily mean this number of systems had no data, just that they did not meet the minimum sampling requirements in accordance with the US EPA monitoring framework described above.

Figure 9. Water Quality Indicator 3: Data Availability. Lower scores represent a better outcome for this indicator; higher scores represent poorer outcomes. For a definition of score values, please consult Table 4.



Non-Compliance Subcomponent

Approach

The non-compliance indicators capture regulatory non-compliance with drinking water standards that can be associated with occasional (or ongoing) increases in contaminant concentrations *at the source or distribution level*.[24] Here, we consider an instance of non-compliance to be based on whether an MCL violation has occurred and is reported for 18 of the 19 primary drinking water contaminants listed in Table 1. The one contaminant not included is lead. Lead is not included because there is no MCL for lead, only an Action Level.

Data Source

Safe Drinking Water Information System (SDWIS) from the State Water Board, 2011-2019. Available at URL:

http://www.swrcb.ca.gov/drinking_water/certlic/drinkingwater/documents/dwdocuments/

Indicators

Water Quality Indicator 4: Non-Compliance with Primary Drinking Water Standards

This non-compliance indicator evaluates the number of contaminants that have been in non-compliance with the MCL during the study period for 18 of the 19 contaminants of interest (see Table 1).

Method

To calculate this indicator, we:

- Counted the total number of contaminants that had at least one MCL violation during the study period.

Scoring Approach

To score this indicator we assessed the distribution of the data and assigned water systems the following scores:

- 0, if the system had 0 contaminants with MCL violations.

[24] Here, the term source refers to a facility that contributes water to a water distribution system, such as one associated with a well, surface water intake, or spring. Distribution level refers to sample sites within the distribution system where compliance is determined for specific contaminants (e.g., Total Coliform, Lead and Copper Rule).

- 1, if the system had 1 contaminant with at least one MCL violation.
- 2, if the system had 2 contaminants with at least one MCL violation.
- 3, if the system had 3 contaminants with at least one MCL violation.
- 4, if the system had 4 contaminants with at least one MCL violation.

Results

As shown in Table 6, two-thirds of systems had no MCL violations in the entire nine-year period. Approximately 27% of systems had one contaminant with at least one MCL violation in the study period. Slightly greater than 5% had two or more contaminants with at least one MCL violation. The most prevalent types of violations were for Total coliform/E.coli, arsenic, TTHMs and nitrate, as shown in Table 7.

Table 6. Water Quality Indicator 4: Number of Contaminants That Had at Least One MCL Violation† and Associated Indicator Scores.

Number of Contaminants with at Least One MCL Violation	Indicator Score	Number of Systems	Percent
0	0	1,926	67.8
1	1	760	26.8
2	2	128	4.5
3	3	23	0.8
4	4	2	0.1
Total		2903	100

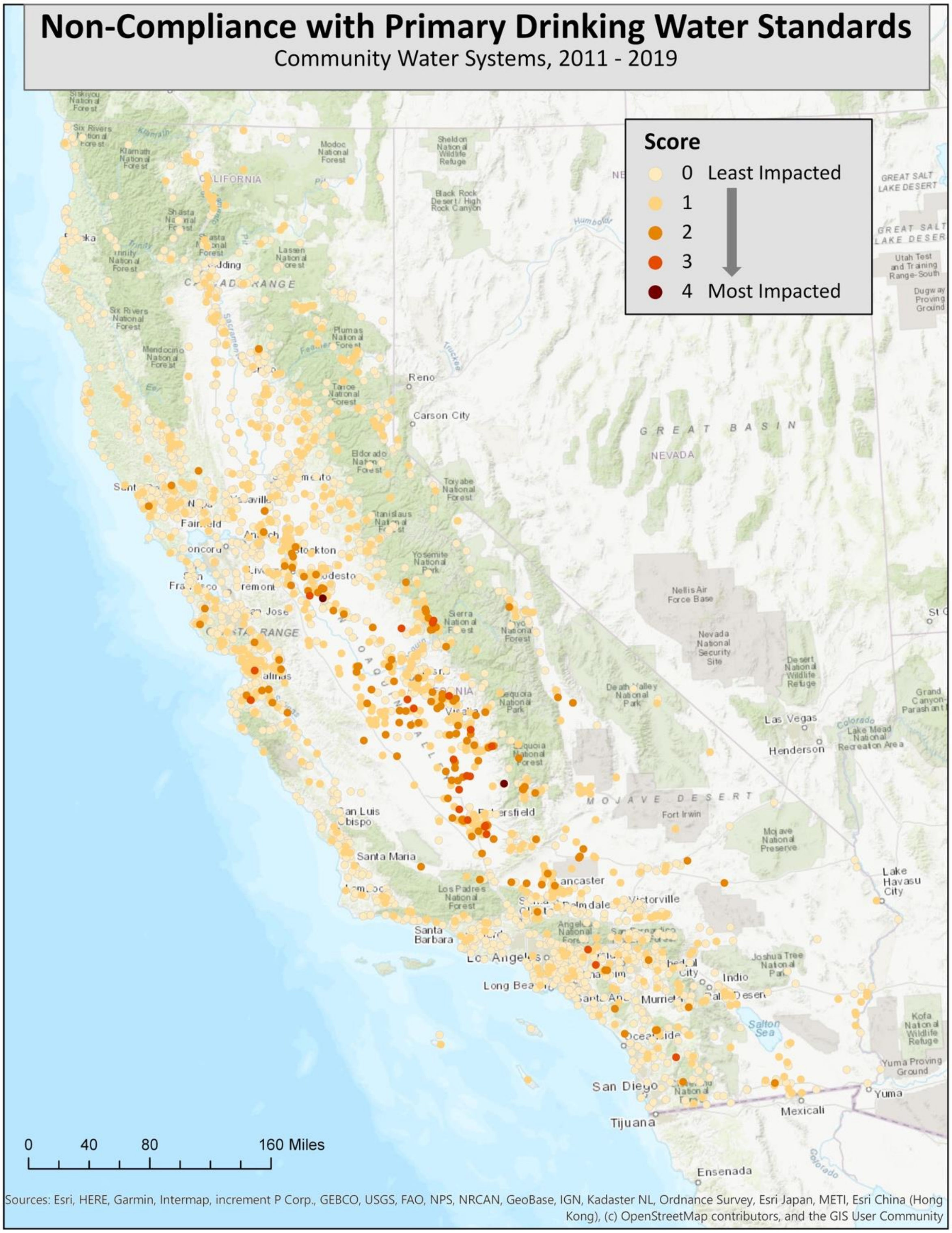
† Lead is not included.

Table 7. Number of Systems with at Least One Recorded MCL Violation, 2011-2019 (n=2,839).

Contaminant	Number of Systems with at Least One MCL Violation
Arsenic	158
Barium	0
Benzene	0
Cadmium	1
Carbon Tetrachloride	0
DBCP	3
Gross Alpha	12
Mercury	0
MTBE	0
Nitrate	91
PCE	0
Perchlorate	6
TCE	2
1,2,3-TCP	76
Toluene	0
Total Coliform	631
TTHMs	113
Xylene	0

While this indicator and Water Quality Indicator 1 (High Potential Exposure) seem similar, the two measures are based on distinct approaches. This indicator addresses violations, which are assessed at the *source* level. For Water Quality Indicator 1, exposure is measured at the *system* level and can indicate different outcomes. For example, while 197 systems had high potential exposure for arsenic at least once in the study period, only 158 systems received an arsenic MCL violation during this time period. This could potentially signal systems that have potential exposure challenges, despite being in compliance with regulatory standards. Or it could signal failure to issue or record an MCL violation. The map below shows the scores for this indicator for each community water system across the state (Figure 10).

Figure 10. Water Quality Indicator 4: Non-Compliance with Primary Drinking Water Standards. Lower scores represent a better outcome for this indicator; higher scores represent poorer outcomes. For a definition of score values, please consult Table 6.



Water Quality Indicator 5: Maximum Duration of Non-Compliance

This indicator assesses the maximum duration of non-compliance across 18 of the 19 contaminants. To do so, for each system, the indicator sums the number of years (from 2011 through 2019) in which a given contaminant has been cited for at least one MCL violation.[25] Importantly, the total number of violations *per year* is not counted, to control for various types of differences in monitoring and reporting across systems. Thus if one system experienced four nitrate violations in a given year, and another experienced only one, both systems would be considered to have had "at least one" nitrate MCL violation in that given year. The indicator then selects the contaminant with the maximum duration of non-compliance for each system.

Method

To create this indicator we:

- Determined whether a system had at least one MCL violation in a given year (excluding lead).
- For each contaminant, summed the number of years with at least one MCL violation.
- Selected the contaminant with the maximum duration of non-compliance across all contaminants, and recorded the duration as the "maximum duration of non-compliance".

Besides water quality itself, the total number of years for which a system has MCL violations may vary for several reasons, including varying monitoring schedules, waivers on monitoring, and reporting bias (e.g., a MCL violation was not issued, recorded or reported, but should have been). Thus while this measure is meant to capture total duration of non-compliance for any given contaminant, some potential for measurement error exists.

Scoring Approach

To score this indicator we assessed the distribution of the data and assigned water systems the following scores:

- 0, if the system had zero years of non-compliance.
- 1, if the maximum duration of non-compliance for a system was 1 year.
- 2, if the maximum duration of non-compliance for a system was 2-3 years of non-compliance.
- 3, if the maximum duration of non-compliance for a system was 4-5 years.

[25] It is important to note that this indicator considers duration in terms of how many years had at least one recorded MCL violation. This is separate from any regulatory determinations of compliance, which are most often based on the running annual average for a given contaminant, and consider compliance during an annual timeframe.

- 4, if the maximum duration of non-compliance for a system was 6 or more years.

Results

Table 8 and Figure 11 provide the number of systems and their maximum duration of non-compliance. Nearly 68% of systems were in compliance with MCLs the entire time period. Nearly 17% of systems had two or more years of non-compliance for any given contaminant, with 124 systems having six or more years of non-compliance.

Table 8. Water Quality Indicator 5: Maximum Duration of MCL Violation. Maximum number of years in which a system had at least one MCL violation is indicated, with associated indicator score.†

Maximum Duration of Non-Compliance (Years)	Indicator Score	Number of Systems	Percent
0	0	1,926	67.8
1	1	438	15.4
2 to 3	2	266	9.4
4 to 5	3	85	3.0
6+	4	124	4.4
Total	0	2,839	100

† Lead is not included.

Figure 12 shows the total number years of non-compliance by contaminant. While Total Coliform/E.coli had the most number of systems with duration of non-compliance greater than 1 year, arsenic is the contaminant for which the most number of systems had the longest duration of non-compliance. The map below shows the scores for each community water system across the state (Figure 13).

Figure 11. Number of Systems by Maximum Years of Non-Compliance, 2011-2019.
N=2,839 community water systems.

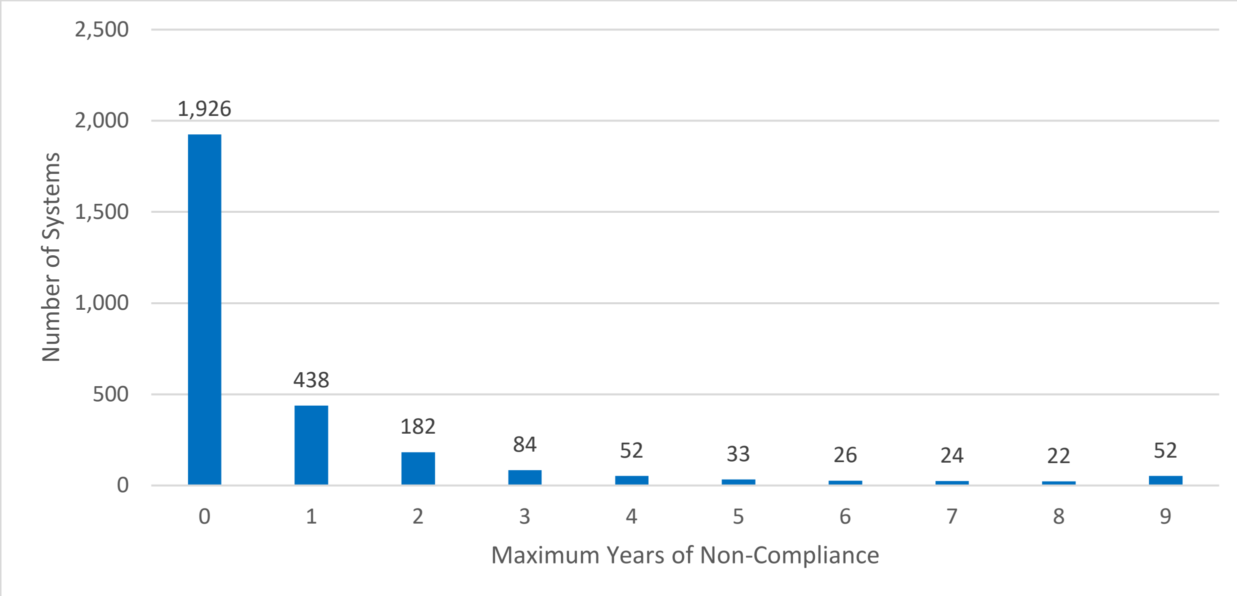


Figure 12. Number of Years, by Contaminant, for which Systems Had at Least One Annual MCL Violation. N=2,839 community water systems.

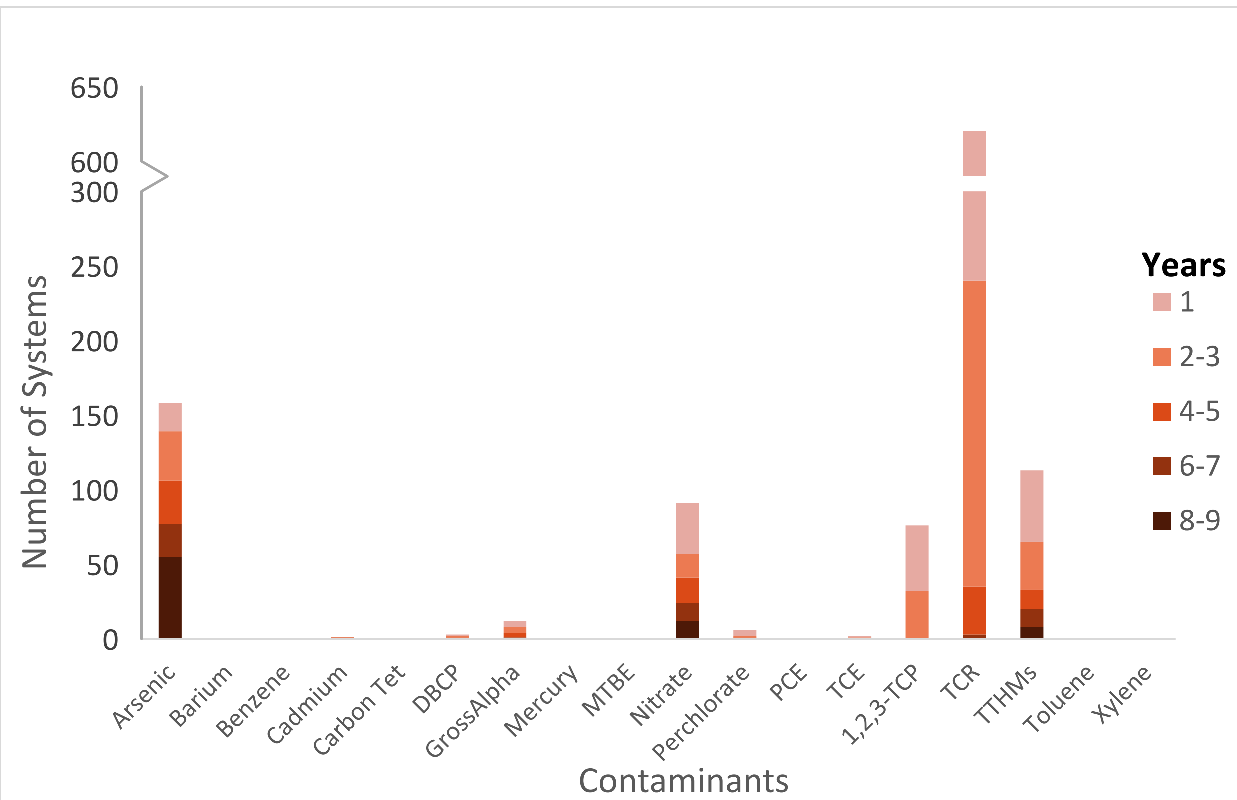
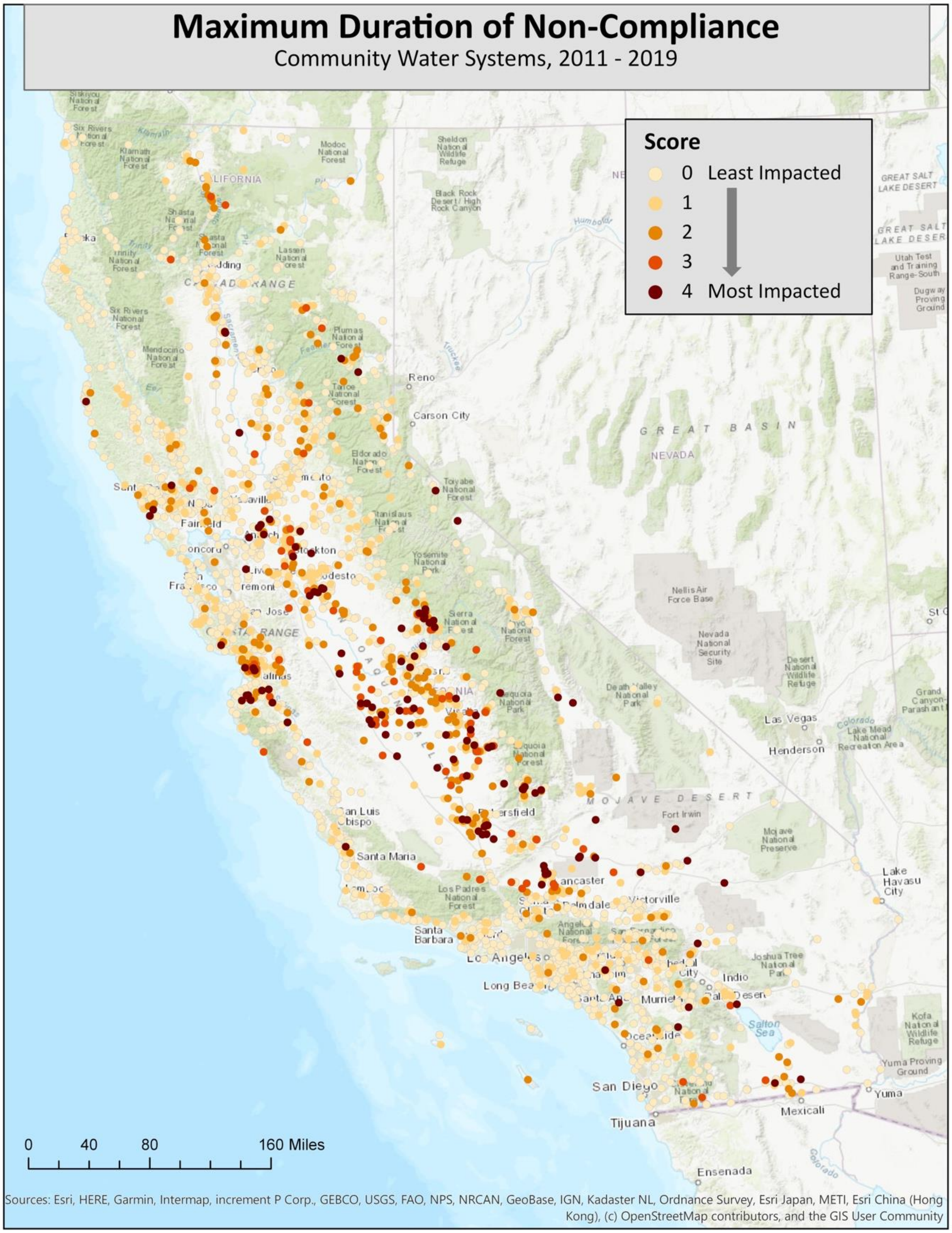


Figure 13. Water Quality Indicator 5: Maximum Duration of Non-Compliance. Lower scores represent a better outcome for this indicator; higher scores represent poorer outcomes. For a definition of score values, please consult Table 8.



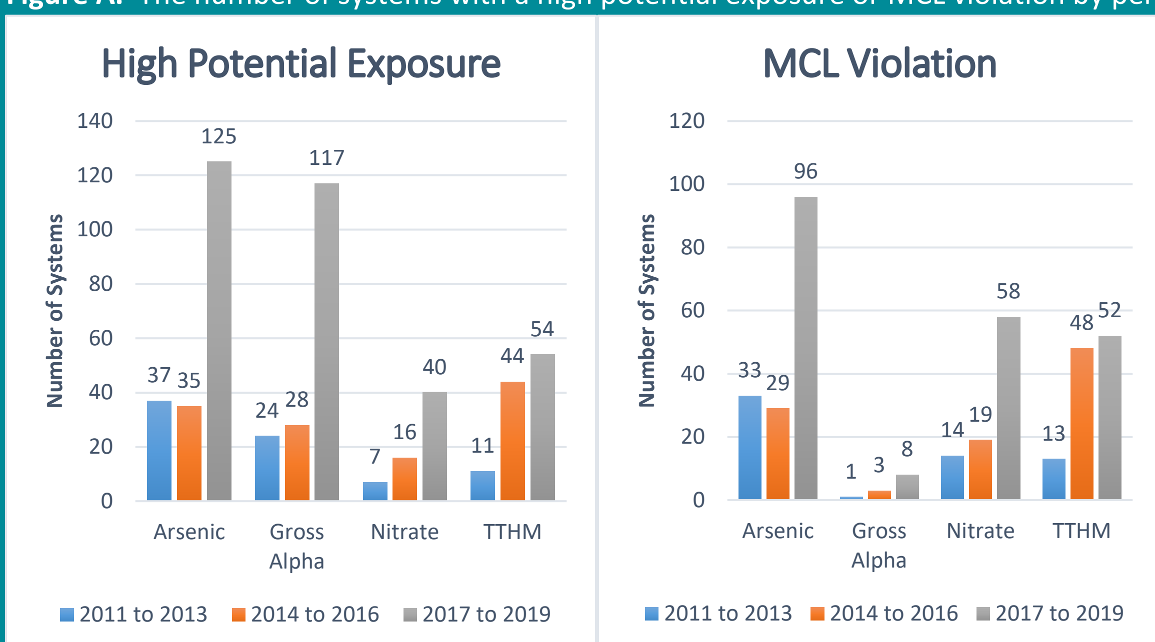
Box 2: Time Since Exceedance

The water quality indicators presented in this chapter highlight results for systems with high potential exposure and non-compliance with MCL standards over a 9-year compliance cycle (2011-2019). This compliance cycle is comprised of three distinct compliance periods: 2011-2013; 2014-2016; and 2017-2019. Measuring water quality indicators over a complete compliance cycle is important for two reasons. First, because different systems monitor for contaminants on different schedules, showing results for only the most recent year or compliance period could yield unrepresentative results. Second, the longer time period allows for an assessment of the duration of exposure or compliance problems for those systems with recurring problems.

Nonetheless, it is still helpful to understand when the most recent high potential exposure or non-compliance event was. Accordingly, OEHHA's Human Right to Water web tool includes information on the most recent compliance period during which a system had a high potential exposure or non-compliance event.

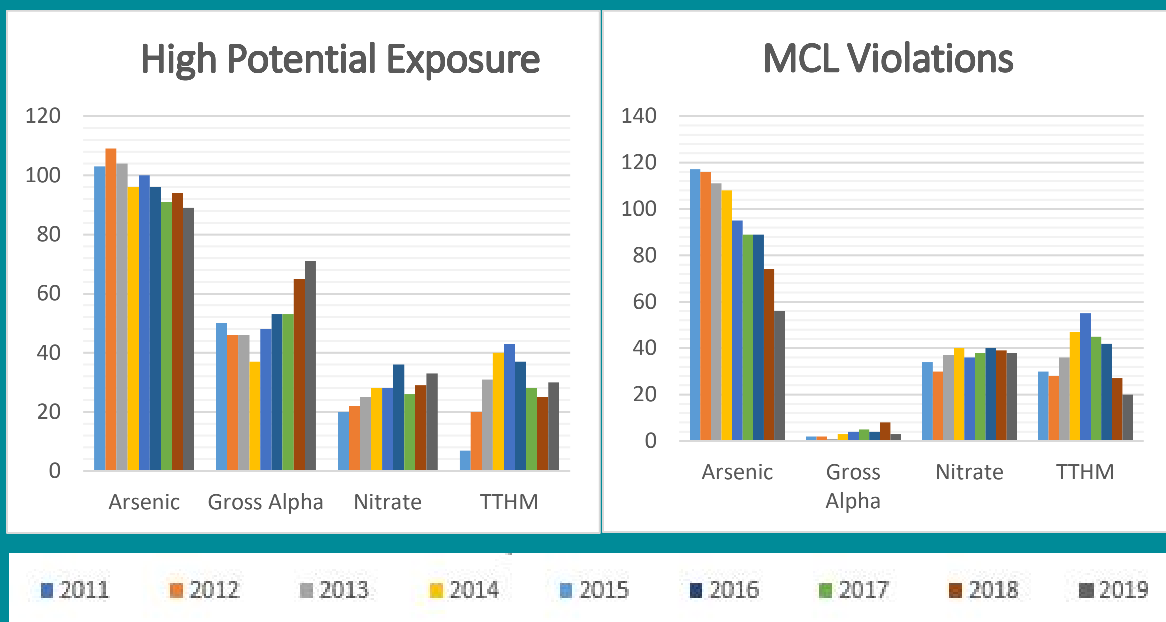
As an example, Figure A below summarizes the most recent compliance period for which systems had either a high potential exposure event or an MCL violation for a select number of contaminants. Among the contaminants shown, it is clear that the largest number of systems experienced their most recent high potential exposure event in the 2017-2019 time period. However, a significant number of systems had their most recent high potential exposure event in earlier compliance periods; the impact in these systems would not be captured were we only to show systems that had a high potential exposure or MCL event prior to 2017-2019.

Figure A. The number of systems with a high potential exposure or MCL violation by period.



Of course, how recent a high potential exposure or non-compliance event occurred does not capture trends over time, or high exposure events that occurred earlier in the compliance cycles. As shown in the figure B below, the number of systems with high potential exposure for arsenic has decreased over time, but for nitrate, TCP, TTHMs and Gross Alpha the trends suggests an increase over time. The use of data from the full 9-year compliance cycle makes it possible to view these long-term trends, and in particular to detect trends where levels of contaminants are increasing.

Figure B. The number of systems with a high potential exposure or MCL violation by year.



A Composite View of Water Quality

Individual water quality indicators help highlight specific water quality problems. However, combining individual indicator scores to create a composite water quality score can highlight the performance of systems across several or all indicators, and which systems have the greatest cumulative water challenges. Figure 14 illustrates how individual indicator scores can be combined to yield a composite water-quality component score.

Scoring Approach

To create a composite component score, a series of steps weighting indicators and combining sub-component scores was taken. In particular, the exposure and compliance subcomponents were treated equally, contributing equal weight to the final component score. Within each sub-component, after each indicator was calculated and scored, a weighted average was calculated applying weights to different indicators to adjust for various factors. The following steps outline the specific weights assigned, and the final equation used to calculate the component score.

- For the maximum duration of exposure (Indicator 2) and duration of MCL non-compliance (Indicator 5), a weight of 2 was applied, to address the importance of a system having long duration periods of high potential exposure or non-compliance.
- Data availability (Indicator 3) was weighted by 0.25. This weight was selected to give some additional weight to systems that lacked data, without conferring the same weight to systems with known problems.
- By definition the other indicators were given a weight of 1.
- Using indicator weights, a weighted average was calculated to determine the final sub-component scores.
- Then, the two sub-component scores were averaged, giving each sub-component equal weight. Ultimately, lower scores reflect better outcomes, and higher scores reflect worse outcomes.

This results in an equation (illustrated in Figure 14):

Composite Water Quality =

(½ × Exposure Subcomponent Score) + (½ × Non-Compliance Subcomponent Score)

where:

Exposure Subcomponent Score =

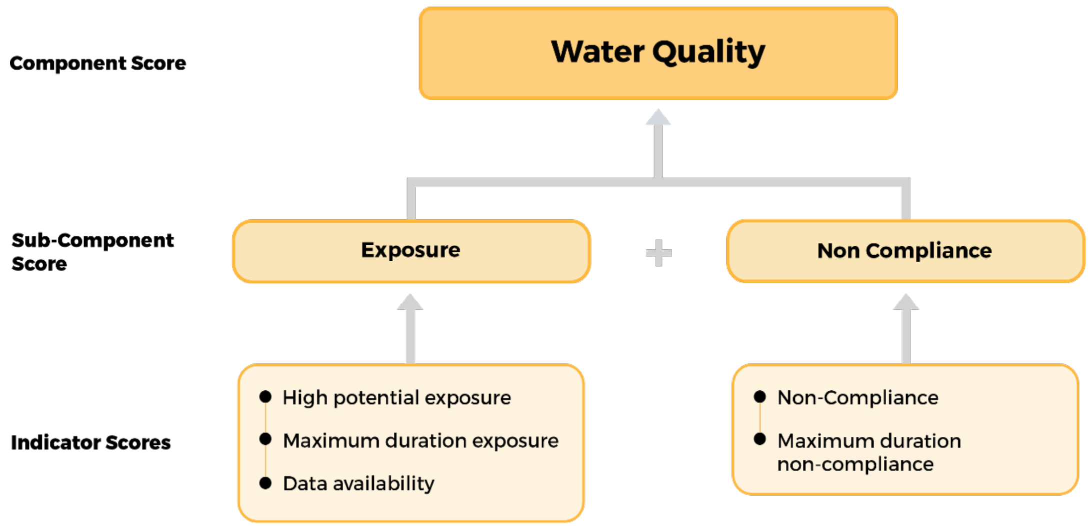
(High Potential Exposure + (2 × Maximum Duration High Potential Exposure) + (¼ × Data Availability Score)) ÷ 3.25

and,

Non-Compliance Subcomponent Score =

(Non-Compliance Score + (2 × Maximum Duration Non-Compliance Score)) ÷ 3

Figure 14. Creation of Composite Water Quality Score.



Results

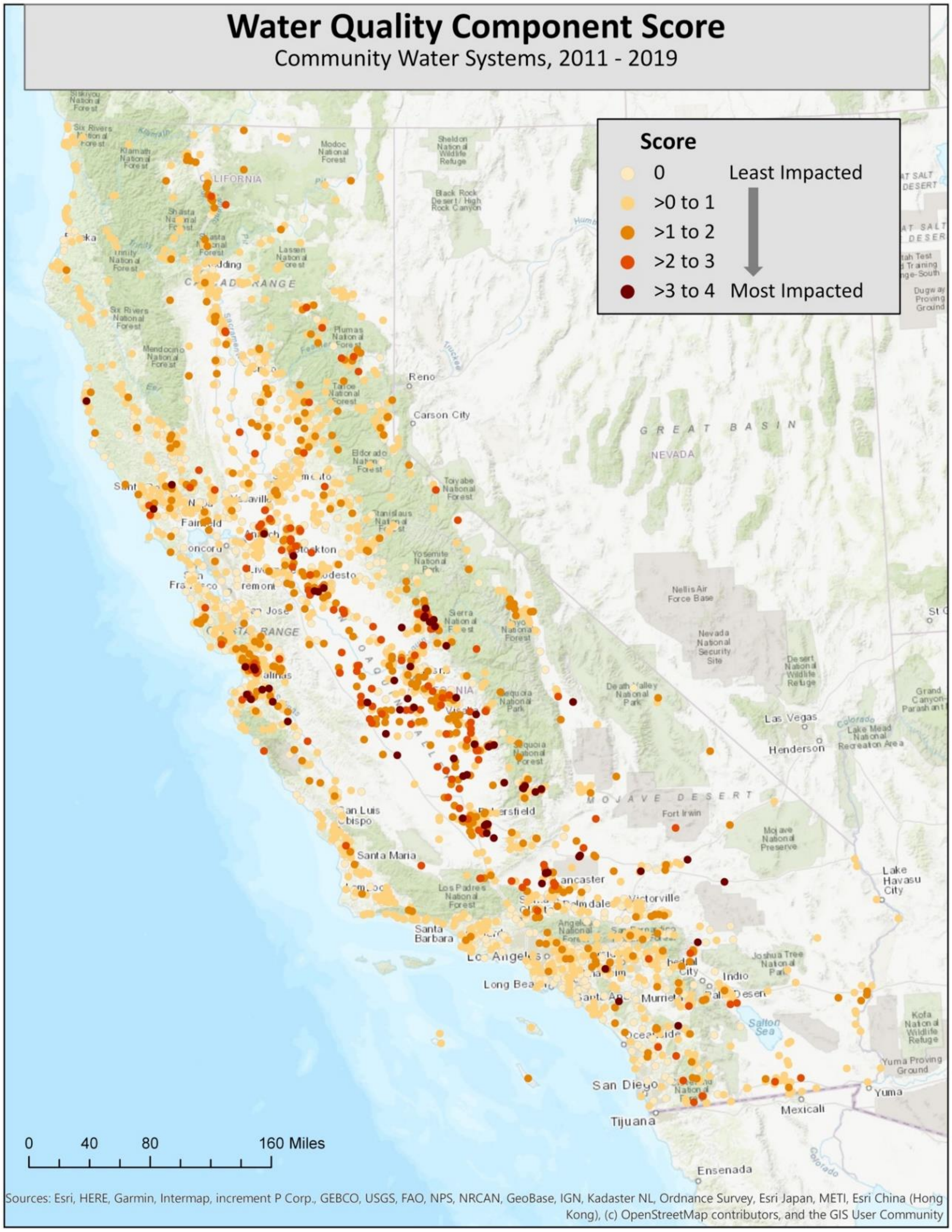
Table 9. Composite Water Quality Scores alongside sub-component scores. shows the 2,839 systems that received a composite water quality score and the number of systems receiving each exposure and non-compliance sub-component score. The exposure sub-component score ranged from 0 to 4. The non-compliance subcomponent score ranged from 0 to 3.8. The final composite scores are highlighted in Table 9.

For this final composite water quality score, approximately 29 percent of systems had a composite score of 0, indicating no water quality problems across all indicators. Roughly 8 percent of systems had scores greater than 3, indicating poor outcomes across multiple water quality indicators. Figure 15 shows the composite water quality score across the state, with higher scores concentrated in the San Joaquin Valley and the northern portion of the Central Coast (regions defined in Figure 16).

Table 9. Composite Water Quality Scores alongside sub-component scores.

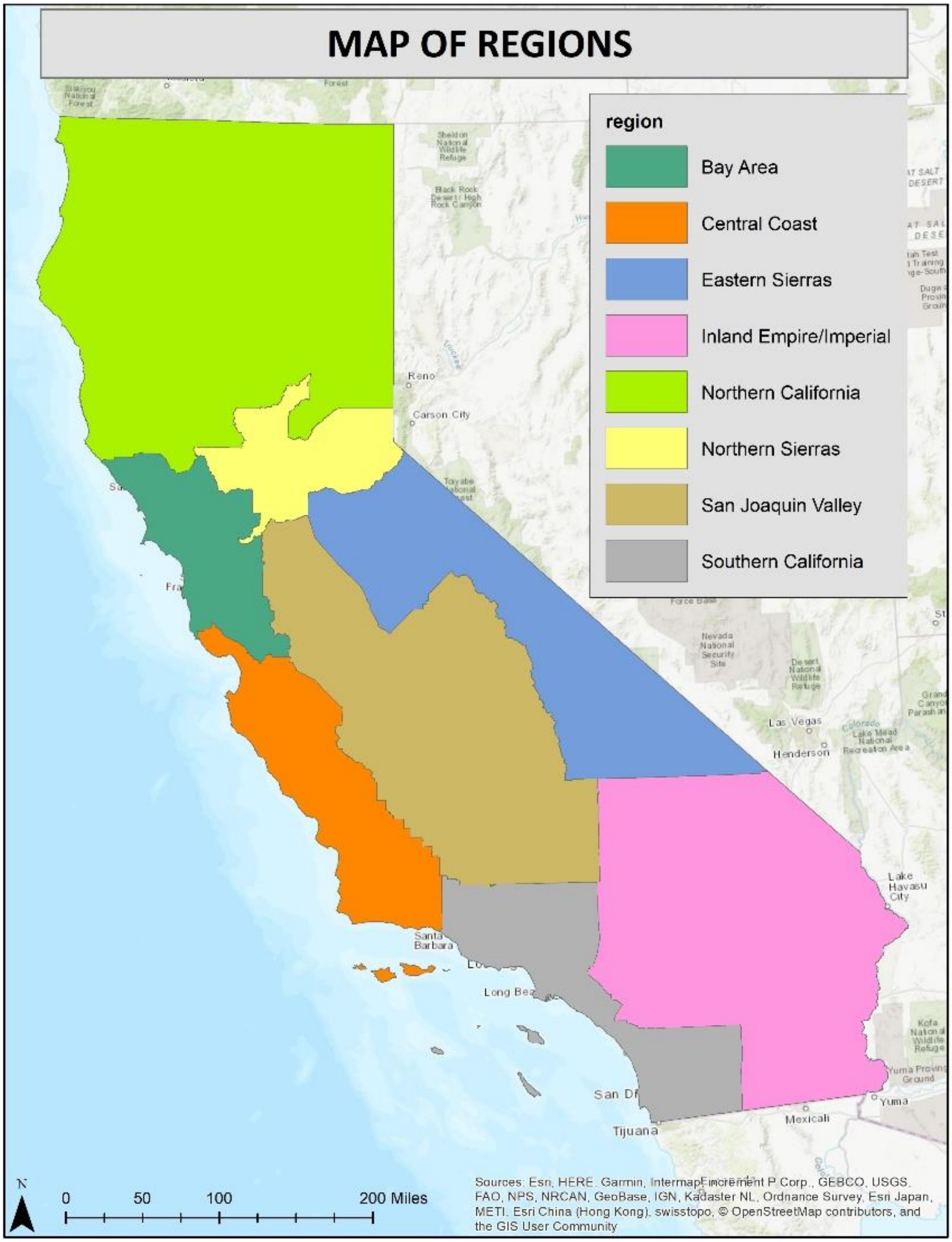
Composite Water Quality Score	Composite Water Quality, Number of Systems (%)	Exposure Subcomponent, Number of Systems (%)	Non-Compliance Subcomponent, Number of Systems (%)
0	829 (29%)	872 (31%)	1926 (68%)
>0-1	1373 (45%)	1270 (45%)	415 (15%)
>1-2	419 (18%)	429 (15%)	286 (10%)
>2-3	150 (5%)	182 (6%)	153 (5%)
>3-4	68 (3%)	86 (3%)	59 (2%)
Total	2839	2839	2839

Figure 15. Map of Composite Water Quality Score (for 2,839 community water systems).+ Lower scores represent a better outcome for the composite score; higher scores represent poorer outcomes.



+ For specific water quality results, system-level data should be consulted.

Figure 16. Map of Statewide Regions.



Key Findings for Water Quality

- 29% of the 2,839 systems (n=829) evaluated had a perfect water quality score (score=0); nearly 45% had scores between 0 and 1, indicating relatively good overall water quality in these systems.
- 26% of systems (n=637) received composite scores greater than 1. These systems face some of the biggest water quality challenges, with 8% of (n= 218) systems receiving scores greater than 2.
- Among the 68 systems with the highest scores, very small systems (i.e. <200 connections) were over-represented. And, on average, very small systems had higher water quality scores.
- Smaller systems had a greater tendency than larger systems to have less data availability and longer duration of MCL violations.
- Regional trends highlight that some of the highest (i.e. worse) composite water quality scores occur in the San Joaquin Valley, the Central Coast and the Inland Empire/Imperial regions (see Map in Figure 16).
- Nearly 60% of systems (n=1,687) had no high potential exposure. However, approximately 32% of systems had one contaminant with high potential exposure. Nearly 9% (n=252) had high potential exposure for two or more contaminants, during the study period.
- Sixty-five systems had 9 years of potential high exposure, encompassing less than 3% of systems. Overall, arsenic had the largest number of systems (n=58) with the longest duration of high exposure, ranging from 8 to 9 years.
- Approximately 68% of systems had no MCL violations for the 18 contaminants assessed. Among the 32% of systems that had at least one MCL violation, approximately 5% had MCL violations for two or more contaminants.
- Nearly 17% of systems had two or more years of non-compliance for any given contaminant, with 52 systems having nine years of recurring non-compliance. Contaminants with the longest duration of non-compliance were arsenic, nitrate and TTHMs.

Component 2: Water Accessibility

Reliable, sufficient and continuous access to water to meet basic household needs is a fundamental component of the human right to water. However, this access is not always assured. Some water systems in the state are particularly vulnerable to supply interruptions. For example, during the 2012-16 drought, a number of water systems could not provide enough water to supply their customers' basic needs, and a large number of domestic wells went dry.

The water accessibility component addresses concerns of this kind. It measures the physical factors that can influence whether a water system can provide adequate supplies of water to meet household needs.

Water access is determined by a number of factors. These typically include:

1) The physical quantity of water that a water system can provide, or that a population can obtain (i.e., adequate volume).
2) The availability and reliability of the supply (i.e., whether the supply is sufficient and continuous, even in periods of drought).
3) How people or water systems access water (e.g., groundwater and/or surface water, location, and collection time).

The institutional capacity of water systems also shapes their ability to provide a reliable and adequate supply. However, as this capacity can also shape the ability to provide high quality, affordable water, factors associated with the institutional capacity of a water system are considered separately, in the Chapter "Human Right to Water Outcomes and Social Equity". This chapter discusses a range of factors that shape a system's ability to meet the human right to water.

Accordingly, the water accessibility component consists of indicators of *physical* vulnerability of a water system to inadequate water supply and provision. *Physical* vulnerability refers to the factors that may influence or determine the availability and reliability of a system's water supply. For example, physical vulnerability may be shaped by how many wells a groundwater-dependent system has, and whether these wells offer an adequate supply of water based on the number of customers served or the storage capacity of the water system. A groundwater-dependent system with only one well is more vulnerable to a water outage than a system with dozens of wells, as the former has no additional supplies to draw on. Also, a system with a well or wells in a groundwater basin that is highly vulnerable to drought is more likely to experience shortages than a system with wells that draw from a more stable groundwater basin. Thus physical vulnerability is shaped by factors internal to the water system (e.g. physical infrastructure), and external environmental factors (e.g. basin conditions).

CalHRTW 1.0 includes one indicator for water accessibility. The indicator represents the potential vulnerability of a water system to water shortages or outages based on the number and types of water sources a system has. In future versions, OEHHA will seek to incorporate additional indicators of physical accessibility related to sufficiency and continuity of supply, and vulnerability to drought (See Table 18). Several other efforts are underway among different state agencies to characterize this type of vulnerability, including assessments being performed for the State Water Board's Needs Assessment and the Department of Water Resources' County Drought Advisory Group. Work from these efforts will be considered for incorporation into future versions of OEHHA's Framework and Data Tool.

In addition to the physical vulnerability indicator described below, this section also includes supplemental information on whether a water system is located in a critically overdrafted water basin (See Box 3). While this information is not an indicator, it provides useful information on the conditions of the basin within which the system lies.

Indicator

Water Accessibility Indicator: Physical Vulnerability to Water Outages

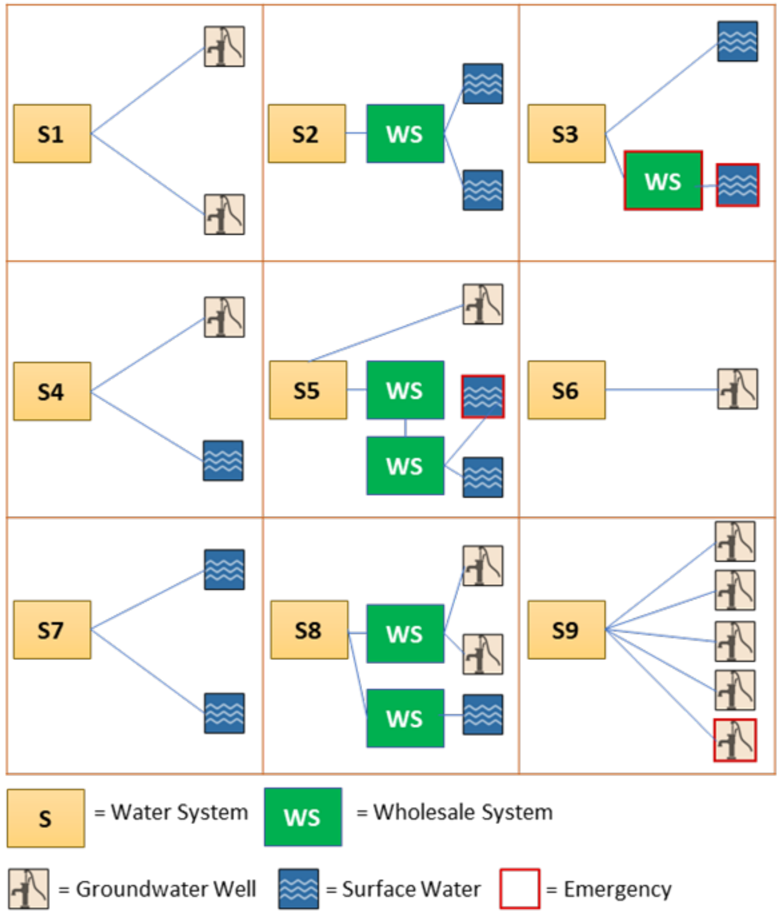
This indicator assesses how vulnerable a water system is to a supply outage (or shortage). It identifies a system's main water source type (e.g., groundwater, surface water, or combined groundwater and surface water), whether the system purchases water from a wholesale system, and how many permanent and backup/emergency sources a system uses in case of emergencies, such as a period of drought. Included in this count are consecutive connections between water systems, also known as interties, which represent water that a system can purchase from another water system provider, or wholesale system.

Figure 17 shows examples of the complexities related to a system's sources, which demonstrates the value in incorporating multiple sets of information to create this indicator, rather than using only the number of sources. For example, the wholesale system may have one or more sources. And many systems also use backup/emergency sources, which are utilized intermittently and could include emergency interties to wholesale systems.

Data Source

Safe Drinking Water Information System (SWRCB - SDWIS), State Water Board, 2017

Figure 17. Examples of Water Sources Used by Community Water Systems.



Method

To create this indicator, we created a scoring matrix based on a system's number of sources, whether the water system purchases water and whether the source of water comes from groundwater, surface water or a combination of both. Our scoring reflects three key assumptions:

1) Groundwater-reliant systems with fewer wells are assumed to be more vulnerable to supply-based outages than either surface water systems with multiple intake points, or systems that rely on combined water types (i.e., systems with surface water and groundwater sources).
2) Systems that have a combination of surface water and groundwater are assumed to have less vulnerability due to their diversity of sources.
3) Whether a system has its own source or relies on a purchased source, each source's reliability is treated equally (as opposed to deciding that a purchased source is itself more reliable, for example).

To compile the data needed in order to apply the scoring criteria to the state's 2839 community water systems we:

- Selected all active, permanent, or emergency/standby/back-up sources based on sample points indicated as sources in the SWRCB - SDWIS database.
- Selected sources that were either wells, reservoirs, springs, intakes, infiltration gallery, non-piped or consecutive connections, for each water system. Here, consecutive connection refers to an intertie (or connection) between a retail system and a wholesale system. The term "*wholesale system*" refers to water systems that operate solely as a wholesale system and sell all their water to other systems, or those that partly serve a residential population and partly operate as a wholesale system. A *retail system* is one that purchases water from a wholesale system (system that sells water).
- Summed the number of main (i.e., non-backup and non-emergency) sources for each system.
- Separately identified if the water system has a backup/emergency source.
- Designated a system as groundwater-only, surface-water only, or groundwater-surface water systems based on each of the water source types used. We did this instead of using the system's federal primary source classification.[26]
- Determined if a water system purchases water if it meets either criteria:
    - The system's federal primary source indicates that it purchases water[27]
    - The system has one or more consecutive connections, not including consecutive connections that are an emergency source
- If a water system has one source that is a wholesale system, information about whether that wholesale system had additional sources was determined from the SWRCB-SDWIS database. For these systems, if there was no information on the wholesale system's sources in SDWIS, OEHHA researched the water system's website to extract the information needed. For systems that had more than one source, no additional information was extracted from the system's website as this was not necessary to determine the scoring.
- Created a scoring matrix using the above information on the number of sources, whether the water system purchases water (and information about the wholesale

[26] Groundwater-only systems were designated as such if all their sources' types (or their purchased water sources' types) were groundwater (GW) or groundwater under-the-influence of surface water (GU). GU sources are typically classified as surface water sources for the purpose of regulation, but here they are treated as a groundwater source for the purpose of this indicator. Surface-water only systems were designated as such if their (or their purchased water) sources' types were only surface water (SW). Systems with combined groundwater-surface water were designated as such if their sources' types (or purchased water sources' types) were both SW and GW or GU. The designation of groundwater, surface water, or combined groundwater-surface water differs from the federal designation status.

[27] Codes of purchased groundwater (GWP), purchased groundwater under the influence (GUP) and purchased surface water (SWP)

system's sources) and whether the system has groundwater sources, surface water sources or both types of sources.

Scoring Approach

This indicator was scored using a matrix approach (Table 10), which took into consideration three main types of information: whether the system relies on purchased water, the total number of sources, and the water type (e.g., groundwater or surface water) for each source within a system. If the system purchases water, the score was based on the number of sources that the wholesale system has, the type of water of these sources, and whether the wholesale system itself purchases water. This scoring approach resembles the method used by the Department of Water Resources (DWR) Small Water Suppliers and Rural Communities at Risk of Drought and Water Shortage Vulnerability report in that identifies interties, emergency interties, source type and number of sources is included (DWR, 2021). However, we combine this information into one indicator and score, and provide more nuance in scoring to capture the range of situations.

Table 10 describes the scoring approach for systems, outlining the process by water source type (e.g., groundwater, surface water or combination). Two main scenarios are described: Scenario 1 where systems do not purchase water from a wholesale system, and Scenario 2, where systems do purchase water from a wholesale system. In Scenario 2, the number of sources that the wholesale system has is further identified. A similar set of scores are given depending on whether the system has groundwater, surface water or a combination of the two. Thus the following scores were applied:

If the system has only groundwater wells, the indicator was scored as follows:

- 0, if the system has 4+ sources
- 2, if the system has three groundwater wells locally, or through one wholesale system
- 3, if the system has two groundwater wells locally, or through one wholesale system
- 4, if the system has one groundwater well, locally (pertaining to the system itself), or through one wholesale system

If the system has only surface water sources, the indicator was scored as follows:

- 0, if the system has 4+ sources
- 0.5, if the system has three surface water sources locally, or through one wholesale system
- 1, if the system has two surface water sources locally, or through one wholesale system
- 2.5, if the system has one surface water source (such as a creek or lake) locally, or through one wholesale system

If the system has a mix of groundwater and surface water sources, the indicator was scored as follows:

- 0, if the system has 4+ sources
- 0.25, if the system has three sources locally, or through one wholesale system
- 0.5, if the system has two sources locally, or through one wholesale system

Additionally,

- A system's score was reduced by 0.25 if the system has at least one emergency source, thereby improving the score slightly. However, if the score was already 0, it stayed at 0.
- In the case of a system with ambiguous data on water sources, a system's score was manually confirmed based on researching sources of water listed in the water system's website or Consumer Confidence Report. OEHHA researched 33 such water systems and manually assigned them scores.

Table 10. Scoring for Retail Systems*, Depending on Whether They Purchase Water, and the Type of Water Source.

SCENARIO 1		SCENARIO 2			Scoring[+]		
Retail System That Does not Purchase Water		Retail Systems that Purchase Water					
Number of Source(s)* Retail System has		Number of Sources Retail System Has	Number of Sources Wholesale System has	Does the Wholesale System Purchase Water?	Score if Groundwater	Score if Surface Water	Score if Groundwater and Surface Water
1	or	1	1	No	4	2.5	NA
2	or	1	2	No	3	1	0.5
3	or	1	3	No	2	0.5	0.25
4+	or	1	4+	Yes or No	0	0	0
		1	1 to 3	Yes**	0	0	0
		2+	>=1	Yes or No	0	0	0

"Retail systems" refers to the same 2,839 community water systems assessed in this report, but is used to distinguish from water systems that are "wholesale systems". Wholesale systems are categorized as such if they only sell water, or if they serve a retail population whose retail population is less than 1% of the wholesale system's population.
***Three systems fell under this category. Their source types were manually researched and resulting score was given based on the specifics of their wholesale sources and the particular decision that these systems were not vulnerable.*
+ Note that scores are then reduced by .25 if the system has any backup/emergency sources.

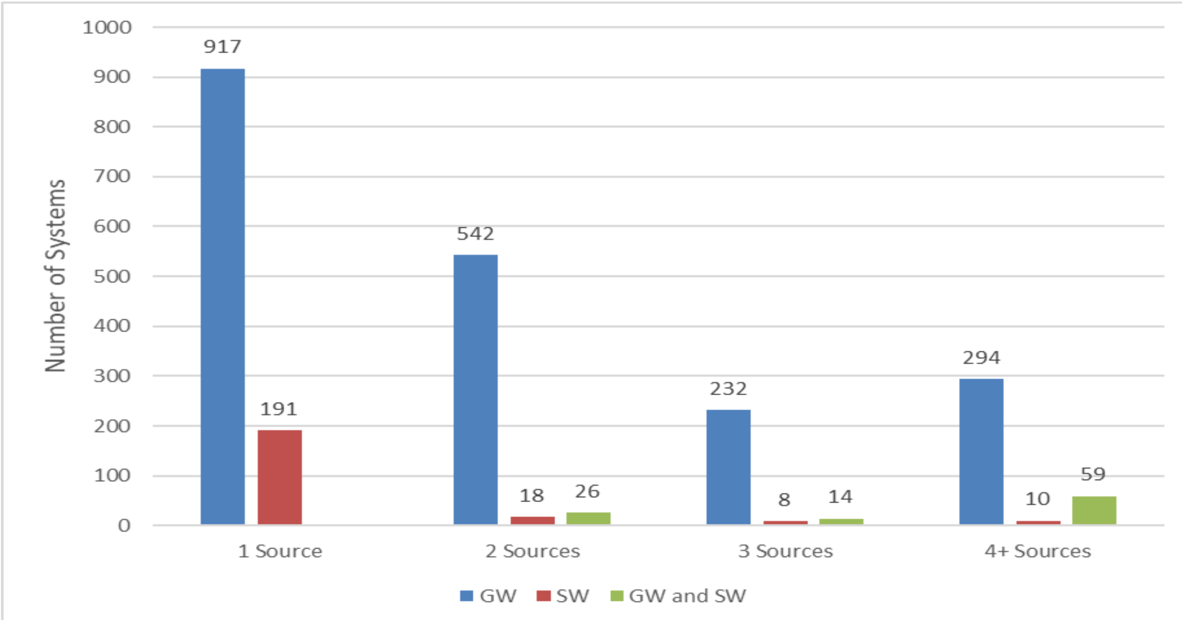
Table 10 summarizes the scoring method in a matrix format. The term "retail systems" refers to the same 2,839 community water systems assessed in this report, but is used to distinguish from water systems that are "wholesale systems" (which are not part of this study, except to account for the wholesale sources). For retail systems that purchase water from wholesale systems, the first column indicates the number of sources a retail system has. Since these water systems all purchase water, if the retail system has 1 source, that source is a wholesale system. If the retail system has 2+ sources, at least one source represents a wholesale system. The next column then summarizes the number of sources contributed by a wholesale system. For example, Castlewood Domestic Water System in Alameda County has one source, a wholesale system called SFPUC-Pleasanton Wells. This wholesale system has two sources (both groundwater wells). Castlewood Domestic Water System would receive a score of 3.

Results

Of the 2,839 systems in our study, 2,086 (73%) were classified as groundwater systems. The remaining 753 (27%) systems were either surface water systems (n=334), or groundwater-surface water systems (n=419). There were 511 water systems with an emergency source.

Of the 2,839 systems, 2,311 (81%) did not purchase water. Among these systems, 1,985 (86%) were groundwater-only systems. Of these, approximately 46% (n=917) had only one main well (Figure 18). Among these 917 systems, 180 had at least one emergency source. The remaining 737 systems – 26% of all systems -- had only one main source and no emergency sources.

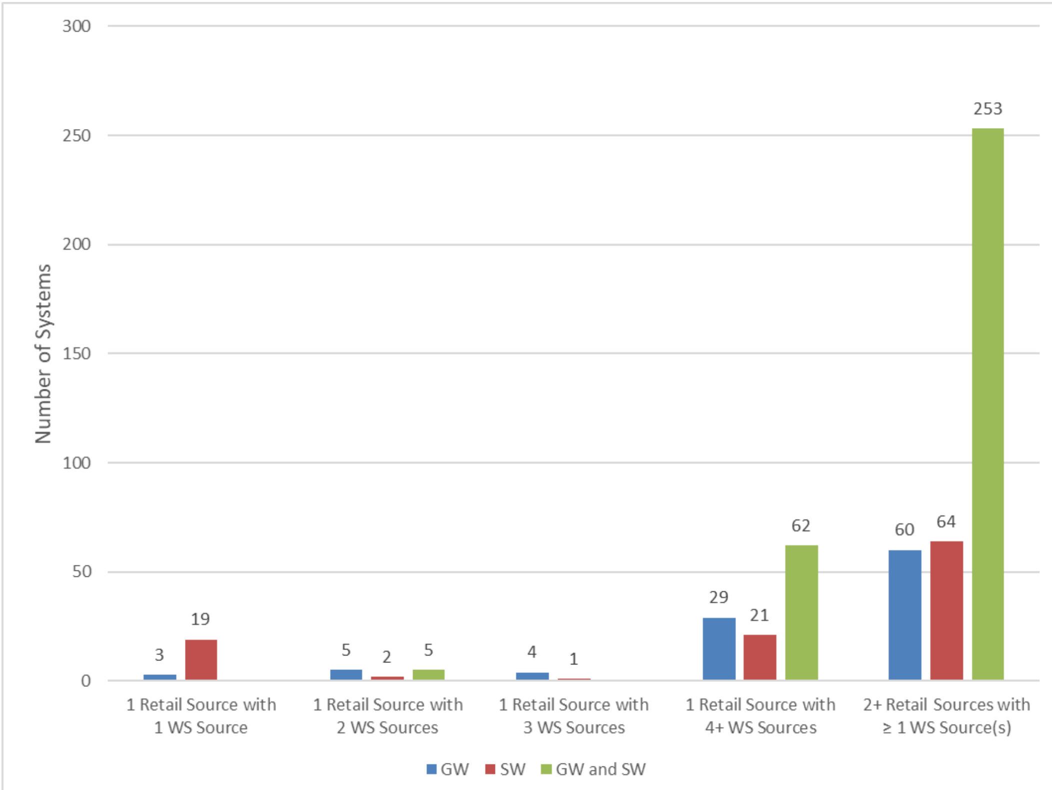
Figure 18. Number of Sources*, by Water Source Type for the 2,311 (Retail) Systems that Do Not Purchase Water.



**The number of sources does not include emergency/backup sources; these are counted separately.*

In contrast, among the 528 (~18%) that purchased water, 151 had only one source; the majority of these single sources were surface water (Figure 19). Among these 151 systems, 20 (13%) had at least one emergency source. Table 11 provides the scores for this indicator. The map in Figure 20 shows these results across the state.

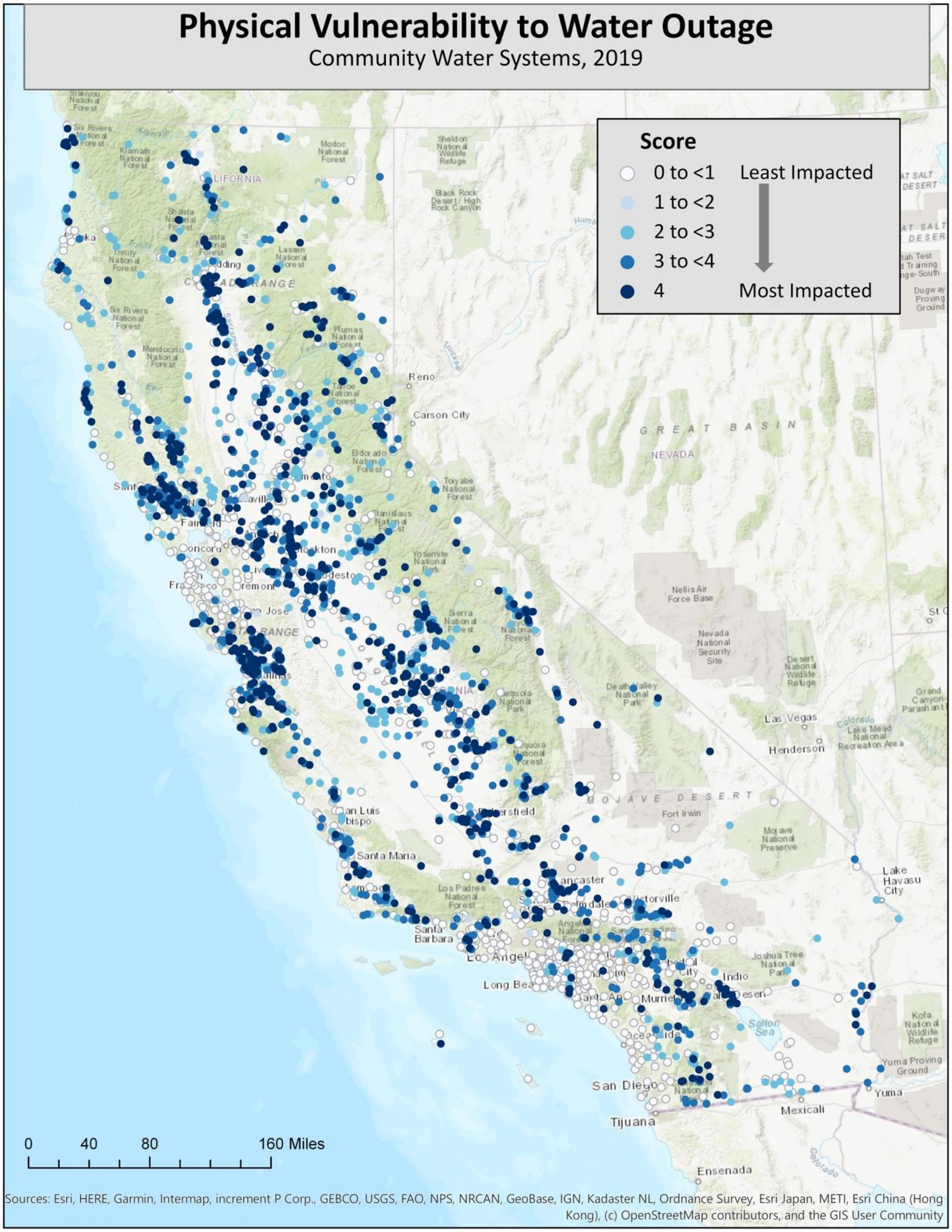
Figure 19. Number of Sources*, by Water Source Type for the 528 (Retail) Systems that Purchase Water from a wholesaler (WS)+.



**The number of sources does not include emergency/backup sources; these are counted separately.*
+ Wholesaler indicated as "WS" in the figure.

Figure 20 shows the physical vulnerability score across the state. There is a relatively large spread of scores from 0 to 4 throughout California. Unlike the composite water quality scores, however, high scores are distributed more evenly across the state. There is a particularly high concentration of low scores in the San Francisco Bay Area and Southern California regions (See Map 16 for definition of regions).

Figure 20. Map of Indicator 1: Physical Vulnerability to Water Outages. Lower scores represent a better outcome for this indicator; higher scores represent poorer outcomes. For a definition of score values, please consult Table 11.



Box 3: Critically Overdrafted Basins

The Department of Water Resources Bulletin 118 provides “an inventory and assessment of available information on the occurrence and nature of California’s groundwater to inform decisions affecting the protection, use, and management of the resource”(California Department of Water Resources). As part of the Sustainable Groundwater Management Act, Bulletin 118 identified 21 of the 515 alluvial basins in the state as critically overdrafted. A critically overdrafted basin is one where the current management practices could result in adverse environmental, social or economic impacts (California Department of Water Resources).

OEHHA considered including information on overdraft as an indicator, but decided against it for two reasons. [1] First, in consultation with DWR it was determined that DWR’s work only characterizes alluvial basins; risk factors for aquifers outside of alluvial basins have yet to be similarly evaluated. OEHHA expects to be able to use information from this type of assessment for a future indicator as additional data become available. Second, a water system may be physically located in a specific groundwater basin, but draw water from a different basin. In other words, a water system’s groundwater sources may not be within its service boundary. Both sets of information would need to be properly confirmed before making a complete characterization of the aquifer’s risk. Future versions will incorporate this information when a more complete characterization of basins is finalized.

Nonetheless, given the significance of this type of information, OEHHA includes the identification of critically overdrafted basins as a spatial layer in its web tool for informational purposes. However, OEHHA will not factor the information into the component scoring. As an example, the below figure shows systems whose centroids falls within critically overdrafted basins.

FIGURE A: Map that shows: alluvial basins, non-alluvial basins and COD basins, with systems overlaid.

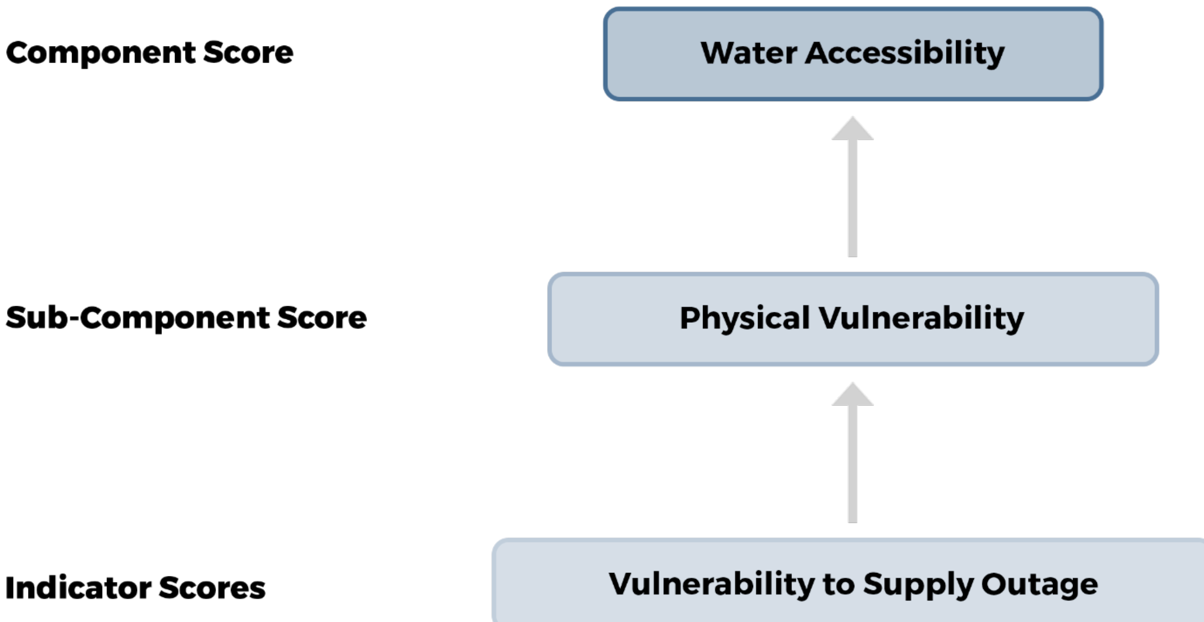
A Composite View of Water Accessibility

The physical vulnerability indicator currently comprises the composite water accessibility score. In the future, as more indicators are added, the composite score can serve to highlight systems that have some of the highest scores across all accessibility indicators, and are therefore the most burdened in the area of accessibility. Figure 21 represents how the current individual indicator score yields the composite water accessibility component score.

Scoring Approach

- The score for Accessibility Indicator (the lone indicator for this component) produces the composite accessibility component score.
- Composite scores ranged from 0 to 4, with higher scores indicating a greater burden.

Figure 21. Creation of Composite Water Accessibility Score.



Results

As the current composite score is comprised of the physical vulnerability indicator, composite scores mirror results for that indicator. The composite score ranged from 0 to 4. Across systems, the mean composite component score was 2.21 (median=2.75). Approximately 26% of systems received a score of 4, meaning they only had one groundwater well and no emergency wells. Approximately 32% of systems had a composite score less than 1 (Table 11). Compared to water quality, the large fraction of systems with high scores can be explained by the fact that 26% of systems had only one source, and no backup.

Table 11. Composite Water Accessibility Score.

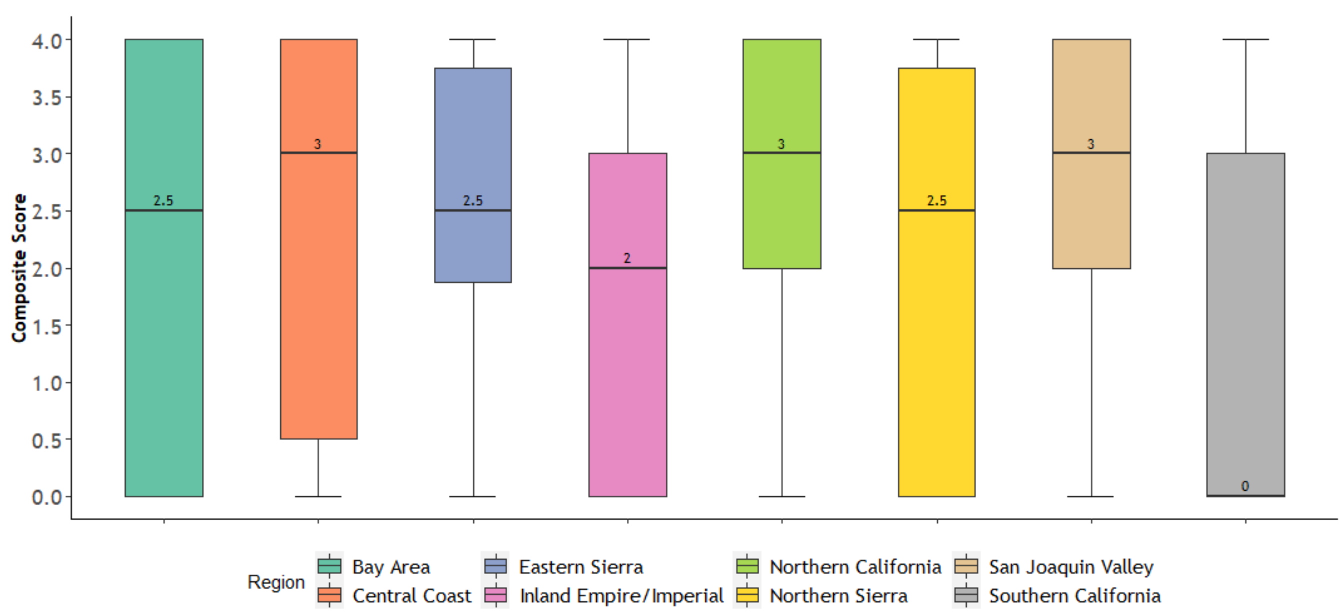
Composite Water Accessibility Score	Number of Systems	Percent
0 to < 1	908	32%
1 to < 2	51	2%
2 to < 3	474	17%
3 to < 4	666	23%
4	740	26%
Total	2839	100%

Geographic Observations

Figure 22 highlights water accessibility scores by region. This figure highlights that the highest scores occurred in Northern California (median=3), the San Joaquin Valley (median=3), and the Central Coast (median=3), though there were high-scoring systems across all regions. For a map of regions, please see Figure 16.

Among the 740 systems that received a composite water accessibility score of 4, several key patterns emerge. First, a disproportionate number of systems (28%) were located in the San Joaquin Valley and Northern California (22%). By comparison, the San Joaquin Valley and Northern California account for 22% and 16.5% of systems statewide, respectively.

Figure 22. Composite Water Accessibility Score by Region.



Additional Research/Next Steps

The current indicator described in this chapter does not capture all aspects of water accessibility. Other aspects can include the quantity of water generally available to serve a specific area based on the condition of its source(s) and regulatory and statutory requirements (e.g., Sustainable Groundwater Management Act). Conditions related to climate change, such as drought, fire, extreme heat, and sea level rise, can also affect accessibility. Future versions of this tool expect to include additional indicators related to supply vulnerability.

Water accessibility has a multi-level nature. Households and individuals can take their own actions to access water, such as purchasing bottled water or obtaining water from other alternative sources (e.g., private wells). The types of alternative sources and distances to them is a relevant consideration (Balazs *et al.*, 2011; Christian-Smith *et al.*, 2013). Although the current draft focuses on a system-level measurement of accessibility, household-level coping approaches are also critical, especially for the most marginalized Californians, such as populations lacking housing, or those that do not have access to water where they live. Future versions could explore whether it is possible to address household and individual accessibility, though such efforts are likely to prove extremely challenging to do data constraints.

Potential future indicators are further outlined in Table 18. Examples of such indicators focused on physical accessibility could include: supply resiliency (e.g., vulnerability to drought) and measures of infrastructure quality (e.g., age of water system infrastructure, main breaks, etc.). The inclusion of any of these metrics would be contingent upon adequate data. OEHHA will coordinate with other state agencies and stakeholders, including the Water Board, the Department of Water Resources, water systems, community organizations, and local governments in considering other possible indicators and datasets, once such indicators are in a final form.

Key Findings for Accessibility

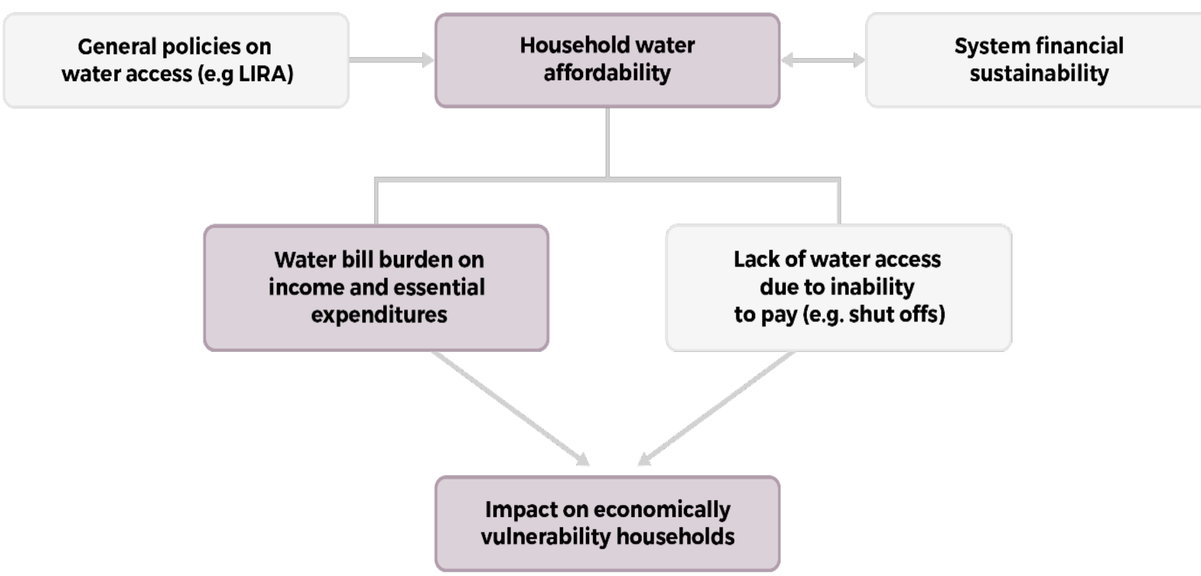
- Approximately 26% of the 2,839 systems studied have only one water source, no emergency source, and rely solely on groundwater. These systems are particularly vulnerable to water outages.
- While the vast majority of the highest-scoring, most vulnerable water systems are groundwater systems, 6% of all water systems have only 1 surface water source.
- Vulnerable systems are found across the state, but the regions that, on average, had the highest scores, indicative of greater vulnerability, were: Northern California, the Central Coast and the San Joaquin Valley.

Component 3: Water Affordability

A central consideration in achieving the human right to water is whether customers can afford to pay for their water. Water affordability is typically assessed by measuring the full costs of water charged to a household, relative to the household's income level. Water should not be considered affordable to households if they are forced to compromise on other essential expenditures, like food and housing. To address issues of non-discrimination and equity, water should be affordable to the most vulnerable populations, and users should be free from unnecessary disconnections (UN CESCR, 2002).

Figure 23 summarizes the concepts that commonly influence affordability and highlights the areas of affordability that form the main focus in this report: the ratio of water bills to income and the impact of water bills on economically vulnerable households. The current assessment focuses on the cost of water for drinking, cooking, and hygiene relative to three income levels within a water system. By evaluating affordability at these income levels, the affordability component approximates the extent to which water costs burden households below the median income level within a system. The affordability component can incorporate the cost of sewer and sanitation charges, or more refined income and expenditure information, when such data become available.

Figure 23. Core Aspects of Affordability. Shaded boxes indicate areas that the Affordability Component focuses on.



Another core aspect commonly considered alongside household-level affordability is the financial capability of water systems, or the adequacy of revenue streams and their management to cover ongoing and long-term infrastructure maintenance, capital costs and upgrades necessary to maintain adequate water quality (Davis and Teodoro, 2014; OECD, 2010; US EPA, 1998). These aspects are not directly captured in the current assessment.

Historically, US EPA has used an affordability ratio (known as the Residential Indicator) to measure the impact of a water system's average water bill on a household earning the median household income (US EPA, 1998). The US EPA and many state agencies use this ratio to screen water systems for affordability challenges when they are meeting compliance standards for water quality. Water is understood to be unaffordable if water bills exceed a pre-established percentage of median household income (See Box 4: What is an affordability ratio?). The Residential Indicator has garnered criticism for inadequately capturing low-income affordability problems. Extensive discussions about best practices and the limitations of this ratio exist (See Appendix A) and inform the use of affordability ratios in this report.

Box 4: What is an affordability ratio?

An affordability ratio captures the impact of a water bill on a household's income. In its most generic form, this ratio typically consists of a water bill at a specified volume of water divided by an income level. The resulting ratio is meant to capture the fraction of a household's income that is spent on water bills. Typically, the affordability ratio is evaluated against a threshold to determine whether water bills are or are not affordable.

Conventional affordability ratios often use average water bills divided by a region's median household income level. However, these ratios have limitations. Ideally, the value used for water bills includes all costs (including any fees, sewer, or other charges). Additionally, water bills should be considered in light of other essential expenditures (such as housing and food), so that water is not misrepresented as affordable at the expense of other basic needs (e.g. food).

Indeed, improved affordability ratios specify the water bill inclusive of all charges for a particular volume of water and aim to measure disposable income minus other essential expenditures. These approaches require statistical modeling to estimate expenditures, and thus studies investigating these methods focus on affordability in medium to large systems in metropolitan areas that have adequate data.

Notably, affordability ratios do not differentiate or capture all economically vulnerable groups. For example, renters and fixed income seniors, people living without homes, and those without access to a water source are not captured in these indicators. Affordability ratios do not explicitly incorporate information about a water system's water quality. As such, these measures should be evaluated in context with other indicators as part of a holistic assessment of water quality, access, and affordability.

Building on this rich discussion, OEHHA developed three affordability indicators to measure affordability at three income levels at the water system scale (see Box 5: Summary of Affordability Measures and (Goddard *et al.*, Forthcoming. 2021). These indicators capture affordability for median income levels (50th percentile) and two county-specific poverty income levels. These ratios are complemented by household poverty indices to estimate the number of households earning below the two poverty levels. The ratios indicate affordability of water relative to income, whereas the household indices reflect a measure of economic vulnerability of households in a water system's service area.[28]

The aims of this approach are to: 1) look at the impact of a system's water bills for essential-needs water at three income levels, including economically vulnerable income levels; 2) show the distribution of this impact across the three income levels; and 3) develop a household-weighted average affordability ratio for households served by a water system that earn below the median income level (i.e. a composite indicator). This approach illuminates household affordability challenges at different incomes, and when viewed at a composite level offers a system-level perspective of affordability challenges for households earning in the lower-half of the income distribution.

This chapter first discusses water bill data and methods used to create the affordability indicators and common thresholds for expressing whether water is affordable. It then presents each of the three affordability indicators, followed by the calculation of a composite affordability indicator and water system affordability score. The affordability component has no subcomponents. The chapter concludes with a discussion of data gaps, which are significant for this component, and observations on water affordability in California's community water systems. Appendix A and the References section contain a literature review relevant to the creation of the affordability indicators and Appendix B includes technical and methodological details about the indicators we present.

[28] OEHHA's affordability indicators align with current state efforts to measure water affordability for different income levels. OEHHA's indicators are currently included as potential indicators for affordability in the Water Board's Needs Assessment as part of the SAFER program(State Water Resources Control Board, 2020b). Similarly, the California Public Utilities Commission developed an affordability ratio for the 20th percentile income levels, focusing on essential-needs water and low-income levels(California Public Utilities Commission, 2020). OEHHA ultimately selected two California-specific poverty level incomes to evaluate affordability rather than the income quintile approach, though both are reflective of economically vulnerable households. OEHHA's poverty level incomes are based on necessary expenditures to stay out of poverty whereas the 20th income percentile reflects a low point in the income distribution of a given area.

Box 5: Summary of Affordability Measures Calculated for Each Water System

This chapter describes three affordability indicators, and one composite metric. The three affordability indicators are based on the generic formula of an affordability ratio (AR) for a specified volume of water:

$$AR = \frac{System\ wide\ Average\ Bill\ for\ 600\ cubic\ feet\ of\ water\ per\ month}{Specified\ Income\ Level}$$

Affordability Ratio at the Median Household Income Level (AR_{MHI})

- Calculates water bills relative to the median household income within a water system's service area.
- Identifies affordability challenges, if any, that median-income households served by the system may face.

Affordability Ratio at the County Poverty Threshold (AR_{CPT})

- Calculates water bills relative to the county poverty income level.
- The number of households below the county poverty level is also calculated.

Affordability Ratio at the Deep Poverty Level (AR_{DP}).

- Calculates water bills relative to the deep poverty level (one-half the income of the poverty level).
- The number of households below the deep poverty level is also calculated.

These three indicators are used to create a **Composite Affordability Ratio** which uses the number of households at the three income levels described above to create a household-weighted affordability ratio for households below the median income level.

Method to Create Affordability Ratios

Four main steps were taken to create the three affordability ratios. The general formula used to calculate the affordability ratios (ARs) is:

$$AR = \frac{Systemwide\ Average\ Annual\ Water\ Bill}{Annual\ Income}$$

To apply this formula to create the affordability indicators, OEHHA followed these steps for each water system:

1. Selected water consumption level (same for all systems) based on available water bill data.
2. Selected water bills reported for the water consumption level.
3. Estimated three income levels for each water system: median household income, county poverty income and “deep poverty” (one-half of the county poverty income level).
4. Estimated the number of households within each system earning below the three income levels.

These data are then used to estimate three affordability ratios for each water system, at three income levels, and to weight them to create a household-weighted average composite affordability ratio for households earning below the median income in each water system.

STEP 1: SELECTING A WATER CONSUMPTION LEVEL

Water systems annually report average residential water bill data at three volumes of monthly consumption (600, 1200, and 2400 cubic feet) to the Water Board through annual electronic reports. OEHHA selected water bills reported at 600 cubic feet (6 HCF) due to this volume’s alignment with basic water needs and conservation goals.[29] This amount is approximately 150 gallons per household per day per household.[30] As such, this volume falls within the range of basic needs water consumption for people in California (though it is significantly above international standards for essential water) and falls near California water conservation goals (Gleick, 1996).[31] For most households, 6 HCF per month would not be enough water to cover landscaping and other water uses that are generally not considered to be basic needs. Even so, some households may require higher levels of essential water use, for example, larger households; households with people facing illness or with disabilities; or households in more water-stressed areas of the state.

OEHHA selected 6 HCF per month as representing essential water needs, given currently available statewide datasets, while acknowledging the diversity of water needs of households in the state. For additional discussion, see Appendix Affordability Methods

B1 Water Bill Dataset Selection & Use.

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[29] The Water Board and the California Public Utilities Commission have also selected 6 HCF as an essential needs volume in their affordability indicators.

[30] This is equivalent to 50 gallons per person per day in a 3-person household or 37 gallons per person per day in 4-person household. The average household size in California in 2015 was 2.9 persons per household.

[31] (Gleick, 1996) proposes a basic water requirement of 50 liters per capita per day (13 gallons). This is equivalent to 150 liters (39.6 gallons) for a three-person household and 200 liters (52.8 gallons) for a four-person household. Gleick’s study presents a range of 57-165 liters per capita per day (15-45.6 gallons), depending on the region, technological efficiencies, and cultural norms. (Feinstein, 2018) recommends evaluating water affordability in California using a measure of 43 gallons per capita per day, equivalent to 129 gallons per three-person household and 172 gallons per four-person household. A provisional standard of 55 gallons per capita per day is identified in (California Water Code, 2009) section 10608.2 for indoor water use for urban water suppliers who are aiming to reduce water demand.

STEP 2: SELECTING AVERAGE WATER BILL AT 6 HCF

We estimated affordability using the annual average water bill for 6 HCF per month (See Box 6: Affordability Considerations: What is in a Water Bill?). We relied on water bill data reported by water systems[32] in the State Water Board's Electronic Annual Reporting survey (eAR) (See Appendix Affordability Methods

B1 Water Bill Dataset Selection & Use for detailed methodology).[33]

Prior to selecting this approach, we reviewed four available datasets on water bills for California community water systems (See Appendix Table B1). Ultimately, OEHHA selected the State Water Board's eAR survey because:

- The eAR data are publicly available.
- The eARs are updated every year, and thus this indicator can be re-calculated each year.
- Despite data gaps discussed below, the eAR data has a high level of coverage of California water systems (compared with other four datasets; See Appendix Table B1).
- The eAR data were reported as average monthly residential water costs for a specific volume of water.

For all three affordability ratios, we:

- Reviewed water bill data for community water systems.
- Applied exclusion criteria for potential outliers (i.e. very low and very high water bills). (See Appendix B3 Data Cleaning & Exclusions for detailed methodology.)

After collecting income data and addressing missing data and data reliability concerns (See Appendix B3.4.1 Data Reliability in Census Data), 1,141 systems were ultimately included in OEHHA's affordability assessment. The median water bill for 6 HCF across water systems with data was $41.36/month (See Appendix B3 Data Cleaning & Exclusions) (State Water Resources Control Board, 2019).

STEP 3: ESTIMATING INCOME LEVELS

We took the following steps to calculate income levels (See Appendix B2 Income Data Selection & Use for more details):

[32] Systems are asked to report average residential water bills at specified water volumes, with no specification in the survey question to include additional fees or sewer charges in the estimate. Therefore, OEHHA interprets the available data provided in the eAR to represent a minimum cost for water at the specified volumes – or the water rate for 6 HCF, excluding sewer charges. Relatedly, OEHHA cannot disaggregate rate blocks, multifamily versus single family bills, rate tiers, or variable costs by region. However, these features may be incorporated into the average bill calculated by water systems and reported in eAR. To the extent that averages incorporate differences across rate structures and variable costs that vary by region, the current numerator will reflect these differences across water systems.

[33] Other approaches to estimating water bills are to calculate an estimated average water usage and use rate information to calculate an average annual water bill.

Median Household Income (MHI)[34]**:**

- Applied the steps described in the Institutional Constraints section (page 51)
- Applied OEHHA's MHI exclusion criteria to remove unreliable estimates where relevant, as discussed in Appendix B3.4.1 Data Reliability in Census Data.

County Poverty Threshold (CPT):

- Collected data from Public Policy of Institute of California on County level poverty thresholds (see Appendix B2.2.1 Selecting Poverty Level Income).
- Assigned each system the County Poverty Threshold of its respective county. (Of California's 58 counties, 38 counties have unique poverty thresholds and the remaining 20 are in three groups with equal thresholds due to Census suppression criteria.) (US Census Bureau, 2016)

Deep Poverty (DP) was calculated to be 50% of the CPT.

STEP 4: ESTIMATING NUMBER OF HOUSEHOLDS BELOW INCOME LEVELS

For each water system, to estimate the number of households below the MHI, County Poverty Threshold, and Deep Poverty Level, OEHHA:

- Estimated the number of households in each of the Census's 16 income brackets from ACS 2011-2015 Table B19001. This was done by apportioning block group level data to water systems through a set of steps. First, we calculated the percent of households in each income bracket for all block groups. Second, we estimated the number of households in each block group served by a given water system by intersecting water system boundaries with populated census blocks. Then, we multiplied the Census data (i.e. the percentage of households in each income bracket) by the estimated number of households in each block group served by a water system. These data were summed across all block groups intersecting a water system, resulting in a household weighted estimate for the number of households in each income bracket for each system (See B2.3.1 Areal-Household Weighting Methodology).
- Excluded systems that do not meet OEHHA's data-inclusion criteria based on Census data reliability (See Appendix B3.4.1 Data Reliability in Census Data).[35]
- Approximated the number of households below the particular income level within each system[36] by using linear interpolation between points across the Census income

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[34] Median household income is gross income, i.e. it does not exclude taxes or other essential expenditures.

[35] OEHHA sought to improve reliability of census estimates used by aggregating data to water system boundaries and excluding systems with unreliable data. Even so, estimates should be considered in light of their potential unreliability per census measures of error. Appendix B3.4 provides further details and discussion on this topic.

[36]PPIC poverty thresholds, indexed against the percentage of households at that income level, may *under-estimate* the actual percentage of households in poverty because PPIC estimates are proxies for disposable income and Census estimates of households by income brackets are estimates of total income. At poverty and deep poverty income levels, it is likely that disposable and gross income levels are not substantially different, but given that we cannot measure this we recognize that our approach results in a more conservative measure of poverty levels and

brackets, summing the number of households below the income level, and dividing that sum by the total households within the water system. (See Appendix B4 Composite Affordability).

Box 6: Affordability Considerations: What is in a Water Bill?

Water bills typically reflect the price of water consumed by a household plus any fees and subsidies for drinking water and sewer services. The price of water may be fixed or vary with the volume consumed. Water bills may vary widely across water systems, even for the same volume of water. Variability in water bills is due to many factors, including water costs, operations and maintenance costs, administrative costs, debt service on capital investments, energy costs, and water quality variations. Water bills cannot fully capture the cost of water in cases where households pay for bottled water (costs referred to as replacement costs).

When measuring affordability, water bills are most frequently used to represent total water costs to households. However, depending on what data is reported and/or collected, water bills do not always include wastewater costs, replacement costs in the context of inadequate water quality, or long-term infrastructure and maintenance costs. Water bills that do not include these costs will therefore underestimate the affordability challenge for households.

California's eAR survey asks systems to report the average water bill at a specified volume of water consumed. Water bills reported at a fixed volume (e.g., 6 HCF in this report) are thus for an average water bill for an essential-use volume and may not reflect what a household *actually* pays for water. While the water bills that water systems report could theoretically include subsidies or fees, it is not explicitly clear whether the reported bills account for subsidies or include additional fees. A completely accurate water bill for 6 HCF would need to include wastewater charges, infrastructure charges, and other important fees that may not be captured in the average water bill estimates reported.

The contractual relationship between renters and homeowners represents another challenge. The Water Board estimates that between 25% and 46% of Californians rent their homes(State Water Resources Control Board, 2019). Water bills are paid by owners, who pass costs on to tenants, in theory, proportional to a renter's water use. However, the relationship between what renters should pay for water and what they actually pay is not generally metered or documented. As a result, the use of water bills may underestimate or overestimate how much renters pay for water. The indicators in this report thus assume that renters pay proportionally to their use (i.e., 6 HCF), but they do not directly consider affordability for renters.

may under-estimate the number of households facing AR_{CPT} or AR_{DP} within a system. In the current study, the average percentages of households in poverty or in deep poverty within water systems corroborates PPIC's state-wide estimates at the county level, despite different overall analyses.

A total of 1,545[37] out of 2,839 community water systems had water bill data that could be included in the affordability calculations (See Appendix Affordability Methods

B1 Water Bill Dataset Selection & Use). After applying a set of exclusion criteria (see Appendix B3 Data Cleaning & Exclusions), this resulted in 1,141 systems, or 40% of community water systems with affordability scores (This contrasts with the Water Quality and Accessibility Components for which OEHHA evaluated 100% of community water systems).

The relatively low number of systems in the assessment is discussed later in this chapter, though it is worth noting that these 1,141 community water systems, while only about 40% of the total number of community water systems, represent approximately 91% of the population served by community water systems in California. However, very small systems and those serving severely disadvantaged communities are under-represented in this analysis. The impact of this smaller sample size relative to the total number of community water systems is likely significant, and is discussed in greater detail below in the "Affordability Data Gap" section. For this reason, the initial results presented below should not be used to represent complete statewide trends, as this would require the complete dataset.

Scoring

Most affordability studies use a specific threshold to determine if the percent of household income spent on water is affordable or not. The present assessment does not select a specific threshold against which affordability ratios are determined to be "unaffordable." Instead, multiple thresholds represent the spectrum from more to less affordable.

There is no single agreed-upon affordability threshold. Instead, there are several thresholds cited internationally, nationally and in California that can be relevant for assessing affordability. Internationally, water is typically considered unaffordable when costs are greater than 3% of disposable incomes (United Nations Development Program, 2006). Nationally, US EPA has applied a threshold of 2.5% to identify drinking water affordability challenges in water systems (US EPA, 2002). There are several potential benchmarks for judging water affordability at the three income levels used in OEHHA's report. In California, State Revolving Fund programs consider loans for water projects to be unaffordable when repayment costs result in water bills that exceed 1.5% of median household incomes in disadvantaged communities (those earning 80% or less than the state's median household income) (State Water Resources Control Board, 2018). See Appendix A2 Approaches to Measuring Affordability for further discussion of approaches to measuring water affordability, including the use of thresholds.

We assigned indicator scores to water systems based on a combination of assessing the distribution of the data and using existing affordability benchmarks as follows:

- 0, when the average water bill is less than 0.75% of the income level.

[37] Los Angeles Department of Water and Power (LADWP) was divided into five smaller sub-systems. The umbrella system was removed before further evaluation of data reliability.

- 1, when the average water bill ranges from 0.75% to less than 1.0% of the income level.
- 2, when the average water bill ranges from 1.0% to less than 1.5% of the income level.
- 3, when the average water bill ranges from 1.5% to less than 2.5% of the income level.
- 4, when the average water bill exceeds 2.5% of the relevant income level (e.g., MHI, CPT, DP).

Indicators

Affordability Indicator 1: Affordability Ratio for the Median Household Income level (AR_{MHI})

This affordability ratio, AR_{MHI}, is based on the median household income level of the population served in each community water system (see Methods Section of Institutional Constraints indicator for information on how MHI is calculated, as well as Appendix B2.3). AR_{MHI} is evaluated using water bills reported for an essential minimum water volume of 600 cubic feet (6 HCF). Across the 1,141 systems, MHI ranged from $17,400 to $250,000 (median=$60,600).

The affordability ratio at MHI (AR_{MHI}) is calculated as:

$$AR_{MHI} = \frac{System\ wide\ Average\ Bill\ for\ 6\ HCF/month\ \times\ 12\ months}{Annual\ Median\ Household\ Income\ of\ Water\ System}$$

The affordability ratio is expressed as a percentage.

An affordability ratio using the median income level indicates the water bill burden for households at the 50th percentile of the income distribution in a water system. Thus, if water bills are high for households at the median income level, water is unaffordable for at least 50 percent of households in a water system. High water bills at the MHI may also indicate that the water system's financial capacity is at risk for being unsustainable, because household affordability and system financial capacity are interrelated.

Data Source

State Water Board's electronic annual reports (eAR), 2015.
US Census American Community Survey (ACS) 5-Year Data: 2011 – 2015
Tracking California, Public Health Institute. Water Boundary Tool. Available at URL: https://trackingcalifornia.org/water-systems/water-systems-landing.

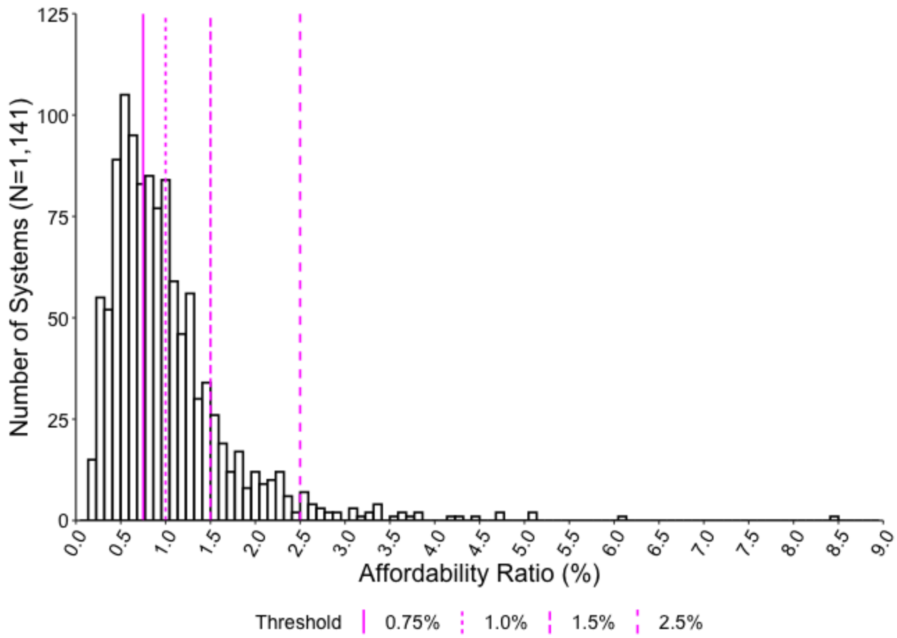
Results

Among the 1,141 systems with data, affordability ratios ranged from 0.16% to 8.49%, with a median of 0.85% (Figure 24). Figure 24 shows how the indicator scores are distributed across the 1,141 systems with data. Among these systems, 15.4% of systems had average water bills exceeding 1.5% of the median household income. Of these, 65.3% serve severely disadvantaged or disadvantaged communities, defined by their overall economic status (see Accessibility Chapter).

provides an indicator score to these affordability values and represents systems not included in analysis (due to missing data or exclusion criteria) as “No Data”.

Figure 25 highlights these indicator scores across the state.

Figure 24. Affordability Ratio and Scores at Median Household Income (as Percent) for Community Water Systems. Data for 1,141 community water systems in 2015†.

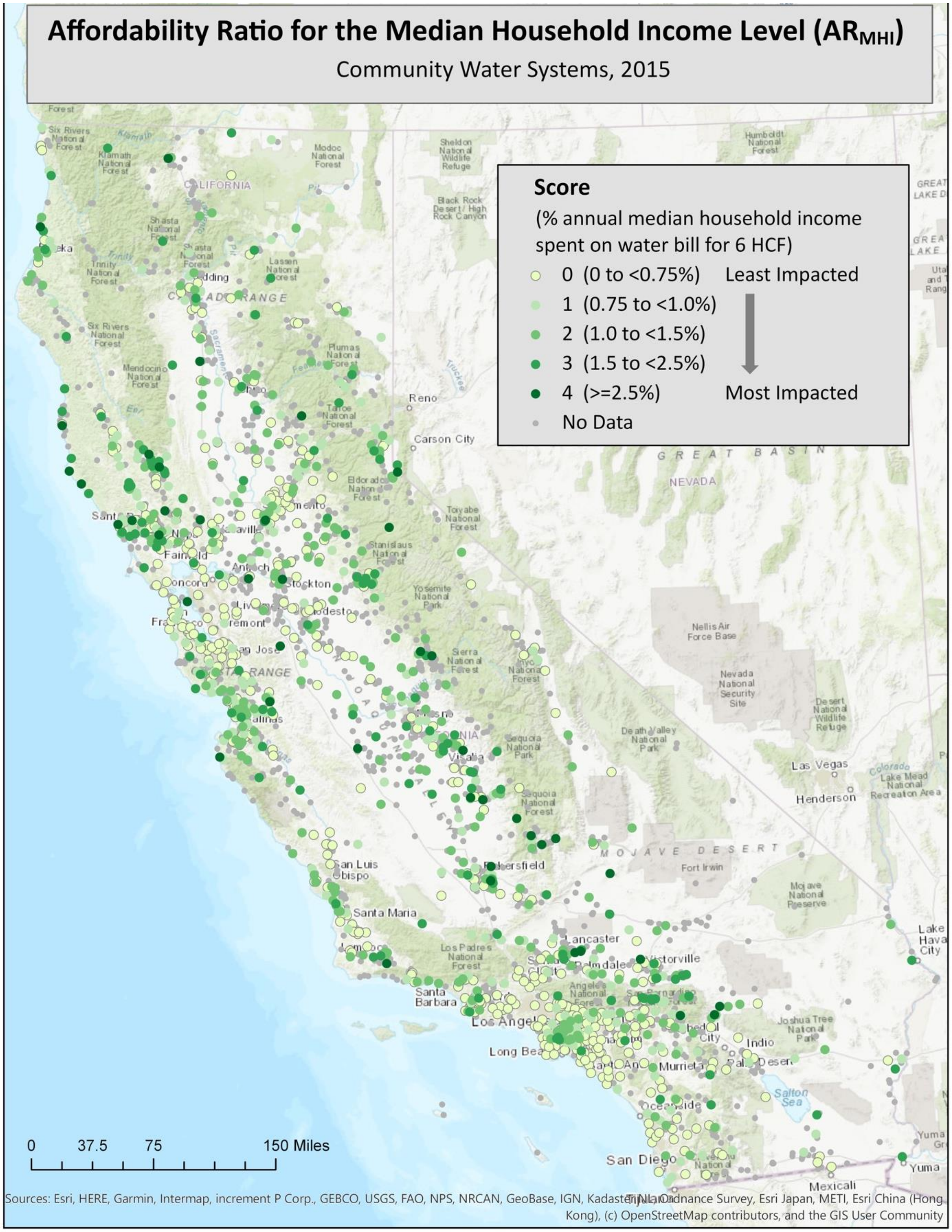


† The four dashed lines delimit the five bins used to score the affordability ratio.

Table 12. Affordability Ratio at Median Household Income. Number of community water systems in various affordability ranges, with associated indicator score. Study period, 2015. The percent of systems shown reflects the state's 2,839 community water systems, with the percent of systems in the affordability analysis indicated in parentheses (n=1,141).

Affordability Ratio Range	Affordability Score	Number of Systems	Percent of All Systems (N=2,839) (Percent of systems in analysis, n=1,141)
0 to <.75%	0	468	16.5 (41)
0.75% to <1%	1	237	8.3 (20.8)
1% to <1.5%	2	260	9.2 (22.8)
1.5% to <2.5%	3	133	4.7 (11.7)
>=2.5%	4	43	1.5 (3.8)
	Sub-total	1,141	40.2 (100)
No Data	N/A	1,698	59.8 (N/A)
	Total	2,839	100

Figure 25. Affordability Ratios at Median Household Income Levels for 1,141 systems. Income data based on ACS 5-Year Summary 2011-2015. See Appendix B3.5 for a map of systems with "No Data".



Affordability Indicator 2: Affordability Ratio for the County Poverty Threshold (AR_{CPT})

This affordability indicator is based on the county poverty income level threshold, which OEHHA refers to as AR_{CPT}. Economically vulnerable households and individuals are expressly considered with regard to their ability to pay for water with this indicator (UN CESCR, 2002).[38]

The AR_{CPT} is calculated as:

$$AR_{CPT} = \frac{System\ wide\ Average\ Bill\ for\ 6\ HCF\ per\ month\ \times\ 12\ months}{County\ Poverty\ Threshold\ for\ Water\ System's\ County}$$

The affordability ratio is expressed as a percentage.

In developing this indicator, OEHHA evaluated several existing datasets and measures of poverty. Ultimately, the county poverty income thresholds calculated by the Public Policy Institute of California (PPIC) were selected (Bohn *et al.*, 2013).[39] The PPIC calculates county poverty income thresholds based on the approach of the US Census, using data on the expenditures needed for a family of four to stay out of poverty within a given county (for more information, see Appendix B2.2.2 Poverty Level Incomes by Water System).

The PPIC thresholds offer two important advantages over other approaches that were considered. First, the income levels identified by each PPIC county poverty income threshold are a proxy for disposable income (e.g., income after taxes)—rather than gross income (See Appendix B2 Income Data Selection & Use).[40] Second, the PPIC's thresholds explicitly account for differences in housing costs across counties in California, thus including a key driver of differential household expenditures across the state (See Box 7: High Cost of Living Considerations). For the 1,141 systems covered, County Poverty Thresholds range from $23,710 to $36,150 (see Appendix B2.2.2 Poverty Level Incomes by Water System for more information).

The affordability ratio AR_{CPT} represents the income of individual households within that county that are at or near the county poverty threshold level. For example, a particular system may have 1% of its households living at the poverty level. In this case, this ratio would only apply to 1% of households. Accordingly, AR_{CPT} is considered in conjunction with information on the

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[38] UN General Comment No. 15 on the Right to Water notes "that poorer households should not be disproportionately burdened with water expenses as compared to richer households."

[39] The PPIC uses these county poverty thresholds to calculate its California Poverty Measure. OEHHA uses the county poverty thresholds in its affordability indicators and thus does not include additional income or benefits households in poverty may receive.

[40] Other studies have explored alternate metrics for poverty-level affordability ratios. Some evaluate affordability at the 20th percentile with discretionary income (Teodoro, 2018) or at every income decile (Sawkins and Dickie, 2005). Alternative sources for poverty-level data include area income estimates produced by the Housing and Urban Development, recommended in the Pacific Institute report (Feinstein, 2018). See Appendix B2 for discussion.

percentage of households within a water system that are at or below the California county poverty threshold. Figure 26 shows the large percentage of households living at or below the county poverty level in many of the 1,141 community water systems covered in our analysis.[41]

Box 7: High Cost of Living Considerations

A household's ability to pay for water hinges on its disposable income, and the cost of other non-water essential expenditures. Ideally, an affordability ratio would reflect disposable income minus non-water essential expenditures. Thus the household's water bill would be compared to its remaining discretionary income and not infringe on other basic needs such as shelter.

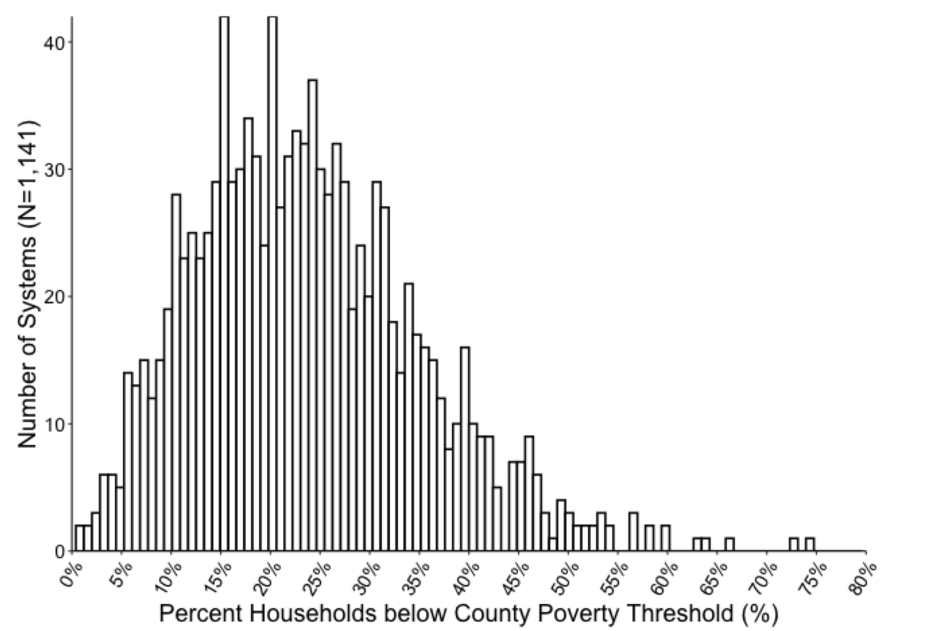
California's high cost of living, which varies regionally, affects the amount of income available to households to pay for water. Two households may pay the same water bill and have the same income level. However, the household in a region with the higher cost of living will have less discretionary income to allot to its water bill.

CPT and DP approximate poverty and deep poverty level disposable incomes with cost-of-living adjustments, but their affordability ratios do not remove housing costs. Therefore, households in expensive housing areas will have a higher CPT but a lower affordability ratio than a household paying the same water bill in a more affordable region. This represents a common limitation. Removing essential expenditures - like housing- from income levels may improve representation of affordability challenges but requires additional assumptions and data that are not readily available at the water system scale, especially in small and rural systems (See Appendix A3 for further discussion).

The affordability ratio AR_{CPT} represents the income of individual households within that county that are at or near the county poverty threshold level. For example, a particular system may have 1% of its households living at the poverty level. In this case, this ratio would only apply to 1% of households. Accordingly, AR_{CPT} is considered in conjunction with information on the percentage of households within a water system that are at or below the California county poverty threshold.

[41] OEHHA sought to improve reliability of census estimates used by aggregating data to water system boundaries and excluding systems with unreliable data. Even so, estimates should be considered in light of their potential unreliability per census measures of error. Appendix B3.4.1 Data Reliability in Census Data provides further details and discussion on this topic.

Figure 26. Percent of Households At or Below County Poverty Thresholds, Across 1,141 Community Water Systems. Data based on ACS 5-Year Summary 2011-2015.



Data Source

State Water Board's electronic annual reports (eAR), 2015.

Public Policy Institute of California (PPIC) California County Poverty Thresholds, 2015.

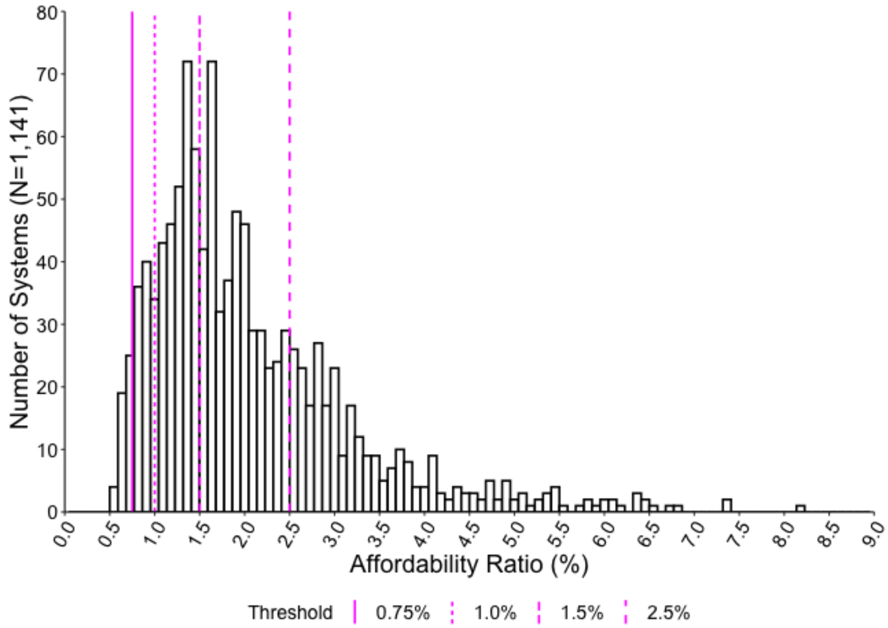
Tracking California, Public Health Institute. Water Boundary Tool. Available at URL: https://trackingcalifornia.org/water-systems/water-systems-landing.

Results

Among the 1,141 systems with the required data, affordability ratios at the poverty threshold (AR_{CPT}) ranged from 0.55% to 8.14%, with a median of 1.75% (Figure 27).

Table 13 scores these AR_{CPT} results accordingly.

Figure 27. Affordability Ratio at County Poverty Threshold (as Percent) for Community Water Systems. Data for 2015, n=1,141 community water systems.†



† The four dashed lines delimit the five bins used to score the affordability ratio.

Table 13. Affordability Ratio at County Poverty Threshold. Number of community water systems in various affordability ranges, with associated indicator score. Study period 2015. Note: the percent of systems shown is reflective of the 2,839 Community Water Systems, with the percent of systems in the affordability analysis indicated in parentheses (n=1,141).

Affordability Ratio Range	Affordability Score	Number of Systems	Percent of All Systems (N=2,839) (Percent of systems in analysis, n=1,141)
0 to <.75%	0	43	1.5 (3.8)
0.75% to <1%	1	95	3.3 (8.3)
1% to <1.5%	2	291	10.3 (25.5)
1.5% to <2.5%	3	411	14.5 (36.0)
>=2.5%	4	301	10.6 (26.4)
Sub-total		1,141	40.2 (100)
No Data	N/A	1,698	59.8 (N/A)
	Total	2,839	100

Affordability Indicator 3: Affordability ratio for the deep poverty threshold (AR_{DP})

This indicator addresses some of the most vulnerable households with an affordability ratio for households in deep poverty (AR_{DP}). Here, deep poverty is defined as being at half the county poverty-level income, based on the PPIC county poverty thresholds. (See discussion in Affordability Indicator 2.) AR_{DP}, the affordability ratio at the Deep Poverty threshold, is calculated as:

$$AR_{DP} = \frac{System\ wide\ Average\ Bill\ for\ 6\ HCF\ per\ month\ \times\ 12\ months}{\frac{1}{2} \times\ County\ Poverty\ Threshold\ for\ Water\ System's\ County}$$

Figure 28 shows that for many community water systems included in the assessment, a substantial fraction of households are at or below the deep poverty level.[42] Deep Poverty levels ranged from $11,860 to $18,080 (median = $14,820) (See Appendix B2.2.2 Poverty Level Incomes by Water System). These households are likely facing affordability challenges across a range of essential needs.

Research into trade-offs among water bills and other essential expenditures is scarce in the U.S., but two recent studies suggests that households facing unaffordable water will forgo housing and health related bills to pay for water (Cory and Taylor, 2017; Rockowitz *et al.*, 2018). Estimating affordability for households with extremely vulnerable income levels allows for representation of economically marginalized groups. The AR_{DP} is considered in conjunction with a measure of the percentage of households that live at or below the deep poverty income level within a water system. Still, this may not capture families or individuals living without homes, or families facing seasonal, temporary or inconsistent work, or other conditions that may result in extreme poverty.

Data Source

State Water Board's electronic annual reports (eAR), 2015.

Public Policy Institute of California (PPIC) California County Poverty Thresholds, 2015.

Tracking California, Public Health Institute. Water Boundary Tool. Available at URL: https://trackingcalifornia.org/water-systems/water-systems-landing.

[42] OEHHA sought to improve reliability of census estimates used by aggregating data to water system boundaries and excluding systems with unreliable data. Even so, estimates should be considered in light of their potential unreliability per census measures of error. Appendix B3.4.1 Data Reliability in Census Data provides further details and discussion on this topic.

Figure 28. Percent of Households At or Below County Deep Poverty Level Thresholds, Across 1,141 Community Water Systems.

(Based on ACS 5-Year Summary 2011-2015).

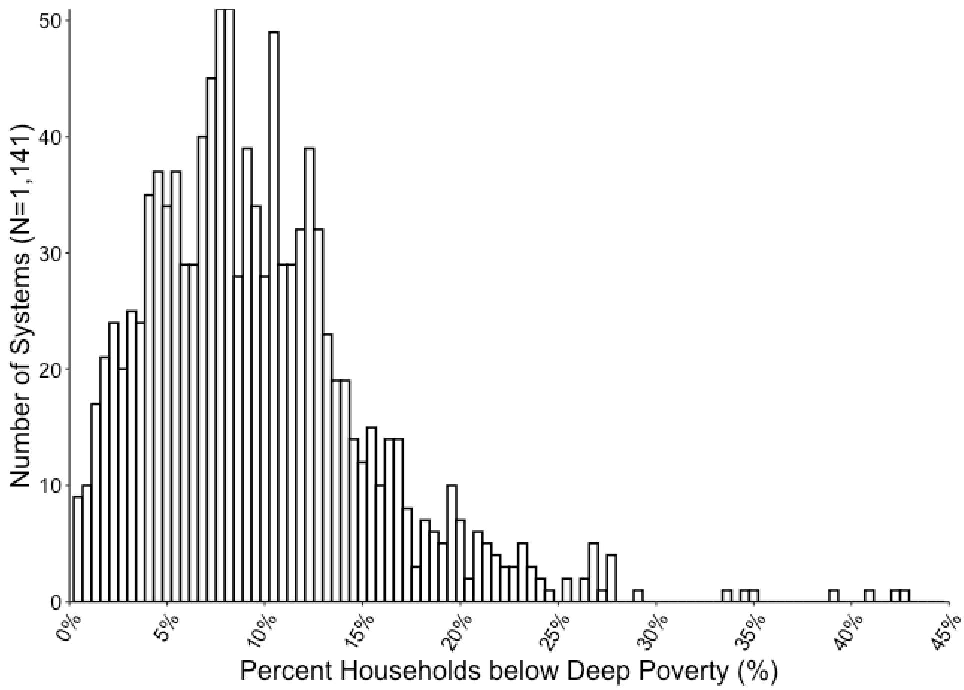


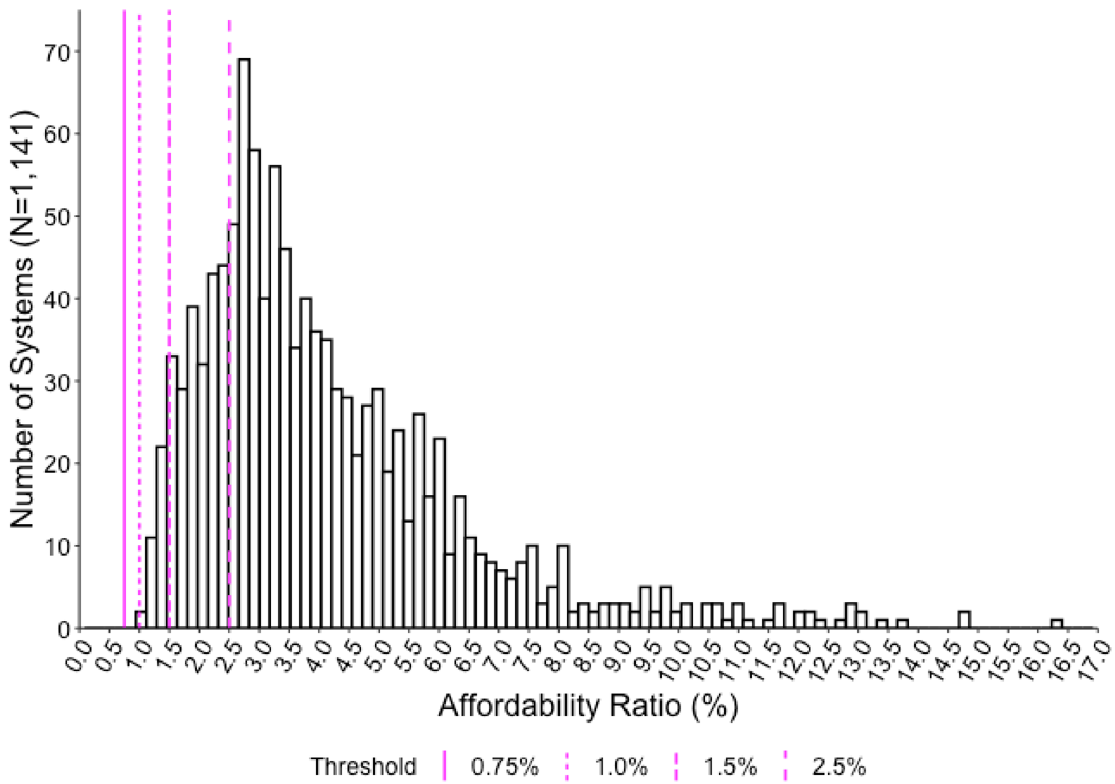
Table 14. Affordability Ratio and Indicator Scores at Deep Poverty Level. Affordability Ratio and Indicator Scores at Deep Poverty Level. Number of community water systems (n=1,141 of 2,839 community water systems) falling in various affordability ranges, with associated indicator score. Note: the percent of systems shown is reflective of the 2,839 Community Water Systems, with the percent of systems in the affordability analysis (n=1,141) indicated in parentheses.

Affordability Ratio Range	Affordability Score	Number of Systems	Percent of All Systems (N=2,839) (Percent of systems in analysis, n=1,141)
0 to <.75%	0	0	0 (0)
0.75% to <1%	1	0	0 (0)
1% to <1.5%	2	43	1.5 (3.77)
1.5% to <2.5%	3	213	7.5 (18.67)
>=2.5%	4	885	31.2 (77.56)
	Sub-total	1,141	40.2 (100)
No Data	N/A	1,698	59.8 (N/A)
	Total	2,839	100

Results

Table 14 and Figure 29 show the affordability ratios for those in deep poverty. They show that, by almost any measure of affordability, water is unaffordable for the majority of people living in deep poverty.

Figure 29. Affordability Ratio at Deep Poverty Level (as Percent) for Community Water Systems. Data for 2015, n=1,141 community water systems.†



† The four dashed lines delimit the five bins used to score the affordability ratio.

A Composite View of Water Affordability

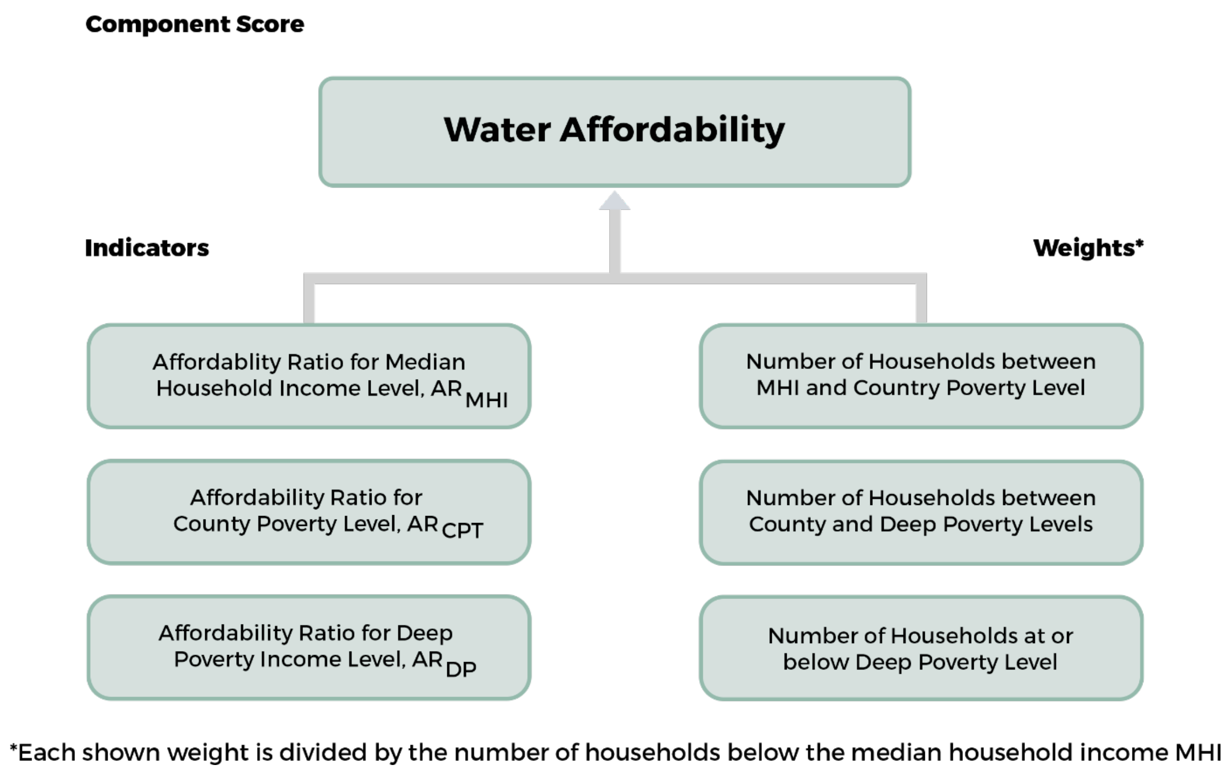
OEHHA's composite affordability score is based on a household-weighted composite affordability ratio that is based on the three aforementioned affordability ratios (Figure 30). Households served by any given system can have a range of income levels. For example, some water systems may serve large proportions of households with very high-income levels, very few households at the poverty level, and no households in deep poverty. Other systems may serve most households earning around the median income level, with few households living in poverty. In other cases, the median income level and poverty income levels may be very similar. Large systems, in particular, may serve large numbers of both high- and low-income households. Ultimately, the percent of households living at different income levels must be assessed in order to understand the representativeness of any one of the three affordability indicators.

Scoring Approach

Our approach addresses these variations by using the three individual affordability indicators, plus information on the percentage of households at the three income levels, to create a household-weighted affordability ratio. To create a composite component score, each of the three affordability indicators is weighted by the percentage of households at or below the corresponding income level within the water system. The composite affordability ratio sums these household-weighted indicators to construct a system-wide, household-weighted affordability ratio focused on the bottom half of the income distribution. This provides a better understanding of how water rates affect a water system's lower-income households while still providing important information on the overall affordability of the system's water bills for an essential volume of water. See Appendix B4 Composite Affordability for more detail and a discussion of the limitations of this approach.

Ultimately, the composite affordability ratio is given a score from 0 (most affordable) to 4 (least affordable). This composite affordability score is best viewed in conjunction with the aforementioned individual indicators so that one can identify particular burdens faced by households at the median, poverty, or deep-poverty income levels. As such, the three affordability indicators and the composite affordability ratio should be considered jointly when screening a system for water affordability challenges.

Figure 30. Creation of a Composite Water Affordability Score for Each Water System.



Data Source

State Water Board's electronic annual reports (eAR), 2015.

US Census American Community Survey (ACS) 5-Year Data: 2011 – 2015

Public Policy Institute of California (PPIC) California County Poverty Thresholds, 2015.

Tracking California, Public Health Institute. Water Boundary Tool. Available at URL:

https://www.trackingcalifornia.org/water-systems/water-systems-landing

Estimating the Composite Affordability Ratio for a Community Water System

The composite affordability ratio is calculated as described in Figure 30:

$$Water\ System\ Composite\ Affordability\ Ratio = \frac{AR_{MHI} \times (HH_{MHI} - HH_{CPT}) + AR_{CPT} \times (HH_{CPT} - HH_{DP}) + AR_{DP} \times HH_{DP}}{HH_{MHI}}$$

where HH_{MHI}, HH_{CPT}, and HH_{DP} are the numbers of households (HH) below the median household income (MHI), county poverty threshold (CPT) and deep poverty (DP).

To estimate the composite affordability ratio for each water system, OEHHA:

- Calculated the number of households within each affected income group associated with an affordability ratio. AR_{MHI} is associated with the number of households in the water system between the median household income (MHI) and the county poverty threshold: HH_{MHI}-HH_{CPT}. Similarly, AR_{CPT} is associated HH_{CPT} - HH_{DP}. AR_{DP} is associated with HH_{DP}.
- Multiplied each AR by the number of associated households. Summed together the three household-weighted affordability ratios and divided by the total number of households below the median income level within the water system. In this way, the bottom 50% of the income distribution, below the MHI, is represented for this composite indicator. For the 22 systems that have the MHI below the CPT, their composite ratio was still measured as the household-weighted ratio below the MHI (See Appendix B4 Composite Affordability).

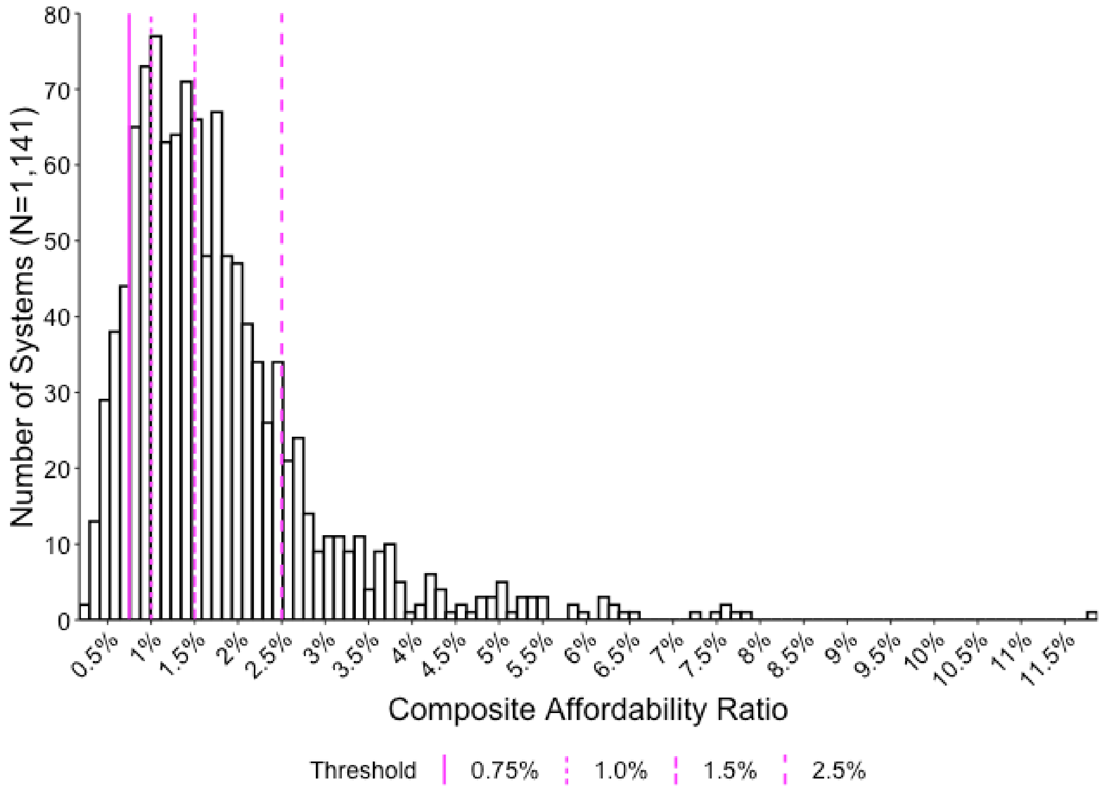
Results

Table 15 and Figure 31 show the distribution of the composite affordability ratio for the 1,141 community water systems with sufficient data to estimate affordability ratios. A substantial fraction of water systems analyzed – 17% of 1,141 systems - had a composite affordability score showing that water bills were greater than 2.5% of income for the average household below the MHI across water systems.

Table 15. Composite Affordability Ratios and Associated Scores for Community Water Systems (n=1,141 with scores), Study Period 2015. Note: the percent of systems shown is reflective of the 2,839 Community Water Systems, with the percent of systems in the analysis indicated in parentheses (n=1,141).

Affordability Ratio Range	Composite Affordability Score	Number of Systems	Percent of All Systems (N=2,839) (Percent of systems in analysis, n=1,141)
0 to <.75%	0	123	4.3 (10.6)
0.75% to <1%	1	151	5.2 (13.06)
1% to <1.5%	2	298	10.4 (25.8)
1.5% to <2.5%	3	383	13.4 (33.4)
>=2.5%	4	203	6.9 (17.2)
	Sub-total	1,141	40.2 (100)
No Data	N/A	1,698	59.8 (N/A)
	Total	2,839	100

Figure 31. Composite Affordability Ratio: Weighted by Prevalence of Households at Different Income Levels At or Below the MHI. Data for 2015, n=1,141 community water systems†.

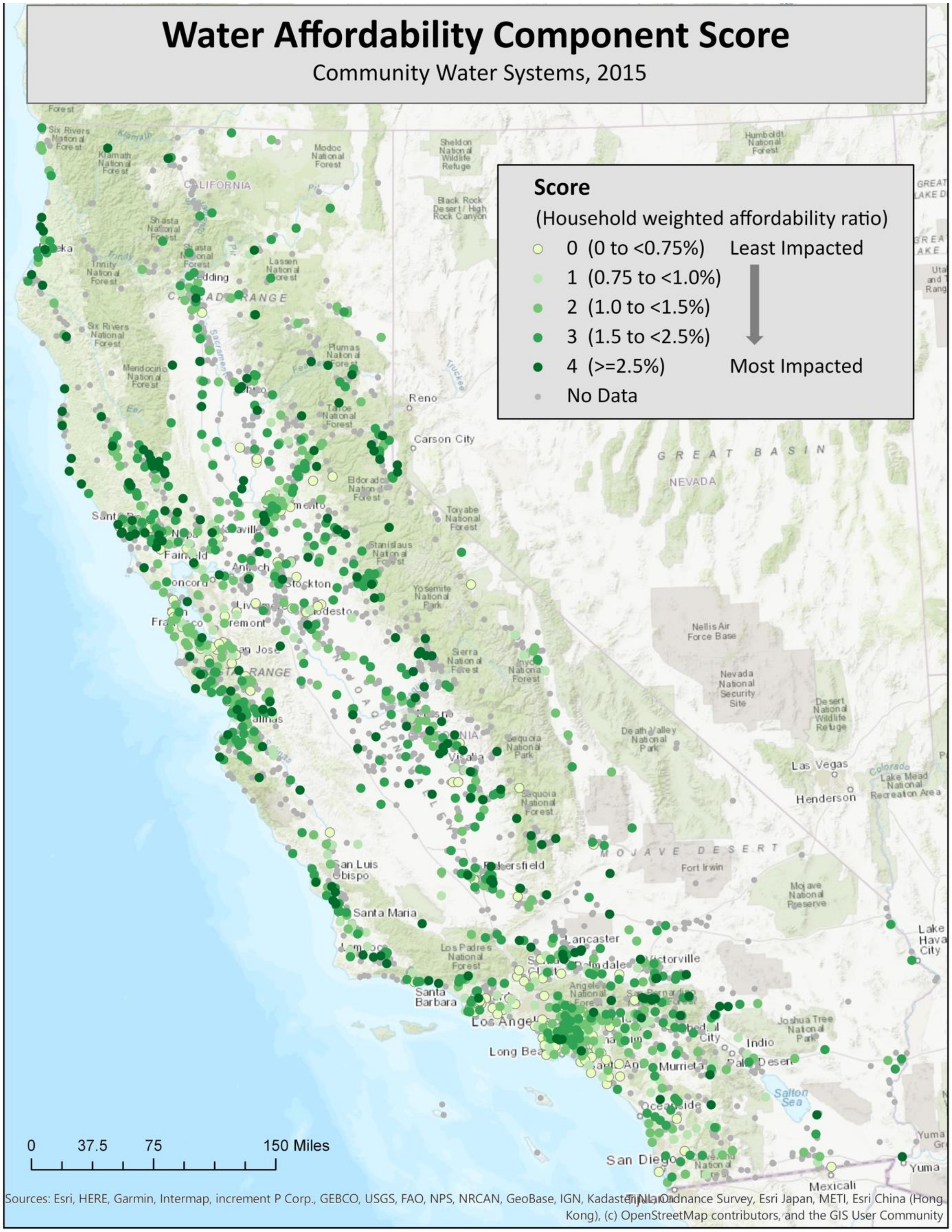


† The four dashed lines delimit the five bins used to score the affordability ratio.

Table 15 also shows the composite affordability scores, which ranged from 0 to 4, with lower scores representing systems with higher water bill burdens for households below the median income level. The mean score was 2.34 and the median was 3. Overall, approximately half of systems analyzed (n= 577 of 1,141) had scores of 3 to 4, corresponding to affordability ratios of greater than 1.5%. Approximately 10.6% of systems analyzed had a composite score of 0, indicating very affordable water.

The scores for the composite affordability ratios for the community water systems with adequate affordability data are marked on a map of California in Figure 32. The map highlights a cluster of systems along the North Coast with high affordability scores (i.e. more unaffordable water), as well as the Central Coast region, the southern San Joaquin Valley and the Imperial Valley/Inland Empire region. However, a number of exceptions are apparent. The next sections analyze the scores by system size, disadvantaged community status and region to further explore factors associated with affordability.

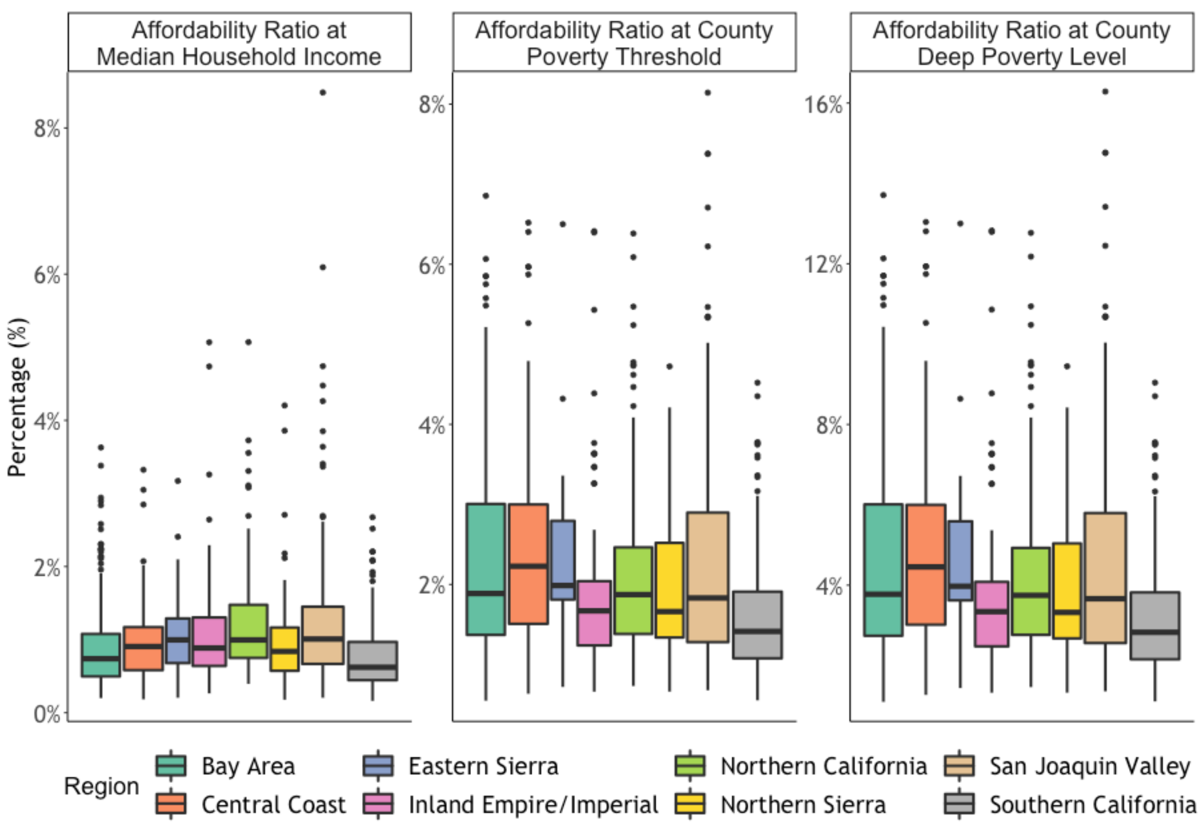
Figure 32. Composite Water Affordability Scores for Community Water Systems across the State. Lower scores mean less affordable water. Colored circles are for 1,141 systems with adequate data to score. Smaller, grey circles indicate systems without data.



Affordability Ratios by Region

Where Figure 32 above maps the composite affordability scores on a statewide scale, Figure 33 shows the affordability ratios by region of the state for the three different income levels – MHI, county poverty threshold and deep poverty. In these box plots, the median affordability ratio is represented by the horizontal line in each of the box plots (See Figure 16 for a map of regions.) The figure shows that, regardless of region, affordability challenges are faced by at least some systems at each of the three income levels. It also shows that, overall, at the median income level, water is fairly affordable for half the systems in the assessment regardless of region. Households earning county poverty and deep poverty level incomes face substantially higher affordability challenges relative to those earning the median income in the same system in every region.

Figure 33. Affordability Ratios for Three Income Levels by Region. Note that y-axes differ in scale across boxplots. Data for water bills (eAR 2015) and income (ACS 5-Year 2011-2015 and PPIC 2015), n = 1,141 community water systems.



Boxplot width is proportioal to the number of systems in each region. The number of systems represented: Bay Area (n=152); Central Coast (n=158); Eastern Sierra (n=58); Inland Empire/Imperial (n=116); Northern California (n=149); Northern Sierra (81); San Joaquin Valley (n=179); Southern California (n=248).

But again, there are challenges for all regions even at median income level. Not shown in the figure, the Northern California, San Joaquin Valley, Eastern Sierra, and Inland Empire/Imperial regions have the highest household-weighted affordability ratios for households earning below the median income level, with averages of 2.1%, 2.05%, 1.9% and 1.9%, respectively. Accordingly, these regions have the lowest composite water affordability scores, indicating that these regions have relatively less affordable water overall. Of course, data for all Community Water Systems would be required to gain a complete view of region wide trends.

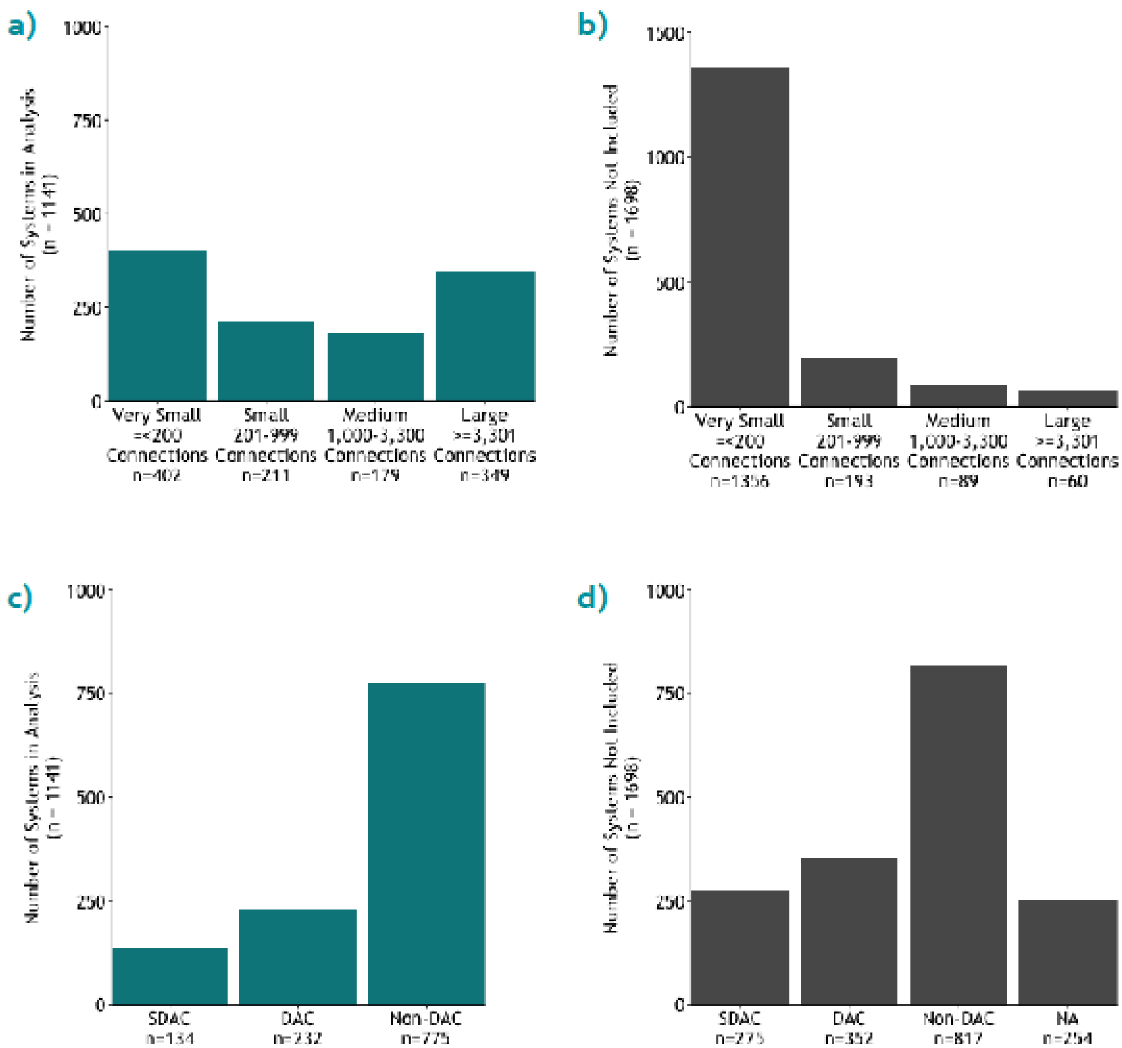
Affordability Data Gaps: A Key Consideration

Of the 2,839 community water systems in OEHHA's list, only 1,545 water systems reported water bill data in the electronic annual report. Therefore, as a starting point, only 54% of community water systems had water bill data with which OEHHA could estimate affordability ratios. Of the 1,545 water systems with water bill data, 1,515 systems also had US Census income data available. Of these 1,515 systems, OEHHA excluded 374 systems due to several exclusion criteria discussed in Appendix B3 Data Cleaning & Exclusions and B4 Composite Affordability and Box 8. Thus, the final list of systems in the affordability analysis included 1,141 systems or 40% of community water systems, compared to 100% and 91% for the Water Quality and Water Accessibility Components, respectively. These 40% of systems serve approximately 91% of the California population.

Missing data is a critical challenge that leaves us with gaps in our understanding, and can also bias our interpretation of results (See Box 8: What About Systems That Were Not Included?). Small systems make up about 62% of community water systems in California. However, just 35% of systems that were included in the affordability assessment are small (i.e., less than 200 connections). Medium and large systems make up approximately 9.4% and 14.4% of the community water systems in California, respectively. However, approximately 15.7% and 30.6% of systems included in the affordability assessment are medium or large, respectively. As such, these systems are overrepresented compared to small systems. In sum, this indicates a bias by system size in the missing data. The proportion of SDAC, DAC, and Non-DAC systems in OEHHA's analysis is relatively similar to the overall distribution among all California community water systems, however SDAC systems are somewhat underrepresented in the current analysis, relative to DAC and Non-DAC systems, and a large number of non-DAC systems have missing data (See Figure 34).

It is important to note that as more system-level affordability data becomes available and methods improve to increase data reliability, the aforementioned affordability findings across water systems would change. Some changes in overall results would be due to having new data availability–e.g. the inclusion of more small water systems. However, results may also change within systems, if water system practices change over time. All things constant, based on the initial findings shown in Figure 32 and Figure 33, OEHHA expects the affordability ratios to indicate more systems with affordability challenges if: 1) data from smaller, SDAC, DAC and non-DAC water systems become available, and 2) current trends of water rates increasing faster than inflation persist. The availability of rate assistance and new efforts to mitigate these challenges could improve affordability ratios, however. A variety of efforts may help address these data gaps, which will be explored in OEHHA's public workshops. Certainly, OEHHA will fold in additional data from the electronic Annual Report as it becomes available. Alternatively, survey or modeling efforts to fill in missing data could also be useful.

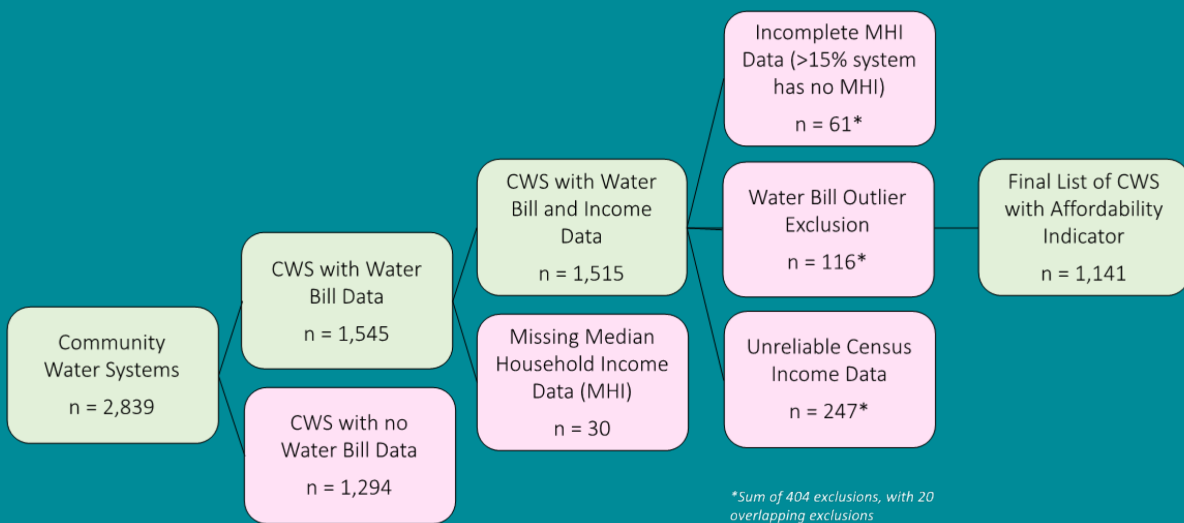
Figure 34. Comparison of System Size and DAC Status for Systems Included in Analysis Versus Systems Not Included in Analysis. Figures indicate systems included in the current analysis (dark green bars, Figures a and c) and systems not included in analysis (dark gray bars, b and d). Figure 34a and Figure 34b indicate system size by connections. Figure 34c and Figure 34d indicate disadvantaged community status for severely disadvantaged (SDAC), disadvantaged (DAC), and non-disadvantaged (Non-DAC) water systems. Data for water bills (2015) and income (ACS 5-Year 2011-2015).



Box 8: What about Systems that Were Not Included?

About 60% of water systems do not have adequate data to estimate affordability ratios. Some systems are not included in the analysis because they lack reported water cost data in the eAR, had potentially inaccurate water bills (outliers), or because they lack reliable census data for which to calculate income-level statistics. The flow chart below indicates why systems are not included in the affordability indicator analysis (See Appendix B3.2 for more details):

- 76% of the 1,698 systems not included in the affordability analysis had no water bill data reported in the eAR.
- 24% of the 1,698 systems not included in the affordability analysis had missing income data or were excluded due to unreliable income or water bill data for calculating affordability ratios.



Characteristics of systems with missing or excluded data:

- The systems with missing or excluded data serve approximately 8.7% of the state's population. This means that while a large fraction of systems are missing data, the 1,141 systems shown in OEHHA's results serve a large majority of Californians.
- Very small systems account for 80% of the 1,698 systems not analyzed for affordability indicators.
- Severely disadvantaged community water systems are overrepresented relative to DAC and Non-DAC water systems in the list of systems not analyzed for affordability indicators. In particular, 21.5% of systems not included in the analysis are SDAC, whereas they make up 15.8% of systems (n=2,585) that have adequate MHI data in the full community water system list.

To truly know what we might expect if data for systems with missing data were filled in, data filling and/or modeling efforts are needed. However, from the above characteristics one might expect:

- OEHHA anticipates that data filling efforts will reveal *more systems with higher water bills* since current results indicate that smaller water systems have the highest water bills, on average, and a majority of systems with missing data are small.
- For systems with missing data that are both small and SDAC or DAC (an estimated 34% of missing systems for which we have adequate income data), we might expect the systems with missing data to have relatively *low* (i.e., more unaffordable) *composite affordability scores*.

Additional Research/Next Steps

Future versions of this tool will explore opportunities to incorporate newer data as well as additional metrics, where possible. Specifically, OEHHA will explore several additional indicators for water affordability (See Table 18), and continue to consider what counts for 'basic' water needs, depending on the number of people in the household. Future areas to incorporate in the affordability component include households relying on private wells or state small systems. From an affordability perspective, indicators could incorporate the costs to households to maintain wells, test and treat their water, and manage well failures. Both data and new approaches are needed to incorporate the affordability challenges faced by people relying on these water sources. Additionally, integrating an analysis of socio-economic indicators, such as the percentage of households using low-income assistance programs to pay for utilities, has been suggested to support the identification of systems and households with a high-water affordability burden (Mack and Wrase, 2017; Teodoro, 2018).

The current report leveraged the dataset of 2015 water bills for community water systems, which will provide a baseline against which future years of data can be compared. This year was also selected to coincide with the Water Board's Low-Income Rate Assistance Report, and to represent water bills during the period of study for water quality (2011 to 2019). As the eAR is being continually updated, and the Water Board is adding new data as part of its Needs Assessment, future versions will update this data accordingly. More recent questions included in the electronic Annual Report surveys could provide data for new indicators, e.g. on water service disconnections.

With respect to income, an improved representation of non-water essential costs could enable better representation of household affordability challenges at income levels within systems. As these data become available, OEHHA can incorporate these costs with water bills to comprehensively assess the affordability of water for domestic use and sanitation.

The human right to water includes the right to affordable water for sanitation purposes. While this report assumes that the 6 HCF reported is used by households to cover basic hygiene, the water bills used do not explicitly consider wastewater and sanitation costs. Future versions will explore the possibility of adding these costs to the affordability analysis.

Summary and Key Findings for Affordability

In the present assessment, water affordability is evaluated for households at the water system scale (US EPA, 1998). The resulting affordability ratios for each water system are a first-order approximation of the types of affordability challenges that individual households face at particular income levels at and below the MHI. To truly measure affordability at the household level, individual water bills and income levels would be required, but to understand trends and the scale of challenges, some level of aggregation to the water system level is needed.

Measuring water affordability at the water system scale provides a useful basis for screening for challenges and tracking progress.

As a tracking tool, OEHHA's set of affordability indicators can be used in a several ways. The three affordability indicators reflect the affordability ratios for households at the median, poverty, and deep poverty income-level within a particular water system, and thus provide measures of affordability both for the general populations served by a system and those facing economic challenges. The AR_{MHI} corresponds to the water bill burden for the 50^{th} percentile household within each water system–if AR_{MHI} is high, water bills are likely a substantial burden for half of the water system's households. This reflects a water-system level challenge wherein household water affordability may threaten the water system's financial capability. AR_{CPT} and AR_{DP} reflect a screen for water bill burden on vulnerable households. Low water bill burdens at these levels reflect affordable rates for households at or near poverty levels. Finally, the household-weighted composite ratio reflects affordability concerns for a water system that may be driven by high water bills and/or high percentages of households at low income levels. The composite ratio should thus be considered in light of its component parts – the three affordability indicators and two household poverty indexes representing the proportion of households at different income levels.

In sum, a number of observations can be observed:

Water Bills

- Water bills at the essential needs level of 600 cubic feet (6 HCF) - corresponding to 150 gallons per household per day range by a factor of ten (approximately $15 per month to $175 per month) across community water systems.
- Some of the highest bills reported are for very small water systems, but there is variability in water bills across all system sizes.

Affordability Ratio for the Median Household Income Level

- At the median household income level, water is relatively affordable across systems. Approximately 62% of water systems have an AR_{MH} (water bills as a proportion of median household income) of less than 1%.
- A majority of water systems with AR_{MHI} greater than 1.5% are economically disadvantaged, i.e. DAC or SDAC. Among the 1,141 water systems with affordability ratios, 15.4% (n=176) had water bills for 6 HCF exceeding 1.5% of the median household income. Of these, 65% (115 systems) are severely disadvantaged or disadvantaged systems.
- For 22.8% of water systems, AR_{MHI} is between 1-1.5%, indicating potential future challenges if water rates increase.

- Geographically, AR_{MHI} outcomes are highest overall in Northern California and the San Joaquin Valley, although there is a substantial spread in affordability ratios within each region, with affordability challenges present for some systems in each region.

Affordability Ratio for County Poverty Threshold Income Level

- In a majority of water systems, water bills exceed 1.5% of county poverty level incomes. In these systems, this signifies that households earning at the county poverty level face significant affordability challenges. The average AR_{CPT} is 2.06% (median = 1.75%).
- One quarter of water systems receive the highest affordability score for county poverty level affordability, indicating that water bills are at least 2.5% of disposable income. In these systems, households earning at the CPT face considerable affordability burdens.
- Geographically, AR_{CPT} outcomes are highest overall for water systems in the Central Coast (mean = 2.4%), San Francisco Bay Area (mean = 2.3%), San Joaquin Valley (mean = 2.26%), and Eastern Sierra (mean = 2.25%), although there is substantial spread with significant affordability challenges present for some systems in each region.

Affordability Ratio for Deep Poverty Threshold Income Level

- The average affordability ratio for households earning deep poverty level incomes (AR_{DP}) is 4.1% (median = 3.5%).
- In the vast majority of systems (77.6%), water bills exceed 2.5% of deep poverty level incomes. In these systems, this signifies that households earning at the deep poverty level face significant affordability challenges.
- Geographically, AR_{DP} outcomes are highest overall in the Central Coast (mean = 4.8%), San Francisco Bay Area (mean = 4.7%), San Joaquin Valley (mean = 4.5%), and Eastern Sierra (mean = 4.5%).

Overall

- Affordability ratios for county poverty and deep poverty level incomes are substantially higher than for median income levels across systems. This underscores the burden that low-income households face in paying for water.
- 50% of water systems have a composite affordability ratio greater than 1.5%. This signifies that households earning below the median income level face substantial affordability challenges in half of the systems with data.
- 60% of systems evaluated did not have adequate data. The systems with missing or excluded data serve approximately 8.7% of the state's population. A majority of systems missing data are small systems. Data gaps in affordability will need to be continually addressed.

A Holistic View of Water Systems: Applications and Cases

Applications

Once CalHRTW is populated with data, it can help shed light on the quality, accessibility and affordability of drinking water in California. The tool's results can then be used in five main ways, at the water system or statewide level:

- To monitor and update progress in achieving the overall human right to water.
- To assess individual indicator scores.
- To assess scores for a particular component (e.g., composite water quality score).
- To compare measures of water quality, accessibility, and affordability at the system level, or across water systems.
- To assess which water systems are most vulnerable

Assessments of CalHRTW's results can be used to monitor California's progressive realization of the human right to water over time. It can be useful to regulators, policy-makers, water system operators, and members of the public, who may approach solutions to water issues in different ways and with different concerns, making our state more collectively equipped to understand and face its water challenges.

For example, regulators or water system operators may have information on the status of compliance for a particular water system. The tool can augment this understanding in several ways. First, the tool provides additional water quality information, such as exposure metrics. This can help decision-makers consider potential exposure threats *alongside* compliance challenges. Similarly, system operators and water planners can utilize previously unquantified metrics, such as those that measure affordability challenges, to weigh the needs and stresses of individual communities in their decision-making. Additionally, by viewing information across the three principal components, those who oversee water systems can consider disparate but interrelated characteristics of water delivery and water service that are not usually considered together.

As for members of the public, including community groups and community members already deeply engaged in water issues, this tool can provide a useful, consolidated source of information across issues, regions, and time periods. For community members who may currently lack access to technical information, this tool offers a useful way to access, decipher and visualize the information they need to have a productive dialogue with water systems and regulators.

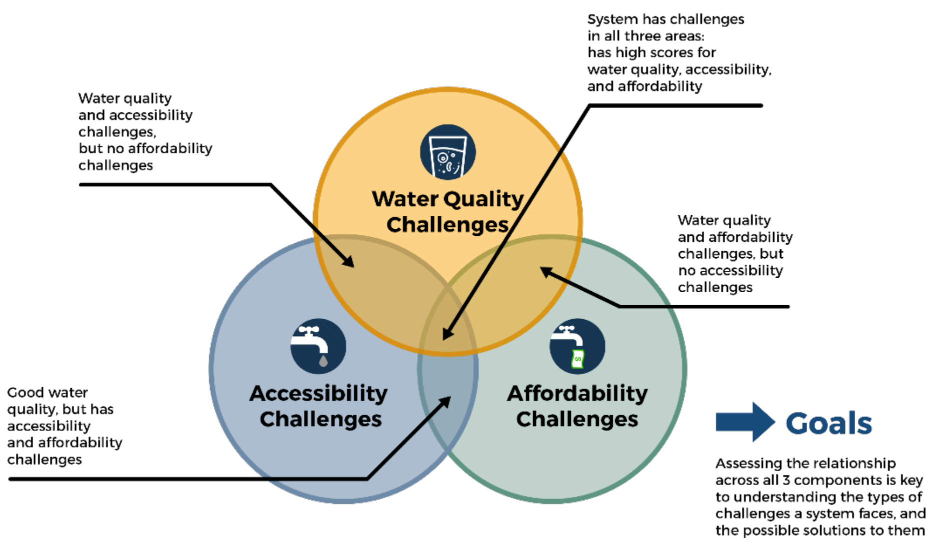
Finally, this tool allows for regional and statewide assessments of key trends across components. Previous initiatives have documented particular water challenges across the state, as well as a wide variety of challenges in particular regions. This tool, however, brings together information on water quality, accessibility and affordability, allowing the state and its residents to gain a holistic understanding of big-picture trends. In doing so, the tool may help Californians achieve the human right to water in a more consistent, equitable way.

The data tool's usefulness is best illustrated by Figure 35. The three components are shown in circles and are described in terms of water quality, accessibility, and/or affordability challenges. Water systems may face one or more challenge—or even all three. These challenges may overlap with and even reinforce each other. In other cases, water systems may have no challenges in any of the three components, which is also critical information to capture. Effectively, the tool helps to highlight systems with challenges, alongside systems that are doing well. Both pieces of information are critical to assessing achievement of the human right to water.

Using this tool, a decision-maker or member of the public may ask: Which systems show particular types of water quality challenges, or which systems face affordability challenges? They can also ask: Which systems face *both* affordability challenges *and* water quality challenges; or which systems enjoy good water quality, but face threats to accessibility? In tracking progress towards the human right to water, the state can also assess how many systems are not facing challenges versus how many are.

This section provides examples of the types of information the data tool generates and shows how multiple, overlapping challenges can be identified. Assessing and understanding these combined challenges is critical for devising relevant, sustainable and equitable solutions to the provision of water statewide.

Figure 35 Diagram of the Three Components in the Human Right to Water Framework and Data Tool, and the Combinations of Challenges a Water System May Face.



Hypothetical Case Studies

Water systems in the state operate under diverse sets of conditions, and face a range of water challenges. This section presents three hypothetical cases to show how the tool functions to understand these conditions. Ultimately, as these cases highlight, the data tool enables an assessment of crosscutting issues, at multiple levels (e.g., at the indicator, subcomponent or component level).[43]

Hypothetical System A

This system faces challenges in all three components: water quality, accessibility and affordability.

This hypothetical small water system is located in a rural agricultural region, has fewer than 200 service connections, and serves 500 people. The median household income is $40,000. The system has one groundwater well and no backup sources. On average, water bills for 6 Hundred Cubic Feet (HCF) in this community are $65 per month, or $780 per year.

From 2011 to 2019, the system faced a number of **water quality** challenges. Exposure levels were high and the system faced a number of compliance hurdles. In particular, during the nine-year time period, the system had average concentration levels of nitrate between 50 and 65 milligrams per liter (mg/L) in eight of the nine years. As the MCL for nitrate is 45 mg/L (or 10 mg/L as Nitrogen), this information indicates that potential exposure was high (i.e., concentration levels exceeded the MCL), and the duration of high potential exposure was long. During this time period, the system also received at least one nitrate MCL violation in eight of the nine years, and at least one TCR/rTCR MCL violation in eight of the nine years. Thus, the duration of the non-compliance period was also long. All data requirements were met.

Regarding **accessibility**, with only one groundwater well and no backups, the system is considered to be physically vulnerable to water outages.

With regard to **affordability**, residents served by the system also face a number of challenges. Twenty percent of households in this system live at or below the county poverty threshold of $21,151. A household earning the median income level would be spending two percent of its income on water. This is nearly double what research has determined is the average spent on water in industrialized countries (Smets, 2017) and 0.5 percent higher than the threshold used to guide financial assistance to DACs in the State Drinking Water Revolving Fund. Households living at the county poverty level of $24,151 would pay 3.2 percent of their income ($780/$24,151) on water. Those living in deep poverty ($12,075) would spend nearly 6.5% of their income on water. Because 20 percent of this water system's households lives at or below the county poverty threshold, a significant portion of economically vulnerable residents living in this community are particularly vulnerable to affordability challenges. Figure 36 depicts results

[43] In this report, we focus on the overall component outcome, rather than subcomponent outcomes.

conceptually for each of the indicators. Table 16 further serves to summarize the key information the tool can provide.

As described above, the results for nearly all indicators provided in the tool signal that this system faces serious challenges. However, how is one to use this information? To begin, the decision-maker may be interested in comparing this system to others to determine whether this is a system with relatively large or average challenges. Doing so could assist the decision-maker in determining what types of solutions might benefit the community served by the water system, and what types of resources might be best suited to address the community's needs. For example, should the system consolidate with a nearby larger system, be assigned an administrator, or be allocated resources (e.g., training and capacity building, technical decision-making support, or financial support)?

Second, the benefit of viewing information specific to each component, and across components, is that when the decision-maker devises solutions to these challenges, she or he can carefully assess trade-offs. For example, it could prove critical to address the fact that System A has had on-going water quality problems for an acute contaminant such as nitrate. The community served by the system may need to consider developing a new well, an intertie with a nearby system, or a treatment facility. However, such solutions could potentially increase the cost of delivering water. Since affordability is already a challenge for households served by this system, a sustainable and equitable solution would need to address the challenges described in all three component areas, including affordability.

Figure 36. Chart Summarizing Hypothetical Case Study Results. The rows show the results for each of the three hypothetical water systems. The columns represent the 9 indicators in the three components. The color of each box indicates the level of concern regarding a specific indicator. Dark blue boxes represent greater concern. Medium-blue boxes indicate a more moderate level of concern, light blue boxes indicate little concern, and white boxes indicate no concern.

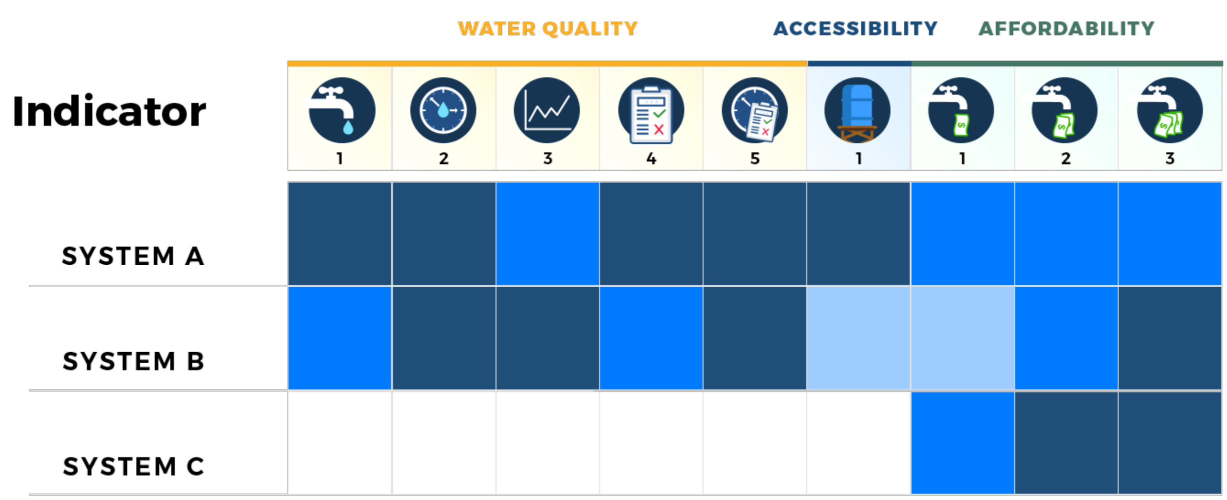


Table 16. Summary Table for Hypothetical System A. This systems faces water challenges in all three areas. This chart provides an example of how information from CalHRTW can be translated into a clearly legible diagram, accessible to all kinds of stakeholders.

Component	Indicator	Description of outcome
Water Quality	**Potential high exposure**	Eight years of potentially high exposure levels of nitrate, averaging between 50-65 mg/L.
	Maximum duration of potential high exposure	Eight years of high nitrate levels.
	Data availability	The system has monitoring data for all contaminants.
	Non-compliance with primary drinking water standards	During the nine-year study period, the system had one or more MCL violations in eight of the nine years.
	Maximum duration of non-compliance	Eight years of nitrate MCL violations.
Water Accessibility	**Physical vulnerability to water outages**	One groundwater well.
Water Affordability	**Affordability ratio at the median household income**	2%
	Affordability ratio at the county poverty threshold	3.2%. Here, 20% of the population lives at or below the county poverty income level.
	Affordability ratio at the deep poverty threshold	6.5%

Hypothetical System B

This system faces some challenges in water quality and accessibility, but the key challenge lies in affordability.

This mid-sized hypothetical system serves roughly 3,300 residents, has 800 connections, and is located in a rural, non-agricultural region of the state. The system has two surface water intakes and one backup well. The median household income is $39,000. Average water bills for 6 HCF of water are $55 per month, or $660 per year. From 2011 to 2019, the water system received notification of on-going total coliform violations, with TCR MCL violations in four of the nine years. All data requirements were met.

With regard to ***accessibility***, the number and type of sources do not signal a physical vulnerability challenge.

However, with regard to ***affordability***, the residents who are served by the system face key challenges. The county poverty level is $25,361. Nearly 30 percent of households served by this water system live at or below this level. Nearly 5 percent of households live at or below the deep poverty level of $12,680. Thus, while the affordability ratio for households at the median income level is 1.7 percent ($660/$39,000), the affordability ratio for households living at or below the county poverty level is significantly higher (2.6 percent), and is even higher for those living in deep poverty level (5.2 percent).

These affordability results highlight the usefulness of having multiple affordability indicators. In this case, while the affordability ratio at the median household income may not signal a major concern, the presence of a large proportion of households who live at or below the poverty level indicates that there are pressing affordability challenges that might otherwise be missed.

As with System A, Figure 36 highlights the indicators that show key challenges in this system. A decision-maker assessing System B would likely want to address the ongoing TCR violations. However, the most urgent area of focus may be affordability challenges. At least 50 percent of households spend 1.7 percent or more of their income on water bills. Thirty percent or more of households face more acute affordability challenges.

Hypothetical System C

Here, a system has relatively high water quality and accessibility, but relatively low affordability.

The third hypothetical system, System C, is located in an urban county, serves nearly 30,000 people and has over 10,000 service connections. The median household income in this community is $42,100. The system has more than ten groundwater wells, one surface water intake and two backup wells. The average water bill for 6 HCF is $85 per month, or $1020 per year.

This system has had no **water quality** challenges in the time period, and has strong physical **accessibility**, based on the physical vulnerability indicator. The main challenge for this system is with regard to **affordability**.

At least 50 percent of the households served by this water system are paying approximately 2.4 percent of their income on water. Ten percent of the community's households earn income levels at or below the county poverty income level of $33,493. These households pay 3 percent of their income on water. While less than 0.5 percent of households in the community earn incomes at or below the deep poverty level of $16,746, these households pay 6.1 percent of their income on water.

These three affordability indicators highlight different affordability challenges. The affordability ratio for the median household income shows that the majority of the system's households (i.e. 50%) face considerable affordability challenges, given the typical affordability thresholds used. At least ten percent of the households served by the water system are economically vulnerable and face special hardship in paying their water bills. While only a small fraction of households pay 6.1 percent or more of their income for water, these are the most vulnerable households, whose cases need to be considered by planners and decision-makers.

Strategies to address the affordability challenges of this system should be explored with care. The fact that water quality and accessibility are high could be a function of the fact that water bills adequately cover the technical, managerial, and financial needs of the system. A simple decrease in rates could potentially compromise the system's high water quality. Thus, the decision maker focused on alleviating affordability burdens for economically vulnerable residents would need to consider how best to do so without compromising the high water quality. The tool helps highlight the need to balance decisions that impact one component, with potential consequences affecting other components.

Cross-Component Assessments

The ability to assess how systems are doing across all three components is an important asset of the tool. Figure 36 represents one manner in which decision-makers or users of the tool could take a holistic view, and look across three components. However, users of the tool may wish to ask more specific questions, such as:

- Which systems have high composite component scores (i.e. challenges) in all three components?
- How do trends in composite component scores change over time?

The United Nation's Joint Monitoring Program (JMP) uses qualitative service levels to define and compare the adequacy of drinking water services (as well as hygiene and sanitation) across countries. For example, the JMP defines its highest level of water adequacy as "Safely Managed", meaning water that is located on the premises, available when needed, and free from fecal and priority chemical contamination.[44] Among other things, its annual report on the state of drinking water across the globe then summarizes the extent to which populations across the globe have Safely Managed drinking water. In a California-oriented version, the Pacific Institute (Feinstein, 2018) proposes a similar approach in which the highest level of water service is defined as Satisfactory and includes a series of qualitative benchmarks to define it.

OEHHA's framework mirrors this laddered approach conceptually, with lower scores at the top of the ladder, and higher scores at the bottom of the ladder (Balazs *et al.*, 2021). However, CalHRTW does not currently define benchmarks for each component that determine whether a

[44] Affordability metrics are still being established.

certain score is "acceptable"/satisfactory or not.[45] Instead, agencies or users may utilize their own thresholds to explore outcomes. For example, a user may wish to highlight all systems with composite component scores below 1. Alternatively, users may not be interested in particular thresholds and may wish to analyze trends over time. For example, users may wish to track how individual systems' composite component scores for water quality, accessibility and affordability improve from the first rendition of this tool to subsequent years in which the tool is updated. When used over time, the tool, with these various uses provides a means against which to measure progressive realization of the human right to water.

Summary

In summary, system-level results can be used to provide a state-level understanding of general progress in achieving the human right to water across water systems. The cases described above show how the tool's results can be used by state and local agencies, water system operators and members of the public to understand the challenges that individual water systems may face, and help them move toward identifying technical solutions. Users can assess overall trends across water systems in each of the three components. This report provides a baseline set of results, which can then be used to assess how trends change over time. As future versions of the tool are released and these results are assessed over time, users could gain a holistic picture of evolving patterns in any one component, or across all three.

In sum, CalHRTW, and this first assessment of the tools results enables users to:

- Evaluate California's progress toward ensuring accessible, safe, and affordable drinking water in community water systems.
- Identify which indicators and components pose significant challenges for a given water system.
- Access information that that can help lead to potential solutions to challenges or combinations of challenges in a particular system.
- Identify particular types of support and assistance for communities based on needed improvements to the water systems.

[45] OEHHA considers that such target-setting is a deliberative, political process to be identified by a larger set of California stakeholders (Balazs et al 2021).

Human Right to Water Outcomes and Social Equity

The United Nations' recognition of the right to water underscores the importance of ensuring that vulnerable and marginalized groups be given special attention when monitoring this human right.[46] In particular, the United Nation's declaration outlines that water and its services be accessible to all, "including the most vulnerable or marginalized…without discrimination…", including discrimination on the grounds of "race, color, sex, age, physical or mental disability…social or other status (UN CESCR, 2002, Section II, paragraph 13)." A complete assessment of the human right to water therefore necessitates consideration of whether certain populations or groups may differentially experience inadequate water quality, accessibility and affordability to a greater degree than other groups. Such considerations resonate with goals of equity and environmental justice, which, among other things, consider unequal and cumulative pollution burdens on vulnerable populations.

In conducting equity-focused analyses, a range of socioeconomic factors are often considered, ranging from the race/ethnicity of a population, to the economic status of populations, to the degree of political representation or linguistic isolation (Cushing *et al.*, 2015) .[47] In the water justice literature, some groups are more likely to experience inadequate water (e.g., poor quality, accessibility or affordability) than others. For example, contaminated water sources disproportionately burden low-income communities and communities of color (Balazs *et al.*, 2011; Balazs *et al.*, 2012; Benfer, 2017; Francis and Firestone, 2011; London, 2018; Meshel, 2018; Montag, 2020; Stillo and MacDonald Gibson, 2017; VanDerslice, 2011). Water equity studies often compare key water outcomes by the racial/ethnic make-up of communities, median household income levels, and other socioeconomic factors (eg. Balazs *et al.*, 2012; Jepson and Vandewalle, 2016; Jepson *et al.*, 2017; McDonald and Jones, 2018; Schaider *et al.*, 2019).

In sum, a variety of characteristics can be used to consider the social vulnerability of water systems and the customers they serve. These include:

- Socioeconomic characteristics that describe the demographics of a water systems' customer base

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[46] See UN CESCR (2002), General Comment 15, Section II, Paragraph 12ciii and Paragraph 13 on "Non-discrimination and equality".

[47] OEHHA's CalEnviroScreen, for example, characterizes educational attainment, linguistic isolation, unemployment and poverty levels because they all are indicators of increased vulnerability (greater adverse outcomes) from a given level of pollution (OEHHA, 2021a). See also Cushing et al (2015).

- Institutional characteristics that describe the institutional or managerial capacity of water systems

These characteristics can be used to assess how human right to water indicators or composite scores vary by key factors, and whether social inequities exist. For example, is there a relationship between water system size and the quality or affordability of drinking water? Is there a relationship between the socioeconomic status of a community and its water quality or affordability? This chapter provides illustrative examples of how to evaluate these questions, offering an equity lens to look at challenges in meeting human right to water goals. Over time these analyses can be used to evaluate statewide trends across a variety of socio-economic vulnerability outcomes.

Socioeconomic Characteristics vs Water Quality and Affordability

The economic status of customers served by a water system describes one aspect of the social vulnerability of residents, and also captures potential economic vulnerability the system may face if its customer base faces economic challenges. Systems with greater proportions of socioeconomically disadvantaged residents tend to face additional financial constraints, as their customer base may be generally less able to afford costs associated with necessary system upgrades. For example, a system whose customers lack strong economic standing may face challenges in paying for necessary system upgrades, while its customers could face affordability challenges in paying for their water bills. This section introduces one socioeconomic measure and uses it to explore whether it may be associated with composite water quality or affordability scores for certain types of water systems.

Socioeconomic Characteristic: Disadvantaged Community Status

In California, one key metric associated with the economic characterization of a customer base is whether the community is a Disadvantaged Community (DAC). This designation is based on the 2012 Proposition 84 and 1E Guidelines that designate a Disadvantaged Community as one whose MHI is below 80% of statewide MHI, and a Severely Disadvantaged Community as one whose MHI is 60% of statewide MHI or lower.

Data Source

US Census American Community Survey (ACS) 5-Year Data: 2011 – 2015

Drinking Water Systems Service Areas, Tracking California, CDPH. Available at URL: https://www.trackingcalifornia.org/water-systems/water-systems-landing[48]

[48] For this version of the report, water system boundaries used in CalEnviroScreen 3.0 are used to calculate demographics. Future versions would use updated boundaries, such as those in CalEnviroScreen 4.0.

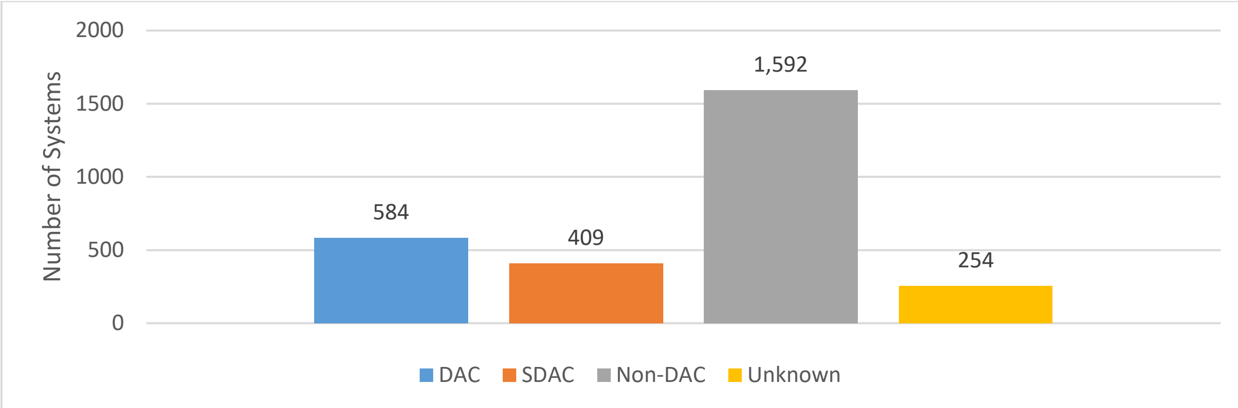
Method

The following steps were taken to categorize systems' socioeconomically disadvantaged status:

- The median household income within the service area of each water system that had a geographic boundary available was calculated using areal, household-based weighting. This calculation combines water system service area boundaries with census blocks and assigns relevant block group income data (See Appendix B2.3).
- Exclusion criteria to MHI calculations were applied to account for unreliable census data. Systems were excluded if block groups had no MHI data, if 15% or more of a system's block groups did not have MHI data, or if the MHI data contained a specified level of uncertainty (see Appendix B3.4 for more details). Of the 2,839 community water systems, 2,814 water systems had reliable income data (Appendix B4 Income Reliability). Of these 2,814 systems, 64 systems had no Median Household Income and 165 systems had over 15% of their household-weighted area with missing data. This resulted in 2,585 systems eligible for inclusion in the analyses below.
- The community served by the water system was designated as a non-disadvantaged community (non-DAC/SDAC), a disadvantaged community (DAC), or a severely disadvantaged community (SDAC). This designation is based on the 2012 Proposition 84 and 1E Guidelines that designate a Disadvantaged Community as one whose MHI is below 80% of statewide MHI, and a Severely Disadvantaged Community as one whose MHI is 60% of statewide MHI or lower. Based on the U.S. Census Bureau's American Community Survey 5-Year Data (2011-2015), the California statewide MHI was $61,094, making a DAC below $49,454, and a SDAC below $37,091. For purposes of this analysis, if a system is an SDAC, it is not counted as DAC.

Figure 37 summarizes the distribution of water systems by DAC-type, indicating that a majority of the state's community water systems serve non-DACs. Among the 35% of systems that serve DACs or SDACs, approximately 21% serve DACs (n=584) and roughly 14% serve SDACs (n=409). Roughly 9% (n=254) of systems do not have a categorization due to unreliable MHI estimates (see Appendix B.3.2 for more information).

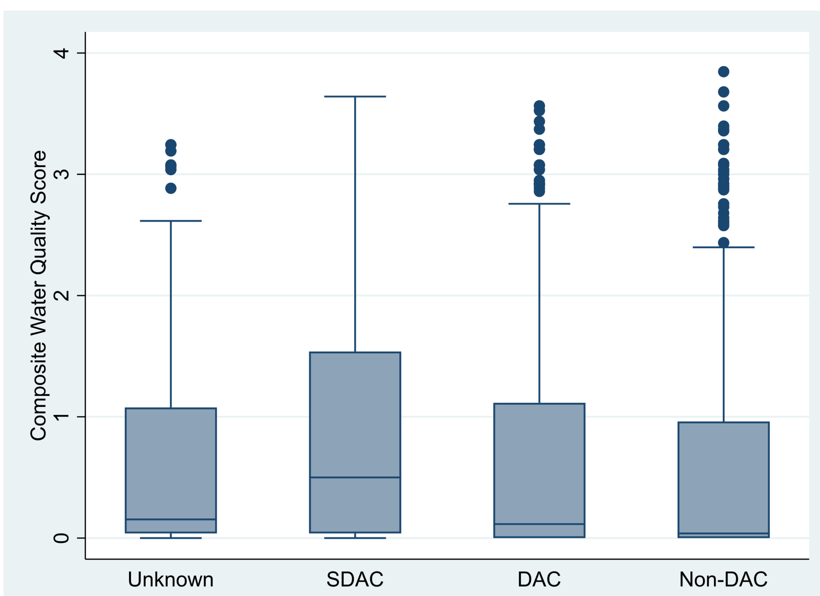
Figure 37. DAC status of Community Water Systems .



Disadvantaged community status and the relationship to water quality

Using the DAC status of the community that the water system serves, we can ask: what is the relationship between the final composite water quality score and DAC status? Figure 38 indicates the median score for SDACs is .5, .1 for DACs and .04 for non-DACs, suggesting higher scores for more economically vulnerable communities. The boxplot also indicates that the 75th percentile water-quality score is higher for SDACs and DACs, indicating a greater number of systems face higher scores for these more economically vulnerable communities. Furthermore, among the sixty-eight systems that received a composite water quality score greater than 3, DACs and SDACs were over-represented in comparison to their distribution in the overall study population (data not shown).

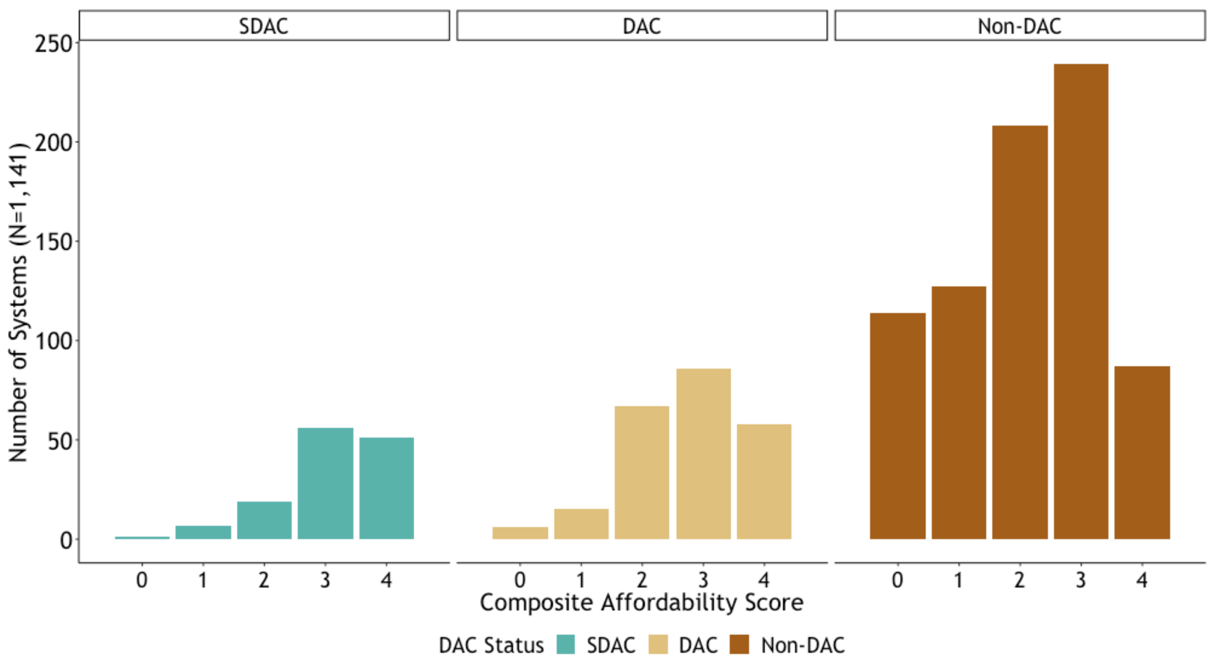
Figure 38. Water Quality Component Score by DAC Status. DAC status identifies disadvantaged communities (DACs), severely disadvantaged communities (SDACs), non-DAC/SDAC communities, and those with unknown status due to unreliable census estimates.



Disadvantaged community status and the relationship to affordability

In a second example, we can ask: what is the relationship between composite affordability scores and disadvantaged community status? Figure shows affordability scores as a function of the DAC and SDAC status of the water systems. The distributions of scores in SDAC and DAC systems are skewed toward higher scores compared with non-DAC systems, suggesting that proportionally there are greater numbers of systems with higher composite affordability scores in systems serving DAC and SDACs. This is further confirmed by fact that the median score in both SDACs and DACs was 3, compared to a score of 2 in non-DAC/SDAC water systems.

Figure 39. Affordability Component Score by DAC Status. DAC status is designated above each histogram. There are 134 SDAC systems, 232 DAC systems, and 776 Non-DAC systems. Data for water bills (2015) and income (ACS 5-Year 2011-2015), n = 1,141 community water systems.



Institutional Vulnerability vs Water Affordability and Quality

The institutional capacity of a water provider to provide adequate amounts of high quality water at sustainable and affordable prices is shaped by multiple types of factors, some external to the water system and some relating to the water system itself. Institutional factors such as the ability to plan financially, the staff's managerial capacity and the mode of governance, all comprise the institutional capacity of the system. Ultimately, these factors impact the ability of a water system to make necessary infrastructure investments and conduct the operations and maintenance needed to provide safe and adequate water to customers. A system that has low institutional capacity may not be able to adequately address water contamination or supply vulnerability because of technical, managerial or financial limitations. Institutional vulnerability is shaped, in part by the strength of these factors and has short and long-term implications for adequate water.

This section outlines two examples of factors that can help characterize institutional vulnerability. The first factor—system size—can represent potential *institutional constraints,* or lack thereof. The second—the number of monitoring and reporting violations—can represent *managerial constraints*. Importantly, a number of other metrics not yet included help capture key components of a system's institutional constraints, including its technical, managerial and financial (TMF) capacity. These include staffing and training levels, governance structure, rate-setting expertise, debt ratio, and operating/expense ratios, and community capacity to pay for necessary infrastructure. In future assessments, OEHHA will seek to include additional metrics that capture such aspects.

Institutional Vulnerability Characteristic 1: System Size

A system's size can help describe a system's potential institutional constraints. For example, larger systems have greater economies of scale that allow them to finance capital improvements and operate more efficiently (McFarlane and Harris, 2018). To characterize system size, we use data on a system's number of service connections.

Data Source

Safe Drinking Water Information System (SDWIS-State), State Water Board, 2017

Method

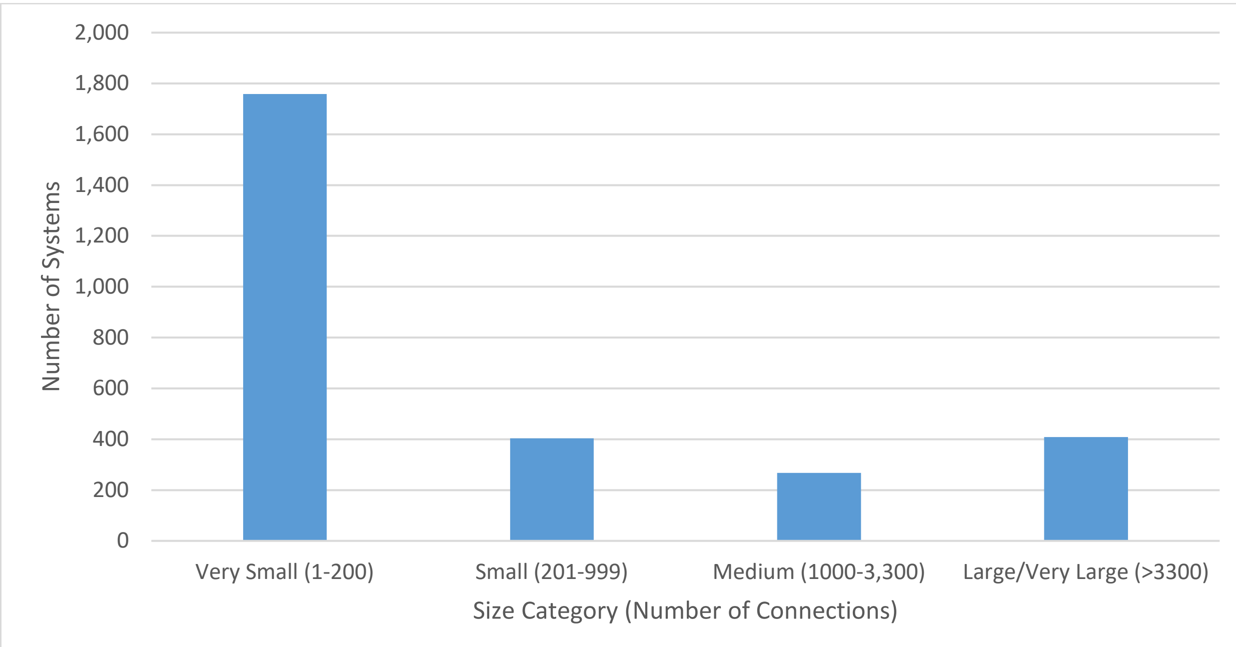
The following steps were taken to categorize systems by system size:

- The number of service connections for a water system was extracted from the SDWIS-State database

- The system was assigned a category of very small (1-200 service connections[49]), small (201-999), medium (999-3,300) and large/very large (>3,301 service connections). [50]

Figure 39 indicates the distribution of system size among the 2,839 systems studied. It shows that 1,758 systems are very small (~62%). Roughly 14% are small (n=404). Approximately 9.5% are medium-sized, and approximately 14.4% (n=409) are large or very large.

Figure 39. System size represented by number of service connections for California's community water systems.



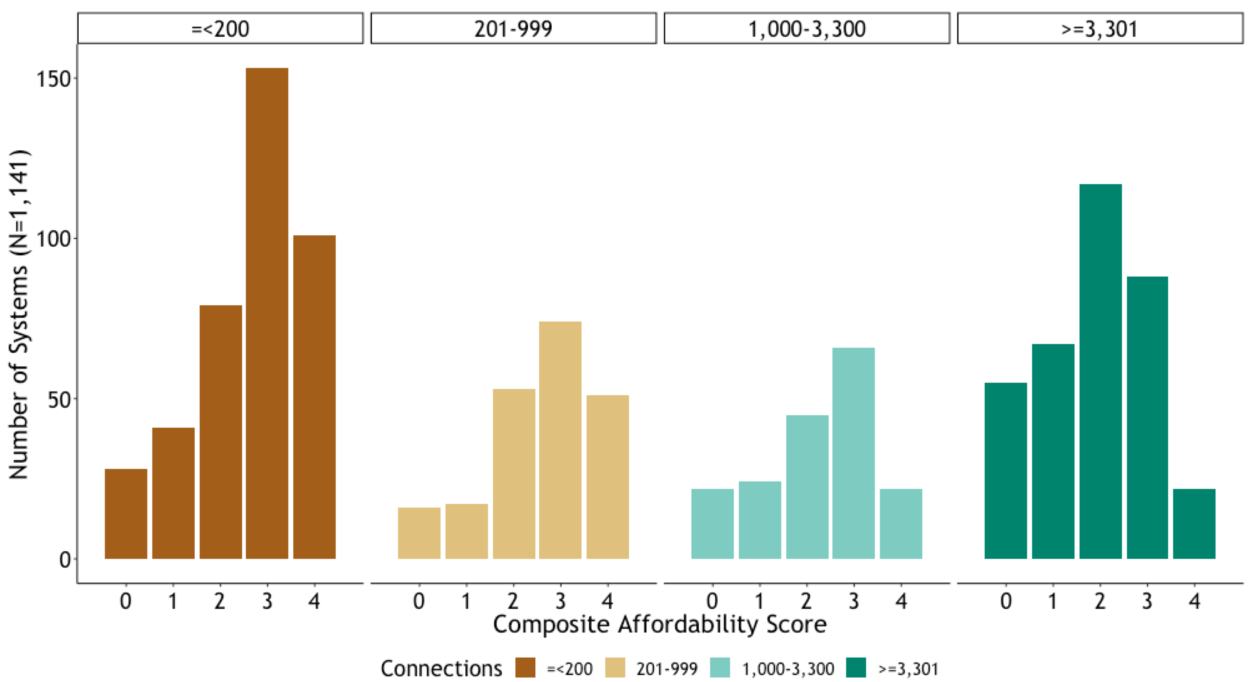
System size and the relationship to water affordability

Figure 40 summarizes the relationship between the composite affordability score and system size, among the 1,141 systems that had affordability scores. In this figure, the total number of systems at each score is displayed across the different system size categories. Here, we see that very small and small-sized systems face greater affordability challenges – as identified by the greater number of systems with higher composite scores–compared to larger systems. The median composite affordability score is 3 for very small (<201 connections) and small systems

[49] Community water systems are typically defined as having 15 or more service connections or serving 25 or more people. In this case, a size range of 1-200 connections included as the SDWIS-State database indicated some systems with fewer than 15 service connections are community water systems.
[50] A variety of commonly used cutoffs are used to designate water systems as small, medium and large (see for example, the Safe Drinking Water Plan for California. Report to the Legislature in compliance with Health and Safety Code Section 16365, State Water Board. June 2015). OEHHA selected four categories to distinguish systems from very small to large, and still align with commonly-used cutoffs. These groups are also at least partially consistent with current statewide efforts that treat systems with over 3,300+ or 3,000 service connections as less at risk (e.g., Needs Assessment and DWR's County Drought Advisory Group, respectively).

(201-999 connections), 2 for medium systems (1,000-3,300 connections), and 2 for large systems (>=3,301 connections). These plots indicate that very small and small systems have a higher proportion of systems with scores of 3 and 4. Of the 402 systems that are very small, 101 systems (25%) have the highest composite score (i.e., 4), indicating particular affordability issues for households earning below the median household income in these communities. The median score for medium and large systems is 2, indicating that affordability challenges exist for some water systems, and in some households but to a lesser extent than those served by the small and very small systems. Of course, as discussed in the Data Gaps section of the Affordability Chapter, there was a large and disproportionate lack of affordability data for very small systems (see Box 8, Affordability Chapter). Consequently, the findings for small systems should be seen as provisional.

Figure 40. Composite Affordability Score by System Size. The connection size categories are indicated above each histogram. There are 402 very small systems (=<200 connections), 211 small systems (201-999 connections), 179 medium systems (1,000-3,300 connections), and 349 large systems (>= 3,301 connections). Data for water bills (2015) and income (ACS 5-Year 2011-2015), n = 1,141 community water systems.



Institutional Vulnerability Characteristic 2: Managerial Constraints (Monitoring and Reporting Violations)

Managerial constraints can also shape institutional vulnerability. Managerial constraints—defined as limitations to the system's institutional capacity based on staffing levels, management and expertise—can impact water quality, accessibility and affordability. Because detailed, consistent data is not yet readily available for all water systems on specific managerial constraints[51], OEHHA worked with the State Water Board's Division of Drinking Water to identify an indicator that could approximate managerial constraints in addressing contamination and/or maintaining adequate water supply.

The selected characteristic is the number of monitoring and reporting violations that a water system receives. These violations assess the degree to which a water system complies with monitoring and reporting requirements for particular contaminants and treatment techniques (Title 22, California Code of Regulations. Section 60098). Systems with a good compliance record for these requirements are deemed to have fewer managerial constraints. Systems with significant monitoring and reporting violations are deemed to have more managerial constraints– inadequate number or training of staff, or some other unresolved issue – that results in the monitoring and reporting violations.

Data Source

Safe Drinking Water Information System (SDWIS-State), State Water Board, 2011-2019

Method

To develop the count of monitoring and reporting violations we:

- Extracted all monitoring and reporting violations for Consumer Confidence Reports, Total Coliform Rule/Revised Total Coliform Rule, nitrate, disinfection byproducts, Surface Water Treatment Rules, the Groundwater Rule, the Lead and Copper Rule. These correspond with violation codes of 3, 4, 3A, 3B, 4A, 4D, 23, 24, 26, 27, 31, 36, 38, 51, 52, 53, 56, 71, and 72.
- Summed all instances of Monitoring and Reporting violations by system for the aforementioned rules, and by the category of violation.

A total of 1,206 systems (42%) had at least one Monitoring and Reporting violation during the study period. A total of 4,543 violations occurred among these systems. The total number of Monitoring and Reporting violations ranged from 0 to 352 (Figure 41). Table 17 summarizes the number of systems with violations, by category of Monitoring & Reporting violation.

[51] The State Water Board's Needs Analysis Unit is developing metrics in this area which may be useful.

Figure 41. Total Number of Monitoring and Reporting Violations, 2011-2019.

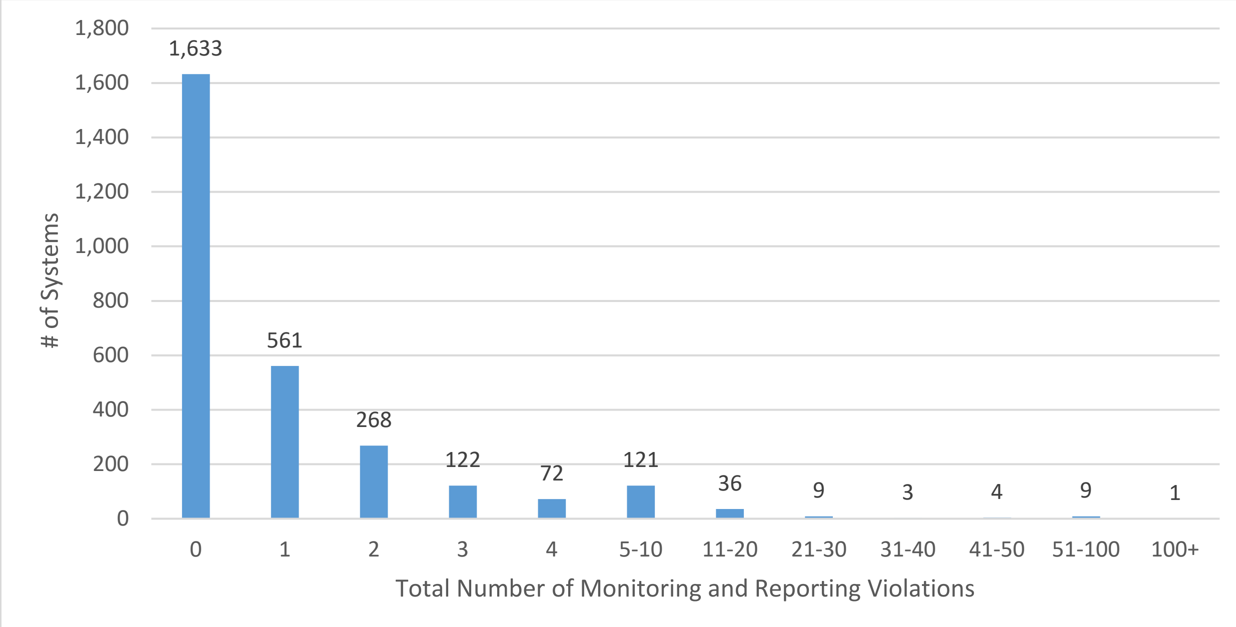


Table 17. Number of systems with Monitoring and Reporting Violations by category of violation for the 2011-2019 Study Period.+

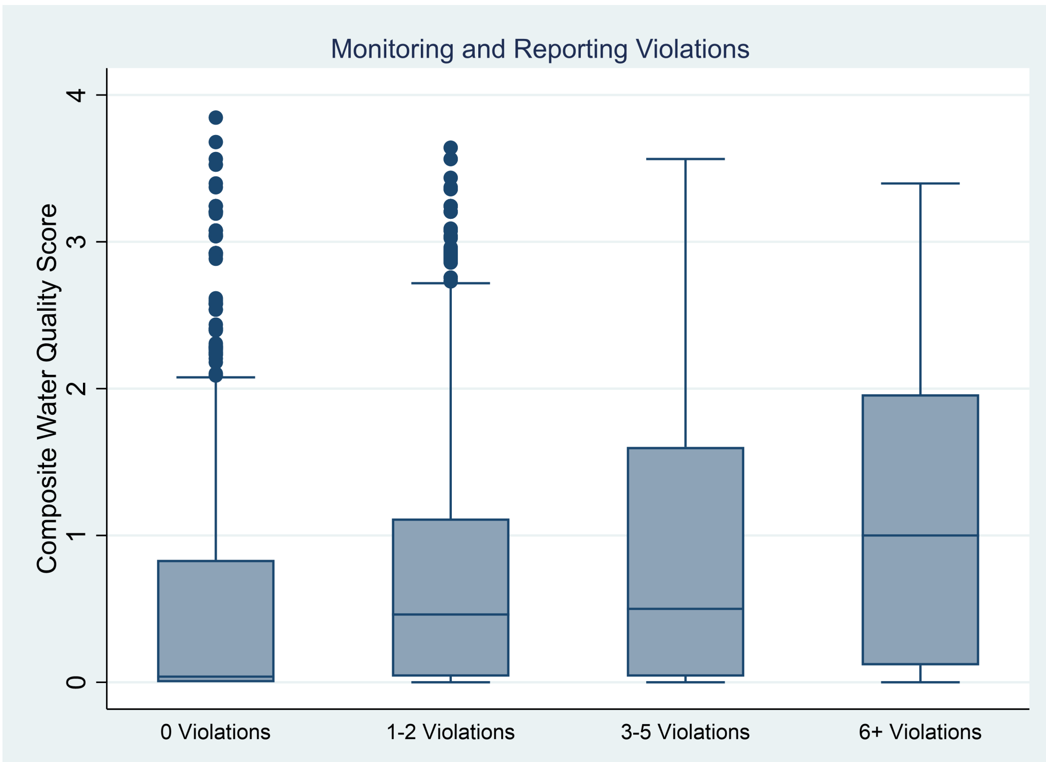
Total Violations	CCR	DBP	LCR	Other Chemical Contaminants	SWTR	TCR/RTCR
0	2,642	2,743	2,400	2,404	2,796	2,240
1	149	19	355	268	31	355
2	32	52	62	78	7	118
3	8	6	16	25	2	51
4	6	15	2	15	2	17
5	1	1	2	6	1	21
6	1	1	1	3	0	6
7+	0	3	1	40	0	31
Total	2,839	2,839	2,839	2,839	2,839	2,839

+CCR indicates monitoring and reporting violations related to Consumer Confidence Report requirements. DBP indicates monitoring and reporting violations related to disinfection by-products. LCR refers to monitoring and reporting violations of the Lead and Copper Rule. SWTR refers to monitoring and reporting violations of the Surface Water Treatment Rule, and TCR/RTCR refers to monitoring and reporting violations of the Total Coliform Rule or Revised Total Coliform Rule. Monitoring and Reporting violations of all other chemical contaminants are in the final column.

Managerial constraints and the relationship to water quality

As above, we can explore the relationship between the final composite water quality score and managerial constraints (measured as the number of monitoring and reporting violations). The boxplot in Figure 42 indicates that that in systems with more monitoring and reporting violations, the median water quality score increases (i.e. becomes worse).

Figure 42. Water Quality Component Score by Managerial Constraints. Managerial constraints measured by number of Monitoring & Reporting Violations.



Next Steps

The indicators described in this section and example analyses are a first step at showing how human right to water outcomes can be assessed not only in and of themselves, but in relation to key vulnerability metrics and social equity. Over time, other metrics and more complex approaches can be developed to analyze the relationship to human right to water outcomes.

Conclusions and Next Steps

The Human Right to Water Framework and Data Tool (CalHRTW) provides a comprehensive, stand-alone assessment that can be used to evaluate progress in achieving the human right to water in California, for use by CalEPA, the State Water Board, other state agencies, community groups, public water systems, and researchers. It is the first such assessment developed by the State of California and plays a foundational role in the state's various efforts to achieve the human right to water. OEHHA and the Water Board envision a role for this assessment and data tool in providing a baseline of information that can inform efforts to ensure that all households receive clean, safe, accessible and affordable water. CalHRTW and the assessment of its results can be used to focus the state's attention on water systems facing the greatest challenges over time. Coupled with the Water Board's existing information and efforts, OEHHA's tool offers a flexible, versatile, and adaptable way for CalEPA and the Board to view and evaluate progress towards achieving the human right to water in California.

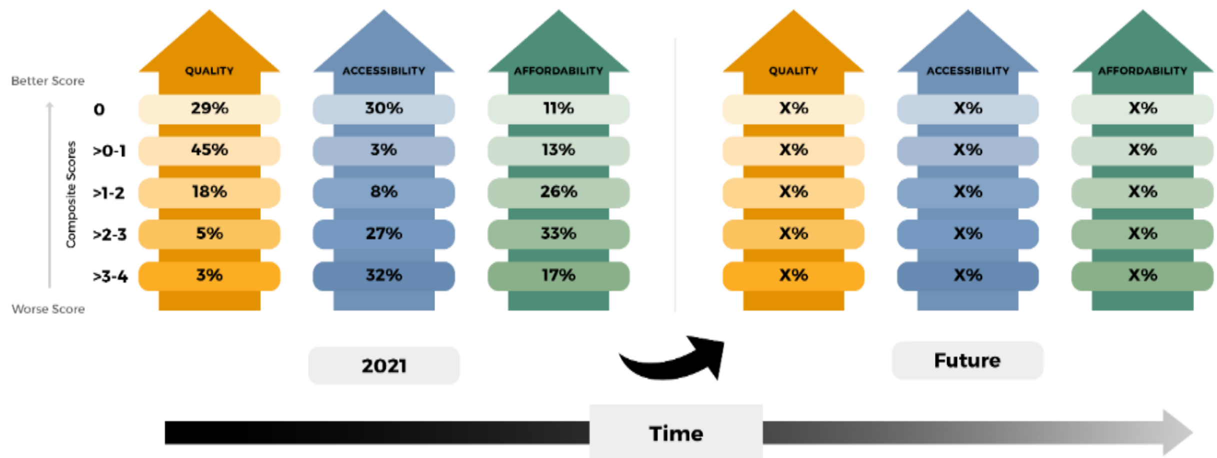
In the near term, this tool and assessment may also be instructive to the Water Board as it implements SB 200. As an urgency measure signed by Governor Newsom in July 2019, SB 200 immediately established the Safe and Affordable Drinking Water Fund in the State Treasury, with funds to be prioritized and administered by the Board. Other state and local agencies, drinking water service providers, and technical assistance program administrators may also find the assessment and data tool useful in prioritizing solutions to unique water system challenges, and in evaluating the effectiveness of proposed solutions to address those challenges.

Ultimately, the strength of this tool lies in its holistic and versatile approach. The tool can provide the user with an overall sense of water quality, accessibility and affordability at a state or regional level, while also demonstrating how individual water systems perform in those areas. This can prompt decision-makers to ask new and probing questions about California communities and the water that sustains them. Which systems face water quality and affordability challenges? Which systems have low water quality, but perform well in other ways? What accounts for this unevenness, and how are water systems addressing it? How do these systems fare over time, and why? The ability to ask these questions facilitates the development of better-tailored approaches to delivering clean, safe, affordable and accessible water to communities across the state.

OEHHA plans to maintain the tool and conduct periodic updates to evaluate progress toward achieving the human right to water. Such updates may include: 1) Updating indicators and 2) evaluating the distribution of each indicator score and how it compared to the previous time period.

Figure 43 exemplifies how these updates can be used to track changes over time. For example, results from CalHRTW 1.0 are shown in the first box on the far left. Over time, the same metrics can be measured and the state can gain a perspective on which components improve over time, thereby capturing progressive realization.

Figure 43. Conceptual view of assessing changes over time. Summary results for 2021 are indicated. Placeholder values are indicated for a future date at which the tool is updated. A comparison between 2021 and the future results allows for tracking the progressive realization of the human right to water.



Future Considerations

This first assessment and data tool focus on households served by community water systems. With time and further data acquisition efforts, additional areas that this framework seeks to incorporate include:

- **Sanitation:** Sanitation is an integral part of the human right to water. Incorporating sanitation into the assessment and data tool will require an assessment of what statewide datasets exist to adequately characterize the adequacy and affordability of sanitation for both centralized and decentralized systems. Incorporating sanitation will also require assessing how to obtain and integrate wastewater costs in order to address the full picture of water costs and related affordability.
- **State Small Water Systems:** These are water systems with 5 to 14 service connections that do not serve more than an average of 25 people for more than 60 days of the year. An assessment of state small water systems will require significant data acquisition, including but not limited to: identifying and compiling the geographic boundaries of these water systems, and developing appropriate methods for how to estimate water quality, accessibility and affordability in these systems. In particular, because water-quality requirements for state smalls are less stringent than for community water systems, this will require an assessment of how to best characterize water quality in these systems, given inherent data limitations.
- **Households reliant on domestic wells:** An estimated 1.5 to 2.5 million Californians rely on domestic wells (Johnson and Belitz, 2014; USGS, 2014). While several efforts are currently underway to approximate the location of domestic-well households and measure their water quality, research is still needed to identify accessibility and affordability concerns for these households. This presents a particular challenge since there are currently no statewide testing or reporting requirements.
- **Schools and daycare centers:** While a majority of schools are served by community water systems, some schools have their own water supply and are designated “non-transient non-community water systems”. It will be important to estimate water challenges in both types of settings, but especially for those with their own water supply.
- **Transient and homeless populations:** People lacking housing are particularly vulnerable to not having clean and accessible drinking water. Assessing the human right to water among this group will require particular data and methodological questions pertaining to how to accurately assess the location and number of people in this group, and the type of drinking water and sanitation services used.

- **Tribal Water Systems:** The right of indigenous peoples to retain the integrity of water resources on their territory is generally protected under international, federal, and state law.[52] The UN Declaration of the Rights of Indigenous Peoples, for example, requires states to "consult and cooperate in good faith with the indigenous peoples concerned" in matters of water and land rights (UN General Assembly, 2007).[53] In California, several tribes hold senior water rights, and others manage their own water systems. In 2017, the State Water Board adopted several beneficial use designations, conferring additional protections for water resources used for tribal traditional cultural, ceremonial, and subsistence purposes. While these other policies are in place to protect access to clean and safe water for California's Native American Tribes, indigenous rights to water can be vulnerable – particularly during periods of drought. OEHHA and the Board recognize the importance of ensuring that the human right to water for indigenous peoples is prioritized, and is currently working to include more comprehensive data to capture water systems located on tribal lands, or otherwise serving tribes in the state, and anticipates updating future versions of the tool with this data.
- **Vulnerability and/or Equity Analyses:** As discussed in this report, analyzing outcomes by vulnerable groups or vulnerability factors is an essential element of considering the human right to water. As such, OEHHA plans to conduct a series of analyses by key system-level characteristics (e.g., income, race, system size, etc.).

A partial list of potential indicators or units of analysis for future versions of the tool is included in Table 18 below.

Table 18. Potential Indicators or Units of Analysis for Future Versions of the Tool and Assessment.

Component or Units of Analysis	Potential Indicator
Water Quality (Safe/Clean)	• Average potential contaminant exposure to secondary contaminants • Violations of Maximum Contaminant Levels (MCLs) for secondary contaminants • Toxicity of contaminant • Time since occurrence

[52] For example, the UN Committee on Economic, Social, and Cultural Rights (2002), General Comment 15, protects water resources on ancestral lands "from encroachment and unlawful pollution."(See, The Right to Water, UN Doc E/C.12/2002/11. Paragraph 16 (d).)

[53] UN General Assembly. United Nations Declaration on the Rights of Indigenous Peoples (2007). UNGA Resolution 61/295. A/61/L.67 and Add.1. September 13, 2007.

Component or Units of Analysis	Potential Indicator
Water Accessibility	• Vulnerability to climate change and/or drought • Drought impacted systems • Applied for emergency interim solutions/drought funding • Supply shortages reported • Availability of alternative sources of water (e.g., proximity to vended water) • Service interruptions • Moratorium on service connections • Degree of reliance on purchased water sources • Curtailments • Amount of water available to customers • Average/median water use of water utility per customer • Total source capacity of system/population • Measures of infrastructure quality (e.g., age of water system infrastructure, main breaks, etc.) • Aquifer vulnerability
Water Affordability	• Water affordability for different volumes of water • Water affordability ratios disaggregated by demographic characteristics of water systems: ○ By socio-economic variables in American Community Survey such as percent unemployed, percent public assistance income, percent disabled, percent food stamps, etc. • Water affordability including replacement costs (for bottled water) • Water affordability including sanitation costs • Number of delinquent or uncollectible bills • Amount of bills in arrears • Number of water shut offs • Percent of water systems providing subsidies • Percent of eligible customers receiving rate assistance
Additional Sub-Groups, Units of Analysis or Topics to Consider	• Private domestic wells • State small water systems • Schools • Day care centers • Sanitation • Persons experiencing homelessness • Private well owners • Tribal water systems

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Appendix A

A1 Affordability in Context

A1.1 Affordability in the International Context

In the international context, issues of affordability fall under the broader topic of "accessibility" within General Comment 15 (GC15). GC15 requires that "direct and indirect costs and charges associated with securing water must be affordable" to all (UN CESCR, 2002). GC15 also emphasizes the role of equity in understanding affordability (UN CESCR, 2002), and includes the "right to be free from interference [of access], such as the right to be free from arbitrary disconnections," (UN CESCR, 2002).[54] Accordingly, the AAAQ Framework articulates two dimensions of economic accessibility: "that water and water facilities must be affordable to all and that the total costs (direct + indirect costs) associated with water must not threaten the realization of other rights or basic needs" (Jensen *et al.*, 2014).

A1.2 Affordability in the US Context

In the U.S. context, the Environmental Protection Agency (US EPA) defines affordability as "both a function of the price of water and the ability of households (and other water users) to pay for water"(US EPA, 1998). In particular, the US EPA recommends that states include affordability considerations when providing loans and assistance to water systems seeking to comply with the Clean Water Act and Safe Drinking Water Act (SDWA). US EPA developed affordability guidelines and criteria over several decades as part of Financial Capability Assessments for water systems(US EPA, 1984, 1998). US EPA's 1998 guidelines for states advise water systems to evaluate drinking water affordability with a two-stage approach similar to that outlined for wastewater in 1997 (US EPA, 1997).[55] This approach calls for:

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[54] This provision was reiterated in the U.S. context when former UN Special Rapporteur on the Human Right to Water, Catarina de Albuquerque responded to large scale water shut offs in Detroit, MI in 2014: "Disconnection of water services because of failure to pay due to lack of means constitutes a violation of the human right to water and other international human rights." Office of the UN High Commissioner for Human Rights, Joint Press Statement by Special Rapporteur on adequate housing as a component of the right to an adequate standard of living and to right to non-discrimination in this context, and Special Rapporteur on the human right to safe drinking water and sanitation, Visit to city of Detroit (United States of America 18-20 October 2014) (October 20, 2014), available at http://www.ohchr.org/EN/NewsEvents/Pages/DisplayNews.aspx?NewsID=15188.

[55] These guidelines present a two-step process focused on household and system-level financial impacts of permittees (e.g., any entity that is granted a National Pollutant Discharge Elimination System (NPDES) permit) coming into compliance with the Clean Water Act. Their "Residential Indicator" is similar to the conventional affordability ratio (water cost/household income) and measures the financial impact of current and future utility

1) Measuring domestic water affordability ratios (water bill divided by median household income, or the Residential Indicator) (US EPA, 1998)[56] and
2) Determining what type of variances[57] or financial support a system may need based on a system's financial capacity.

Implicit in these guidelines is the notion that affordability comprises both the ability of a water system and its customers (the community) to support the cost of compliance with the SDWA (US EPA, 1998).

Two essential points emerge from US EPA guidelines. Firstly, household affordability is a unique topic, to be represented at the *household level*, though it is most often measured at the *system-level*, for the median household. Secondly, affordability is a component of a water system's financial capacity. In both cases, a system-level metric of affordability (i.e., average water costs relative to median household income) is used to characterize household affordability burdens and screen for system level financial capacity.

US EPA's recent proposal to revise the 1997 guidelines for Combined Sewer Overflow and Wastewater incorporate several key insights from recent debates on affordability measurement described in Appendix A2. US EPA proposes adding a measure of affordability for the lowest income quintile (i.e. a Lowest Quintile Residential Indicator) and adding a Poverty Indicator (US EPA, 2020). These additional foci relate a third component of water affordability in US EPA's broader framework, which is the importance of identifying and representing economically vulnerable households in an affordability assessment.

In California, water affordability is a pressing issue leading to its inclusion in California's human right to water bill(Assembly Bill No. 685., 2012. Eng, Chapter 524). In 2015, the State Water Board found that water costs had increased by 42 to 47 percent in the last two decades, and that small water systems (i.e., fewer than 200 service connections) pay approximately 20 percent more for water than larger systems(State Water Resources Control Board, 2015). The Water Board has developed a proposal for low income rate assistance (LIRA) to target households struggling to pay for water. The LIRA recommendations include three approaches: 1) providing varying levels of direct credit to households earning below 200% of the federal poverty line (FPL); 2) providing a credit to renters that do not pay a water bill but earn below 200% FPL ; and 3) providing crisis assistance to households with past due bills (State Water Resources Control Board, 2020c)

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cost requirements on residential customers to establish the degree of financial impact posed by rates.

[56] US EPA also proposes several alternate approaches to calculating this indicator: 1) including wastewater charges in addition to drinking water charges; 2) using the average household income rather than the median; and 2) adjusting income for poverty effects (US EPA, 1998).

[57] Variances allow water systems to use treatment technologies that remove the maximum amount of a specific contaminant with affordable technologies in cases where such technologies are protective of public health but do not meet drinking water standards. See (US EPA).

A2 Approaches to Measuring Affordability

A2.1 Conventional Affordability Ratio

Generally, there are two main approaches to measure water affordability (Hancock K. E. 1993).[58] First, and most conventionally, affordability is measured as an affordability ratio as in EPA guidelines –EPA refers to this as the Residential Indicator, and academically it is frequently known as the conventional affordability ratio.

Most often, this is assessed as what fraction of a household income is needed to cover direct and indirect costs of obtaining water services (including for drinking, hygiene and sanitation) (UN CESCR, 2002).[59] If the resultant ratio exceeds a designated threshold (See Appendix Table A1), households are considered to face unaffordable water costs. Importantly, these thresholds reflect policy choices about the appropriate or socially accepted ratio of what counts as affordable and have previously been implemented at the state level.[60] Where household level income data is not collected, this ratio has been evaluated at an area-level, using an average or median income.

A2.2 Affordability Thresholds

A range of thresholds exist to evaluate affordability ratios. In general, these thresholds range from 1.5% - 10% and vary as to whether they include both drinking water and sanitation (Appendix Table A1) as well as what type of income is used in the denominator (gross income or income less taxes and other expenses). In the U.S., two common water system-scale thresholds are used to assess water system-level affordability of water costs as a proportion of median household income: 2% and 2.5%. The 2% threshold was initially used to measure drinking water affordability nationally at the household level to understand if a water system was eligible for variance from regulations in the 1986 Safe Drinking Water Act (US EPA, 1998). Subsequent state-level affordability assessments related to water system eligibility status for disadvantaged assistance have used a range of affordability ratios and additional criteria.[61] The threshold of 2.5% for drinking water was developed as a metric to assess affordability relative to the cost of compliance with the SDWA at a national level (US EPA, 2002).[62] This threshold of

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[58] It should be noted that affordability approaches to drinking water reflect those of housing affordability, which economists have been analyzing for decades. For a summary of ratio and residual income approaches, see article.

[59] Direct costs usually refer to the price per unit of water, whereas indirect costs may be related to lifeline rates, connection surcharges etc.

[60] For example, for California. See (US EPA, 2000).

[61] Thresholds implemented at the state level to determine affordability criteria range from 1% to 5% among case studies reported in two US EPA studies: (US EPA, 1998) and (US EPA, 2000). In these, affordability thresholds are sometimes combined with other criteria to determine affordability such as: socioeconomic conditions of a system and comparison of pre and post-SDWA costs on median household income.

[62] Note: A water system is eligible for variances if the maximum increase in costs to the water system does not exceed the "expenditure margin" of the system, which is defined as the difference between the affordability threshold (2.5%) and the baseline component (actual water bills relative to median household income). The affordability threshold of 2.5% is used to determine the maximum water costs a water system can afford given the

2.5% is also commonly cited as the affordability threshold for the cost of drinking water provision at the household level. The origin of the 2.5% threshold derived from an assessment of what median-level households pay for other basic expenses (based on Consumer Expenditure Surveys), the average costs of avoidance-behavior (like consuming bottled water), and a motivation to minimize water system variances to the Clean Water Act (US EPA 1998b). In California, the California Department of Public Health (CDPH), which previously oversaw provision of drinking water in the state, set an affordability threshold of 1.5% for disadvantaged communities as part of its Safe Drinking Water State Revolving Fund (SDWSRF) program, which primarily targets small water system technical, managerial, and financial (TMF) capacity and assisted disadvantaged communities(California Department of Public Health, 2009).[63] This threshold continues to be used in recent SDWSRF Intended Use Plans (State Water Resources Control Board, 2020a). This lower threshold is on par with thresholds in other SDWSRFs around the country, where ranges of affordability thresholds vary, e.g., between 1.25% and 1.5% (US EPA, 2000).

Appendix Table A1. Commonly Used Affordability Ratio Thresholds.

Thresholds shown by organization or study.

Affordability Ratio Threshold	Water Cost Included	Organization Using Threshold (Studies Applying Threshold)
1.5% of MHI	*Drinking water services*	*California Department of Public Health* (California Department of Public Health, 2009) *State of California Drinking Water State Revolving Intended Use Plan 2020-2021* (State Water Resources Control Board, 2020a) *UCLA Luskin Center for Innovation* (Pierce *et al.*, 2015)
2% of MHI	*Wastewater services*	*U.S. Environmental Protection Agency* (US EPA, 1997)[64]
2% of MHI	*Drinking water services*	*U.S. Environmental Protection Agency* (US EPA, 1998) *AB 2334* (Assembly Bill No. 2334, 2012)[65]

median household income among water districts of specific size classes. For example, a median household income is determined at the level of all large water systems across districts, e.g., and not at the household or water system level.

[63] In cases where financial assistance is requested for disadvantaged communities, the CDPH aimed to help communities achieve a "target user cost" for water services of 1.5% MHI.

[64] Note that here, affordability of water costs to households is calculated prior to a secondary screening of water system financial capability.

[65] Note that AB 2334 did not pass and was not added to the State Water Code, despite significant support for the

Affordability Ratio Threshold	Water Cost Included	Organization Using Threshold (Studies Applying Threshold)
		Public Policy Institute of California 2014 (Hanak *et al.*, 2014)[66] *Christian-Smith et al 2013 (Pacific Institute, Community Water Center and California State University, Fresno)* (Christian-Smith *et al.*, 2013)
2.5% of MHI	*Drinking water services*	*U.S. Environmental Protection Agency* (US EPA, 2002)[67]
3% of Income (often disposable)	*Drinking water & wastewater services*	*United Nations Development Program*(UNDP, 2006) *UN Office of the High Commissioner for Human Rights* (OHCHR, 2010) [68]
4.5% of MHI	*Drinking water & wastewater services*	*U.S. Environmental Protection Agency*[69] *Mack and Wrase (2017)* (Mack and Wrase, 2017)
5% of MHI	*Drinking water & wastewater services*	*AAAQ (Jensen et al., 2014)*; *German International Water Policy and Infrastructure group (GTZ)* (Deutsche Gesellschaft für Technische Zusammenarbeit, 2009).[70]

bill by non-profit and activist groups across California (see hearings on California Water Plan: Affordable Drinking Water Analysis from 2012). Nonetheless, the Pacific Institute study using this threshold has been widely cited and used in other legislative, non-profit, and policy support circles to highlight the high burden of water costs on Californian community water systems.

[66] This study estimated drinking water affordability at the county-level and estimated that 13% of single-family households may face unaffordable water rates (i.e., greater than 2% of estimated annual income).

[67] Note: This document is frequently referenced as a source for US EPA's affordability threshold criteria. However, as noted above, the scale and focus of this threshold criteria are to assess affordability to determine a system's ability to comply with Safe Drinking Water Act related regulations (e.g., MCL compliance). Few make these distinctions in considering the threshold level for application at the household scale (however see comments and considerations in (Fisher, Sheehan et al. 2005) and (Rubin S. J. 2011). Additionally, US EPA commissioned the 2002 review to consider the 2.5% threshold, and while the committee found the threshold to be generally acceptable, they also proposed that some systems are likely struggling to keep water costs below 2.5% of median household income. A 2003 review by the Small Systems Working Group for National Drinking Water Advisory Council (NDWAC) cited above was inconclusive on the threshold and instead suggested an incremental threshold approach based not on existing expenditures but direct affordability impacts specific to a given ruling.

[68] UN-Water Decade Programme on Advocacy and Communication. "The Human Right to Water Media Brief." Available at URL: www.un.org/waterforlifedecade

[69] This study used the combined US EPA drinking water and wastewater affordability thresholds of 2.5% and 2%, respectively, to determine the minimum incomes required to adequately afford 4.5% MHI based on water costs obtained from a survey of 296 water systems across the US Identifying the number of households with incomes incapable of staying below the 4.5% MHI threshold for average annual water costs, this study estimates that 11.9% of households face unaffordable water rates across the US.

[70] Note that the GTZ report does not cite or reference support for the 5% threshold here.

Affordability Ratio Threshold	Water Cost Included	Organization Using Threshold (Studies Applying Threshold)
		World Bank (Banerjee and Morella, 2011)
10% of Discretionary Income for 20th Income Percentile	*Drinking water and wastewater*	*Pacific Institute 2018 (Feinstein, 2018)* *Teodoro (2018)* (Teodoro, 2018)

A2.3 Residual Income Approach

A second way to measure affordability is the "residual income" approach. In this method, the proportion of income going to household costs for drinking water and sanitation is measured in relation to:

a) household expenditures on all essential goods and services related to other protected rights (Kessides *et al.*, 2009), [71]
b) household expenditures in general, and
c) the poverty line.

Data requirements for this type of analysis are hard to fulfill, however.[72] Water affordability is thus commonly assessed using affordability ratios and thresholds (UN CESCR, 2002).[73]

A2.3 Hours at Minimum Wage

Teodoro 2018 suggested representing affordability as a measure of hours worked at minimum wage (HM) with the explicit use for "purposes of budgeting, planning, rate-setting, and policy design"(Teodoro, 2018). The HM metric was developed for water and sewer costs combined, but could feasibly be developed for each bill separately. Teodoro argues that HM is familiar and intuitive as a complementary metric to affordability ratios. The CPUC proposed incorporating HM as a metric to complement their affordability assessments (California Public Utilities Commission, 2020).

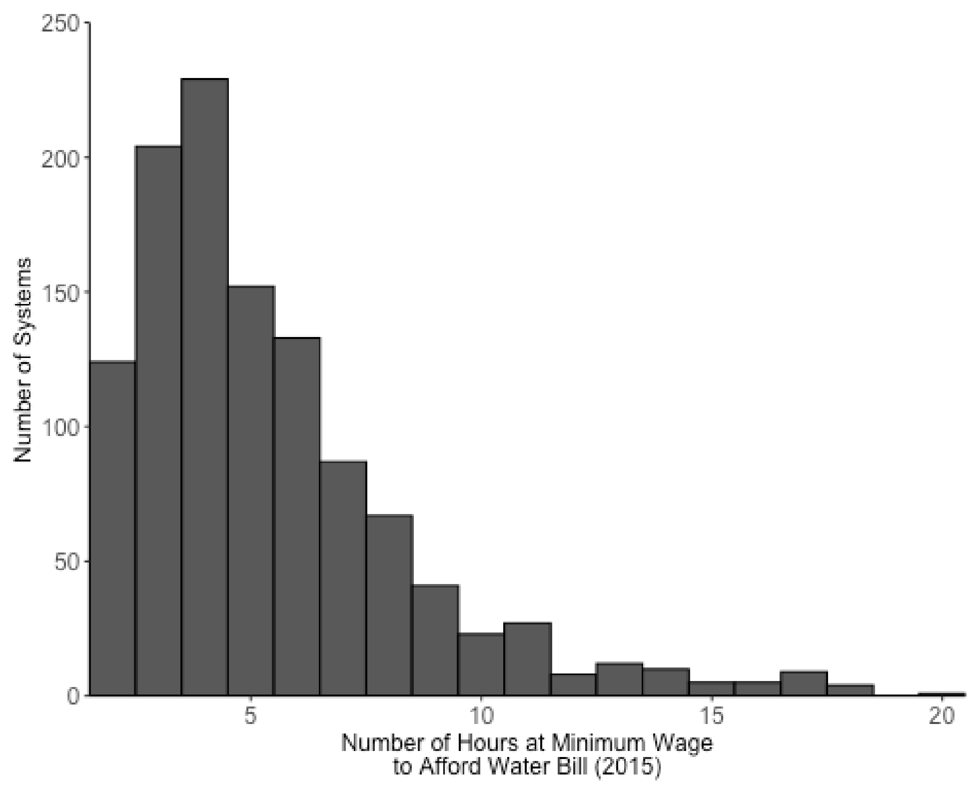
OEHHA determined that as an outcome indicator, HM is not as applicable for the human right to water approach in California given the available alternatives. Firstly, minimum wages do not

[71] In this approach, a minimum and maximum standard for consumption is set to ensure that under-consumption is not seen as 'affordable' (or as a solution to an affordability problem becomes the choice to decrease consumption) or that over-consumption is not mistaken as 'unaffordable'.
[72] Though a recent study by (Teodoro, 2018) indicates how expenditures might be incorporated into affordability ratios.
[73] Direct costs usually refer to the price per unit of water, whereas indirect costs may be related to lifeline rates, connection surcharges etc.

vary much across a state except in select cities. As such, HM simply reflects a re-scaling of the water bill data. For example, in the case of California in 2015, the minimum wage was nine dollars per hour for all but 14 cities (Department of Industrial Relations, 2015; LA Times, 2016). Water systems falling outside of these 14 cities share the same scaling factor of nine dollars per hour (i.e. all water bills would simply be divided by 9). Secondly, tying affordability to a set number of minimum wage hours worked risks normalizing inadequate minimum wages. Finally, while the indicator has appeal, it is unclear if HM would provide additional information that is not captured in the AR_{DP} indicator.

For reference, OEHHA estimated results for HM given the final affordability dataset of 1,141 systems, using the statewide minimum wage number of nine dollars per hour. Results indicate that the average HM is 5.4 hours worked (median = 4.6 hours), or 67% of a full eight-hour workday. In other words, to pay the average bill across systems, one would have to work the equivalent of 5.4 hours at minimum wage. Over half the systems have water bills that would require someone to work more than 4.6 hours at minimum wage. (Teodoro, 2018) suggests an HM greater than 8 hours for a family of four would be considered unaffordable. demonstrates a histogram of this data, which is right-skewed like the water bill data. 180 systems, or 15.8% of systems with affordability data (n=1,141), have water bills that would require more than 8 hours of labor at minimum wage to afford. This number likely overestimates the number of systems with HM >= 8 hours given those water systems falling within cities that have higher minimum wage values.

Figure A1. Hours at Minimum Wage to Afford Water Across Systems (N = 1,141).



A3 Limitations to Affordability Ratios, Adjustments, and Alternatives

The water system-level affordability ratio (and other aggregated indicators), while often the best possible option given data constraints, suffers from limitations relating to the numerator, denominator, and the threshold. In terms of water costs (i.e., the numerator in affordability ratios) the affordability ratio approach does not typically specify what volume of drinking water should be protected as a human right. This is particularly important in drought-stricken states like California, where fees and rate structures aiming to incentivize conservation during dry spells may lead to affordability issues (Cooley H *et al.*, 2016). High water costs to disincentive excessive consumption may benefit environmental outcomes but could compromise the right to water for vulnerable households that require more water (e.g., sick individuals or pregnant women). What is more, what should be considered a 'basic' amount to be protected by this human right to water can vary by context. Additionally, lacking access to safe drinking water, households may purchase bottled or vended water (Allaire *et al.*, 2019). These are additional, expensive costs that can increase the unaffordability of water (Moore E *et al.*, 2011). Ideally all costs for water, sanitation, and hygiene are incorporated in a human right to water context (Hutton, 2012) .

In terms of income (i.e., the denominator in affordability ratios), median household incomes at the water system scale do not reflect the vulnerability of low-income households within a water system. Variations of the median income ratio approach to address these concerns include using different denominators, for example the 20th percentile income level to capture low income households (Gawel *et al.*, 2013) or income less expenditures on other essential goods (i.e. discretionary income) (Teodoro, 2018; Teodoro and Saywitz, 2020). Such an approach takes into consideration the fact that water bills may be paid at the expense of other essential costs to households like food, fuel, healthcare, and housing by modeling expenditures and removing them from the 20th income percentile in an area. Without information about essential expenditures like food and housing, use of gross income overlooks trade-offs households may be forced to make among essential expenditures (Cory and Taylor, 2017). Such studies require data that is often difficult to acquire at a water system scale or in non-urban areas. For example, while one might be able to calculate a crude income distribution for each water system based on the 16 income brackets provided by the Census (Table B19001), the 20th percentile income for each water system may not represent economically vulnerable groups in wealthier systems. Relatedly, in smaller systems that are very low-income, even the 70th percentile may be considered 'low income'. The percentile approach advanced by AR_{20} thus becomes less applicable in smaller, more rural systems (as opposed to the urban areas evaluated by (Teodoro, 2018). Using the 20th percentile income for a larger geography could address this concern, but modeling expenditures in small areas poses a challenge. In applying this method to a small system, Jensen et al. 2019 found a negative denominator when removing modeled expenditures from 20th percentile (Jensen *et al.*, 2019). CPUC recently noted inadequate data for modeling expenditures in their affordability indicator, choosing to instead remove housing costs from the 20th percentile income (California Public Utilities Commission, 2020). Raucher et al. 2019 proposed measuring combined water and sewer costs as a percentage of the lowest income quintile without removing expenditures and evaluating this against the percentage of households within a system living below 200% the Federal Poverty Level (Raucher *et al.*, 2019). Others advocate evaluating affordability *within* a water system where income levels of residents can vary widely within a community (Christian-Smith *et al.*, 2013). These approaches aim to address the limitation that median income levels are less representative of households with incomes that diverge substantially from the median.

Another limitation of affordability ratios concerns selection of a threshold to evaluate whether water is affordable or unaffordable. Preexisting thresholds to determine what counts as affordable were recently argued to be too high or inadequately supported (NAPA, 2017). Concern over this threshold has existed for nearly two decades. A 2002 Scientific Advisory Board review of US EPA's affordability criteria for the SWDA's threshold of 2.5% and the National Drinking Water Affordability Working Group recommendations to US EPA in 2003 both suggested lowering US EPA's 2.5% threshold. In the latter case, a lower threshold–i.e., 1.5%–was suggested as a way to better enable lower-income systems to acquire representation through the indicator and thus financial support for water system compliance (National Drinking Water Advisory Council, 2003; US EPA, 2002).[74] The United States Conference of Mayors compared water costs in major California cities to the mid-point of each income bracket in the Census to show that households far from the median income of a region were misrepresented with the application of the 2.5% threshold (US Conference of Mayors, 2014). Their exercise highlights both the importance of the threshold choice and the need to look at various income levels. (Teodoro, 2018) also emphasizes these limitations noting that affordability is rarely as simple as a yes/no phenomenon. At the same time, (Teodoro M.P. 2018) and recently the Pacific Institute (2018) develop thresholds of 5% for drinking water as a proportion of income less essential expenditures, but acknowledge this is a somewhat arbitrary number itself. More research is required to identify whether these–and existing thresholds–are appropriate. Affordability analyses in California already use lower thresholds for affordability at the median income level (See Appendix Table A1). Tradeoffs exist between aggregate indicators and the choice of thresholds used, which may risk obscuring vulnerable populations in the process of representing water affordability (Kessides *et al.*, 2009).

Additional proposals to address limitations with the water system scale affordability ratio include tabulations of households by income levels within a water system, or using geographic scales (i.e., block groups) that capture finer spatial heterogeneity within a water system (Christian-Smith *et al.*, 2013).

[74]There was some disagreement and ambivalence about the value of the fixed-threshold approach and value, and the report also proposes a variety of approaches outside of the income threshold method.

Appendix B

Affordability Methods

B1 Water Bill Dataset Selection & Use

B1.1 WATER BILL DATASET SELECTION

To date, no comprehensive database on water rates, water usage, average water costs, or average water bills exists in the state of California. The Public Utility Commission (PUC) maintains water rate information for PUC-regulated systems. The State Water Board's Division of Drinking Water collects information on water rates (e.g., price of water at different tiers or the price of a fixed rate) and bills (e.g., reported average monthly water bill), and requires that systems report this information in annual electronic reports, but coverage is incomplete (see Appendix Table B1). Various private entities, including consulting firms and private water companies also collect water rate information which is then used to estimate average bills. OEHHA reviewed various datasets that have compiled water rate (or cost) data across the state (Appendix Table B1). We selected the Electronic Annual Reporting (eAR) dataset to be used in our affordability calculation, as it had the largest coverage and is publicly accessible, and has the highest chances of being continually updated and maintained.

Appendix Table B1. California Relevant Datasets with Monthly Water Cost Data by Water System.

Dataset	Year of Dataset	% Coverage (Systems with Cost Data)*	Entity Collecting Data
Electronic Annual Reporting (eAR)	2015	52%	State
American Water	2014	19%	Private water company
Pacific Institute	2013	2%	Non-governmental organization
Black & Veatch	2006	<10%	Private consulting firm

**Coverage estimates based on calculations prior to removing outliers. In other words, these values do not consider data quality concerns within each dataset but simply show the overlapping systems that have water cost data between each dataset and OEHHA's community water system list (n=2,839). Black & Veatch data did not identify water systems by unique system numbers, thus the reported coverage is an approximation based on the number of water systems they report data for.*

B1.2 WATER BILL CHOICE OF VOLUME TO USE IN AFFORDABILITY STUDY

Overall, California's residential water use is declining. The average use in 2016 was 85 gallons per capita per day.[75] The question of what counts as essential or basic needs for protection in the human right to water is an important topic that varies depending on location and situation (e.g., sick populations and pregnant women require more water to meet basic needs, as might different climatic regions). Affordability ratios can invoke a basic needs approach to exclude luxury uses like extensive landscaping (National Consumer Law Center, 2014)[76], while still attending to water needs for vulnerable populations and larger families (e.g., those with undocumented persons and lower-income multi-family homes).

The affordability indicators use water bills for 6 HCF, or nearly 50 gallons[77] per person per day given a household of three or 37 gallons per person per day assuming a household size of four. Appendix Table B2 demonstrates how the volume used in OEHHA's affordability indicators compares to California-specific studies on water needs and conservation goals.

In the future, OEHHA may choose to evaluate a range of affordability ratios including an average monthly water volume of 12 HCF, 300 gallons per household per day, or approximately 100 gallons per person per day assuming a household size of three, or 75 gallons per person per day assuming a household size of four.

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[75] Water use varies substantially depending on season. 85 gallons per day on average reflects a range from 64 gallons per day to 109 gallons per day between winter and summer use. See:(Legislative Analyst's Office, 2017) See, for example: (National Consumer Law Center, 2014)

[76] See, for example: (National Consumer Law Center, 2014)

[77] Note: The system wide average bill for 6 hundred cubic feet (6 HCF) of water as given by eAR, and does not include or account for any disaggregation or categorization based on the end use of the water (e.g., direct consumption or gardening).

Appendix Table B2. Water Bill Volume in eAR Reports Compared to California-Relevant Water Needs.

Water Bill Volume is equivalent to …	Volume per person per day assuming 3-person HH	Volume per person per day assuming a 4-person HH	Gleick (1996) Basic Water Requirements[78]: *13 gallons (50 liters) per person per day with a range of 15 to 53 gallons (57 to 200 liters) per person per day*	Pacific Institute (2018)[79]: *43 gallons (163 liters) per person per day*	California Water Code Conservation[80] *55 gallons (208 liters) per person per day*
6 HCF (4488 gallons or 16,990 liters)	**50 gallons** (189 liters)	**37 gallons** (144 liters)	IN RANGE; ABOVE BASIC WATER REQUIREMENT	IN RANGE	RANGE FALLS BELOW
12 HCF (8977 gallons or 33,980 liters)	**100 gallons** (378.5 liters)	**75 gallons** (283 liters)	RANGE FALLS ABOVE	RANGE FALLS ABOVE	RANGE FALLS ABOVE

B2 Income Data Selection & Use

B2.1 INCOME IN AFFORDABILITY RATIOS OVERVIEW

Ideally, income for all three indicators would be disaggregated into *gross income*, *disposable income*, and *essential expenditures* (Teodoro, 2018; Teodoro and Saywitz, 2020) This would allow OEHHA to experiment with additional affordability measures (namely the residual income approach (Gawel *et al.*, 2013) and better articulate the water bill burden for median and low-

[78] Here, (Gleick, 1996) proposes a basic water requirement of 50 liters per capita per day (13 gallons). This is equivalent to 150 liters (39.6 gallons) for a 3-person household and 200 liters (52.8 gallons) for a 4-person household, but presents a range of 57-200 liters per capita per day (15-53 gallons per capita per day) depending on region, technological efficiencies, and cultural norms.

[79] In this report, Pacific Institute recommends evaluating water affordability in California at 43 gallons per capita per day, equivalent to 129 gallons per 3-person household and 172 gallons per 4-person household.

[80] A provisional standard of 55 gallons per capita per day is identified in (California Water Code 2009) indoor water use for urban water suppliers aiming to reduce water demand.

income households within a water system. As and if this data becomes available, OEHHA will incorporate it into its human right to water assessment.

With respect to the denominator of affordability ratios (income levels), it is important to note a few caveats. When interpreting AR_{MHI}, it should be noted that the affordability ratio at the median income level is representative of the central tendency of affordability ratios for a water system. It is therefore unlikely to adequately depict households with incomes substantially below or above the median, especially in systems where there is a wide distribution of income.

When interpreting AR_{CPT} and AR_{DP} it is important to recognize that their denominator derives from county-level poverty thresholds (discussed more below), which are based on expenditure estimates within a given county that best reflect a "basic needs budget"–approximating *disposable* income (i.e. gross income less taxes). Disposable income is preferred to gross income because of its ability to better reflect real income constraints for households. However, in the current assessment the economic burden of other rights (health, shelter, food) and essential expenses are not accounted for, and thus water affordability as it relates to other essential rights is not possible to measure.

B2.2 POVERTY LEVEL INCOME DATASET SELECTION

B2.2.1 Selecting Poverty Level Income

Human right to water frameworks emphasize that affordability should consider issues of equity—i.e. more vulnerable households and individuals should be expressly considered with regards to their ability to pay for water (UN CESCR, 2002).[81] Additionally, reviews of US EPA's conventional affordability ratio(NAPA, 2017; OEHHA, 2017; US EPA, 2014).[82] as well as academic studies (Teodoro M.P. 2018) have emphasized the importance of evaluating affordability for lower-income households. In line with the view that the affordability analyses should explicitly consider lower-income levels, the second and third affordability indicator measures the impact of water bills on households living at the poverty and deep poverty level.

OEHHA looked for income data for poverty levels that enabled the best representation of water bill burden on vulnerable households. Disposable income reflects the available income to households better than total income (which includes taxes unavailable for spending on essentials).[83]

[81] General Comment No. 15 on the Right to Water, by the Office of the United Nations High Commissioner for Human Rights, notes that equity considerations regarding affordability "demand that poorer households should not be disproportionately burdened with water expenses as compared to richer households." (UN CESCR 2002:9).
[82] Note: early suggestions to amending EPA's residential indicator–which looks at affordability at the median income level–included evaluating affordability at the 10th or 25th income percentiles.
[83] Understanding a household's disposable income and their expenditures on non-water related essential needs (e.g. housing, health care, food) allows for an even better representation of a water bill's impact on a household's budget.

OEHHA evaluated two types of poverty income data due to their California-specific context: California County Poverty Thresholds[84] created by PPIC and Housing Income Limits (HCD 2015) created by the California Department of Housing and Community Development (HCD). While both PPIC and HCD aim to represent vulnerable income levels, their methodologies and aims are distinct. PPIC primarily aims to provide a California-specific version of the US Census's Supplemental Poverty Measure, which requires adjustments to the national poverty thresholds in order to capture differences in housing costs across the state (Bohn *et al.*, 2013).[85] HCD primarily aims to capture housing affordability challenges in the California context, which requires adjustments to national level income levels set by the U.S. Department of Housing and Urban Development (HUD).

The key distinction between PPIC's County Poverty Thresholds and HCD's Income Limits is that PPIC uses *expenditure-based* estimates to construct thresholds, whereas HCD uses *income-based* estimates to determine its income limits for Section 8. As such, PPIC's thresholds can be understood as a "basic needs budget"–or an approximation of disposable income–to remain out of poverty in the California context, whereas HCD's income limits reflect estimates of gross income. Consequently, in most cases, HCD's income limits are *higher* than PPIC's poverty thresholds.

B2.2.2 Poverty Level Incomes by Water System

OEHHA assigned each water system the poverty level income threshold and the deep poverty income threshold of its respective county.

Figure B1 and

Figure B2 demonstrate the distribution of water systems by county poverty and deep poverty threshold levels, respectively.

[84] OEHHA collected data directly from PPIC based on the assumption of a 4 person household (2 adults, 2 children) and a dual housing-adjustment index weighted for the number of homeowners and renters in the state.
[85] Note: this document contains the same technical methodology applied for developing poverty thresholds in 2015.

Figure B1. Histogram of California County Poverty Thresholds. Data for 2015, n = 1,141 Systems.

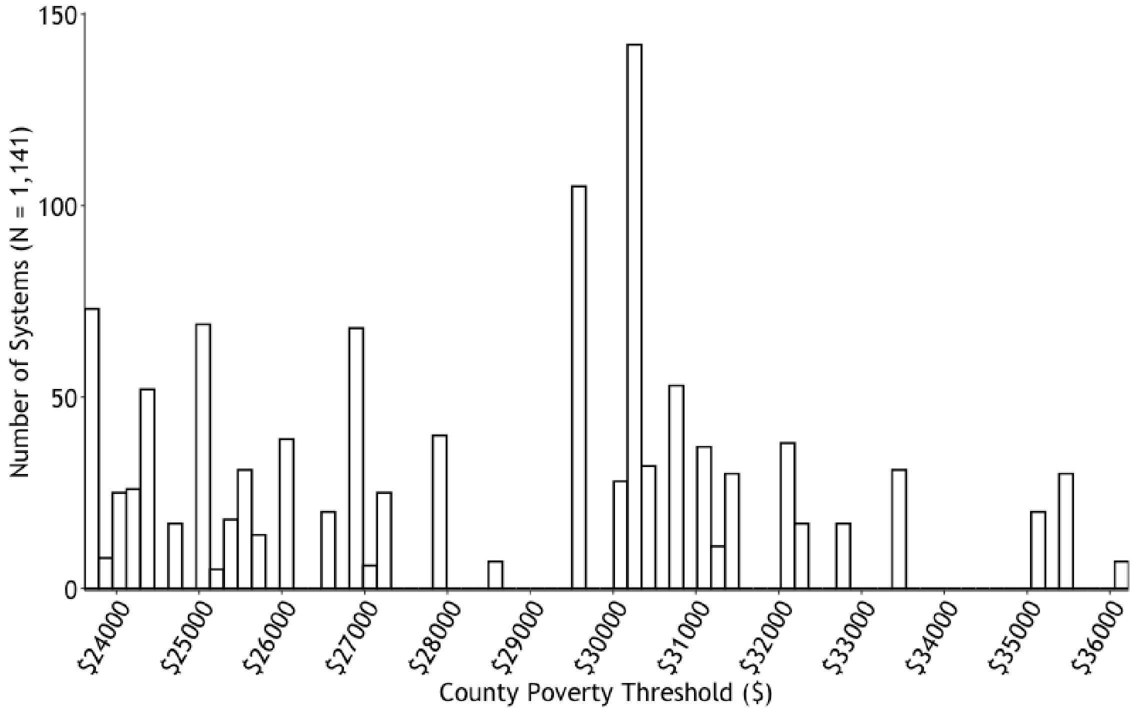
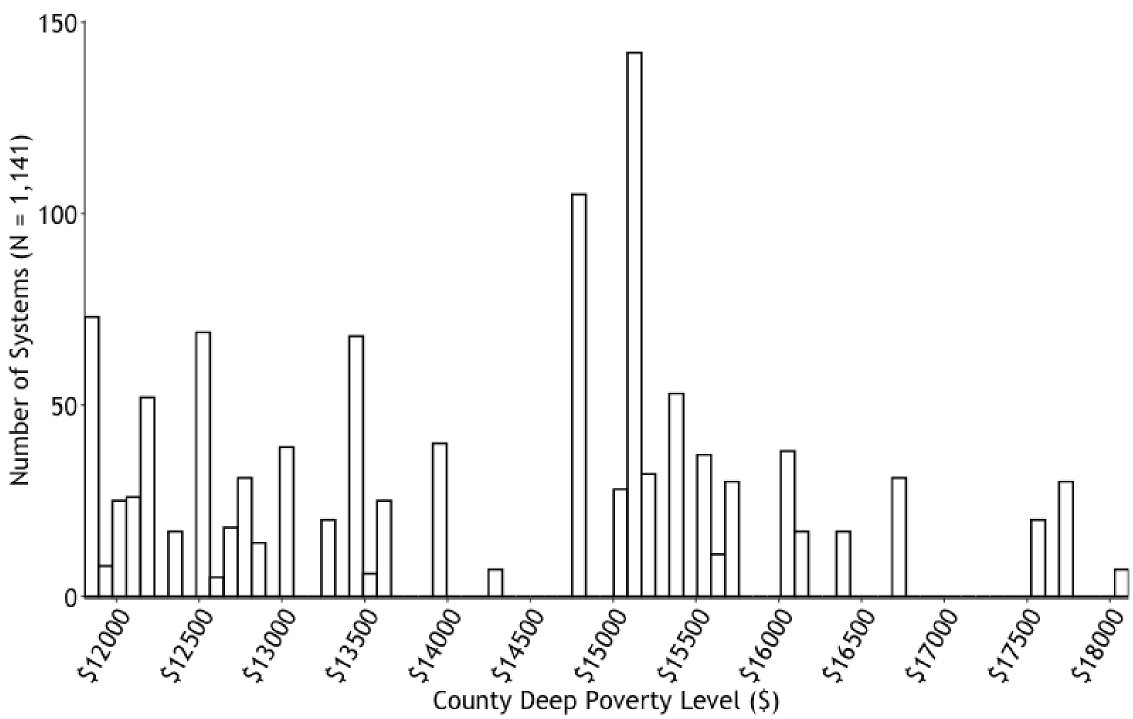


Figure B2. Histogram of California County Deep Poverty Thresholds. Data for 2015, n = 1,141 systems.



OEHHA chose PPIC's poverty thresholds because of its focus on poverty level budgets rather than income, and because PPIC poverty thresholds meet more of OEHHA's selection criteria for developing ratios that capture water bill burden for vulnerable income levels (Appendix Table B3).

Appendix Table B3. California Relevant Datasets with Poverty Level Incomes.

Selection Criteria for Demonstrating Water Bill Burden	HCD: State Income Limits for Housing	PPIC: County Poverty Thresholds
Income that captures 'lower income' households to represent acute affordability challenges	✓	✓
Income levels that reflect cost-of-living variations	✓	✓
Income that does not include taxes ('disposable income')	×	✓
Disposable income level AND essential expenditures *disaggregated* (to enable calculation of discretionary income)	×	×

B2.3 INCOME DATA AT WATER SYSTEM BOUNDARY

B2.3.1 Areal-Household Weighting Methodology

Because census geographies do not overlap with water system boundaries, OEHHA uses the area of a water system overlapping with populated census geographies to apportion households to water system boundaries. OEHHA follows CalEnviroScreen 3.0 methodology of intersecting populated blocks and block groups with water system boundaries to estimate the number of households (rather than population as in CalEnviroScreen) within each water system. For each system, an estimated median household income and an estimated number of households within each income bracket is constructed as follows:

1) Blocks and block groups are linked to water systems by OEHHA
2) Each water system is assigned a number of households based on the area intersecting between populated blocks and water system boundaries (this is also known as the "areal weight")
3) The number of households intersecting water systems at the block level is aggregated to the respective block group level, resulting in an estimated number of households within each block group served by the water system.

4) Block group estimates are multiplied by the portion of households within the block group that are determined to be served by the water system
5) For each system, the weighted block group estimates calculated in 4) are summed across all block groups intersecting the water system
6) The resultant sum is divided by the total number of households in the water system for (a household weighted average) MHI or for an estimated percentage of households in each income bracket within the water system.

B2.3.2 Limitations of Approach

Two main limitations should be considered when interpreting results:

1) Underlying block-level estimates of populated households to create block group level weights for water systems have sampling error.
2) Areal-household weighting assumes that block group level data are homogenously distributed across the block group; this can result in the under or over estimation of estimates if there is spatial heterogeneity within the block group. This assumption likely leads to inaccuracy for water systems in very rural, large areas.
3) Several water system boundaries have been approximated, and the accuracy of reported system boundaries could impact the weights assigned to each water system (OEHHA, 2017).

B3 Data Cleaning & Exclusions

B3.1 CLEANING WATER BILL DATA

The eAR database includes 6,656 systems. The eAR dataset contains information from water systems about water rates in addition to a question about the "average monthly residential customer water bill" using three different volumes (6 HCF, 12 HCF, and 24 HCF).[86] We cleaned the water bill data according to the following steps:

1) All zeros, blanks and N/A were not included;
2) Any water cost values were averaged when a range of values was reported;
3) Where Flat Base Rate reported as rate structure and the Flat Base Rate were provided along with the billing frequency as monthly, but reported average monthly water bill was left blank, the Flat Base Rate value was used as the average monthly water bill.

After applying these steps, 1,625 systems had cleaned, reported water bill data. All changes were tracked for every system. This list of systems with water bill data were merged with

[86] Reported values are not disaggregated by rates and fees, but additional costs to users based on other surcharges, fire suppression surcharges, as well as discounts to users based on lifeline subsidies, should be included in the calculation.

OEHHA’s list of 2,839 Community Water Systems (CWSs), resulting in 1,545[87] water systems with water bill data present in the OEHHA CWS list.

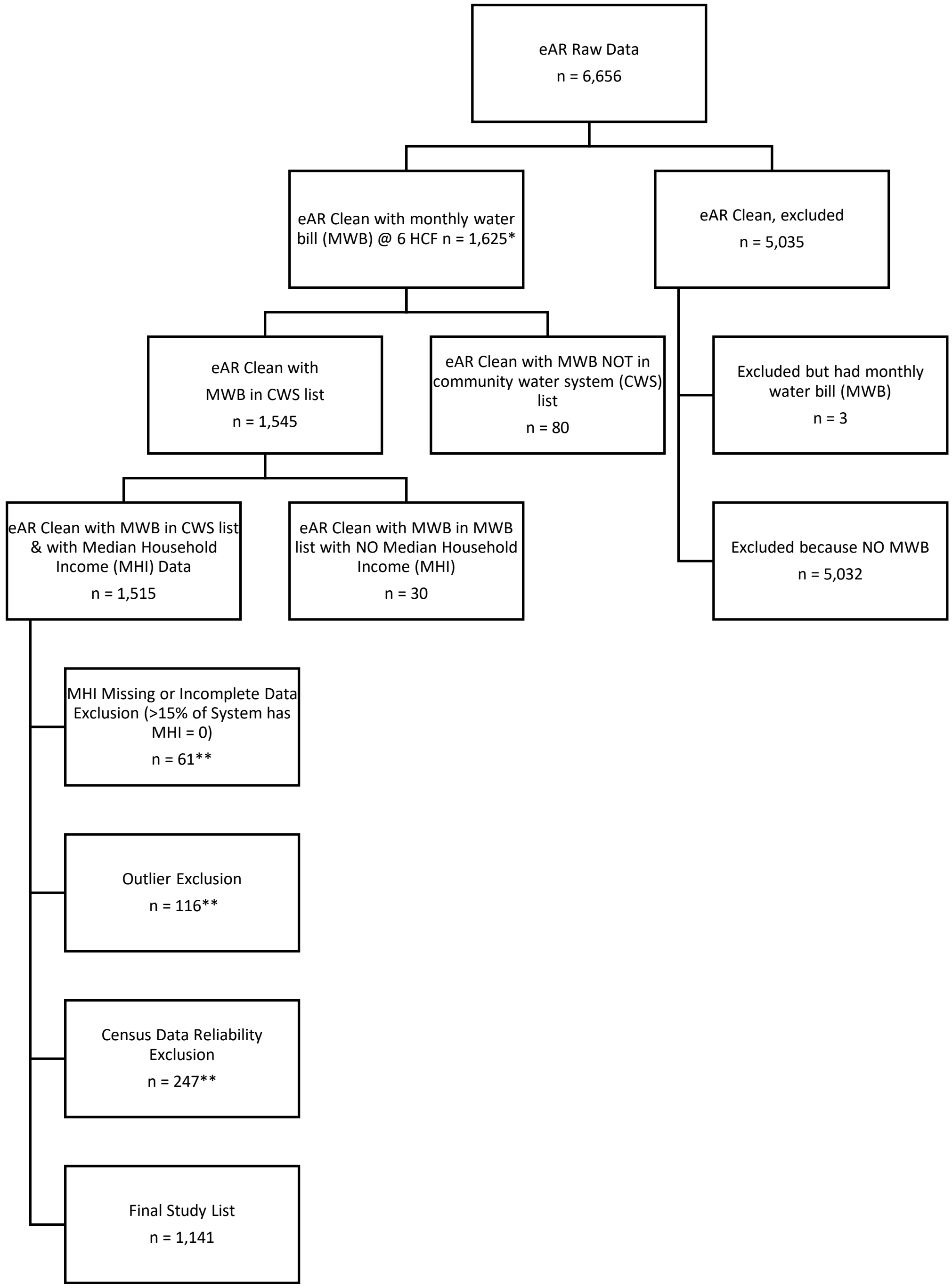
B3.2 OVERVIEW OF EXCLUSIONS & FINAL ASSESSMENT LIST BIAS

Due to the wide range of monthly water bills in the electronic Annual Report (eAR), we determined several steps were necessary to crosscheck this data. Ultimately, OEHHA chose to exclude 116 systems with very high and very low water bill data. Additionally, OEHHA excluded several systems for the affordability assessment due to data reliability concerns or missing data. Systems with very high and very low water bills were excluded in a potential outlier assessment (n = 116). Systems with more than 15% of their block groups missing MHI data were excluded (n = 61). Systems with unreliable data according to exclusion criteria discussed below were excluded (n = 247). Of the 424 systems in these exclusion lists, 20 systems overlapped, for a total of 404 unique systems that OEHHA excluded. Therefore, from the list of 1,545 systems with water bills, 404 systems were excluded to create a final list of 1,141 systems for the affordability assessment. Below, these exclusions are discussed in detail (See Appendix B4 Composite Affordability).

[87] To this list, we broke Los Angeles Department of Water and Power (LADWP) into five smaller LADWP sub-systems and removed the umbrella system. The reported average monthly water cost for the LADWP umbrella system was used as the average monthly water cost for the five smaller sub-systems, whose median household incomes were different based on the MHI study explained previously.

Figure B3 shows the sequence of exclusions based on the available data.

Figure B3. Data Cleaning Tree for Monthly Water Bills at 6 HCF and Income Data for Affordability Study.



** This includes 5 LA subsystems which acquire the same monthly water bill assigned for the parent system.*
***Twenty systems fell into more than one exclusion category.*

Overall, small systems and those serving severely disadvantaged communities are under-represented in the study (See Appendix B3.5 and "Missing Data: A Key Consideration" in the main report). Approximately 35% of systems included in the water affordability assessment are small systems (<200 connections), but small systems make up about 62% of the full community water system list. We see the effects of this bias in the overall list of missing data (1,698 systems)–a disproportionate number of smaller systems are excluded from the study (80% of systems without data are small). The final study list also has a slightly lower percentage of SDAC systems (12%) than the list of 2,585 community water systems with adequate MHI data (15.8%). Both biases appear to be driven due to water systems that do not report water bills; but a similar bias occurs through system exclusions based on census data unreliability.

B3.3 EXCLUSIONS – WATER BILL DATA

B3.3.1 Method of Excluding Water Bills

We conducted an outlier study to verify extreme values in the dataset in the prior report (OEHHA 2019). We considered several criteria for excluding systems with very high or very low water bills in the cleaned monthly water bill dataset for community water systems (n=1,561 water systems with water bill data from prior study list before any exclusions):

1) Tukey box plots (1977);
2) Hubert and Vandervieren adjusted box plots for skewed distributions (Hubert and Vandervieren, 2008);
3) Qualitative threshold based on prior knowledge.

We used these methods to identify systems on the ends of the distribution. No prior baseline previously existed to determine whether systems with very low or very high water bills are true outliers among California's community water systems. As such, we used thresholds determined using (Hubert and Vandervieren, 2008) method for skewed distributions. This approach established a lower monthly water bill threshold of $14.20 and an upper monthly water bill threshold of $180.20 (Appendix Table B4). Using these thresholds on the 2015 water bill data in the current report's community water system list, 87 systems had monthly water bills that fall below the lower threshold and 29 systems have monthly water bills that fall above the upper threshold.

OEHHA has conducted two small surveys of water systems with bill data that fell into very high or very low ranges during 2014 and 2015. The results largely indicated that while many systems *do* have water bills above $180.02 and below $14.20 per month for 6 HCF, the reporting is frequently inaccurate in the direction we expected (e.g. higher water bills were often over reported and vice versa). Further research is required to understand the quality of water bill data overall, however. OEHHA is open to alternate methods of outlier assessment and data verification and will consider including the systems excluded in this analysis in future reports.

It is important to note that the water systems falling above or below the threshold set by the (Hubert and Vandervieren, 2008) method are statistical outliers, not necessarily real outliers. As such, these results provide OEHHA with a conservative list of systems to evaluate water affordability during this first round of indicator creation.

Appendix Table B4. Identification of Upper and Lower Thresholds Used to Exclude Outliers.*

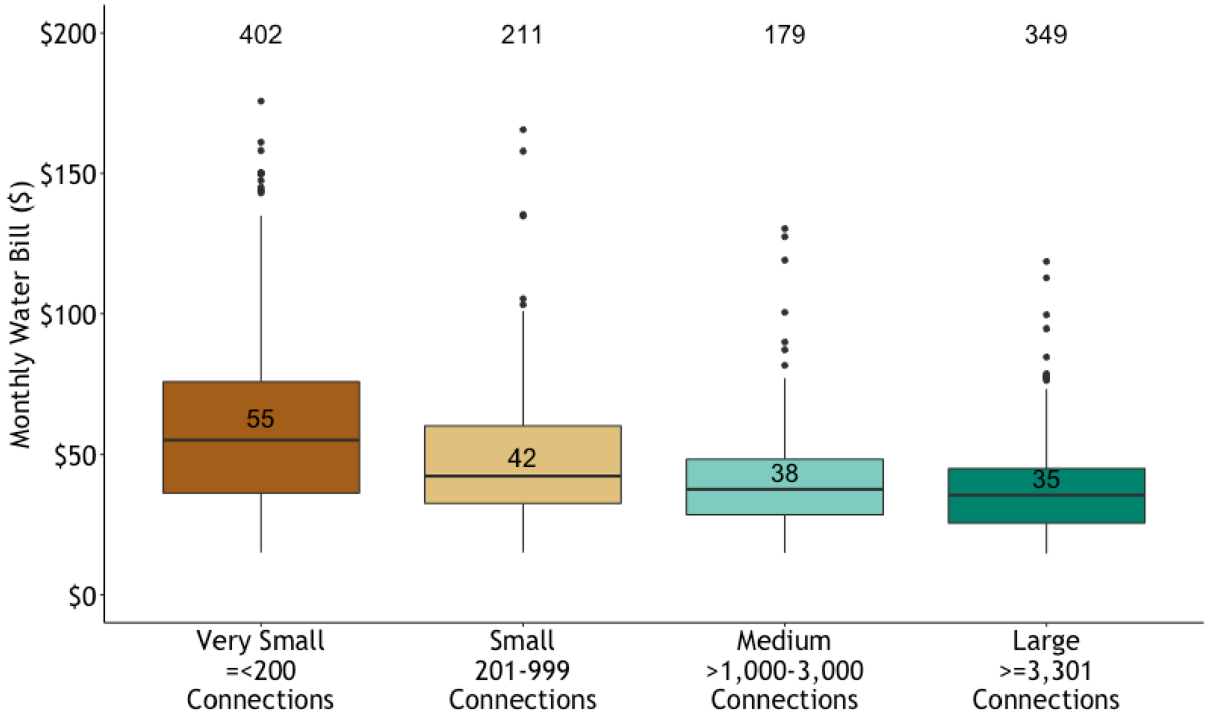
Metrics	Results
Q1	$28.76
Median of Dataset	$40.87
Q3	$61.00
Interquartile Range (IQR)	$32.20
Medcouple (MC) [+]	0.3
Lower Fence (threshold) = Q1 – [1.5 × exp(-4 × MC) × IQR]	$14.20
Number of systems below threshold (in affordability study)	87
Upper Fence (threshold) = Q3 + [1.5 × exp(3 × MC) × IQR]	$180.02
Number of systems above threshold (in affordability study)	29

**All calculations were conducted using adjboxStats in the robustbase package of R 3.3.2.*
[+]*The medcouple is the median of an array calculated using the kernel function as reported in the adjusted box plot method. A positive value (MC > 0) reflects a right-skewed distribution.*

B3.3.2 Results of Water Bill Data for Final Study List

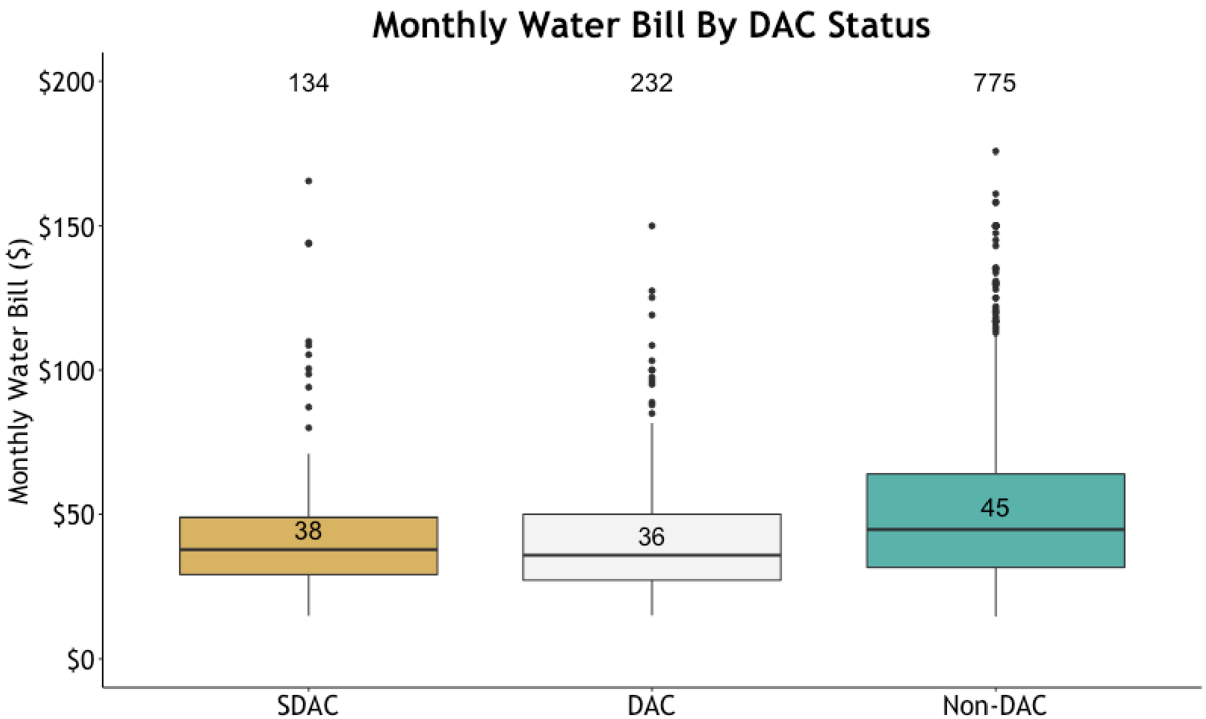
Among the 1,141 systems included in OEHHA's affordability assessment, the median water bill for 6 HCF across all systems was $41.36/month (average = $48.76 per month). Small water systems (i.e., less than 200 connections) have the highest median water bill ($55.00/month across systems) and more variability in the water bills in the upper quartile relative to intermediate and large systems. Figure B4 indicates the range of monthly water bills across water systems by system size. Very small systems have a greater range of average water bill overall (e.g., $15.00/month to $175.74/month) relative to large systems with more than 10,000 connections (ranging from $14.62/month to $118.57/month on average). Water bills also vary by the disadvantaged community (DAC) status of a water system. Figure B5 highlights that non-DACs (those with median household incomes greater than 60% of the California statewide median household income) have more variability in the upper quartile of water bills relative to intermediate and small systems. Non-DAC systems also have a higher median water bill ($44.83) than the median water bill of DACs ($35.86) and severely disadvantaged communities (SDAC) ($37.82).

Figure B4. Average Monthly Water Bill for 6 HCF for Community Water Systems by System Size.



Results shown for systems in affordability study sample for all systems (n=1,141), very small (n=402), small systems (n=211), medium systems (n=179), and large (n=349) systems. Study period 2015.

Figure B5. Average Monthly Water Bill for Community Water Systems by DAC Status.



Results shown for systems in affordability study sample (n=1,141) for SDAC (n=134), DAC (n=232), and Non-DAC/SDAC (n=775) systems. Study period 2015.†

† Disadvantaged Community Status is based on the statewide Median Household Income from the U.S. Census American Community Survey 5-Year Data (2011-2015). The California statewide MHI was $61,818. DAC = Disadvantaged Community status defined as a system with MHI below $49,454, or 80% of statewide MHI. SDAC = Severely Disadvantaged Community status defined as a system with MHI below $37,091, or 60% of statewide MHI. For purposes of this analysis, if a system is an SDAC, it is not counted as DAC. Non-DAC/SDAC are those systems greater than 60% of the MHI.

These findings must be viewed in a relative sense, based on income. A household in an SDAC community whose monthly water bill is $45, and has an annual median household income of $23,844 (as per data) would be spending roughly 2.3% of annual income on water. A household in a DAC community whose monthly water bill is $45.25 bill and whose median household income is $47,728 would be spending 1.2% of annual income on water bills. And a household in a non-DAC/SDAC community whose water bill is $60.50 and MHI is $74,595 would be spending 0.97% annually on water bills. Thus the slightly lower median bills in DAC and SDAC systems can still pose a financial burden in those communities. Furthermore, as water affordability impacts the most vulnerable households in any water system, higher bills in non-DAC systems could have the greatest impacts on households who earn well below the median income of that community. In essence, until an affordability ratio is calculated, the monthly bill carries less particular meaning.

B3.4 EXCLUSIONS – INCOME DATA

B3.4.1 Data Reliability in Census Data

The American Community Survey (ACS) provides quantitative information on sample error for their estimates. The Census provides margins of error (MOE) for each ACS estimate to quantify the magnitude of error between an estimated data point and its actual value, which is a measure of precision (US Census Bureau, 2015). The ACS creates MOEs at 90% confidence levels[88]:

$$Margin\ of\ Error_{90\%\ Confidence\ Interval} = Standard\ Error\ \times\ 1.645$$

The Coefficient of Variation (COV) for each data point can be calculated by back-calculating the standard error for each estimate from the Census-reported MOEs. COV is equivalent to the relative standard error, which measures the ratio between an estimate's standard error and the estimate itself:

$$Coefficient\ of\ Variation = \frac{Standard\ Error}{Estimate} \times 100$$

Coefficients of variation can then be used to determine the reliability of ACS estimates.

B3.4.2 Reliability Criteria using Coefficients of Variation

Three sets of estimates are impacted by data reliability concerns: median household income, number of households in income brackets (16 brackets), and total number of households. Median household income data is used in both the Institutional Capacity Indicator and the first Affordability Indicator (AR_{MHI}). Total Households and the Number of Households in each Income Bracket are used for creating household indexes of systems falling below income levels; these are used as weights in the Composite Affordability Ratio.

To our knowledge, no methodology exists to construct new margin of error estimates for a block group estimate that has been weighted by household counts and aggregated to a new, non-census designated geography. As such, we developed exclusion criteria for census block group estimates for systems falling within one block. Future assessments will investigate the potential for alternate exclusion criteria that better captures error propagation for systems intersecting more than one block group.

[88] Note: In the Panel's assessment of the ACS data, they point out that the 90% CI used by ACS is not standard survey research practice; rather 95% CI are typically used (thus MOE would be equivalent to the SE divided by 1.96). Using 95% CI will result in larger COVs and reflect greater uncertainty in the data.

Each estimate has margin of error data from which we can calculate coefficients of variation. We use the following exclusion criteria for water systems that are within one block group, as outlined in CalEnviroScreen 3.0:

a. Coefficient of error greater than 50 (meaning the Standard Error was less than half of the estimate) **AND**
b. Standard Error was greater than the mean Standard Error of all California census tract estimates for the data of interest.

For the 16 estimates of Number of Households in Income Brackets, we chose to exclude the system from the affordability assessment if more than two of the sixteen estimates were unreliable by these exclusion criteria.

B3.4.3 Results of Reliability Assessment–Institutional Constraints Indicator

Reliability of Median Household Income

OEHHA evaluated the total community water system list for data reliability regarding Median Household Income. Of the 2,839 water systems in OEHHA's community water system list, 1,323 systems fall into one block group. Of the 1,323 systems within one block group, 1,180 of them (89%) have fewer than 200 connections. The average number of connections is 105 (median = 46), and 75 percent of the systems have below 100 connections. In sum, systems within one block group are typically very small.

Of the 1,323 water systems within one block group, 25 systems did not meet the data reliability criteria for Median Household Income. This resulted in 25 exclusions, or 2,814 water systems in the full community water system list included for further analysis for the Institutional Capacity Indicator.

Institutional Capacity Indicator Final Study List

Of the 2,814 water systems remaining for analysis after excluding data based on reliability criteria, 64 systems had no Median Household Income Data (MHI = 0) and 165 systems had over 15% of their household-weighted area with missing data (MHI = NA). This resulted in 2,585 systems eligible for the Institutional Capacity Indicator before calculating disadvantaged community status by the number of service connections.

B3.4.4 Results of Reliability Assessment–Affordability Indicators

Of the 1,515 systems with water bill and income data prior to any exclusions, 518 systems fall within one block group. Of the 518 systems with one block group, 435 of them (84%) have fewer than 200 connections. The average number of connections is 122 (median = 54), and 75 percent of the data fall below 135 connections. In sum, the systems within one block group are typically very small.

Overall, the results suggest that MHI and Total Household estimates are relatively reliable. The other data–households by income bracket, used to construct HH_{MHI}, HH_{CPT}, and HH_{DP}–are more unreliable according to the criteria.

Total Households Data Reliability

There are no estimates in the “Total Households” data that meet the unreliability criteria.

Median Household Income Data Reliability

Of the 518 systems with data to evaluate reliability, there is one MHI estimate with no MOE. Of the 518 estimates for Median Household Income, 8 systems have unreliable estimates (or 1.5% of the 518 systems).

Household Income Brackets Data Reliability

On average, across all 518 systems, 239 systems had unreliable estimates for more than 20% of the 16 Number of Households in Income Bracket estimates. Of these 239, 5 systems overlapped with the 8 systems found to have unreliable MHI estimates.

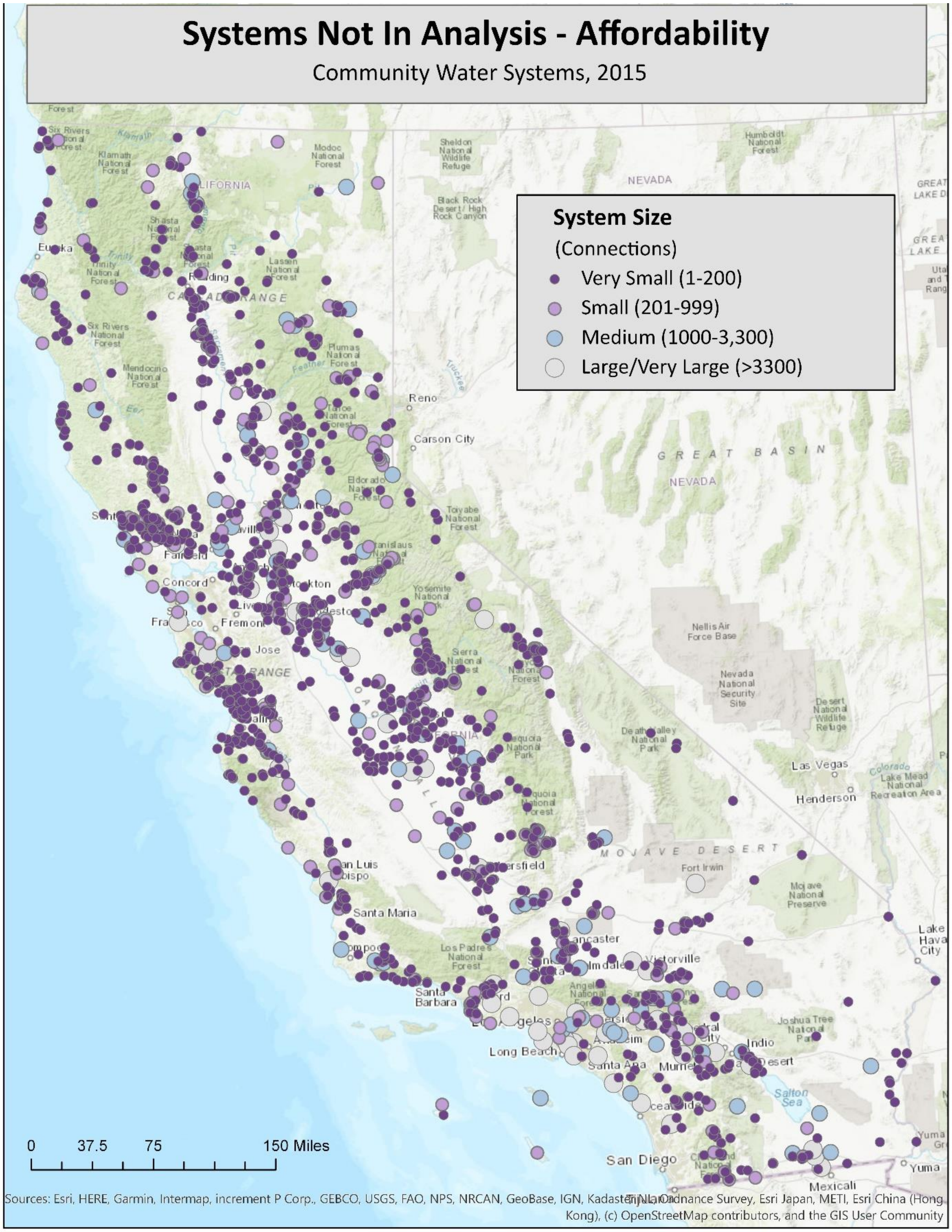
Affordability Indicator Final Study List

Of the 1,515 systems with income and water bill data, we eliminated 234 unique systems from the affordability study due to exclusion criteria for Census reliability.

B3.5 MAP OF SYSTEMS NOT INCLUDED IN FINAL ANALYSIS

Figure B6 shows water systems not included in the affordability analysis due to: missing water bill data (Appendix B3 Data Cleaning & Exclusions), potential outlier water bill data (Appendix B3 Data Cleaning & Exclusions), and/or unreliable or missing census data (Appendix B4 Composite Affordability). See “Missing Data: A Key Consideration” in main report for more detailed analysis.

Figure B6. Water Systems Not Included in Affordability Analysis by System Size. n = 1,698 systems of 2,839 community water systems.



B4 Composite Affordability Ratio and Scores

B4.1 HOUSEHOLDS POVERTY INDICES

As noted in the Affordability Chapter of the main report, OEHHA's composite affordability indicator is calculated using a household-weighted average of the three affordability indicators. To calculate the number of households below each income level for the Composite Affordability Indicator, OEHHA used the American Community Survey (ACS) 5 Year 2011-2015 Data "Household Income in the Last 12 Months" from Table B19001. Table B19001 provides the number of households in each income bracket, across 16 income bins, as well as data on the Total Number of Households.

Using this data, OEHHA calculated the total percentage of households in the water system at or below the Median Household Income, County Poverty Threshold, and Deep Poverty Level for each water system in the study. Because these incomes do not correspond perfectly with the upper or lower value of the income bins designated by the Census, OEHHA used linear interpolation to sum the proportion of households within each system below the two poverty levels. [89]

As noted above, we then estimated the approximate number of households living at or below the MHI, County Poverty Threshold, or Deep Poverty level within a system, as follows:

Household Index 1: HH_{MHI}

$$\#\ of\ Households\ Below\ Median\ Household\ Income = \sum Households\ in\ Water\ System\ below\ MHI$$

Household Index 2: HH_{CPT}

$$\#\ of\ Households\ Below\ County\ Poverty\ Threshold = \sum Households\ in\ Water\ System\ below\ CPT$$

Household Index 3: HH_{DP}

$$\#\ of\ Households\ Below\ Deep\ Poverty\ Level = \sum Households\ in\ Water\ System\ below\ DP$$

B4.2 ASSUMPTIONS AND LIMITATIONS FOR COMPOSITE AFFORDABILITY INDICATOR: AR_{WTAVG}

As described in the Main text, OEHHA estimate a household-weighted average across the three affordability ratios to estimate a composite affordability ratio focused on the lower-half of the income distribution, for each system, as follows:

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89 Linear interpolation analysis was conducted using the "approx." function in the stats package from R Version 3.3.2.

$$Water\ System\ Composite\ Affordability\ Indicator = \frac{AR_{MHI} \times (HH_{MHI} - HH_{CPT}) + AR_{CPT} \times (HH_{CPT} - HH_{DP}) + AR_{DP} \times HH_{DP}}{HH_{MHI}}$$

Twenty-five systems had Median Household Incomes that are lower than the California county poverty threshold. To maintain consistent approximations for the bottom 50th percentile of households in the composite ratio, these systems were household weighted from the median level down:

$$Water\ System\ Composite\ Affordability\ Ratio\ for\ Systems\ where\ MHI \leq CPT = \frac{AR_{MHI} \times (HH_{MHI} - HH_{DP}) + AR_{DP} \times HH_{DP}}{HH_{MHI}}$$

While the composite affordability indicator for each system represents an improvement on using one screening indicator to represent a water system's potential affordability problems, the current metric is not without its limitations. Specifically, the composite affordability indicator has four types of error that OEHHA identified and attempted to mitigate. First, individual census estimates were evaluated for reliability and an exclusion criterion applied (Appendix B3.4.1 Data Reliability in Census Data), but only for systems falling within one block group. Census data reliability improves through the use of geographic aggregation (i.e. multiple block groups combined) as well as the use of percentages as opposed to absolute numbers. However, OEHHA did not evaluate error for areal-household weighted census estimates in water systems with more than one block group. Future work is needed to assess the potential unreliability of these estimates.

Second, due to the methodology to assign census data to water systems discussed in Appendix B2.3.2 Limitations of Approach, the underlying data does not reflect a full representation of each system but rather an approximation. For example, while the proportion of households below the median household income within a water system is, on average, 50%, this is not always the case. This is likely due in part to the methodology assigning census data to water systems, which takes a weighted average of median incomes from the block groups that make up the water system. This is not a true median, and as such, will not always reflect 50% of the population. Of 1,141 systems in the affordability study, the average percentage of households below the estimated median income level is 50.9% with a standard deviation of 3.6%. Household estimates (e.g. HH_{CPT}) are best used as proportions of households at the different income levels, rather than the absolute number of households.

Third, household indexes may under-estimate the actual number of households facing poverty levels. This is largely because census income brackets are based on total income, whereas CPT and DP are estimates of disposable income. At these lower income levels, it is likely that gross and disposable income are relatively similar–but OEHHA does not evaluate this. As such the composite affordability indicator may under-estimate the average household affordability challenge within a water system.

Finally, the composite ratio reflects a weighted average affordability indicator for households living below the median income level of the water system. However, the average is based on three specific income levels which makes the average more specific than choosing one income to represent affordability, but coarser than a household weighted average that considers many income levels.

OEHHA will continue to investigate ways to improve and build upon and improve the methodology and data reliability concerns in future versions of the report.