PUBLIC REVIEW DRAFT

ACHIEVING THE HUMAN RIGHT TO WATER IN CALIFORNIA

AN ASSESSMENT OF THE STATE'S COMMUNITY WATER SYSTEMS

AUGUST 2019

Office of Environmental Health Hazard Assessment

California Environmental Protection Agency

OEHHA

SCIENCE FOR A HEALTHY CALIFORNIA

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Abbreviations

AB 685	Assembly Bill No. 685
AL	Action Level
ACS	American Community Survey
CAR	Conventional Affordability Ratio
CPT	County Poverty Threshold
COV	Coefficient of Variation
CWS	Community Water System
DAC	Disadvantaged Communities
DBCP	1,3-Dibromo-3-Chloropropane
DP	Deep Poverty
eAR	Electronic Annual Report
GW	Ground Water
HCF	Hundred Cubic Feet
IQR	Interquartile Range
JMP	Joint Monitoring Program
LCR	Lead and Copper Rule
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
SDAC	Severely Disadvantaged Community
SDWIS	Safe Drinking Water Information System
SJV	San Joaquin Valley
SW	Surface Water
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

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 300 communities rely on water sources that contain elevated levels of arsenic, which can cause cancer, birth defects, and heart disease. Other Californians depend on small water systems, and domestic wells impacted by contaminants like nitrate, which can likewise cause detrimental health outcomes. Across the state, contaminated water sources disproportionately burden low-income communities and communities of color, further exacerbating persistent inequities. 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 our 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.”

State Agency Efforts to Develop and Implement Policy Solutions

The State Water Board strives to protect the quality, accessibility, and affordability of California’s water by developing and enforcing environmental and drinking water standards, tracking comprehensive water quality data, and administering water conservation programs, among various other efforts. As such, the Board plays a critical role in delivering safe, clean, affordable and accessible drinking water to state residents.

In 2016, the Board adopted a Human Right to Water Resolution making the human right to water, as defined in AB 685, a primary consideration and priority across all of the state and regional boards' programs (State Water Resources Control Board Resolution No. 2016-0010. 2016). As part of its efforts to achieve the human right to water, the Board also enlisted the expertise of the Office of Environmental Health Hazard Assessment (OEHHA), to develop a framework for evaluating the quality, accessibility, and affordability of the state's drinking water supply. The Human Right to Water Assessment and Data Tool—comprised of this draft written report and an accompanying web platform—marks a first step toward developing a baseline from which to comprehensively track challenges in water quality, accessibility and affordability that individual California water systems face. This baseline assessment includes an examination of our state's community water systems' capacities, deficiencies, and vulnerabilities. This draft report also provides a conceptual framework and method for tracking the state's progress in delivering clean, safe, affordable, and accessible water through community water systems.

Other complementary methods to assess and track water system needs and vulnerabilities include:

- The 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 or unsustainable systems;
- The 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 working assessment of small and rural system supply vulnerabilities (Assembly Bill No. 1668. 2017).[4]

Each of these efforts focuses on current water system and household issues, and specific policy mechanisms to address them.

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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. 2017) directed the Department of Water Resources, in consultation with the Water Board and other stakeholders, to evaluate supply vulnerabilities for small and rural water systems.

OEHHA's Assessment and Data Tool

OEHHA's tool uniquely complements past and ongoing efforts, including those listed above, by offering 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 policy planning and implementation, and in designing programs to deliver safe and affordable water to households and individuals. The data tool is also designed to show how our various community water systems might be assessed and tracked over time.

OEHHA intends to expand the scope of the assessment and refine the 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, private 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.

This draft report first presents 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 draft 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. The draft 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.

After receiving public comment on this updated draft, OEHHA intends to finalize this first version of the framework and tool. OEHHA welcomes and looks forward to receiving the public's input on this draft document and suggestions for how to incorporate additional data and indicators into future versions.

Assessment Framework and Data Tool: Approach and Overview

Approach to Building the Assessment

In developing this baseline assessment and data tool, OEHHA drew on existing international approaches to tracking 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 (Villumsen M. and Jensen M. H. 2014).[5] These efforts are also intended to complement and build upon the work of the State Water Board and other agencies to ensure the quality, accessibility, and affordability of California's drinking water supply.[6]

The goals of this assessment and data tool are to:

1) Reflect core, California-specific objectives for safe, clean, affordable, and accessible water for all state residents.
2) Create a system of indicators of water quality, accessibility and affordability that can be examined individually or in groups to allow for a nuanced understanding of key domestic water issues.
3) Develop a working data set and analytic framework for evaluating trends in the provision of clean, safe, accessible and affordable water to all Californians, and assess progress over time.

In moving toward these goals, the data tool will serve as an adaptable approach for adding or refining indicators in the future, based on public input, policy needs and data availability.

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

[5] OEHHA followed Villumsen and Jensen's (2014) methodology for developing the 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.

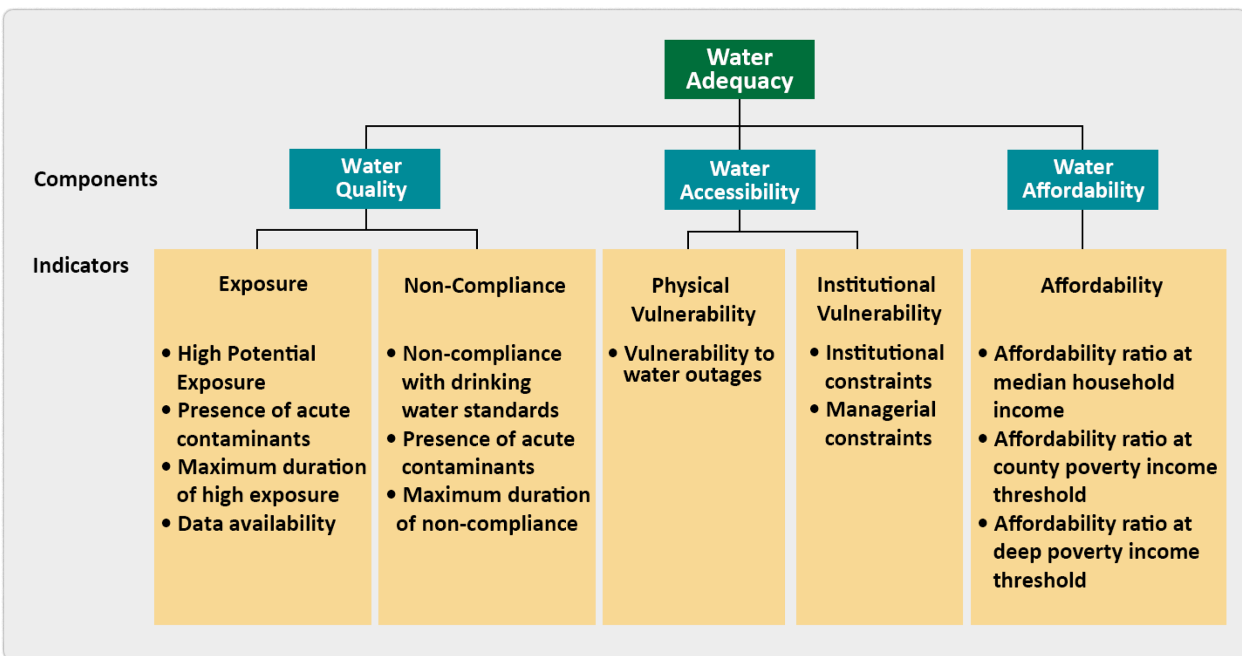
of chemical contaminants such as solvents and pesticides, nitrates, heavy metals, and radioactivity should not pose significant public health risks.

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.

The assessment uses indicators to characterize these three components. A total of 13 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 has been chosen based on current data availability, data coverage and data quality. Other indicators that have not been included due to data limitations may be added or refined in future versions, as improvements in data collection permit (see Appendix, Table A1).

Figure 1. Proposed Assessment 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 2008-2016 study period. A total of 2,903 community water systems met this criterion (OEHHA 2017).[7]

Time Period

This assessment focuses on data from the most recent time period available across each dataset. For most indicators, the data are from 2016, or as close to 2016 as possible. However, the assessment offers a long-term view of water quality, as the water-quality indicators cover the period from 2008 to 2016 (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, 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 safe and affordable 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:

- Assess sources of data for quality, coverage, and availability.
- Select data for the relevant time period that is high quality, provides broad coverage, and is publicly available.

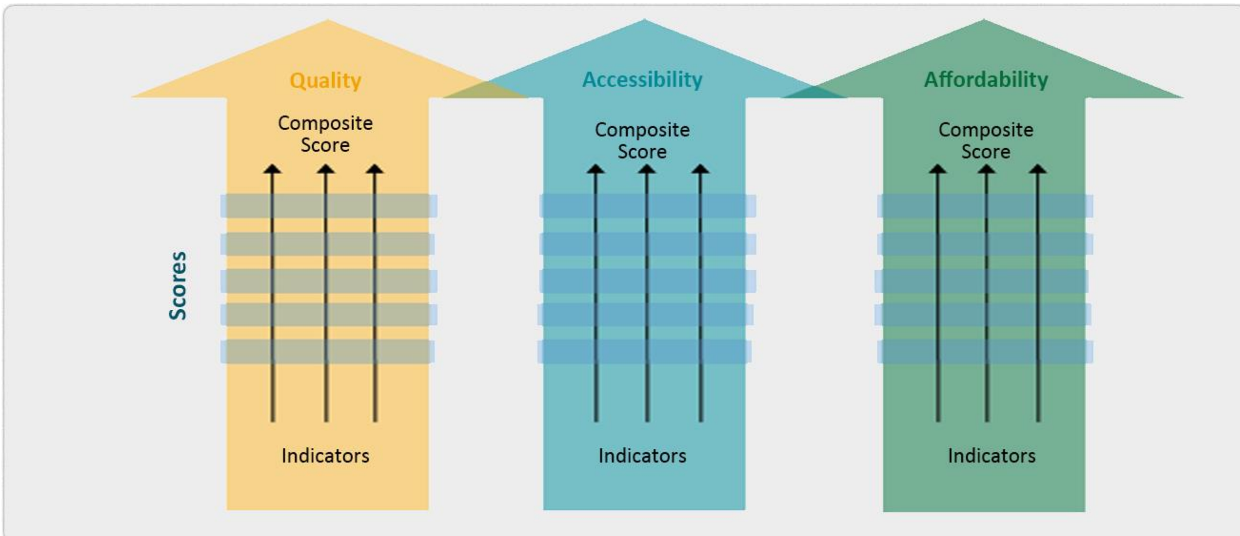
As shown conceptually in Figure 2, we then:

- Calculate each indicator value.
- Assign scores to each indicator, with higher values given to systems that perform favorably in the area that the indicator represents, and lower values given to systems

[7] This number includes five service areas provided by the Los Angeles Department of Water & Power, as well as 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 3.0 report (OEHHA 2017).

that perform less favorably. This results, for example, in a higher water-quality score for better water quality, and a lower score for poorer water quality. Develop 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.

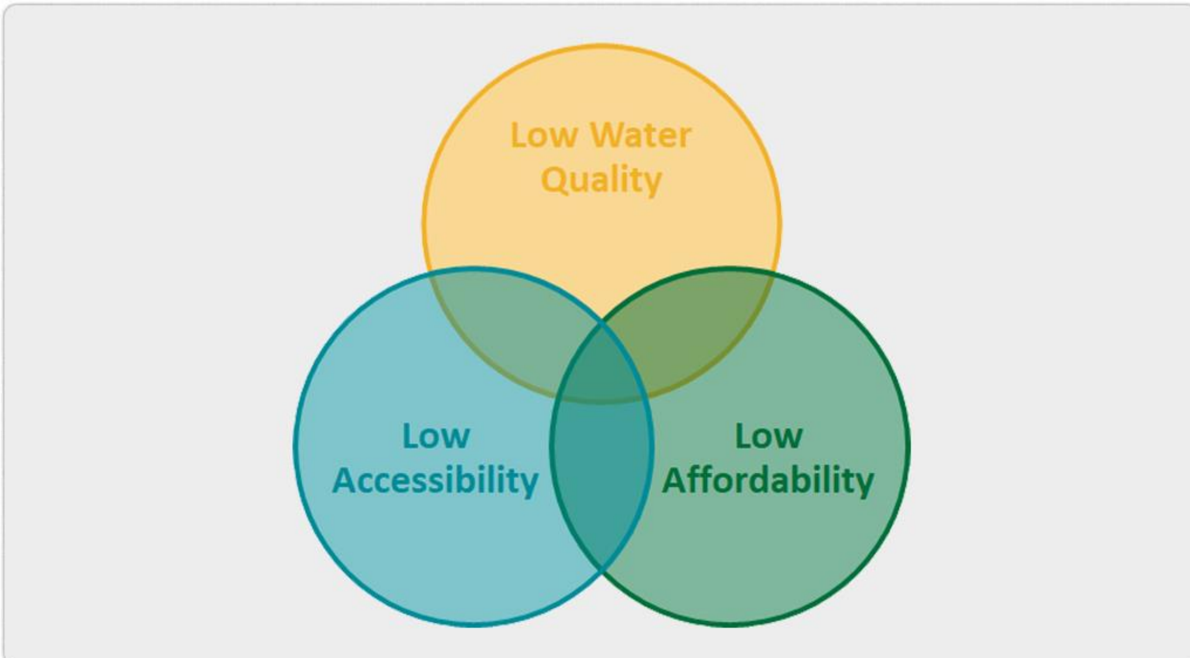
Figure 2. Conceptual View of the Proposed Assessment and Tool. The assessment is composed of three core components, with indicators assigned to each component. Higher indicator scores reflect better water quality, accessibility or affordability.



A Holistic View of Water Systems

While individual indicators associated with each of the assessment's three components provide useful information, 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 can allow users 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 41). The cross-component view offered by this assessment can help 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 three areas. 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 proposed 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 their associated indicators, offer important data and scores that are useful for planning and shaping policy solutions to local water system challenges. A holistic view of an individual or set of water systems should not replace a more specifically 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 single component should not be outweighed or downplayed by more favorable performance in the other components.

This first assessment and data tool focus on households served by community water systems. With time and further data acquisition efforts, later 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.

Measuring which contaminants people can be exposed to at the tap is important. Compliance status also 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] Figure 4 illustrates the various points that each subcomponent focuses on (Balazs, Morello-Frosch et al. 2011; OEHHA 2017).[10] It highlights how the compliance sub-component is based on measurements at Points A and C, while the exposure sub-component is based on measurements at Point D.

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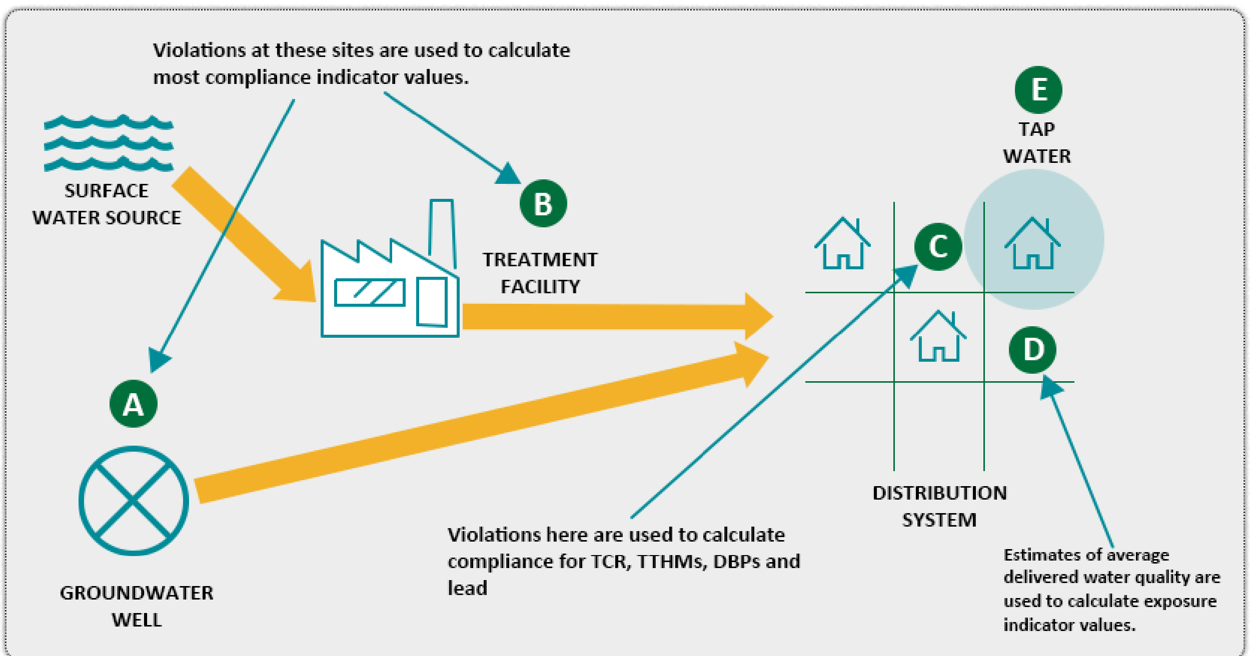
[8] Most human right to water efforts, such as the United Nations’ Joint Monitoring Program, only evaluate water quality in relation to compliance with regulatory standards.

[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, Morello-Frosch et al. 2011; OEHHA 2017).

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



Time Period of Coverage

Water-quality data for this initial version of the tool was drawn from a nine-year period from 2008 to 2016, the three most recent consecutive three-year compliance periods for which data are available (US EPA 2004).[11] 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. This nine-year period reflects information for the most

[11] 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). Our study period spans the third compliance period of the 2002-2010 compliance cycle (i.e., 2008-2010), and the first and second compliance period of the 2011-2019 compliance cycle (i.e., 2011-2016). Data collection for the 2016-2019 compliance period data collection is currently ongoing, as data for 2019 is still being collected.

recent three full compliance periods.[12] However, since the most recent data are from 2016, the water quality component does not reflect current compliance and exposure status.

Contaminants Selected

Approximately 122 drinking water contaminants are regulated in California under federal and state law. Of these, nearly 100 have primary drinking water standards, and the remaining have secondary standards. From a human-right-to-water perspective, consideration of all such contaminants is important. However, for this first version of the tool, OEHHA selected a subset of contaminants to characterize the water quality component of the tool. Each contaminant was selected based on whether there was significant coverage of water quality sampling data for that contaminant in the Water Quality Monitoring database across water systems in the 9-year time period between 2008 and 2016.

OEHHA started with 19 contaminants that had been considered for use in the CalEnviroScreen 3.0 drinking water quality indicator (OEHHA 2017). From this list, OEHHA selected 14 contaminants for which at least 80% of community water systems in the state reported at least one monitoring sample[13]:

> Arsenic, barium, benzene, cadmium, carbon tetrachloride, lead, mercury, methyl tertiary butyl ether (MTBE), nitrate, perchloroethylene (PCE), perchlorate, trichloroethylene (TCE), toluene, and xylene (See Table 1).[14]

Four additional contaminants associated with significant health effects, and for which there are a significant number of MCL violations (but for which less than 80% of water systems had samples), were deemed to be "high priority" and were also selected:

> 1,2-dibromo-3-chloropropane (DCP), 1,2,3-trichloropropane (1,2,3-TCP), total trihalomethanes (TTHM) and uranium (See Table 1).[15]

Finally, total coliform was included since it is an important measure of microbiological contamination, though there is no statewide sampling data available of coliform samples (but

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[12]The current compliance status of a system is available in the USEPA annual compliance report and on the Water Board's Human Right to Water Portal: https://www.waterboards.ca.gov/water_issues/programs/hr2w/

[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] While radium-226 and radium-228 (radioactive breakdown products of uranium) meet the criteria for inclusion, an assessment is underway regarding how best to include sampling data for these contaminants. The current assessment does not currently include these contaminants.

[15] The presence of hexavalent chromium is a serious health concern, but this chemical is not currently included because it does not have an MCL (State Water Board 2017).

data is available for compliance status). Future versions of this tool will explore additional contaminants, including those with secondary drinking water standards.

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 2008 to 2016.

Contaminant	Used in Exposure Indicators	Used in Compliance Indicators	Percent of Systems with Water Quality Monitoring Data
Arsenic	Yes	Yes	95%
Barium	Yes	Yes	95%
Benzene	Yes	Yes	93%
Cadmium	Yes	Yes	95%
Carbon tetrachloride	Yes	Yes	93%
Dibromochloropropane (DBCP)	Yes	Yes	59%
Lead	Yes	**No**	95%
Mercury	Yes	Yes	95%
Methyl tertiary butyl ether (MTBE)	Yes	Yes	93%
Nitrate	Yes	Yes	97%
Perchloroethylene (PCE)	Yes	Yes	92%
Perchlorate	Yes	Yes	96%
Trichloroethylene (TCE)	Yes	Yes	92%
1,2,3-Trichloropropane (1,2,3-TCP)	Yes	**No**	63%
Toluene	Yes	Yes	92%
Total coliform	Yes	Yes	Not available
Total trihalomethanes (TTHM)	Yes	Yes	74%
Uranium	Yes	Yes	45%
Xylene	Yes	Yes	92%

Exposure Subcomponent

Approach

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

1. The nature of contaminant concentrations (“high potential exposure”).
2. Whether contaminants are acutely toxic.
3. The duration of high potential exposure.
4. 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, it is not practical to use the PHGs as a benchmark for these indicators, as the detection limits for many contaminants are well above their corresponding PHGs.

OEHHA made the following adjustments for specific contaminants:

- For 1,2,3-TCP, the 2017 MCL is used as the benchmark.
- For lead, tap water sampling results for the 90th percentile of samples (as per the Lead and Copper Rule) are 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).[16]
- Total coliform counts are monitored regularly.[17] Here, MCL violations of the Total Coliform Rule (TCR) 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 are used to calculate both exposure and compliance indicators.[18]

[16] 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.

[17] TCR 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.

[18] Future assessments and data tools may include new measures of bacteriological contamination to reflect the

Data Source

Water Quality Monitoring (WQM) Database, 2008-2016, 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 2017).
- An average contaminant level for each relevant source was calculated.
- An annual, time-weighted, system-level average concentration was calculated for each contaminant, using 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)
- 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)
- Added a count if the system exceeded the TCR MCL at least once during the study period.

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implementation of the recently revised TCR.

[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.

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 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.

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

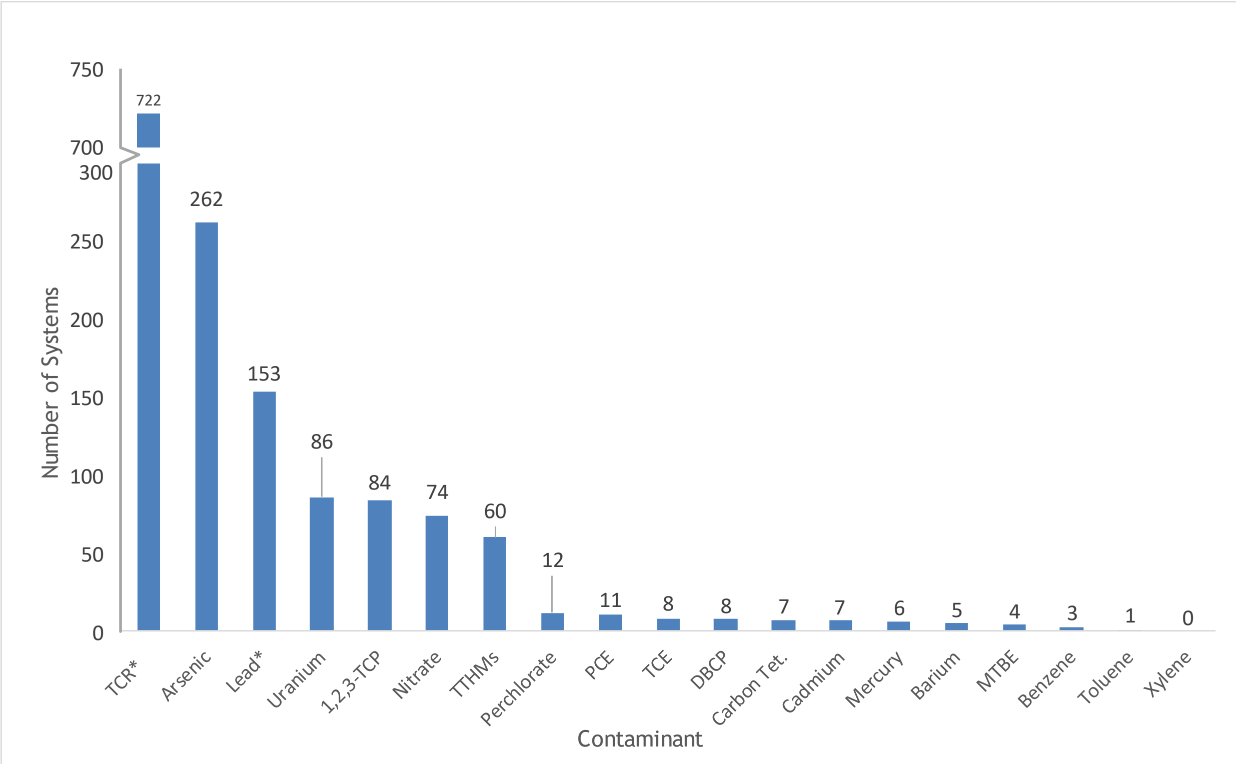
Results

All 2,903 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 (~58%) did not have any contaminants with high potential exposures. For the majority of those that did, it was due to one contaminant (~33%). As illustrated in Figure 5, the most common high exposure contaminant was Total Coliform, followed by arsenic and lead.

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 2008-16, with associated indicator score.

Number of Contaminants	Indicator Score	Number of Systems	Percent
0	4	1,696	58.4
1	3	953	32.8
2	2	210	7.2
3	1	39	1.3
4 to 5	0	5	0.2
Total		2,903	100

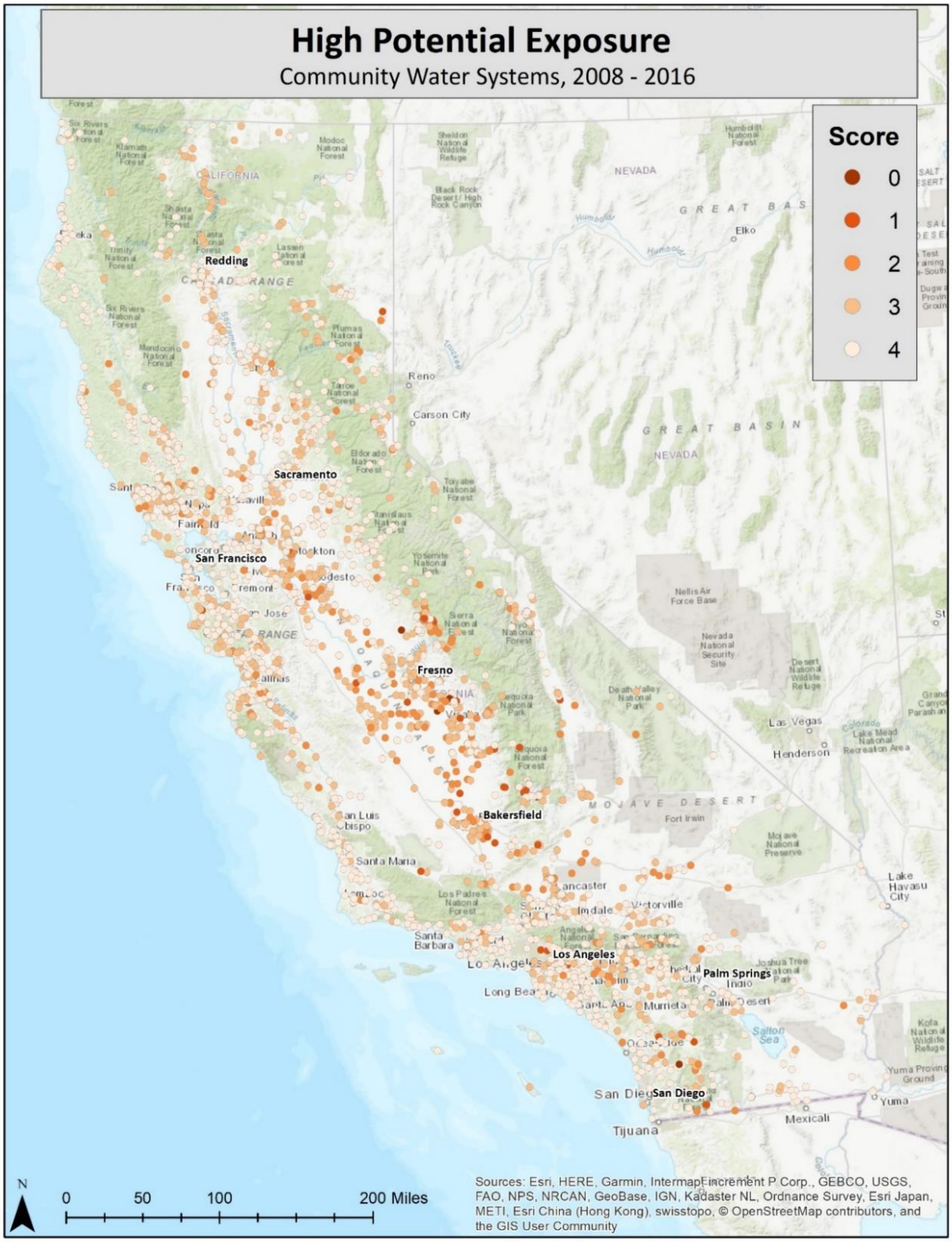
Figure 5. Number of Systems with High Potential Exposure (Annual average concentration exceeds MCL at least once in nine-year period, 2008-16)†. N=2,903. Maximum contaminant or relevant threshold used*.



** 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 is used as a proxy measure of exposure.*

Figure 6 plots the scores for each community water system across the state.

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



Water Quality Indicator 2: Presence of Acute Contaminants

This indicator assesses if any of the contaminants for which there was high potential exposure are *acute contaminants*. Here, *acute contaminants* refer to those that pose *an acute risk*, defined as a situation in which there is the potential for a contaminant or disinfectant residual to cause acute health effects (i.e., death or illness) as a result of a single short period of exposure measured in seconds, minutes, hours, or days (Health and Safety Code section 64400). Among the contaminants regulated in California, the following are considered acute or semi-acute for the purpose of Tier 1 Public Notice: nitrate, nitrite, or nitrate plus nitrite, perchlorate, and E. coli/fecal coliform (Title 26).[20]

Method

To create the indicator of acute contaminants we:

- Determined whether there was a high potential exposure for any of the aforementioned contaminants.
- For each system, we summed the total number of acute contaminants that had a high potential exposure (sum can equal 0, 1, 2 or 3). This approach does not measure an acute exposure event, but rather identifies whether the high potential exposure was for an acute contaminant.

Only 'acute' TCR MCL violations are considered for this indicator (i.e., E. coli/fecal coliform), as opposed to all TCR MCL violations in the high potential exposure indicator.

Scoring Approach

To score this indicator we assigned water systems the following scores:

- 0, if the system had 2 to 3 acute contaminants with high potential exposure.
- 2, if the system had 1 acute contaminants with high potential exposure.
- 4, if the system had no acute contaminants with high potential exposure.

Results

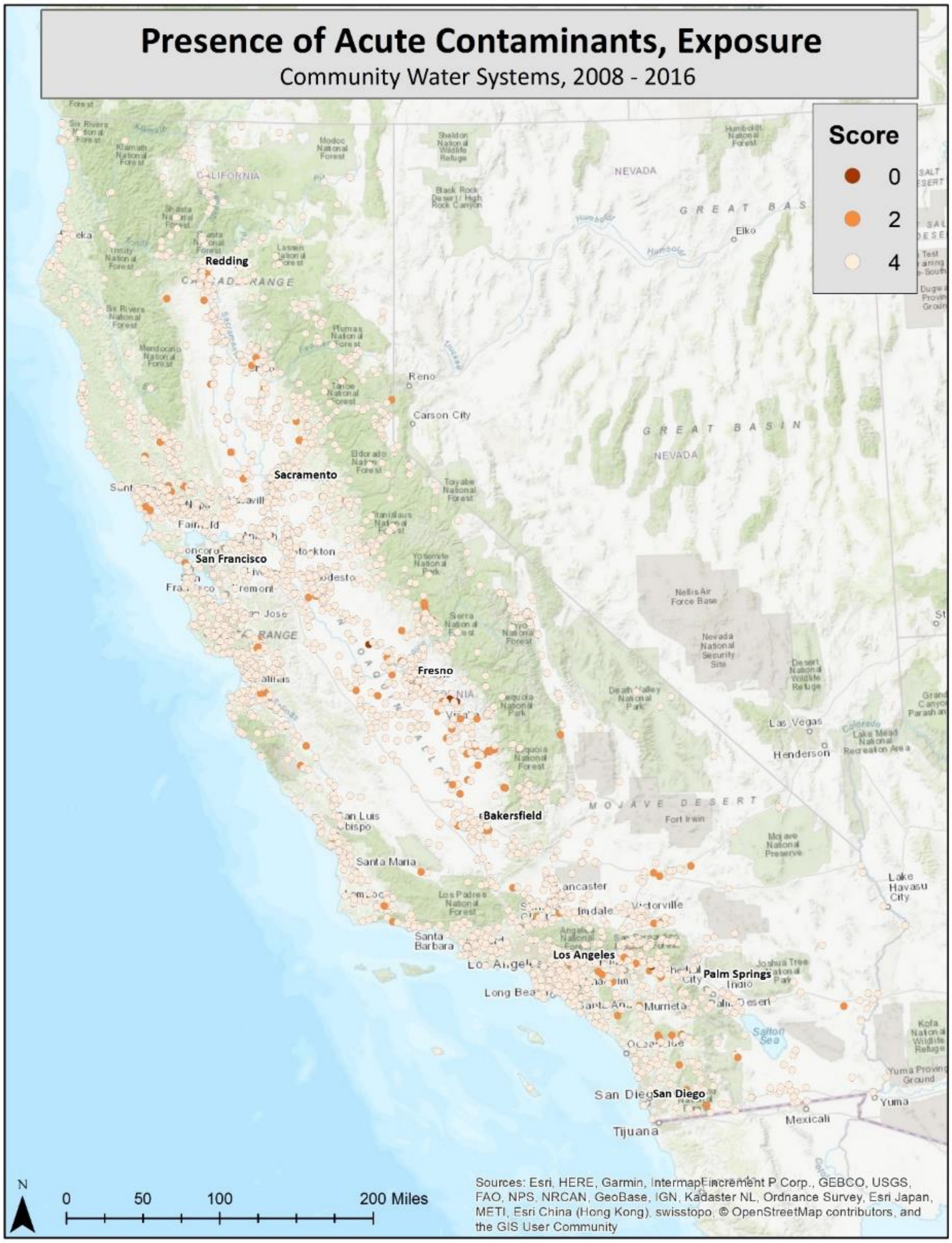
In the 9 year study period, 151 systems had high potential exposure for only one acute contaminant (Table 3). Of these, 74 were for nitrate, 74 were for TCR, and 12 were for perchlorate. Three systems had 2 acute contaminants, nitrate and TCR. One system had violations for all 3 acute contaminants. The map below shows the scores for each community water system across the state (Figure 7).

[20] Chlorine dioxide is also an acute contaminant, but is not included in this assessment. (Health and Safety Code section 64463.1a)

Table 3. Water Quality Indicator 2: Number of Acute Contaminants with High Potential Exposure. High potential exposure for nitrate and perchlorate assessed, alongside acute MCL violations of the Total Coliform Rule, with associated indicator score.

Number of Acute Contaminants	Indicator Score	Number of Systems	Percent
0	4	2,748	94.7
1	2	151	5.2
2 to 3	0	4	0.1
Total		2,903	100

Figure 7. Water Quality Indicator 2: Presence of Acute Contaminants. Higher scores represent a better outcome for this indicator; lower scores represent poorer outcomes. For a definition of score values, please consult Table 3.



Water Quality Indicator 3: 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 2008 to 2016). The indicator score is based on the maximum duration of high potential exposure across all contaminants during the nine-year study period (2008-2016). 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 TCR).
- Summed the number of years (from 2008 to 2016) 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 MCL violations.
- Selected the maximum duration of across the 19 contaminants.

Scoring Approach

For this indicator we assigned water systems the following scores:

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

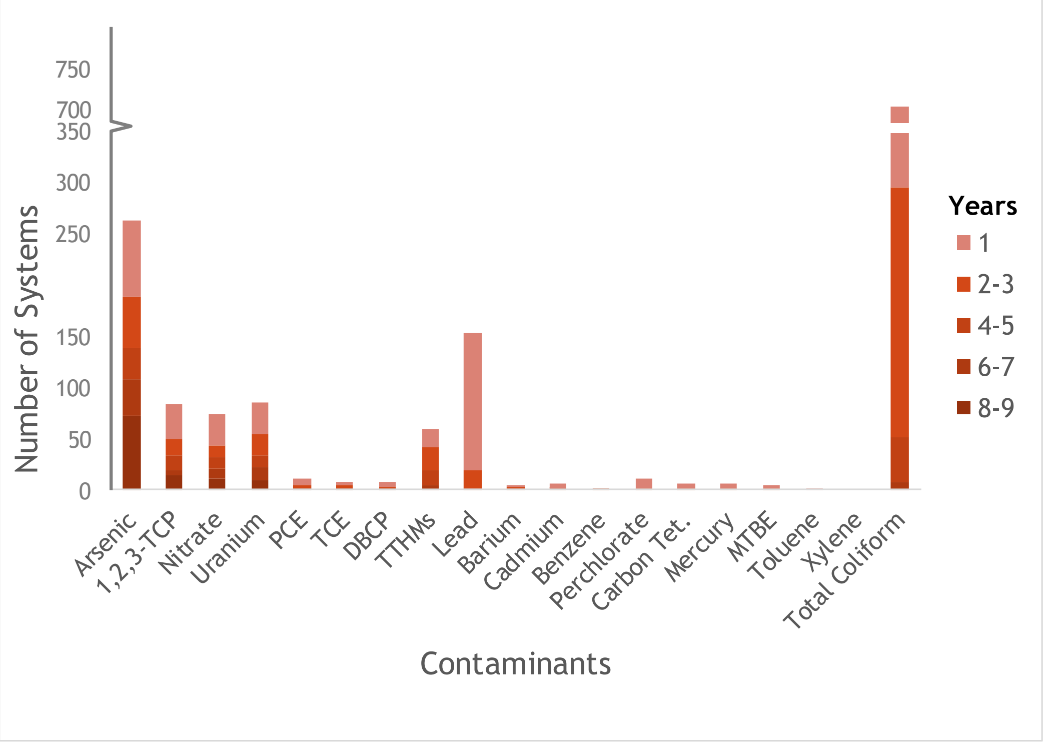
Results

As shown in Table 4, most water systems had no year or one year of high potential exposure. However, roughly 20 percent of systems had multiple years of high exposure. Figure 8 shows that this was mostly for arsenic. Also shown in Figure 8, arsenic had the largest number of systems (n=72) with the longest duration of high exposure (8 to 9 years). Only one contaminant—xylene—had no systems with high potential exposure.

Table 4. Water Quality Indicator 3: Maximum Duration of High Potential Exposure. Indicator score is applied to systems based on maximum years of high potential exposure across all contaminants, 2008-2016.

Maximum Duration of High Potential Exposure (Years)	Indicator Score	Number of Systems	Percent
0	4	1,696	58.4
1	3	592	20.4
2 to 3	2	325	11.2
4 to 5	1	112	3.9
6+	0	178	6.1
	Total	2,903	100

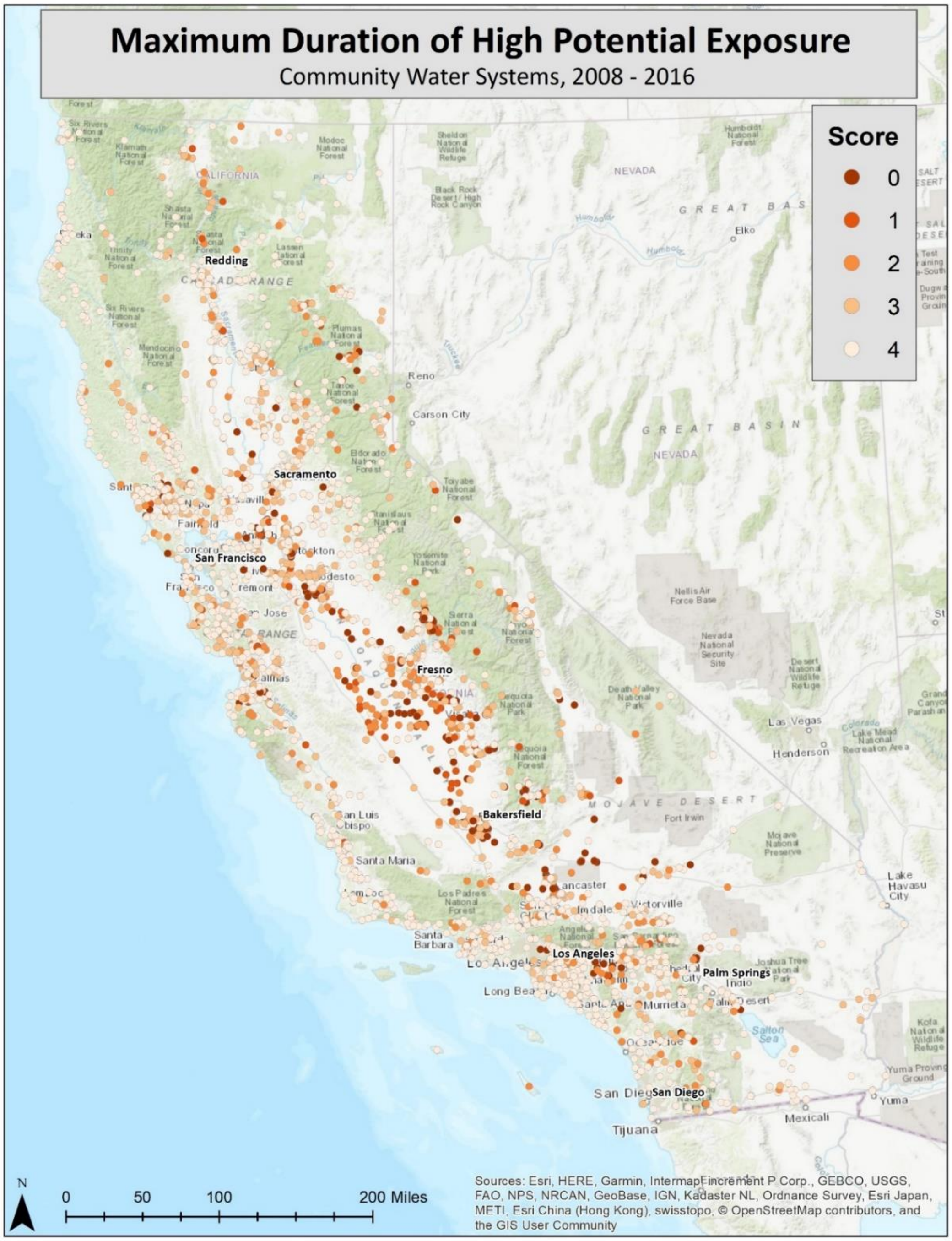
Figure 8. Duration of High Potential Exposure, by Contaminant. Maximum contaminant or action level (for lead) used*,† N= 2,903 community water systems.



** 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 is based on systems that received at least one TCR MCL violation in a given year.

The map below shows the scores for each community water system across the state (Figure 9).

Figure 9. Water Quality Indicator 3: Maximum Duration of High Potential Exposure. Higher scores represent a better outcome for this indicator; lower scores represent poorer outcomes. For a definition of score values, please consult Table 4.



Water Quality Indicator 4: 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. Indicator 4 measures how much data is available to evaluate water quality in current water sampling databases (Title 22).[21] It is used to characterize the adequacy of information with respect to a system's 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. 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.

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 no contaminants with the minimum required data in the time period.

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[21] Note that this indicator is different than 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),

[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 2008 to 2016 are considered sufficient.

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

Results

Table 5 shows that more than 60% of systems did not have the minimum data required for the 14 contaminants.

Table 6 lists by contaminant the number of systems that did not have the minimum required data. The contaminants with the largest number of systems lacking the minimum required data were nitrate and lead.[23] The locations of systems with missing data were dispersed throughout the state, as shown in Figure 10.

Table 5. Water Quality Indicator 4: Data Availability for 14 Contaminants. Indicator scores are shown†.

Number of Contaminants with Required Data	Indicator Score	Number of Systems	Percent
14	4	1,120	38.7
12 to 13	3	1,317	45.4
8 to 11	2	238	8.2
1 to 7	1	153	5.3
0	0	75	2.6
	Total	2,903	100

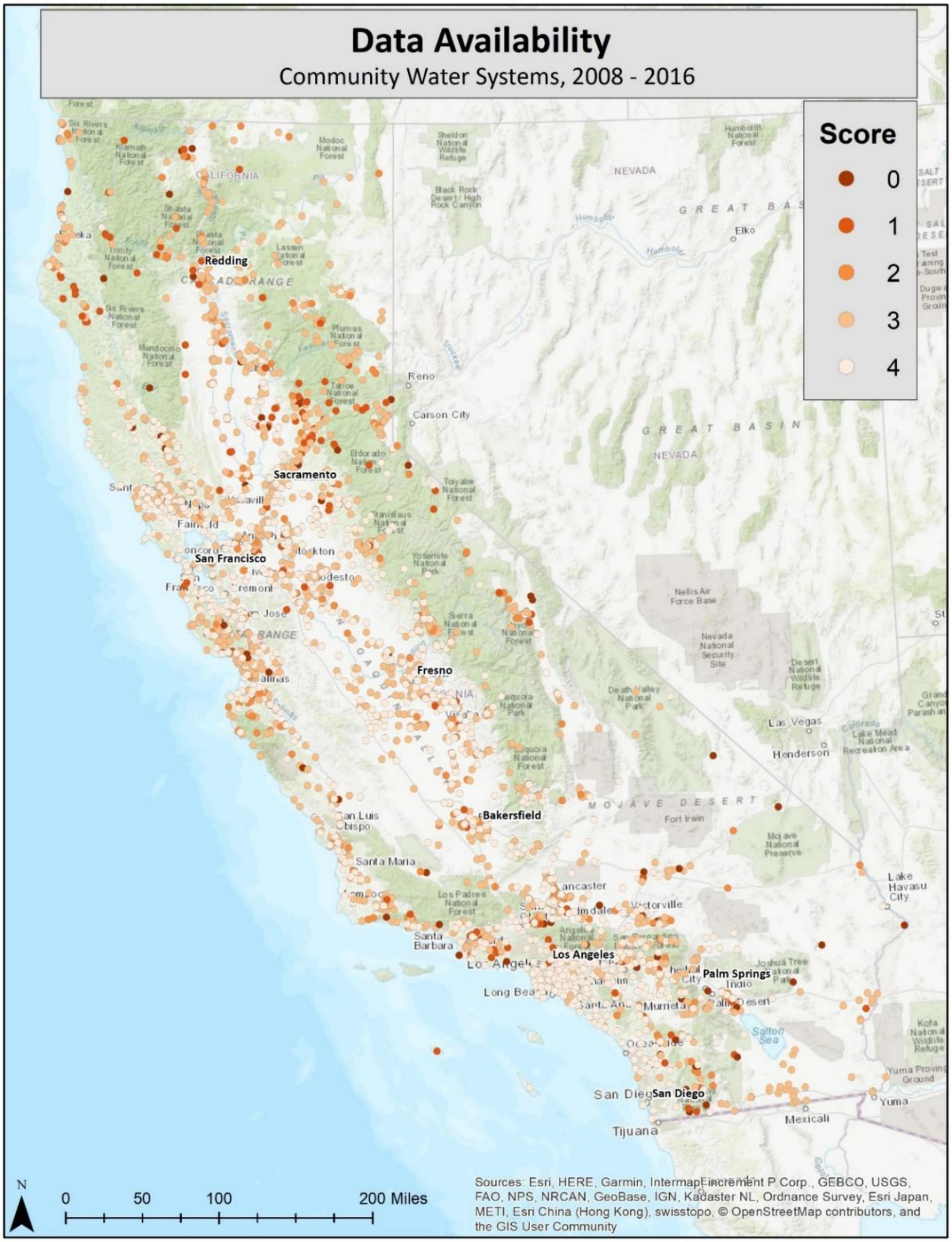
† Number of systems with contaminants that had available data in the 9-year time period.

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

Table 6. Number of Systems without Required Water Quality Data by Contaminant, as per minimum sampling requirements under the monitoring framework.

Contaminant	Number of systems without required data	Percent of Total (N=2,903)
Arsenic	131	4.5
Barium	154	5.3
Benzene	217	7.5
Cadmium	153	5.2
Carbon Tetrachloride	217	7.5
Lead	1,163	40.0
Mercury	154	5.3
MTBE	208	7.2
Nitrate	1,401	48.3
PCE	219	7.5
Perchlorate	525	18.0
TCE	219	7.5
Toluene	218	7.5
Xylene	229	8.0

Figure 10. Water Quality Indicator 4: Data Availability. Higher scores represent a better outcome for this indicator; lower scores represent poorer outcomes. For a definition of score values, please consult Table 5.



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 the 19 primary drinking water contaminants listed in Table 1.

Data Source

Safe Drinking Water Information System (SDWIS) from the State Water Board, 2008-2016. Available at URL:

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

Indicators

Water Quality Indicator 5: 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 17 of the 19 contaminants of interest (see Table 1). The two excluded contaminants are 1,2,3-TCP and lead. The chemical 1,2,3-TCP is excluded because its MCL was not effective until 2017, meaning that no MCL violations were issued during the study period. Lead is not included because there is no MCL for lead, only an Action Level. However, monitoring and reporting violations of the Lead and Copper Rule (LCR) are included in the count of Monitoring and Reporting violations, which is part of the accessibility component.

Method

To calculate this indicator, we:

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

[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).

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 4 contaminants with at least one MCL violation.
- 1, if the system had 3 contaminants with at least one MCL violation.
- 2, if the system had 2 contaminant with at least one MCL violation.
- 3, if the system had 1 contaminants with at least one MCL violation.
- 4, if the system had 0 contaminants with MCL violations.

Results

As shown in Table 7, two-thirds of systems had no MCL violations in the entire nine-year period. Approximately 29% of systems had one contaminant with at least one MCL violation in the study period. Slightly over 5% had two or more contaminants with at least one MCL violation.

Table 7. Water Quality Indicator 5: 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	4	1,909	65.8
1	3	841	29.0
2	2	135	4.6
3	1	16	0.6
4	0	2	<0.1
Total		2903	100

† 1,2,3-TCP and lead are excluded.

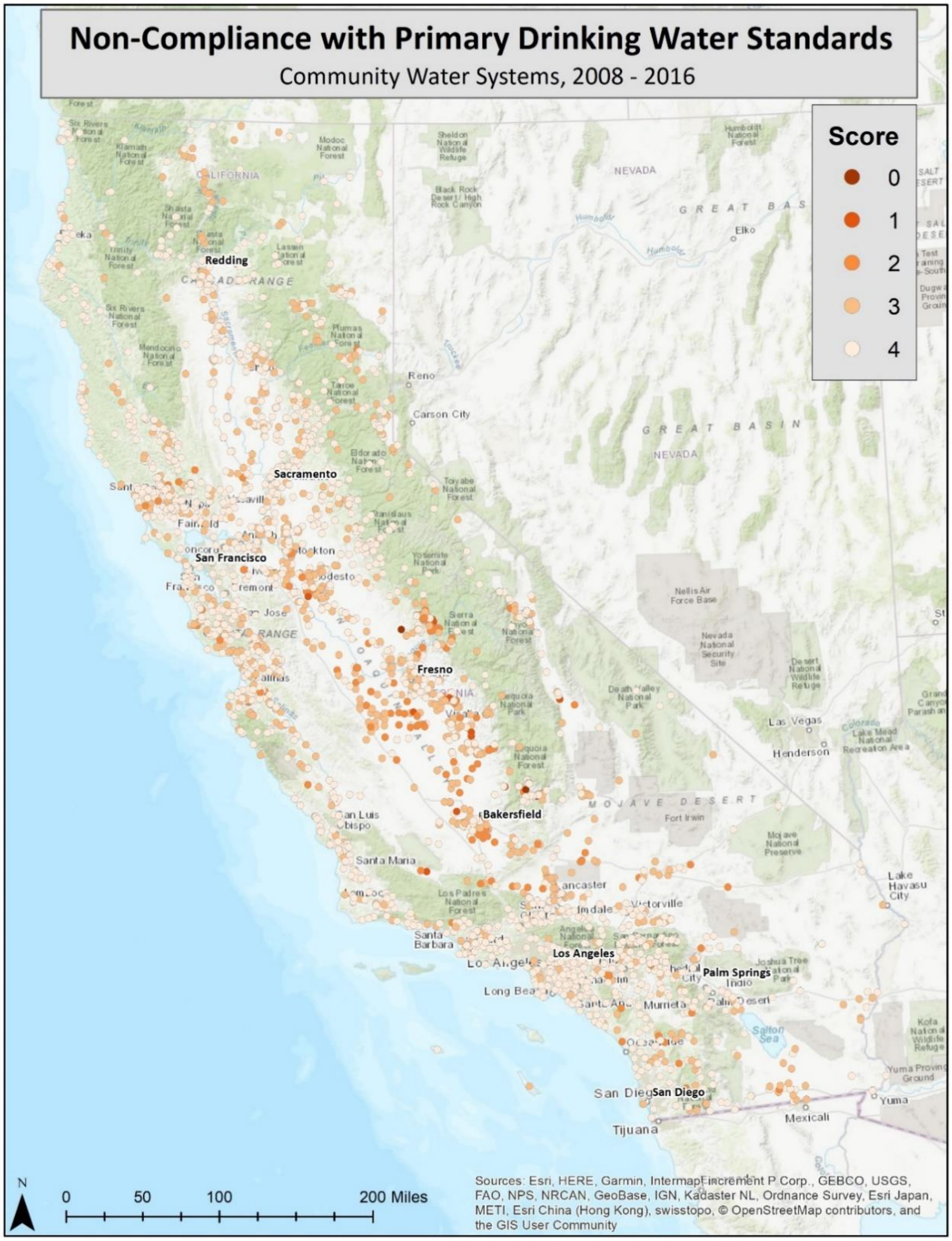
The most prevalent types of violations were for total coliform, arsenic, nitrate, TTHMs, and uranium, as shown in Table 8.

Table 8. Number of Systems with at Least One Recorded MCL Violation, 2008-2016 (n=2,903).

Contaminant	Number of Systems with at Least One MCL Violation
Arsenic	187
Barium	0
Benzene	0
Cadmium	1
Carbon Tetrachloride	0
DBCP	5
Mercury	0
MTBE	1
Nitrate	80
PCE	1
Perchlorate	5
TCE	2
Toluene	0
Total Coliform	722
TTHMs	112
Uranium	51
Xylene	0

While this indicator and Water Quality Indictor 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. Of the 262 systems that had high potential exposure at least once in the study period, 97 did not receive an MCL violation. This could potentially signal systems that have potential exposure challenges, despite being in compliance with regulatory standards. The map below shows plots the scores for each community water system across the state (Figure 11).

Figure 11. Water Quality Indicator 5: Non-Compliance with Primary Drinking Water Standards. Higher scores represent a better outcome for this indicator; lower scores represent poorer outcomes. For a definition of score values, please consult Table 7.



Water Quality Indicator 6: Presence of Acute Contaminants

This non-compliance indicator assesses which, if any, of the non-compliance events have involved acute contaminants, namely nitrate, nitrite, or nitrate plus nitrite, perchlorate and E. coli/fecal coliform violations.

Method

To create the indicator of acute contaminants we:

- Determined whether an acute MCL violation for nitrate, perchlorate or E. coli/fecal coliform had occurred at any point during the time period (2008-2016).
- For each system, we summed the total number of acute contaminants in violation.

Scoring Approach

To score this indicator we assigned water systems the following scores:

- 0, if the system had 2 to 3 acute contaminants with relevant MCL violations.
- 2, if the system had 1 acute contaminant with relevant MCL violations.
- 4, if the system had no acute contaminants with relevant MCL violations.

It is important to note that, for systems with more than one MCL violation, this indicator does not consider whether the MCL violations occurred at the same time. Thus this indicator assesses the extent to which an acute MCL event happened between 2008 and 2016, not the timing of multiple MCL violations.

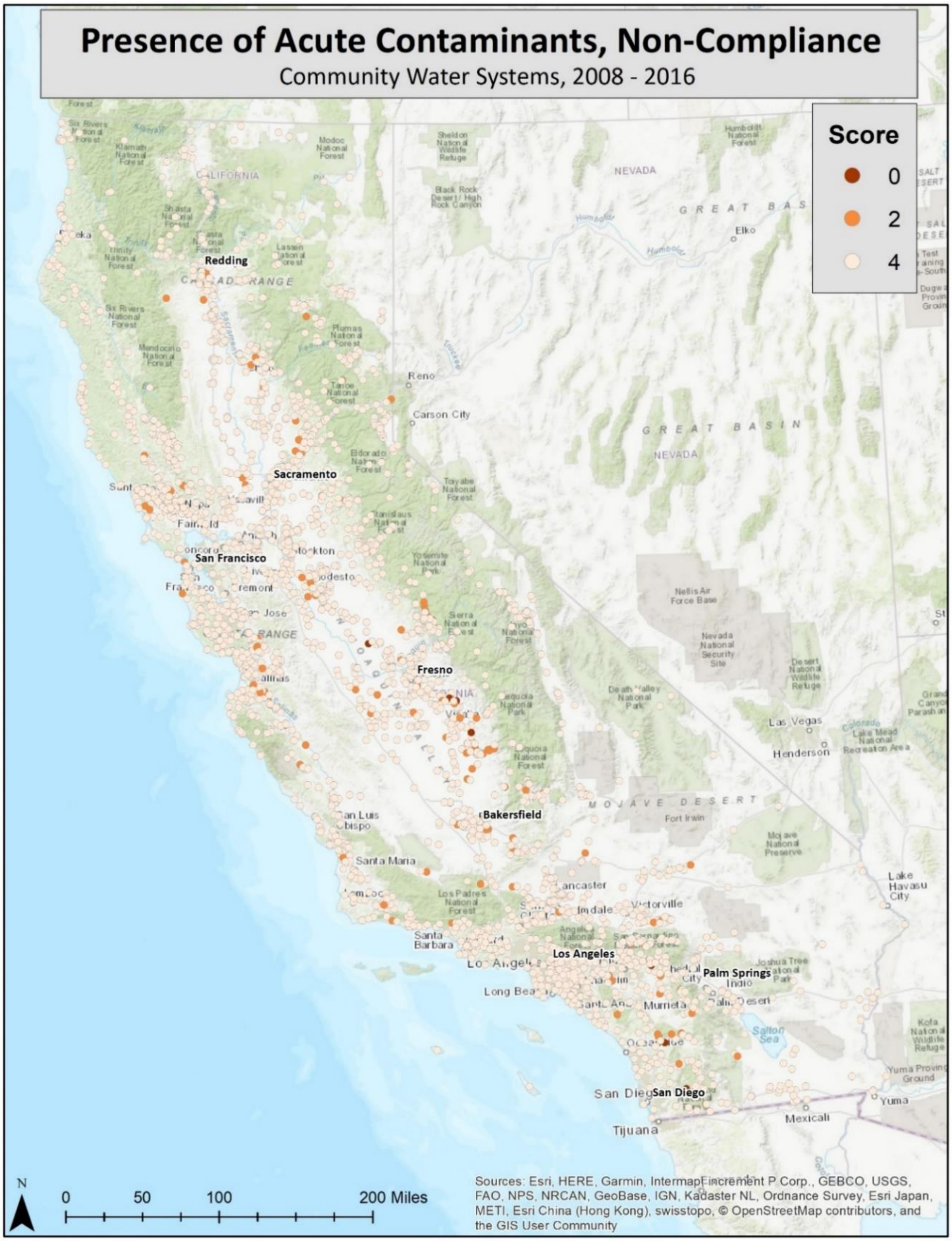
Results

Nearly 95% of systems had no acute MCL violation during the time period (Table 9). Among the remaining 5% (n=151), 81 were for TCR MCLs, 80 were for nitrate MCL violations and 5 were for perchlorate MCL violations. Among the 81 systems with acute TCR violations, five also had nitrate MCL violations. Among the 80 systems with nitrate MCL violations, three also had perchlorate MCL violations. The map below shows plots the scores for each community water system across the state (Figure 12).

Table 9. Water Quality Indicator 6: Number of Acute Contaminants with Non-Compliance. MCL violations for nitrate and perchlorate assessed, alongside acute MCL violations of the Total Coliform Rule.

Number of Acute Contaminants	Indicator Score	Number of Systems	Percent
0	4	2,745	94.6
1	2	151	5.2
2 to 3	0	7	0.2
Total		2,903	100

Figure 12. Water Quality Indicator 6: Presence of Acute Contaminants, Non-Compliance. For a definition of score values, please consult Table 9.



Water Quality Indicator 7: Maximum Duration of Non-Compliance

This indicator assesses the maximum duration of non-compliance across all contaminants. To do so, for each system, the indicator sums the number of years (from 2008 to 2016) 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 and 1,2,3-TCP).
- 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 maximum duration of non-compliance for a system was 6 or more years.
- 1, if the maximum duration of non-compliance for a system was 4-5 years.
- 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 1 year.

---

[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 system had zero years of non-compliance.

Results

Table 10 and Figure 13 provide the number of systems and their maximum duration of non-compliance. Two thirds of systems had no MCL violation. Nearly 19% of systems had two or more years of non-compliance for any given contaminant, with 51 systems having nine years of non-compliance.

Table 10. Water Quality Indicator 6: 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	4	1,909	65.8
1	3	460	15.9
2 to 3	2	287	9.9
4 to 5	1	100	3.4
6+	0	147	5.0
Total		2,903	100

† 1,2,3-TCP and lead are not included.

Figure 13 shows the total number years of non-compliance by contaminant. While TCR has the most number of systems with duration of non-compliance more 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 plots the scores for each community water system across the state (Figure 15).

Figure 13. Number of Systems by Maximum Years of Non-Compliance. N=2903 community water systems.

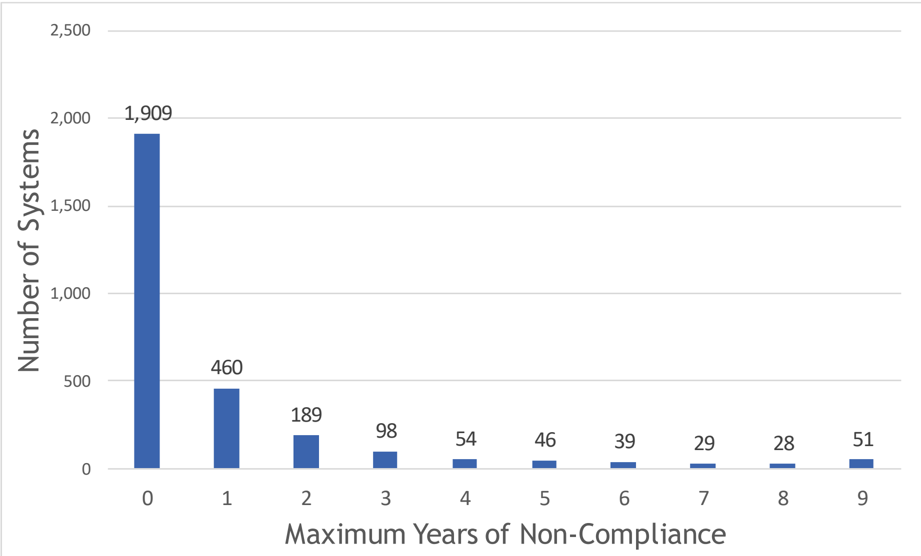


Figure 14. Number of Years, by Contaminant, for which Systems Had at Least One Annual MCL Violation. N=2903 community water systems.

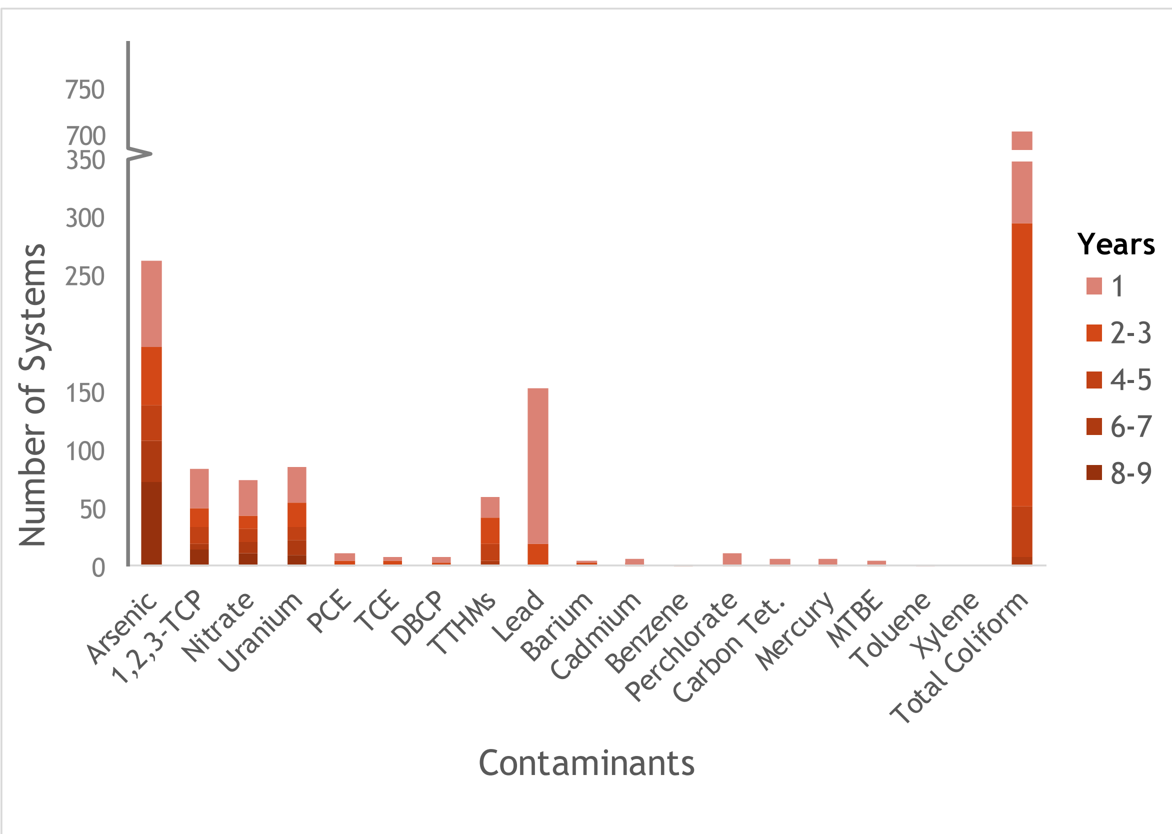
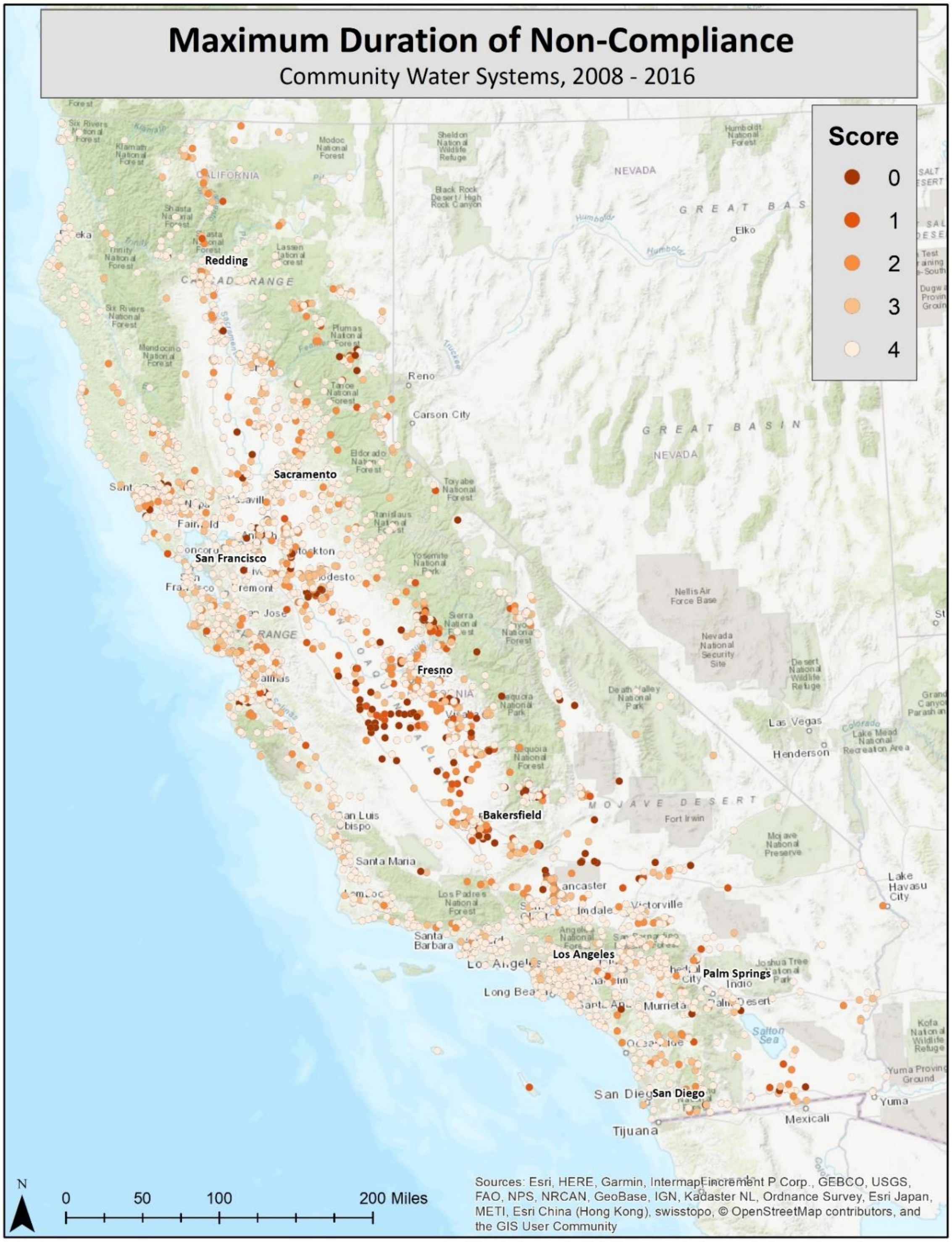


Figure 15. Water Quality Indicator 7: Maximum Duration of Non-Compliance. Higher scores represent a better outcome for this indicator; lower scores represent poorer outcomes. For a definition of score values, please consult Table 10.



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 16 illustrates how individual indicator scores can be combined to yield a composite water-quality component score.

Scoring Approach

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, weights were applied to different indicators to adjust for various factors. The following steps outline the particular weights assigned, and the final equation used to calculate the component score.

- For the acute exposure (Indicator 2) and acute non-compliance (Indicator 6), a weight of 0.25 was applied, as a way of providing additional weight for exposures and violations of acute contaminants beyond what is captured in Indicators 1 and 5.
- For the maximum duration of exposure (Indicator 3) and duration of MCL non-compliance (Indicator 7), 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 4) was weighted by 0.25. This weight was selected to give some additional weight to lack of data, without conferring the same weight as known problems.
- Sub-component scores were calculated after applying the appropriate aforementioned weights to each sub-component's indicators. In particular, the weighted indicator scores in each sub-component were added to come up with sub-component scores. Each sub-component score was placed on a scale of 0 to 4. Then, the two sub-component scores were averaged, with higher scores reflecting better outcomes.

This results in an equation of:

$$\textbf{\textit{Composite Water Quality Score}} = \frac{1}{2} \times (\text{Exposure Subcomponent Score}) + \frac{1}{2} \times (\text{Non-Compliance Subcomponent Score})$$

where:

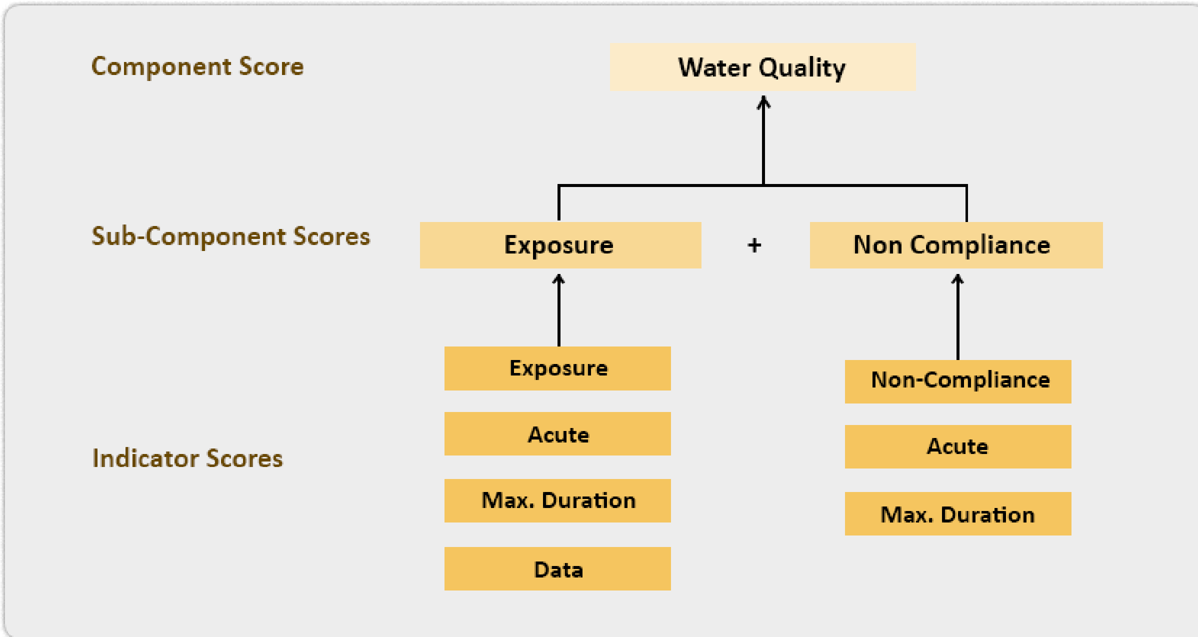
$$\textbf{\textit{Exposure Subcomponent Score}} = \text{Potential High Exposure Score} + 2 \times (\text{Maximum Duration Potential High Exposure Score}) + \frac{1}{4} \times (\text{Acute})\ \frac{1}{4} \times (\text{Data Availability Score})$$

and,

$$\textbf{\textit{Non} − \textit{Compliance Subcomponent Score}} = \text{Non-Compliance Score} + 2 \times (\text{Maximum Duration Non-Compliance Score}) + \frac{1}{4} \times (\text{Acute Score})$$

Figure 16 illustrates the composite approach.

Figure 16. Creation of Composite Water Quality Score.



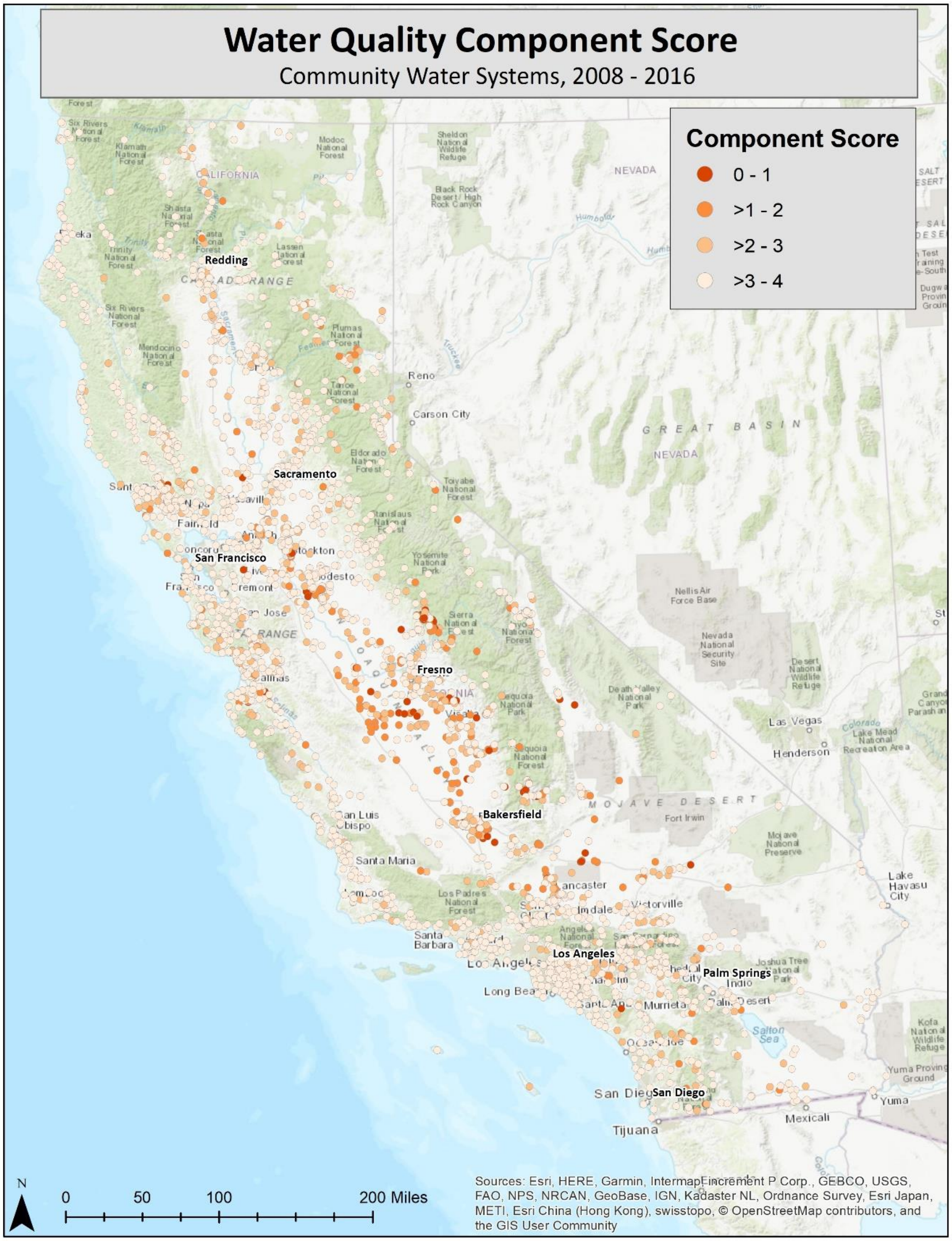
Results

2,903 systems received a composite water quality score, shown in Figure 17, and Table 11. The composite water quality component score ranged from 0.29 to 4, with a score of 4 indicative of high water quality. Twenty three percent of systems had a composite score of 4. Seventy-seven percent of systems had a score less than 4, meaning these systems had some type of water quality problem for at least one indicator. Still, 1153 systems had a score less than 4 but greater than 3.5. For these systems, 23% of systems had a score of 3 for the data availability indicator, and scores of 4 for all other indicators. Roughly 9% of systems scored with values less than 2 indicating lower scores across multiple water quality indicators. Figure 17 shows the composite water quality score across the state, with lower scores concentrated in the San Joaquin Valley.

Table 11. Composite Water Quality Scores.

Composite Water Quality Score	Number of Systems	Percent
4	660	23
3-<4	1,551	53
2-<3	439	15
1-<2	201	7
0-<1	52	2
Total	2,903	100

Figure 17. Map of Composite Water Quality Score (for 2,903 community water systems).+



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

Key Findings for Water Quality

- 23% of the 2,903 systems evaluated had a perfect water quality score (score=4); 53% had scores between 3 and 4, indicating relatively good overall water quality.
- 24% of systems (692) received composite scores of less than 3. These systems face some of the biggest water quality challenges.
- When looking at these trends by system size, small systems consistently had lower average individual-indicator and composite scores than medium- and large-size systems.
- Smaller systems had a greater tendency than larger systems to have less data availability and longer duration of MCL violations. The difference in average scores for smaller and larger water systems was the greatest for those two indicators.
- Regional trends highlight that some of the lowest composite water quality scores occur in the San Joaquin Valley and the Central Coast regions of the state.
- Nearly 60% of systems (n=1,696) had no high potential exposure. However, approximately 33% of systems had at least one contaminant with high potential exposure. Nearly 10% had high potential exposure for two or more contaminants, during the study period. If counts of total coliform rule are excluded, nearly 77% of systems had no high potential exposure events.
- Eighty systems had 9 years of potential high exposure, encompassing less than 3% of systems. Overall, arsenic had the largest number of systems (n=72) with the longest duration of high exposure, ranging from 8 to 9 years.
- Approximately 66% of systems had no MCL violations among the 17 contaminants assessed. Excluding TCR MCL violations, approximately 86% of systems had no MCL violation in the entire study period. Among the 34% of systems that did have at least one MCL violation, 6% had MCL violations for two or more contaminants.
- Nearly 19% of systems had two or more years of non-compliance for any given contaminant, with 51 systems having nine years of recurring non-compliance. Contaminants with the longest duration of non-compliance were arsenic, nitrate, TTHMs and uranium.

Component 2: Water Accessibility

Water Accessibility and Its Subcomponents

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 both the physical and institutional 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).
4) The water system's institutional capacity to provide a reliable and adequate supply.

The water accessibility component consists of two subcomponents: 1) the *physical* vulnerability of a water system to inadequate water supply and provision, and 2) the *institutional* 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 highly vulnerable to drought is more likely to experience shortages than a system with wells that draw from a more stable groundwater basin.

Institutional vulnerability refers to the ability of a water system to make necessary infrastructure investments and conduct the operations and maintenance needed to provide adequate water to customers. Institutional vulnerability is shaped, in part, by a water system's capacity to meet its water supply challenges. For example, 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. Generally, indicators in both subcomponents shape water accessibility in both the short and long-term. In later versions, OEHHA will seek to include additional measures of current access problems, as well as future risks.

Physical Vulnerability Subcomponent

Overview

The physical vulnerability subcomponent currently contains one indicator that 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 assessments OEHHA will seek to incorporate additional indicators of physical accessibility related to sufficiency and continuity of supply, such as vulnerability to drought, etc. (See Appendix, Table A1).

Indicator

Water Accessibility Indicator 1: 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-surface water), and how many permanent and backup sources a system can use in case of emergency, such as a period of drought. These backup sources include emergency sources that a system would only use intermittently, as well as interties to other systems (i.e., "consecutive connections"). The indicator assumes that groundwater-reliant systems with fewer wells are more vulnerable to supply-based outages than either surface water systems with multiple intake points, or combined systems (i.e., systems with surface water and groundwater sources).

Data Source

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

Method

To create this indicator we:

- Selected all active, permanent or emergency/standby/back-up sources based on the Source Availability code in SDWIS-State.

- Selected sources that were either wells, reservoirs, springs, intakes or consecutive connections, for each water system. Here, consecutive connections refers to connections (or interties) that a system has to other systems.
- Designated a system as groundwater-only, surface-water only, or groundwater-surface water systems based on the federal primary source type[26].
- Summed the total number of sources for each system, by federal source type.

Scoring Approach

This indicator was scored as follows:

- 0, if the system was "groundwater only" with one source.[27]
- 1, if the system was a "groundwater only" system with 2 sources, or a surface water or groundwater-surface water system with 1-2 sources.
- 2, if the system was a surface water, groundwater or combined groundwater-surface water system with 3-4 or more sources.
- 3, if the system was a surface water, groundwater or combined groundwater-surface water system with 5-9 or more sources.
- 4, if the system was a surface water, groundwater or combined groundwater-surface water system with 10 or more sources.

Results

Of the 2,903 systems in our study, 2,078 (72%) were classified as groundwater systems. The remaining 746 (26%) systems were either surface water systems (n=288), or groundwater-surface water systems (n=458). The remaining 79 (~3%) systems had unknown source types.

Of the 2,078 groundwater-only systems, approximately 16% (n=478) had only one well (Figure 18). Approximately 15% (n=419) of systems of any source type had 10 or more sources. Table 12 indicates the number of systems with varying numbers of sources, and the associated indicator score. The map in Figure 19 shows these results across the state.

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[26] Groundwater-only systems were designated as such if their federal primary source type was groundwater, purchased groundwater (GWP), groundwater under-the-influence of surface water or purchased groundwater under-the-influence (GUP). Surface-water only systems were designated as such if their federal primary source type was either surface water (SW) or purchased surface water (SWP). Systems with combined groundwater-surface water were designated as such if their federal primary source type was SW or SWP, but the system had at least one GW/GUP/GWP well indicated. This indicator, including its scoring, was developed in consultation with the State Water Board's Division of Drinking Water. The designation of groundwater, surface water, or combined groundwater-surface water differs from the federal designation status.
[27] A source can be a groundwater well or a spring.

Figure 18. Number of Sources, by Water Source Type.* 2,903 systems in study.†

** Sources include active permanent or active back-up/standby/emergency sources that are wells, reservoirs, intakes, consecutive connections, or springs. Groundwater-only systems were designated as such if their federal primary source type was groundwater (GW), purchased groundwater purchased (GWP), groundwater under-the-influence of surface water or purchased groundwater under-the-influence (GUP). Surface-water only systems were designated as such if their federal primary source type was either surface water (SW) or purchased surface water (SWP). Systems with combined groundwater-surface water (GW-SW) were designated as such if their federal primary source type was SW or SWP, but the system had at least one GW/GUP/GWP well indicated.*

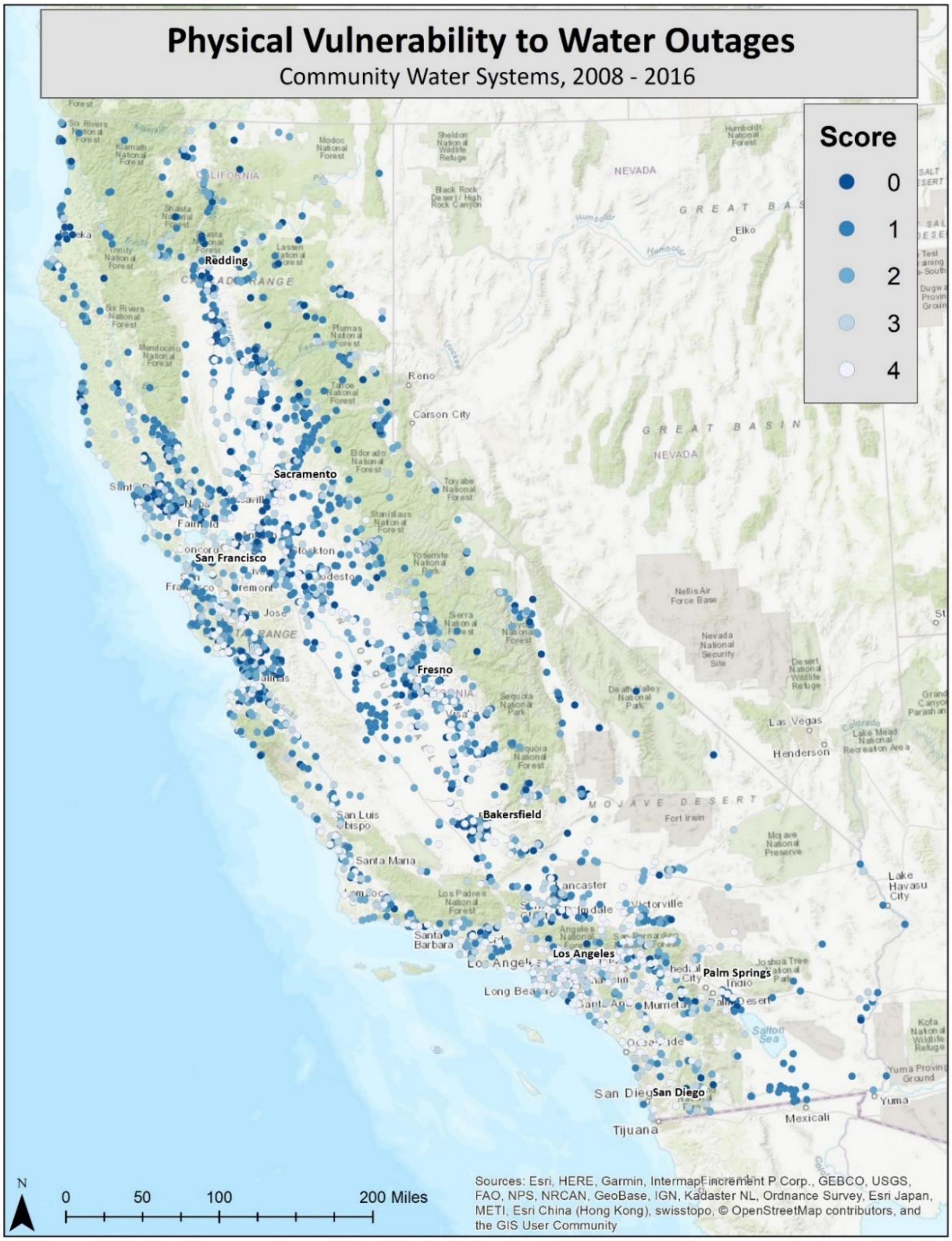
† Data represented is for 2017.

Table 12. Access Indicator 1: Vulnerability of Systems to Water Outages.†

Number and Type of Sources	Indicator Score	Number of Systems	Percent
10+ Sources	4	419	14.4
5 - 9 Sources	3	453	15.6
3 - 4 Sources	2	577	19.9
2 Sources in GW-only, or 1 - 2 Sources in GW-SW, or SW only system	1	897	30.9
1 Source in GW-only system	0	478	16.5
Unknown	NA	79	2.7
Total		2,903	100

† GW=groundwater; SW=surface water; GW-SW= groundwater & surface water system.

Figure 19. Map of Indicator 1: Physical Vulnerability to Water Outages. Higher scores represent a better outcome for this indicator; lower scores represent poorer outcomes. For a definition of score values, please consult Table 12.



Institutional Vulnerability Subcomponent

Overview

Institutional vulnerability refers to the ability of a water system to make necessary infrastructure investments and to conduct the operations and maintenance needed to provide safe and adequate water to customers. The subcomponent of institutional vulnerability includes two indicators that measure institutional characteristics of a system that can impede access to an adequate water supply. The first indicator represents potential institutional constraints. The second represents 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. In future assessments, OEHHA will seek to include additional metrics that capture such aspects.

Indicators

Water Accessibility Indicator 2: Institutional Constraints

This indicator uses a combination of information about a system's size and available economic resources to jointly define a system's institutional constraints. For example, larger systems have greater economies of scale that allow them to finance capital improvements and operate efficiently. Although some systems in disadvantaged communities are well run and successfully operated, systems with greater proportions of socioeconomically disadvantaged residents tend to face additional financial constraints, as their customer base may be generally less financially able to afford necessary system upgrades.

Challenges and benefits due to system size and socioeconomic status of the community can mutually exacerbate, or reinforce, each other. For example, a small system that serves a more socioeconomically disadvantaged population may have less institutional capacity than a small system that serves an affluent population. Likewise, a system that is large and serves a disadvantaged population presumably benefits from economies of scale to overcome some of the population's economic disadvantages. Thus, disadvantaged communities served by small systems face even greater challenges to maintain safe, accessible, and affordable water.

To characterize system size, this indicator draws on data on a system's number of service connections. To characterize socioeconomic status, the indicator uses state definitions of disadvantaged and severely disadvantaged communities. The term disadvantaged community (DAC) has multiple definitions. For drinking water applications, it is defined by the State of California as a community with an annual Median Household Income (MHI) that is less than 80 percent of the statewide MHI (Public Resources Code section 75005[g]). A severely disadvantaged community (SDAC) is a community with less than 60 percent the statewide MHI. According to US Census American Community Survey (ACS) 5-Year Data for 2011-2015, the statewide MHI was $61,818; hence, the calculated household income threshold is $49,454 for DACs, and $37,091 for SDACs.

Data Source

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

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

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

Method

The following steps were taken to categorize systems by system size and socioeconomically disadvantaged status:

- The number of service connections for a water system was determined, and the system was assigned a category of large (10,000+ service connections), medium (200-9,999 connections), or small (15-199 service connections) (State Water Resources Control Board 2015). [28]
- The median household income for the service boundary of each water system that had a geographic boundary available was calculated, using areal, household-based weighting that combined water system service area boundaries with census blocks and assigned relevant block group income data (See Appendix B2.3).
- Exclusion criteria to MHI calculations were applied. Systems were excluded if block groups had no MHI, if 15% or more of a system's block groups did not have MHI data, or if the MHI data contained a certain amount of error (see Appendix B3.4 for more details).
- The community served by the water system was designated as a non-disadvantaged community, a disadvantaged community, or a severely disadvantaged community. This designation is based on the 2012 Proposition 84 and 1E Guidelines.
- The system was categorized based on the joint combination of size and the community's DAC status

[28] The three size categories follow common cutoffs, as indicated in (State Water Board 2015). For our purposes, intermediate and medium-sized systems are combined into one category of "intermediate/medium" following common cutoffs (Safe Drinking Water Plan for California. Report to the Legislature in compliance with Health and Safety Code Section 16365, State Water Board. June 2015)

Scoring Approach

Scores for this indicator were assigned based on pre-determined categories. Systems received the following scores:

- 0, if the system was small and serves a DAC or SDAC.
- 1, if the system was small and serves a non-DAC/SDAC.
- 2, if the system was medium size and serves a DAC or SDAC.
- 3, if the system was medium size and serves a non-DAC/SDAC.
- 4, if the system was large, regardless of the community's DAC status.

Results

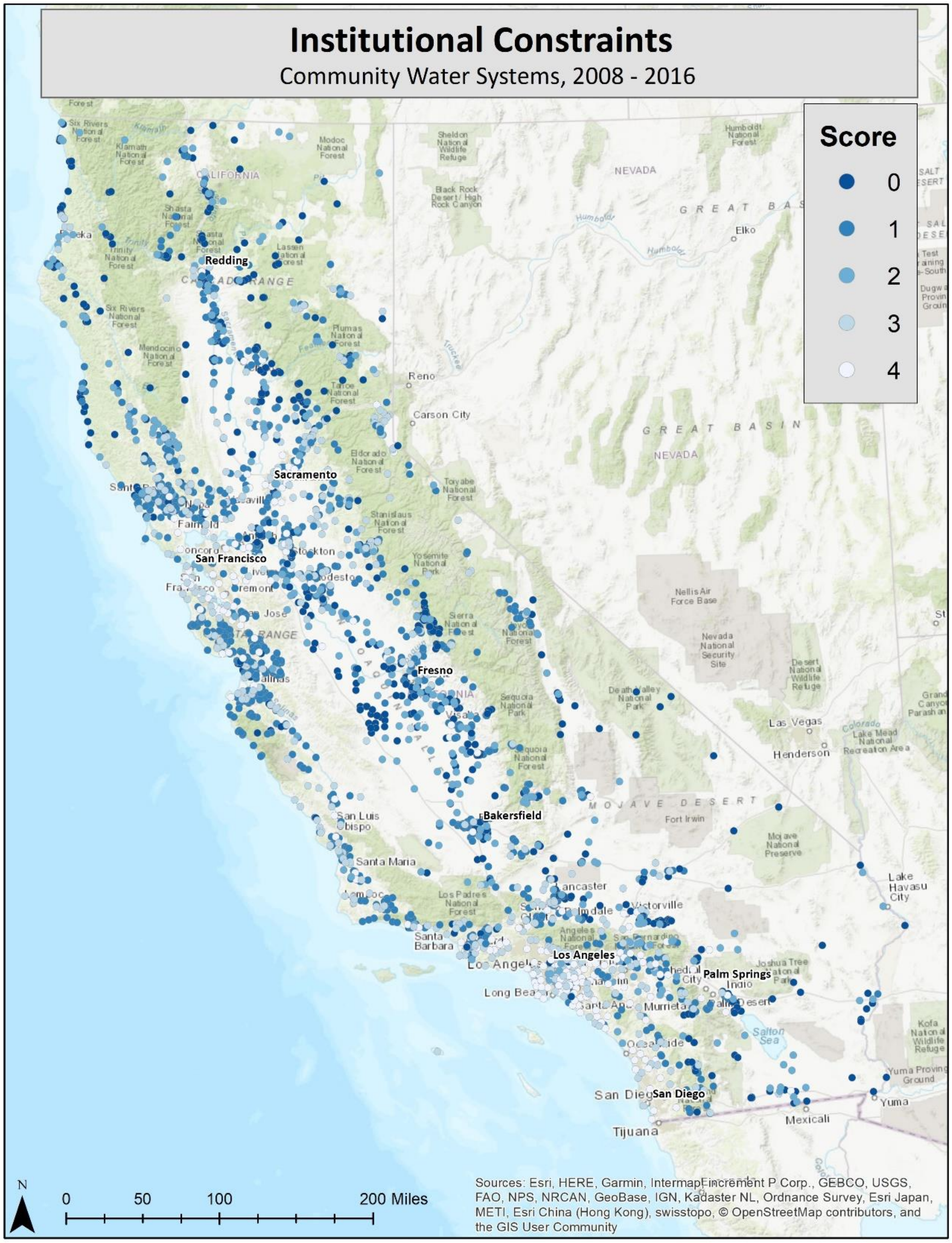
We calculated MHI for the 2,903 systems in our evaluation. Of these, 20 systems did not have adequate population data to estimate system-level weighted MHI, 69 systems were excluded based on 15% or more of block groups missing MHI data, 69 systems had no MHI data, and 27 were excluded because of error criteria. Of the remaining 2,718 systems, 11 did not have connections information. Therefore, 2,707 systems are covered by this indicator because they have both MHI data and connections information.

Table 13 highlights the indicator score based on combinations of system size and DAC status. Categories are divided as large systems (i.e., with 10,000+ connections) that are DAC, SDAC or non-DAC; medium-sized systems that are non-DAC; medium-sized systems that are SDAC or DACs; small systems that are non-DAC; small systems that are SDACs or DACs. Figure 20 shows these results across the state.

Table 13. Access Indicator 2: Overall Institutional Constraints. Associated indicator scores are shown. Study period 2008-2016, with DAC status calculated for 2011-2015.

System Size (No. Connections)	Disadvantaged Community Status	Indicator Score	Number of Systems	Percent
Large (10,000+)	Non-DAC, DAC, SDAC	4	223	7.7
Medium/Intermediate (200 – 9,999)	Non-DAC	3	463	15.9
Medium/Intermediate (200 – 9,999)	DAC, SDAC	2	333	11.5
Small (15 – 199)	Non-DAC	1	1,011	34.8
Small (15 – 199)	DAC, SDAC	0	677	23.3
Unknown	Unknown	*NA*	196	6.8
Total			2,903	100

Figure 20. Map of Indicator 2: Institutional Constraints. Higher scores represent a better outcome for this indicator; lower scores represent poorer outcomes. For a definition of score values, please consult Table 13.



Water Accessibility Indicator 3: Managerial Constraints

The third accessibility indicator represents certain managerial constraints. The managerial constraints of a water system depend on various factors, such as a water system's staffing levels and the training and technical expertise of the staff. Because this data is not readily available for all water systems, OEHHA worked with the State Water Board's Division of Drinking Water to identify an indicator that could show managerial constraints in addressing contamination and/or maintaining adequate water supply.

The selected indicator represents 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). 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, 2008-2016

Method

To develop this indicator we:

- Extracted all monitoring and reporting violations for Consumer Confidence Reports, 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, 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.
- Scored the indicator based on the distribution of this sum.

Scoring Approach

We assessed the distribution of the data and assigned systems the following scores:

- 0, if the system had 16 or more Monitoring and Reporting (M&R) violations, across the years 2008-2016.
- 1, if the system had 6-15 M&R violations.
- 2, if the system had 3-5 M&R violations.
- 3, if the system had 1 to 2 M&R violations.

- 4, if the system had zero M&R violation.

Results

We found that 1,035 systems (36%) had at least one Monitoring and Reporting violation during the study period (Figure 21). The total number of Monitoring and Reporting violations ranged from 0 to 37 violations.

Table 14 summarizes the types of analytes that had monitoring and reporting violations for each type of Monitoring & Reporting violation of interest. The largest contributors to the total count of Monitoring and Reporting violations were Chemical Contaminant violations (for nitrate, n=173) and TCR violations (n=623).

Table 15 indicates the distribution of this indicator and the associated indicator score. Figure 22 shows a map of the statewide distribution of these scores.

Figure 21. Total Number of Monitoring and Reporting Violations by System.

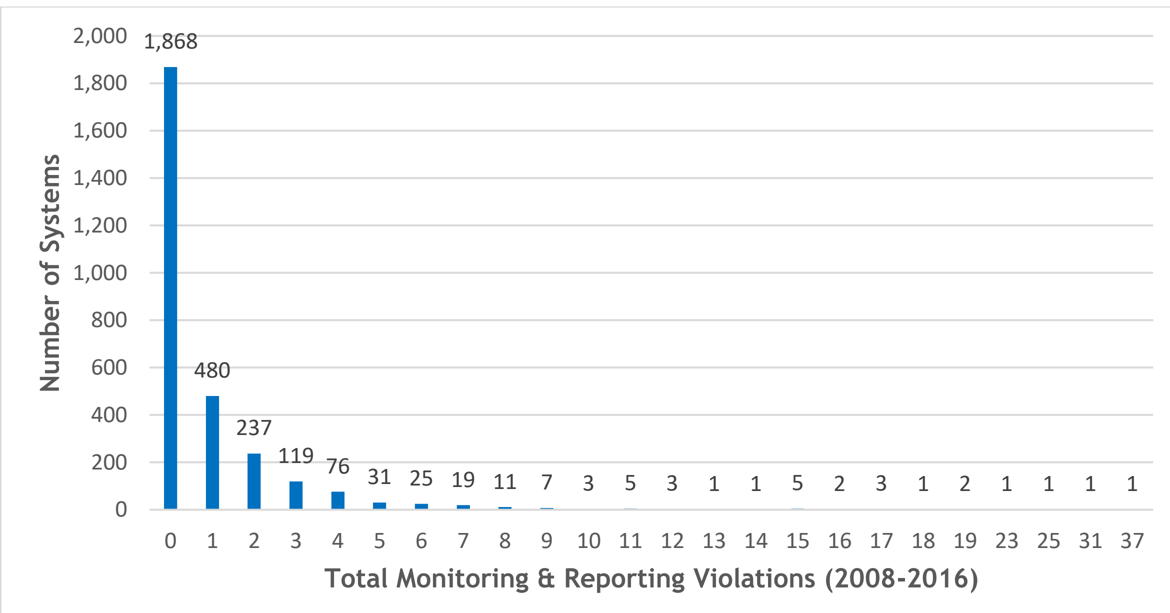


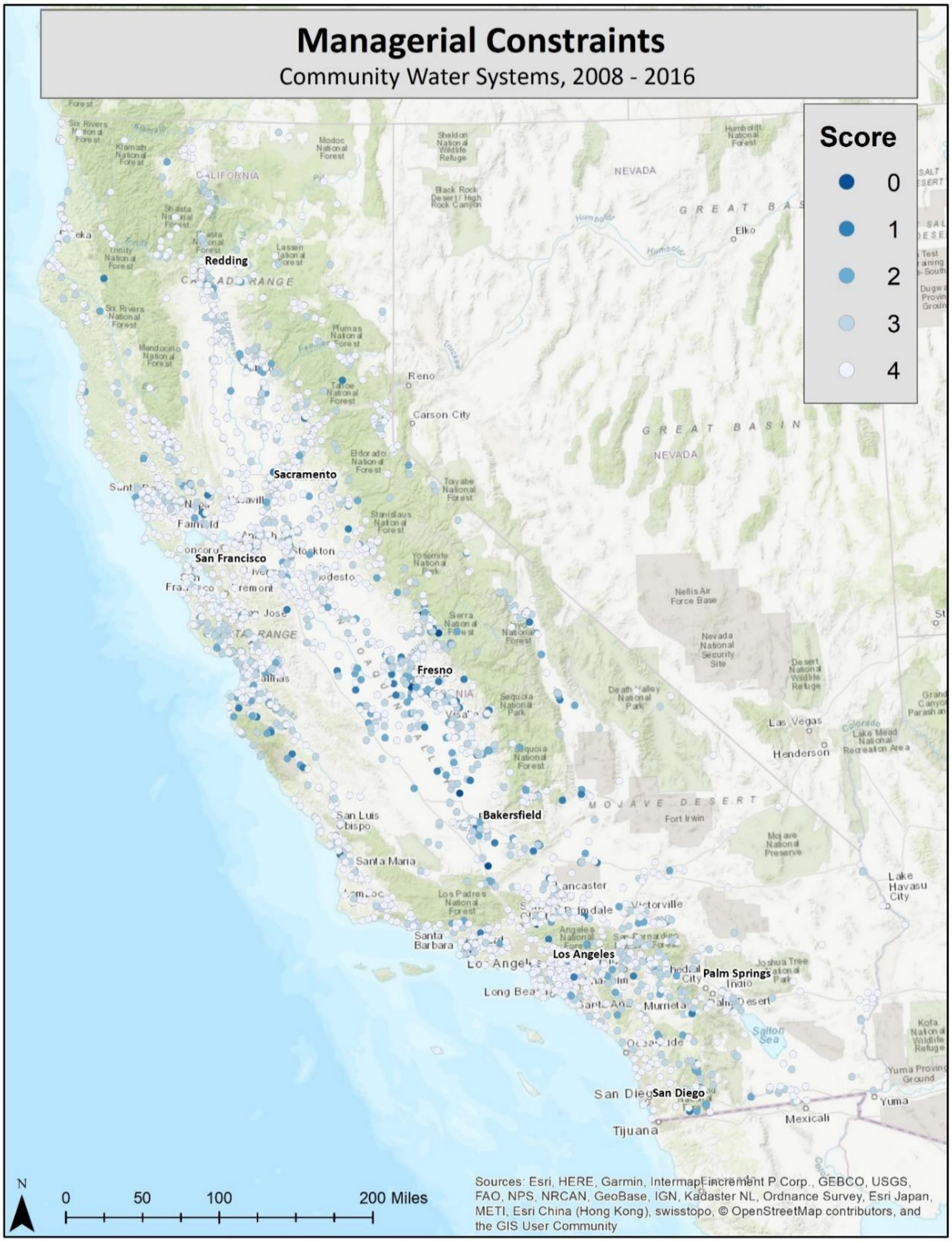
Table 14. Types of Monitoring and Reporting Violations for the 2008-2016 Study Period.

Type of Violation	Number of Violations
Consumer Confidence Report	68
Lead & Copper Rule	58
Chemical Contaminant Monitoring	173 (all for nitrate)
Disinfection By-Product Monitoring	79, includes 1 for bromate, 1 for total carbon, 7 for chlorine, 33 for total haloacetic acids, and 37 for total trihalomethanes
Surface Water Treatment Rule	32, includes 3 for chlorine, 1 for coliphage, 2 for Groundwater Rule, 5 for Interim Enhanced Surface Water Treatment Rule, 19 for Surface Water Treatment Rule, and 4 for turbidity
Total Coliform Rule Monitoring	623

Table 15. Access Indicator 3: Managerial Constraints. Indicator based on total monitoring and reporting violations in the study period.

Total Monitoring & Reporting Violations	Indicator Score	Number of Systems	Percent
0 violations	4	1,868	64.4
1-2 violations	3	717	24.7
3-5 violations	2	226	7.8
6-15 violations	1	80	2.8
16+ violations	0	12	0.4
Total		2,903	100

Figure 22. Map of Indicator 3: Managerial Constraints. Higher scores represent a better outcome for this indicator; lower scores represent poorer outcomes. For a definition of score values, please consult Table 15.



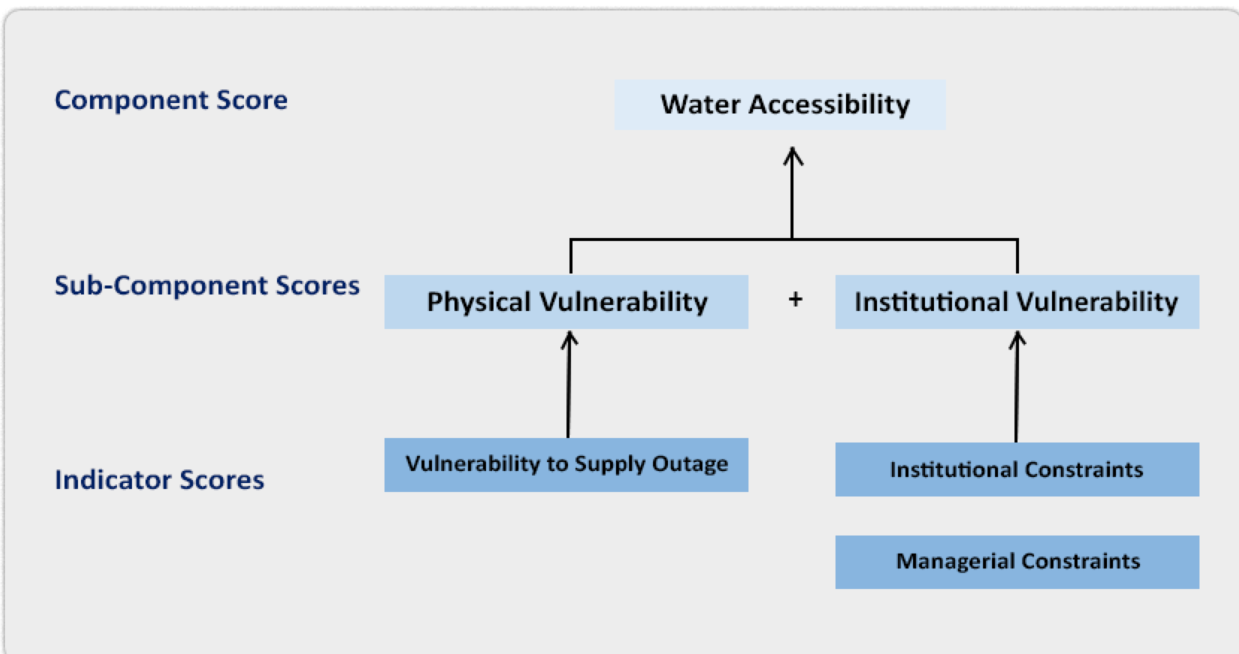
A Composite View of Water Accessibility

The three water accessibility indicator scores can be combined to create a composite water accessibility score. This composite score can serve to highlight systems that have some of the lowest scores across all accessibility indicators, and are therefore the most burdened in the area of accessibility. Figure 23 represents how individual indicator scores are combined to yield a composite water accessibility component score.

Scoring Approach

- After each individual indicator was calculated and scored (see individual indicator scoring approach, above), Accessibility Indicators 2 and 3 were averaged to produce a score for the Institutional Vulnerability subcomponent.
- The score for Accessibility Indicator 1 (the lone indicator for the Physical Vulnerability component) was averaged with the Institutional Vulnerability subcomponent score to produce a composite accessibility component score.
- Composite scores ranged from 0-4, with lower scores indicating a greater burden.

Figure 23. Creation of Composite Water Accessibility Score.



Results

2,637 systems had a composite water accessibility score. The composite score ranged from 0 to 4. Across these systems, the mean composite component score was 2.1. Overall, approximately 24.5% of systems received a score of 3 or higher. Approximately 46% of systems had a score of 2 or lower, with just over 5% of systems had a composite score less than one (Table 16). Compared to water quality, the larger fraction of systems with lower scores can be explained by a few key trends. First, as shown in earlier sections, 16% of systems were groundwater reliant and had only one source, and thus received a score of 0. With regards to institutional indicators, approximately 25% of systems are small and serve either disadvantaged or severely disadvantaged communities. Finally, 11% of systems received a score of 2 or lower for managerial constraints.

Table 16. Composite Water Accessibility Score.

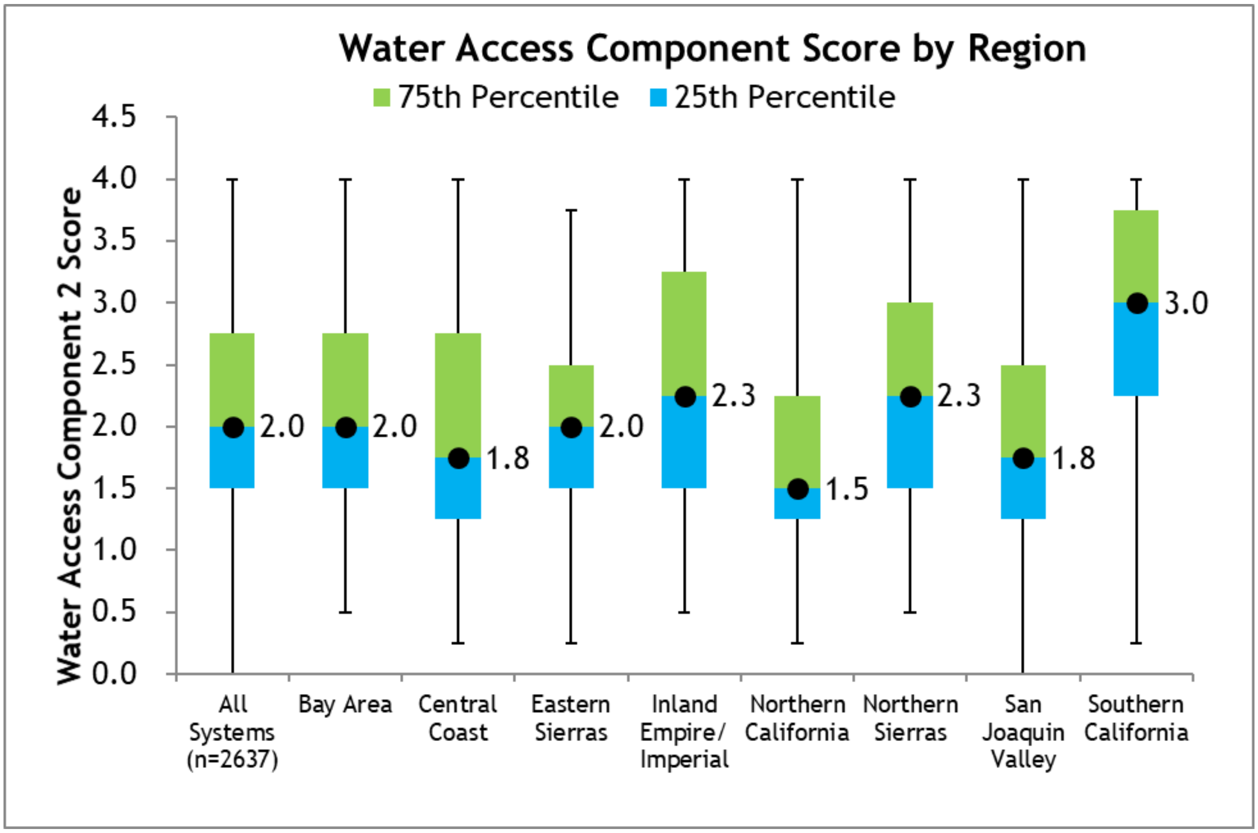
Composite Water Accessibility Score	Number of Systems	Percent
4	144	5.5
3-<4	502	19.0
2-<3	767	29.1
1-<2	1076	40.8
0-<1	148	5.6
Total	2,637	100

Geographic Observations

Figure 24 highlights scores by region (See Figure 25 for a map of regions). This figure highlights that the lowest water accessibility scores occurred in Northern California (median=1.5), the Central Coast (median=1.8) and the San Joaquin Valley (median=1.8), though there were low-scoring systems across all regions. For a map of regions, please see Figure 25.

Figure 26 shows the composite water accessibility 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, lower scores are distributed more evenly across the state.

Figure 24. Composite Water Accessibility Score by Region.



Among the 148 systems that received a composite water accessibility score of 1 or less, several key patterns emerge. First, a disproportionate number of systems (33%) were located in the San Joaquin Valley. By comparison, the SJV accounts for 22% of systems statewide. A disproportionate number (73%) were severely disadvantaged or disadvantaged, compared to 38% of systems statewide being DAC or SDAC. In addition, all systems with composite scores of 1 or lower (100%) were small, compared to 62% of systems being small statewide.

Figure 25. Map of Statewide Regions.

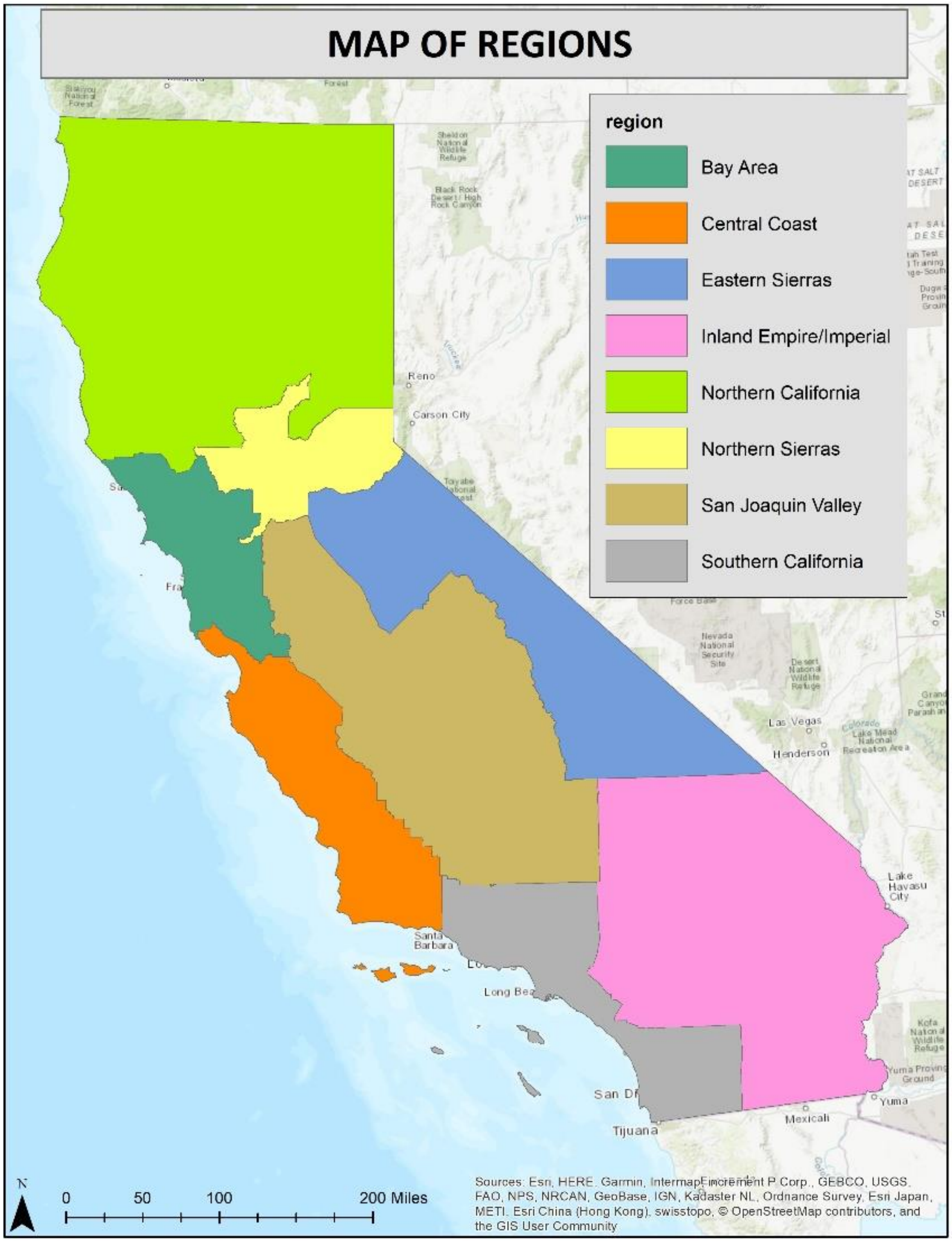
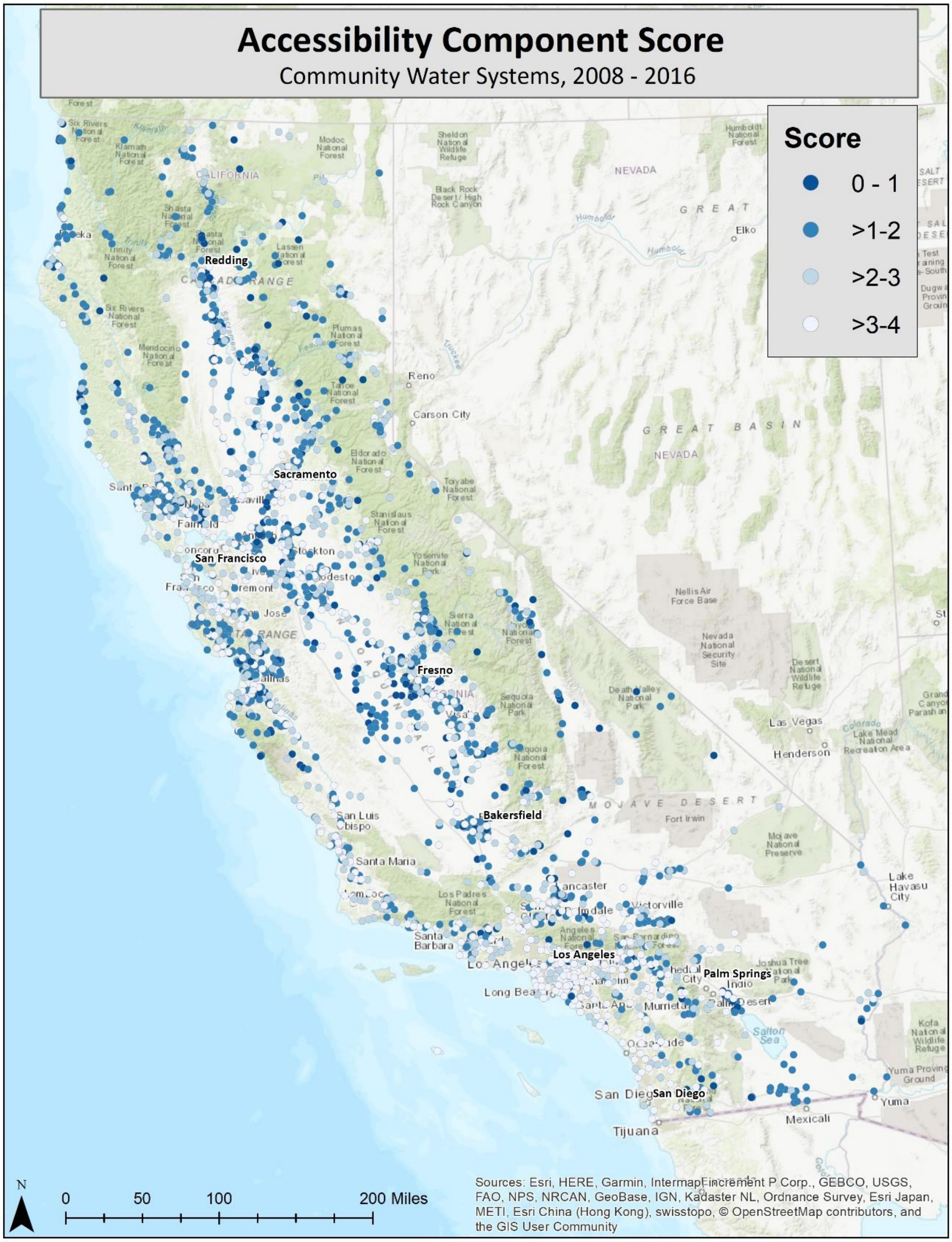


Figure 26. Map of Composite Water Accessibility Scores across the State. Study period 2008-2016; n = 2,637.



+ Given the aggregate nature of this component these scores do not mean a water system did not have high accessibility scores for individual indicators. For specifics, system-level data should be consulted.

Additional Research/Next Steps

The current indicators described in this chapter do 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 are expected 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, Morello-Frosch et al. 2011; Christian-Smith J, Balazs C et al. 2013). Although the current draft focuses on system-level measurements of accessibility, household-level coping approaches are also critical, especially as the most marginalized Californians, such as populations lacking housing, or those that do not have access to water where they live. Future versions explore the 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 described in Table 22. 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.). Additional institutional indicators could include metrics related to staffing and governance capacity, training and funding received, and community capacity to pay for necessary infrastructure. The inclusion of any of these metrics would be contingent upon adequate data. OEHHA is coordinating 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.

Key Findings for Accessibility

- Approximately 16% of systems have only one water source and rely solely on groundwater. These systems are particularly vulnerable to water outages.
- Roughly 25% of systems are small and serve DAC or SDAC populations. While future work is needed to measure institutional constraints, these systems likely face significant institutional constraints.
- The vast majority of systems have no monitoring and reporting violations.
- Overall, nearly 46% of systems have composite water accessibility scores of 2 or lower, indicating particularly low scores. These low scores are mainly the result of systems vulnerable to physical water outages and systems that are both small and DAC/SDAC.

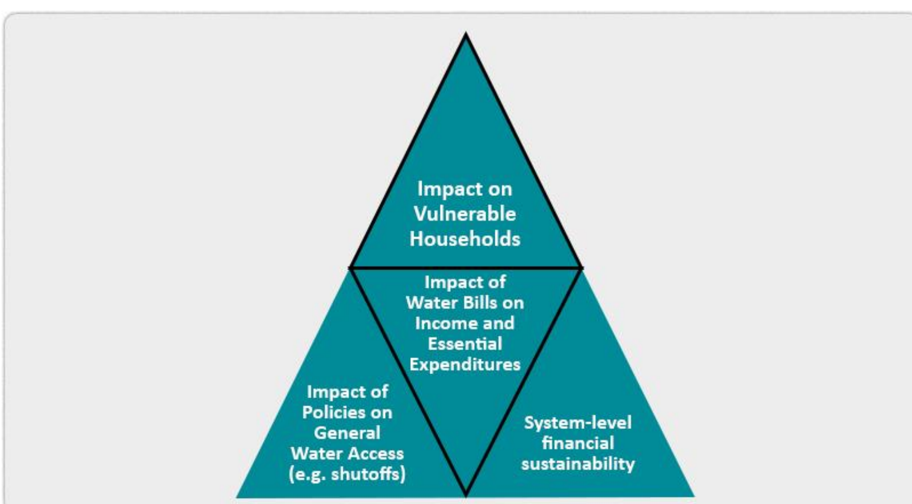
Component 3: Water Affordability

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 direct and indirect costs of water charged to a household, relative to the household's income level. Measuring water affordability can help inform how water costs affect the attainment of households' other basic needs such as housing and food. 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 27 summarizes the concepts that commonly influence affordability considerations, and highlights the two areas of affordability that form the main focus here: the ratio of water bills to income and the impact of water bills on economically vulnerable households. The current assessment is focused on the cost of water for drinking, cooking, and hygiene, but could easily incorporate the cost of sewer and sanitation charges should such data become available.

Another core aspect highlighted in Figure 27 is the sustainable 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 JP and Teodoro MP 2014; OECD 2010; US EPA 1998a). These aspects are not directly captured in the current assessment.

Figure 27. Core Aspects of Affordability. Triangles highlighted in black indicate areas that the Affordability Component focuses on.



Historically, US EPA has used affordability ratios to measure the impact of a water system's average water bill on a household earning the median household income (US EPA 1998a). US EPA's affordability ratio (known as the Residential Indicator) is an indicator used primarily 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 2: What is an affordability ratio?). Concerns about the adequacy of this approach have resulted in extensive discussions about best practices and about the limitations of the conventional affordability ratio approach (See Works Cited for further discussion).

Box 2: 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, household income should represent total household income minus 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.

Building on this rich discussion, OEHHA developed three affordability indicators to measure affordability at three income levels at the water system scale (see Box 3: Summary of Affordability Measures and (Goddard J.J., Ray I. et al. 2019).[29]

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 chapter concludes with a

[29] Data limitations make it hard to analyze affordability at the household level. Information about household water bills and income level would be needed. Therefore, indicators that screen for potential household concerns are often developed at larger geographic scales (for example, at the water system or census-tract scale).

discussion of data gaps, which are significant for this component, and observations on water affordability in California's community water systems.

Works Cited contains a literature review relevant to the creation of the affordability indicators and Appendix B includes technical and methodological details about the indicators we present.

Unlike the Water Quality and Water Accessibility components outlined above, the Affordability Component has no subcomponents.

Box 3: 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 State 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. 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 P 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

[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 P 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 L 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.

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 B1 Water Bill Dataset Selection & Use.

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 4: 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 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), 1,158 systems were ultimately included in OEHHA's affordability assessment. The median water bill for 6 HCF across water systems with data was $41.39/month (See Appendix B3 Data Cleaning & Exclusions) (State Water Resources Control Board 2019).

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[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 given 6 HCF, excluding sewer charges.

[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.

STEP 3: ESTIMATING INCOME LEVELS

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

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]

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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.

- Approximated the number of households below the particular income level within each system[36] by using linear interpolation between points across the Census income 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).

[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 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.

Box 4: 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, or long-term infrastructure and maintenance costs.

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. 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.

A total of 1,561[37] out of 2,903 community water systems had water bill data that could be included in the affordability calculations (See Appendix B1 Water Bill Dataset Selection & Use). After applying a set of exclusion criteria (see Appendix B3 Data Cleaning & Exclusions), this resulted in 1,158 systems, or 40% of community water systems, assigned affordability scores (This contrasts with the Water Quality Component for which OEHHA evaluated 100% of community water systems, and 91% in the Water Accessibility Component).

[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.

The relatively low number of systems in the assessment is discussed later in this chapter, though it is worth noting that these 1,158 community water systems, while only about 40% of the total number of community water systems, represent approximately 90% 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 exceeds 2.5% of the relevant income level (e.g., MHI, CPT, DP).
- 1, when the average water bill ranges from 1.5% to less than 2.5% 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 0.75% to less than 1.0% of the income level.
- 4, when the average water bill is less than 0.75% of the income level.

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 1,158 systems, MHI ranged from $17,400 to $250,000 (median=$60,500).

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.

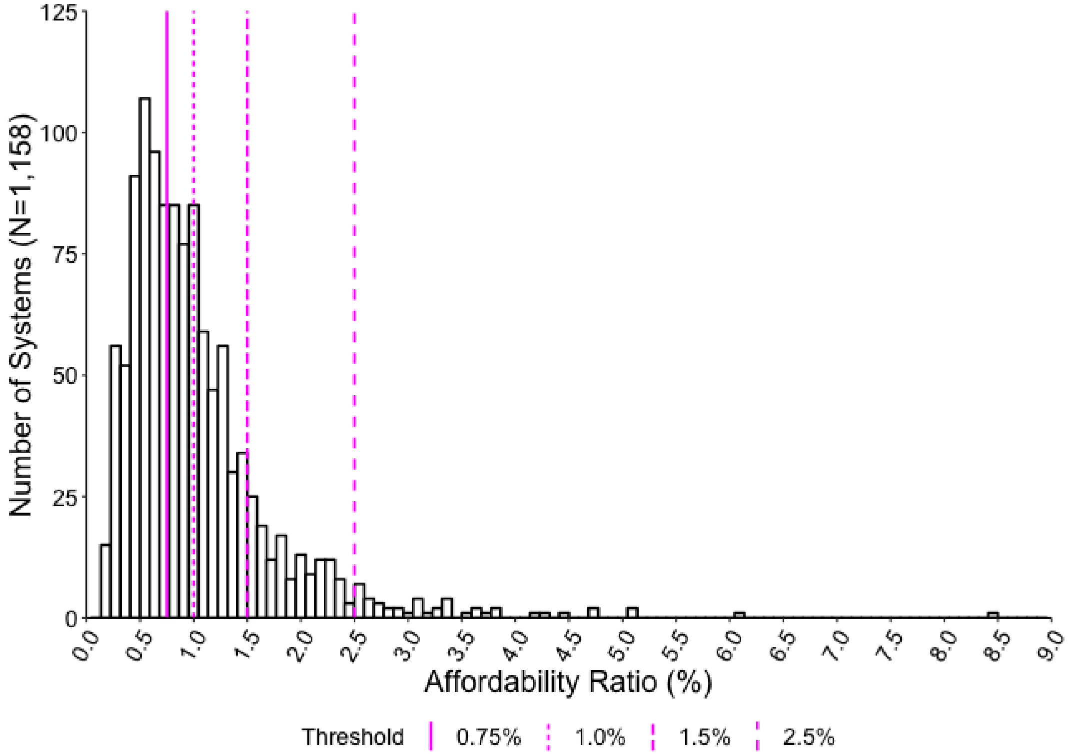
Data Source

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 1,158 systems with data, affordability ratios ranged from 0.16% to 8.49%, with a median of 0.85% (Figure 28). Figure 28 shows how the indicator scores are distributed across the 1,158 systems with data. Among these systems, 15.8% of systems had average water bills exceeding 1.5% of the median household income. Of these, 66.5% serve severely disadvantaged or disadvantaged communities, defined by their overall economic status (see Accessibility Chapter). Table 17 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 29 highlights these indicator scores across the state.

Figure 28. Affordability Ratio and Scores at Median Household Income (as Percent) for Community Water Systems. Data for 1,158 community water systems in 2015[†].



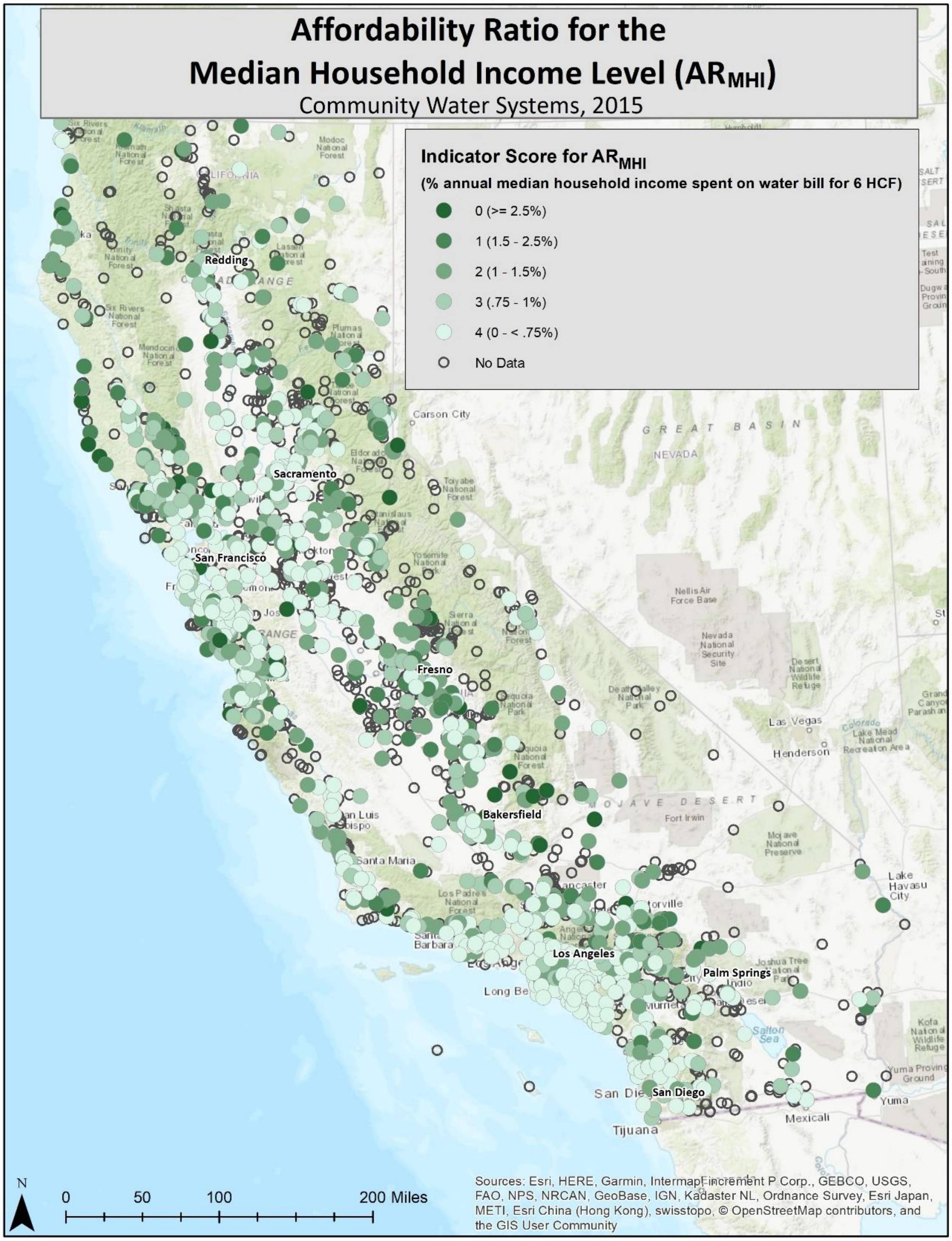
† The four dashed lines delimit the five bins used to score the affordability ratio.

Table 17. Affordability Ratio at Median Household Income. Number of community water systems in various affordability ranges, with associated indicator score. Study period, 2015. Note: the percent of systems shown reflects the state's 2,903 community water systems, with the percent of systems in the analysis indicated in parentheses (n=1,158) [†].

Composite Affordability Ratio Range	Composite Affordability Score	Number of Community Water Systems (CWS)	Percent of All CWS (N=2,903) (Percent of systems in Analysis, n=1,158)	Population*	Percent Population (among 2903 systems)
0 to <.75%	4	475	16.4 (41)	21,500,000	61.1
0.75% to <1%	3	238	8.2 (20.6)	5,790,000	16.5
1% to <1.5%	2	262	9.0 (22.6)	4,280,000	12.2
1.5% to <2.5%	1	138	4.7 (11.9)	437,000	1.2
>=2.5%	0	45	1.6 (3.9)	25,000	0.1
	Sub-total	1,158	39.9 (100)	32,000,000	91.1
No Data	N/A	1,745	60.1 (N/A)	3,110,000	8.9
	Total	2,903	100	35,100,000	100

[†] OEHHA used census block population data from 2010 to estimate a total of approximately 35.1 million people living in areas served by water systems.
** Population reported at three significant figures. The population figure shown indicates the number of people served by systems with that given affordability ratio; it does not represent the number of people facing that actual affordability ratio.*

Figure 29. Affordability Ratios at Median Household Income Levels for 1,158 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 (CESCR (United Nations Committee on Economic 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 S, Danielson C 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 5: High Cost of Living Considerations). For the 1,158 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). Figure 30 shows the large percentage of households living at or below the county poverty level in many of the 1,158 community water systems covered in our analysis.[41]

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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 M.P. 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 L 2018). See Appendix B2 for discussion.

[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

Box 5: High Cost of Living Considerations

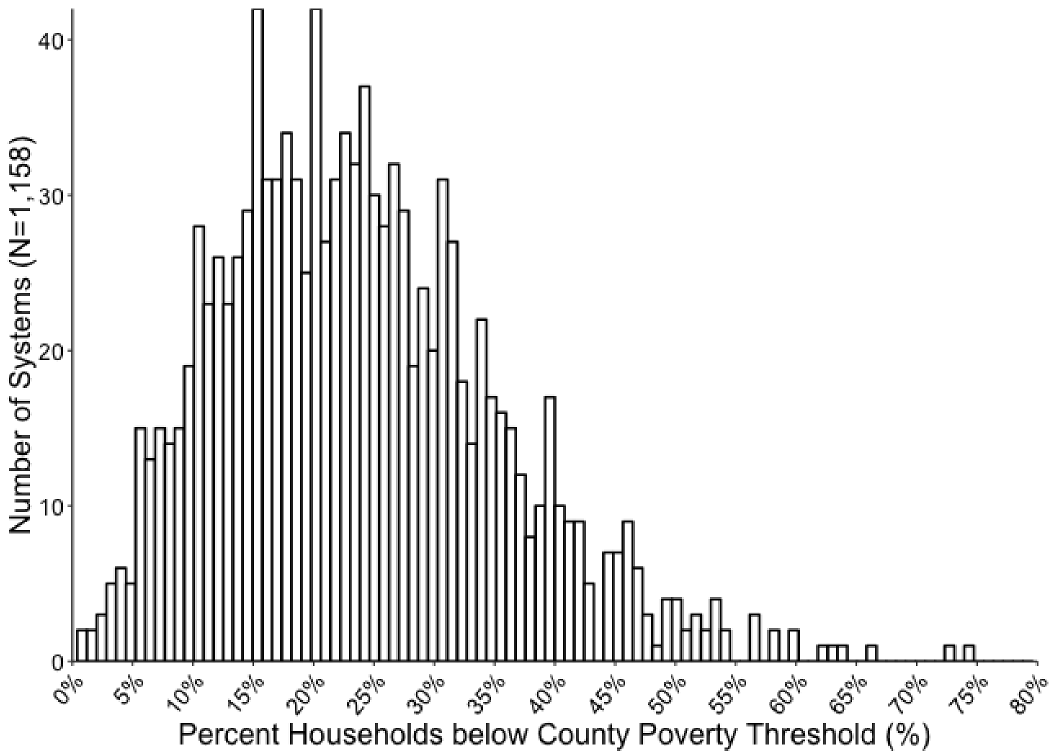
A household's ability to pay for water hinges on its disposable income, and the cost of other non-water essential expenditures. Ideally, an affordability ratio would reflect disposable income minus non-water essential expenditures. Thus the household's water bill would be compared to its remaining discretionary 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 for 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).

and discussion on this topic.

Figure 30. Percent of Households At or Below County Poverty Thresholds, Across 1,158 Community Water Systems. Data based on ACS 5-Year Summary 2011-2015.



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.

Data Source

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

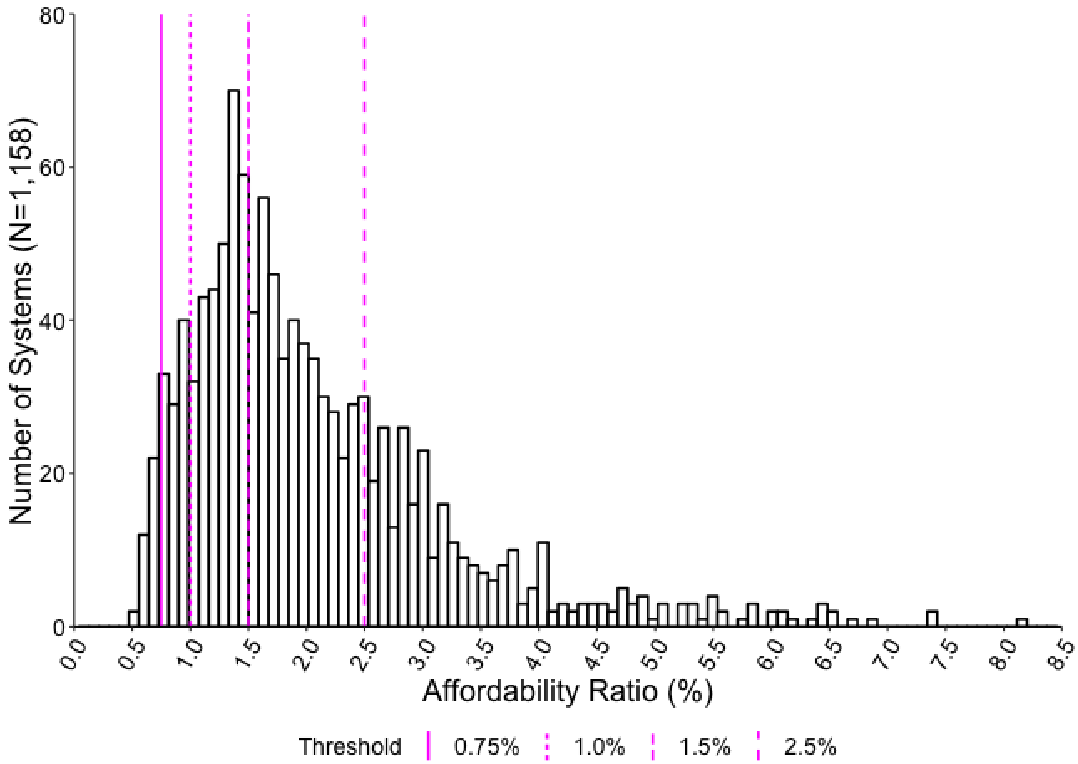
Public Policy Institute of California (PPIC) California County Poverty Thresholds, 2015.

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

Results

Among the 1,158 systems with the required data, affordability ratios at the poverty threshold (AR_{CPT}) ranged from 0.55% to 8.14%, with a median of 1.76% (Figure 31). Table 18 scores these AR_{CPT} results accordingly.

Figure 31. Affordability Ratio at County Poverty Threshold (as Percent) for Community Water Systems. Data for 2015, n=1,158 community water systems.†



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

Table 18. 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 2,903 Community Water Systems, with the percent of systems in the analysis indicated in parentheses (n=1,158) †.

Composite Affordability Ratio Range	Composite Affordability Score	Number of Community Water Systems (CWS)	Percent of All CWS (N=2,903) (Percent of systems in Analysis, n=1,158)	Population*	Percent Population (among 2903 systems)
0 to <.75%	4	44	1.5 (3.8)	2,560,000	7.3
0.75% to <1%	3	96	3.3 (8.3)	3,480,000	9.9
1% to <1.5%	2	294	10.2 (25.4)	12,800,000	36.4
1.5% to <2.5%	1	418	14.4 (36.1)	11,500,000	32.7
>=2.5%	0	306	10.5 (26.4)	1,680,000	4.8
Sub-total		1,158	39.9 (100)	32,000,000	91.1
No Data	N/A	1,745	60.1 (N/A)	3,110,000	8.9
	Total	2,903	100	35,100,000	100

† OEHHA used Census block population data from 2010 to estimate a total of approximately 35.1 million people living in areas served by water systems.
** Population shown to three significant figures. The population figure shown indicates the number of people served by systems with that given affordability ratio; it does not represent the number of people facing that actual affordability ratio.*

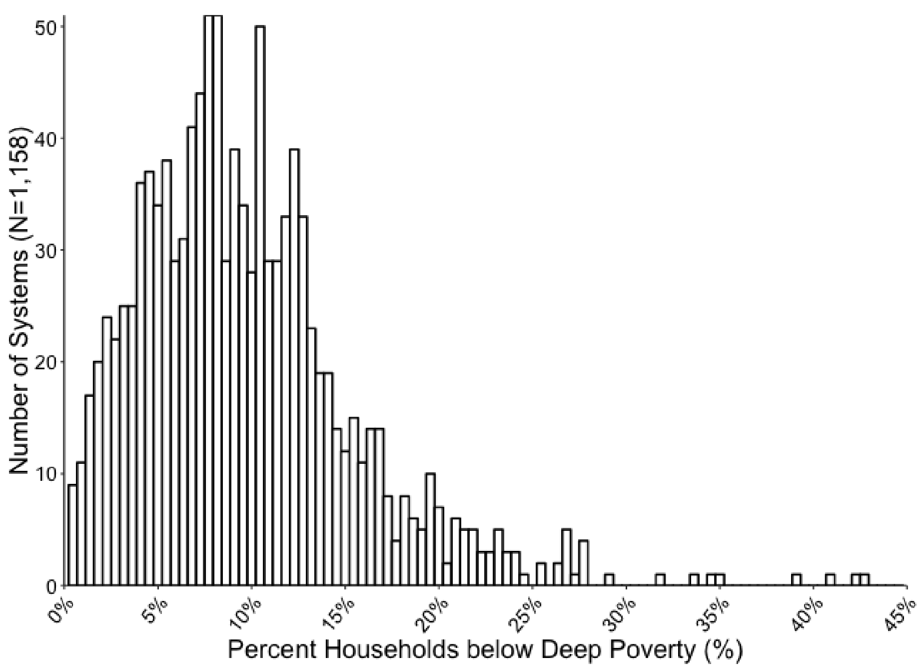
Affordability Indicator 3: Affordability ratio for the deep poverty threshold (AR_{DP})

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 32 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.

Figure 32. Percent of Households At or Below County Deep Poverty Level Thresholds, Across 1,158 Community Water Systems. (Based on ACS 5-Year Summary 2011-2015).



[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.

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 D.C. and Taylor L.D. 2017; Rockowitz, Askew-Merwin 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.

Results

Table 19 and Figure 33 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.

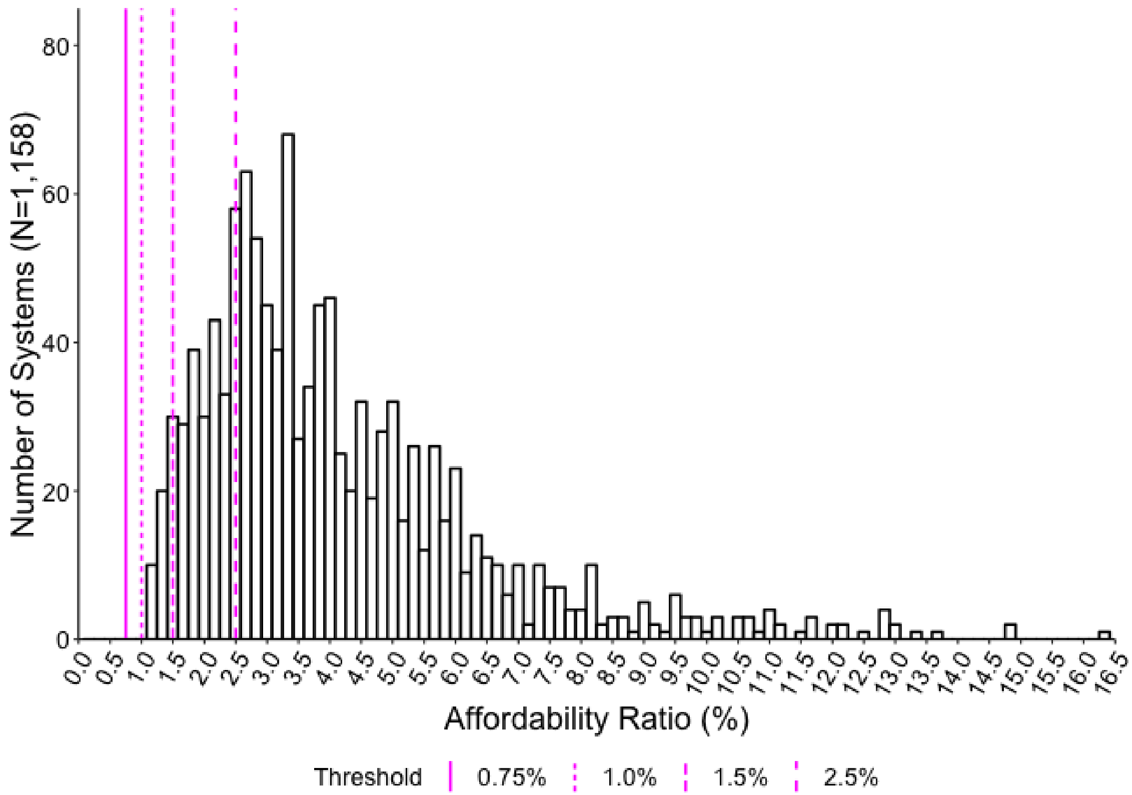
Table 19. Affordability Ratio and Indicator Scores at Deep Poverty Level. Number of community water systems (n=1,158 of 2,903 community water systems) falling in various affordability ranges, with associated indicator score. Note: the percent of systems shown is reflective of the 2,903 Community Water Systems, with the percent of systems in the analysis (n=1,158) indicated in parentheses [†].

Composite Affordability Ratio Range	Composite Affordability Score	Number of Community Water Systems (CWS)	Percent of All CWS (N=2,903) (Percent of systems in Analysis, n=1,158)	Population*	Percent Population (among 2903 systems)
0 to <.75%	4	0	0 (0)	0	0
0.75% to <1%	3	0	0 (0)	0	0
1% to <1.5%	2	44	1.5 (3.8)	2,560,000	7.3
1.5% to <2.5%	1	214	7.4 (18.5)	11,000,000	31.3
>=2.5%	0	900	31.0 (77.7)	18,400,000	52.5
	Sub-total	1,158	39.9 (100)	32,000,000	91.1
No Data	N/A	1,745	60.1 (N/A)	3,110,000	8.9
	Total	2,903	100	35,110,000	100

[†] *OEHHA used Census block population data from 2010 to estimate a total of approximately 35.1 million people living in areas served by water systems.*

** Population rounded to nearest thousand. The population figure shown indicates the number of people served by systems with that given affordability ratio; it does not represent the number of people facing that actual affordability ratio.*

Figure 33. Affordability Ratio at Deep Poverty Level (as Percent) for Community Water Systems. Data for 2015, n=1,158 community water systems.†



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

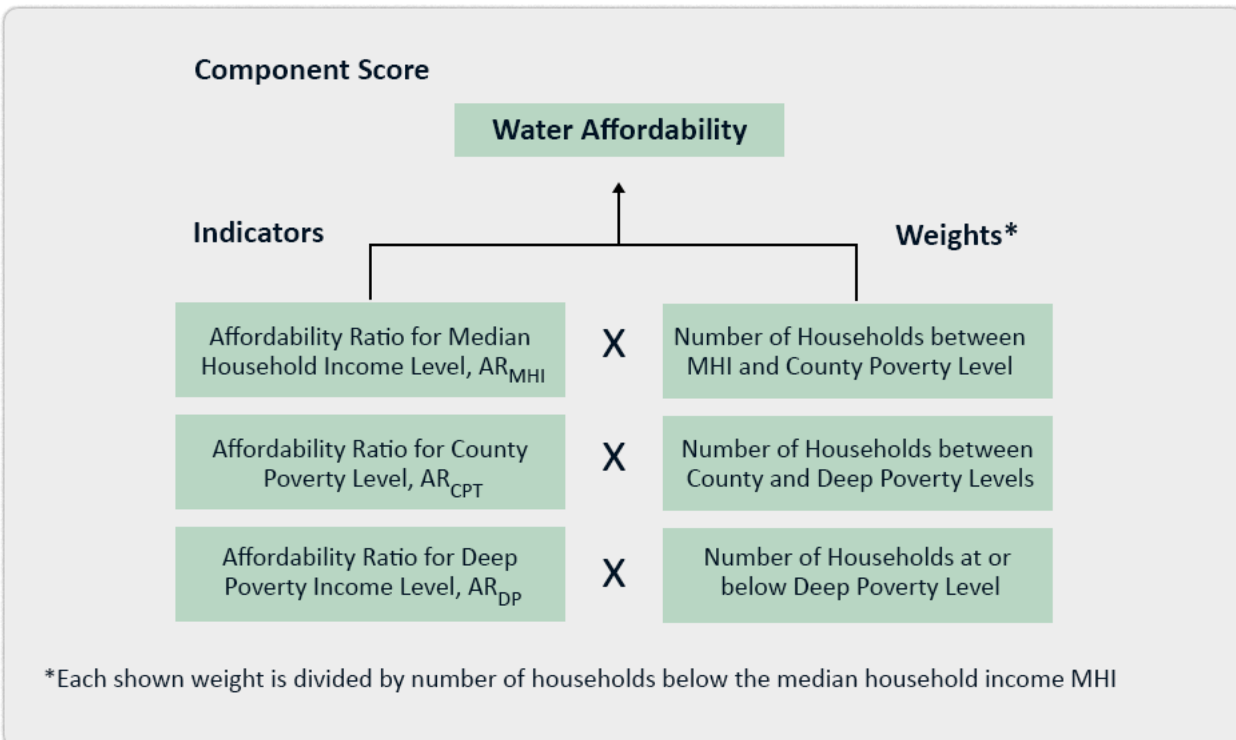
A Composite View of Water Affordability

OEHHA's composite affordability score is based on a household-weighted composite affordability ratio that is based on the three aforementioned affordability ratios (Figure 34). Any given system can have a range of income levels among the households it serves. For example, some water systems may have 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 have 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 have 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.

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. 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 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 (least affordable) to 4 (most 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 34. 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 34:

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

where HH_{MHI}, HH_{CPT}, and HH_{DP} are the numbers of households 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, was represented. For the 26 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).

General Results

Table 20 and Figure 35 show the distribution of the composite affordability ratio for the 1,158 community water systems with sufficient data to estimate affordability ratios. A substantial fraction of water systems analyzed – 17% of 1,158 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.

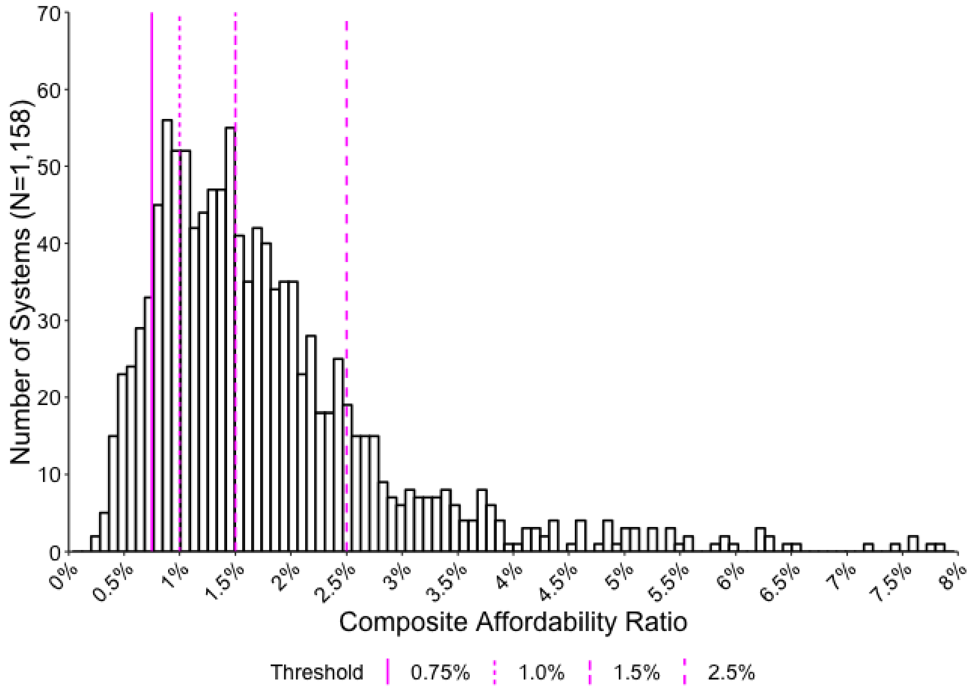
Table 20. Composite Affordability Ratios and Associated Scores for Community Water Systems (n=1,158 with scores), Study Period 2015. Note: the percent of systems shown is reflective of the 2,903 Community Water Systems, with the percent of systems in the analysis indicated in parentheses (n=1,158) †.

Composite Affordability Ratio Range	Composite Affordability Score	Number of Community Water Systems (CWS)	Percent of All CWS (N=2,903) (Percent of systems in Analysis, n=1,158)	Population*	Percent Population (among 2903 systems)
0 to <.75%	4	123	4.2 (10.6)	4,230,000	12.0
0.75% to <1%	3	151	5.2 (13.1)	6,770,000	19.3
1% to <1.5%	2	298	10.3 (25.7)	13,100,000	37.3
1.5% to <2.5%	1	383	13.2 (33.1)	6,780,000	19.3
>=2.5%	0	203	7.0 (17.5)	1,110,000	3.2
	Sub-total	1,158	39.9 (100)	32,000,000	91.1
No Data	N/A	1,745	60.1 (N/A)	3,110,000	8.9
	Total	2,903	100	35,100,000	100

† OEHHA used Census block population data from 2010 to estimate a total of approximately 35.1 million people living in areas served by water systems.

** Population rounded to nearest thousand. The population figure shown indicates the number of people served by systems with that given affordability ratio; it does not represent the number of people facing that actual affordability ratio.*

Figure 35. Composite Affordability Ratio: Weighted by Prevalence of Households at Different Income Levels At or Below the MHI. Data for 2015, n=1,158 community water systems†.

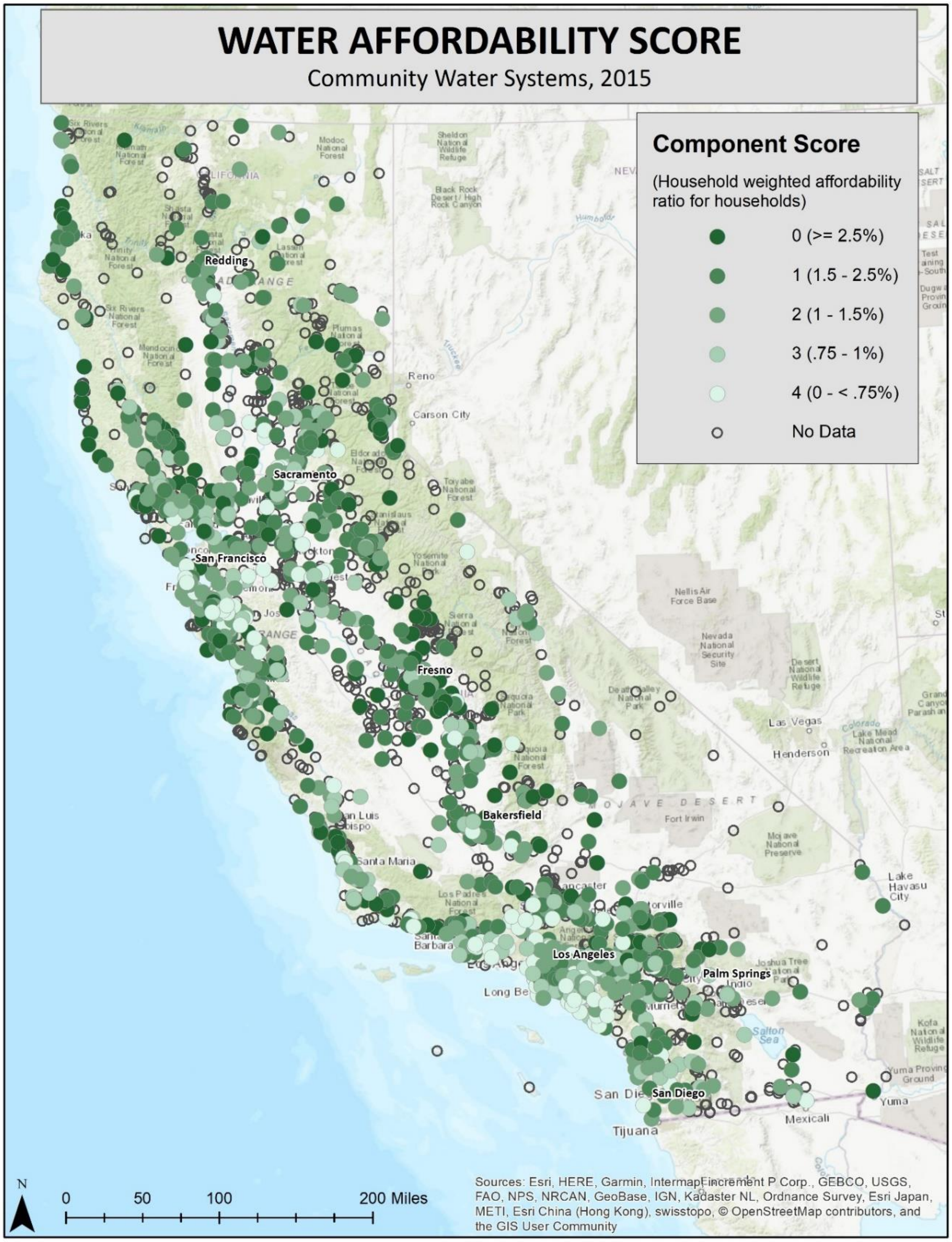


† The four dashed lines delimit the five bins used to score the affordability ratio.

Table 20 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 1.66 and the median was 1. Overall, approximately half of systems analyzed (n= 586 of 1,158) had scores of 0 to 1, corresponding to affordability ratios of greater than 1.5%. Approximately 10.6% of systems analyzed had a composite score of 4, 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 36. The map highlights a cluster of systems along the North Coast with low affordability scores, 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.

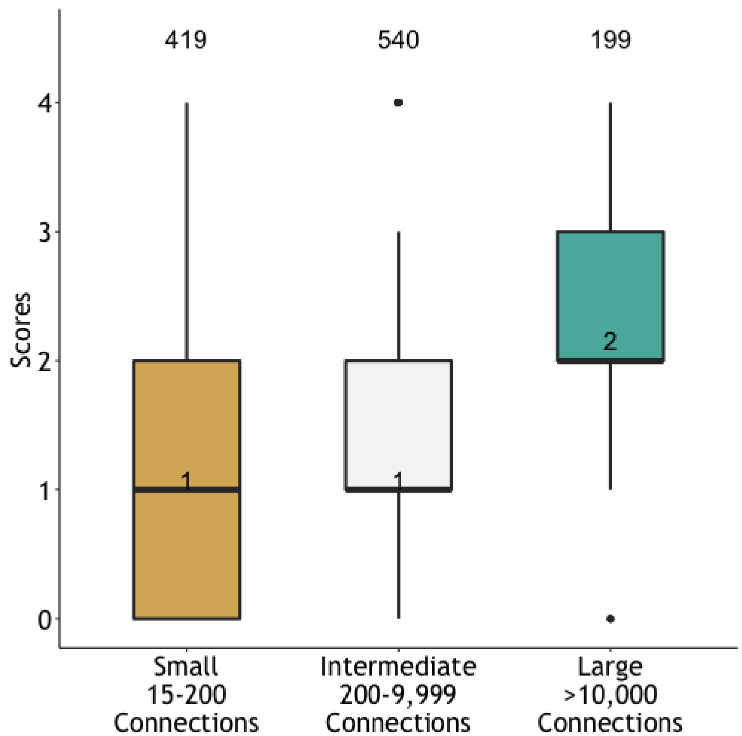
Figure 36. Composite Water Affordability Scores for Community Water Systems across the State. Lower scores mean less affordable water. Colored circles are for 1,158 systems with adequate data to score. Open circles outlined in black indicate systems without data.



Composite Affordability Scores by Water System Size and DAC Status

As shown in Figure 37, small and medium-sized systems face greater affordability challenges – as identified by their lower composite scores–compared to larger systems. In this figure, the horizontal bar on the box plots in the diagram represents the median composite affordability score, the lower end of the box represents the 25th percentile the upper end of the plot represents the 75th percentile, the "whiskers" show 1.5 times the interquartile range, and the top and bottom-most points represent the maximum and minimum scores, respectively. The figure shows the median composite affordability score is 1 for small systems (15-199 connections), 1 for medium systems (200-9,999 connections), and 2 for large systems (10,000+ connections).

Figure 37. Composite Affordability Score by System Size. The number of systems by size category are indicated above boxplot. Data for water bills (2015) and income (ACS 5-Year 2011-2015), n = 1,158 community water systems.

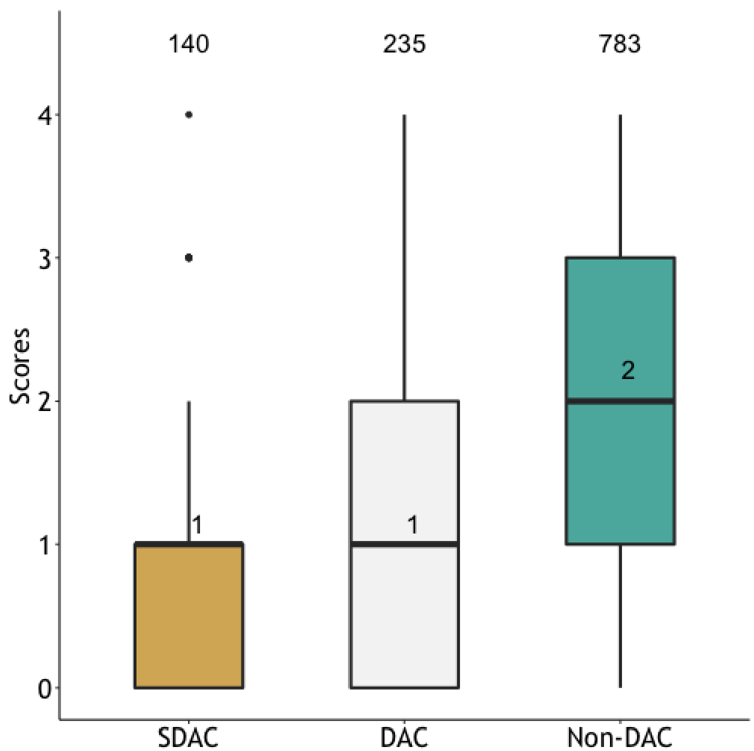


Thus 25% of small water systems included in the assessment have the lowest score (0), indicating substantial lack of affordability for the households served. The median score for large systems is 2, indicating that those households below the median household income that are served by large systems face some affordability challenges, but generally to a lesser extent than those served by the medium and small systems. There was a large and disproportionate lack of affordability data for small systems (see section on data gaps below). Consequently, the findings for small systems should be seen as provisional.

Affordability scores can also be compared across disadvantaged community status for the different water systems. A disadvantaged community (DAC) for the purpose of water system service is defined as a community with 80% of the statewide MHI and a severely disadvantaged community (SDAC) is defined as a community with less than 60% of the statewide MHI (Cal. Wat. Code §79505.5 and §13476). Statewide MHI in the American Community Survey (2011-2015) was $61,818; hence the calculated threshold is $49,454 for DACs and $37, 091 for SDACs.

Figure 38 shows affordability scores as a function of DAC and SDAC status of the water systems. The median score in both SDACs and DACs was 1, compared to a score of 2 in non-DAC/SDAC water systems. The upper end of the box indicates the 75th percentile, and the lower end of the box indicates the 25th percentile. Thus 25% of water systems for both SDAC and DAC have the lowest score, indicating a potential affordability challenge for the households served.

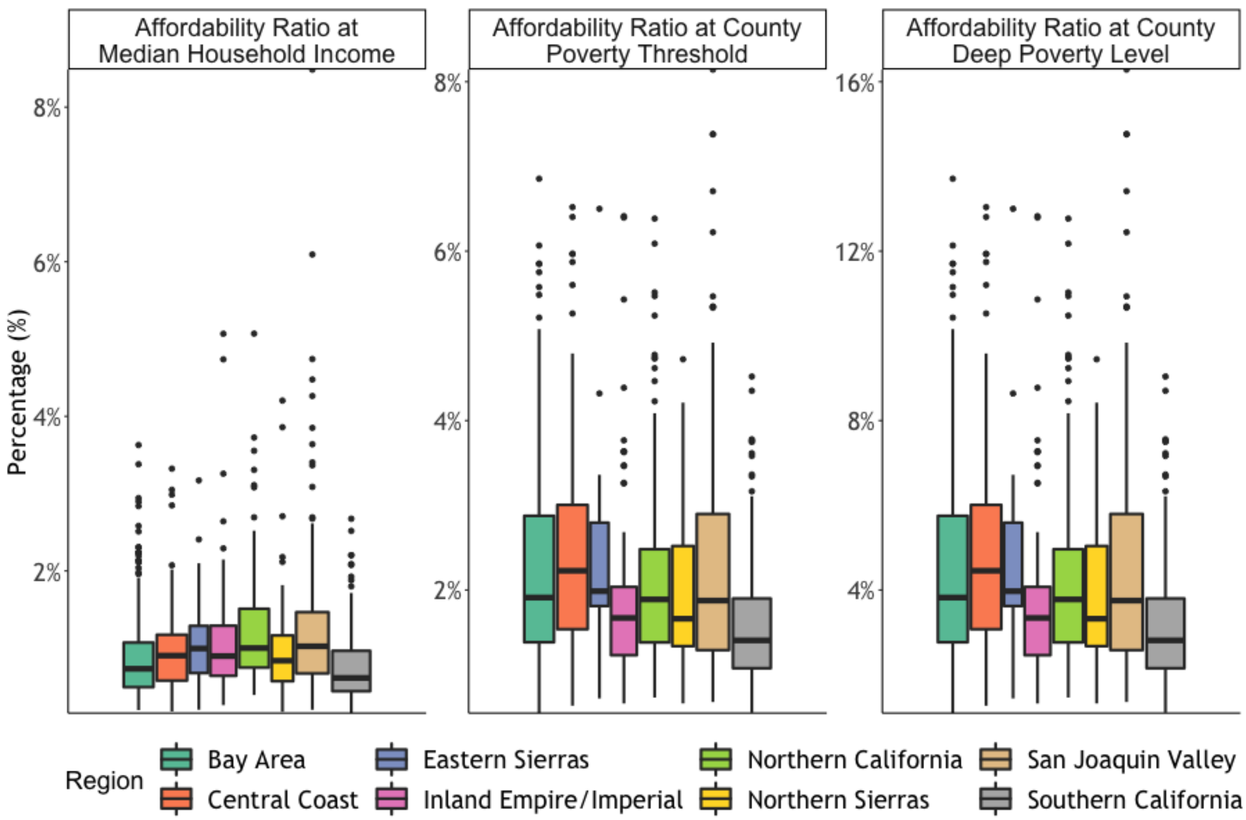
Figure 38. Affordability Component Score by DAC Status. System counts indicated above boxplots. Data for water bills (2015) and income (ACS 5-Year 2011-2015), n = 1,158 community water systems.



Affordability Ratios by Region

Where Figure 36 above maps the composite affordability scores on a statewide scale, Figure 39 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 25 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 39. 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 = 1,158 community water systems.



The number of systems represented: Bay Area (n=155); Central Coast (n=161); Eastern Sierra (n=58); Inland Empire/Imperial (n=117); Northern California (n=153); Northern Sierra (81); San Joaquin Valley (n=183); Southern California (n=250).

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 Sierras, and Inland Empire/Imperial regions have the highest household-weighted affordability ratios for households earning below the median income level, at levels of 2.1%, 2.1%, 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.

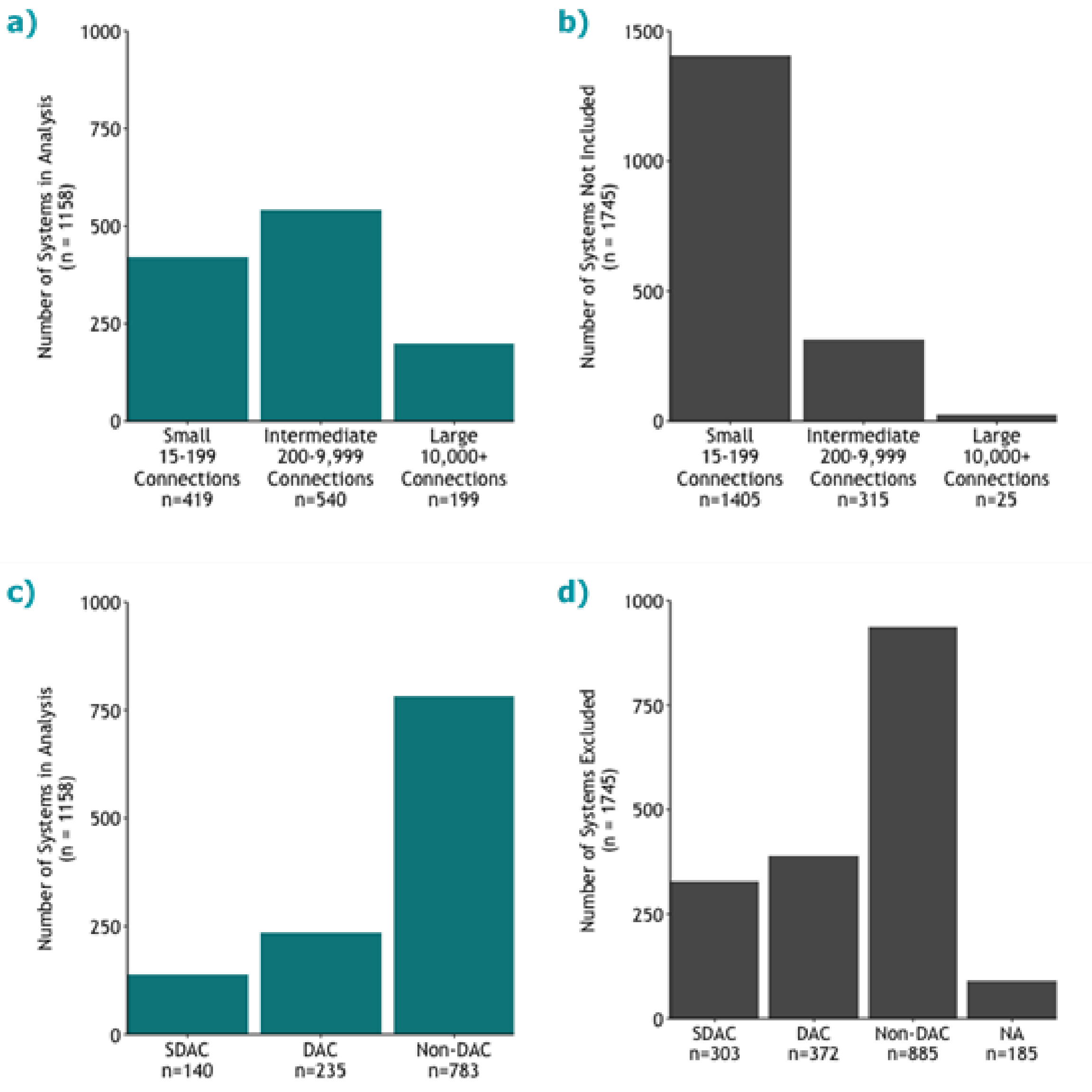
Affordability Data Gaps: A Key Consideration

Of the 2,903 community water systems in OEHHA's list, only 1,561 water systems reported water bill data in the electronic annual report. Therefore, as a starting point, only 53% of community water systems had water bill data with which OEHHA could estimate affordability ratios. Of the 1,561 water systems with water bill data, 1,530 systems also had US Census income data available. Of these 1,530 systems, OEHHA excluded 372 systems due to several exclusion criteria discussed in Appendix B3 Data Cleaning & Exclusions and B4 Composite Affordability and Box 6. Thus, the final list of systems in the affordability analysis included 1,158 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 90% 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 6: What About Systems That Were Not Included?). Small systems make up about 63% of community water systems in California. However, just 36% of systems that were included in the affordability assessment are small (i.e., less than 200 connections). Intermediate and large systems make up approximately 34% of the community water systems in California. However, approximately 56% of systems included in the affordability assessment are intermediate or large. 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 40).

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 37 and Figure 38, 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.

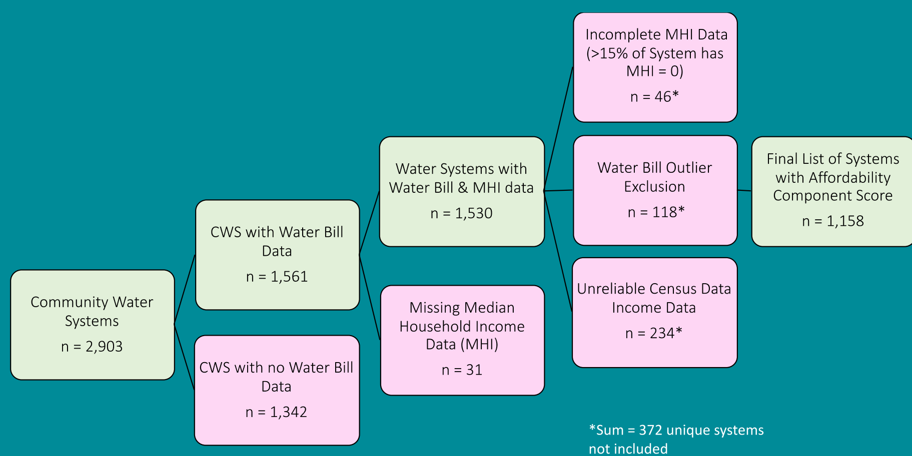
Figure 40. Comparison of System Size and DAC Status for Systems Included in Analysis Versus Systems Not Included in Analysis. Figures indicate systems included in the current analysis (dark green bars, Figures a and c) and systems not included in analysis (dark gray bars, b and d). Figures 39a and 39b indicate system size by connections. Figures 39c and 39d 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 6: 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):

- 77% of the 1,745 systems not included in the affordability analysis had no water bill data reported in the eAR.
- 23% of the 1,745 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 8.9% of the state's population. This means that while a large fraction of systems are missing data, the 1,158 systems shown in OEHHA's results serve a large majority of Californians.
- Small systems account for 81% of the 1,745 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, 26.5% of systems not included in the analysis are SDAC, whereas they make up 19% of systems 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 38% 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

OEHHA will explore several additional indicators for water affordability (See Table 22), and explore what counts for 'basic' water needs, depending on the number of people in the household. 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 E.A. and Wrase S 2017; Teodoro M.P. 2018). Additional future areas to explore include: households relying on private wells or state small systems, and 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.

Finally, 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. 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.

Summary and Key Findings for Affordability

In the present assessment, water affordability is assessed for households at the water system scale (US EPA 1998a). 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 50th 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 small water systems, but there is variability in water bills across all system sizes.

Affordability Ratio for the Median Household Income Level

- Water is relatively affordable for a majority of households at the median household income level of community water systems.
- A majority of water systems with water bills greater than 1.5% of the system's median household income would be identified as economically disadvantaged according to the Water Board's criterion. *[Among the 1,158 water systems with affordability ratios, 15.8% (n=182) had water bills for 6 HCF exceeding 1.5% of the median household income. Of these, two-thirds (121 systems) are severely disadvantaged or disadvantaged systems.]*
- For approximately a fifth of water systems, affordability ratios for median household incomes are between 1-1.5%, indicating potential future challenges if water rates increase.
- Geographically, affordability ratios for households earning median household income levels in their water system 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

- Water is relatively affordable for households earning disposable incomes at the county poverty level in a majority of water systems.
- Some households at the poverty level have substantial water bill burdens. For 16% of water systems, water bills at the essential use level amount to 3% or more of disposable income, a common threshold for low-income water affordability.
- Geographically, affordability ratios for households earning county poverty income levels are highest overall for water systems in the Central Coast (mean = 2.4%), San Francisco Bay Area (mean = 2.3%), San Joaquin Valley (mean = 2.25%), and Eastern Sierra (mean = 2.2%), although there is substantial spread with significant affordability challenges present for some systems in each region.

Affordability Ratio for Deep Poverty Threshold Income Level

- Water is relatively unaffordable for households earning disposable incomes at the deep poverty level in for the majority of water systems.
    - For 62% of water systems, water bills at the essential use level amount to greater than 3% of disposable income at the deep poverty level. Geographically, affordability ratios for households earning deep poverty income levels are highest overall in the Central Coast (mean = 4.8%), San Joaquin Valley (mean = 4.5%), San Francisco Bay Area (mean = 4.6%), and Eastern Sierra (mean = 4.5%).

Overall

- There is a large disparity in water affordability between households earning the county poverty income level and those earning median household income levels.
- The composite affordability score shows slightly different geographic patterns of unaffordability compared to individual indicators. There is a substantial overall spread in the composite affordability ratios within each region, with significant affordability challenges present for some systems in each region.
- Data gaps in affordability will need to be continually addressed. The systems with missing or excluded data serve approximately 8.9% of the state's population. A majority of systems missing data are small systems.

A Holistic View of Water Systems: Applications and Cases

A Holistic View of Water Systems: Applications and Cases

Applications

Once the tool 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 four main ways, at the water system or statewide level:

- To assess 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.
- To track and update progress in achieving the overall human right to water.

The tool offers a holistic view of California's drinking water and the challenges associated with it that many California communities are facing. 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.

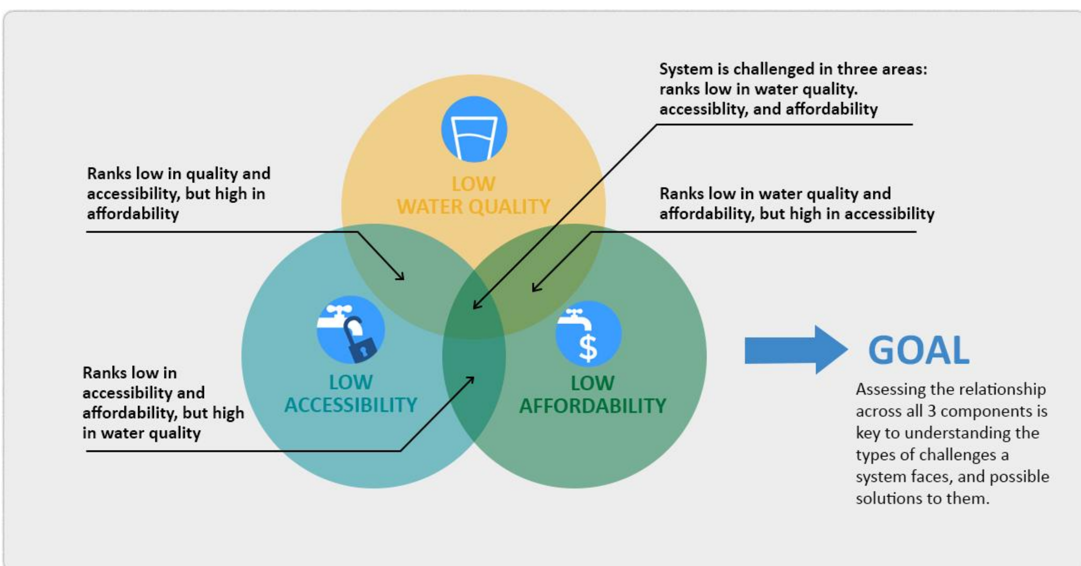
Finally, this tool allows for regional and statewide assessments of key trends across components. Previous initiatives have documented particular water challenges across the state, as well as a wide variety of challenges in particular regions. This tool, however, brings together information on water 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 41. The three components are shown in circles and are described as types of challenges: low water quality, low accessibility, and/or low affordability. Water systems may face one or more—or even all three—of these challenges, and 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.

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?

This section provides examples of the types of information the data tool could help generate, 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 41. Diagram of the Three Components in the Human Right to Water Assessment 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 could function 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: Here, this system faces challenges in all three components. Water quality, accessibility and affordability are all low.

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 2008 to 2016, 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 45 and 65 milligrams per liter (mg/L) in eight of the nine years. As the MCL for nitrate is 45 mg/L, 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 acute TCR 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, the system is considered to be physically vulnerable to water outages. As a small system serving a predominantly economically disadvantaged community, it is estimated to have relatively high institutional constraints (i.e., low score). It had ten monitoring and reporting violations, indicating potential managerial constraints.

With regard to **affordability**, residents served by the system also face a number of challenges. 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 population lives at or below the county poverty threshold, a significant portion of economically vulnerable residents living in the community are particularly vulnerable to affordability challenges. Figure 42 depicts results for

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

each of the indicators. Table 21 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, whether to consolidate with a nearby larger system, assign an administrator, or allocate resources (e.g., training and capacity building, technical decision-making support, or financial support), and what types of resources might be best suited to address the community's needs.

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 may need to 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 42. Chart Summarizing Case Study Results. The rows show the results for each of the three hypothetical water systems. The columns represent the 13 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 21. Summary Table for Hypothetical System A. Water challenges in all three areas. This chart provides an example of how information 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 45-65 mg/L.
	Presence of acute contaminants	Yes: nitrate and total coliform.
	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.
	Presence of acute contaminants in non-compliance	Yes: nitrate and total coliform.
	Maximum duration of non-compliance	Eight years of nitrate MCL violations.
Water Accessibility	**Physical vulnerability to water outages**	One groundwater well.
	Institutional constraints	Small, disadvantaged community.
	Managerial constraints	The system had no monitoring and reporting violations.
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: Here, a system faces some challenges in water quality and accessibility, but the key challenge lies in affordability.

This mid-sized hypothetical system, serving roughly 3,300 residents, is located in a rural, non-agricultural region of the state. The system has four groundwater sources and two surface water intakes. Median household income is $39,000. Average water bills for 6 HCF of water are $55 per month, or $660 per year. From 2008 to 2016, the water system received notification of on-going total coliform violations, with TCR MCL violations in six of the nine years. All data requirements were met.

With regard to ***accessibility***, the indicators do not signal major accessibility challenges, other than those challenges stemming from the system's potential institutional constraints.

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 the residents served by this water system live at or below this level. Nearly 5 percent of residents 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 residents 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 42 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, making them some of the most economically vulnerable residents served by the system.

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 and serves nearly 30,000 people. The median household income in this community is $42,100. The system has more than ten groundwater wells and one surface water intake. The average water bill for 6 HCF is $85 per month, or $1020 per year. The system had no monitoring and reporting violations.

This system has had no **water quality** challenges in the time period, and has relatively strong **accessibility**, based on the current indicators. 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. Thus, 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 42 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 low composite component scores 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 L 2018) proposes a similar approach in which the highest level of

[44] Affordability metrics are still being established.

water service is defined as Satisfactory and includes a series of qualitative benchmarks to define it.

This human right to water assessment and data tool do not currently define thresholds for each component that determine whether a score is “acceptable” or not. Instead, 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.

The tool, with these various uses provides a means against which to measure progressive realization of the human right to water.

Summary

In summary, 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. These system-level results can also be used to provide state-level understanding of general progress in achieving the human right to water across water systems. For example, when users view the results in combination, they can assess overall trends across water systems in each of the three components. As updated 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, this assessment and tool enable 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.
- Quantify overall trends across the state and/or regions to gain a picture of the overall level of challenge in one or more components. In particular, this report provides a baseline set of results, which can then be used to assess how trends change over time.

Public workshops and discussions can help guide consideration as to how to holistically assess systems *across* all three components.

Conclusions and Next Steps

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. The data tool and assessment 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, OEHHA's tool offers a flexible, versatile, and adaptable way for 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 on 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 will take several next steps in developing and refining this tool. In addition to soliciting feedback on this draft report and its associated web platform through public and scientific workshops, OEHHA intends to expand the scope of the assessment and refine the data tool to offer the most comprehensive view of drinking water possible.

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 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 T.D. and Belitz K 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.[45] 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.[46] 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.

A partial list of potential indicators or units of analysis for future versions of the tool is included in Table 22 below.

Table 22. 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
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

[45] 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).)

[46] 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
	• 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.).
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),.[47] 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" (Villumsen M. and Jensen M. H. 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 1998a). 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 (US EPA 1984, 1998a). 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).[48] This approach calls for:

[47] 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.

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

1) Measuring domestic water affordability ratios (water bill divided by median household income)(US EPA 1998a)[49] and
2) Determining what type of variances[50] 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 1998a).

Two essential points emerge from 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.

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).

A2 Approaches to Measuring Affordability

A2.1 Conventional Affordability Ratio

Generally, there are two main approaches to measure water affordability (Hancock K. E. 1993).[51] 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 (CAR).

Most often, this is assessed as what fraction of a median household income is needed to cover direct and indirect costs of obtaining water services (including for drinking, hygiene and sanitation) (UN CESCR 2002).[52] If the resultant ratio exceeds a designated threshold (See Appendix Table A1), households in the area of analysis are considered to face unaffordable water costs. Importantly, these thresholds reflect policy choices about the appropriate or

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[49] 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 1998a)

[50] 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).

[51] 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.

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

socially accepted ratio of what counts as affordable and have previously been implemented at the state level.[53]

A2.2 Affordability Thresholds

A range of thresholds exist to evaluate affordability ratios. In general, these thresholds range from 1.5% - 5% 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 1998a). Subsequent state-level affordability assessments related to water system eligibility status for disadvantaged assistance have used a range of affordability ratios and additional criteria.[54] 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).[55] This threshold of 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).[56] 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).

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

[54] 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 1998a) 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.

[55] 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 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.

[56] 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.

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) *UCLA Luskin Center for Innovation* (Pierce G, McCann H et al. 2015)
2% of MHI	*Wastewater services*	*U.S. Environmental Protection Agency* (US EPA 1997)[57]
2% of MHI	*Drinking water services*	*U.S. Environmental Protection Agency* (US EPA 1998a) *AB 2334* (Assembly Bill No. 2334 2012)[58] *Public Policy Institute of California 2014* (Hanak E, Gray B et al. 2014)[59] *Christian-Smith et al 2013 (Pacific Institute, Community Water Center and California State University, Fresno)* (Christian-Smith J, Balazs C et al. 2013)
2.5% of MHI	*Drinking water services*	*U.S. Environmental Protection Agency* (US EPA 2002)[60]

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

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

[59] 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).

[60] 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.

Affordability Ratio Threshold	Water Cost Included	Organization Using Threshold (Studies Applying Threshold)
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) [61]
4.5% of MHI	*Drinking water & wastewater services*	*U.S. Environmental Protection Agency*[62] *Mack and Wrase (2017)* (Mack E.A. and Wrase S 2017)
5% of MHI	*Drinking water & wastewater services*	*AAAQ* (Villumsen M. and Jensen M. H. 2014); *German International Water Policy and Infrastructure group (GTZ)* (Deutsche Gesellschaft für Technische Zusammenarbeit 2009).[63] *World Bank* (Banerjee S.G. and Morella E 2011)
5% of Discretionary Income for 20th Income Percentile	*Drinking water (or wastewater)*	*Pacific Institute 2018* (Feinstein L 2018) *Teodoro (2018)* (Teodoro M.P. 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 I, Miniaci R et al. 2009), [64]
b) household expenditures in general, and

[61] UN-Water Decade Programme on Advocacy and Communication. "The Human Right to Water Media Brief." Available at URL: www.un.org/waterforlifedecade
[62] 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.
[63] Note that the GTZ report does not cite or reference support for the 5% threshold here.
[64] 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'.

c) the poverty line.

Data requirements for this type of analysis are hard to fulfill, however.[65] Water affordability is thus commonly assessed using affordability ratios and thresholds (UN CESCR 2002).[66]

A2.3 Hours at Minimum Wage

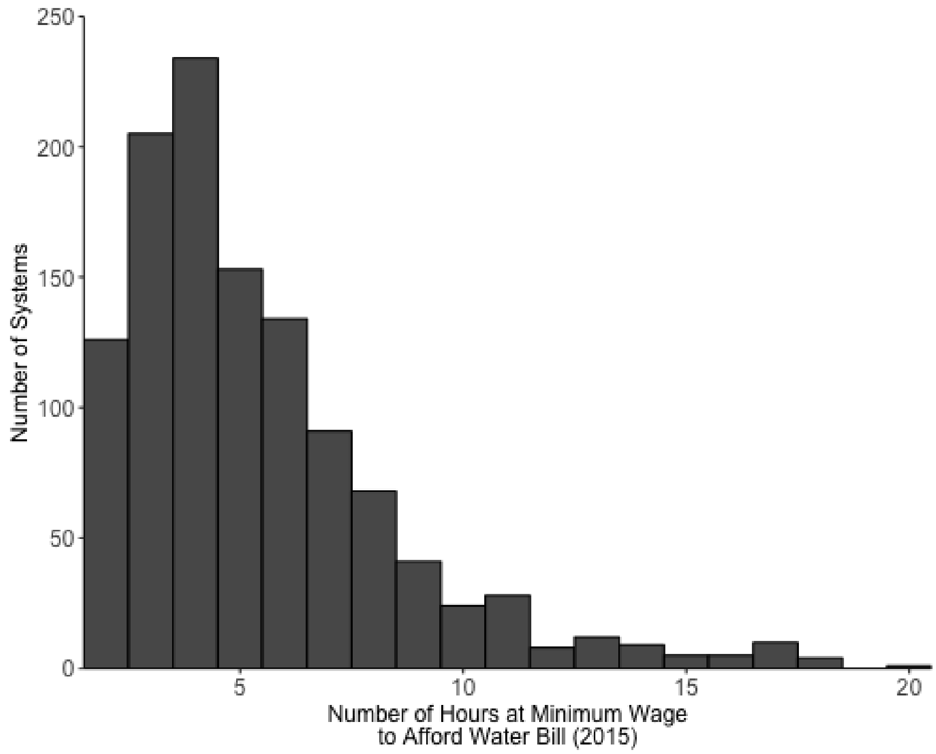
Teodoro 2018 suggested representing affordability as a measure of hours worked at minimum wage (HM) with the explicit use for "purposes of budgeting, planning, rate-setting, and policy design" (Teodoro M.P. 2018). The HM metric was developed for water and sewer costs combined, but could feasibly be developed for each bill separately. Teodoro argues that HM is familiar and intuitive as a complementary metric to affordability ratios. 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 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 1,158 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 M.P. 2018) suggests an HM greater than 8 hours for a family of four would be considered unaffordable. Figure A1 demonstrates a histogram of this data, which is right-skewed like the water bill data. 183 systems, or 15.8% of systems with affordability data (n=1,158), 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.

[65] Though a recent study by (Teodoro M.P. 2018) indicates how expenditures might be incorporated into affordability ratios.

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

Figure A1. Hours at Minimum Wage to Afford Water Across Systems (N = 1,158).



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, Donnelly K 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. Water affordability ratios also ideally include water costs for sewer or storm water services (Teodoro M.P. 2018).

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 E, Sigel K et al. 2013) or income less expenditures on other essential goods (i.e. discretionary income) (Teodoro M.P. 2018). 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. 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 D.C. and Taylor L.D. 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 M.P. 2018). Others advocate evaluating affordability *within* a water system where income levels of residents can vary widely within a community (Christian-Smith J, Balazs C 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). [67] 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 M.P. 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

[67]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.

and the choice of thresholds used, which may risk obscuring vulnerable populations in the process of representing water affordability (Kessides I, Miniaci R 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 J, Balazs C et al. 2013).

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=2,903). 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.[68] 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)[69], 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[70] per person per day given a household of three or 37 gallons per person per day assuming a household size of four.

[68] 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)

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

[70] 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 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.

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[71]: *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)[72]: *43 gallons (163 liters) per person per day*	California Water Code Conservation[73] *55 gallons (208 liters) per person per day*
6 HCF (4488 galllons 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

[71] Here, (Gleick P 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.

[72] 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.

[73] 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.

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 M.P. 2018). This would allow OEHHA to experiment with additional affordability measures (namely the residual income approach (Gawel E, Sigel K et al. 2013) and better articulate the water bill burden for median and low-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). [74] Additionally, reviews of US EPA's conventional affordability ratio (NAPA 2017; OEHHA 2017; US EPA 2014)[75] 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.

[74] 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).
[75]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.

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).[76]

OEHHA evaluated two types of poverty income data due to their California-specific context: California County Poverty Thresholds[77] 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 S, Danielson C et al. 2013).[78] 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.

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[76] 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.

[77] 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.

[78] 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 = 1,158 Systems.

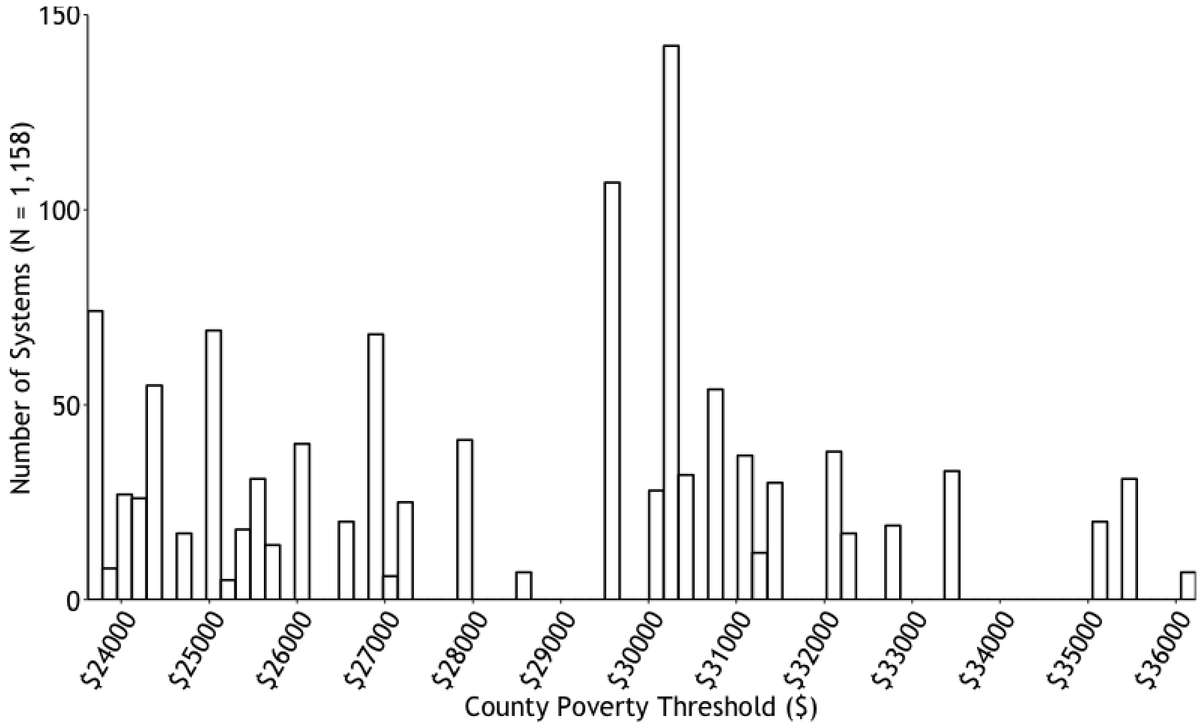
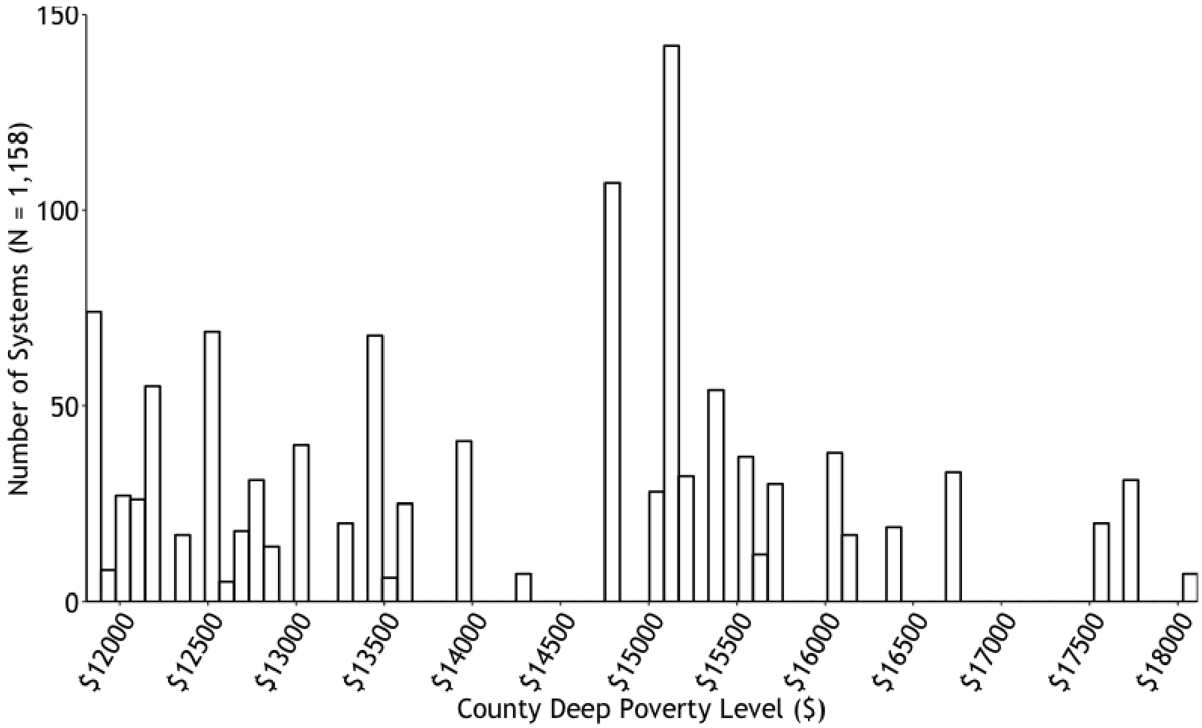


Figure B2. Histogram of California County Deep Poverty Thresholds. Data for 2015, n = 1,158 systems.



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')	✗	✓

Selection Criteria for Demonstrating Water Bill Burden	HCD: State Income Limits for Housing	PPIC: County Poverty Thresholds
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).[79] 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, 1,689 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 OEHHA's list of 2,903 Community Water Systems (CWSs), resulting in 1,561[80] water systems with water bill data present in the OEHHA CWS list. Of these 1,561 community water systems with water bill data, 1,530 systems had both water bill, median household income, and total households across income bracket data prior to any exclusions.

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 118 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 = 118). Systems with more than 15% of their block groups missing MHI data were excluded (n = 46). Systems with unreliable data according to exclusion criteria discussed below were excluded (n = 234). Of the 401 systems in these exclusion lists, 26 systems overlapped, for a

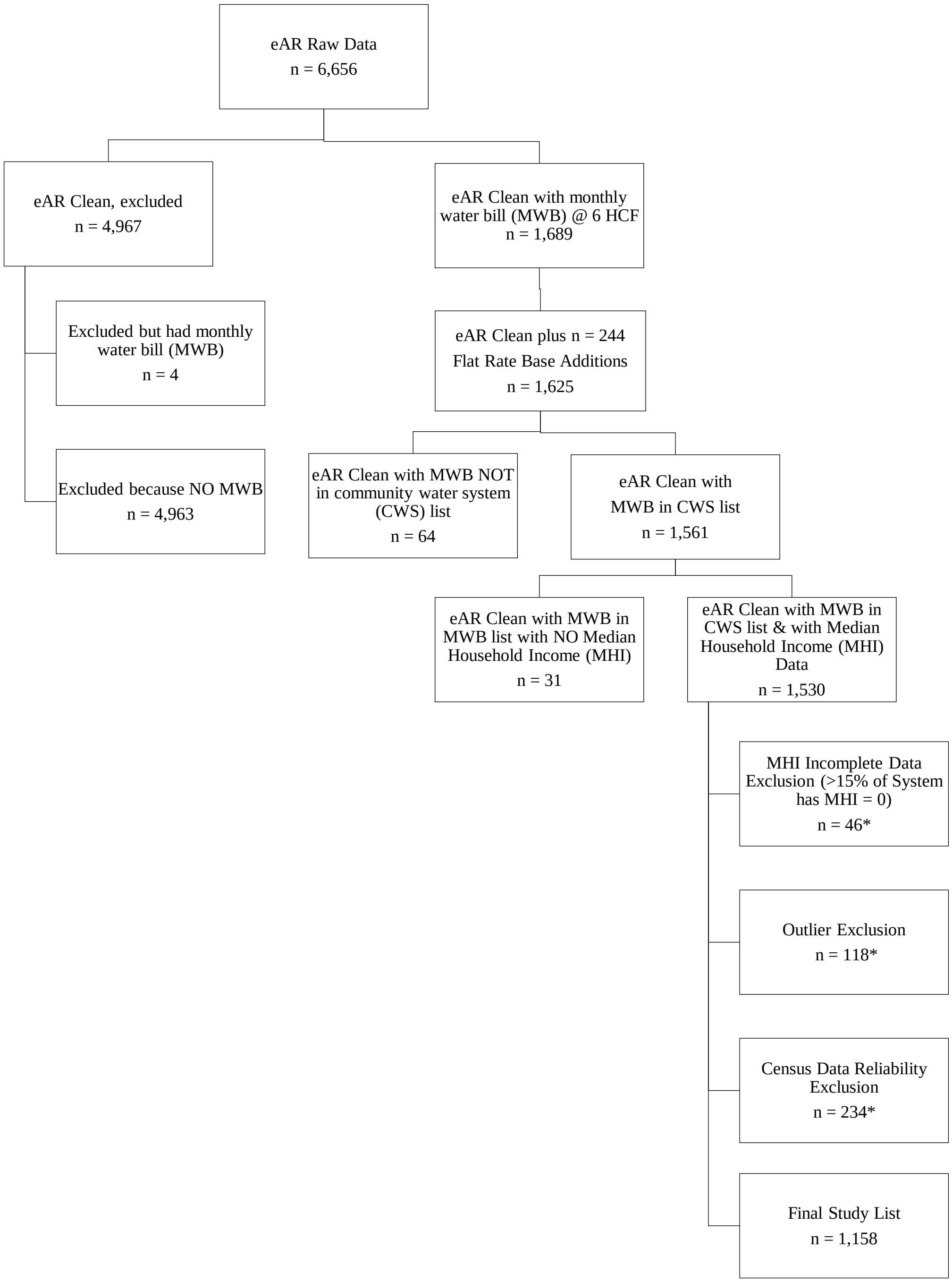
[79] Reported values are not disaggregated by rates and fees, but additional costs to users based on other surcharges, fire suppression surcharges, as well as discounts to users based on lifeline subsidies, should be included in the calculation.

[80] 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.

total of 372 unique systems that OEHHA excluded. Of the 1,530 systems with water bill and income data, the 372 systems were excluded to create a final list of 1,158 systems for the affordability assessment. Below, these exclusions are discussed in detail (See Appendix B4 Composite Affordability).

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.



** Three systems overlap between outlier systems and MHI incomplete data systems and 23 systems overlap between outlier systems and Census data reliability study for a total of 26 systems falling 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 36% of systems included in the water affordability assessment are small systems (<200 connections), but small systems make up about 63% of the full community water system list. We see the effects of this bias in the overall list of missing data (1,745 systems)–a disproportionate number of smaller systems are excluded from the study (81% of systems without data are small). The final study list also has a slightly lower percentage of SDAC systems (12%) than the overall community water system list (18.5%). 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. . As such, 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 prior to any exclusions):

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

We used these methods to identify systems on the ends of the distribution. No prior baseline exists to truly 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 M and Vandervieren E 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, 89 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 M and Vandervieren E 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)	89
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 1,158 systems included in OEHHA's affordability assessment, the median water bill for 6 HCF across all systems was $41.39/month (average = $48.81 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. 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 $15.00/month to $94.72/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 ($36.00) and severely disadvantaged communities (SDAC) ($37.85).

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=1,158), small systems (n=419), intermediate/medium systems (n=540), and large (n=199) systems. Study period 2015.

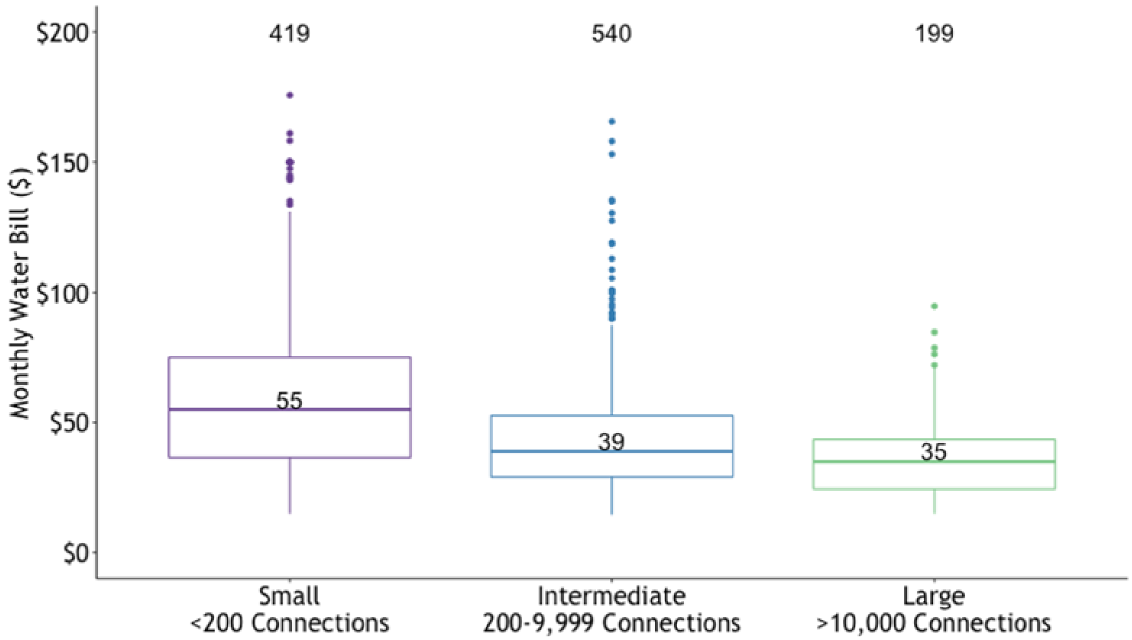
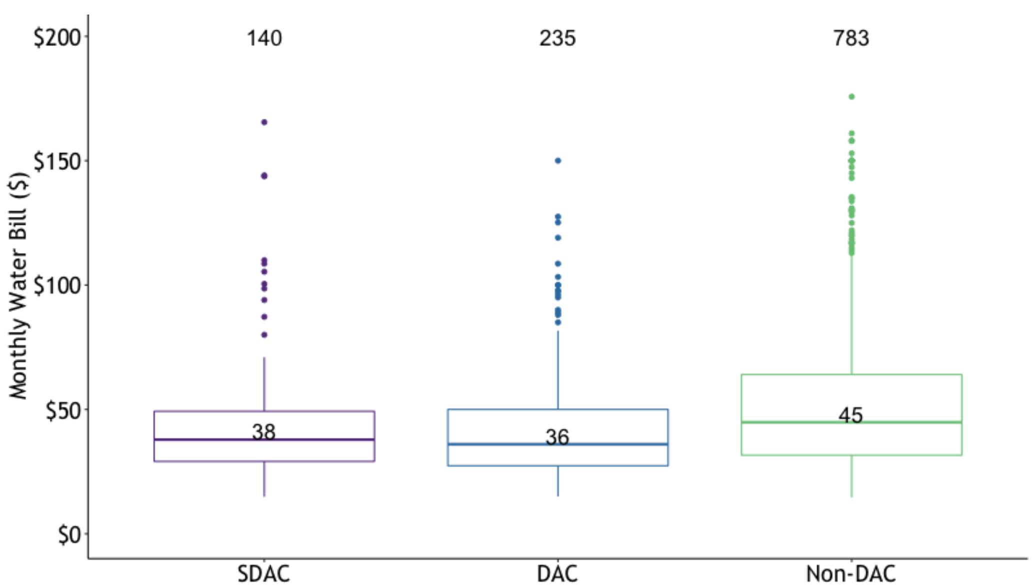


Figure B5. Average Monthly Water Bill for Community Water Systems by DAC Status. Results shown for systems in affordability study sample (n=1,158) for SDAC (n=140), DAC (n=235), and Non-DAC/SDAC (n=783) systems. Study period 2015.†



† 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 $61,094. 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[81]:

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

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.

[81] 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.

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.

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 this 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 2,903 water systems in OEHHA's community water system list, 1,418 systems fall into one block group. Of the 1,418 systems within one block group, 1,265 of them (89%) have fewer than 200 connections. The average number of connections is 98 (median = 45), and 75 percent of the systems have below 95 connections. In sum, systems within one block group are typically very small.

Of the 1,418 water systems within one block group, 27 systems did not meet the data reliability criteria for Median Household Income. This resulted in 27 exclusions, or 2,876 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 2,876 water systems remaining for analysis after excluding data based on reliability criteria, 89 systems had no Median Household Income Data (MHI = 0) and 69 systems had over 15% of their household-weighted area with missing data (MHI = NA). This resulted in 2,718 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 1,530 systems with water bill and income data prior to any exclusions, 505 systems fall within one block group. Of the 505 systems with one block group, 430 of them (85%) have fewer than 200 connections. The average number of connections is 118 (median = 53), and 75 percent of the data fall below 130 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 505 systems with data to evaluate reliability, there is one MHI estimate with no MOE. Of the 504 estimates for Median Household Income, 8 systems have unreliable estimates (or 1.5% of the 504 systems).

Household Income Brackets Data Reliability

On average, across all 505 systems, 231 systems had more than 2 unreliable estimates among the 16 Number of Households in Income Bracket estimates. Of these 231, 5 systems overlapped with the 8 systems found to have unreliable MHI estimates.

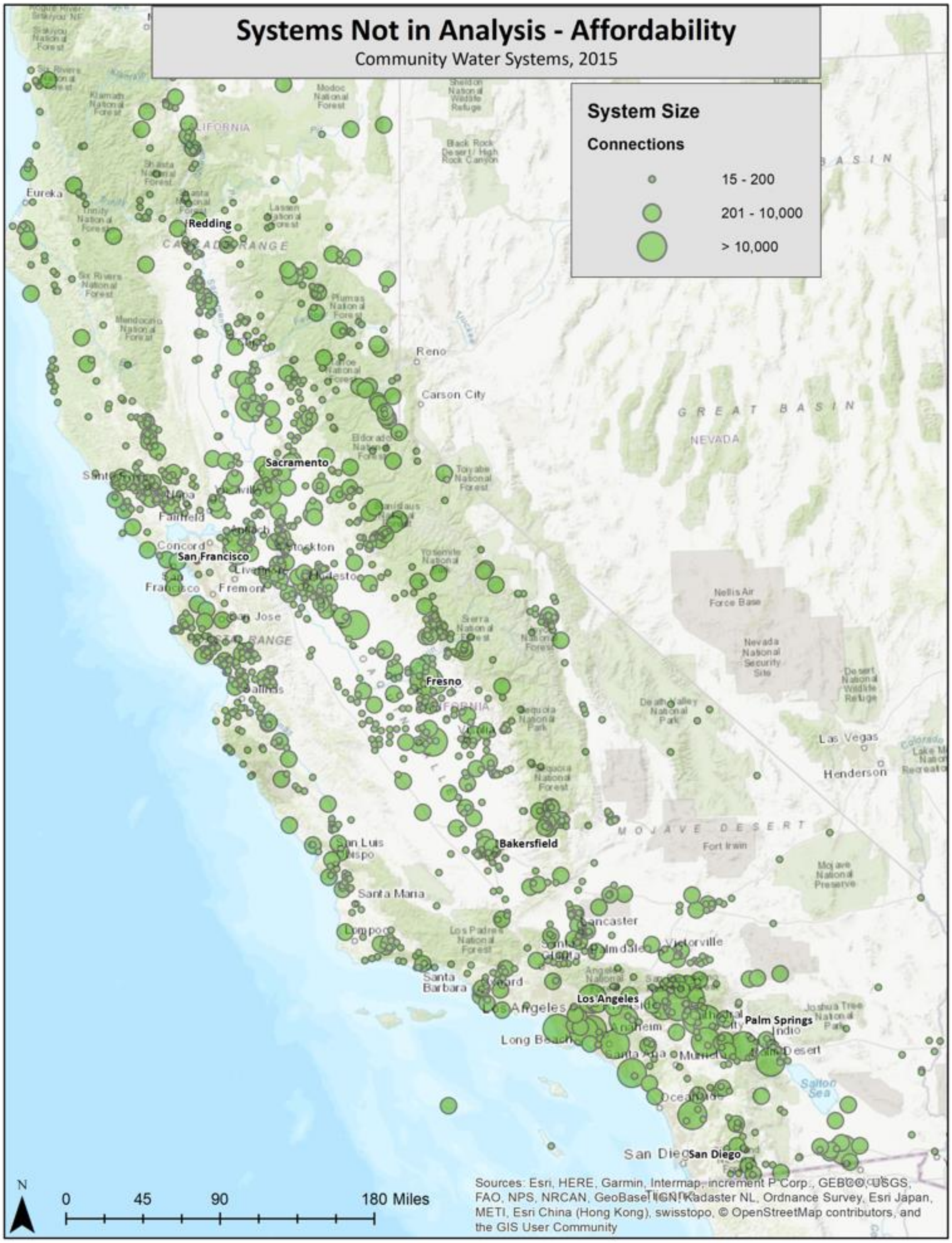
Affordability Indicator Final Study List

Of the 1,530 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 = 1,745 systems of 2,903 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. [82]

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:

[82] 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 50^{th} 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 1,158 systems in the affordability study, the average percentage of households below the estimated median income level is 50.7% with a standard deviation of 3.9%. 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 such low-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.