CALIFORNIA DEPARTMENT OF WATER RESOURCES

CALIFORNIA'S GROUNDWATER UPDATE 2020



HIGHLIGHTS

The *California's Groundwater Update 2020 Highlights* has a companion detailed statewide report, called *California's Groundwater Update 2020*. This companion report can be accessed on DWR's California's Groundwater (Bulletin 118) webpage.

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California's Groundwater Update 2020 Highlights

Bulletin 118

November 2021

State of California

The Natural Resources Agency

Department of Water Resources

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Governor
State of California

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Natural Resources Agency

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Using California's Groundwater Update 2020

- **California's Groundwater (CalGW) Update 2020** is the State's most up-to-date compendium of statewide data and information on the occurrence, nature, use, and conditions of California's groundwater resources and its management. It is a continuation of a series of earlier DWR publications, known as Bulletin 118. It builds on the past progress and state of knowledge, synthesizes the most recent data to close current gaps in knowledge, and focuses on statewide groundwater management and planning efforts, including drought planning and response.
- CalGW consists of a summary **Highlights** and a detailed **Statewide Report,** supported by a series of appendices, and **CalGW Live** as described below.
- **Highlights (English and Spanish):** A stand-alone summary document describing the value and state of groundwater conditions and management in California with findings and recommendations to foster and achieve sustainable groundwater management.
- **Statewide Report (Chapters 1 to 6):** A detailed report on the state of groundwater in California including history of California's Groundwater reports, economic value of groundwater, and groundwater management before and after the enactment of the sustainable groundwater management act (SGMA). It provides a status of statewide groundwater monitoring and the latest knowledge on statewide groundwater conditions including groundwater levels, change in storage, groundwater quality, and land subsidence.
- **Statewide Report (Chapter 7):** A hydrologic-region summary and regional status of land and water use, monitoring and conditions of groundwater levels, groundwater quality, land subsidence, seawater intrusion, and surface water groundwater interactions. It includes a map and a list of all groundwater basins in each hydrologic region with their current designated priority under SGMA's Basin Prioritization process.
- **Appendices A to H**: A series of appendices that provide details supporting the content of the various chapters of the statewide report, including methods and assumptions, citations, and references.
- **CalGW Live:** A user-friendly interactive website that allows users to explore, analyze, and visualize the latest groundwater data and information for California.

Message from the Director



Groundwater is a precious natural resource. Over the last several decades, California's increasing reliance on groundwater and reoccurrence of drought underscore the critical importance of groundwater to the state. As climate change has accelerated, droughts have become more frequent, more severe, and longer in duration. There has been a shift from using the less available snowpack, precipitation, and surface water to our reserves – groundwater.

Often unseen, groundwater serves a multitude of purposes and uses including for the environment, businesses, agriculture, and for household use, where some Californians rely solely on groundwater for drinking water. Groundwater supports our communities, rich biodiversity, economy, industries, jobs, and human health. As demands continue to increase with the variability in climate, the State and Governor Newsom are keenly focused on ensuring that our water supplies continue to be reliable now and more resilient into the future. The passage and implementation of the Sustainable Groundwater Management Act (SGMA) marks a new era of improved science, understanding, and access to groundwater information. Which provides the foundation for data-driven decision-making to both inform and transform groundwater management.

California's Groundwater – Update 2020 (Bulletin 118), builds upon past efforts and represents the most comprehensive compilation of groundwater information for California to date. Required by SGMA, this bulletin and future updates serve to enhance our understanding of groundwater conditions and management statewide by supporting actions in the Governor's Water Resilience Portfolio and providing groundwater data and information to support progress towards achieving sustainability and improving drought resilience. This bulletin includes new data and analyses – providing pivotal information for near-term drought response and long-term groundwater planning. An accompanying online application, called California's Groundwater Live, establishes a publicly accessible platform that organizes the increasing flow of groundwater data and information and visualizes it for greater public education and awareness.

With increased knowledge and understanding comes a responsibility to continue working collaboratively and adapting how we manage our groundwater resources. There will be challenges as we continue our collective efforts to achieve statewide sustainable groundwater management, however with durable and innovative solutions underpinned by up-to-date information, we can overcome these obstacles and continue on our path towards a more reliable and resilient future.

Karla A Nemeth

Director, California Department of Water Resources

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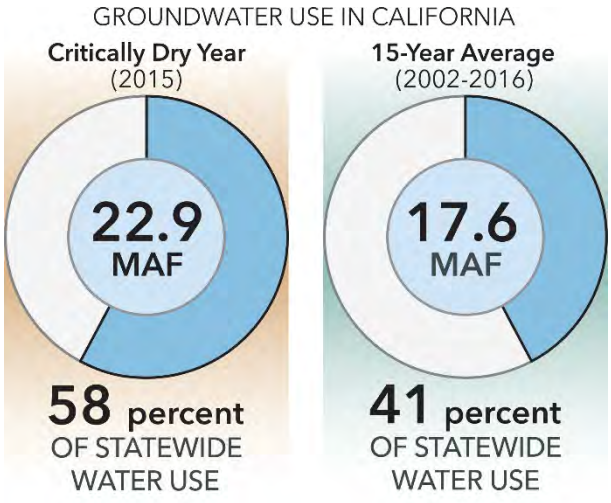
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Executive Summary

Groundwater is a vital resource in California. It sustains our ecosystems, supports our agriculture, fuels our economy, quenches our thirsts, and reduces the impacts of droughts and a changing climate. Groundwater accounts for 41 percent of the state's total annual water supply on an average basis and as much as 58 percent of the total annual water supply in a critically dry year (Figure H-1). About 83 percent of Californians depend on groundwater for some portion of their water supply and many communities are 100 percent reliant on groundwater for all their water needs.

Figure H-1: Total Groundwater Use and Percentage of Statewide Water Supply in a Critically Dry Year ver–sus 15-Year Average



California's Groundwater (CalGW) Update 2020 is the State's comprehensive inventory and analysis of groundwater data and information. It is a continuation of a series of earlier California Department of Water Resources (DWR) publications, known as Bulletin 118, on California's groundwater. It provides a foundation for knowledge supporting statewide groundwater management and planning efforts, including drought planning and response.

CalGW Update 2020 synthesizes the latest groundwater data to empower local water agencies and groundwater practitioners, and inform elected officials, decision-makers, and the public about the protection, use, and sustainable management of groundwater. It is the start of a new platform for tracking statewide groundwater management to advance near-term actions and long-term strategies for improved decision-making, management, education, and access.

CalGW Update 2020 presents findings and recommendations related to the state's groundwater conditions and long-term statewide management of our groundwater resources.

- **Findings**: The current state of groundwater conditions and management in California, serving as guideposts to focus and prioritize future monitoring, data collection, and assistance efforts.
- **Recommendations**: Actions to be implemented by DWR and groundwater sustainability agencies (GSAs) in partnership with other local, State, and federal agencies, non-governmental organizations, Tribal Governments, and other

interested parties to strengthen efforts to better characterize, evaluate, and sustainably manage California's groundwater resources.

The CalGW Update 2020 recommendations are organized into four broad categories.

1. **Advance Data Driven Decision-Making**: Groundwater data and information are critical for improving the understanding of groundwater basins and their hydrogeologic characteristics. The State has strengthened coordination with local entities to increase the collection and reporting of groundwater data. CalGW and the enhanced online content, CalGW Live, will serve as a comprehensive repository of statewide data. Making this data publicly available on the California Natural Resources Agency (CNRA) Open Data platform will improve access and advance data-driven decision-making related to groundwater management and drought planning and response.

2. **Maintain Momentum for Sustainability:** The State's assistance and assessment programs empower local agencies to manage groundwater more diligently and comprehensively. The State will continue to enhance existing planning, technical, and financial assistance as part of statewide groundwater management efforts, so that local agencies, working with their interested parties, can maintain momentum toward their long-term goals of sustainable groundwater management.

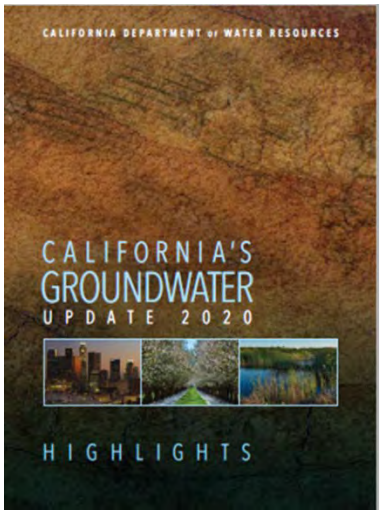
3. **Engage, Communicate, and Educate:** The State will continue to foster engagement, communication, and outreach support to local agencies, Tribes, interested parties, decision-makers, and other State and federal agencies to build collaborative connections. CalGW Update and CalGW Live will continue to provide a platform to educate water managers, decision-makers, and the public about the importance of groundwater.

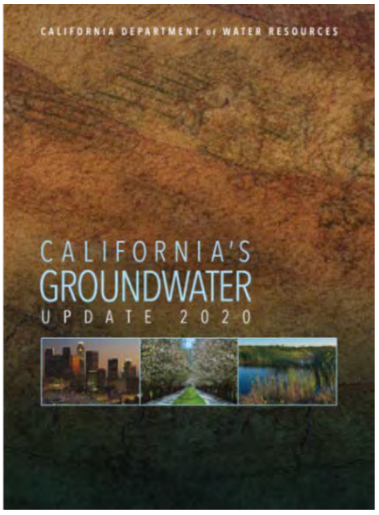
4. **Invest, Innovate, and Incentivize:** Financial and nonfinancial incentives will be needed over the next 20 years and beyond to support the implementation of groundwater projects as well as related surface water projects and management actions across the state that will be used to achieve and maintain sustainable groundwater management.

The recommendations and findings will evolve over time with better monitoring and understanding of groundwater resources and aquifers. Moving forward, CalGW will improve access to essential groundwater data and analyses, track progress toward statewide sustainable groundwater management, and will evolve with time as the public, local agencies, and the State continue to understand and improve the management of water resources.

I. Groundwater in Focus: California's Groundwater

California's Groundwater (CalGW) Update 2020 is the State's most up-to-date compendium of statewide data and information on the occurrence, nature, use, and conditions of California's groundwater resources and its management. It is a continuation of a series of earlier DWR publications, known as Bulletin 118. It builds on the past progress and state of knowledge, synthesizes the most recent data to close the gap in knowledge, and provides a foundation for statewide groundwater management and planning efforts.





CalGW consists of this **Highlights** and a detailed **Statewide Report,** supported by a series of appendices. The purpose of CalGW is to (1) inform local water agencies, groundwater practitioners, statewide elected officials, decision-makers, and the public about the state of California's groundwater, (2) provide an updated inventory and analysis of the statewide conditions, use, and management of groundwater using data through 2018, and (3) identify recommendations charting a path toward a better understanding and sustainable management of groundwater resources in light of our changing climate and variable drought conditions while continuing to support our environment, our agriculture, our economy, and our communities that rely on groundwater. CalGW Update 2020 is accompanied by , a rich online content platform providing a simple, user-friendly interactive experience that allows users to access and explore up-to-date groundwater information. CalGW Update 2020 is a tool that provides insight into regional and statewide drought impacts by presenting groundwater data and analysis that show current conditions and trends. CalGW also presents new data and analysis that were not available prior to the 2012–2016 drought, such as satellite based Interferometric Synthetic Aperture Radar (InSAR) land subsidence data, which enables local agencies to monitor the impacts of drought and increased groundwater use. In addition, it discusses DWR's voluntary dry well database (Household Water Supply Shortage Reporting System), which fills in data gaps that enables the State, working with local agencies, to improve statewide drought response and resiliency. Comprehensive information on drought resources and assistance can be found on DWR's drought webpage.

CalGW Update 2020 also provides enhanced information on groundwater resources in non-basin areas where the majority of domestic wells are located. This information is essential for an improved understanding of the effects of drought outside the state's 515 alluvial groundwater basins. One of the key findings from the 2012–2016 drought in California is that the groundwater in non-basin areas is at higher risk of decreasing groundwater levels and

storage depletions, leading to many wells going dry. The State is advancing strategies to address drinking water well impacts and generating broader awareness of these impacts to be able to continue drought preparedness efforts.

California Water Code Section 12924 requires DWR to update CalGW every five years to report timely information on the conditions of California's groundwater basins, patterns of groundwater extraction and recharge, and the current groundwater basin boundaries and priorities. Future CalGW Updates will continue to report on the status of groundwater across all groundwater basin and non-basin areas, showing progress toward filling data gaps and implementing recommendations. In addition, between five-year updates of CalGW, DWR will continue enhancing the CalGW Live content on an ongoing basis to provide timely access to statewide groundwater information necessary for understanding impacts of droughts and climate change.



II. Statewide Groundwater Management

A. The Framework – Statewide Groundwater Management

The changing climate is affecting water resources in California today and will continue to do so as the state's population and demand for water for urban, agricultural, and environmental purposes increase. Overall, warmer temperatures will continue to melt the snowpack faster and earlier, making it more difficult to store and use surface water during dry periods. By the end of this century, California's Sierra Nevada snowpack is projected to experience a 48 to 65 percent loss from the historical April 1 average (Griggs et al. 2017, Bedsworth et al. 2018). Climate change is also expected to result in more variable weather patterns throughout California, including longer and more severe droughts and floods, occurring more frequently. During drought periods, Californians depend on groundwater to support the many uses and needs in our state because surface water becomes less available. California's 515 groundwater basins offer a natural infrastructure that can store far more water than all of the state's surface reservoirs can, which will become increasingly important for drought planning. Existing groundwater storage capacity can be further used to capture runoff, prevent the loss of snowpack, and more flexibly manage California's changing climate conditions expected in the future.

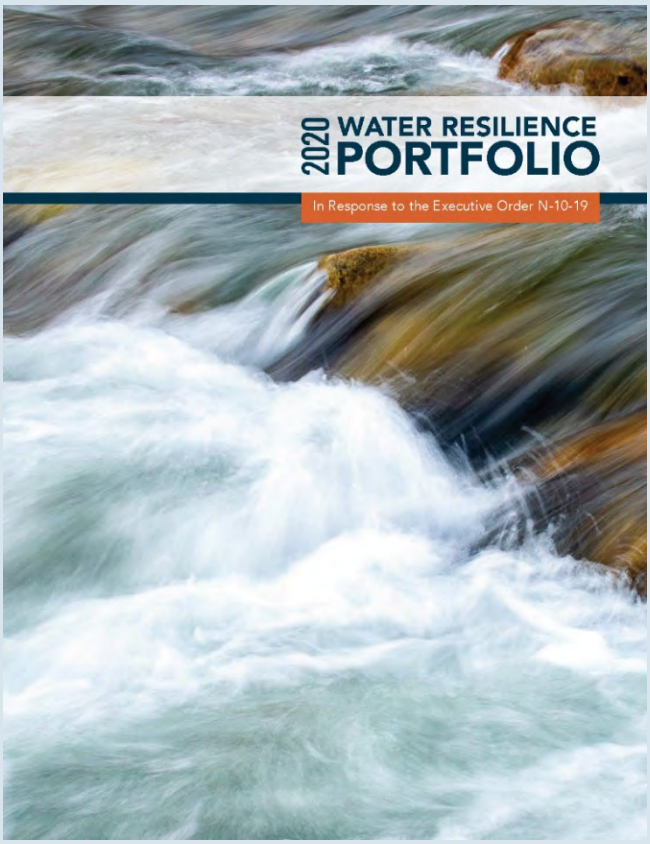
Effective statewide groundwater management is vital to ensuring that the state's future water supply is reliable and resilient. While surface water has been regulated for more than a century, groundwater has not been regulated in California prior to the enactment of SGMA, resulting in overutilization of groundwater in the past. The practice of excessive groundwater use particularly during dry periods has resulted in critically overdrafted conditions in 21 basins that cover about one-fifth of the total groundwater basin area of the state. In 2014, groundwater pumping in these basins accounted for 63 percent of the state's groundwater use. Proactive local, regional, and statewide actions are needed in the near term and must be sustained into the future to prevent further impacts to California's groundwater resources that support the environment, economy, and agriculture.



California's new groundwater regulatory framework under the Sustainable Groundwater Water Management Act (SGMA) provides the foundation for bolstering local management of groundwater resources. Statewide groundwater management includes the State's role of providing statewide data and technical planning support and assistance, ensuring strong alignment with other statewide programs, and continuing to invest in groundwater recharge, infrastructure, and conveyance options to comprehensively manage surface water and groundwater, water quality improvements, drinking water solutions, agricultural efficiencies, and overall ecosystem health. These coordinated State efforts aim to develop alignment at the State level, enhance support for local agencies, and foster inclusivity and engagement, public awareness, and education around groundwater management.

A CLIMATE & WATER RESILIENT FUTURE

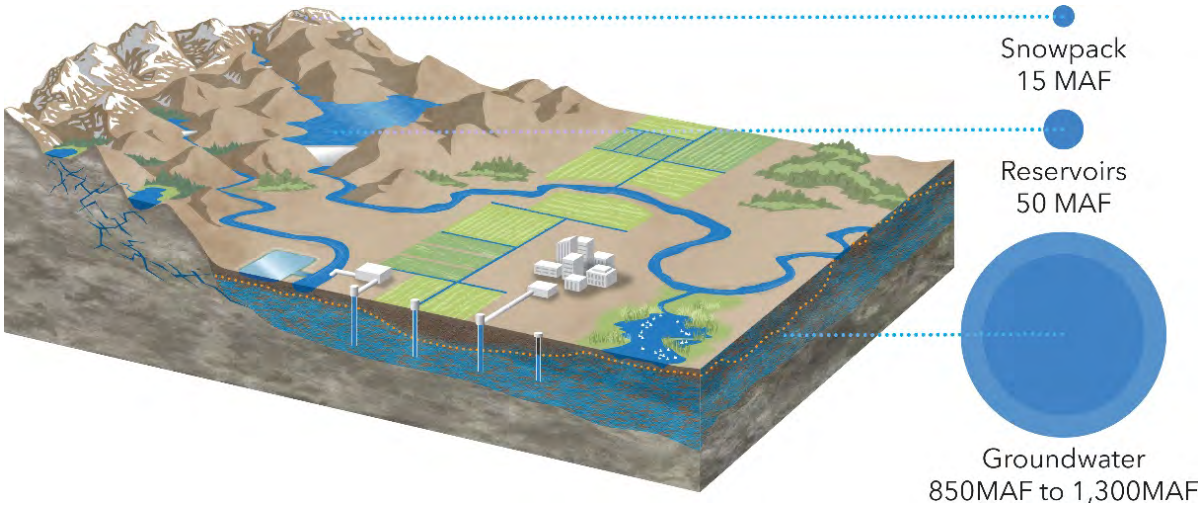
Governor Newsom signed an executive order on April 29, 2019, directing the California Natural Resources Agency, California Environmental Protection Agency, and California Department of Food and Agriculture to develop a comprehensive strategy to build a climate resilient water system and ensure healthy waterways through the 21st century. These agencies solicited extensive public input to prepare the Water Resilience Portfolio, released by the governor on July 28, 2020. The Water Resilience Portfolio includes 142 actions that encourage harnessing the best science, engineering, and innovation to support long-term water resilience and improve California's capacity to prepare for disruptions, withstand and recover from climate-related shocks, and adapt into the future. Groundwater is featured prominently in the Water Resilience Portfolio, which directs State agencies to help regions secure groundwater supplies by supporting the transition to sustainable use and identifies a set of groundwater-related actions to be carried out by various State entities.



Coordinated local, regional, and statewide groundwater management will allow for the management of the entire water cycle and will help secure water reliability and resiliency.

Support for healthy, stable groundwater aquifers, watersheds, and ecosystems: The total storage capacity of California's 515 groundwater basins has been estimated to be between 850 million acre-feet (maf) and 1,300 maf (California Department of Water Resources 1975). After taking into account that less than half the groundwater is available for use because it is either too deep to be pumped economically or of poor quality, the state's usable groundwater storage is approximately 8 to 12 times larger than the combined storage capacity (50 million acre-feet) of all major reservoirs in California (Figure H-2) The available storage capacity in groundwater basins can be utilized to store wet-period surface water supplies. The ability to move surface water to groundwater aquifers offers an opportunity to better manage water resources, increase water supply reliability and resiliency, and support natural ecosystems, including watersheds, wetland habitats and streamflows. Investing in replenishing groundwater will also improve the ability to manage droughts when the lack of precipitation and available surface water supplies creates a greater reliance on groundwater.

Figure H-2: Relative Storage Volumes in Snowpack, Reservoirs, and Groundwater Aquifers



Build resilient water management systems through informed statewide groundwater management planning: With statewide sustainable groundwater management efforts in an early stage, local and State agencies are gaining better knowledge and a deeper understanding of hydrogeologic characteristics and conditions of our groundwater basins through increased monitoring, analysis, and implementation of management actions. As more information and data become available and management activities mature, DWR will be enhancing existing CalGW online content to organize and improve access to the most up-to-date statewide groundwater information, which will help water managers to adaptively manage aquifers as part of a more resilient water management system.

Sustain communities with reliable drinking water supply: Both surface water and groundwater support the state's drinking water supply. According to a 2019 State Water Resources Control Board (State Water Board) study, there are 7,403 public water systems in California and approximately 85 percent of public water systems, serving roughly 20 percent of the state's population, rely on groundwater as their primary water supply (California State Water Resources Control Board 2019). Many small water systems provide drinking water supplies throughout California's rural communities. During the recent 2012–2016 drought, an estimated 3,500 domestic wells in the San Joaquin Valley, and hundreds more in the rest of the state, went dry leaving households and communities without water (Chappelle et al. 2017). Enhanced data reporting from groundwater basins and non-basin areas, through CalGW and CalGW Live, will help facilitate improved coordination among counties, local water agencies, and the State to track dry wells, manage drought risks, and better sustain communities.

Support California's strong agricultural industry and economy: Agriculture is a significant sector of California's economy, generating nearly $50 billion in revenue in 2018 (California Department of Food and Agriculture 2019) and employing more than 820,000 people (Martin et al. 2016). California agriculture irrigates more than 9 million acres using approximately 33 million acre-feet of water, of which approximately 14 million acre-feet (about 41 percent) comes from groundwater on average (California Department of Water Resources 2019). Approximately 80 percent of the total groundwater used in the state is for agricultural purposes, but that number changes substantially from a low of 8 million acre-feet in 2005, to a high of 20 million acre-feet in 2015, depending on surface water availability. Improved estimates of agricultural water use and basin water budget information will help water managers develop a more comprehensive understanding of local and regional water availability and demands and allow for coordinated land use and water use planning.

Foster inclusive engagement, public awareness, and education around the significance of groundwater management: California is the last western state to institute a comprehensive regulatory framework for managing groundwater. With statewide sustainable groundwater management at such an early stage in California, state and local agencies must foster inclusive engagement with all users of groundwater to broaden public awareness and education around the important role groundwater plays in California's water supply future, both during drought periods and wet years.

Support California's drought management planning, and response: California is experiencing a greater frequency of droughts and a changing climate. After the severe drought conditions from 2012 through 2016, California is facing another drought cycle. During droughts, less surface water is available which leads to an increased reliance on and use of groundwater. With less precipitation and snowpack, groundwater recharge during droughts is reduced. Improved data and information on groundwater resources in basin areas and non-basin areas will help decision-makers continue and enhance long-term statewide proactive drought response strategies consistent with the State's water resilience and sustainability goals.

Key Groundwater Related Drought Actions & Response:

Governor Newsom and the Legislature have recently approved $5.1 billion for immediate drought response and long-term water resilience investments to address emergency needs and build regional capacity to endure future droughts and safeguard water supplies for communities, the economy, and the environment.

Governor Newsom has also issued several drought emergency proclamations that direct DWR and other agencies to actively respond to the current drought and continue preparing for future droughts. These proclamations include the following groundwater related orders for which DWR is the lead implementing agency:

- Work with counties to encourage reporting of household water shortages, such as dry residential wells, on the website that DWR maintains for that purpose, to enable tracking of drought impacts.

- Work with counties, and GSAs as appropriate, to help ensure that well drillers submit required groundwater well logs for newly constructed and deepened wells in a timely manner.

- Accelerate updating the land subsidence data DWR is providing to support implementation of SGMA.

- To ensure the potential impacts of drought on communities are anticipated and proactively addressed, DWR, in coordination with the State Water Board, shall develop groundwater management principles and strategies to monitor, analyze, and minimize impacts to drinking water wells.



B. The Foundation – Sustainable Groundwater Management Act

The Sustainable Groundwater Management Act (SGMA) was signed into law in 2014 during the middle of California's most recent five-year drought from 2012 to 2016. SGMA fundamentally changed the course of California's water history by creating a regulatory framework for groundwater including the "…management and use of groundwater in a manner that can be maintained during the (50 year) planning and implementation horizon without causing undesirable results." SGMA is the culmination of several State plans and legislative actions over the last decades (Figure H-3).

SGMA now serves as the foundation and catalyst for advancing statewide groundwater management, which advances both near-term drought strategies and long-term groundwater planning efforts. The six undesirable results (Figure H-4) identified in SGMA serve as performance metrics to track progress toward achieving groundwater sustainability.

Figure H-3: Timeline of Groundwater Legislation

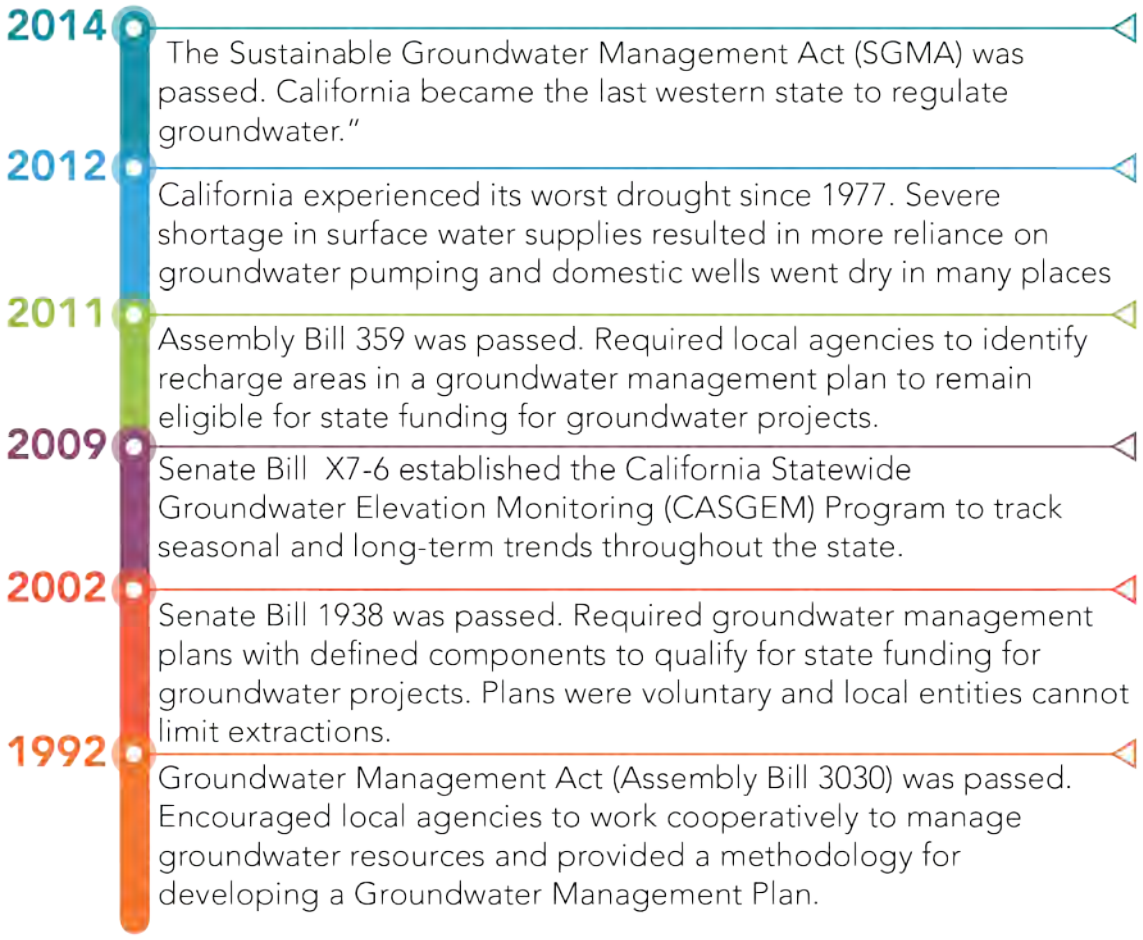


Figure H-4 : Six Undesirable Results of SGMA



chronic lowering of groundwater elevations;

significant and unreasonable reduction in groundwater storage;

significant and unreasonable seawater intrusion;

significant and unreasonable degradation of water quality;

significant and unreasonable land subsidence that substantially interferes with surface land uses; and

depletion of interconnected surface water with adverse effects on beneficial uses of surface water.

SGMA and State's Role: SGMA is founded on the premise that groundwater is best managed at the local level. DWR serves in two roles under SGMA to support local agencies to enable sustainable groundwater management: (1) a regulatory role, which includes development and implementation of the regulations governing basin boundaries and groundwater sustainability plan development and evaluation, annual progress reports, and five-year updates; and (2) an assistance role, which includes providing technical information and models, planning tools, and data, facilitation and outreach support, and financial support to local agencies. SGMA also gave regulatory and intervention power to the State Water Board as the enforcement agency if local efforts are inadequate or if they are not able to sustainably manage groundwater use in their basin through a process called "State intervention."

Groundwater Sustainability Agencies: SGMA established a new governance structure for managing California's groundwater resources at the local level by authorizing the establishment of local public agencies, called groundwater sustainability agencies (GSAs). Specific high- and medium-priority groundwater basins, were required to form GSAs by June 30, 2017, to empower local management of groundwater resources. Within this statutory deadline, 260 GSAs were formed in 143 groundwater basins to manage groundwater resources — a resounding success in the early years of SGMA. The formation of GSAs in low- and very-low-priority basins is encouraged, though not required under SGMA.

Groundwater Sustainability Plans: SGMA gave local agencies the tools and authority to develop and implement groundwater sustainability plans (GSPs) to bring groundwater basins

into balance of supply and demand through the understanding of basin conditions, establishing of sustainable management criteria, and implementing projects and management actions. SGMA requires the high- and medium-priority basins submit GSPs to DWR and provide updates every five years to determine if the plans and implementation are likely to achieve the sustainability goal for the basin. Critically overdrafted basins were required to adopt and submit GSPs by January 31, 2020 and achieve groundwater sustainability by 2040. The remaining high- and medium-priority basins are required to adopt GSPs by January 31, 2022 and achieve groundwater sustainability by 2042. Other than annual reporting, SGMA does not apply to existing adjudicated areas because they have existing court-mandated governance, oversight, and management in place. Local agencies in low- or very-low-priority basins, while not required to form GSAs and develop GSPs, may do so voluntarily. They may also develop groundwater management plans to actively manage their groundwater resources.

SGMA and Drought: Groundwater basins serve as the state's most dependable water source during drought periods when we have less rain and snowmelt. However, for decades, more water has been pumped out of many groundwater basins than has been replenished. With the enactment of SGMA, the State set forth a statewide regulatory framework for achieving sustainable groundwater management in 20 years and thereby safeguard groundwater, through local management, as a reliable resource for future droughts and long-term use. Since groundwater is an available resource and relied on more when surface water supplies are low, SGMA does acknowledge that additional pumping during times of drought is needed. However, SGMA also requires locals to implement projects and balance groundwater use over the 20-year timeframe to reach a sustainable condition.

With the goal of sustainability, SGMA also provided an approach for tracking conditions in the near-term by requiring GSAs to submit annual reports and information to show measurable progress in meeting their groundwater basin goals, which will inform management decisions, especially during drought periods but also in average and wet years. GSAs are developing projects and actions that will both reduce the reliance of groundwater and replenish groundwater basins during average and wet years when there is excess surface water available. These longer-term actions under SGMA will help make California's groundwater resources more resilient to future droughts and sustainable for future generations.

III. The State of Groundwater in California

California's groundwater occurs in a variety of geologic settings across the state, within basin and non-basin areas. The state's 515 defined groundwater basins provide approximately 94 percent of the total groundwater used in the state, while the non-basin areas provide the remaining 6 percent. CalGW **Highlights** (this document) summarizes the State's groundwater conditions and management, while the CalGW **Statewide Report** provides detailed information on the statewide and regional groundwater conditions and management activities, including the distinct conditions in non-basin areas and California's 10 hydrologic regions (Figure H-5).

The current state of groundwater conditions and management in California is briefly described below along with the key findings which will serve as guideposts to focus and prioritize future monitoring, data collection, and assistance efforts.

Figure H-5 : Hydrologic Regions, Basin, and Non-Basin Areas



A. Groundwater Occurrence

1. Groundwater Basins

The concept of a groundwater basin was first introduced around the turn of the 20th century as California's population and agricultural industry were rapidly expanding and becoming more reliant on groundwater. In the state's groundwater basin areas, groundwater occurs in aquifers or stacked series of aquifers comprised of porous and permeable sediment and can yield significant quantities of groundwater to wells and springs (Figure H-6). Over the next half-century, the understanding of, and reliance on, groundwater basins in California grew, which led to the release of the first official list of groundwater basins in 1952 (California Department of Public Works 1952). Since then, DWR, working with other local, State, and federal agencies, has periodically updated the definitions, boundaries, and locations of California's groundwater basins in various updates of CalGW (Figure H-7). A promising new geophysical technology, airborne electromagnetic (AEM) surveying, is being deployed to help improve the understanding of the hydrogeologic characteristics of the state's groundwater basins. A few pilot studies have recently been completed and full-scale implementation of AEM surveys in the high- and medium-priority basins are planned in the coming years.

What is a groundwater basin?

A groundwater basin is an ". . . aquifer or stacked series of aquifers with reasonably well-defined boundaries in a lateral direction, based on features that significantly impede groundwater flow, and a definable bottom . . ." - Title 23, Division 2, Chapter 1.5, Subchapter 1, Article 2, Section 341(g)(1) of the California Code of Regulations.

Figure H-6: Groundwater Basin and Aquifers

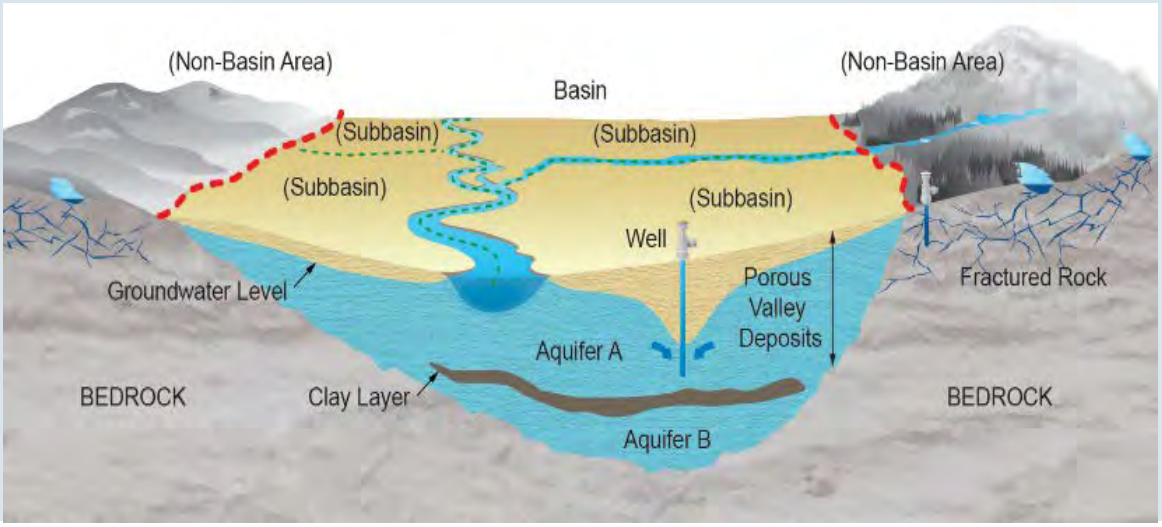
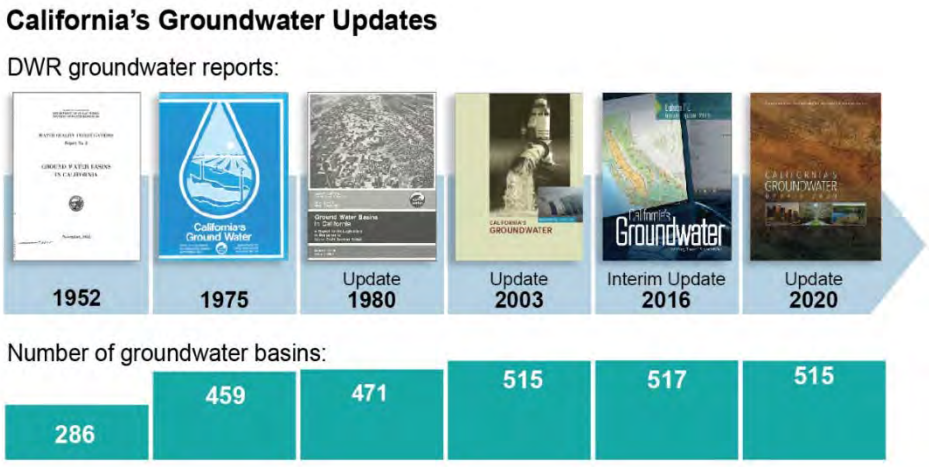


Figure H-7: Evolution of Groundwater Basin Delineation



Key findings regarding the groundwater basins are:

- Currently, there are 515 groundwater basins identified in California, which encompass almost 40 million acres, or more than 40 percent of the California's total land area.
- Approximately 82 percent of the state's population, and 97 percent of the State's agricultural lands, are in these groundwater basins.

Basin Boundaries: Past CalGW documents have provided information on the state's groundwater basins and included modifications to basin boundaries in response to improved knowledge of local conditions gained through additional data collection or special studies. With the passage of SGMA in 2014, Section 10722.2 was added to the California Water Code. It directed DWR to establish regulations to allow local agencies, or an entity directed by the court in a groundwater adjudication, to request that DWR revise the boundaries of a basin.

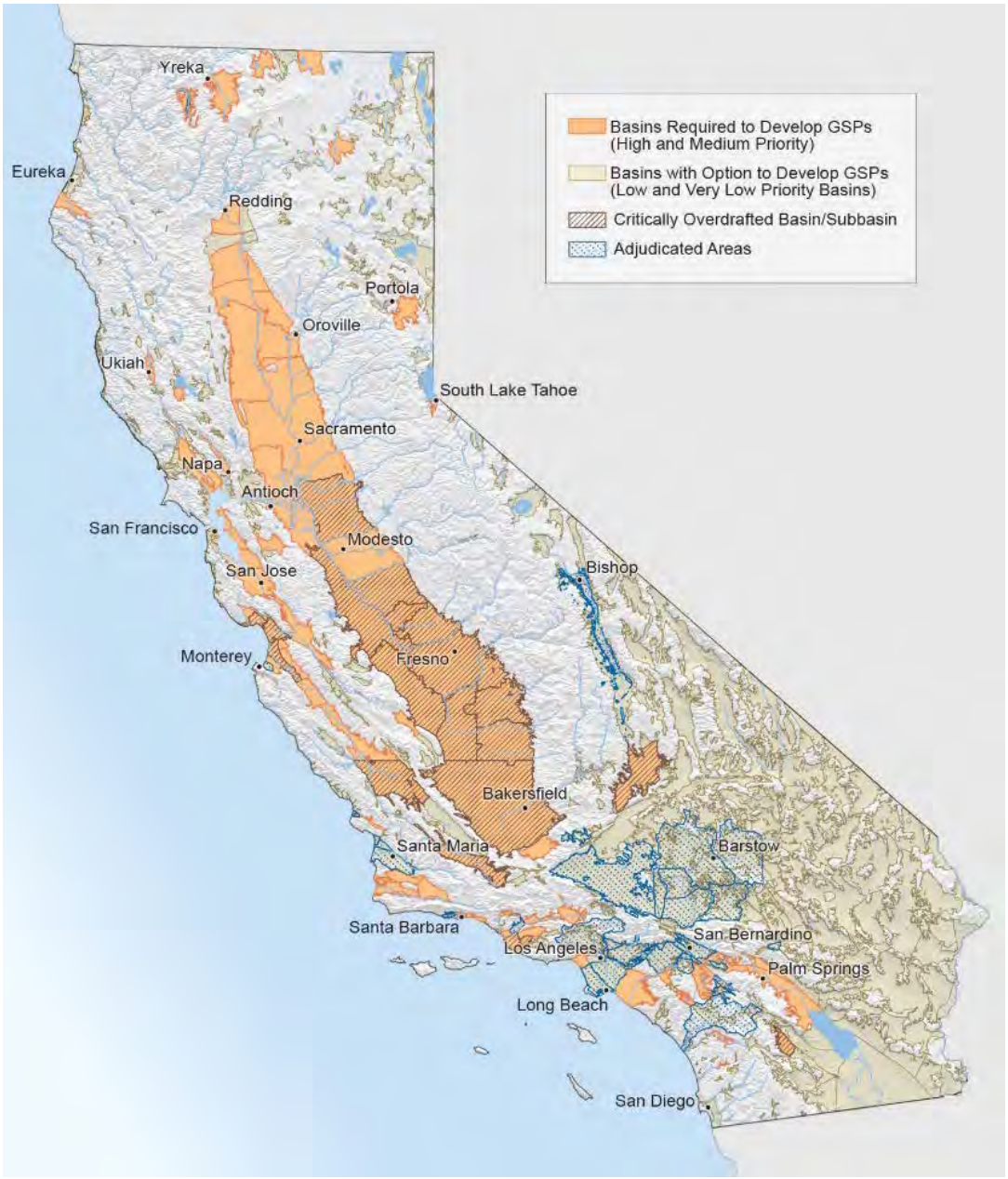
Key findings regarding the basin boundary regulations are:

- Basin boundary regulations were adopted on October 21, 2015, and the provisions of the regulations became effective November 16, 2015.
- Since the adoption of these regulations, there have been two rounds of local-agency-requested basin boundary modifications, in 2016 and 2018, that resulted in the approval of 78 basin boundary modification requests. SGMA requires DWR to reassess basin prioritization any time basin boundaries are modified.
- Of the 78 basin boundary modifications, 40 were based on jurisdictional information, 27 based on scientific information, and 11 were a combination of both.

Basin Prioritization: As required in SGMA, California's 515 groundwater basins are prioritized into one of the four categories: high, medium, low, or very low priority. Basin

prioritization is a technical process that utilizes the best available data and information and considers several factors (e.g., current, and projected population, number of wells, irrigated acreage, amount of groundwater used, degree of reliance on groundwater, and documented adverse impacts) to assign a priority. Ninety-four basins and sub-basins were identified as medium or high priority through the basin prioritization technical process; these basins are required to form GSAs and develop GSPs in compliance with SGMA. The low- and very-low-priority basins are encouraged to form GSAs and develop GSPs, update existing groundwater management plans, or coordinate with others to develop a new groundwater management plan in accordance with Water Code Section 10750 et seq. (Figure H-8).

Figure H-8: Basin Priorities and GSP Requirements



Currently, there are 30 adjudicated areas, mostly in Southern California, that are not subject to SGMA compliance requirements other than annual reporting; because, they already have existing court-mandated governance and oversight in place. Key findings regarding the prioritized groundwater basins are:

- The 94 high- and medium- priority basins and adjudicated areas account for 98 percent of the groundwater pumping (20 million acre-feet), 83 percent of the population (25 million Californians), and 88 percent of all irrigated acres (6.7 million acres) within the state's 515 groundwater basins.
- Of the 94 high- and medium-priority basins, 20 basins are classified as basins subject to critical conditions of overdraft. One adjudicated basin is also identified as a basin subject to critical conditions of overdraft.
- The 21 basins that are subject to critical conditions of overdraft cover almost one-fifth of the total groundwater basins area in the state and account for close to two-thirds of total groundwater pumping in the state in a typical year.

2. Groundwater in Non-basin Areas

California's non-basin areas are defined as any area outside of a defined groundwater basin or subbasin and it consists of impermeable granitic, metamorphic, volcanic, or consolidated rocks (carbonates), with groundwater stored within fractures or other voids. The connectivity of these fractured rock systems is often limited and difficult to predict and characterize. These areas are typically found in the mountains and foothills upgradient of, or adjacent to, groundwater basins and include many of California's national parks, forests, and other wildland areas, the importance of which is acknowledged in the Water Resilience Portfolio. Forests are identified as an asset to help California water systems adapt to climate change in more beneficial and durable ways than human engineering. Upper watersheds in general were identified as natural assets that are viable locations for multi-benefit water projects and large-scale habitat restoration efforts that can build community and economic resilience. The enhanced characterization of the non-basin areas is explained in greater detail in the statewide report. Additional data will continue to be compiled and reported as it becomes available.

Key findings regarding California's non basin areas are:

- Approximately 60 percent (62 million acres) of California's total land area is in non-basin areas. The majority (53 percent) of domestic wells in California are in these areas and groundwater extraction in non-basin areas accounted for about 6 percent (1.3 million acre-feet) of the state's total groundwater extraction in 2014.
- Approximately 6.8 million people, 18 percent of the state's population, live in non-basin areas and account for approximately 60 percent of California's disadvantaged and severely disadvantaged communities (U. S. Census Bureau 2017).

- Many residents in the non-basin areas rely on private groundwater wells as their primary source of water. In non-basin areas 90 percent of wells are domestic wells, making the non-basin area residents more susceptible to drinking water shortage during dry periods. Among the small water suppliers and self-supplied communities in the state that are at a high risk of drought and water shortage vulnerability, 68 percent are in non-basin areas.
- California has approximately 30 million acres of managed national parks, forests, and other wildland areas, 88 percent of which are in non-basin areas.

B. Groundwater Use

Groundwater is a vital part of California's water portfolio because it provides more than 40 percent of the state's total water supply during average years and nearly 60 percent in dry years (Figure H-9). The distribution of groundwater use across the state's 10 hydrologic regions is highly variable (Figure H-10). Groundwater provides as little as 6 percent of the Colorado River Hydrologic Region's water supply and as much as 90 percent of the Central Coast Hydrologic Region's water supply.

Figure H-9: Groundwater Use as Percentage of Total Water Use

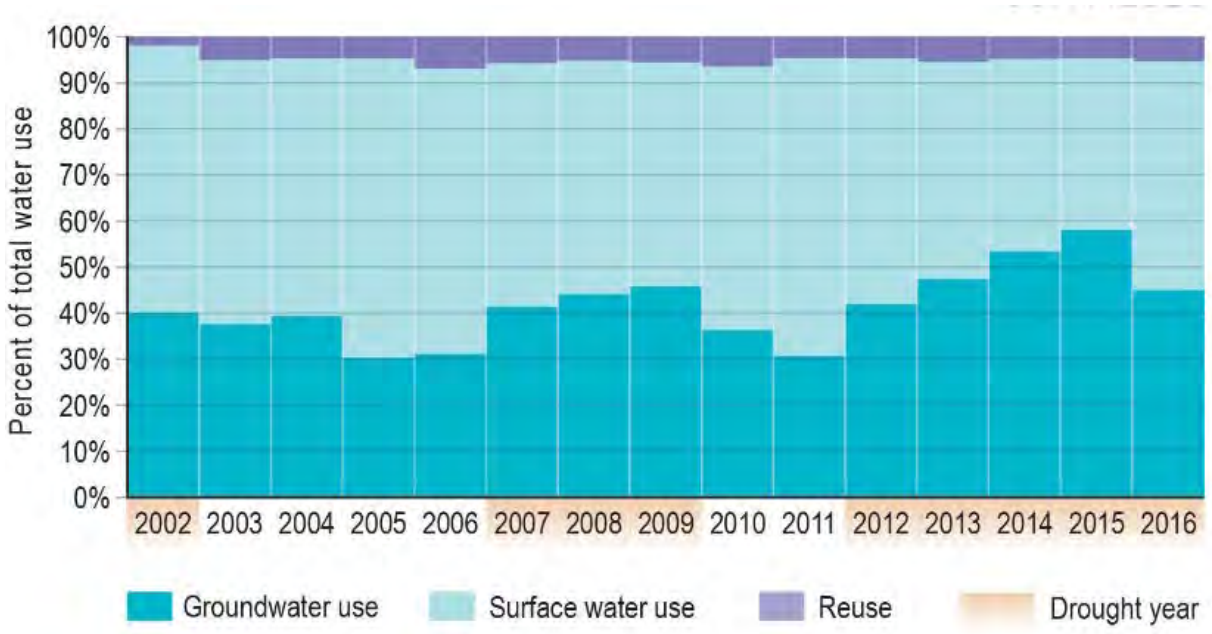
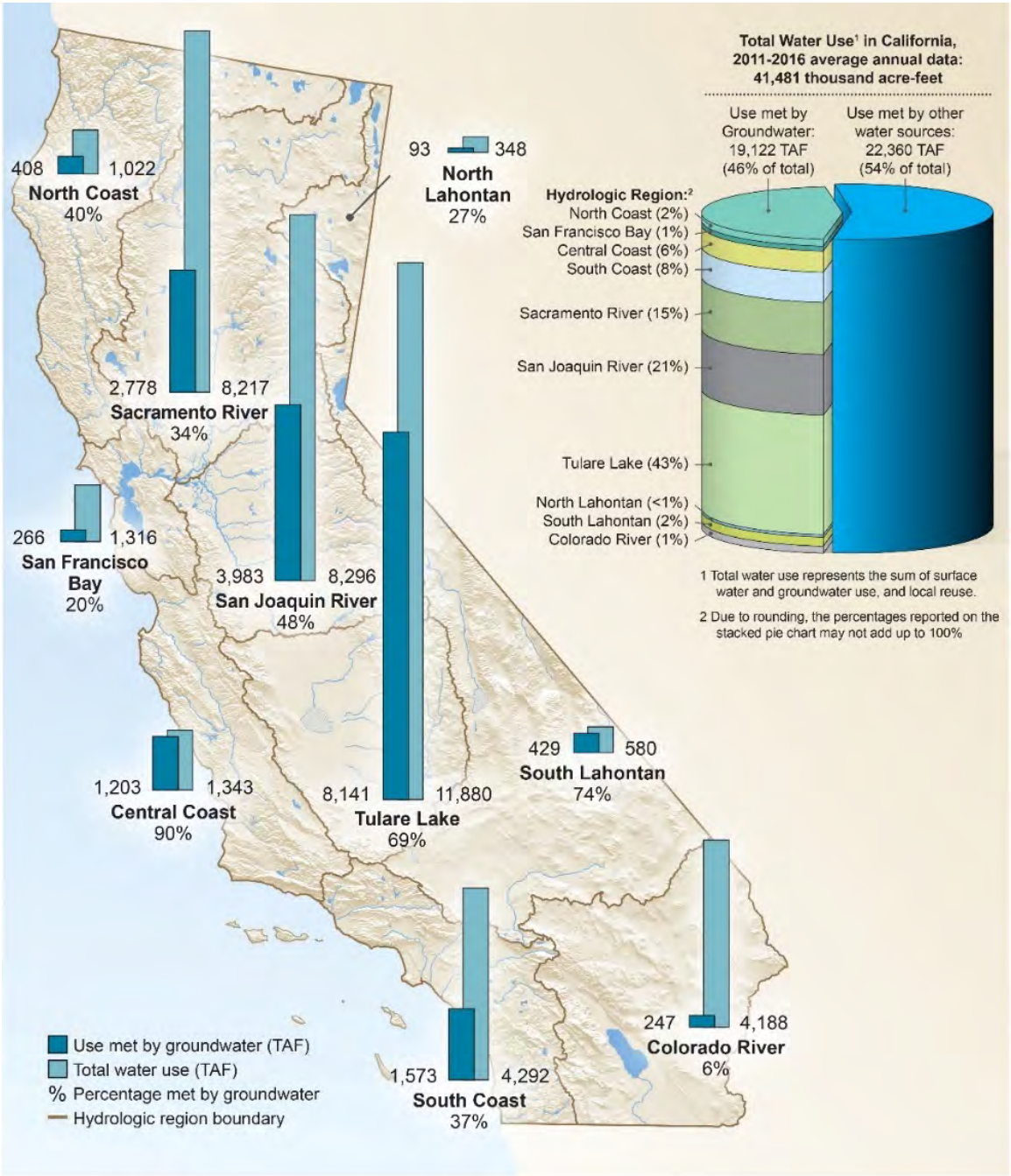


Figure H-10: Water Use by Hydrologic Region



Key findings related to groundwater use in California are:

- Approximately 33 million Californians (82 percent of the state's population) use groundwater for drinking water or other household uses.
- Approximately six million Californians, mostly in small- to moderate-sized towns and cities, are entirely dependent on groundwater for drinking water supplies.

- On average, 79 percent of the total groundwater use in the state each year is used for agricultural purposes, 19 percent for urban, and 2 percent for managed wetlands.
- Groundwater acts as a drought buffer and climate change adaptation strategy for California. It provided 58 percent of the total water supply in 2015 at the height of the 2012–2016 drought, whereas the 2002–2016 average contribution from groundwater to the total water supply was 42 percent.
- Groundwater use data by sector is not available at groundwater basin scale limiting the ability to effectively manage the state's groundwater basins. SGMA annual reporting will provide this important water use data from more than 130 basins that account for almost all (98 percent in 2014) of the groundwater use in the basins.
- Groundwater supports ecosystems and perennial streams and provides substantial supplies to the state's wetlands. During the 2011–2016 period, in the Tulare Lake Hydrologic Region, groundwater provided an average of 47 percent of the total managed wetlands water supply for the region.
- There is a lack of accurate measurement of groundwater use in the state. In many basins, groundwater extraction is not measured by using meters; rather, it is indirectly estimated by using crop evapotranspiration demands, acreage of each crop type, and known surface water deliveries. As a result, there is uncertainty in the total groundwater use across the state.
- Groundwater's contribution to California's water supply is not universally understood by all communities who use and benefit from it; this highlights the need for educational materials and informational workshops on groundwater in multiple languages to reach the state's diverse population.

C. Groundwater Management

The state's increasing population and expanding agricultural industry in the 20th century brought greater water demands and increased use of groundwater to meet the demand. In response to the growing reliance on groundwater and associated impacts, the use of groundwater adjudications as a management tool began in the 1920s. The need for more formal and coordinated groundwater management became apparent beginning in the 1940s with rapidly declining groundwater levels concomitant with land subsidence. The late 1970s through 1990s saw water markets launch and grow in California, largely driven by the need to move water from one region to another during multi-year droughts. In the 1990s, the California State Legislature began taking active interests in protecting this precious resource. Lawmakers enacted legislation and provided financial assistance to local agencies to encourage voluntary groundwater management.

In 2014, the Legislature enacted the Sustainable Groundwater Management Act (SGMA) during the middle of a five-year drought in California. SGMA is the culmination of two-and-a-half decades of State-provided guidance and financial assistance on groundwater

management by local agencies on a voluntary basis. The enactment of SGMA made California the last western state to regulate groundwater.

SGMA is built on the premise that groundwater is best managed at the local level. But SGMA recognizes the legacy and necessity of State's support to local agencies for successful groundwater management because the complexities of groundwater management require the reliance on advanced management tools (data, models, and decision support tools), where the State can play a major and effective role. As a result, SGMA directs DWR to provide planning, financial, and technical assistance to locals, in addition to DWR's regulatory role and State Water Board's intervention role in the implementation of the SGMA. Several federal agencies also supply studies, data, and funding to support local agencies in developing and implementing groundwater management plans and projects.

The discussion on the current state of groundwater management below is organized into three subsections:

1. Local groundwater management efforts: Provides a summary of the progress made by the local agencies as they began implementation of the SGMA.
2. DWR's local assistance: Provides a summary of the local assistance activities.
3. Emerging water markets and water transfers: Provides a summary of how water markets and water transfers are emerging as an effective tool for achieving sustainability.

1. Local Groundwater Management Efforts

Local agencies in high- and medium-priority basins have stepped up their efforts for groundwater management under SGMA. GSPs or alternatives to GSPs have been submitted in many basins, including all 20 basins subject to critical conditions of overdraft. Local agencies in other high- and medium-priority basins are in the process of preparing GSPs (Figure H-11). There are ongoing efforts to encourage and support the work in low- and very-low-priority basins, as well as non-basin areas, to improve groundwater management to achieve sustainability. SGMA addresses groundwater management in 515 groundwater basins that provided 94 percent of state's total groundwater use in 2014; but there is localized groundwater use outside of these basins that would benefit from improved groundwater management. Although SGMA authority under the Water Code is available to local groundwater managers in low- and very-low-priority basins, few incentives exist for them to implement SGMA, and many are lacking in financial resources and technical capacities to plan for and implement sustainable groundwater management. In addition, there is a need for greater attention, engagement, and groundwater data collection across the state for underrepresented communities, which include disadvantaged communities, severely disadvantaged communities, economically distressed areas, Tribal lands/Tribes, environmentally disadvantaged communities, and fringe communities (California Department of Water Resources 2019).

Highlights

Key findings related to the current state of groundwater management are:

- There are 260 GSAs that have been formed in 143 groundwater basins that include all 94 high- and medium-priority basins where SGMA compliance is mandatory.
- As of January 31, 2020, 46 GSPs were submitted and are being implemented in 21 groundwater basins. Local agencies in nine basins submitted and began implementing alternatives to groundwater sustainability plans.
- Of the 21 basins that are subject to critical conditions of overdraft, 18 basins are included in the 46 GSPs submitted to DWR; one basin has an approved alternatives to GSP; one basin has an alternative to GSP which is still under review; and one basin is adjudicated and is not required to submit a GSP.
- Substantial effort continues toward the development of GSPs for the remaining high- and medium-priority basins, which are due by January 31, 2022 (GSPs are due by 2024 in three basins, where priority was changed in 2018).
- There have been 30 adjudications that cover portions of 42 groundwater basins where existing governance and management is occurring.
- Of the 421 low- and very-low-priority basins, 45 are managed under groundwater management plans that were developed before SGMA was enacted. These 45 basins as well as all other low and very low-priority basins have the option to develop GSAs and GSPs.
- Groundwater dependent ecosystems and interconnected surface water are management topics in need of greater attention, engagement, and data collection across the state.
- Many basins where GSPs are being developed have other formal water resource management plans, such as urban water management plans, agricultural water management plans, and integrated regional water management plans in effect. These efforts present opportunities for collaboration for mutual benefit, knowledge sharing, and efficient use of resources.

Figure H-11 : Statewide Groundwater Sustainability Plans



Key Data, Tools, and Guidance Documents Developed by DWR to Support SGMA Implementation

- SGMA Portal: to submit, modify, and view required SGMA information.
- Web applications: SGMA Data Viewer, Land Use Viewer, Natural Communities Commonly Associated with Groundwater, Water Transfer Information Management System.
- C2VSim: California Central Valley Simulation Model, a comprehensive integrated groundwater surface water model for the Central Valley of California.
- IWFM: Integrated Water Flow Model, a robust modeling platform for developing a numerical model in any groundwater basin.
- Six best management practices (BMP) documents on various related topics in support of sustainable groundwater management.
- Guidance documents on climate change, interested parties' engagement, Tribal engagement, and GSP preparation.
- Draft Handbook for Water Budget Development – With or Without Models.

(California Department of Water Resources 2020)

2. DWR's Local Assistance

DWR's roles and responsibilities under SGMA include a suite of planning, financial, and technical assistance services for GSAs and other interested parties. Planning assistance services include facilitation and written translation for GSAs and interested parties participating in sustainable groundwater management. DWR also provides local assistance through regular outreach, engagement, and communication with GSAs and interested parties. During this 2020-21 drought, Governor Newsom and the legislature have recently invested $5.1 billion over the next four years for drought support, water supply and natural habitat restoration projects around the state to build climate resilience in the face of more extreme cycles of wet and dry.

Prior to the most recent funding, DWR administered multiple State grant programs to provide financial assistance to local agencies on groundwater projects. Technical assistance provided by DWR includes a Technical Support Services (TSS) program to provide education, data, and tools to GSAs to build the capacity needed to achieve sustainability. DWR also developed an assortment of tools to facilitate access and transparency and allow local agencies, GSAs, and watermasters to submit, modify, and view the information required by SGMA.

Key findings related to DWR's local assistance are:

- Since 2010, DWR has provided $342.3 million in grants for groundwater projects, including $6.7 million to stressed basins, $132.8 million for planning and $202.8 million for implementation.

- DWR installed 78 monitoring wells and funded 75 facilitation support efforts to support local agencies.
- The financial support provided by DWR is far less than the total anticipated cost of approximately $6 billion for the projects and management actions identified in the 46 GSPs submitted as of January 31, 2020. The State's continued support in grant funding for GSAs is needed to supplement the local funding for the implementation of the projects and management actions included in the GSPs.
- Limited resources affect how underrepresented communities are able to participate in SGMA planning and implementation processes.
- Limited availability of educational and informational materials on the value and need for protection of groundwater affects the public understanding of and support for sustainable groundwater management.
- The establishment of consistent data sharing protocols for local, State, and federal agencies, who collect and manage groundwater data, are in the early stages of development and needs to be aligned with the Open and Transparent Water Data Act (Assembly Bill 1755).
- State and local agencies need assistance in capacity building to support development and use of technical tools that are necessary to evaluate long-term impacts of projects and management actions under climate change as well as track progress toward meeting sustainability goals.

3. Emerging Water Markets and Water Transfers

Water markets in California have come to the forefront of policy and management discussions as State and local agencies work to implement SGMA, address drought shortages and build a more resilient water supply future. Water markets are locally driven programs where the sustainable groundwater yield cannot meet existing demands. Water transfers and trades have been utilized for many decades. Transfers and trades can be an effective management tool to address water supply shortages particularly during droughts through conjunctive use of surface water and groundwater and provide much needed flexibility in the allocation and use of water in California. The Water Resilience Portfolio identified actions to advance the development of water markets; most of which follow a common thread of regulatory and policy reform and improved access to accurate data recognizing that a totally unregulated market could have negative consequences. The Water Resilience Portfolio directs State agencies to facilitate emergence and proliferation of water markets and water transfers by streamlining regulations and approval processes. The California Water Commission is advancing this action by creating a public forum for discussions among the water community to identify what safeguards are needed in markets to support the involvement of disadvantaged communities, small farmers, and the environment in the development of markets within groundwater basins. DWR and the State Water Board are supporting the California Water Data Consortium and the Environmental Defense Fund to explore the

creation of a statewide water accounting platform for greater efficiency and understanding of groundwater use and trading in basins.

Key findings related to water markets and water transfers are:

- Of the 46 GSPs submitted to DWR, 20 include groundwater market activities as a strategy or management actions to achieve sustainability.
- Statewide, approximately 1maf to 1.5 maf of water is traded annually, with more than 40 percent occurring within the same county (Hanak et al. 2019).
- From 2008 to 2018, water transfers reported in DWR's Water Transfer Information Management System included approximately 400 thousand acre-feet (taf) as crop idling, about 243 taf as groundwater substitution, and approximately 106 taf as reservoir releases. This data represents only the portion of statewide water transfer volumes that require use of a DWR facility.
- Access to, and success of, water markets is critically dependent on making relevant information more readily available and accessible.
- Most water trading in California does not occur in a centralized marketplace; federal and State agencies coordinate and permit water transfers in an ad hoc market. There are no statewide trading platforms or other venues for tracking availability, value, or sales of water, or for connecting willing buyers and sellers.
- Local agencies find administrative burdens of the water transfer process, including the time it takes for the approval process, limit their ability to trade water and explore potential opportunities for beneficial cross-Delta transfers.
- Additional constraints to effective water transfers are infrastructure challenges, water rights, and streamlined coordination of State, federal, and local agencies.

D. Groundwater Monitoring and Conditions

As many as two million water wells tap California's groundwater, with approximately 7,000 to 15,000 new wells constructed each year. They range from hand-dug, shallow wells to carefully designed large-production wells drilled to great depths. An understanding of groundwater conditions, locally as well as regionally, is key to effective groundwater management. Groundwater data, such as trends of groundwater elevations, changes in groundwater storage, groundwater quality, land subsidence, seawater intrusion, and stream depletion can be used to understand groundwater conditions.

1. Groundwater Level and Quality Monitoring

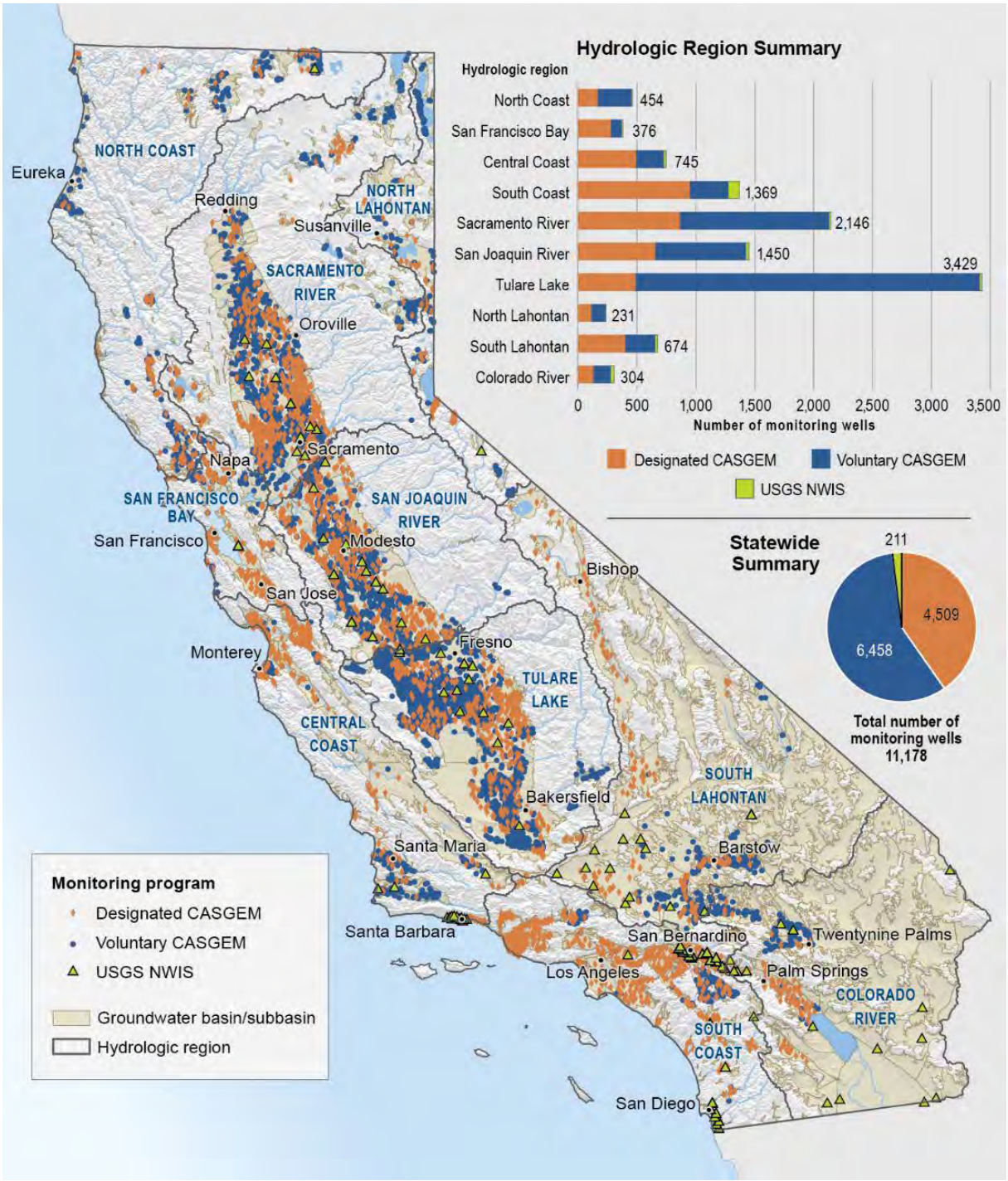
The collection and reporting of groundwater level data and the identification of seasonal and long-term trends are fundamental to assessing and sustaining California's groundwater resources. For decades groundwater level monitoring efforts were limited and highly

dispersed across the state. As the reliance on groundwater has increased, the statewide monitoring efforts have also improved through the enactment of two major groundwater monitoring laws. Senate Bill X7 6 (SBX7 6), passed in 2009, authorized DWR to establish permanent, locally managed, groundwater elevation monitoring and reporting in California's groundwater basins. To implement SBX7 6, DWR developed the California Statewide Groundwater Elevation Monitoring (CASGEM) program that has substantially improved the collection, analysis, and reporting of groundwater level data throughout the state (Figure H-12). The passage of SGMA in 2014 builds on the CASGEM efforts and further strengthens monitoring efforts. As SGMA monitoring and reporting efforts continue to expand there will be a significant increase in the number of monitoring stations and related measurements from those new stations.

Key findings related to groundwater level monitoring are:

- Between 2015 and 2018, there were 11,178 active groundwater level monitoring wells statewide with 10,948 monitoring wells in groundwater basins and 230 monitoring wells located in non-basin areas.
- Groundwater monitoring is occurring in 253 (49 percent) groundwater basins which produce 99.5 percent of total annual groundwater use in the state. But there are 35 (14 percent of the monitored basins) basins which have only one known monitoring well in the basin.
- There are 2,911 (26 percent) active monitoring wells that have unknown or incomplete well construction information. The lack of information limits analysis of aquifer response.
- Approximately 20 percent (1,687) of 8,267 monitoring wells with known depths monitor groundwater at depths greater than 800 feet, limiting the ability to assess deeper aquifer conditions.
- Approximately 13 percent (1,080) of 8,267 monitoring wells with known depths are monitoring groundwater at depths less than 100 feet, limiting the ability to assess groundwater dependent ecosystems (GDEs), domestic wells vulnerability, and interconnected surface water systems.
- More than 1,300 new groundwater level monitoring wells and more than 100,000 groundwater level measurements have been included as part of the 46 GSPs that were submitted in January 2020. A substantial number of additional monitoring wells and measurements are expected to be included in GSPs that are due in January 2022 and with ongoing GSP annual reports.
- The low number of groundwater monitoring wells (230) in the state's non-basin areas severely limits the ability to monitor and assess groundwater reliability in these areas.

Figure H-12: CASGEM Monitoring Wells

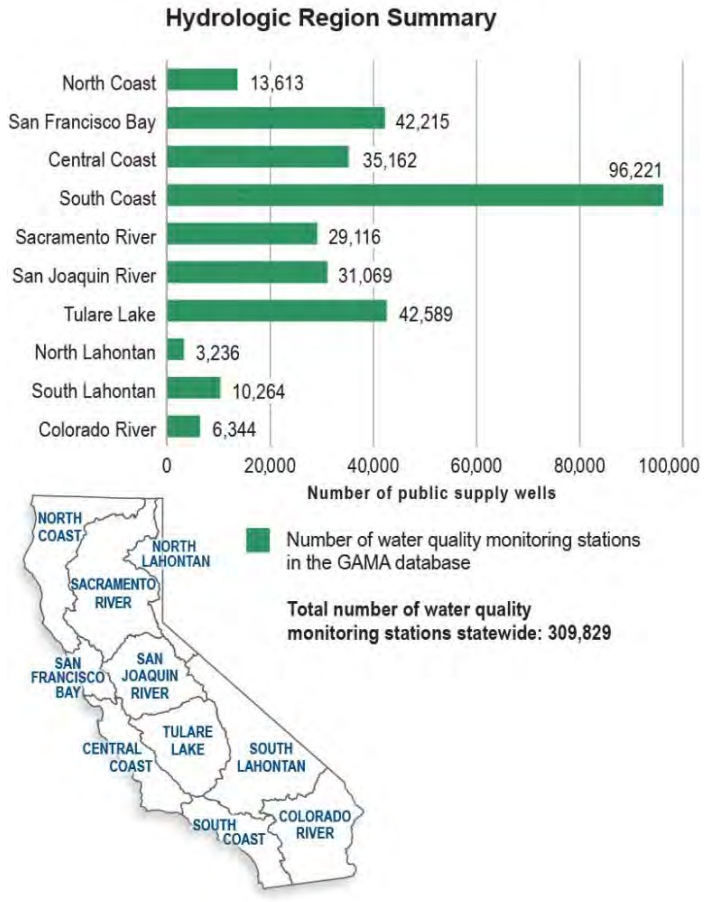


Groundwater quality monitoring wells are sampled primarily through two programs, State Water Board's Division of Drinking Water's (DDW's) Public Supply Well (PSW) Testing Program and DWR's Water Quality Monitoring Program. The DDW regulations require wells that provide water for public supply be tested for various constituents on a routine basis to ensure the water delivered from each supply well meets drinking water standards. The State Water Board's Groundwater Ambient Monitoring Assessment (GAMA) program maintains a large database of groundwater quality data)), which provides insights into the overall groundwater quality conditions in the state. The U.S. Geological Survey and other federal agencies, as well as DWR, have separate groundwater quality databases. Local agency water quality monitoring networks and protocols also vary from one agency to another.

Key findings regarding groundwater quality monitoring are:

- The GAMA data set contains nearly 310,000 monitoring stations; of which, 28,006 were used for the groundwater quality conditions analysis presented in the CalGW Update 2020. The remainder of the wells are site-specific, event-specific, or contaminant-specific monitoring wells.
- Of the 28,006 water quality stations, 78 percent are in groundwater basin areas; the remaining 22 percent are in non-basin areas.

Figure H-13: Water Quality Monitoring Stations



2. Groundwater Conditions by Sustainability Indicators of SGMA

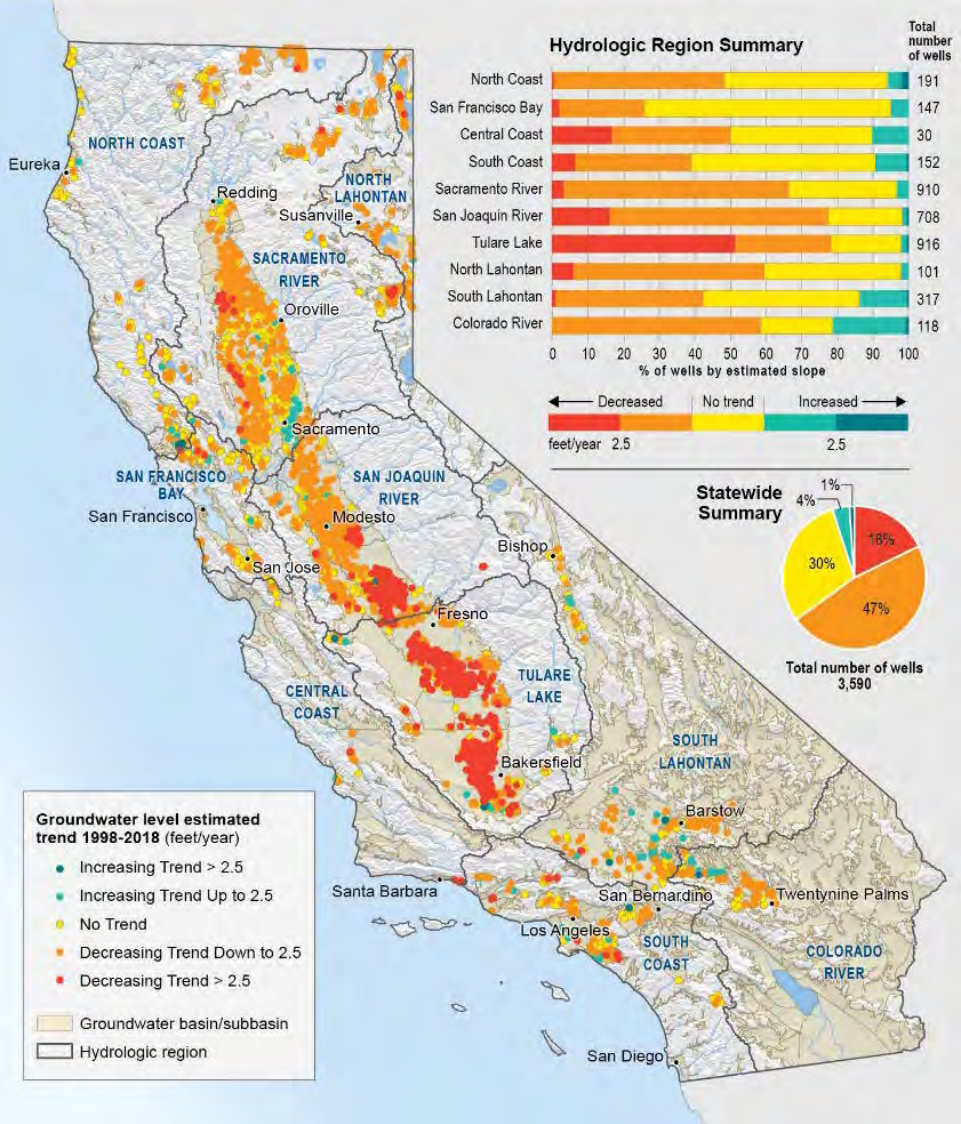
Lowering of Groundwater Levels: Groundwater levels are measured from a variety of groundwater wells located throughout the state. The data are collected by DWR and also reported to DWR by CASGEM Monitoring Entities, GSAs implementing GSPs, and other local agencies. Changes in groundwater levels illustrate how groundwater in storage varies over time and are influenced by many factors including pumping volumes and precipitation patterns. Since 1998, groundwater elevations have been generally declining in most areas of the state.

Key findings related to lowering of groundwater levels are:

- A trend analysis of the groundwater elevations data for the 20-year period from 1998 through 2018 indicates that approximately 65 percent of wells statewide demonstrated a decreasing trend in groundwater elevations, with approximately 30 percent a neutral trend, and approximately 5 percent an increasing trend (Figure H-14).
- The median depth to groundwater in California was 57 feet below ground surface (bgs) in spring of 2018. Depth to groundwater is variable across the state ranging from approximately 25 feet bgs in the North Coast, San Francisco Bay, Sacramento River and North Lahontan hydrologic regions, to as much as 195 feet bgs in the Tulare Lake Hydrologic Region.
- Trends in groundwater levels from 2010 through 2018 indicate stable conditions with 67 percent of wells showing less than 10 feet of elevation change over this period. Twenty-five percent of wells showed a decline in groundwater elevation of more than 10 feet and 8 percent showed a rise in groundwater elevation of more than 10 feet.
- Many groundwater level monitoring wells in the state do not have well construction information or adequate data for those wells to be included in a long-term or short-term groundwater level conditions analysis.



Figure H-14: Statewide Groundwater Level Trends (1998–2018)

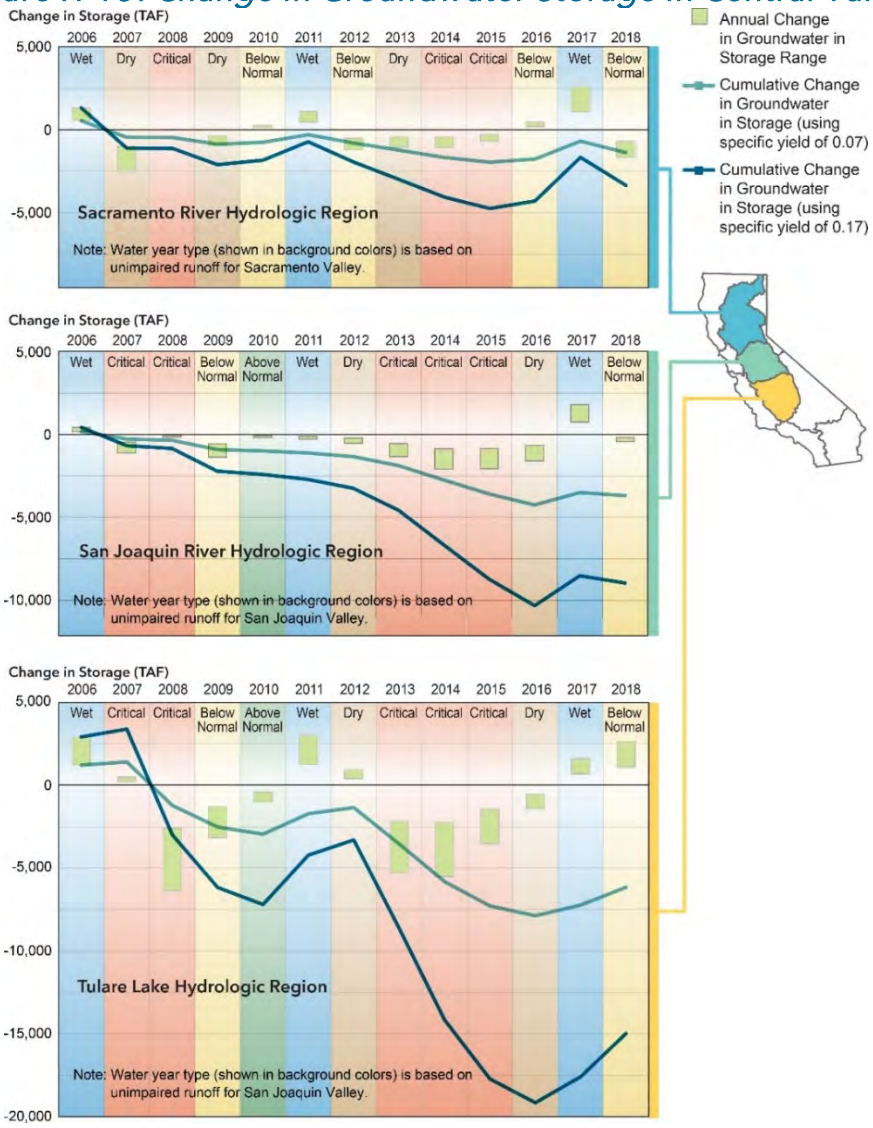


Reduction of Groundwater in Storage: Groundwater in storage in California has been in decline in various parts of the state, but the most prominent decline is in the Central Valley. It is estimated that there is a loss of more than 100 million acre-feet of groundwater from storage in Central Valley aquifers in the past 100 years (Faunt 2009). Groundwater basins in the Central Valley are the most used groundwater basins in the state, contributing about 78 percent of total statewide groundwater use in 2014. Of the 21 critically overdrafted basins in the state, 13 are in the Central Valley, contributing to the majority of state's total annual groundwater overdraft of about 2 maf.

Key findings related to reduction in groundwater storage are:

- From 2005 through 2018, there was an average annual reduction of 900 taf to 2,100 taf in the Central Valley, with almost 50 percent of the reduction occurring in the Tulare Lake Hydrologic Region (Figure H-15).
- Estimates of change in storage requires accurate data on groundwater pumping, which are not widely available or measured.
- Water budgets, which provide estimates of change in groundwater storage, are developed across the state by various methods and models, leading to definitions of water budget terms that often vary. DWR published a Draft Handbook for Water Budget Development: With or Without Models in February 2020 as a guidance document for local agencies.

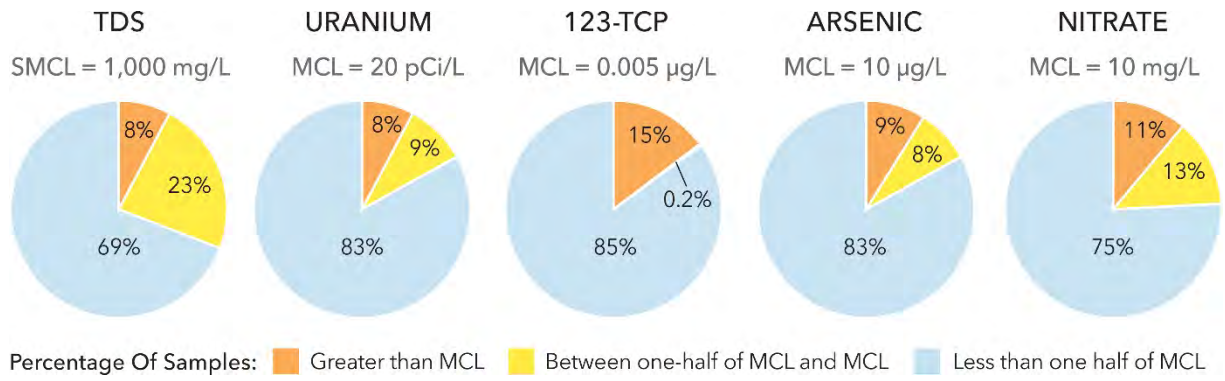
Figure H-15: Change in Groundwater Storage in Central Valley



Degraded Water Quality: Groundwater quality varies greatly in California's groundwater basins because of a broad range of natural and anthropogenic influences. According to the State Water Board's 2019 Annual Compliance Report, there are 369 public water systems that had one or more violations of a maximum contaminant level (MCL) or a treatment technique (TT) outlined in the Safe Drinking Water Act.

Groundwater quality information available from the State Water Board's GAMA Program's groundwater information system was used to summarize raw groundwater quality conditions in California, as presented below. Data from water quality monitoring stations were queried from 2009 through 2018. Statewide results are presented in Figure H-16 with reference to the MCL or secondary MCL (SMCL) for five common constituents of concern: 1,2,3-trichloropropane (1,2,3-TCP), nitrate as nitrogen (NO3N), arsenic (As), uranium (U), and total dissolved solids (TDS).

Figure H-16: Statewide Water Quality Summaries for Five Constituents of Concern



Key findings based on 10-year groundwater quality monitoring data from 2009 to 2018, are as follows:

- Water quality monitoring stations with TDS concentrations above the SMCL were identified in all hydrologic regions. The majority of affected water quality monitoring stations were in the San Francisco Bay, Central Coast, South Coast, San Joaquin River, and Tulare Lake hydrologic regions.
- Water quality monitoring stations with uranium concentrations above the MCL were identified in all hydrologic regions. The majority of affected water quality monitoring stations were in the South Coast, San Joaquin, and Tulare Lake hydrologic regions.
- Water quality monitoring stations with 1,2,3-TCP concentrations above the MCL were identified in all hydrologic regions. The majority of affected water quality monitoring stations were in the Tulare Lake, San Joaquin River, Sacramento River, and South Coast hydrologic regions.

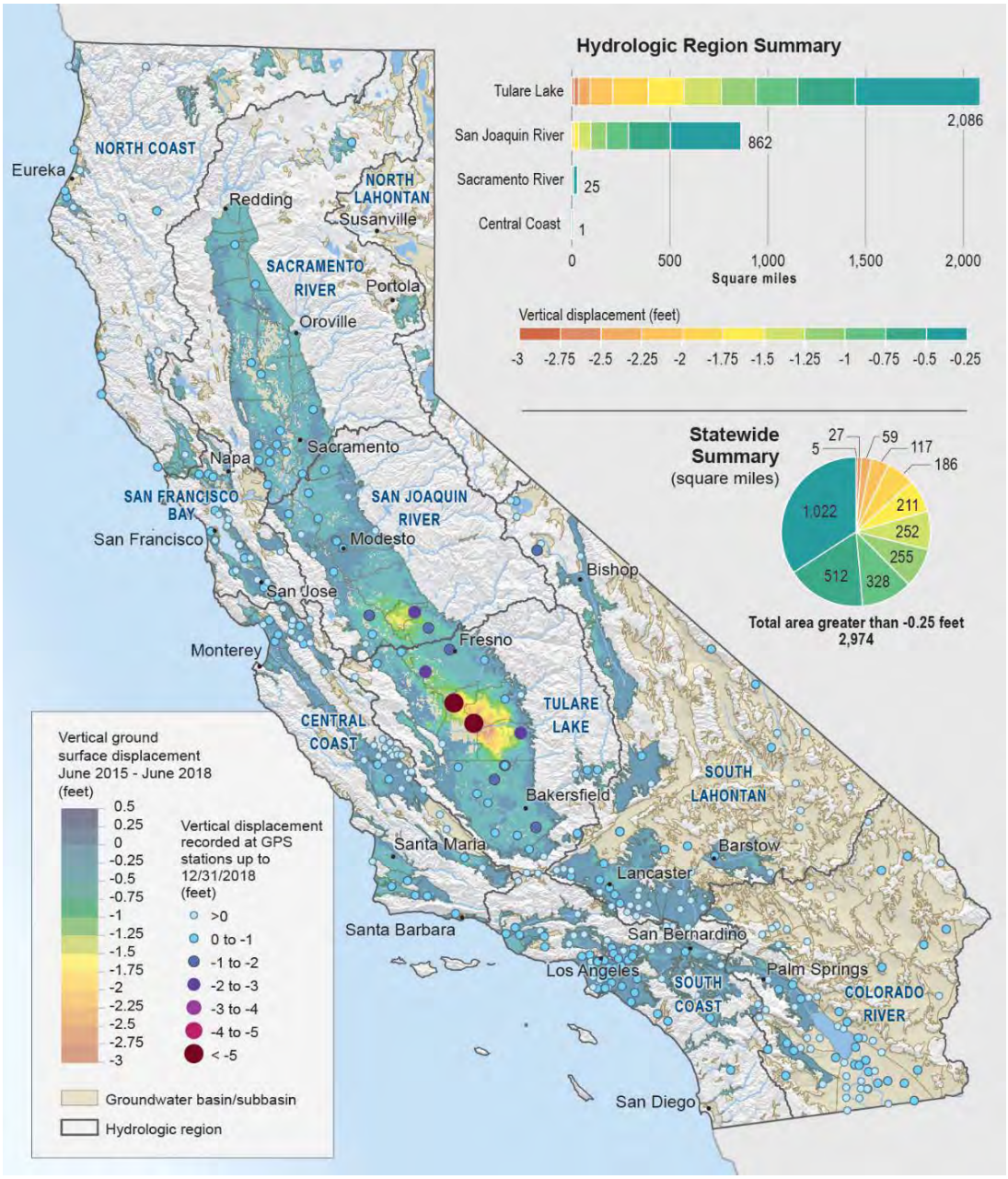
- Water quality monitoring stations with arsenic concentrations above the MCL were identified in all hydrologic regions. The majority of affected water quality monitoring stations were in the Sacramento River, San Joaquin River, Tulare Lake, and South Lahontan hydrologic regions.
- Water quality monitoring stations with nitrate as nitrogen concentrations above the MCL were identified in all hydrologic regions. The majority of affected water quality monitoring stations were in the Tulare Lake, San Joaquin River, Central Coast, and South Coast hydrologic regions.

Land Subsidence: Land subsidence caused by excessive groundwater pumping has historically occurred and continues to occur in portions of California. Portions of Central Valley have been experiencing land subsidence at differing rates since the 1920s. Some areas are estimated to have subsided as much as 28 feet (Faunt et al. 2016). From 2015 through 2018, which included the last two years of the most recent severe statewide drought (2012-2016), significant amounts of land subsidence occurred primarily in the San Joaquin Valley that caused impacts to critical water infrastructure including reduced conveyance capacity in local, State, and federal conveyance facilities, reduced levee heights, and damaged well casings (Borchers et al. 2014). The statewide land subsidence from June 2015 through June 2018 is presented in Figure H-17 .

Key findings regarding land subsidence are:

- More than 2,000 square miles in the Tulare Lake Hydrologic Region experienced subsidence of 0.25 foot (3 inches) to 3 feet, with a maximum rate of 1.5 feet per year.
- Nearly 900 square miles in the San Joaquin River Hydrologic Region experienced subsidence ranging from 0.25 foot (3 inches) to 2.25 feet, with a maximum rate of almost 1 foot per year.
- More than 20 square miles of the Sacramento River Hydrologic Region experienced subsidence ranging from 3 inches to 9 inches.
- Land subsidence has reduced flow capacity of the California Aqueduct, Delta-Mendota Canal, and other canals that deliver irrigation water and transport floodwater.
- Operational- and drought-related reductions in surface water deliveries and an increase in crop acreage in areas with only groundwater supplies have resulted in increased groundwater pumping and associated groundwater level declines and land subsidence.
- There have been significant improvements in the State's subsidence monitoring network, most notably the processing and reporting of satellite based InSAR data, which now provides monthly subsidence data for more than 160 groundwater basins.

Figure H-17: Statewide State of Land Subsidence



Seawater Intrusion: Seawater intrusion is the process of the natural seawater-freshwater interface migrating toward a groundwater basin because of changes in the hydraulic gradient in the basin that can be caused by groundwater extraction. Seawater intrusion results in higher TDS levels and corresponding negative water quality impacts. The monitoring for seawater intrusion has been conducted locally in some coastal basins for decades with the goal of tracking changes in water quality conditions. In addition, sea water barriers have been installed in several places by pumping water into the aquifer and creating a pressurized subsurface hydraulic "mound" or "ridge" that prevents the inland flow of saline groundwater

within the affected aquifers. It is expected that as GSPs are submitted, DWR will have more data and information on seawater intrusion in different coastal groundwater basins.

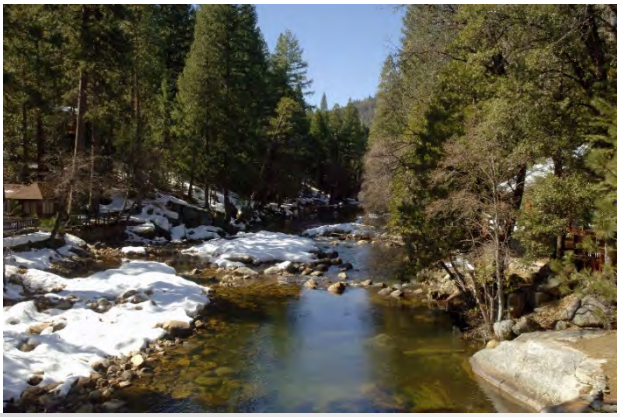
Key findings regarding seawater intrusion are:

- There are nearly 100 groundwater basins that are adjacent to an ocean, bay, or delta. Some of the basins are already experiencing seawater intrusion and others might be at risk for future seawater intrusion because of over pumping and sea-level rise.
- There are five basins subject to critical conditions of overdraft along the California coast, four in the Central Coast Hydrologic Region and one in South Coast Hydrologic Region.

Surface Water Depletion: California is crisscrossed by numerous rivers, streams, and creeks that carry runoff from precipitation and agricultural return flows. The majority of these streams are hydraulically connected to the underlying groundwater aquifers and either gains or loses water from the aquifer depending on the hydraulic gradient between the stream stage and the groundwater level. The interaction between groundwater and surface water and the effects of groundwater extraction on interconnected surface water varies greatly in California's groundwater basins. Surface water-groundwater interaction estimation involves multiple factors, such as streamflow measurements, pumping volumes and their timing, location and depth, groundwater level in shallow wells located near streams, subsurface hydrogeologic characteristics, and modeling of stream-aquifer interaction. It is expected that as GSPs are submitted, DWR will have more data and information on surface water-groundwater interaction in different groundwater basins.

Key findings related to monitoring of surface water groundwater interactions are:

- There are 1,295 active stream gages located throughout the 10 hydrologic regions.
- Because every basin is unique, an evaluation of the interaction between groundwater and surface water is more appropriately done at the local and regional levels. Currently, there is a general lack of data and understanding in this regard, but groundwater-surface water interaction monitoring efforts are increasing throughout the state in response to SGMA.
- In cases where stream systems create regional groundwater basin boundaries or cross several basins, there is a need for a more robust statewide and regional monitoring with public data access.



IV. Moving Forward to Sustainable Groundwater Management

Groundwater resources vary greatly across California. Different regions in the state have unique water supplies, groundwater conditions, natural environments, climate impacts, user needs and priorities, and vulnerabilities. Various regions, basins, and GSAs are employing various means to implement SGMA; some agencies have a long history of groundwater management, while others are just embarking in this new effort and will need more support, financially, technically, and educationally. Given these differences, a one-size-fits-all approach to statewide groundwater management does not work in California. Rather, locally developed, comprehensive GSPs, monitoring and measuring, and projects and management actions will enable longer term, adaptive management practices that will lead to sustainable groundwater management.

GSAs, as well as other local and regional entities, are well positioned to deliver needed improvements to water systems and water management for long-term sustainability. Effectively managing groundwater resources statewide will require a comprehensive approach in managing both surface and groundwater supplies. This will require the cooperation and collaboration of GSAs, water agencies, Tribes, federal agencies, local governments, communities, educators, and industries.

Recommendations of CalGW Update 2020

The following recommendations were developed based on the state of groundwater conditions and findings presented in CalGW Update 2020. Some of these recommendations are a continuation of ongoing DWR or GSA actions with emphasis on strengthening and enhancements; while some are new near- and long-term actions that are to be implemented by DWR or GSAs to strengthen efforts to better characterize, evaluate, and sustainably manage California's groundwater resources.

These recommendations will be implemented in partnership with other local, State, and federal agencies and will support actions in the Water Resilience Portfolio. Those that require funding or additional support will be prioritized as resources are available. The recommendations provided below will help improve management of groundwater to achieve long-term sustainability and water resilience while building climate adaptability that works for the people, environment, and economy of California.

The recommendations are organized into four broad categories:

1. **Advance Data Driven Decisions.**
2. **Maintain Momentum for Sustainability.**
3. **Engage, Communicate, and Educate.**
4. **Invest, Innovate, and Incentivize.**

Advance Data Driven Decisions

Groundwater data and information are critical for improving the understanding of groundwater basins and their hydrogeologic characteristics. The State has strengthened coordination with local entities to increase the collection and reporting of groundwater data. CalGW and the enhanced CalGW website content will serve as a comprehensive repository of statewide data. Making this data publicly available on the California Natural Resources Agency (CNRA) Open Data platform will improve access and advance data driven decision-making related to groundwater management and drought response and planning.

The following recommendations are made to advance data-driven decision-making.

1	**Strengthen and support long-term groundwater data collection programs at State, local, and regional levels and enable statewide sustainable groundwater management and drought response.**
1.1	Continue to collect groundwater data in high- and medium-priority basins and expand existing data collection programs (CASGEM) in low- and very-low-priority basins and non-basin areas.
1.2	Enhance existing groundwater level data collection programs to expand spatial coverage and increase the frequency of groundwater level measurements to quarterly, monthly, or more frequently to improve understanding of the seasonal variations and enable real-time decision-making.
1.3	Collect and compile agricultural, urban, and environmental water use data to expand data coverage and improve data accuracy for statewide water accounting and inform sustainable water management.

1.4	Coordinate with the State Water Board and other agencies on the collection of statewide groundwater quality and seawater intrusion monitoring data.
1.5	Enhance and expand data collection necessary to be able to monitor the groundwater and surface water interaction in both basin and non-basin areas by augmenting stream gage monitoring networks (consistent with Senate Bill 19), compiling groundwater pumping data, and increasing groundwater level monitoring in the vicinity of streams.
1.6	Coordinate with State and local agencies, Tribes, and environmental interest groups to improve data collection, mapping, and understanding of groundwater dependent ecosystems.
1.7	Enhance the State's subsidence monitoring network, in collaboration with local, State, and federal agencies, by increasing the frequency of satellite-based InSAR data collection and increasing the number of ground-based continuous global positioning systems and extensometers to monitor existing subsidence locations and detect new occurrences specifically near critical water infrastructure.
1.8	Improve the reporting of subsurface data by requiring geophysical logs to be submitted with well completion reports and work with local agencies to reduce the number of existing monitoring wells with missing or incorrect well construction and depth information.
1.9	Enhance and enrich the State's voluntary Household Water Supply Shortage Reporting System, to minimize under-reporting of data, errors, and omissions, through outreach and local assistance to underrepresented communities, domestic users, and Tribes.
1.10	Expand data collection and synthesis programs and conduct groundwater investigation studies to develop a better understanding of non-basin areas, including contribution of snowpack and streams to groundwater recharge from non-basin areas and and associated climate change and drought impacts.
2	**Enhance SGMA reporting systems and align them with the Open and Transparent Water Data Act (Assembly Bill 1755) to make groundwater data easily accessible, useful, timely, and transparent to support short-term and long-term planning for sustainable groundwater management.**

2.1	Continue and enhance the State's groundwater databases to handle the new groundwater basin data submitted by groundwater sustainability agencies (GSAs) and other local agencies and establish a high level of data quality by incorporating necessary quality assurance procedures.
3	**Develop and enhance analysis methods, standards, and modeling tools to support decision making for sustainable groundwater management.**
3.1	Incorporate new groundwater basin data, including groundwater basin water budgets, submitted by GSAs and other local agencies, to inform and update how statewide water balance information is synthesized and reported in the California Water Plan Updates and the Water Resilience Portfolio.
3.2	Update the California Well Standards and provide training to local enforcing agencies in administering the updated standards.
3.3	Continue to support and enhance DWR's integrated water flow model (IWFM), the California Central Valley Simulation Model (C2VSim) and the Sacramento Valley Simulation Model (SVSim) based on user feedback.
3.4	Expand airborne electromagnetic (AEM) and related geophysical surveys to collect data of subsurface hydrogeologic characteristics of aquifer systems statewide, develop methods to incorporate geophysical data in groundwater models, and provide training to local agencies on use of geophysical data in local models.
4	**Build upon the California's Groundwater (Bulletin 118) legacy by collaborating with local agencies on the application of new technology and tools for geologic and hydrogeologic characterization of groundwater basins and water budgets to inform long-term planning for sustainability under average and dry conditions.**
4.1	Work with applicable State agencies to improve knowledge and understanding of California's groundwater basins by enhancing basin characterizations with the latest data and information, including climate change data to improve groundwater management.
4.2	Identify optimal areas for enhanced recharge and critical connections in aquifer systems to enable local governments to maximize opportunities for managed aquifer recharge.

Maintain Momentum for Sustainability

The State's assistance and assessment programs empower local agencies to manage groundwater more diligently and comprehensively. The State will continue to enhance existing planning, technical, and financial assistance as part of its statewide groundwater management efforts, so that local agencies, working with their interested parties, can maintain momentum toward their long-term goals of sustainable groundwater management.

The following recommendations are made to maintain momentum for sustainability.

5	**Continue the implementation of the Sustainable Groundwater Management Act by effectively performing regulatory oversight, monitoring progress towards achieving sustainability goals, and supporting the adaptive management of groundwater to achieve sustainability within regulatory timeframes.**
5.1	Support the implementation of projects and management actions identified in the groundwater sustainability plans (GSPs) and track and report on statewide sustainability performance measures.
5.2	Ensure local agencies are tracking and reporting on sustainability performance measures and assist local agencies to manage groundwater basins adaptively and collaboratively.
5.3	Ensure ongoing, consistent, and timely evaluation and review of GSPs, annual reports, and alternatives and their updates to assess the likelihood of achieving sustainability.
6	**Promote and support groundwater projects that achieve multiple benefits to reduce statewide overdraft, replenish groundwater basins, reduce drought risks, and secure ecosystem benefits.**
6.1	Collaborate with State, federal, Tribal, local, and regional agencies to support and provide financial and non-financial incentives for a comprehensive approach to local and regional groundwater recharge and storage projects that would achieve multiple benefits.
6.2	Promote streamlining and acceleration of managed aquifer recharge and groundwater banking permitting processes to support long-term proactive drought management strategies.

6.3	Encourage multi-benefit projects, such as groundwater recharge with recycled and reuse water, to increase water supply reliability and offset water demand.
6.4	Work with local agencies, under-represented communities, domestic users, and Tribes in basins and non-basin areas to identify and understand their use of and reliance on groundwater and historical impacts from droughts to reduce risks and better prepare for future droughts, in particular, through the development of the drinking water well principles and strategies to anticipate and proactively address drought impacts.
7	**Foster and strengthen local and regional water markets and streamline water transfers to optimize the economic value of groundwater while providing protections for the environment and communities.**
7.1	Streamline groundwater substitution and water transfer permitting and approval processes by allowing consolidated basin-level environmental reviews to facilitate water market transactions.
7.2	Facilitate the efficient, fair, and equitable development and implementation of water markets by creating an adaptable standardized framework for market structure, governance, and operations.
7.3	Continue to create a voluntary statewide water transfer database and support efforts to develop a groundwater accounting platform.
8	**Continue and enhance the local assistance program and build capacity within agencies to maintain momentum toward sustainability.**
8.1	Continue local assistance, in the form of training, technical support, and financial grants to GSAs, other groundwater management entities, underrepresented communities, and Tribes, in both basin and non-basin areas, to gradually build capacity to manage groundwater and reduce drought risks, including advancing guidance on drinking water well-related drought impacts.
8.2	Identify groundwater basins where water budgets and management practices have not been established and provide technical assistance and financial incentives to establish basin-wide water budgets for average years and dry years.
8.3	Encourage and support local agencies to utilize existing local authority to effectively manage groundwater in low- and very-low-priority basins and non-basin areas.

Engage, Communicate, and Educate

The State will continue to foster engagement, communication, and outreach support to local agencies, Tribes, interested parties, decision-makers, and other State and federal agencies to build collaborative connections. CalGW and its companion website will continue to provide a platform to educate water managers, decision-makers, and the public about the importance of groundwater.

The following recommendations are made to continue efforts to engage, communicate, and educate.

9	**Engage with a comprehensive range of interested parties, including underrepresented communities, to communicate the value of groundwater and listen to the issues, challenges, and needs of the interested parties.**
9.1	Continue to engage with local agencies and under-represented communities through groundwater basin points-of-contact and regional coordinators to identify and understand local needs and priorities, tools needed, opportunities for grants and loans, and obstacles to data sharing.
9.2	Publish an annual report summarizing the status and accomplishments of the sustainable groundwater management program, its benefits, and progress toward achieving statewide sustainability.
10	**Communicate and collaborate with local agencies, counties, Tribes, and non-governmental organizations on finding synergistic solutions to challenging problems.**
10.1	Increase coordination among various local and regional water resource planning efforts, including SGMA, integrated regional water management, agricultural water management, and urban water management to maximize the effectiveness of individual efforts and foster synergistic collaborations for multi-benefit and multi-partner projects.
10.2	Provide State incentives to local water management agencies and counties to coordinate with Tribes, underrepresented communities, and other agencies for taking actions to ensure the long-term sustainability of groundwater supply and human right to water, including the advancement of funding to support the implementation of strategies to address drinking water well and drought impacts.

10.3	Increase communication, collaboration, and coordination between land use planning agencies and GSAs to link land use development and water management and protect the interests of all beneficial users and uses of groundwater in California.
11	**Build groundwater education program for local agencies, elected officials, students, well owners, underrepresented communities, and general population to garner support for sustainable groundwater management programs and projects.**
11.1	Collaborate with non-governmental organizations and other agencies to distribute existing groundwater educational material more broadly and develop targeted educational materials that can be used to brief local agency board members, county supervisors, and local elected officials.
11.2	Work with the California Department of Education, appropriate education institutions, the Groundwater Resources Association, GSAs, Tribes, and other key interested parties to develop groundwater related educational materials for use in K–12 classrooms, colleges, and universities to instill the value and importance of groundwater and sustainability.
11.3	Develop groundwater educational material in English, Spanish, Hmong, and other languages representing large population groups in California to communicate the value of groundwater and importance of sustainability. Continue public awareness efforts and support local agencies in promoting consistent and effective messaging that water conservation also saves groundwater.
11.4	Work with educational institutions to develop multi-disciplinary programs to attract talent and promote diversity and leadership in groundwater professions to support building capacity at State and local levels.

Invest, Innovate, and Incentivize

Financial and nonfinancial incentives will be needed over the next 20 years and beyond to support the implementation of groundwater projects as well as related surface water projects and management actions across the state that will be used to achieve and maintain sustainable groundwater supplies.

The following recommendations are made to promote investment, innovations, and incentives.

12	**Secure sustained funding to support sustainable groundwater management projects and management actions that will improve water resiliency.**
12.1	Secure sustained funding for programs supporting sustainable groundwater management, including technical assistance, data collection and dissemination, GSP evaluation, guidance documents, hydrogeologic investigations, models and tools development, outreach and education, and capacity building.
13	**Promote innovation and new technology adoption in sustainable groundwater management.**
13.1	Continue to enhance and update the **CalGW Live** website with the latest information on groundwater data, best available science, drought conditions, and new technologies to support innovations in sustainable and resilient groundwater management
13.2	Provide incentives to promote adoption and use of new approaches and technologies in groundwater, such as flood-managed aquifer recharge (Flood-MAR) and remote sensing (e.g., Interferometric Synthetic Aperture Radar (InSAR), airborne electromagnetic and other geophysical surveying).
14	**Work with the Legislature and government agency executives to create and provide non-financial incentives (e.g., streamlined permitting) for activities that support sustainable groundwater management.**
14.1	Incentivize GSAs and grant applicants to consider statewide priorities in formulating inter-regional projects for sustainable groundwater management.
14.2	Incentivize GSAs and grant applicants to undertake projects that directly improve the human right to water and reduce drought risks for underrepresented communities, Tribes, and rural communities.

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V. Conclusions

Carrying out the recommendations of CalGW Update 2020 will require sustained leadership, support, oversight, funding, and cooperation. Some recommendations can be implemented in the near term, while others with equal priority, may take longer to carry out because of progress that needs to be made related to implementation of SGMA, data innovation, and necessary investment. CalGW Update 2020 sets forth a new paradigm to monitor progress toward achieving all the recommendations.

Water managers at the local, regional, State, and federal levels are crucial in fostering collaboration within and across basins and alignment at all levels of government to fill data gaps and achieve these recommendations. This will require focus and emphasis on cooperation among State and federal agencies involved with groundwater management, and with GSAs and other local and regional water management entities. With shared commitment, resources, and strategies, a sustainable groundwater future is within reach.







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DEPARTMENT OF WATER RESOURCES
STATE OF CALIFORNIA

CALIFORNIA DEPARTMENT OF WATER RESOURCES

CALIFORNIA'S GROUNDWATER

UPDATE 2020



California's Groundwater Update 2020 has a companion summary document, called *California's Groundwater Update 2020 Highlights*, available in English and Spanish. This companion document can be accessed on DWR's California's Groundwater (Bulletin 118) webpage.



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California's Groundwater

Update 2020

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State of California

The Natural Resources Agency

Department of Water Resources

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Using California's Groundwater Update 2020

- California's Groundwater (CalGW) Update 2020 is the State's most up-to-date compendium of statewide data and information on the occurrence, nature, use, and conditions of California's groundwater resources and its management. CalGW Update 2020 is a continuation of a series of earlier DWR publications known as Bulletin 118. It builds on the past progress and state of knowledge, synthesizes the most recent data to close current gaps in knowledge, and focuses on statewide groundwater management and planning efforts, including drought planning and response.
- CalGW consists of a summary highlights document and a detailed statewide report, supported by a series of appendices, and CalGW Live as described below.
- **Highlights (English and Spanish)**: A stand-alone summary document describing the value and state of groundwater conditions and management in California with findings and recommendations to foster and achieve sustainable groundwater management.
- **Statewide Report (Chapters 1 to 6)**: A detailed report on the state of groundwater in California including the history of California's Groundwater reports, economic value of groundwater, and groundwater management before and after the enactment of the Sustainable Groundwater Management Act (SGMA). The statewide report provides a status of statewide groundwater monitoring and the latest knowledge on statewide groundwater conditions including groundwater levels, change in storage, groundwater quality, and land subsidence.
- **Statewide Report (Chapter 7)**: A hydrologic-region summary and regional status of land and water use, monitoring and conditions of groundwater levels, groundwater quality, land subsidence, seawater intrusion, and surface water-groundwater interactions. Chapter 7 includes a map and a list of all groundwater basins in each hydrologic region with their current designated priority under SGMA's Basin Prioritization process.
- **Appendices A to H**: A series of appendices that provide details supporting the content of the various chapters of the statewide report, including methods and assumptions, citations, and references.
- **CalGW Live**: A user-friendly interactive website that allows users to explore, analyze, and visualize the latest groundwater data and information for California.

Director's Message



Groundwater is a precious natural resource. Over the last several decades, California's increasing reliance on groundwater and reoccurrence of drought underscore the critical importance of groundwater to the state. As climate change has accelerated, droughts have become more frequent, more severe, and longer in duration. There has been a shift from using the less-available snowpack, precipitation, and surface water, to using reserves – groundwater.

Often unseen, groundwater serves a multitude of purposes and uses including for the environment, businesses, agriculture, and for household use, where some Californians rely solely on groundwater for drinking water. Groundwater supports California's communities, rich biodiversity, economy, industries, jobs, and human health. As demands continue to increase with the variability in climate, the State and Governor Newsom are keenly focused on ensuring that our water supplies continue to be reliable now and more resilient into the future. The passage and implementation of the Sustainable Groundwater Management Act (SGMA) marks a new era of improved science, understanding, and access to groundwater information. It provides the foundation for data-driven decision-making to inform and transform groundwater management.

California's Groundwater Update 2020 (also known as Bulletin 118) builds upon past efforts and represents the most comprehensive compilation of groundwater information for California to date. Required by SGMA, this bulletin, and future updates, serve to enhance our understanding of groundwater conditions and management statewide by supporting actions in the Governor's Water Resilience Portfolio and providing groundwater data and information to support progress toward achieving sustainability and improving drought resilience. This bulletin includes new data and analyses – providing pivotal information for near-term drought response and long-term groundwater planning. An accompanying online application, called California's Groundwater Live, establishes a publicly accessible platform that organizes the increasing flow of groundwater data and information and visualizes it for greater public education and awareness.

With increased knowledge and understanding comes a responsibility to continue working collaboratively and adapting how we manage our groundwater resources. There will be challenges as we continue our collective efforts to achieve statewide sustainable groundwater management, but with durable and innovative solutions underpinned by up-to-date information, we can overcome these obstacles and continue on our path toward a more reliable and resilient future.

Karla A Nemeth

Director, California Department of Water Resources

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Gavin Newsom, Governor

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Acronyms and Abbreviations

1,2,3-TCP	1,2,3-trichloropropane
AB	Assembly Bill
AEM	airborne electromagnetic
alternative	alternative to groundwater sustainability plan
Alpha	gross alpha radionuclides
AR	atmospheric river
AS	arsenic
ASR	aquifer storage and recovery
AWMP	agricultural water management plan
BBMRS	Basin Boundary Modification Request System
BCM	Basin Characterization Model
bgs	below ground surface
BMP	best management practice
C2VSim	California Central Valley Groundwater-Surface Water Simulation Model
C2VSim-FG	C2VSIM-Fine Grid
C2VSim-CG	C2VSIM-Coarse Grid
CDS	coastal distribution system
CalGW Update 1975	California's Ground Water (1975)
CalGW Update 1980	Ground Water Basins in California: A Report to the Legislature in Response to Water Code Section 12924
CalGW Update 2003	California's Ground Water (2003)
CalGW webpage	California's Groundwater webpage
Caltrans	California Department of Transportation

CASGEM	California Statewide Groundwater Elevation Monitoring
CCTAG	Climate Change Technical Advisory Group
CDAA	California Disaster Assistance Act
CDFA	California Department of Food and Agriculture
CDFW	California Department of Fish and Wildlife
CGPS	continuous global positioning system
CNRA	California Natural Resources Agency
COD	conditions of critical overdraft
CSVSim	Central Valley Groundwater-Surface Water Simulation Model
CVHM	Central Valley Hydrologic Model
CVP	Central Valley Project
CWD	climate water deficit
CWAP	California Water Action Plan
CWP	California Water Plan
Delta	Sacramento-San Joaquin Delta
DBCP	1,2-Dibromo, 3-chloropropane
DDW	Division of Drinking Water
DEW	drier with extreme warming
DPR	California Department of Pesticide Regulation
DTSC	California Department of Toxic Substances Control
DWR	California Department of Water Resources
EDB	ethylene dibromide
ETaw	evapotranspiration of applied water
EPA	U.S. Environmental Protection Agency

ESA	Endangered Species Act
FEMA	Federal Emergency Management Agency
Flood-MAR	flood-managed aquifer recharge
FSS	Facilitation Support Services
GAMA	Groundwater Ambient Monitoring Assessment
GCM	global climate model
GIS	geographic information system
GPS	global positioning system
GRS	groundwater replenishment system
GSA	groundwater sustainability agency
GSP	groundwater sustainability plan
HCM	hydrogeologic conceptual model
HR	hydrologic region
InSAR	interferometric synthetic aperture radar
Interim Update 2016	California's Groundwater Interim Update 2016
IRWM	integrated regional water management
IWFM	Integrated Water Flow Model
LiDAR	light detection and ranging
maf	million acre-feet
MAR	managed aquifer recharge
MCL	maximum contaminant level
MNM	Monitoring Network Module
MODFLOW-OWHM	MODFLOW-One Water Hydrologic Model

Monitoring BMPs	Best Management Practices for the Sustainable Management of Groundwater Monitoring Networks and Identification of Data Gaps
MRP	Monitoring and Reporting Program
NAVD88	National Vertical Datum 1988
NO_3N	nitrate as nitrogen
NOAA	National Oceanic and Atmospheric Administration
NPS	nonpoint source pollution
NSF	National Science Foundation
NWIS	National Water Information System
OSWCR	Online Statewide Well Completion Report database
PCE	tetrachloroethylene
POC	point of contact
Reclamation	U.S. Bureau of Reclamation
RWQCB	regional water quality control board
SB	Senate Bill
SB X7-7	Water Conservation Act of 2009
SGMA	Sustainable Groundwater Management Act
SGMO	Sustainable Groundwater Management Office
SGMP	sustainable groundwater management plan
SMCL	secondary maximum contaminant level
State Water Board	State Water Resources Control Board
subsidence	inelastic land subsidence
SVSim	Sacramento Valley Groundwater-Surface Water Simulation Model
SWP	State Water Project

taf	thousand acre-feet
TCE	trichloroethylene
TDS	total dissolved solids
TSS	Technical Support Service
U	uranium
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
UWMP	urban water management plan
WAFR	Water Available for Replenishment
Water Code	California Water Code
WaterSMART	Sustain and Manage America's Resources for Tomorrow
WCR	well completion report
WMW	wetter with moderate warning
WQ Conditions Dataset	Statewide Groundwater Quality Data
WRP	Water Resilience Portfolio
WTIMS	Water Transfer Information Management System

Chapter 1. Introduction

California's Groundwater – A Precious Resource

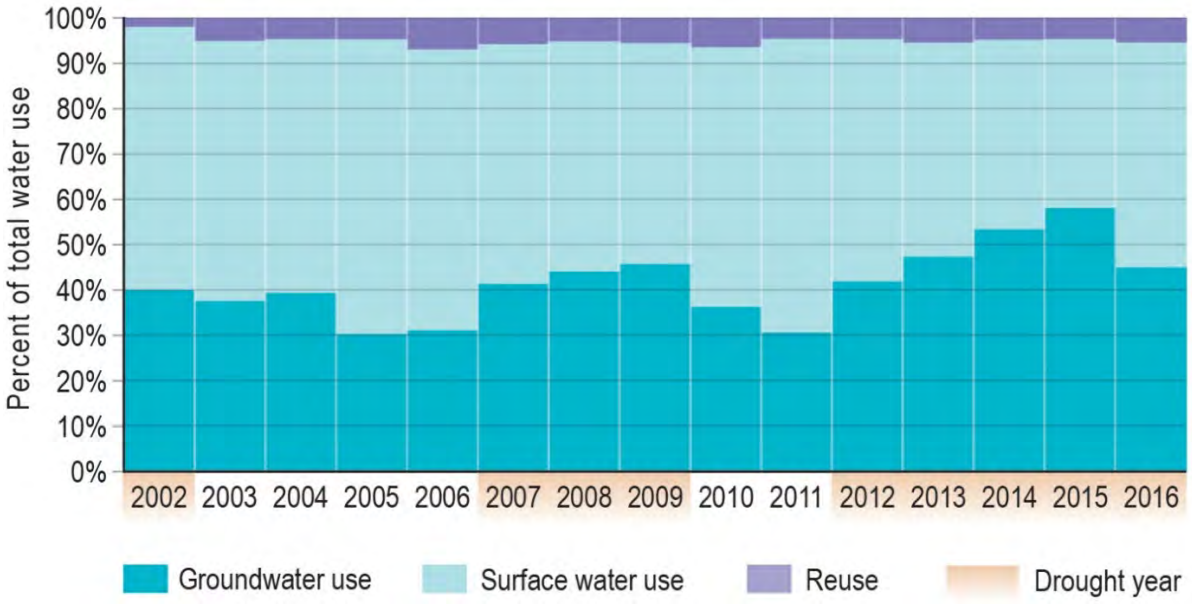
Groundwater is a precious and limited resource that is used in meeting the needs of California's large and small urban areas, rural groundwater users, irrigated agriculture, and the environment. Since the last California's Groundwater (CalGW) Update in 2003, there has been significant changes to land use, water use, water application practices, and water allocations. In addition, the effects of climate change have affected California's reliance on groundwater. It is expected that there will be additional changes in land use, water use, and water allocations, and that climate change will continue to affect the environment, thus elevating the importance of the reporting in CalGW updates.

According to the last comprehensive report, *California's Groundwater Update 2003* (CalGW Update 2003), California's reliance on groundwater is approximately 30 percent during a wet-to-average precipitation water year and approximately 40 percent during dry periods. Since then, the percentage of groundwater reliance has increased to 30 to 40 percent during above normal to-wet years and to as much as 58 percent during dry periods (California Department of Water Resources 2018) (Figure 1-1).

Figure 1-1 shows annual groundwater use as a percentage of total water use for Water Years 2002 to 2016. A water year runs from October 1 through September 30 and is referenced in the year it ends. For example, the water year that began October 1, 2001, and ended September 30, 2002, is referenced as Water Year 2002.

Groundwater use during the 2002–2016 period averaged approximately 17.6 million acre-feet (maf). An acre-foot is approximately 326,000 gallons. An average California household uses between one-half and one acre-foot of water per year for indoor and outdoor use (Water Education Foundation 2021). During the wet water years of 2005, 2006, and 2011, groundwater use was approximately 12.0 maf to 13.1 maf, representing 30 to 31 percent of total water use. Total water use during these water years ranged from 39.6 maf to 42.1 maf. During the dry water years of 2014 and 2015, groundwater use was approximately 23.0 maf and 22.9 maf, respectively, representing 53 and 58 percent of total water use. Total water use for water years 2014 and 2015 was 43 maf and 39.4 maf respectively. (California Department of Water Resources 2018).

Figure 1-1 Annual Groundwater Use as a Percentage of Total Water Use (Water Years 2002–2016)



Most of the state's water supply comes from precipitation that falls during the wet seasons and is stored in surface water reservoirs throughout the state. This surface water is transported through a series of conveyance facilities including rivers, canals, and pipelines. One of the state's largest water conveyance systems, the State Water Project (SWP), is operated by the California Department of Water Resources (DWR). The SWP supplies water to more than 27 million Californians and supplies water to approximately three-quarters of a million acres of agriculture annually. The complex system of major reservoirs and conveyance facilities in California is shown in Figure 1-2.

Stored groundwater is not as visible as the supplies in reservoirs, aqueducts, rivers, and lakes, but it does amount to substantially more useable fresh water. It is estimated that the volume of California's total groundwater storage capacity is between 850 maf and 1,300 maf (California Department of Water Resources 1975). It is important to note that not all groundwater is useable because it is either too deep to be pumped economically or of poor quality. Even with only the groundwater that could be available for use, the storage capacity is many times greater than that of all major reservoirs in California combined.

Figure 1-2 Major Reservoirs and Conveyance Facilities in California



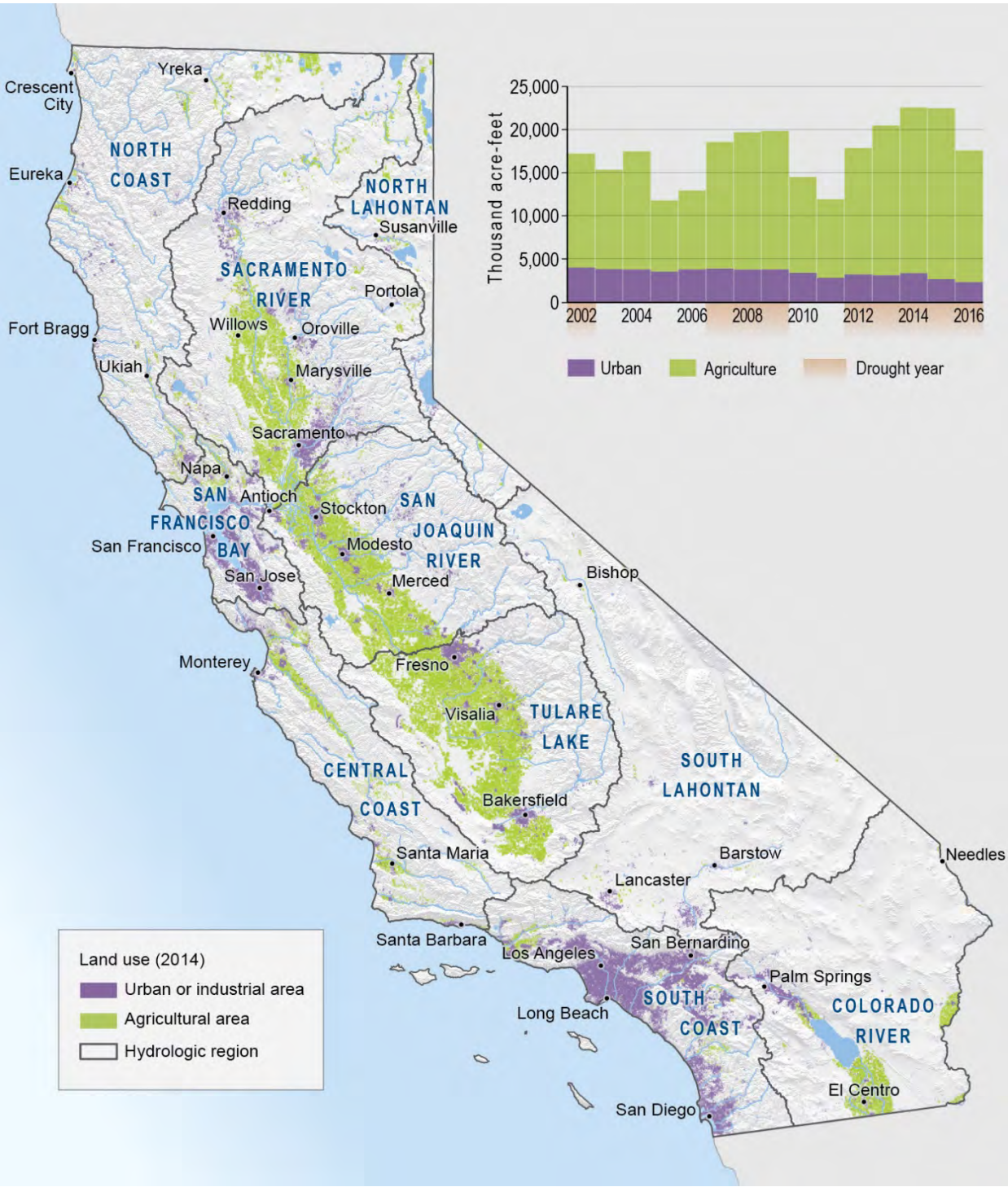
In California, it takes the combination of groundwater and surface water to support urban, agricultural, and environmental needs. DWR's *California Water Plan Update 2018* reports the 2011–2015 (primarily drought years) statewide average water use is 8 maf for urban, 34 maf for agricultural, and 33 maf for environmental needs. The distribution of agricultural and urban areas throughout the state is shown in Figure 1-3 (California Department of Water Resources 2014; U.S. Department of Agriculture 2014).

Figure 1-3 includes a graph depicting the amount of groundwater used for agricultural and urban purposes from 2002 through 2016 (California Department of Water Resources 2018). Total groundwater use increased during periods of drought, but the increase was not proportionally distributed among agricultural and urban users. The agriculture sector had the greatest influence on the increases in groundwater use during drought periods, mainly because of the surface water supply limitations with continued demands. Interestingly, droughts had very little effect on urban groundwater use. The amount of urban groundwater use steadily decreased even though the population continued to increase during this time period. This slight decline in urban groundwater use was likely the result of securing additional surface water supplies and implementing water conservation measures.

It is important to note that the declining groundwater use in the face of increasing population and periods of drought presented in Figure 1-3 represents a statewide response. Local analyses are needed to fully understand the effects of droughts on local areas, which may be as much as 100 percent reliant on groundwater. Chapter 3, "Groundwater: Use, Extraction, and Water Budgets," and Appendix G, "Water Use Data," contain more in-depth information on water use in the state.

For planning and analysis purposes, DWR divides California into 10 hydrologic regions, corresponding to the state's major watersheds (California Department of Water Resources 1993). This report presents data summarized by these hydrologic regions, as shown in Figure 1-3.

Figure 1-3 Distribution of Agricultural and Urban Areas and Annual Groundwater Use, 2002–2016



Improving Groundwater Management – A Historic Responsibility

Water resources management in California has changed from what it was prior to the most recent five-year drought (2012–2016). Since 2013, State legislators and policy-makers have taken significant strategic and legislative actions toward managing California's water resources, including the enactment of the Sustainable Groundwater Management Act (SGMA) in 2014 and the preparation of drought reports that provide the public with updates on groundwater conditions throughout the state.

Californians are becoming increasingly more aware of the need for a significant transformation in the way California's water is managed. With the passage of SGMA, California has, for the first time in its history, a framework "to provide for the sustainable management of groundwater basins" (California Water Code Section 10720.1).

In addition to the enactment of SGMA, DWR and other State agencies were provided with additional groundwater management guidance through the release of the following documents.

- The California Water Action Plan (CWAP) was issued by Governor Jerry Brown in 2014 and updated in 2016. It established a comprehensive water strategy for State government and set in motion a new era of cooperation and collaboration among State, local, and federal water agencies. The CWAP was designed to re-align actions being taken by State agencies to promote more reliable water supplies, the restoration of important species and habitat, and a more resilient, sustainably managed water resources system. Improving groundwater management was one of the 10 actions recommended in the CWAP. DWR has been entrusted to assist, support, and guide local agencies toward implementing this action.
- Executive Order N-10-19 was issued by Governor Gavin Newsom in April 2019. It directed State agencies to develop recommendations to enable water security for the people of California.
- The Water Resilience Portfolio (WRP) was released in July 2020 in response to Executive Order N-10-19. The WRP strives to improve California's capacity to prepare for water supply disruptions, withstand and recover from climate-related shocks, and adapt into the future. The WRP builds on a strong foundation established by prior statewide plans and legislative- and policy-level actions. It underscores that no single solution exists to solve California's water challenges and prioritizes a broad array of State actions.

> Goal 3 of the WRP is focused on groundwater and states: "Help regions secure groundwater supplies by supporting the transition to sustainable use." This goal includes nine actions (3.1 to 3.9). DWR is identified as a key State agency in implementing most of these actions.

DWR is committed to the implementation of the SGMA program (WRP Actions 3.1 and 3.3) in conjunction with other State agencies (WRP Action 3.2) to make the transition to sustainable groundwater management as smooth as possible. DWR, and the State Water Resources Control Board, are working together to improve recharge opportunities (WRP Actions 3.4 and 3.9) with streamlined approaches (WRP Actions 3.5 and 3.8), funding (WRP Action 3.6), and are assisting in water trades while ensuring safeguards to protect the natural resources, small- and medium-size farms, and water supply and quality for disadvantaged communities (WRP Action 3.6). DWR has already started the aerial electromagnetic surveys to improve the understanding of subsurface characteristics of underlying basins (WRP Action 3.7).

The State, with DWR as a primary implementing agency, is entrusted with a responsibility to regulate, assist, guide, and support local agencies in implementing the provisions of SGMA, the actions of the California Water Plan, and the actions of the WRP. To support the implementation of SGMA, the actions of the California Water Plan and the WRP, DWR, working with other State agencies, initiated a suite of programs and activities including development of regulations, technical guidance documents, modeling tools, data portals, and technical and financial assistance for local agencies to promote sustainable groundwater management. Additional details on these activities can be found in Chapter 4, "Groundwater Management."

California's Groundwater – A Compendium of Information

Over the past 70 years, the CalGW series and related documents have provided a source and historical archive of the State's collective knowledge and evolving understanding of the occurrence, use, and management of California's groundwater resources. This existing body of knowledge and each successive update facilitates informed decision-making by the public, local water agencies, and elected officials affecting the protection, use, and sustainable management of groundwater, and future investments in water management.

DWR publishes CalGW updates to meet the requirements of California Water Code Section 12924. CalGW identifies California's groundwater basins; provides the status of groundwater management; describes groundwater conditions, monitoring efforts,

and patterns of groundwater extraction within those basins; assigns basin priority; and designates basins subject to critical conditions of overdraft.

Brief History of California's Groundwater

In 1952, prior to the establishment of DWR, the California Department of Public Works, Division of Water Resources published *Water Quality Investigations Report No.3 – Ground Water Basins in California*. This document is the first statewide compilation of information on groundwater basins. At that time, 286 groundwater basins and subbasins were identified.

In 1975, *California's Ground Water* (CalGW Update 1975) was published. It identifies 459 groundwater basins and subbasins and provides summary information on basin and aquifer characteristics, groundwater use, and water quality concerns. CalGW Update 1975 is commonly referred to as the first California's Groundwater update because it is the first report to discuss all the groundwater basins in the state.

In 1980, DWR published *Ground Water Basins in California: A Report to the Legislature in Response to Water Code Section 12924* (CalGW Update 1980). It identifies 471 groundwater basins and subbasins and provides summary information on basin characteristics, groundwater use, and the extent of the basins. CalGW Update 1980 also identifies 11 basins as subject to critical conditions of overdraft and four basins as having "special problems."

CalGW Update 2003 includes a status report on groundwater management in California and an inventory of California's groundwater information. CalGW Update 2003 provides additional information on the groundwater basins and identifies 515 basins and subbasins listed by hydrologic region. The groundwater basins subject to critical conditions of overdraft identified in CalGW Update 1980 are not evaluated in CalGW Update 2003.

In 2016, DWR published *California's Groundwater Interim Update 2016* (CalGW Interim Update 2016) in response to the enactment of SGMA. The update was necessary because SGMA established a basin boundary modification process through emergency regulations that allowed local agencies to request that DWR modify basin boundaries. CalGW Interim Update 2016 identifies 517 basins and subbasins.

In addition, DWR updated the method for assessing critical conditions of overdraft and identified 21 basins subject to critical conditions of overdraft. The method used

for identifying basins subject to critical conditions of overdraft and the results of the analysis are published in CalGW Interim Update 2016.

A detailed history of CalGW with reference to major legislative actions is provided on DWR's CalGW webpage. Figure 1-4 shows the chronology of the California's Groundwater series and the number of groundwater basins and subbasins identified in each published report from 1952 through 2020.

Figure 1-4 Number of Groundwater Basins Identified in California's Groundwater Updates



California's Groundwater Update 2020

California's Groundwater Update 2020 (CalGW Update 2020) is the first comprehensive update of California's Groundwater since 2003. It builds on the strong foundation of previous California's Groundwater reports and *California Water Plan Update 2013*. CalGW Update 2020 formalizes and reports the subsequent 2018 basin boundary modifications and basin prioritization results from 2018 and 2019.

Figure 1-5 shows the current 515 groundwater basins and subbasins in California based on the 2016 and 2018 basin boundary modifications. For additional information on the hydrologic regions and groundwater basins, see Chapter 7, "Groundwater at a Glance: Hydrologic Region Summaries" and Appendix H, "Hydrologic Region, Basin, and County Data."

Figure 1-5 California Groundwater Basins and Subbasins



CalGW Update 2020 inventories, assesses, and reports on data gaps; presents findings and recommendations; discusses groundwater management and SGMA-related activities; evaluates statewide and regional groundwater use, supply, and well infrastructure; describes groundwater monitoring efforts; and assesses groundwater conditions using the best available data as of the end of 2018. Also, for the first time, CalGW Update 2020 discusses topics such as water markets, water transfers, managed aquifer recharge, climate change, non-basin areas, and drought resiliency.

CalGW Update 2020 is accompanied by the release of a new online, content-rich platform called CalGW Live. CalGW Live provides a simple, user-friendly interactive experience that allows users to explore both real-time groundwater information and information presented in CalGW Update 2020.

California's Groundwater Updates 2025 and 2030

California's Groundwater Update 2025 will include many of the topics developed in CalGW Update 2020, with updated data and information. Much of the newer data and information will be obtained through the groundwater sustainability plan (GSP) submittals, annual reports and data uploads from groundwater sustainability agencies (GSAs), California Statewide Groundwater Elevation Monitoring (CASGEM), and watermasters in basins with adjudications. DWR will continue to collect, compile, and analyze data and information from basins and non-basin areas that are not subject to SGMA compliance.

California's Groundwater Update 2030, and future five-year updates, will continue to compile and summarize the status of SGMA groundwater management as well as summarize the groundwater data and information submitted by GSAs, watermasters, CASGEM monitoring entities, and DWR. This will be accomplished through staff research and analysis and online applications to collect, analyze, and present information on a statewide basis and by hydrologic region, basin, and non-basin areas.

Future Basin Reports

In 2003, DWR developed a basin report for each of the 515 groundwater basins and subbasins. These reports, which are available on the CalGW webpage, contain descriptions of the boundaries, geology, hydrology, groundwater development, water budget information, water quality, and other related content.

While not part of CalGW Update 2020, DWR is updating and expanding the format of the basin reports to incorporate the additional data that will become available during SGMA implementation and from other groundwater programs. As the updated basin reports become available, they will be accessible on the CalGW webpage.

California's Groundwater Data Availability

DWR's CalGW webpage provides access to current and historical groundwater documents and current basin boundary geographic information systems (GIS) data. The current and historical documents that are available at the time of this publication can be viewed on-line or downloaded from the website. Some documents are only available upon request. All data used in this report are available on the California Natural Resources Agency's (CNRA's) Open Data web portal or other sites as identified. Data collection and analysis will continue after CalGW Update 2020 is published. These data and analyses will be posted on the CNRA's Open Data web portal as they become available.

Organization of California's Groundwater Update 2020

CalGW Update 2020 is organized as follows:

Highlights

A stand-alone summary document describing value and state of groundwater in California with findings and recommendations.

Chapter 1. Introduction (this chapter)

Chapter 2. Groundwater: Occurrence, Economic Value, Climate Change, and Policy

This chapter introduces a few of the key concepts discussed in this report: aquifers, hydrologic regions, basins, non-basin areas, the economic value of groundwater; and climate change, including drought.

Chapter 3. Groundwater: Use, Extraction, and Water Budgets

This chapter reports on the groundwater and surface water use for agricultural, urban, and a subset of environmental uses referred to as managed wetlands uses, both statewide and within hydrologic regions. This chapter also discusses water use

data for basin, non-basin, agricultural, and urban areas. Groundwater extraction in production wells is analyzed at the statewide, hydrologic region, basin, and non-basin area levels.

Chapter 4. Groundwater Management

This chapter reviews the legislation and programs that were in place to encourage local groundwater management prior to SGMA. There is an overview of SGMA programs, activities, technical assistance, and funding opportunities that are available to local agencies. To complete the groundwater management overview, there is information on other State and federal agencies that have programs and activities to support SGMA and local agencies.

To support the groundwater management programs there are additional discussions in this chapter concerning emerging groundwater markets, water transfers that benefit the supply imbalances around the state, and conjunctive management with managed aquifer recharge.

Chapter 5. Groundwater Monitoring

Groundwater monitoring is key to successful groundwater management. This chapter provides detailed information on the groundwater monitoring throughout the state, including monitoring of groundwater levels, groundwater quality, land subsidence, groundwater and surface water interaction, and seawater intrusion.

Chapter 6. Groundwater Conditions

This chapter provides an overview of the groundwater conditions throughout the state, including an extensive analysis of groundwater levels, groundwater quality, and land subsidence.

Chapter 7. Groundwater at a Glance: Hydrologic Region Summaries

Using much of the data that are reported in the first six chapters, the hydrologic region summaries provide brief, data-rich summaries for each of the 10 hydrologic regions. The summaries include details concerning water use, groundwater management, production well infrastructure, groundwater monitoring, groundwater conditions and local assistance in each hydrologic region. This chapter is being made available as a separate document.

Appendix A. Findings and Recommendations

This appendix provides a list of all findings and recommendations included in the highlights document.

Appendix B. Glossary

This appendix provides a list of key groundwater terms and definitions found in CalGW Update 2020.

Appendix C. Methods and Assumptions

This appendix provides the details on methods and assumptions that were used to create the figures and tables in CalGW Update 2020. These methods and assumptions focus only on new data and analysis. Figures and tables are briefly discussed along with the datasets used to create them, where applicable.

Appendix D. Citations, Reference Materials, and Links

This appendix contains the citations identified throughout CalGW Update 2020 and a comprehensive list of recommended additional reference material and data. This appendix may be updated periodically to reflect new information.

Appendix E. Groundwater Basics

This appendix is an online interactive story map that provides some basic information on groundwater to help readers understand the concepts and data presented in CalGW Update 2020.

Appendix F. Hydrologic Region Basin Maps with Basin Tables

This appendix contains a complete list of basins in each of the 10 hydrologic regions along with hydrologic region maps to aid the reader in locating individual basins and subbasins.

Appendix G. Water Use Data

This appendix contains supplemental water use data that were used in processing of the information presented in Chapter 3, "Groundwater: Use, Extraction, and Water Budgets," and elsewhere in CalGW Update 2020.

Appendix H. Hydrologic Region, Basin, and County Data

This appendix contains supplemental hydrologic region, basin, and county data.

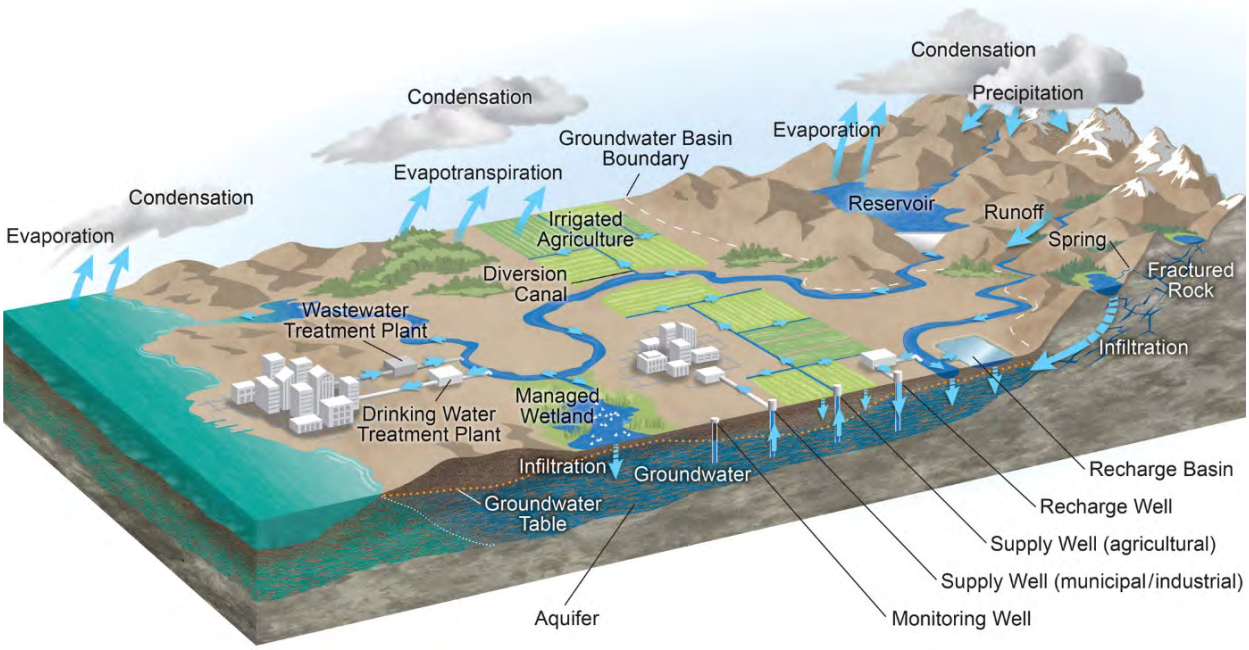
Chapter 2. Groundwater: Occurrence, Economic Value, Climate Change, and Policy

Introduction

Groundwater is the water that occurs beneath the Earth's surface in rocks or sediments that are saturated. Given that all rock has some voids, groundwater can be found in varying amounts underlying nearly any location in California.

Groundwater is an important part of the hydrologic cycle in which water continuously cycles from the atmosphere to the Earth's surface and subsurface, and then back to the atmosphere (Figure 2-1).

Figure 2-1 The Hydrologic Cycle



Groundwater resources play a key role in sustaining California's communities, farms, and ecosystems. An estimated 40 million people live in California (California Department of Finance 2019). Most of the population rely on groundwater for at least a portion of their water supply. Some communities in California use very little

groundwater, while many communities are 100-percent reliant on groundwater for all their water needs. California is also home to one of the largest and most important agricultural areas in the world (i.e., the Central Valley), which relies on groundwater resources to maintain its economic prosperity. Groundwater will continue to play a vital role in meeting the needs of California's urban areas, irrigated agriculture, and the environment. The challenges will come from changes in land use, population, water allocations, and climate.

The volume of groundwater used in California varies from year-to-year depending on many factors including climate conditions, local weather, cropping patterns, and availability of surface water supply. On average, from 2002 through 2016, 41 percent of California's total water supply was groundwater. In 2015, when agricultural users turned to groundwater as a "drought buffer" to supplement their surface water supplies, groundwater was 58 percent of the total supply. Even during wet years, such as, 2005, groundwater was 30 percent of the state's total water supply.

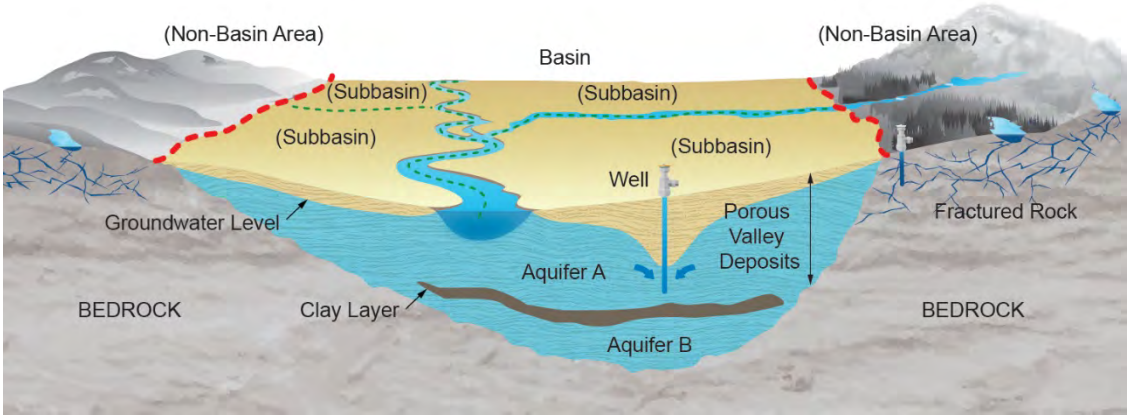
This chapter includes discussions on the occurrence of groundwater; groundwater basins and non-basin areas, including Tribal lands and location of disadvantaged communities; the economic value of water; and how climate change might affect groundwater resources.

Where Groundwater Occurs in California

California's groundwater can be described at different scales: aquifer, basin, subbasin, non-basin area, or hydrologic region. While each of these terms has a general definition, California has created legal definitions for aquifer, basin, and subbasin for the purposes of sustainable groundwater management. Figure 2-2 shows the spatial relationship among aquifers, basins, subbasins, and non-basin areas.

This section describes, with respect to the California Water Code and Basin Boundary Regulations, terms and concepts related to groundwater occurrence and movement. Further, this chapter explores how land use influences where and when water is used in California and provides a detailed discussion of how California's precipitation, droughts, climate change, and groundwater policy can significantly influence groundwater use.

Figure 2-2 Spatial Relationship Among Aquifers, Basins, Subbasins, and Non-basin Areas



Aquifers

An aquifer, as defined in Title 23 California Code of Regulations Section 341(f), is:

> "A three-dimensional body of porous and permeable sediment or sedimentary rock that contains sufficient saturated material to yield significant quantities of groundwater to wells and springs."

Rocks that do not readily store and transmit water are called aquitards.

Sediment or sedimentary rock aquifers typically are capable of storing significant quantities of groundwater. These aquifers are usually formed by stream-deposited alluvium which is composed of layers of sand and gravel interspersed within fine-grained sediments. Additionally, basin deposits can contain aquifers with sediments that were deposited via lacustrine (lake) or marine settings. An aquifer can span an entire basin (see "Groundwater Basins" section below) or extend beyond the basin. Many larger or deeper basins have multiple aquifers that are separated by impermeable to semi-impermeable aquitards or faults.

Aquifers exist under both unconfined and confined conditions. Unconfined aquifers are those into which water seeps from the ground surface directly above the aquifer through unconsolidated sediments. Confined aquifers are those in which an aquitard layer impedes water from seeping into the aquifer from the ground surface located directly above. Instead, water seeps into confined aquifers from farther away where the aquitard layer does not exist.

Groundwater Basins

In California, most major aquifers are found in groundwater basins. The concept of a groundwater basin was first introduced around the turn of the 20th century as California's population and agricultural industry were rapidly expanding and becoming more reliant on groundwater. Over the next half-century, the understanding of, and reliance on, groundwater basins in California grew, which led to the release the first official list of groundwater basins in 1952 (California Department of Public Works 1952). Since then, DWR, working with other local, State, and federal agencies, has intermittently updated the definitions, boundaries, and locations of California's groundwater basins in various updates of California's Groundwater. The definition of a groundwater presented here was developed to further the objectives of the Sustainable Groundwater Management Act (SGMA), as such, a groundwater basin, as defined in Title 23 California Code of Regulations Section 341 (g)(1), is:

> "An area specifically defined as a basin or 'groundwater basin' in Bulletin 118 [California's Groundwater] and shall refer generally to an aquifer or stacked series of aquifers with reasonably well-defined boundaries in a lateral direction, based on features that significantly impede groundwater flow, and a definable bottom, as further defined or characterized in Bulletin 118."

Lateral boundaries are features that significantly impede groundwater flow. Those features can include rock or sediments with relatively low permeability or a geologic structure, such as a fault. The definable bottom of a basin can be based on physical properties such as rock or sediment with very low permeability. Another approach is using the geochemical properties of the groundwater. This approach uses the specific total dissolved solids levels outlined by the U.S. Geological Survey (USGS), the U.S. Environmental Protection Agency, or the State Water Resources Control Board. Although only the upper surface of a groundwater basin can be readily mapped, the basin is three-dimensional and includes all subsurface fresh-water-bearing material. These boundaries often do not extend straight down but are dependent on the spatial distribution of geologic materials or water quality in the subsurface (Figure 2-2).

As of 2020, 424 basins (Figure 2-3) are designated. California's groundwater basins and subbasins underlie almost 62,000 square miles, or 42 percent, of California. Approximately 82 percent of the state's population and 97 percent of the state's

agricultural lands overlie groundwater basins (California Department of Water Resources 2019a).

Figure 2-3 California's 515 Groundwater Basins and Subbasins



Subbasins

A groundwater subbasin, as defined in Title 23 California Code of Regulations Section 341(g)(2), is:

> "An area specifically defined as a subbasin or 'groundwater subbasin' in Bulletin 118 [California's Groundwater] and shall refer generally to any subdivision of a basin based on geologic and hydrologic barriers or institutional boundaries, as further described or defined in Bulletin 118."

Subbasin boundaries are established using geologic features such as faults or rock-type contacts; hydrologic features such as rivers; geomorphic features such as topographic changes; or jurisdictional boundaries such as county, water district, or city boundaries (Figure 2-2).

As described above, there are 424 groundwater basins and 30 have been divided into 121 subbasins that make up the 515 groundwater basins and subbasins in California (Figure 2-3). The largest group of subbasins is in the Central Valley, which is comprised of three groundwater basins: the Sacramento Valley, San Joaquin Valley, and Redding Area. The surficial expression of the basin boundaries has been divided, primarily along physical or jurisdictional boundaries, into 40 subbasins.

Basin Boundary Descriptions

A detailed description for each of California's basins and subbasins was completed in 2003. Since 2003 and prompted by SGMA, two rounds of basin boundary modifications have occurred and resulted in general basin boundary adjustments for more than 100 basins and subbasins. Detailed basin reports are being updated and are expected to be completed over the next 5 to 10 years.

Non-Basin Areas

Any area outside of a defined groundwater basin or subbasin is referred to as a non-basin area. Non-basin areas consist of impermeable granitic, metamorphic, volcanic, or sedimentary rocks, where groundwater is found in fractures or other voids (California Department of Water Resources 2013).

In groundwater basins, groundwater occurs and moves through pore spaces in unconsolidated sediments or porous sedimentary rocks, where the porosity and hydraulic conductivity are high enough to allow groundwater to be readily available

and reliable. In contrast, groundwater in non-basin areas occurs and is transmitted through connected fractures and through cavities formed by dissolution of the rock. But not all fractured-rock conduits are connected to allow groundwater flow. Additional details on the non-basin hydrology are provided below.

History of Non-Basin Areas and California's Groundwater Update

California's Groundwater (CalGW) 1975 and CalGW updates in 1980 and 2003 are primarily focused on characterizing groundwater basins, where most of the groundwater production in the state occurs. These updates describe California's non-basin areas in a general sense, acknowledging their occurrence and local importance as a water source for domestic use, agricultural, municipal, and industrial users, and the natural environment.

The CalGW 1975 broadly describes groundwater that occurs in non-basin areas, such as the groundwater-bearing volcanic rocks in the northeast portion of the state, northeast of San Francisco Bay, and along the eastern side of the Central Valley. Groundwater in fractured rock is acknowledged as occurring in many upland areas of California, where "fractures and other spaces in harder rock formations yield small quantities of water sufficient for a domestic supply for an individual home or for stock water" (California Department of Water Resources 1975).

CalGW Update 1980 recognizes the local significance of non-basin groundwater and that a growing number of wells are in the foothills of the Sierra Nevada, outside of identified groundwater basins. The public outreach process that accompanied the draft release of the update made DWR aware of potential issues, including "the water-quality and well-yield problems caused by excessive pumping in some non-basin areas, such as the Sierra-Nevada foothills." It is also noted that in non-basin areas "well yields diminish during the late summer months because ground water storage is limited to the cracks and fissures in the underlying formations" (California Department of Water Resources 1980).

CalGW Update 2003 (California Department of Water Resources 2003) provides more details about, and examples of, groundwater in non-basin areas. This update refers to non-basin areas that provide groundwater as "groundwater source areas." Significant volcanic groundwater source areas are identified and recommendations for furthering the understanding of non-basin areas are made. CalGW Update 2020 builds upon past updates to present additional information on non-basin areas.

Statewide Overview of Non-Basin Areas

Groundwater is extracted from non-basin areas throughout California, including the fractured rock areas of the Sierra Nevada, Coast Ranges, and Peninsular Ranges; the volcanic formations in Northern California; and the carbonate formations in Southern California. Approximately 60 percent (61,663,897 acres) of California is non-basin area (Figure 2-4), yet groundwater extraction in this area accounted for only 5.7 percent, or approximately 1.3 million acre-feet, of the state's total groundwater extraction in 2014. In some non-basin areas, groundwater serves as the principal water source (Page et al. 1984). Nearly all groundwater extracted in non-basin areas comes from rock fractures. One exception is in the Sierra Nevada foothills where there are small and thin deposits of alluvium (often associated with meadows as shown in Figure 2-4), but they often do not yield the quantities of water necessary for domestic water supply. In these areas most groundwater production is from rock fractures below the alluvium.

The full extent and groundwater capacity of these areas remains unknown. Non-basin areas comprise more than half the area in eight of the 10 hydrologic regions in California. The two exceptions are the South Lahontan (nearly half the area) and Colorado River (less than half the area) hydrologic regions.

Unlike most groundwater basins, groundwater storage and production capacity in non-basin area rocks is difficult to quantify because of the irregular, and often non-linear, fracture variability that exists both laterally and vertically. Further investigation, data evaluation, and management is likely needed to ensure future sustainable supplies of fractured rock non-basin groundwater for all users.

Figure 2-4 Extent of Non-basin Areas in California



Source: University of California, Davis 2017

Fractured Rock

The conduits that hold and allow groundwater to move in non-basin areas are most commonly fractures (Figure 2-2). Fractures are planar discontinuities that occur at every scale (microscopic to macroscopic) and quantity (few or many may exist). Groundwater movement within fractured rock non-basin areas can be highly variable from place to place, as the availability and transmission of groundwater is controlled by the orientations and conductive properties of fractures (Ferrill et al. 1999). Plutonic igneous rocks, such as granite, form at great depths and under tremendous pressures. As these rocks are exhumed and overlying rocks are eroded away the pressure on the rock is reduced, allowing the rock to expand and subsequently fracture, making space for water.

Groundwater supply wells in fractured rock non-basin areas are designed to intercept water-bearing rock fractures. But specific conclusions about groundwater availability in fractured rock non-basin areas may not be possible because the fractures are not always interconnected or continuous and may become smaller with depth (California Department of Water Resources 1980). Ultimately, the reliability, volume, and recharge of groundwater in fractured rock non-basin areas is dependent on precipitation; rock type; and the geometry, density, interconnectedness, and extent of fractures in the rock.

Volcanic Formations

Over the last 2.5 million years, volcanic eruptions and lava flows have deposited extensive amounts of volcanic rocks throughout California. The hydrologic properties of these rocks can vary widely depending on volcanic rock type and the depositional environment. Rock types include basalt lava flows, rhyolite welded tuffs, and ash bed deposits. The formation of lava tubes, faults, cooling joints, and layering of volcanic deposits can result in conduits capable of storing and conducting groundwater. For a basalt lava flow, permeable zones can develop at the top and bottom of the flow where broken basalt rubble forms as the flow is deposited. Later, the movement of groundwater though a stack of cooled lava flows commonly occurs through cooling joints and in the rubble zones that exist between individual lava flows (Planert and Williams 1995).

In northeastern California, volcanic rocks cover much of the landscape where widespread volcanism and lava flows have occurred in recent geologic history. There are also groundwater basins in the area partially or completely underlain by volcanic rocks that may function as the principal source of groundwater. Other areas, such as Fall River Valley, operate as a spring-fed system of rivers and lakes, with groundwater

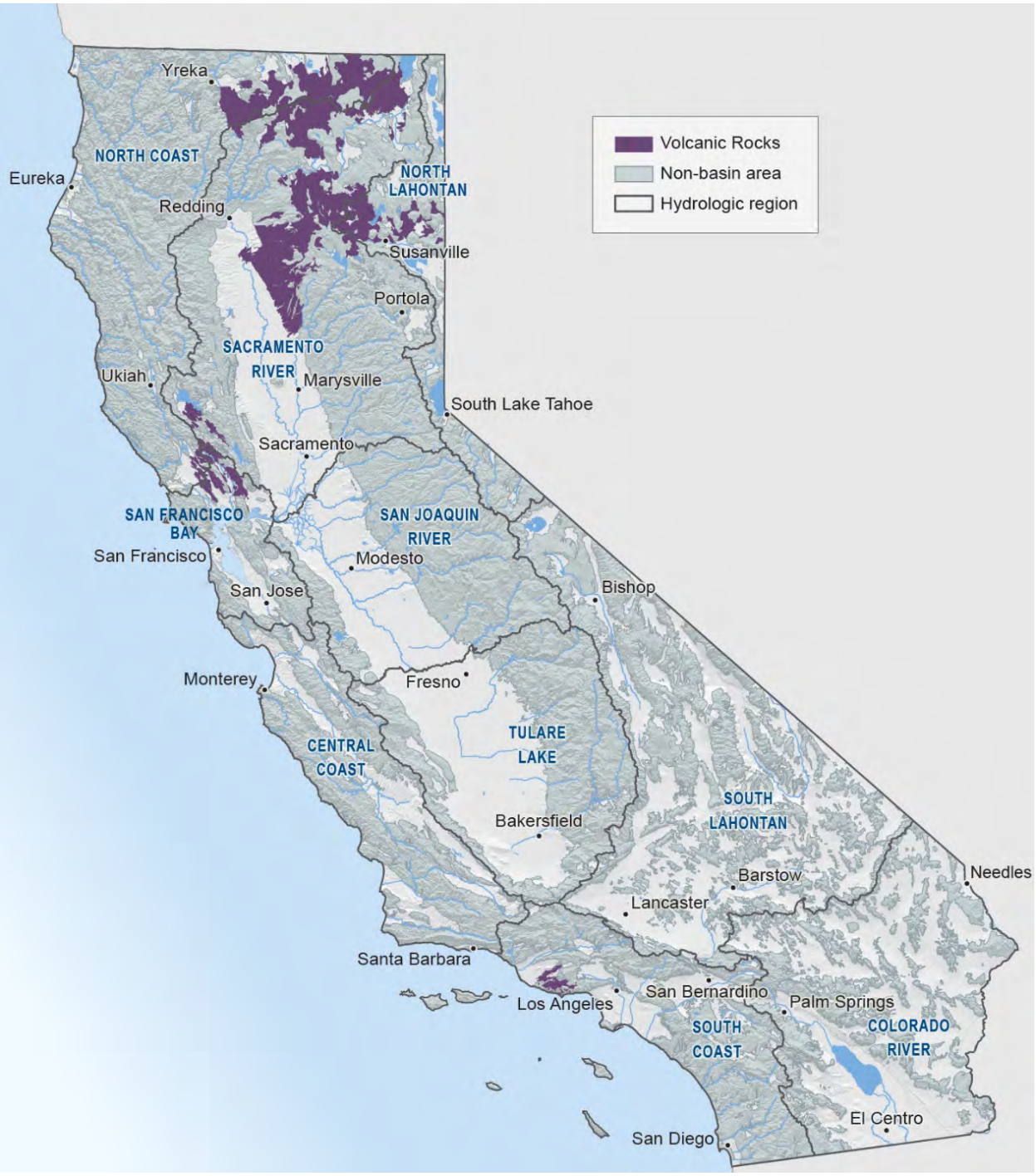
originating in the volcanic formations of the Medicine Lake Volcano area (Davisson and Rose 2014). Large volume springs in Northern California provide a significant component of the base flow to the Upper Sacramento, McCloud, and Pit rivers. These rivers contribute nearly half of the inflow to Shasta Lake annually (Davisson and Rose 2014). Figure 2-5 shows the approximate location of the volcanic deposits discussed here plus those that can be found in Northern California's Napa, Sonoma, Solano, and Lake counties and in Southern California along the boundary between Ventura and Los Angeles counties.

Carbonate Formations

Voids, or cavities, can occur within carbonate sedimentary rocks, such as limestone, because of dissolution of the rocks by slightly acidic water. Over time, voids can accumulate and connect, creating pathways for groundwater movement and storage. As noted in *CalGW Update 2003*, flow velocities in larger voids can reach high rates; but California's carbonate formations contain limited storage capacity.

The Amargosa Desert, in Inyo County, is underlain by limestone and dolomite. These carbonate rocks extend regionally across the state line into Nevada. These carbonate rocks have been estimated to store approximately 3.6 million acre-feet of groundwater (Burbey 1997) which supplies nearby springs, domestic well water users, native vegetation, and wildlife.

Figure 2-5 California's Significant Volcanic Areas as Defined in California's Groundwater Update 2003



Importance of Groundwater in Non-Basin Areas

Domestic Well Users

Typically, groundwater wells in non-basin areas yield quantities sufficient only for household uses. Reviews of well logs submitted to DWR indicate that wells extracting from fractures within non-basin areas yield less than 10 gallons per minute on average and frequently serve as the only water source for many rural households and some small communities. But, in other non-basin areas, such as the volcanic rocks of northeastern California, wells can yield as much as 4,000 gallons per minute (Planert and Williams 1995).

From 1977 through 2018, more than 140,000 well completion reports for production wells (domestic, industrial, irrigation, and public supply) from non-basin areas were submitted to DWR. Of the total production wells in non-basin areas, nearly 90 percent (130,000) are classified as domestic, compared to the about 71 percent of in groundwater basins. For more information on the statewide spatial density of domestic and irrigation wells, with completion reports submitted to DWR's Online System for Well Completion Reports, refer to Figures 3-8 and 3-9 in Chapter 3, "Groundwater: Use, Extraction, and Water Budgets."

Small Community Water Systems

In 2010, 6.8 million people, or about 18 percent of California's population, lived outside of designated groundwater basins (California Department of Water Resources 2019b). Water sources for residents, agriculture, and industry in these non-basin areas can vary, with users relying on surface water diversions, groundwater extractions, personal storage systems, or municipal water deliveries.

Most of the population in the non-basin areas is supplied by small community water systems, defined as having fewer than 3,000 connections. In its statewide report on drought risk and water shortage vulnerability, DWR determined that of the 662 small community water systems examined that serve populations in non-basin areas, 465 (70 percent) rely primarily on groundwater (California Department of Water Resources 2020). Figure 2-6 shows the location of small community water systems in fractured rock non-basin areas and indicates which systems are primarily reliant on groundwater (greater than 50 percent of total water supply is supplied by groundwater).

Figure 2-6 Small Community Water Systems in Non-basin Areas, Including Those Primarily Reliant on Groundwater



Meadow Ecosystems

California has approximately 30 million acres of federal-managed or State-managed parks, forests, and other wildland areas, 88 percent of these lands are in fractured rock non-basin areas. California's *Water Resilience Portfolio* (WRP) acknowledges the importance of these natural areas. Forests are identified as an asset to help California water systems adapt to climate change in more beneficial and durable ways than human engineering. Upper watersheds, in general, are also identified as natural assets that lend themselves to multi-benefit water projects and large-scale habitat restoration that can enhance community and economic resilience.

The fractured rock non-basin areas are predominately covered by native vegetation and are home to most of the state's wildlife. Many of California's large reclamation and reservoir water projects begin in the upper and middle watersheds of the fractured rock non-basin areas, where groundwater flow contributes to streamflow and ultimately helps to recharge downstream groundwater basins.

Nearly all the mapped meadows in California are in the fractured rock non-basin areas (Figure 2-4) of the Sierra Nevada and Cascade Range. Meadows are mostly native vegetation and typically found in the upper watersheds. When healthy, they function as local groundwater storage areas and contribute to the baseflow of nearby streams and rivers. But many of the state's meadows in the non-basin areas do not function as such largely because of impairment from human activities including cattle grazing, timber harvesting, and road building dating back to the mid-1800s (Crain 2007). There are efforts to improve grazing and management practices in meadows, which are helping restore the health of upper watersheds in California. The WRP has identified the importance of these natural systems and the need to further invest in restoration projects in the upper watersheds to protect water supply and quality. The portfolio's Action 11 supports the expansion of wetlands, including mountain meadows, to create habitat, filter runoff, buffer floods, and recharge groundwater.

Forest Ecosystems

During the drought of 2007–2009, insect infestation, disease, and dry weather led to the die-off of millions of trees throughout California's forests (Bentz et al. 2010; Goulden and Bales 2019; Moore 2018). The vast majority of dead trees are located in fractured rock non-basin areas. Although the long-term effects of millions of dead trees are yet to be fully understood, the increase in catastrophic wildfires in these areas over the last decade is evident. Wildfires in fractured rock non-basin areas have increased in frequency and intensity because of the combined effects of land

management, fire suppression, warming temperatures, dense vegetation, extensive tree mortality, climate-driven atmospheric moisture deficits, and increased development within the wildland-urban interface (Williams et al. 2019).

It is not clear whether there is a direct relation between groundwater and these tree die-offs, but progress is being made in identifying potential relations. Areas burned by intense high-temperature wildfires may affect fractured rock non-basin groundwater recharge rates because of reduced canopy cover, scorched hydrophobic soils with greatly reduced infiltration and water holding capacities, and increased volumes of runoff and erosion (Hubbert et al 2006).

Economic Value of Groundwater

Groundwater is a vital resource of California that fuels the state's economy and supports the natural environment. Valuing this resource is important for local, regional, and State water management purposes. Land use practices, climate change, population growth, and continued economic growth put pressure on surface water, environmental needs, and groundwater resources. As a result, water supply planning increasingly requires evaluation of tradeoffs among multiple uses and users of groundwater.

The values provided by groundwater vary substantially across different locations and uses; aggregate measures of value from a statewide perspective would mask that variability. But location and use-specific values can be developed for the purposes of water supply planning. Future water supply planning requires understanding of how key factors are likely to change the value of groundwater, jointly and individually, so that future water management is resilient and responsive to these changes. This section provides a summary of different types of economic value of groundwater, associated factors affecting the value of groundwater, and how to quantify them with various examples.

California's groundwater resource provides multiple benefits in various forms and locations, ranging from drinking water and irrigation for specialty crops to ecosystems and ecosystem services, water quality, dry-year water supply buffer, and conjunctive management. Groundwater benefits are spread across many users and uses, so quantifying them can present a challenge.

Groundwater will also need to be managed in the context of its overall value as a regional resource because an understanding of the economic value of groundwater provides a common basis for understanding tradeoffs among various water

management options within a groundwater basin. For example, if individual users only consider benefits to their own use and do not adequately consider the costs or reductions in benefits that their use imposes on other uses, individual decisions may result in overuse of groundwater in a basin and increase current and future costs on other groundwater users and uses in the basin. Sustainable groundwater management is based on the premise of groundwater as a shared resource within a basin and encourages all users to work together to optimize the economic value of groundwater with appropriate social and environmental safeguards.

Types of Economic Values of Groundwater

Economic values of groundwater can be described in the following broad categories:

- Use value is the value of groundwater reflected in its use by agriculture, cities, industries, the environment, and rural domestic users.
- Storage values are provided by groundwater stored in an aquifer and available to many users, and for many uses. Stored groundwater acts as a bank account for future water use. Other values of adding to storage are to reduce the costs associated with pumping by decreasing the distance pumps need to lift the water to the surface, impede or reduce seawater intrusion, and possibly prevent land subsidence. Moreover, stored groundwater can provide risk-offset benefits in the event of interruptions in surface water supply resulting from droughts, earthquakes, or other emergencies.
- System value is the value that can be achieved by using a groundwater aquifer as part of a broader water management system. It is the outcome of managing groundwater and surface water conjunctively, including storing flood water, storm water, or recycled water in an aquifer. System value is not a separate value from use and storage values, but rather is the additional use and storage values that the system can achieve over time from improved management.

The categories provide a useful framework for valuing groundwater but are not intended to be exclusive accounting quantities that can be added together to obtain a total value. Over time, these three types of values interact with each other. Stored groundwater now (providing storage value) yields a use value when it is pumped from storage later. System value is generated when use and storage values increase over time through conjunctive management of the groundwater and surface water system. For example, flood water diverted into groundwater storage provides benefits to the regional water management system, then the stored water provides one or more values, and subsequently provides value to an individual or the environment when it is extracted and used. In the following sections, the components

are described and quantified where possible – there is no attempt to add them together or provide a systematic accounting of values as they change over time within a groundwater basin.

Figure 2-7 illustrates total California water use, by surface water and groundwater during the five-year period, 2011–2015. Figure 2-8 splits that total groundwater use by agriculture, urban/domestic, and managed wetlands sectors from 2011 through 2015. In 2011, a wet year, groundwater was about one-third of the state's developed water supply, but by the last year of the four-year drought period, 2012–2015, more than half (58 percent) of the water supply was from groundwater.

As shown in the figures, groundwater use for agriculture accounted for nearly all the increase in use during the 2012–2015 drought years, more than doubling between 2011 and 2015. The figures illustrate two of groundwater's most important roles in supporting the state's population and economy: It provides an important source of water supply every year, and it is a reservoir of stored water that can be tapped during periods when annual surface supplies are cut.

Figure 2-7 Total Water Use by Surface Water and Groundwater (2011–2015)

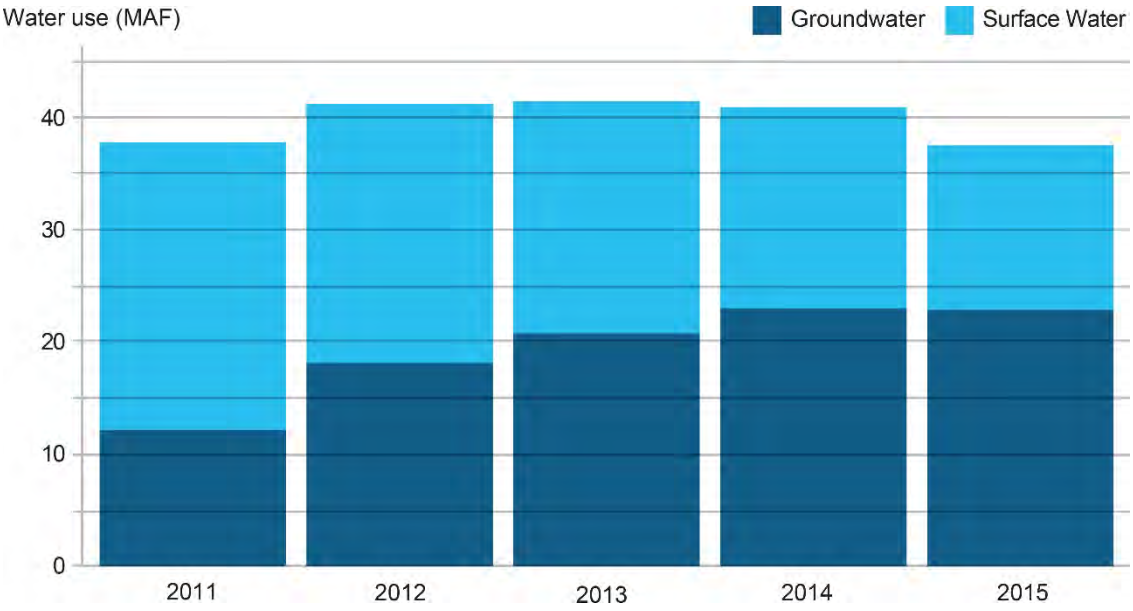


Figure 2-7 note: MAF = million acre-feet

Figure 2-8 Total Groundwater Use, by Type of Use (2011–2015)

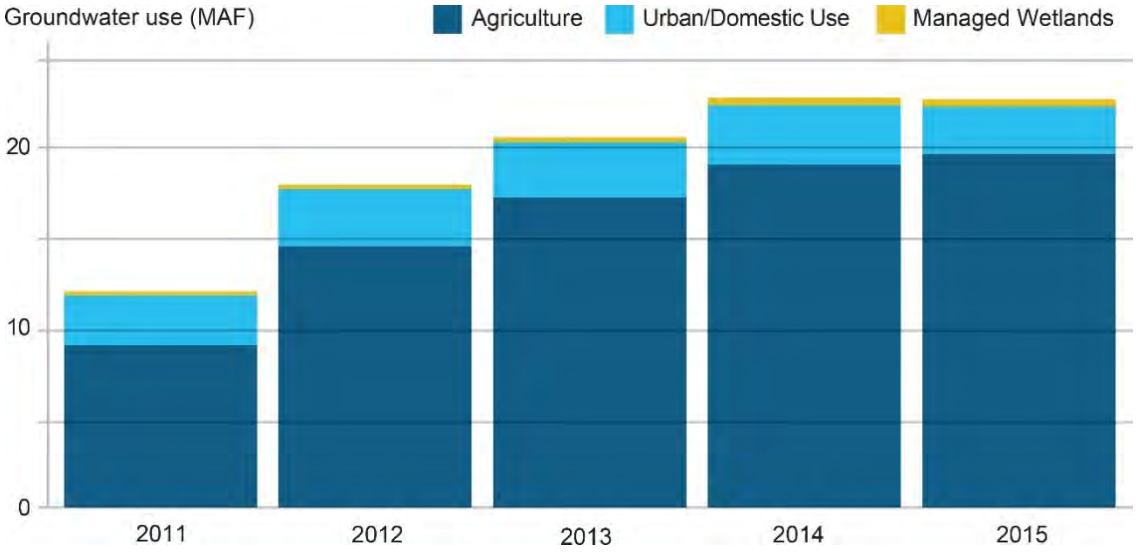


Figure 2-8 note: MAF = million acre-feet

Whenever total water use statistics are presented, as in Figure 2-7, it is important to understand that they can obscure important differences among smaller regions or localities. For example, some areas have no usable groundwater, so when they lose surface water during an extended drought, they either must purchase temporary water supply at high cost or implement extraordinary rationing. Some severely affected communities can lose access to water supply completely because of a dry reservoir or because of dry wells caused by declining groundwater levels. This underscores the point that the values provided by groundwater are specific to the location, timing, and situation.

Factors Affecting the Value of Groundwater

Groundwater value changes over time because of factors including water policy, system operation, and market conditions. For example, SGMA fundamentally changes groundwater users' access to groundwater in high- and medium-priority basins, changes in water system operations affect water availability to different users, and changes in agricultural commodity prices can change the value of groundwater. Careful hydrologic and economic analysis is necessary to quantify the different values of groundwater in the context of current and future conditions.

Changes in the economic value of groundwater are fundamentally driven by changes in the underlying supply and demand for the various attributes of water, including quantity, quality, and reliability. This section provides some examples of recent or anticipated changes and how they affect groundwater values in California.

Changes in the supply of water in general include short-term events, such as drought years, and long-term policy changes, such as changes proposed in the State Water Resources Control Board's water quality control plans. For groundwater, the most important change is the implementation of SGMA. How SGMA will be implemented varies by groundwater basin, but the fundamental conclusion is that the amount of groundwater that can be sustainably pumped may be less than current extraction in parts of many basins.

In areas where groundwater is conjunctively used with surface water, groundwater provides a stabilizing buffer that offsets variability in surface water supply. As surface water supplies become more variable, the value of groundwater increases as it provides an assurance of reliability of water supply. As climate change continues to affect water and other resources in California, the frequency and severity of surface water supply shortages are expected to increase, thus increasing the value of groundwater to get through these dry periods.

Changes in water demand also affect the value of water. Demand hardening describes the decreasing flexibility or willingness over time of water users to adjust their use of water in response to changes in conditions. For example, irrigating a permanent crop requires on-demand water supply in every year, so the cost of reducing acreage of a permanent crop during a drought is extremely high because the investment in growing plants to maturity may be lost.

Another driver of future water demand is population growth. Although gains in water efficiency and reduced per-capita use have partially offset demands from population growth in recent years, opportunities for further efficiency have been reduced and costs of water will likely increase, barring major technology breakthroughs. If population continues to grow, overall demand for domestic water will ultimately increase. In addition, the State has recently adopted policies establishing the human right to water. California law (Assembly Bill 685) has declared that every human being has a right to clean, safe, affordable, and accessible water adequate for human consumption, cooking, and sanitary purposes. In 2019, Governor Newsom signed Senate Bill 200 to provide funding to achieve the goal to "provide safe drinking water

in every California community, for every Californian." These policies may ultimately translate to demands for more reliable and higher-quality water.

Demand for water also changes as a result of the value of goods produced with that water. The value of agricultural water has increased recently in response to increased value of some crops. For example, in 2014–2015, the price of nut crops, in particular almonds, reached all-time highs. As the value of agricultural products increases, the value of water used to produce those crops increases. Similarly, increasing demand for water used to maintain environmental communities may decrease the available supply and increase the value of remaining water supplies, including groundwater, to provide those services.

Quantifying the Economic Value of Groundwater

The economic value of an item (water, in this case) is not a property that the item possesses, like mass, color, or genetic code. It is a relative measure, a description of how humans, individually or collectively, view water in relation to other things that they also value. Economic value is not simply what something costs in dollars, although that can be a very useful indicator. The standard way to explain economic value of a resource (e.g., groundwater) is through the idea of willingness-to-pay (WTP). A person, group, or society reveals the economic value of an item based on the other things of value it is willing to give up in order to get, keep, or protect the item in question. Payment need not take the form of actual currency in exchange for the item.

Economic value always depends on the context of value to whom, when, where, and under what conditions. Any quantification of economic value has these features, either explicitly or implicitly. Many goods or services, and especially natural resources like groundwater, provide a suite of values that vary according to the situation.

To quantify economic values, economists do not try to measure the WTP relative to physical quantities of all possible other goods or services. Rather, economists use a common unit of measurement, dollars, that allows relatively consistent comparisons across numerous other goods. Quantifying economic value in dollars is not perfect by any means and can be quite difficult to apply to some goods or services.

Economists use a range of methods to quantify the different types of groundwater value in different situations. Example methods commonly used by economists for establishing the value of water include statistical analysis of observed prices and transactions, optimization and simulation modeling of water used to produce crops

or other goods, methods based on avoided costs and alternative costs, and various indirect valuation techniques. Indirect valuation methods, such as hedonic pricing and survey techniques, are commonly applied to estimate the value of goods that are not explicitly traded in a market, including ecosystems and many ecosystem services. Ecosystem services refers to the ability of natural systems to provide a set of services and values, perhaps including wildlife habitat, recreation, open space amenities, and water quality benefits.

The methods listed above are applied in two general approaches to quantifying the economic value of groundwater: aggregate value approach and incremental value approach. Aggregate values correspond to broad regional measures that give a general sense of magnitude (importance) of groundwater. Incremental values are more relevant for project and planning purposes, corresponding to the additional value provided by groundwater in a specific use, situation, and location.

The Aggregate Value of Groundwater

Studies that measure the aggregate value of groundwater are sometimes called contribution analyses. These studies attempt to establish the total value of goods and services produced using groundwater in a specific region or sector.

The average value of water to a sector can be expressed as the output or net return of that sector per acre-foot of water used. As a result, the aggregate value of groundwater to that sector can be estimated by applying the share of groundwater used (as a fraction of total water used) to the sector's net return or total output, thereby attributing that share to groundwater. Measuring the aggregate value of groundwater in this way provides a sense of scale but it has several problems. First, not all groundwater use is equally productive within a sector. Second, this kind of calculation implies that all the net return or output of the sector is a result of a single input (water), even though all factors (e.g., land, labor, capital, management, environmental services) contribute to the output. Third, this approach does not consider that producers within a sector can adjust water use to reduce the effects of shortage.

A better method for quantifying the aggregate use value (contribution) of groundwater in a sector is to use an econometric or optimization model to calculate the change in net return or output that would result from a change in the amount of groundwater available. This approach acknowledges that groundwater is one of many inputs that are required to generate value (including economic output or environmental benefits) to a specific region. This type of aggregate groundwater

value provides a better sense of the scale of the importance of groundwater to the region.

The Incremental Value of Groundwater

A more useful way to describe and quantify the economic value of groundwater, especially for management and planning purposes, is the concept of incremental value, or what economists call marginal value. The incremental value is defined as the value generated by a small change in the amount of groundwater supply. For example, the incremental use value would be the additional net return to crops that would be produced, or the additional value of domestic water supply provided by an additional amount of groundwater.

From a regional or state perspective, net value of groundwater should also consider direct costs required to get the water from its source to its point of use, plus costs imposed on other uses like supporting streamflow or reducing seawater intrusion. In some cases, these third-party costs can outweigh the direct costs (to the pumper) of groundwater use.

Incremental value, like incremental cost, is used to make management and planning decisions. If a water agency is considering a new water supply investment to meet service area growth, or to avoid anticipated shortages, it compares (among other considerations) the incremental value (say, in avoided shortage) to the incremental cost of the new supply and to the incremental cost of other options like recycling or demand reduction activities.

Most goods that can be bought and sold in a well-functioning market tend to equalize in incremental value across users and areas in the form of the going market price. Groundwater is different because it is not easily traded in California because of numerous physical, institutional, and environmental restrictions. As a result, there can be large differences in the incremental values of groundwater across regions and uses.

Estimates of California Groundwater Values

The following sections provide examples of the use value, different types of storage value, and the system value of groundwater that are based on previously published reports and other data. The values cited include incremental, aggregate, and project-specific values, depending on how value was reported by the studies cited. Again, these examples may not apply to other regions and situations.

Use Value of Groundwater

The most prominent and obvious economic value of groundwater is associated with irrigation, domestic, and industrial uses. Agencies, businesses, and individuals pump groundwater to meet their current demands, provided they have the means and authority to do it and the incremental cost of pumping does not exceed the cost of other supplies and the additional benefit the water provides.

In regions with unmanaged access to groundwater, pumpers will extract water if its value in use exceeds the cost of pumping. If groundwater is expensive to pump (i.e., pumping lift is high), its use value must be high because only higher-valued uses can justify the incremental pumping cost.

It is difficult to generalize the use value of groundwater in California. Recent estimates of use value for agricultural purposes vary from less than $50 to more than $1,000 per acre-foot. But these values are expected to rise in basins where pumping will be most affected by the implementation of SGMA. The value of water for irrigation in regions of the Central Valley was estimated in a 2016 study based on early estimates of SGMA-imposed sustainable yield (California Water Commission 2016). The study indicated that the incremental value of water (i.e., the "going price" for water traded within a region) could double or more than double, especially in the San Joaquin River and Tulare Lake hydrologic regions, because they contain significant lands that rely on groundwater as both an annual water supply source and a water supply buffer against variable surface supply.

Values Generated by Stored Groundwater

Stored groundwater can generate different values. These values interact with the use and system values of groundwater. For example, the storage value of groundwater as an on-demand source of irrigation during droughts depends on the expected use value of that groundwater when it is extracted and applied to crops. As a result, these values are sometimes different ways of thinking about, and describing, the benefits of groundwater in different ways and at different points in time rather than separate, independent benefits that can be added together. The following subsections describe key storage-related values.

Water Supply Buffer Value

The stored groundwater in the aquifer generates storage value by providing a source of supply that is available in the future. Even if future weather, economic conditions, and surface supply were fully known and predictable, current use of stored

groundwater carries with it a loss of future value. The value of stored groundwater becomes even more important when it allows uncertain future conditions to be offset by dry-year pumping. This is known as the water supply buffer value.

In regions where groundwater is used conjunctively with surface water, and surface water alone is not enough to meet all human and environmental demands, the water supply buffer value of groundwater can be high. This is particularly true in agricultural regions dependent on variable surface water supplies. These regions use larger amounts of surface water in wetter years but switch their supply source to increased groundwater pumping in drier years when surface supplies are short.

As an example of the water supply buffer value, Figure 2-9 illustrates what occurred in the Tulare Lake Hydrologic Region between 2011 and 2015. Surface supplies were relatively abundant in 2011, but steadily declined over the next four years. Most of this reduction in surface water was offset by increasing groundwater pumping, with land fallowing and other agricultural production changes making up the balance of the reduction. Groundwater represented 31 percent of irrigation water in 2011, but that rose to approximately 90 percent of irrigation water by 2015 (California Department of Water Resources 2019b). As a result, groundwater supported the value of agricultural production during the extended drought, as shown by generally

Figure 2-9 Agricultural Water Supply and Value of Production in the Tulare Lake Hydrologic Region

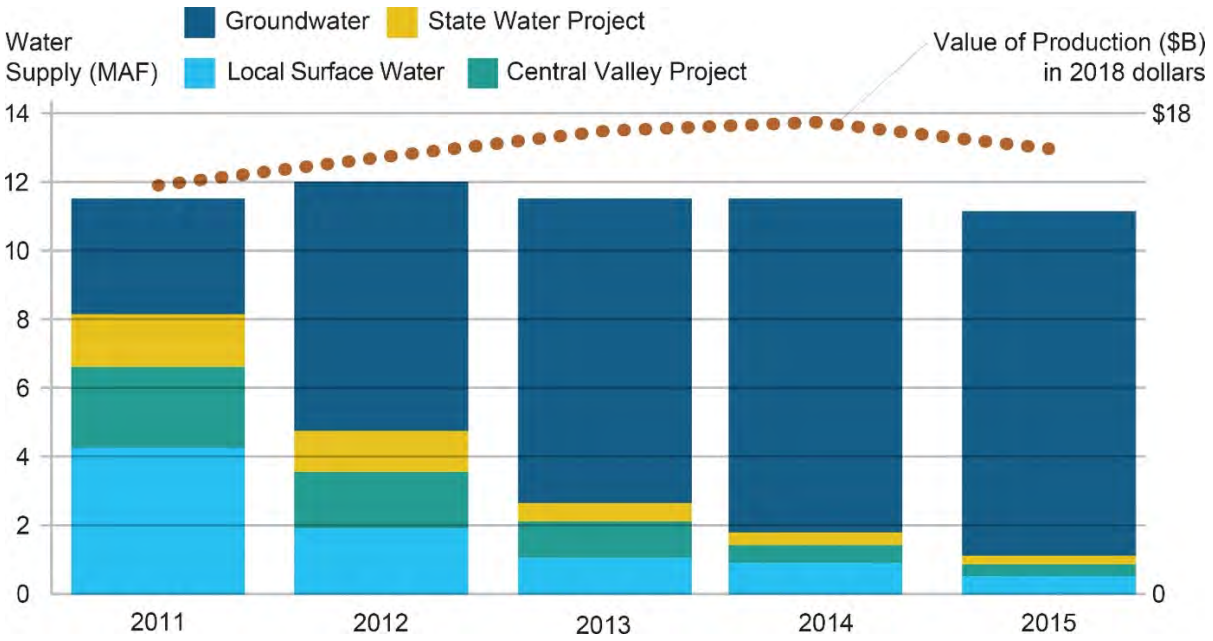


Figure 2-9 note: Calculations using U.S. Department of Agriculture's National Agricultural Statistics Service (U.S. Department of Agriculture 2012)

increasing agricultural value in the Tulare Lake Hydrologic Region. Strong agricultural prices and crop shifts played a dominant role in the rising agricultural values, but the ability to increase groundwater use enabled that rise.

Pumping Lift Reduction Value

Stored groundwater generates a pumping lift reduction value by maintaining higher groundwater levels which reduces the energy required for a well pump to lift groundwater out of the aquifer. An acre-foot added to (or left in) the groundwater provides a small increment of cost saving to all users withdrawing water from the same aquifer. The cost saving depends on physical properties of the aquifer, the design and efficiency of the wells and pumps, and the cost of power to run the pumps.

As a simple example for an unconfined aquifer, assuming a typical aquifer storativity of 20 to 30 percent, recharging 1 acre-foot of water volume to a 1-acre soil column would raise the groundwater elevation (and as a result, reduce the pumping lift) by between 3.3 and 5 feet. The total cost savings depends on the cost of power and efficiency of pumping, but a representative range in cost savings in pumping during the subsequent year could be $1 to $6 per acre-foot recharged. If that cost savings were maintained for an extended period, say 40 years, the present value could range from $20 to $120 per acre-foot recharged. This calculation assumes a one-time recharge of 1 acre-foot that is not subsequently pumped back out. The analysis would be similar if the recharge spread out over a wider area. The elevation rise, and so the cost savings per acre-foot pumped, would be much less, but the benefit would be spread over proportionately larger acreage and volume of subsequent pumping.

Ecosystem Services Value

Stored groundwater generates ecosystem services value when groundwater interaction with surface water and vegetation supports a range of ecosystems and ecosystem services, such as wetland habitat and streamflow for aquatic and riparian habitats. Estimates of the value of groundwater to these habitats can be large and are very site-specific. No comprehensive estimate of the value of restored groundwater for habitat support is available, though specific restoration projects are being evaluated.

A recent project in southern Sacramento County provides an example of the kind of benefits groundwater can provide. The project by Sacramento Regional Sanitation will provide highly treated recycled water for agricultural use in lieu of groundwater

pumping, allowing groundwater levels near the Cosumnes River to recover. The project received funding from the State for work that improved the value of the river flow to approximately $79 million and improved the value of several thousand acres of wetlands to approximately $74 million (Sacramento Regional County Sanitation District 2017). Both values were estimated as the alternative cost of providing flow or restoring wetland.

Rural Domestic Water Supply Value

Stored groundwater in an aquifer generates storage value by providing a source of supply that is available in the future, particularly in areas where other sources are more difficult to access. Groundwater is the only supply of drinking water in many rural parts of California. Dropping water levels and water quality concerns have made, or threaten to make, many domestic wells unreliable or unsafe.

During the recent drought, an estimated 3,500 domestic wells in the San Joaquin Valley went dry and even more wells experienced impairment of function caused primarily by the overdraft of groundwater (Public Policy Institute of California 2017). Similar problems affected some municipal and industrial suppliers. Options for replacing that lost supply are expensive, including drilling new, deeper wells; extending local municipal water systems out to serve the more remote users; or even using water trucks to transport potable supply on a temporary basis.

Loss of drinkable water imposes an immediate hardship on the rural users, especially those in disadvantaged communities. Replacement costs vary greatly according to the design requirements of new wells and the distance from alternative sources of drinking water. In a recent draft groundwater sustainability plan, the cost to replace a typical small domestic well was estimated for planning purposes to be $25,000 (Madera County 2020). Maintaining a sustainable groundwater resource would avoid most, or all, these costs in the future.

Barrier Against Seawater Intrusion Value

Seawater intrusion into freshwater aquifers is a threat to coastal regions in California where extraction of groundwater exceeds recharge. Sea level rise worsens the threat as well. Seawater intrusion can be mitigated by injecting or otherwise storing enough freshwater to maintain a hydraulic barrier to intrusion. The prevention of seawater intrusion through groundwater storage or injection generates a storage value by protecting inland groundwater resources from increased salinity that could make them costly to treat or unusable. Some regions and agencies facing these problems

over many years are in the Salinas and Pajaro valleys, the Orange County Water District (OCWD), and the Los Angeles County Department of Public Works. The storage value of groundwater in preventing salinity intrusion can be estimated by taking the cost of prevention by additional groundwater injection, in-lieu water supplies, and pumping reduction incentives that collectively result in a barrier to saline intrusion and comparing it with the avoided cost of desalination of groundwater extracted from the basin under more saline conditions.

Statewide, several saline intrusion control projects have been operating for more than 40 years and, while extensive engineering and cost information exists, economic analysis of benefits is scarce. In cases where WTP estimates of the value are not available, alternative or avoided costs provide a useful lower bound of economic value per acre-foot of groundwater injected. For example, OCWD estimates its cost of stabilization operations in 2010 at nearly $900 per acre-foot, excluding all subsidies. In 2018 dollars, and allowing for some subsidies, the cost is well more than $1,000 per acre-foot injected at two seawater barriers. The economic value of the benefit was not estimated, but OCWD believes it is greater than the cost of its stabilization operations.

Land Subsidence Avoidance Value

Groundwater generates a storage value by maintaining higher groundwater levels which can assist in avoiding or minimizing land subsidence and associated damage to overlying infrastructure sometimes caused by groundwater extraction. Land subsidence can occur as groundwater is extracted from aquifers that include unconsolidated fine sediments. As water is pumped out, the sediments compact causing the land above to subside. In some cases, the loss of pore space cannot be reversed, resulting in a permanent loss of storage capacity and permanent subsidence. NASA recently estimated subsidence in some parts of the San Joaquin Valley of 1 to 2 feet between 2006 and 2011 (Borchers and Carpenter 2015).

Land subsidence can cause damage to and reduce the capacity of infrastructures including roads, power lines, water and sewer systems, canals, and flood control facilities. Few comprehensive analyses of the full costs of land subsidence have been published. A report prepared for the California Water Foundation compiled existing information about subsidence and its costs, drawing from studies by State and local agencies, USGS, and others (Borchers and Carpenter 2015). An earlier estimate of damages from subsidence in the San Joaquin Valley from 1955 to 1972 was $1.3 billion (in 2013 dollars), or an average rate of $76 million per year. This figure did not include all costs. Significant overdraft of groundwater has continued in the

San Joaquin Valley since 1972; meaning $76 million per year cost is likely to be an extremely low estimate. The same report notes a partial estimate for one-time repair and replacement because of cumulative subsidence in the Santa Clara Valley was $756 million (in 2013 dollars).

In addition to local water supply impacts, major water supply canals including the Delta-Mendota, Friant-Kern, and San Luis canals have been damaged or lost capacity because of subsidence. These impacts include loss of delivery capabilities for fish and wildlife habitats. A 2019 bill in the California Legislature that would have provided $400 million to repair or replace parts of the Friant-Kern Canal did not pass.

On-demand Irrigation Water Value

Groundwater generates a storage value by providing on-demand irrigation water and avoiding costs of alternative on-site water storage. Pressurized drip and sprinkler irrigation systems are increasingly used in California to reduce water use and improve application uniformity and yields. Groundwater provides an on-demand, local reservoir of irrigation water that is relatively free of debris and particles that can clog low-volume irrigation systems. The value of an on-demand, clean supply can be estimated as the alternative cost of an on-farm surface reservoir from which a grower could pump as needed to deliver filtered, pressurized irrigation. Cost estimates developed for the Imperial Irrigation District Efficiency Conservation Plan indicate that on-farm pond storage costs about $7 to $10 per acre-foot of water delivered over the pond's useful life (Imperial Irrigation District 2007).

System Value of Groundwater

One of the groundwater system's greatest contributions to the economic and environmental health of the state is its ability to store large amounts of water. Groundwater is, by far, the largest water storage reservoir in the state.

One example of the system value of the groundwater that has received much attention in recent years is the ability to capture flood flows either in dedicated recharge areas or by spreading onto existing crop fields. Diverting flood flow reduces the risk of flood damage and stores the water for future uses. This ability can improve the flexibility and performance of the entire surface and groundwater management system. DWR has initiated several programmatic evaluations of these system effects, including regional conjunctive operation and re-operation studies and the Flood-Managed Aquifer Recharge (Flood-MAR) program.

The Value of Groundwater for Water Planning

Uses and values of groundwater are often competitive – immediate extraction of groundwater for a beneficial consumptive use at the time of extraction reduces the availability of the water to provide other current and future values. Different types of values provided by groundwater over time can be increased by improved management that alters the mix of groundwater uses, their timing, and location. Estimating the value of improved management requires an understanding of how the groundwater system provides its portfolio of values for different uses over time.

Sustainable water management and climate change will challenge traditional patterns of water supply and management. Population growth, economic growth, and environmental needs will continue to compete for existing surface and groundwater resources. New supplies and methods to moderate or reduce per capita demands are increasingly costly. As a result, water supply planning increasingly requires evaluation of tradeoffs between multiple uses and users of groundwater, which can be accomplished with careful valuation approaches. In addition, future water supply planning requires understanding how key factors are likely to change the value of groundwater, jointly and individually, so that future water management is resilient to these changes.

Future water supply planning generally involves managing for incremental changes in supply and use. Quantifying the incremental economic value of groundwater provides a common basis for comparing tradeoffs and assessing current and future costs and benefits. Economic feasibility, financial feasibility, and cost allocation for multi-benefit projects are examples of groundwater-related studies that require quantification of value.

One of the most significant changes in California groundwater management that will affect groundwater values across the state is SGMA. Prior to SGMA, groundwater use was largely unmanaged in many parts of California. As a result, users have historically made decisions based on the current use value to them and had insufficient incentive to consider the additional storage and system values provided by groundwater. This led to overdraft in many parts of the state. SGMA requires management that avoids six specific undesirable results, but it allows for a 20-year transition period to achieve sustainability to allow time for local agencies to implement smaller and more manageable changes, including building new supply and recharge projects, or reducing pumping.

Decisions about local groundwater management in regions where groundwater is scarce are likely to require evaluation of tradeoffs. For example, allowing overdraft to continue for a period of years will allow irrigated agriculture to stay in production longer, supporting jobs and other industries in the subbasin, but will also cause groundwater levels to decline, which could affect groundwater dependent ecosystems, rural domestic wells, land subsidence, and future pumping costs. Quantifying the value of groundwater for these alternative purposes allows users and managers to compare relative costs and benefits of different approaches. This type of quantitative information can support agency and stakeholder-driven decision-making at the local agencies.

Flexibility in SGMA Implementation

Groundwater sustainability agencies (GSAs) developing groundwater sustainability plans (GSPs) in critically overdrafted subbasins may consider a range of projects to develop new sources of water supply. But the availability and cost of new water supply projects may limit economic and financial feasibility of these projects. Where agricultural uses are a significant share of groundwater use, it is likely that meeting sustainability goals would require a reduction in irrigated acreage. Implementing flexible management targets can reduce adjustment costs by allowing water users (usually growers in this example) to consider shifting their portfolio of crops, improving water use technologies and reuse, and, in some situations, reducing the consumptive use of water on certain crops. Growers facing groundwater sustainability limits will attempt to meet those limits in the least costly way. An example analysis recently completed for a region in the San Joaquin Valley suggests that a 20 percent reduction in water supply would result in a smaller percent reduction in irrigated acreage and an even smaller percent reduction in farm revenue (Bryant et al. 2020).

Flexibility in managing for sustainable yield reduces costs by including the use, storage, and system values of groundwater. Recognizing that groundwater is more valuable in dry and critical conditions, a sustainable yield management regime could increase allowable pumping in those years and reduce it in average or wet years. The variation could be accomplished either by the GSA varying the pumping amounts by year type or by the GSA allowing pumpers to manage their own pumping by carrying over pumping credits. Recognizing the value of groundwater under different hydrologic conditions allows users to make the best use of groundwater over time. A 2015 study commissioned by the California Water Foundation, *Modeling Groundwater Sustainability in the Kings-Tulare Lake Region* (California Water Foundation 2015), estimated that a sustainable pumping limit that varies by year type (higher limit in dry conditions and lower in average and wet conditions) could

substantially reduce the implementation cost to growers in areas that can conjunctively manage groundwater.

But flexibility in annual or seasonal pumping should be limited in cases where excessive drawdown or other third-party effects would result from excessive concentration in pumping. Similarly, markets for trading pumping allocations can improve flexibility and reduce total costs, but trading should have limits that prevent excessive, localized drawdown that can affect groundwater dependent ecosystems and domestic and agricultural wells. Informal or "bulletin board" trading markets in pumping rights may seem simple, but without such limits against excessive and localized drawdown, water markets are likely to result in social costs and litigation.

Benefits of Groundwater Management

To date, all assessments of the effect of SGMA on agriculture in the San Joaquin Valley have projected losses of irrigated land, value of production, and net returns during the early periods of SGMA implementation. But SGMA is designed to improve reliability of the entire groundwater system over an extended time (i.e., sustainability). A recent study in the Kings River basin (California Water Foundation 2015) showed that initial costs of groundwater control were offset by long term benefits to the use, storage, and system values of groundwater. It is important to acknowledge that aggregate improvement over the long term still allows for substantial costs to some uses and some locations in the near term. Flexible implementation that recognizes the different values provided by the groundwater system could help the state remain focused on the long-term vision and benefits of sustainable groundwater management.

Drought and Climate Change as Drivers of Groundwater Use

California's Climate

California's climate is dominated by Pacific storms and the numerous mountain ranges that cause orographic lifting of eastward-moving air masses. This lifting generates clouds and precipitation mostly on the western slopes and leaves a rain shadow on most eastern slopes. The Pacific storms can also deposit large amounts of precipitation in the form of rain on the northern coastal mountain ranges and accumulations of snow in the Cascade Range and Sierra Nevada during the winter months.

An important Pacific storm or weather phenomenon that occurs in California is the atmospheric river (AR). It is a flowing column of condensed water vapor in the

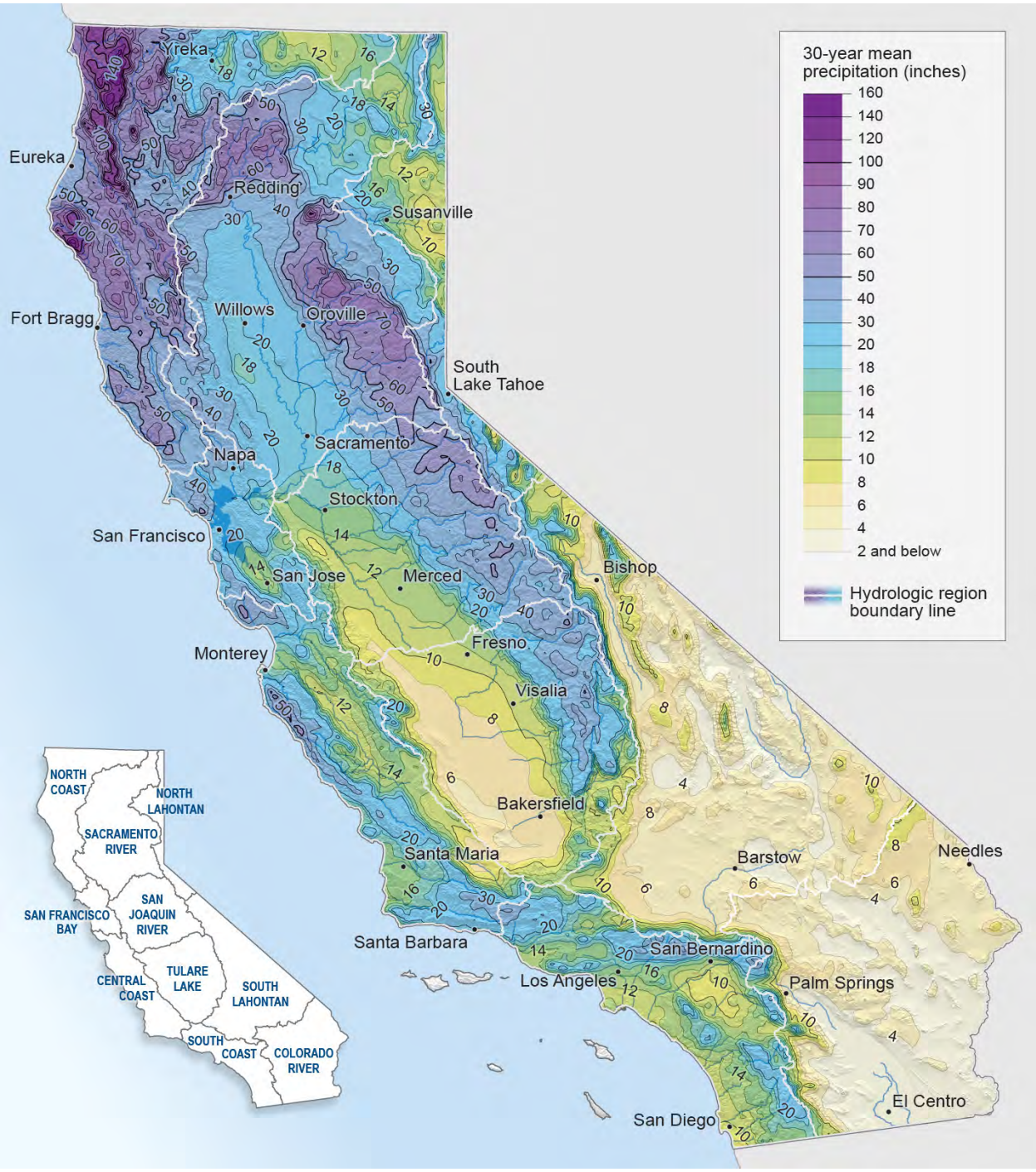
atmosphere responsible for producing significant levels of rain and snow, especially in the western United States. When ARs move inland and sweep over the mountains, the water vapor rises and cools to create heavy precipitation. Though many ARs are weak systems that simply provide beneficial rain or snow, some of the larger, more powerful ARs can create extreme rainfall and floods (National Oceanic and Atmospheric Administration 2020).

It is these storm events that determine where, when, and how much precipitation falls. The variability of the type and amount of precipitation drives much of the management and planning for surface water and groundwater. The precipitation that falls as rain is needed for reservoir storage, river diversions, and groundwater recharge. Snowpack provides late-season runoff for additional reservoir storage, river diversions, and groundwater recharge. Precipitation, and its timing, ultimately influences the availability of surface water deliveries, which in turn influences the amount of groundwater that is pumped or the number of acres that are fallowed.

The 2018 running 30-year (1989–2018) mean annual precipitation in California was approximately 23.2 inches. During this time, the range of annual rainfall varied from more than 83.2 inches estimated in 2018 in the North Coast Hydrologic Region to less than 3 inches estimated in 2002 in the South Lahontan Hydrologic Region (PRISM Climate Group 2018). Figure 2-10 shows the 30-year mean annual precipitation within California using contours.

To account for the differences between where precipitation occurs and where Californians live and grow food, local, State, and federal agencies created and maintain a large surface water conveyance system shown in Figure 1-2 (Chapter 1, "Introduction"). While the surface water infrastructure in California is extensive, it is important to note not all areas within the state have access to it and that surface water deliveries are highly variable based on reservoir storage and hydrologic patterns.

Figure 2-10 Statewide Precipitation Based on the 30-Year Mean (1989–2018)



Drought Cycles

Drought is a recurring feature of California's climate. Defining drought is challenging because it is based on effects to water users that vary by location. Dry hydrologic conditions that affect water users in one location may not affect water users in a different part of the state. Other criteria that may define the presence of drought conditions could include the following:

- Prolonged dry conditions.
- Low water supplies in reservoirs, snowpack, rivers, and groundwater basins.
- Conditions and solutions associated with the dry conditions are bigger than locals can handle.
- Lack of precipitation that negatively affects drinking water supplies, crops, farmer investment, agriculture employment, and ecosystems and wildfires risk.

Drought conditions generally develop at a relatively slow pace and effects can become multi-faceted over longer periods. Storage, whether in surface water reservoirs or in groundwater basins, buffers drought impacts and influences the timing of when drought impacts occur. A single dry year does not necessarily result in drought conditions for most Californians because the State's extensive system of water infrastructure and groundwater resources limit the effects.

Major droughts in California's recent history occurred during 1976–1977, 1987–1992, 2001–2002, 2007–2009, and 2012–2016. The severity of each of these droughts and the effects on groundwater basins varied because of differences in the timing, length, and degree of dry weather. During 2021, Governor Newsom declared a drought state of emergency in many of parts of California. For the latest information on this drought and the declarations, visit the California Drought Action website. The link can be found in Appendix D, "Citations, Reference Materials, and Links."

Drought Impacts on Groundwater Use

Groundwater and drought are interconnected. During a drought, farmers receiving reduced amounts of surface water often resort to short-term strategies such as fallowing land, purchasing water from others, and more commonly, increasing groundwater pumping, an unsustainable practice leading to serious long-term consequences, such as storage depletion, land subsidence, and water quality degradation. In addition, rural communities with high dependence on groundwater – mainly in the Central Valley – struggle to identify alternative water sources when their domestic wells go dry. Dry forest and vegetation conditions are also causing more

frequent and intense wildfires in recent years with lasting effects on watershed ecosystems and water quality.

The severity and effect of drought on groundwater use is influenced by many factors, including location, access to alternative water sources, ability to adapt to changing hydrologic conditions, surface water rights, and duration of drought. For example, if areas with a heavy reliance on surface water are subjected to reduced surface water deliveries, groundwater pumping may be increased to make up for surface water supply curtailment, resulting in lowered groundwater levels. Areas that are reliant on groundwater may also experience a lowering of groundwater levels caused by reduced recharge and increased pumping resulting from reduced precipitation.

Drought impacts are typically first experienced by people most dependent on precipitation to meet their water needs – such as ranchers using dryland range or rural residents relying on shallow wells in non-basin areas – where impacts to groundwater supply can occur more rapidly. In most groundwater basins, effects on groundwater supply resulting from drought are generally more delayed, occurring over periods of many years. Drought impacts can increase significantly in a multi-year drought, as carry-over supplies in reservoirs are depleted during consecutive years and groundwater levels exhibit steeper than normal rates of decline.

Generally, groundwater use in very dry regions can be more resilient to drought because there is less relative reduction in precipitation caused by droughts and lower water use in general. These areas are already rain-starved, so there is a limited need to increase groundwater pumping during droughts; as a result, effects on groundwater supplies are limited. Droughts are normally associated with higher temperatures, which can result in increased evapotranspiration rates and can result in increases in groundwater pumping for irrigation. This scenario excludes dry regions heavily reliant on imported water supplies, in which case an increase in groundwater use could occur if surface water supplies are reduced because of drought.

The factors that affect groundwater levels during droughts can occur in three general ways:

1. Irrigation water use can increase during a drought because of often coinciding warmer temperatures that result in increased evapotranspiration rates for crops and other vegetation. This increased demand can result in increased groundwater extraction.

2. Surface water supplies reduced during a drought lead to increased groundwater extraction. The increased extraction can be offset by fallowing cropland, shifting to crops with less water demand, or purchasing or acquiring surface water from other sources.
3. A significant reduction in groundwater recharge can occur during drought because of reduced water in the streams and rivers, reduced precipitation causing less direct infiltration, and reduced deep percolation of applied water resulting from increased irrigation water conservation and crop fallowing.

Each of these factors can have a different temporal effect on groundwater levels. Reduced groundwater recharge will likely be the most-delayed effect on groundwater conditions because of the time it takes for deep percolation to occur. Likewise, when a drought ends and increased precipitation leads to increased recharge, a similar lag response can occur; groundwater levels will not begin recovering for some time.

The groundwater level Mann-Kendall trend analysis in Chapter 6, "Groundwater Conditions," (Figure 6-5) shows that 65 percent of the groundwater levels monitored around the state are in decline. Increasing groundwater extraction, combined with reduced recharge caused by the reduced precipitation during the three most recent droughts that occurred within the analysis period (1998–2018), are placing local agencies in a difficult position to reverse the declining trends. There will be a need to increase recharge, naturally or artificially, increase the efficiency of the application of available water, or reduce the groundwater extraction to sustainable levels.

All other mechanisms of drought's effect on groundwater can be cumulative. It is important to recognize that each mechanism will have a unique effect, varying in degree of severity, from one region to another or within individual regions. Some effects will be more widespread than others and some will vary depending on local land-use practices and proximity to surface-water bodies or groundwater-pumping centers.

Lessons Learned from 2012–2016 Drought and the Role of Groundwater

During the 2012–2016 drought, increased groundwater extraction in the Central Valley resulted in a large groundwater storage decline, estimated to be between 10.3 million acre-feet and 25.2 million acre-feet (Chapter 6, Table 6-3). The increased groundwater extraction accelerated land subsidence in parts of the San Joaquin Valley. That resulted in damage to water supply and flood risk management infrastructure. Increased groundwater extraction by growers also contributed to the

drying of hundreds of wells used by individual families and small water systems. At the drought's peak, the State was spending about half a million dollars a month for bulk and bottled water delivery to these communities, including many that are entirely dependent on groundwater as a source of drinking water. Growers fallowed an estimated 500,000 acres of farmland, and the State delivered more than two million boxes of food to community food banks in counties with the highest drought-related unemployment that was caused by agricultural job losses related to drought. There was high fish mortality in some waterways and the state experienced massive tree mortality in the central and southern Sierra (California Natural Resources Agency 2021). Waterbirds and terrestrial wildlife also suffered from declining access to habitat and sources of food because of lack of water. In some areas of the state, dry conditions also have sent wildlife, such as bears, into residential areas in search of food.

Voluntary water transfer agreements among local agencies have long been in practice to mitigate the impacts of droughts. These water transfers involve groundwater transfers under the State's groundwater substitution program. Voluntary water trades are viewed as an effective drought response strategy, which can reduce the costs of drought. During the 2012–2016 drought, DWR did not operate a drought water bank or dry year water purchasing program, but it did convey water for transfers initiated by local agencies. DWR provided conveyance for 83,460 acre-feet of groundwater substitution transfers that occurred during 2013–2015. The Central Valley Project also facilitated 100,100 acre-feet of groundwater substitution transfers in 2014 and 2015 (California Natural Resources Agency 2021).

According to a 2021 California Natural Resources Agency report to the Legislature on 2012–2016 drought, "California's most significant historical droughts share some common themes and lessons. Historically, there have been important gaps in information or tools uniquely associated with drought: the ability to characterize statewide groundwater conditions, to predict whether the next months will be wet or dry (seasonal forecasting), and to improve resilience of small water systems and communities that do not have multiple water sources or are geographically isolated." (California Natural Resources Agency 2021). CalGW Update 2020 is a significant step toward making progress on obtaining and summarizing groundwater level data in both groundwater basins and non-basin areas, as well as providing easy data access to local and State agencies and individual users. Improved data and information on groundwater resources in groundwater basin areas and non-basin areas will help decision-makers develop a long-term statewide proactive drought response strategy consistent with the State's water resilience and sustainability goals. In addition,

climate change underscores the need for local investment in drought resilience and creation of contingency plans, where groundwater plays an important role as a provider of more than 40 percent of state's total water supply.

Climate Change

Greenhouse gas emissions from human activity have altered the Earth's climate. The effects observed since the mid-20th century, include warming of the Earth's atmosphere and oceans, declines in the amount of snow and ice, and rising sea levels (Intergovernmental Panel on Climate Change 2014). Globally, 19 of the 20 warmest years on record have occurred since 2001 (National Aeronautics and Space Administration 2020). In California, the 30-year period of 1990 through 2019 was the warmest on record with average annual temperatures rising by 1.2 °F to 2.3 °F since the mid-20th century (Western Regional Climate Center 2019).

By the end of the 21st century, California is projected to experience continued average maximum daily temperature increases of 5.6 °F to 8.8 °F, sea level rise from 1 foot to 10 feet, decline in springtime snowpack of 48 to 65 percent, and increasing heavy precipitation, drought severity, and area burned by wildfire (Griggs et al. 2017, Bedsworth et al. 2018). Reliance on historical hydrological patterns alone will no longer ensure successful management of California's water resources. Climate science, projections, and risk-based planning frameworks are critical tools for understanding the vulnerability of water resource systems and planning for the future.

Consistent with the growing acknowledgement of climate effects on California resources and infrastructure, California's latest water policy directive, the 2020 WRP, outlines strategies and actions to improve California's capacity to prepare for disruptions, withstand and recover from climate-related effects, and adapt into the future. Central to the portfolio is a recognition that the specific character and magnitude of climate change impacts will differ according to the nature and makeup of water supplies, environmental conditions, user needs, and vulnerabilities that vary widely across the state.

Where the portfolio emphasizes regional resilience, recent State legislation including Chapter 603 of Assembly Bill 1482 (Gordon, 2015) and Chapter 580 of Assembly Bill 2800 (Quirk, 2016) provide legal and policy directives to State agencies to consider climate-change impacts on investments of statewide importance. Implementation of these directives in connection with the WRP demands close

partnership between State agencies and regional and local entities to advance broad, multi-benefit projects critical to achieving water resilience.

Climate Change Effects on Groundwater

Climate and groundwater are dynamically linked across multiple timescales through hydrometeorological and hydrogeological processes. California persistently fluctuates between wet and dry conditions on an interannual basis and on scales of decades or more. Tree-ring-based reconstructions of California's past 1,100 years of hydroclimate (streamflow and precipitation) indicate extended periods (as much as 100 years) of average annual runoff of as much as 12 percent above and below 20th-century averages (Meko et al. 2014). The variability in the temporal and spatial distribution of precipitation in California is linked to multiple modes of climatic variability and affects the amount and distribution of streamflow and recharge to the state's groundwater basins. Consideration of longer-term fluctuations of groundwater levels associated with California's multi-decadal fluctuations in precipitation is crucial to the assessment of long-term supply and demand of the state's groundwater resources. For example, groundwater basins operated at the margins of sustainable yield might build capacity to capture streamflow for managed recharge during wet periods in anticipation of persistent dry periods when demands on groundwater supplies are at their highest.

Drought conditions in California are increasing in intensity and length (Diffenbaugh et al. 2010). Climate change is expected to amplify droughts in California because of rising temperatures (Cayan et al. 2010) and increasing interannual precipitation variability (Berg and Hall 2015, Yoon et al. 2015, Swain et al. 2018). Most climate model precipitation projections for the state anticipate drier conditions in Southern California, heavier and warmer winter precipitation in Northern California, and greater proportions of winter precipitation falling as rain instead of snow. Decrease in snowpack storage and the concentration of streamflow in winter months would increase dry-season deficits during periods of high irrigation-water demand. Higher sea levels necessitate release of more water from storage to meet Sacramento-San Joaquin Delta outflow and salinity requirements. The higher sea levels also threaten coastal aquifers with seawater intrusion and associated water quality concerns. The effects of these changes on California's statewide surface water delivery infrastructure will indirectly exacerbate challenges in achieving and maintaining sustainable groundwater management. A decline in the performance of the State's major inter-regional water conveyance systems is expected, including reductions in average annual reservoir carryover storage and surface water export reliability from the Sacramento-San Joaquin Delta (Schwarz et al. 2018, Wang et al. 2018).

Data and Tools for Estimating Climate Change Effects on Groundwater

Simulations of the Earth's climate by global climate models (GCMs) are the primary means of anticipating future shifts in climatic conditions. Although it is not possible to predict future hydrology and water use with certainty, appropriate use of models, data, and tools that leverage GCM projections provides water managers with a valuable resource to probe possible future conditions. On the other hand, the sheer size of the hundreds of available GCM simulations creates challenges for many users and decision makers. To help overcome this challenge, DWR's Climate Change Technical Advisory Group (CCTAG) developed a more manageable subset of GCMs for use in California's water planning (California Department of Water Resources 2015).

Based on CCTAG recommendations, DWR provides a realistic ensemble of climatological and hydrological data to groundwater sustainability agencies for use in groundwater sustainability plan development (California Department of Water Resources 2018). The central tendency scenario, centered around future climate horizons of 2030 and 2070, indicates to planners what might be considered a more likely future condition as evidenced by relative model agreement. The drier with extreme warming (DEW) and wetter with moderate warming (WMW) extreme scenarios, centered around the future climate horizon of 2070, help water planners consider the range of potential climate shifts. Outputs from these models are best used for sensitivity analysis to better understand the resiliency of a groundwater basin under projected climate change constraints and to assess potential projects and management actions to achieve or maintain sustainability in a groundwater basin over the long term. DWR delivered three types of data to facilitate this analysis: (1) climate variables of monthly temperature, precipitation, and evapotranspiration rates statewide, (2) major stream inflows to the Central Valley and gridded hydrologic streamflow factors statewide, and (3) water operations data including Central Valley reservoir outflows and State Water Project and Central Valley Project water deliveries.

Figure 2-11a shows the percent change in average annual climatic water deficit (evaporative demand that exceeds available water) and Figure 2-11b shows the percent change in the average annual recharge (net infiltration below the root zone) modeled under the 2070 DEW and WMW extreme climate projection scenarios. The percent change for each metric is calculated using 1981–2010 as the historical modeled 30-year period, and 2056–2085 as the future 30-year period. Although not shown here, results for the 2070 central tendency scenario for these two hydrologic metrics fall approximately in between the two extreme scenarios.

As a means to broadly demonstrate the potential range of climate change effects on groundwater resources across the state, the 2070 DEW and WMW extreme climate scenarios were input to the USGS's Basin Characterization Model (BCM) which computes a monthly water balance at high-spatial resolution across California (Flint and Flint 2014). The BCM can be used for regional comparisons of watersheds, even in the absence of independent validation for ungaged basins (Flint et al. 2013). Statewide maps of the percent change in average annual climatic water deficit (CWD) (Figure 2-11a) and recharge (Figure 2-11b) provide high-level information on the sensitivity of key hydrologic processes affecting groundwater as modeled by the two extreme climate scenarios. CWD, which represents evaporative demand that exceeds available water, is an indicator of the irrigation demand required to satisfy the seasonal deficit accumulated over the full water year.

Because CWD is limited by the capacity of soils to hold additional precipitation that would become runoff or recharge during the wet season, CWD increases are seen in both WMW and DEW climate change scenarios, particularly along mid-elevation regions of California mountain ranges in the wetter extreme scenario. The result suggests increases in both demands for crop irrigation and hydrologic stresses on natural vegetation, especially during years with below average precipitation.

Natural recharge in BCM represents net infiltration of water below the root zone. With climate change, changes in the seasonal timing of precipitation and snowmelt combined with soil conditions will influence how much water recharges groundwater basins rather than runs off. In the drier extreme, the 2070 DEW scenario indicates significant reductions in recharge in the Sierra Nevada because of declines in snowpack accumulation, earlier snowmelt, and less frequent atmospheric river conditions. In the wetter extreme, the 2070 WMW scenario indicates large scale increases in recharge across the state associated with more frequent and intense atmospheric river conditions. The wetter extreme scenario suggests a significant increase in the potential for capture of winter, wet season runoff and replenishment of groundwater basins.

Figure 2-11a Statewide Percent Change in Average Annual Climatic Water Deficit

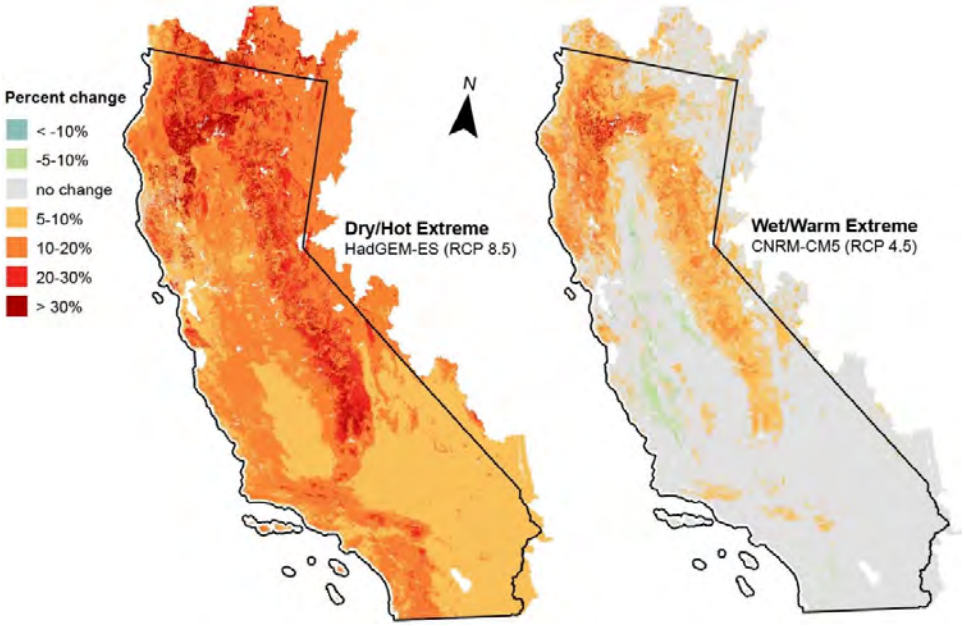


Figure 2-11a notes: Visual representation of drier with extreme warming scenario (left) and wetter with moderate warming scenario (right).
HadGEM = Hadley Centre Global Environment Model, CNRM = National Centre for Meteorological Research model

Figure 2-11b Statewide Percent Change in Average Annual Natural Recharge

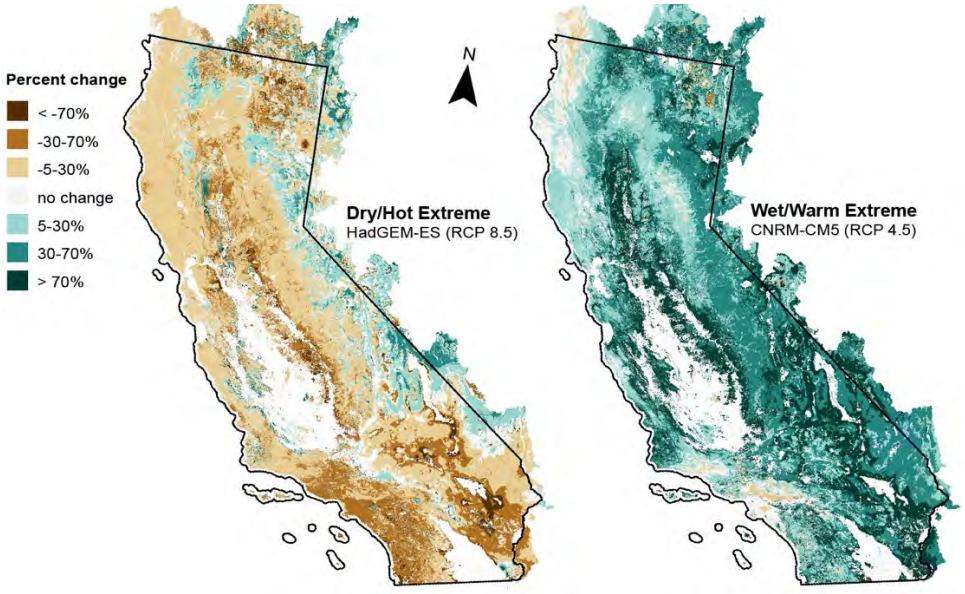


Figure 2-11b notes: Visual representation of drier with extreme warming scenario (left) and wetter with moderate warming scenario (right)
HadGEM = Hadley Centre Global Environment Model, CNRM = National Centre for Meteorological Research model

Groundwater Policy and Legislation

With California's reliance on groundwater growing amid the state's ever-changing climate, policy-makers have recently passed a series of bills and executive orders that address groundwater availability and reliability in the state. Three important groundwater policies are Executive Order B-26-14, SGMA, and the Making Water Conservation a California Way of Life Act; these policies are discussed below. Each of these policy packages are currently in effect in California and will shape the way Californians use and manage groundwater for decades to come.

Executive Order B-26-14

In 2014, Governor Jerry Brown issued Executive Order B-26-14, authorizing the Office of Emergency Services to provide California Disaster Assistance Act (CDAA) funding for the repair, restoration, or replacement of public real property damaged or destroyed by a disaster, including funding for emergency water supplies to households without water for drinking or sanitation purposes. CDAA funding provided reimbursements to county response agencies for the installation, filling, and removal of temporary water tanks used primarily for households previously served by domestic groundwater wells that had gone dry during the prolonged drought. The California Emergency Services Act authorizes the governor to declare a drought emergency; provisions of the California Emergency Services Act were used to declare a statewide drought emergency during the 2007–2009 and 2012–2016 drought events.

The Sustainable Groundwater Management Act

On September 16, 2014, Governor Brown signed into law a three-bill legislative package, composed of Assembly Bill 1739 (Dickinson, 2014), Senate Bill 1168 (Pavley, 2014), and Senate Bill 1319 (Pavley, 2014), collectively known as SGMA. SGMA requires the "management and use of groundwater in a manner that can be maintained during the planning and implementation horizon without causing undesirable results."

In his signing statement, the governor emphasized that "groundwater management in California is best accomplished locally." The Sustainable Groundwater Management Programs of DWR, the State Water Resources Control Board, and other related State agencies provide ongoing support to local agencies through planning, financial, and technical assistance. More information about SGMA and groundwater management in California can be found in Chapter 4, "Groundwater Management."

The Making Water Conservation a California Way of Life Act

In 2018, Governor Brown signed into law Senate Bill 606 (Hertzberg) and Assembly Bill 1668 (Friedman), collectively known as the Making Water Conservation a California Way of Life Act, to improve the state's water supply sustainability. The act established statewide water efficiency standards and required effective water shortage contingency planning. The legislation stemmed from a framework developed by five State agencies in response to Executive Order B-37-16. The goals of the order were to use water more wisely, eliminate water waste, strengthen local drought resilience, and improve agricultural water use efficiency and drought planning.

The act requires strengthening local drought resilience with urban water shortage contingency plans that include adequate actions to respond to droughts lasting at least five years rather than the previous requirement of three years. As a result, many urban water agencies will have to be more reliant on groundwater supplies to meet this higher drought contingency standard. DWR is also required to assist counties to facilitate improved drought planning for small water suppliers and rural communities.

Sustainable Groundwater Management in a Changing Climate

Access to groundwater resources increases the resilience of cities and agriculture during drought. Managed unsustainably, groundwater extraction exceeding rates of replenishment contributes to numerous undesirable results. Climate change-driven hydrologic effects, including greater irrigation demand and reduction of surface water supplies, increases the risk of overdraft conditions.

Listed below are the four broad approaches identified in the WRP that are necessary to prepare water systems and support sustainable groundwater management in a warmer, more variable climate. DWR's role in implementing each of these approaches in coordination with other State, federal, and local agencies is discussed below.

- **Maintain and Diversify Water Supplies**: Diversification of supplies enhances water system flexibility to manage degrading reliability and increased variability of surface water imports and local runoff. The portfolio of diversified supply will differ region to region in relation to user types and available resources. But recycled water treatment, more efficient water use, increased capture of stormwater runoff, and desalination can all provide a crucial buffer to cope with drought and climate change. As average temperatures warm in

the state's higher-elevation watersheds, more precipitation will fall as rain than snow. This effect has the potential to greatly challenge flood control systems, but also represents an increased opportunity for capture and storage of peak runoff in groundwater aquifers for use in later dry times. DWR is working with several partners to pursue this strategy through expanded implementation of flood-managed aquifer recharge projects.

- **Protect and Enhance Natural Systems**: Climate change poses serious threats to the health of natural ecosystems. Warmer air and water temperatures place greater stress on aquatic and terrestrial species, as well as on the vegetation that is their habitat. More dynamic integration of environmental protection and enhancement into water management is needed, but it requires investment in the assessment of ecosystem needs and ecological flows. Green infrastructure including wetlands, upper watersheds, soils, and floodplains are crucial for reliable functioning of water systems in the face of climate change. Broad-benefit water management projects can sustain the state's biodiversity and serve important water system benefits including groundwater recharge, water filtration, and flood peak attenuation. DWR is working to improve the condition of natural ecosystems by implementing the *Central Valley Flood Protection Plan Conservation Strategy*, which includes a comprehensive and science-based approach to vegetation management, improvements to habitats and benefits for fish and wildlife, and clear ecological targets with measurable objectives.
- **Build Connections**: Climate change effects are felt most acutely by the most vulnerable communities in the state and by the most vulnerable aspects of water systems. Building on integrated regional water management and other regional efforts to conduct watershed-based vulnerability assessments and adaptation plans can help prioritize actions and investments that increase community-wide resilience to climate change. Modernization and increasing the capacity of the State's inter-regional conveyance system builds redundancy, reliability, and transferability of water supplies in a highly variable climate. Coordination, networking, and stakeholder engagement are critical to enhancing the value and application of best available climate science, which water managers and decision-makers can leverage to better manage water supplies and flood risk. The sharing of information, ideas, and potential solutions, and bringing together local water managers and users with experts in climate science and infrastructure, will increase the ability to respond to the challenges facing California in the coming decades. To build these connections, DWR will explore the formation of a California-based climate

change network that regularly convenes climate scientists and water management practitioners.

- **Be Prepared**: California is well-versed in preparing for droughts and floods. But as climate change intensifies California's weather patterns, greater preparation for the years of "too much" and "too little" is of paramount importance. At the core of preparing for climate change is supporting regional decision making with watershed-based climate vulnerability and adaptation assessments. Risk-based planning that considers the full range of projected conditions sheds light on opportunities for improving performance of water systems and identifies which strategies are robust to multiple potential futures. Enhanced monitoring of weather and watershed conditions can help water managers adjust and cope with changing conditions in real time. Groundwater monitoring and data management systems help groundwater managers to better characterize groundwater basins and adapt groundwater management plans to changing conditions over the long term. DWR will contribute to the development, sharing, and broader implementation of innovative approaches in evaluating climate change vulnerabilities and adaption strategies for California water systems by creating scientific and engineering product(s) for watershed-based vulnerability and adaptation analysis.

Chapter 3. Groundwater: Use, Extraction, and Water Budgets

Introduction

Groundwater plays a critical role in California's agricultural, urban, and environment. Understanding groundwater use, long- and short-term trends, extraction characteristics, and how it could be budgeted to meet the various needs is vital to successful groundwater management.

This chapter includes discussions on groundwater use and their trends presented by hydrologic region, basin area, and non-basin area. Groundwater use includes summaries for agriculture, urban, and managed wetlands.

Extraction data, also referred to as production well infrastructure, are presented for irrigation, domestic, industrial, and public supply wells.

Water budgets have been important and will continue to contribute to the state's water management in the coming years, especially in the basins implementing groundwater sustainability plans. This chapter provides overview information on the development and use of water budgets.

Water Use

The water resources of California support cities and communities, agriculture, and the environment. The timing, quantity, and location of precipitation and streamflow in California often do not coincide with the areas of the state where most of agriculture and urban water use occur. Urban water reported in CalGW includes single family residential, multi-family residential, commercial, industrial, and landscape irrigation. This difference between where the water originates and where it is used, has resulted in the development of a complex series of local, State, and federal conveyance systems. Some of the larger water projects in the state include the federal Central Valley Project, the California State Water Project, the City and County of San Francisco's Hetch Hetchy Aqueduct, and the Metropolitan Water District's Colorado River Aqueduct (Figure 1-2). Parts of the state also rely heavily on imported water that can originate hundreds of miles away.

In contrast, groundwater can be found throughout most of the state, providing easily accessible local supplies. Because of the ease of access and the increased reliance on groundwater in times of limited precipitation and streamflow, a thorough understanding of the quantity, timing, and trends of surface water and groundwater use are needed.

Refer to Chapter 2, "Groundwater: Occurrence, Economic Value, Climate Change, and Policy," for related water use and groundwater discussions in the "Economic Value of Groundwater" section. It discusses how future water supply planning requires understanding of how key factors are likely to change the value of groundwater, jointly and individually.

In this section, water use data are presented for two periods: 2011–2016, to demonstrate the recent trend; and 2002–2016, to demonstrate the long-term trend. It should be noted that the 2011–2016 period includes the major drought of 2012–2016, whereas the longer period includes the 2007–2009 drought as well as the 2012–2016 drought. Detailed information on the analysis is provided in Appendix C, "Methods and Assumptions." Additional water use data can be found in Appendix G, "Water Use Data." It should be noted that CalGW Update 2020 did not generate the water use data used in the following analyses. Refer to the California Water Plan for additional information.

Additional water use information is being submitted for basins as part of the annual reports for adjudications, alternatives, and groundwater sustainability plans. This water use information has not been complied in time to report in California's Groundwater (CalGW) Update 2020, the water use data will be available on the California Natural Resources Agency Open Data platform and further summarized in CalGW Update 2025.

Recent Trends in Groundwater Use (2011–2016)

Figure 3-1 illustrates the 2011–2016 average annual groundwater use relative to total water use from all sources and the percentage of the total water use in each hydrologic region met by groundwater. Additionally, each region's percentage of total statewide groundwater use is graphically shown for its portion of the average annual groundwater use of 19.1 million acre-feet (maf) for the 2011–2016 period.

The state's 2011–2016 average annual groundwater extraction volume for the agriculture, urban, and managed wetlands sectors was 19.1 maf. This volume was 46 percent of the total water used within the three sectors. Table 3-1 provides the

2011–2016 statewide groundwater use, surface water use, and total use. When looking at the trend from 2011 through 2016, groundwater use steadily increased from 31 percent (12.1 maf) of total water use in 2011 to 58 percent (22.9 maf) of total water use in 2015.

California experienced a wet year in 2011, which was followed by five years of drought (2012–2016). The increase in groundwater use from 12.1 maf in 2011 to nearly 23 maf in 2015 is primarily because of a reduction in surface water supplies during drought. Surface water use declined 43 percent from 25.7 maf in 2011 to 14.7 maf in 2015. A rebound occurred in 2016 with surface water use increasing to 19.7 maf and a corresponding decrease in groundwater use to 17.9 maf.

Table 3-1 Total Groundwater and Surface Water Used by Year and Average (2011–2016)

Year	Groundwater Use (taf)	Surface Water Use (taf)	Reuse (taf)	Total Water Use
2011	12,127	25,650	1,836	39,613
2012	18,116	23,098	2,029	43,243
2013	20,758	20,695	2,408	43,862
2014	22,966	17,980	2,071	43,017
2015	22,869	14,665	1,850	39,384
2016	17,893	19,703	2,173	39,770
6-Year Average	**19,122**	**20,298**	**2,061**	**41,481**

Table 3-1 notes: taf = thousand acre-feet
Numbers may not total precisely because of rounding.

Figure 3-1 Groundwater Use and Total Water Use Met by Groundwater, by Hydrologic Region (2011–2016)

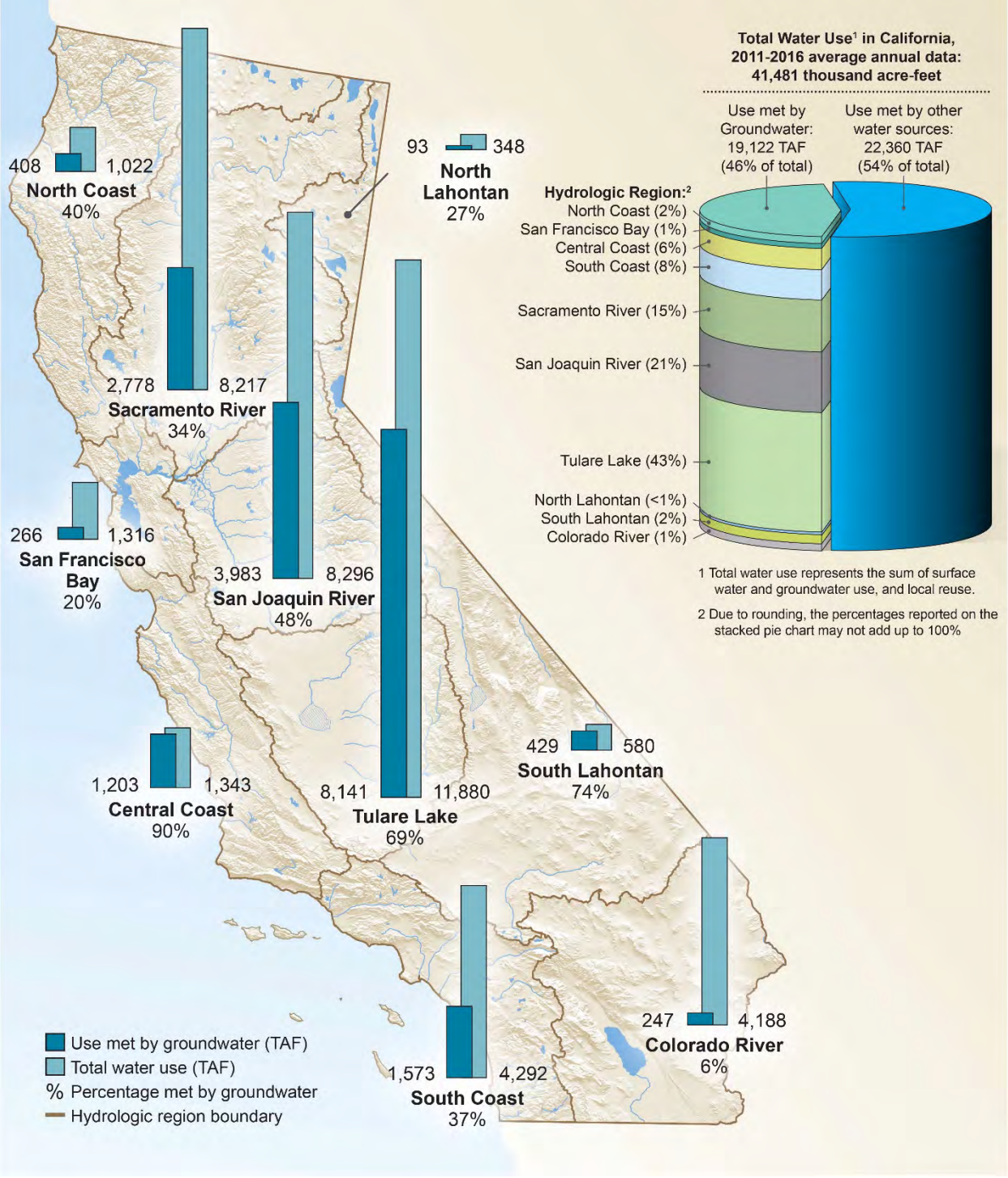


Figure 3-1 note: TAF = thousand acre-feet

Groundwater is a critical source of water for different sectors of use because of high spatial and temporal variability of surface water supplies. Table 3-2 shows the hydrologic region and statewide average annual groundwater use in acre-feet and as a percentage of the regions' and statewide total water use for 2011–2016. As shown in Table 3-2, the groundwater use varies widely from one region to another, with groundwater representing as little as 6 percent of the total water use in the Colorado River Hydrologic Region and as much as 90 percent of the total water use in the Central Coast Hydrologic Region. Groundwater accounts for 46 percent of the statewide average annual total water use for the same time period.

Table 3-2 Average Annual Groundwater Use by Hydrologic Region and Statewide (2011–2016)

Hydrologic Region	Groundwater Use (taf)	Percent of Total Water Use[a]
North Coast	408	40%
San Francisco Bay	266	20%
Central Coast	1,203	90%
South Coast	1,573	37%
Sacramento River	2,778	34%
San Joaquin River	3,983	48%
Tulare Lake	8,141	69%
North Lahontan	93	27%
South Lahontan	429	74%
Colorado River	247	6%
Statewide	**19,122**	**46%[b]**

Table 3-2 notes: taf = thousand acre-feet
Numbers and percentages may not total precisely because of rounding.
[a] Percent of total water use is the region's groundwater use divided by the region's total water (groundwater and surface water) used.
[b] Statewide percent of total water use is the statewide groundwater use divided by statewide total water (groundwater and surface water) used.

Table 3-3 provides the hydrologic regions' percentage distribution of groundwater use by agriculture, urban, and managed wetlands use sectors for the 2011–2016 period. The last column in Table 3-3 shows hydrologic regions total groundwater use as a percent of statewide total groundwater use. Of the 10 hydrologic regions, Tulare Lake uses the highest percentage (43 percent) of groundwater in the state. Statewide percentages are also provided in Table 3-3. Agriculture accounts for the primary use of groundwater in the state, totaling approximately 83 percent of the average annual statewide groundwater use during the 2011–2016 period. Urban and managed

wetlands account for 15 percent and 2 percent of the statewide groundwater use, respectfully.

Table 3-3 Percent of Average Annual Groundwater Use by Type of Use and by Hydrologic Region and Statewide (2011–2016)

Hydrologic Region	Agriculture	Urban	Managed Wetlands	Percent of Statewide Total Groundwater Use[a]
North Coast	85%	15%	0%	2%
San Francisco Bay	34%	66%	0%	1%
Central Coast	86%	14%	0%	6%
South Coast	34%	66%	0%	8%
Sacramento River	87%	12%	1%	15%
San Joaquin River	86%	8%	6%	21%
Tulare Lake	94%	5%	1%	43%
North Lahontan	68%	25%	7%	<1%
South Lahontan	68%	32%	0%	2%
Colorado River	22%	78%	0%	1%
Statewide	**83%**	**15%**	**2%**	**100%**

Table 3-3 notes: taf = thousand acre-feet. Percentages may not total precisely because of rounding.
[a] Percent of statewide total groundwater use is the region's total groundwater use divided by the statewide total groundwater use.

Table 3-4 presents the average annual agricultural groundwater use by hydrologic region and the average annual agricultural groundwater use as a percentage of total agricultural water use by hydrologic region from 2011 through 2016. The three hydrologic regions (Sacramento River, San Joaquin River, and Tulare Lake) that comprise California's Central Valley account for 13,507 thousand acre-feet (taf) of groundwater use (85 percent of statewide agriculture total groundwater use) on an annual average basis during the 2011–2016 period to irrigate approximately 6.2 million acres of productive agricultural lands (California Department of Water Resources 2014).

With 1,032 taf of groundwater use for agriculture, the Central Coast Hydrologic Region had the greatest reliance (94 percent) on groundwater for agriculture during the 2011–2016 period. The Colorado River Hydrologic Region, which is most reliant on surface water sources (99 percent) for agriculture, pumped the least amount of groundwater at an annual average of 55 taf, or 1 percent of the region's total water use for agriculture. Overall, the state's agriculture sector relied on groundwater

sources for approximately 49 percent of its water supply, on average, during the 2011–2016 period.

Table 3-4 Average Annual Agriculture Use Met by Groundwater by Hydrologic Region (2011–2016)

Hydrologic Region	Agriculture Groundwater Use (taf)	Percent of Total Agriculture Water Use in the Region[a]
North Coast	346	46%
San Francisco Bay	91	64%
Central Coast	1,032	94%
South Coast	528	67%
Sacramento River	2,423	35%
San Joaquin River	3,430	48%
Tulare Lake	7,654	68%
North Lahontan	63	21%
South Lahontan	291	81%
Colorado River	55	1%
Statewide	**15,913**	**49%[b]**

Table 3-4 notes: taf = thousand acre-feet.
Percentages may not total precisely because of rounding.
[a] Percent of total water use for agriculture is the region's total agriculture groundwater use divided by the regions total water (groundwater and surface water) used for agriculture.
[b] Statewide percent of total water use for agriculture is the statewide agriculture groundwater use divided by the regions total water (groundwater and surface water) used for agriculture.

Groundwater is an important source of water for the urban sector as well, supplying nearly 39 percent of the average annual total urban water use (Table 3-5). Throughout the state, numerous rural communities, individual residences, and businesses rely heavily, or completely, on groundwater. In many locations within these regions, high reliance on groundwater results from the absence of a reliable supply of surface water. Urban water agencies with inadequate surface water availability may incorporate groundwater, if feasible, as a water source to meet the needs of their customers. Urban water reported in CalGW includes single family residential, multi-family residential, commercial, industrial, and landscape irrigation.

Table 3-5 presents the average annual urban groundwater use by hydrologic region and the average annual urban groundwater use as a percentage of total urban water

use by hydrologic region from 2011 through 2016. The hydrologic region with the most urban groundwater use over the 2011–2016 period is the South Coast. As shown in Table 3-5, the South Coast Hydrologic Region uses the highest amount of groundwater in the state for urban purposes, which is more than twice as much as any other hydrologic region.

Table 3-5 Average Annual Urban Use Met by Groundwater, by Hydrologic Region (2011–2016)

Hydrologic Region	Urban Groundwater Use (taf)	Percent of Total Urban Water Use in the Region[a]
North Coast	60	44%
San Francisco Bay	175	16%
Central Coast	171	69%
South Coast	1,045	30%
Sacramento River	335	44%
San Joaquin River	312	54%
Tulare Lake	440	81%
North Lahontan	23	79%
South Lahontan	138	62%
Colorado River	192	53%
Statewide	**2,890**	**39%[b]**

Table 3-5 notes: taf = thousand acre-feet
Percentages may not total precisely because of rounding.
[a] Percent of total water use for urban is the region's total urban groundwater use divided by the regions total water (groundwater and surface water) used for urban.
[b] Statewide percent of total water use for urban is the statewide urban groundwater use divided by the regions total water (groundwater and surface water) used for urban.

Some of California's hydrologic regions have managed wetlands that are reliant on groundwater. Table 3-6 presents the average annual managed wetlands groundwater use by hydrologic region and the average annual managed wetlands groundwater use as a percentage of total managed wetlands water supplies by hydrologic region from 2011 through 2016. The San Joaquin River Hydrologic Region used an average of 242 taf of groundwater annually for managed wetlands during the 2011–2016 period. This volume represents 47 percent of the total water use for managed wetlands in that region. Groundwater use for the managed wetlands sector in the state averaged 318 taf annually during the 2011–2016 period, representing 23 percent of the total annual water use for managed wetlands.

Table 3-6 Average Annual Managed Wetlands Use Met by Groundwater, by Hydrologic Region (2011–2016)

Hydrologic Region	Managed Wetlands Groundwater Use (taf)	Percent of Total Managed Wetlands Water Use in the Region[a]
North Coast	1	1%
San Francisco Bay	0	0%
Central Coast	0	0%
South Coast	0	>1%
Sacramento River	20	4%
San Joaquin River	242	47%
Tulare Lake	47	52%
North Lahontan	7	43%
South Lahontan	0	0%
Colorado River	0	0%
Statewide	**318**	**23%[b]**

Table 3-6 notes: taf = thousand acre-feet.
Percentages may not total precisely because of rounding.
[a] Percent of total water use for managed wetlands is the region's total managed wetlands groundwater use divided by the regions total water (groundwater and surface water) used for managed wetlands.
[b] Statewide percent of total water use for wetlands is the statewide managed wetlands groundwater use divided by the regions total water (groundwater and surface water) used for managed wetlands.

Long-Term Trends in Groundwater Use (2002–2016)

Variation in average annual groundwater use may be related to several factors such as surface water availability, urban and agricultural growth or decline, changes in crop types, weather, drought, economic fluctuations, and water use efficiency practices. Hydrologic conditions throughout the state in any given year may vary widely, which can directly and indirectly affect groundwater use. A decrease in the amount of available surface or imported water may not change anything for crops already dependent on groundwater, but irrigators that rely on the surface water deliveries for some, or all, of their needs may require reductions or changes to their crops, institute the fallowing of fields, or switch or increase their demand for groundwater. The decision on what to do depends in part on the magnitude and duration of the decreased surface water deliveries.

Figure 3-2 illustrates the 2002–2016 water use trend for the state based on total water use volume by source of supply (groundwater, surface water, and reuse water); data used to create the figure is provided in Table 3-7. Figure 3-3 displays the percentage of total water use by source of supply; data used to create the figure is provided in Table 3-8. Time periods of drought in California are shown in both figures to highlight the increase in groundwater use during those times.

From 2002 through 2016, total annual water use for the state fluctuated between a high of 45.5 maf in 2007, to a low of 39.4 maf in 2015, with an annual average of 42.4 maf. Annual groundwater use during the 2002–2016 period averaged 17.6 maf, which represented 41 percent of total water use in the state. From 2011 through 2015 there was a steady increase in groundwater use, which peaked at 58 percent of total water use in 2015.

During the wet water years of 2005, 2006, and 2011, annual groundwater use decreased respectively to 12.0 maf, 13.1 maf, and 12.1 maf, representing 30 to 31 percent of total water use during those three wet years. During the dry years of 2014 and 2015, groundwater use was 23.0 maf and 22.9 maf, respectively, representing 53 and 58 percent of total water use.

Figure 3-4 shows the 2002–2016 groundwater use trends for the urban, agriculture, and managed wetlands sectors in the state; data used to create the figure are provided in Table 3-9. Figure 3-5 displays the same data as a percentage of total groundwater use by sector; data used to create the figure are provided in Table 3-10.

The percentage of groundwater used for agriculture ranged from a low of 69 percent in 2005 to a high of 87 percent in 2015. Groundwater use was 8.3 maf in 2005 and 19.8 maf in 2015. Groundwater use for the urban sector decreased during the 2002–2016 period. In 2002, 4.0 maf of groundwater was used, while in 2016, 2.3 maf was used. This change represents a 43 percent decrease during this period that could be attributed to statewide water conservation efforts (2015–2016) and increases in surface water supplies for urban use.

Groundwater use for managed wetlands ranged from 0.2 maf in 2011, to 0.4 maf in 2014. Groundwater use for managed wetlands typically represents 1 to 2 percent of the annual groundwater use in the state.

Figure 3-2 Statewide Annual Water Use by Source of Water (2002–2016)

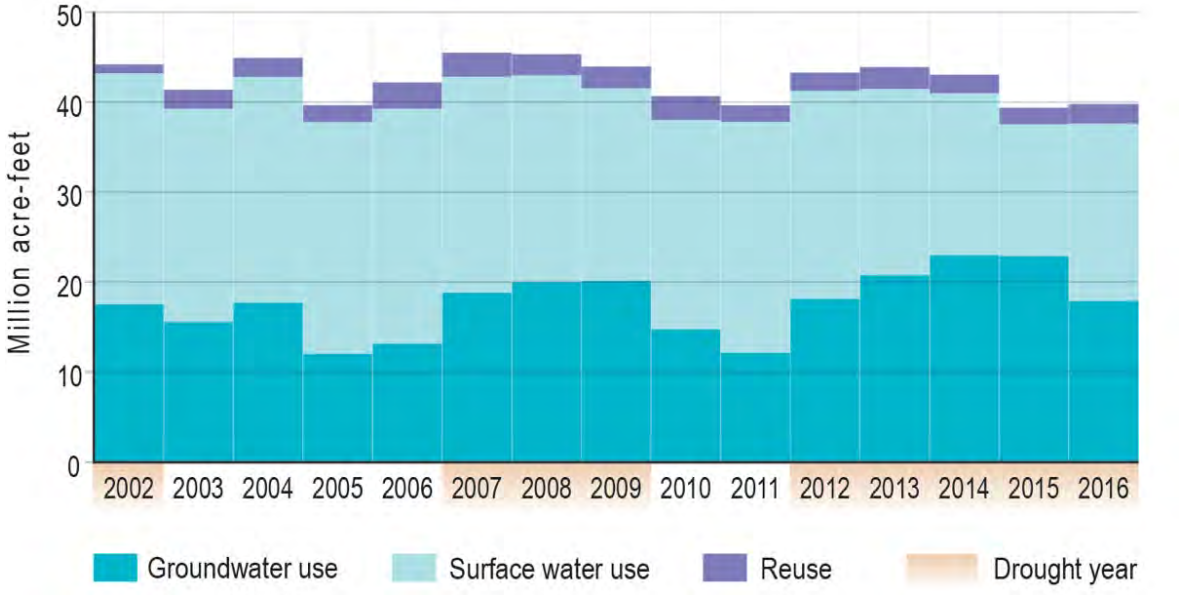


Table 3-7 Statewide Annual Water Use by Source of Water (2002–2016)

Year	Groundwater Use (taf)	Surface Water Use (taf)	Reuse (taf)	Total Water Use (taf)
2002	17,520	25,675	967	44,161
2003	15,549	23,692	2,121	41,362
2004	17,685	25,086	2,124	44,895
2005	12,019	25,742	1,893	39,654
2006	13,127	26,101	2,932	42,160
2007	18,808	24,010	2,641	45,459
2008	19,976	22,982	2,351	45,308
2009	20,093	21,393	2,435	43,920
2010	14,743	23,267	2,635	40,644
2011	12,127	25,650	1,836	39,613
2012	18,116	23,098	2,029	43,243
2013	20,758	20,695	2,408	43,862
2014	22,966	17,980	2,071	43,017
2015	22,869	14,665	1,850	39,384
2016	17,893	19,703	2,174	39,770
15-Year Average	**17,617**	**22,649**	**2,164**	**42,430**

Table 3-7 notes: taf = thousand acre-feet.
Numbers may not total precisely because of rounding.

Figure 3-3 Statewide Annual Water Use by Source as a Percentage of Total Water Use (2002–2016)

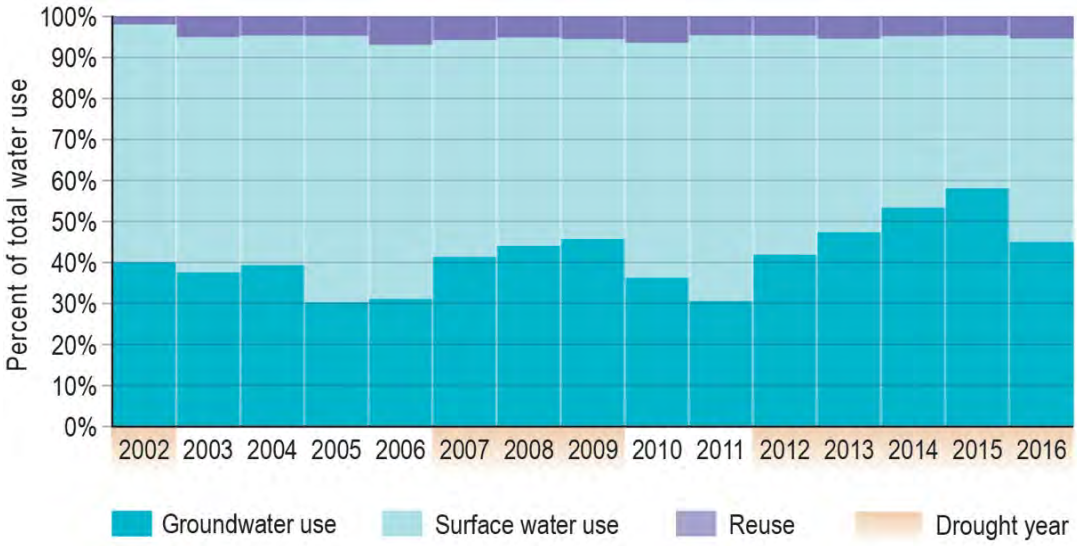


Table 3-8 Statewide Annual Percent Water Use (2002–2016)

Year	Groundwater Use	Surface Water Use	Reuse
2002	40%	58%	2%
2003	38%	57%	5%
2004	39%	56%	5%
2005	30%	65%	5%
2006	31%	62%	7%
2007	41%	53%	6%
2008	44%	51%	5%
2009	46%	49%	6%
2010	36%	57%	6%
2011	31%	65%	5%
2012	42%	53%	5%
2013	47%	47%	5%
2014	53%	42%	5%
2015	58%	37%	5%
2016	45%	50%	5%
15-Year Average	**41%**	**53%**	**5%**

Table 3-8 notes: Percentages may not total precisely because of rounding.

Figure 3-4 Statewide Annual Groundwater Use by Sector (2002–2016)



Table 3-9 Statewide Annual Groundwater Use by Sector (2002–2016)

Year	Urban Use (taf)	Agriculture Use (taf)	Managed Wetlands (taf)	Total Groundwater Use (taf)
2002	3,983	13,231	306	17,520
2003	3,805	11,531	214	15,549
2004	3,751	13,710	224	17,685
2005	3,515	8,260	244	12,019
2006	3,757	9,163	208	13,127
2007	3,854	14,691	262	18,808
2008	3,734	15,965	277	19,976
2009	3,746	16,083	264	20,093
2010	3,368	11,113	262	14,743
2011	2,794	9,126	207	12,127
2012	3,185	14,661	270	18,116
2013	3,077	17,392	290	20,758
2014	3,328	19,222	415	22,966
2015	2,635	19,834	400	22,869
2016	2,321	15,244	328	17,893
15-Year Average	**3,390**	**13,948**	**278**	**17,617**

Table 3-9 notes: taf = thousand acre-feet.
Numbers may not total precisely because of rounding.

Figure 3-5 Statewide Percentage of Total Groundwater Use by Sector (2002–2016)

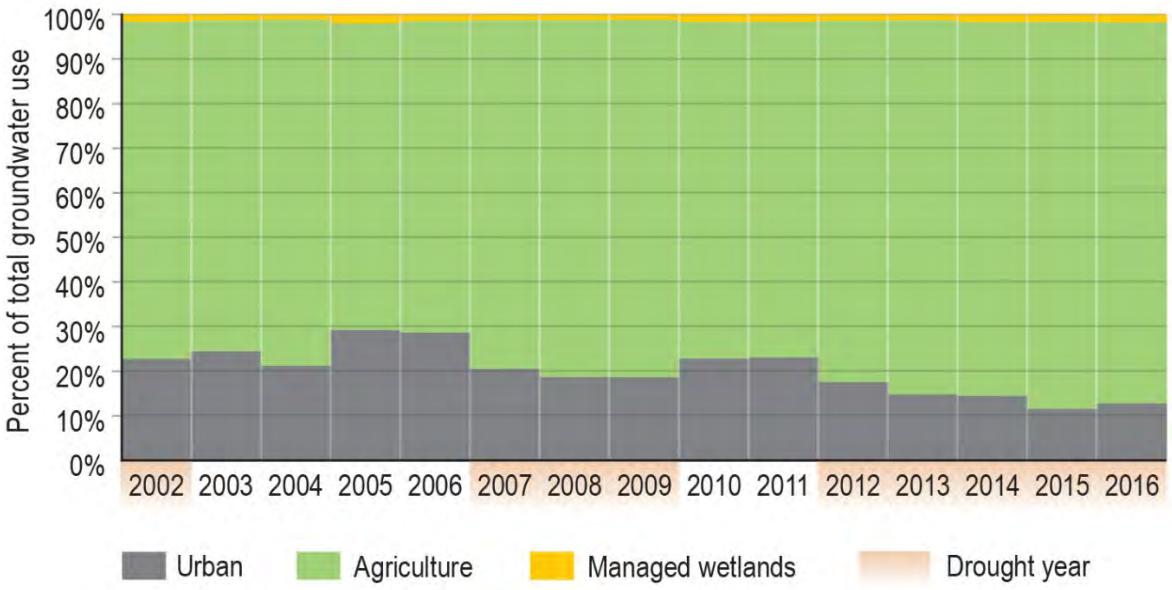


Table 3-10 Statewide Percentage of Total Groundwater Use by Sector (2002–2016)

Year	Urban	Agriculture	Managed Wetlands
2002	23%	76%	2%
2003	24%	74%	1%
2004	21%	78%	1%
2005	29%	69%	2%
2006	29%	70%	2%
2007	20%	78%	1%
2008	19%	80%	1%
2009	19%	80%	1%
2010	23%	75%	2%
2011	23%	75%	2%
2012	18%	81%	1%
2013	15%	84%	1%
2014	14%	84%	2%
2015	12%	87%	2%
2016	13%	85%	2%
15-Year Average	**19%**	**79%**	**2%**

Table 3-10 note: Percentages may not total precisely because of rounding.

Relation Between Water Use and Land Use

Identification of land development types provides information that is key to understanding the relationship between land use and water use. Land use surveys, as well as remote sensing technologies using satellite imagery and other data, help to identify the various crops grown across millions of acres of agricultural lands in the state. Urban areas are identified using similar processes.

The 2014 land use datasets for agriculture and urban were analyzed and summarized below (California Department of Water Resources 2014). The total agriculture and urban groundwater and surface water use for each hydrologic region is provided in Table 3-11. Managed wetlands data from 2014 are not used in this analysis.

The total 2014 agricultural acreage is summarized by hydrologic region in Table 3-12 along with the percentage of statewide agricultural acreage within each region. In Table 3-13, agricultural acreage is further summarized based on its location within groundwater basins versus non-basin areas. The information provided is the total agriculture area and percent of the agriculture area in the hydrologic region that occur within basin and non-basin areas.

Table 3-11 Agriculture and Urban Water Use by Hydrologic Region (2014)

Hydrologic Region	Agriculture Groundwater Water Use (taf)	Agriculture Surface Water Use (taf)	Urban Groundwater Use (taf)	Urban Surface Water Use (taf)
North Coast	368	368	60	76
San Francisco Bay	71	62	203	919
Central Coast	1,212	48	191	73
South Coast	709	350	1,277	2,486
Sacramento River	2,470	4,283	346	407
San Joaquin River	4,186	3,105	325	272
Tulare Lake	9,724	1,776	528	68
North Lahontan	71	262	24	6
South Lahontan	350	80	169	55
Colorado River	61	4,289	205	83
Statewide Total	19,222	14,622	3,328	4,446

Table 3-11 notes: taf = thousand acre-feet.
Numbers may not total precisely because of rounding.

Table 3-12 Agricultural Land Use by Hydrologic Region (2014)

Hydrologic Region	Agriculture Acres	Percent of Statewide
North Coast	317,203	4%
San Francisco Bay	93,829	1%
Central Coast	453,544	6%
South Coast	158,679	2%
Sacramento River	1,699,302	22%
San Joaquin River	1,867,523	24%
Tulare Lake	2,616,205	33%
North Lahontan	86,062	1%
South Lahontan	52,185	<1%
Colorado River	515,265	7%
Statewide Total	**7,859,797**	**100%**

Table 3-12 note: Numbers and percentages may not total precisely because of rounding.

Table 3-13 Agricultural Land Use by Basin and Non-basin Area in each Hydrologic Region (2014)

Hydrologic Region	Agriculture Acres in Basin Area	Percent of Region Total Agriculture in Basin Area[a]	Agriculture Acres in Non-basin Area	Percent of Region Total Agriculture in Non-basin Area[a]
North Coast	280,098	88%	37,105	12%
San Francisco Bay	66,933	71%	26,896	29%
Central Coast	416,003	92%	37,541	8%
South Coast	113,897	72%	44,782	28%
Sacramento River	1,645,581	97%	53,721	3%
San Joaquin River	1,858,897	100%	8,626	<1%
Tulare Lake	2,605,766	100%	10,439	<1%
North Lahontan	84,408	98%	1,654	2%
South Lahontan	52,043	100%	142	<1%
Colorado River	515,199	100%	66	<1%
Statewide Total	**7,638,825**	**97%[b]**	**220,972**	**3%[b]**

Table 3-13 notes: Numbers and percentages may not total precisely because of rounding.

[a] Percent of region total agriculture in basin area or non-basin area is the agriculture acres in basin or non-basin area divided by the total area of the region.

[b] Percent of statewide total agriculture in basin area or non-basin area is the statewide total agriculture acres in basin or non-basin area divided by the total area of the state.

Total urban acreage is summarized by hydrologic region in Table 3-14 along with the percentage of statewide urban acreage within each region. In Table 3-15, urban areas are summarized by percentage in groundwater basins and in non-basin areas. The information provided is the total urban area and percent of the urban area in the hydrologic region that occur within basin and non-basin areas.

The California Water Plan does not provide water use data by basin or non-basin area. Below is an estimate of water use that is based on the total area of agriculture and urban within the basin and non-basin areas of each hydrologic region.

Hydrologic region agriculture and urban water use estimates for surface water and groundwater were calculated by multiplying 2014 hydrologic region agriculture and urban water use data provided in Table 3-11 by the percentage of agriculture or urban area provided in Tables 3-13 and 3-15. Additional information on the process used in this analysis is found in Appendix C, "Methods and Assumptions."

Table 3-14 Urban Land Use by Hydrologic Region (2014)

Hydrologic Region	Urban Acres	Statewide
North Coast	208,823	4%
San Francisco Bay	574,189	12%
Central Coast	224,490	5%
South Coast	1,861,073	39%
Sacramento River	672,030	14%
San Joaquin River	381,392	8%
Tulare Lake	437,245	9%
North Lahontan	42,080	1%
South Lahontan	148,292	3%
Colorado River	259,682	5%
Statewide Total	**4,809,296**	**100%**

Table 3-14 note: Numbers and percentages may not total precisely because of rounding.

Table 3-15 Urban Land Use by Basin and Non-basin Area in each Hydrologic Region (2014)

Hydrologic Region	Urban Acres in Basin Area	Percent of Region Total Urban in Basin Area[a]	Urban Acres in Non-basin Area	Percent of Region Total Urban in Non-basin Area[a]
North Coast	110,929	53%	97,894	47%
San Francisco Bay	421,895	73%	152,294	27%
Central Coast	171,481	76%	53,009	24%
South Coast	1,323,269	71%	537,804	29%
Sacramento River	404,210	60%	267,820	40%
San Joaquin River	274,339	72%	107,053	28%
Tulare Lake	416,036	95%	21,209	5%
North Lahontan	28,495	68%	13,585	32%
South Lahontan	135,709	92%	12,583	8%
Colorado River	248,508	96%	11,174	4%
Statewide Total	**3,534,871**	**74%[b]**	**1,274,425**	**26%[b]**

Table 3-14 notes: Numbers and percentages may not total precisely because of rounding.

[a] Percent of region total urban in basin area or non-basin area is the urban acres in basin or non-basin area divided by the total urban area of the region.

[b] Percent of statewide total urban in basin area or non-basin area is the statewide total urban acres in basin or non-basin areas divided by the total area of the state.

Based on the method described above, Table 3-16 presents the estimated 2014 total groundwater and surface water use for the basin and non-basin areas within each hydrologic region. Tables 3-17 and 3-18 present the estimated 2014 agriculture and urban water use data, respectively, in the basin and non-basin areas within each hydrologic region.

Table 3-16 Basin and Non-basin Total Water Use Estimates in Thousand Acre-feet (2014)

Hydrologic Region	Basin Total Groundwater Use	Non-basin Total Groundwater Use	Basin Total Surface Water Use	Non-basin Total Surface Water Use
North Coast	357	71	366	79
San Francisco Bay	200	74	720	262
Central Coast	1,258	146	100	21
South Coast	1,417	569	2,019	817
Sacramento River	2,600	216	4,392	298
San Joaquin River	4,400	111	3,286	91
Tulare Lake	10,188	64	1,834	10
North Lahontan	86	9	261	7
South Lahontan	504	15	130	5
Colorado River	257	9	4,368	4
Statewide Total	**21,266**	**1,284**	**17,474**	**1,593**

Table 3-16 note: Numbers may not total precisely because of rounding.

Table 3-17 Basin and Non-basin Agriculture Water Use Estimates in Thousand Acre-feet (2014)

Hydrologic Region	Agriculture Groundwater Use in Basin Area	Agriculture Groundwater Use in Non-basin Area	Agriculture Surface Water Use in Basin Area	Agriculture Surface Water Use in Non-basin
North Coast	325	43	325	43
San Francisco Bay	51	20	44	18
Central Coast	1,112	100	44	4
South Coast	509	200	251	99
Sacramento River	2,392	78	4,147	135
San Joaquin River	4,166	19	3,091	14
Tulare Lake	9,685	39	1,769	7
North Lahontan	70	1	257	5
South Lahontan	349	1	79	<1
Colorado River	61	<1	4,288	1
Statewide Total	**18,720**	**502**	**14,295**	**326**

Table 3-17 note: Numbers may not total precisely because of rounding.

Table 3-18 Basin and Non-basin Urban Water Use Estimates in Thousand Acre-feet (2014)

Hydrologic Region	Urban Groundwater Use in Basin Area	Urban Groundwater Use in Non-basin Area	Urban Surface Water Use in Basin Area	Urban Surface Water Use in Non-basin Area
North Coast	32	28	40	36
San Francisco Bay	149	54	675	244
Central Coast	146	45	56	17
South Coast	908	369	1,768	718
Sacramento River	208	138	245	162
San Joaquin River	234	91	196	76
Tulare Lake	503	26	65	3
North Lahontan	16	8	4	2
South Lahontan	154	14	51	5
Colorado River	196	9	79	4
Statewide Total	**2,546**	**782**	**3,179**	**1,267**

Table 3-18 note: Numbers may not total precisely because of rounding.

Groundwater Extraction

A key to understanding California's groundwater development is identifying the number, age, spatial distribution, depth, and type of wells used statewide to extract groundwater.

DWR is the steward of the State's well completion reports (WCRs), also known as well logs, that are required to be submitted to DWR by licensed well drillers when wells are installed, modified, or destroyed (California Water Code Section 13751). The WCRs are available from DWR's Online Statewide Well Completion Report (OSWCR) (California Department of Water Resources 2019) database. The information in WCRs includes the well location, date of completion, type of well (use), construction details, and subsurface lithology. The database has an estimated 1 million WCRs.

The results of analysis presented in this chapter are based only on WCRs for water wells constructed between January 1, 1977, and December 31, 2018. There are two reasons why 1977 was used for the starting point in the analysis. First, the peak well installation for the 1970s was at the end of the 1976–1977 drought, and second, in 1977 a statewide system for tracking WCRs became available for use.

The OSWCR database is the best statewide data available to review and estimate the quantities, ages, distributions, depths, and types of installed wells. But there are limitations that can cause under- or over-counting.

1. Despite statutory requirements, WCRs may not have been submitted to DWR within the required 60 days, or at all, for constructed, altered, abandoned, or destroyed wells. This is also the case for wells constructed prior to the statutory requirements for WCR submittal. This may cause an under-reporting of wells in the state.
2. WCRs do not indicate whether a well is currently active and well owners are not required to report a well status to DWR. OSWCR tracks WCRs, not the active or inactive status of the well. WCRs for the destruction of wells are not paired to the original WCRs for the construction of those same wells. In this analysis, it is assumed each WCR represents an active well. This could mean that, in this analysis, some wells assumed to be active may no longer be active, leading to an over-reporting of wells in the state. WCRs indicating that the well has been altered, abandoned, or destroyed were excluded from this analysis.
3. WCRs may include errors in the reported well locations. Coordinates supplied on the WCRs may place the well in a different basin, county, region, or in some cases, another state. On some WCRs, the location information may be missing. WCRs without location information or locations plotted outside the state were excluded unless they could be corrected. These exclusions could cause an under-reporting of wells.
4. WCRs may have inaccurate or incomplete well construction information. For part of this analysis, a known well depth is required. WCRs missing the depth-of-well information were excluded from the analysis.
5. WCRs may not provide the date of completion or well use classification. WCRs that are missing one or both pieces of information were excluded from some or all of the analysis.

Despite these limitations, the WCR dataset is the best-available information to evaluate statewide quantities of wells and trends. Approximately 461,000 WCRs were submitted to DWR for newly constructed water wells in California from 1977 through 2018. This analysis focuses on 306,055 wells that are considered groundwater production wells. The well types include domestic, irrigation, public supply, and industrial. Excluded from this analysis are monitoring wells (109,000) and wells identified as “other” (46,000).

Groundwater Production Wells

There are many types of wells in use across California. This analysis includes only groundwater production wells, which are wells used to extract groundwater.

Wells constructed and identified for groundwater monitoring purposes were not included in the analysis of production wells, but these wells are important to California. They provide a great source of data for subsurface geology, water quality, groundwater levels, subsidence, and saline intrusion. The monitoring well infrastructure is discussed in Chapter 5, "Groundwater Monitoring." Additional information on the use of WCRs in this chapter is provided in Appendix C, "Methods and Assumptions."

Figure 3-6 depicts the number of WCRs submitted for groundwater production from 1977 through 2018 by well use type statewide. Table 3-19 presents the statewide distribution of production wells by type of use, by hydrologic region.

Within groundwater basins, 71 percent of the wells completed are domestic wells and 24 percent are irrigation wells. Outside of groundwater basins (non-basin area), 90 percent of wells are classified as domestic, 8 percent are classified as irrigation.

Statewide, domestic wells account for 80 percent of the production well WCRs. The Sacramento River Hydrologic Region has the largest number of domestic wells with 85,460 WCRs. The San Joaquin River Hydrologic Region is second with nearly 51,900 WCRs. The North Lahontan and Colorado River hydrologic regions have a total of 8,551 WCRs for domestic wells.

The distribution of irrigation wells with respect to basins also reflects the large amount of agricultural groundwater extraction that occurs from California's groundwater basins (approximately 18.7 maf in 2014) compared to that in non-basin areas (approximately 0.5 maf in 2014). While irrigation wells account for 16 percent of the statewide total for production wells, these wells are responsible for most of the statewide groundwater use (approximately 19.2 maf in 2014).

Figure 3-6 Statewide Production Well Completion Reports by Well Use Type (1977–2018)

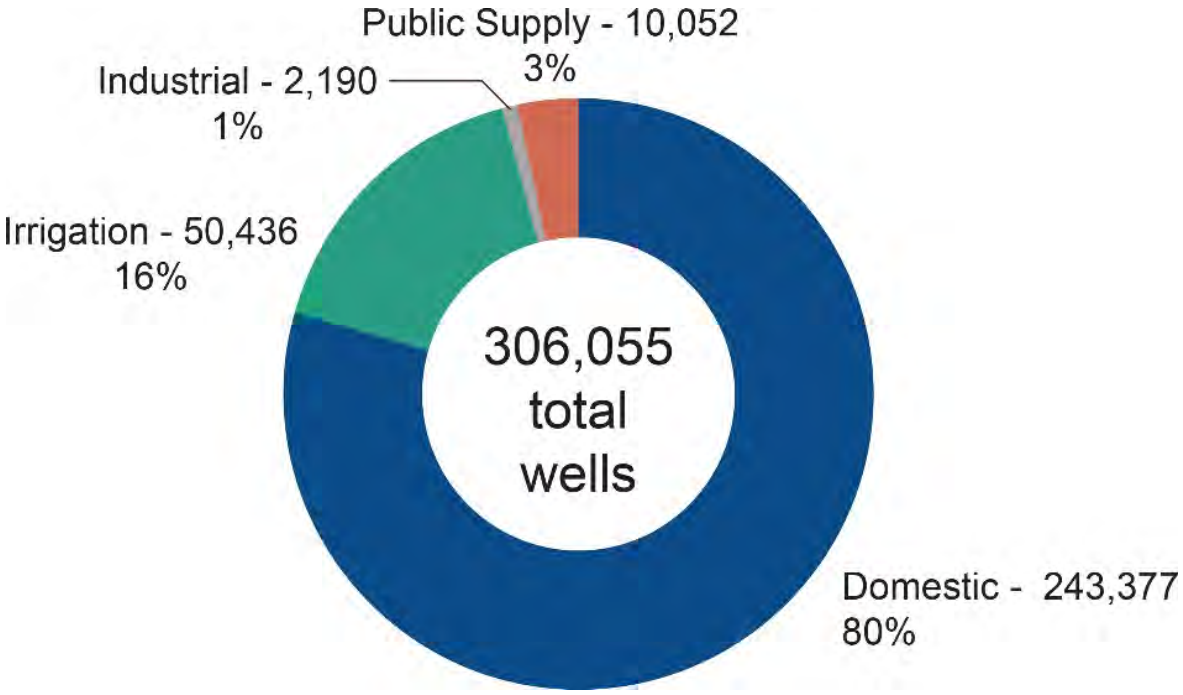


Table 3-19 Statewide Production Well Completion Reports by Well Use Type and Hydrologic Region (1977–2018)

Hydrologic Region	Domestic	Irrigation	Industrial	Public Supply	Total
North Coast	26,164	2,493	153	713	29,523
San Francisco Bay	11,459	3,997	187	473	16,116
Central Coast	12,080	3,790	124	484	16,478
South Coast	17,709	6,493	243	1,924	26,369
Sacramento River	85,460	8,852	419	1,693	96,424
San Joaquin River	51,900	8,333	287	1,625	62,145
Tulare Lake	22,061	14,657	360	1,272	38,350
North Lahontan	4,163	405	39	187	4,794
South Lahontan	7,993	708	256	1,030	9,987
Colorado River	4,388	708	122	651	5,869
Total	**243,377**	**50,436**	**2,190**	**10,052**	**306,055**
Percent	**80%**	**16%**	**1%**	**3%**	**100%**

Figure 3-7 depicts the number of WCRs submitted for groundwater production wells from 1977 through 2018 by well use type within groundwater basin areas. Table 3-20 summarizes the same basin data by hydrologic region.

The distribution of irrigation wells with respect to basins also reflects the large amount of agricultural groundwater production that occurs within California's groundwater basins (approximately 18.7 maf in 2014) compared to that in non-basin areas (approximately 0.5 maf in 2014).

Figure 3-8 depicts the number of WCRs submitted for groundwater production wells from 1977 through 2018 by well use type within non-basin areas. Table 3-21 summarizes the same data by hydrologic region. The domestic wells dominate the production well types in the non-basin area by a 9-to-1 ratio.

Figure 3-7 Production Well Completion Reports in Groundwater Basins by Well Use Type (1977–2018)

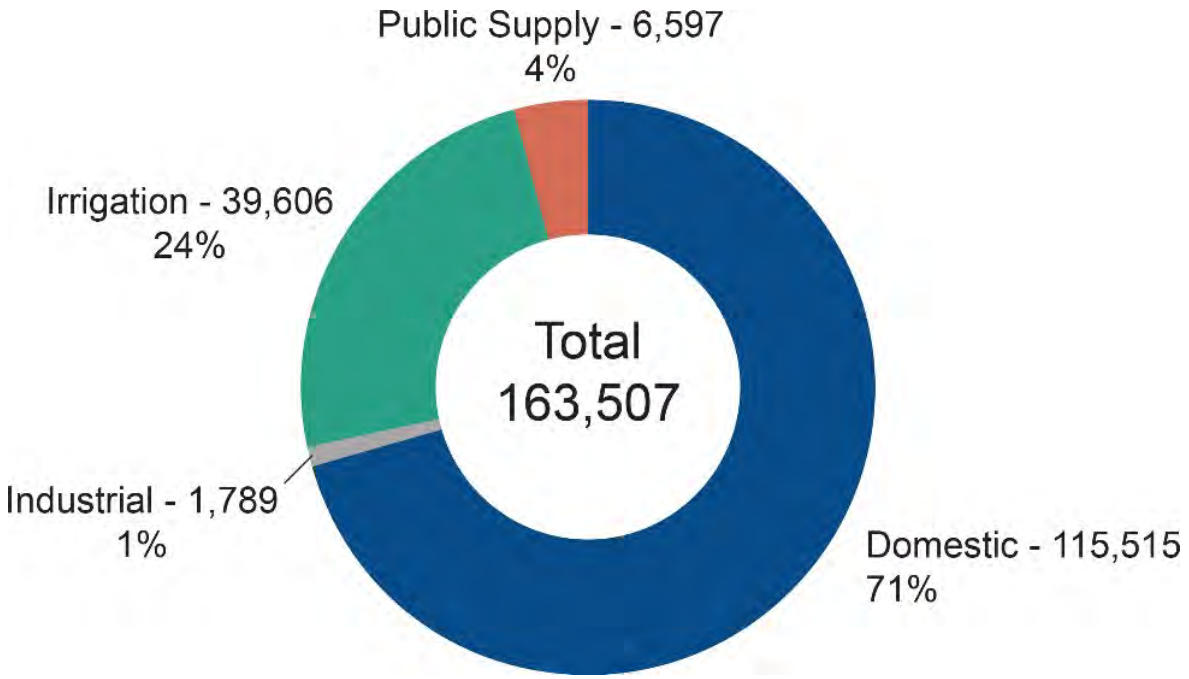


Table 3-20 Production Well Completion Reports in Groundwater Basins by Well Use Type and Hydrologic Region (1977–2018)

Hydrologic Region	Domestic	Irrigation	Industrial	Public Supply	Total
North Coast	12,869	1,584	116	397	14,966
San Francisco Bay	5,220	2,045	159	347	7,771
Central Coast	7,589	2,896	104	374	10,963
South Coast	4,933	1,831	143	1,348	8,255
Sacramento River	30,073	7,828	337	858	39,096
San Joaquin River	25,603	7,602	209	693	34,107
Tulare Lake	16,485	14,173	348	1,038	32,044
North Lahontan	2,486	333	32	107	2,958
South Lahontan	6,949	655	227	864	8,695
Colorado River	3,308	659	114	571	4,652
Total	**115,515**	**39,606**	**1,789**	**6,597**	**163,507**
Percent	**71%**	**24%**	**1%**	**4%**	**100%**

Figure 3-8 Production Well Completion Reports in Non-basin Areas by Well Use Type (1977–2018)

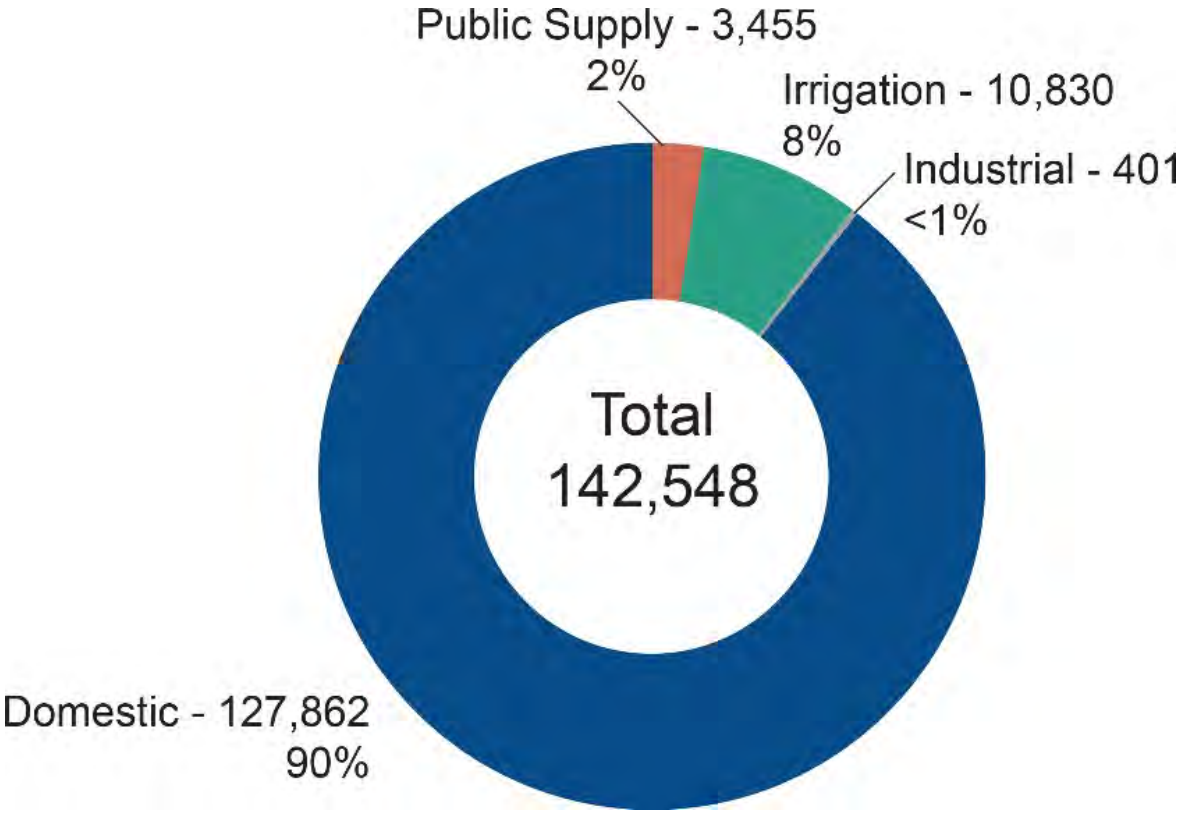


Table 3-21 Production Well Completion Reports in Non-basin Areas by Well Use Type and Hydrologic Region (1977–2018)

Hydrologic Region	Domestic	Irrigation	Industrial	Public Supply	Total
North Coast	13,295	909	37	316	14,557
San Francisco Bay	6,239	1,952	28	126	8,345
Central Coast	4,491	894	20	110	5,515
South Coast	12,776	4,663	100	576	18,114
Sacramento River	55,387	1,025	82	835	57,328
San Joaquin River	26,297	731	78	932	28,038
Tulare Lake	5,576	484	12	234	6,306
North Lahontan	1,677	72	7	80	1,836
South Lahontan	1,044	53	29	166	1,292
Colorado River	1,080	49	8	80	1,217
Total	**127,862**	**10,830**	**401**	**3,455**	**142,548**
Percent	**90%**	**8%**	**<1%**	**2%**	**100%**

Domestic Wells and Irrigation Wells

Domestic wells and irrigation wells accounted for approximately 96 percent of all WCRs submitted to DWR from 1977 through 2018. This section contains further analysis of these wells with maps showing the installation density in the state and trend information on the constructed depths and timing of installations.

Figures 3-9 and 3-10 show the estimated density and spatial distribution of domestic wells and irrigation wells per square mile within the state based on submitted WCRs. The highest concentration of domestic wells occurs near less-densely populated rural residential areas, both within and outside groundwater basins. In the Sacramento River Hydrologic Region, the high concentration of domestic wells in the non-basin areas is possibly the result of the abundant number of residences using private domestic wells versus water supplied by a municipal or public water system. Further analysis of the domestic well data is needed to better understand the total number of residences that rely on groundwater for some, or all, of their water needs. It is estimated that 3.7 percent of California's population relies on domestic wells for their water supply (Johnson, Belitz, Lombard 2019). The state's population for 2020 is estimated to be 40.8 million, equating to the total estimated population on domestic wells is 1.5 million people.

Figure 3-9 Density and Spatial Distribution of Domestic Wells Estimated from Well Completion Reports (1977–2018)

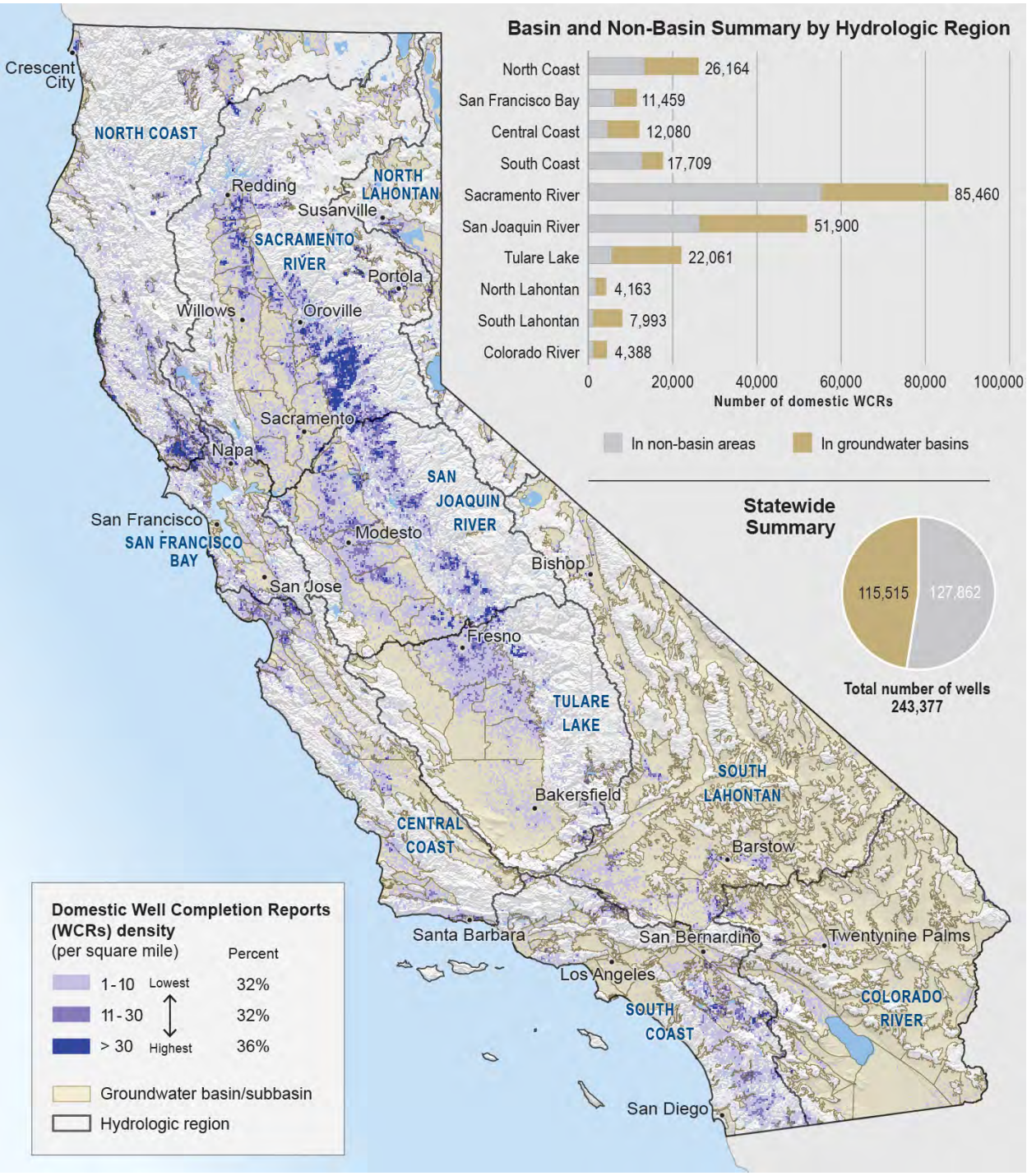
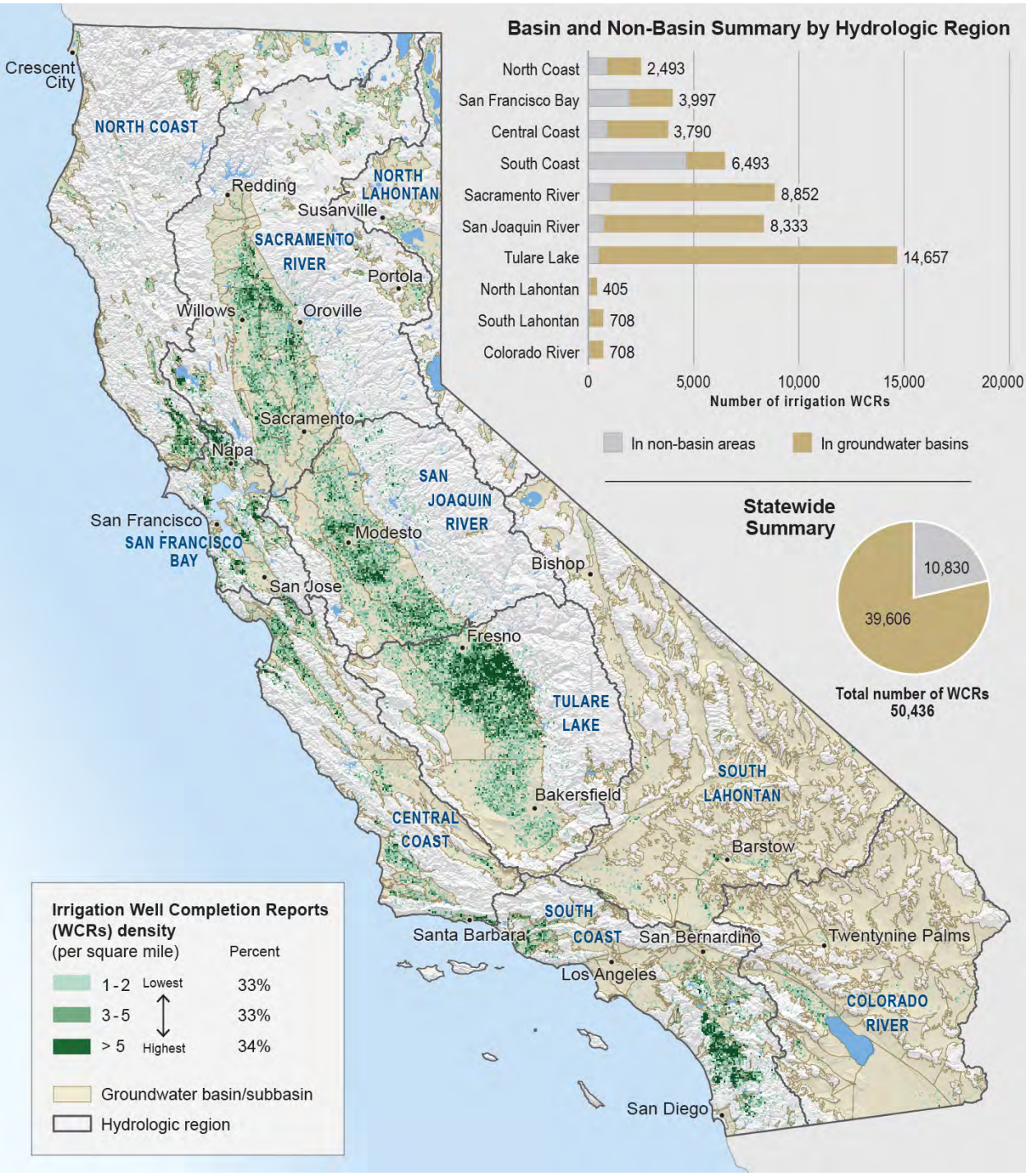


Figure 3-10 Density and Spatial Distribution of Irrigation Wells Estimated from Well Completion Reports (1977–2018)



Irrigation wells are largely concentrated in groundwater basins with 39,606 WCRs in basins (Figure 3-7) and 10,830 WCRs outside basins (Figure 3-8). Irrigation wells are indicative of high groundwater use because they are generally designed to be much higher-capacity wells than domestic wells. Most of the state's agricultural groundwater production occurs within the Central Valley, consistent with the high concentration areas of irrigation wells indicated in Figure 3-10.

Figures 3-11 and 3-12 depict the well-depth distribution and cumulative totals of domestic wells and irrigation wells across the state based on WCRs. The bars in these figures indicate the number of wells with depths that fall within a given depth interval; the line indicates the number of wells that are shallower, or equal to, a given depth interval. Depth distributions on the figures are only shown in discrete intervals to 1,000 feet. There are 1,063 domestic wells and 503 irrigation wells throughout the state that exceed 1,000 feet, but when compared to the first 1,000 feet, the distribution curve beyond 1,000 feet reveals very little about the differences among hydrologic regions.

Figure 3-11 Total of Domestic Wells by Well Depth with a Cumulative Curve Based on Well Completion Reports (1977–2018)

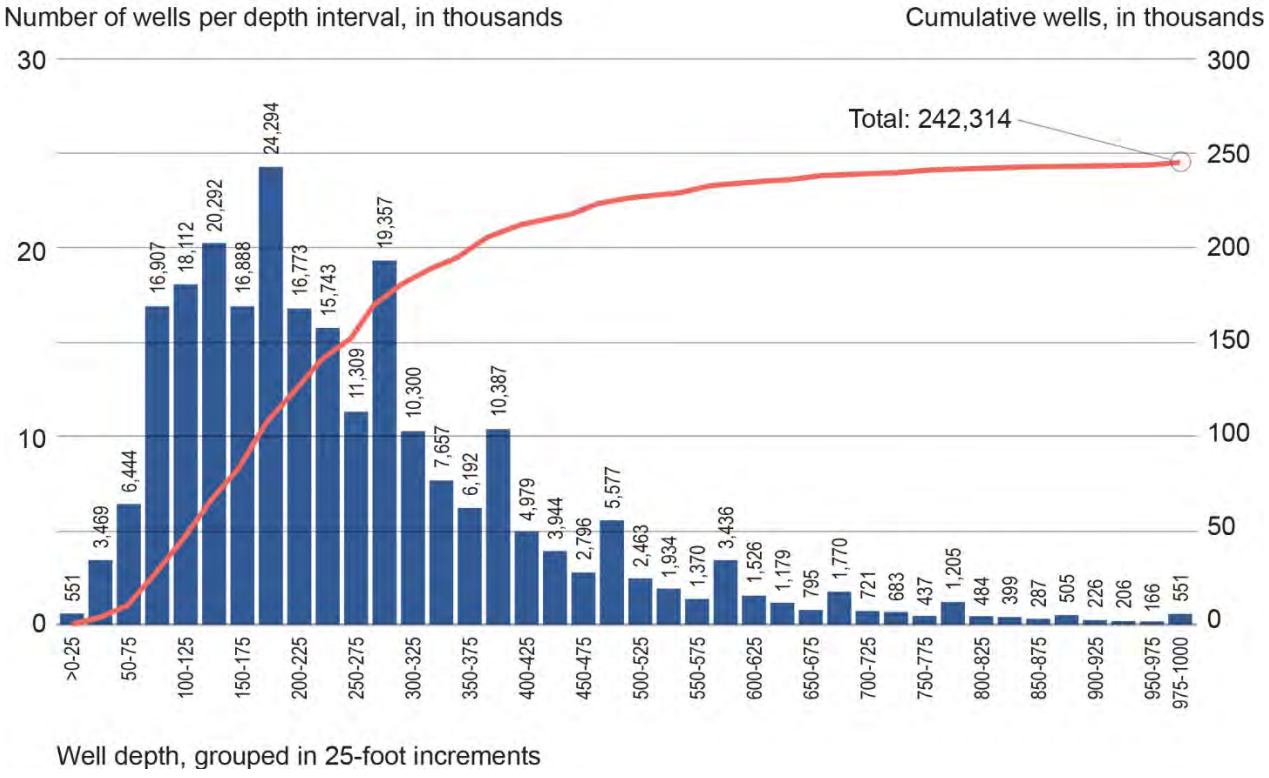


Figure 3-11 note: There are an additional 1,063 domestic wells throughout California that exceed 1,000 feet.

Figure 3-12 Total of Irrigation Wells by Well Depth with a Cumulative Curve Based on Well Completion Reports (1977–2018)

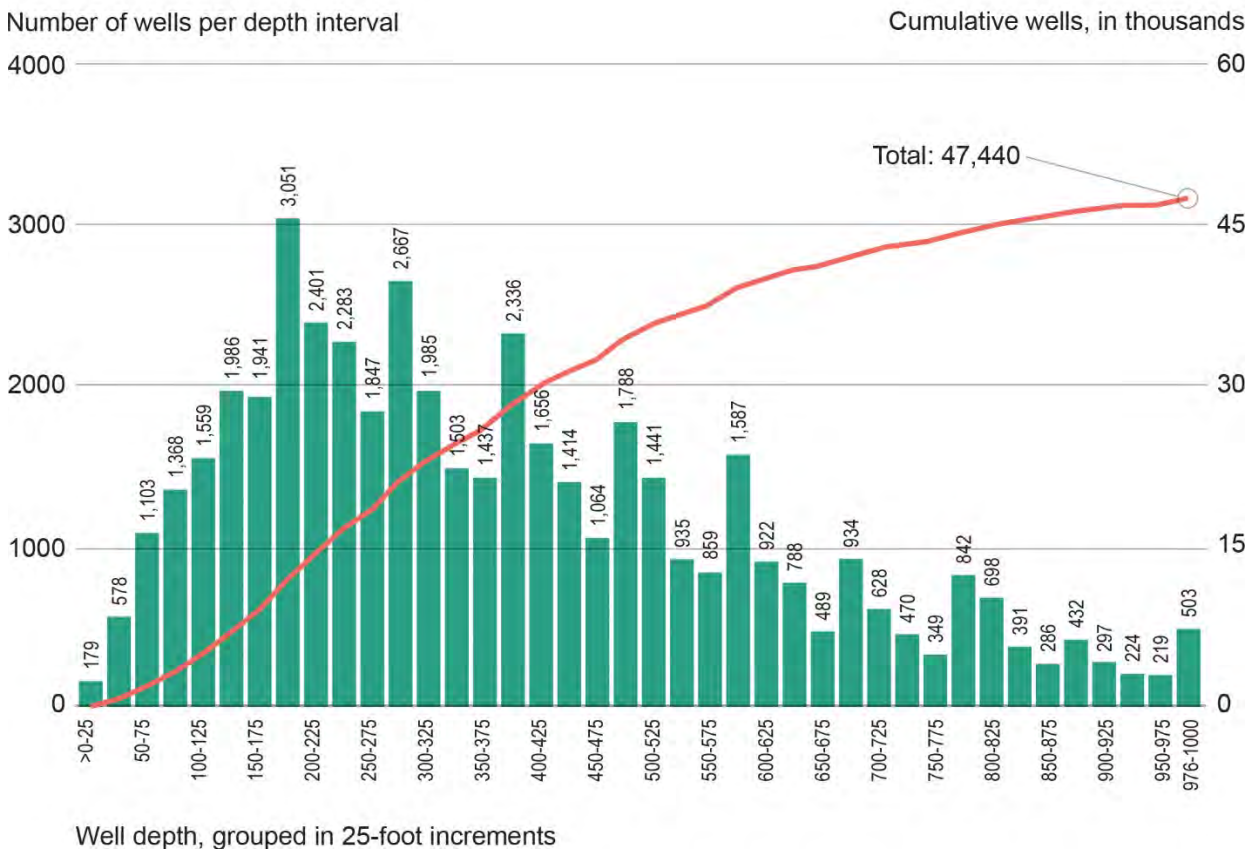
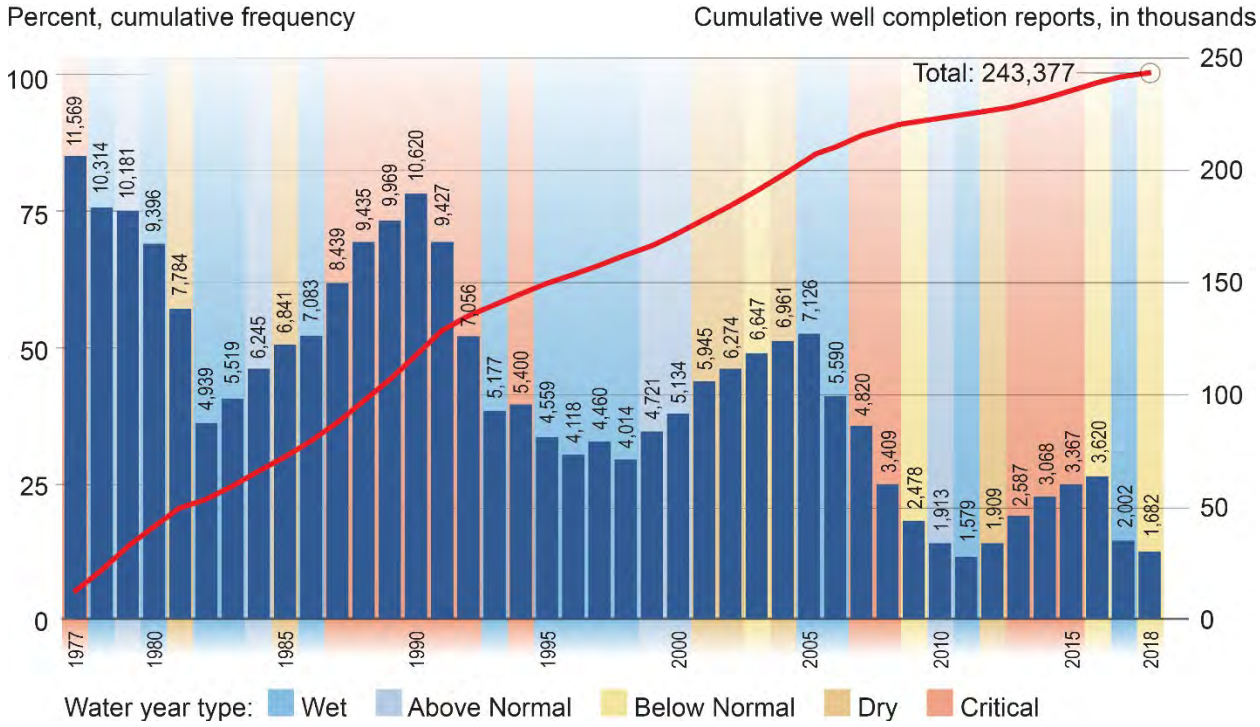


Figure 3-12 note: There are an additional 2,996 irrigation wells throughout California that exceed 1,000 feet.

Figures 3-12 and 3-13 depict the annual and cumulative installations of domestic and irrigation wells estimated from submitted WCRs. The figures include water-year types that are defined by DWR and use the San Joaquin Valley Water Year Hydrologic Classification Index which includes critical, dry, below normal, above normal, and wet classification year designations. No statewide water-year index currently exists.

The number of WCRs submitted for domestic wells is typically influenced by changes in populations and new home construction, which is strongly influenced by economic cycles. The housing booms of the 1970s and late 1980s resulted in years with more than 10,000 wells installed. The end of the Cold War (1991) caused the significant scaling back of the aerospace industry that contributed to a statewide softening of housing construction, particularly in the Los Angeles area, and ultimately a housing

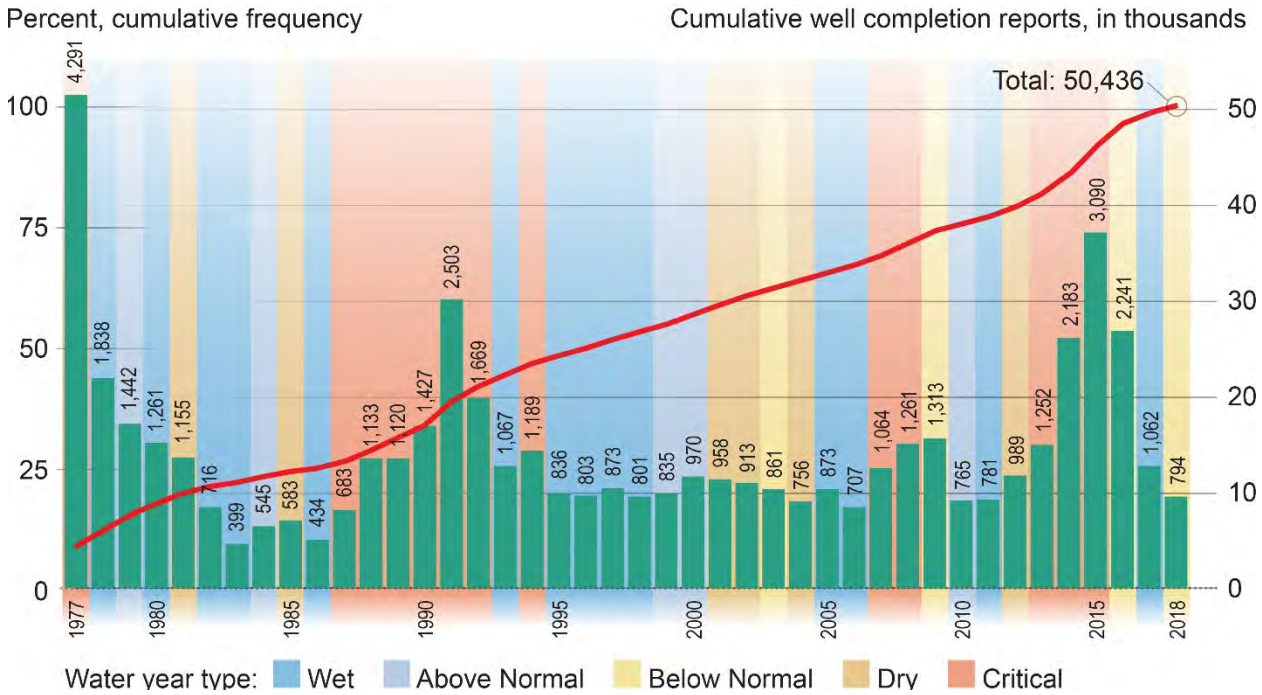
Figure 3-13 Domestic Well Installations by Year with Cumulative Curve Based on Well Completion Reports (1977-2018)



recession statewide in the early 1990s (Construction Industry Research Board 2019). The housing recession coincided with several years of reductions in the number of new domestic well installations beginning in 1991 (Figure 3-12). The decline in domestic well installations between 2008 and 2010 coincided with the Great Recession that led to a reduction in housing construction and ultimately in domestic well installations. Based on submitted WCRs, 243,377 domestic water wells were installed in California from 1977 through 2018.

Installation trends for irrigation wells reflect changes in annual precipitation conditions but may be influenced by other factors such as cropping trends, irrigation methods, or the availability of alternative agricultural water supplies. The number of WCRs received for irrigation well installations ranged from a high of approximately 4,300 in 1977 during the 1976–1977 drought, to more than 3,000 in 2015 during the 2012–2016 drought, to a low of 399 during the wet year of 1983. The number of new irrigation wells installed generally correlates with regional water-year types, with considerable increases in the number of well installations during dry to critical water years as shown in 2012 through 2015. WCR data indicate that approximately 50,000 irrigation wells were installed in California from 1977 through 2018.

Figure 3-14 Statewide Irrigation Well Installations by Year with Cumulative Curve Based on Well Completion Reports (1977–2018)



Even though the ratio of domestic-well to irrigation-well installations from 1977 through 2018 is approximately 5-to-1, the irrigation wells produce, on average, 83 percent of the groundwater used in the state (Table 3-2).

Water Budgets

Water budgets are defined in California Water Code Section 10721 as "an accounting of the total groundwater and surface water entering and leaving a basin including the changes in the amount of water stored." A water budget is a critical element of sustainable groundwater management because it provides an understanding of historical conditions as well as how future changes to supply, demand, hydrology, population, land use, and climatic conditions will affect water management in a geographic area, such as a groundwater basin. Water agencies may use water budgets for a variety of purposes, such as water supply planning, preparing feasibility studies, facilitating integrated water resources management, estimating and quantifying water resources, identifying data gaps, and forecasting optimum water management actions.

Water budget development is mandated by recent legislation in California. The Groundwater Sustainability Plan Regulation, adopted pursuant to SGMA, requires all

high- and medium-priority groundwater basins in California prepare a groundwater sustainability plan (GSP) that "shall include a water budget for the basin that provides an accounting and assessment of the total annual volume of groundwater and surface water entering and leaving the basin, including historical, current and projected water budget conditions, and the change in the volume of water stored." Moreover, Assembly Bill 1668, passed in 2018, requires agricultural water management plans to include "an annual water budget based on the quantification of all inflow and outflow components for the service area of the agricultural water supplier."

DWR Guidance on Water Budget Development

DWR developed two technical documents to assist local and regional agencies in developing and utilizing a water budget. These documents are not prescriptive in what methods a water agency should apply to develop water budgets; rather, these documents provide a catalog of approaches and methods that a water agency may consider based on its needs, data and tool availability, and expertise.

The *Water Budget BMP* (California Department of Water Resources 2016) includes best management practices designed to assist groundwater sustainability agencies with developing water budgets as part of their GSPs. The *Water Budget BMP* describes the fundamental water budget concepts and the relations among water budget components, including a general working framework and guidance.

The draft *Handbook for Water Budget Development: With or Without Models* (California Department of Water Resources 2020) provides a systems-based three-dimensional conceptual schematic of water budget components with associated common vocabulary; a water budget accounting template to organize and present inflows (credits) and outflows (debits) for the land, surface water, and groundwater systems; decision trees to streamline selection of a modeling or non-modeling approach for water budget development; case studies demonstrating development of water budgets with and without a model; and a compilation of relevant data sources with tips and practical advice on how to use the sources to develop estimates of various water budget components.

Additional Information for Compilation of a Water Budget

In addition to the two water budget guides summarized above, DWR provides other resources for developing water budget information. Along with the estimates of water use provided in this section, Chapter 6, "Groundwater Conditions," of this report describes existing groundwater conditions across the state, including

information directly related to compilation of groundwater budgets, such as estimates of change in stored groundwater. Also, *California Water Plan Update 2013* and *California Water Plan Update 2018* contain regional and statewide water budget information.

Many water agencies conduct a variety of water budgeting efforts through various water management plans, in addition to those mandated under SGMA for high- and medium-priority basins (described in Chapter 4, "Groundwater Management"). These water budgeting efforts include groundwater management plans, agricultural water management plans, and urban water management plans. Many of these plans include important water supply and use information that could be used in development of a water budget for the area of interest.

Finally, several numerical hydrologic models are used in the state to help develop water budgets at various spatial scales. The Integrated Water Flow Model (IWFM) is developed and supported by DWR. A few model applications, including the California Central Valley Simulations (C2VSim) model, have been developed by DWR using the IWFM modeling platform. Similarly, MODFLOW and MODFLOW-One Water Hydrologic Model (MODFLOW-OWHM), developed by the U.S. Geological Survey (USGS), can be used to estimate water budget components. MODFLOW and MODFLOW-OWHM have several applications within California, most notably the Central Valley Hydrologic Model.

A full list of MODFLOW applications within California is available on USGS's California Water Science Center website. Additionally, more simplified models exist that can be applied throughout the state, such as DWR's IWFM Demand Calculator and California Simulation of Evapotranspiration of Applied Water (CalSIMETAW). Other useful water budget development tools are available, such as the Water Evaluation and Planning Model (WEAP) developed by the Stockholm Environment Institute's U.S. Center, with DWR as a contributor in its development, and other spreadsheet-type models.

History of Water Budgets with Respect to SGMA Implementation

SGMA defined water budget as an accounting of both surface water and groundwater inflows and outflows of a basin. Prior to SGMA, groundwater basins were often managed by considering only "groundwater budget," which was defined in CalGW Update 2003 (California Department of Water Resources 2003) as "an analysis of a groundwater basin's inflows and outflows to determine the change in groundwater storage." The focus of water budgeting was on the change in groundwater storage within a groundwater basin. In CalGW Update 2003, basins are

classified into the categories Type A, B, or C based on the extent of groundwater budget information available. A "Type A" budget indicates that much of the information needed to characterize the groundwater budget for the basin or subbasin is available. "Type B" indicates that enough data were available to estimate the groundwater extraction to meet local water demands. "Type C" indicates that insufficient data are available to provide either an estimate of the basin's groundwater budget or the groundwater extraction from the basin.

Before implementation of SGMA, many local agencies involved in groundwater management developed groundwater management plans. Assembly Bill 3030 (1992) and Senate Bill 1938 (2002) provide a systematic procedure for local agencies to follow when developing groundwater management plans. Neither of these bills require the development of a comprehensive water budget, involving both surface water and groundwater, required to meet the GSP regulations. Local entities may have developed water budget information for those plans, and perhaps they could be used as the basis for future water budget development.

With the passage of SGMA and the subsequent development of the GSP regulations, all high- and medium-priority basins are required to develop and submit either a GSP, which must contain an assessment of water budgets, or an alternative plan that will achieve the same outcome as a GSP. After all the GSPs have been reviewed by DWR, relevant information from those plans will be used to inform water budgets by groundwater basin in updates of CalGW.

Next Steps for Statewide Water Budgets

The latest water budget information compiled as part of SGMA implementation and related groundwater management activities will provide an improved understanding of the inflows, outflows, and changing conditions at the groundwater basin and regional scale. DWR is also taking initiatives to collect water use and hydrologic data for low- and very-low priority basins and non-basin areas to better understand their water use and the local effects of the use. This information will inform the *Water Resilience Portfolio* actions that include an assessment of existing demand for water on a statewide and regional basis, as well as an assessment of available water supply to address the demand. Additionally, water budgets created as part of SGMA implementation and summarized by the CalGW updates will become an important source of information to inform planning efforts including the California Water Plan, other statewide plans, model development, and related water management activities.

Chapter 4. Groundwater Management

Introduction

California's increasing population and expanding agricultural industry in the twentieth century brought greater water demands and increased use of groundwater to meet the demand. The need for groundwater management became apparent beginning in the 1940s with rapidly declining groundwater levels concomitant with land subsidence occurring in various parts of the state. Initial groundwater management efforts included self-governance by the users within a groundwater basin or court-adjudicated basin operations.

In the early 1990s, the California State Legislature began taking significant interest in protecting this precious resource. Lawmakers enacted legislation and provided financial assistance to local agencies to encourage voluntary groundwater management. In 2014, the Legislature enacted the Sustainable Groundwater Management Act (SGMA) during the middle of a five-year drought in California. SGMA is the culmination of two-and-a-half decades of State-provided guidance and financial assistance for voluntary groundwater management by local agencies.

An understanding of the history of groundwater management in California is critical for collaborative development of plans and projects to achieve sustainability, protect the state's groundwater resources, and endure future droughts. This chapter discusses the history of groundwater management before the enactment of SGMA, the activities and progress to support the implementation of SGMA, the emerging water market in response to SGMA, and potential for managed aquifer recharge.

Groundwater Management Prior to the Enactment of SGMA in 2014

Historically, California managed groundwater based on a landowner's overlying rights and the reasonable and beneficial use doctrine. At the doctrine's most basic sense, any landowner has the right to install wells and extract unlimited water from beneath that property as long as the water is put to a beneficial use. As the practice of unmanaged extraction of groundwater resources persisted for decades, aquifers were drained lower and lower to meet increasing water demands. It became apparent that groundwater was not an infinite resource and unfettered use had led to adverse conditions that threatened the quality and sustainability of the resource.

In response to the growing reliance and associated impacts on groundwater as a resource, groundwater adjudications issued by the courts to resolve overdrafted conditions as a management tool began in the 1920s. Further groundwater basin adjudications are still occurring. Special act districts were enacted to provide local agencies with additional management authorities to address local groundwater management. Subsequently, voluntary groundwater management, with incentives for management planning, were enacted by the Legislature in the 1990s and 2000s. The detailed evolution of groundwater management in California, up until the enactment of SGMA in 2014, is described below.

Groundwater Rights

The groundwater use in California is governed by three types of groundwater rights: overlying, appropriative, and prescriptive.

Overlying rights are the most common. They afford the landowner overlying a groundwater supply the right to beneficially use an amount of groundwater that is reasonable when considering the competing demands of all other overlying landowners.

Appropriative rights apply to two types of uses – where the groundwater pumper does not own the overlying land, or where the overlying landowner moves the pumped water outside of the groundwater basin. Appropriative rights require continued use of the resource. Any break in the continued use could result in the loss of that right. Overlying groundwater rights have a higher priority than appropriative rights.

A prescriptive right is a right that is acquired through adverse possession of someone else's water right. Prescriptive rights were decided by the California Supreme Court in the 1949 *Pasadena v. Alhambra* case. The court decided "that various users, including appropriators, had acquired prescriptive rights – rights to infringe upon the established water right of others by means of trespass or unauthorized taking." The court held that prescriptive rights were determined based upon demonstrated use in the previous five years. Total extraction amount from a groundwater basin was limited to its safe yield.

Refer to Appendix D, "Citations, Reference Materials, and Links," for additional information on California's water rights from the State Water Resources Control Board (State Water Board).

Groundwater Adjudications

Court adjudications of groundwater rights have occurred in California for nearly 100 years. In the early twentieth century, increased water needs of a growing population and the agricultural industry resulted in the increased reliance on groundwater as part of California's water supply. As precursors to formal groundwater management, groundwater adjudications were used to address disputes in groundwater rights and the adverse effects of over-use.

In some California groundwater basins, as the water supply is extracted beyond the capability of the basin to recharge that supply, landowners and other groundwater users turn to the courts to determine how much groundwater can be extracted. Typically, a lawsuit is filed to determine the rights of pumpers to extract water. The courts address the controversy among parties and designate the path to provide a physical solution in the form of groundwater adjudications (Langridge et al. 2016).

Groundwater adjudications can cover an entire basin, a portion of a basin, or a group of basins, and may include non-basin areas. Groundwater rights are defined for the overlying landowners and appropriators within the adjudicated area. The court decides who is allowed to extract groundwater, how much they are allowed to extract, and designates a watermaster who ensures the adjudicated areas are managed in accordance with the court ruling.

Since 1924, courts have been involved in 30 groundwater adjudication areas that cover portions of 42 groundwater basins. Five of the 42 basins are covered with two or more adjudications. Groundwater adjudicated areas in California, as of 2020, are shown in Figure 4-1 and listed in Table 4-1.

Figure 4-1 Areas with Groundwater Adjudications



Table 4-1 Groundwater Basins with Areas Under Groundwater Adjudications

Map ID	Basin Numbers	Adjudicated Area Name	Court Judgment Date
A01	7-021.04, 8-002.08	Beaumont Basin	2004
A02	8-002.01	Chino Basin	1978
A03	8-002.02	Cucamonga Basin	1978
A04	4-011.04	Central Basin	1965
A05	4-011.03	West Coast Basin	1961
A06	3-016	Wright Judgement	1989
A07	4-013	Main San Gabriel Basin	1968
A08	6-037, 6-038, 6-040, 6-041, 6-042, 6-043, 6-044, 6-047, 6-049, 6-050, 6-089, 7-015, 7-018.01, 7-019	Mojave Basin Area	1996
A09	4-023	Raymond Basin	1944
A10	8-002.03, 8-002.06, 8-005	San Bernardino Basin Area	1969
A11	8-002.04	Rialto-Colton	1961
A12	8-005, 9-004, 9-005, 9-006	Santa Margarita River Watershed	1966
A13	3-012.01	Santa Maria Valley Management Area	2008
A14	4-004.04	Santa Paula Basin	1996
A15	1-005	Scott River Stream System	1980
A16	3-004.08	Seaside Basin	2006
A17	4-013	Six Basins	1998
A18	5-028, 6-045	Tehachapi Basin	1971
A19	5-027	Cummings Basin	1972
A20	5-080	Brite Basin	1970
A21	4-012	Upper Los Angeles River Area	1979
A22	4-013	Puente Basin	1987
A23	7-012	Warren Valley Basin	1997
A24	8-005	Hemet-San Jacinto Basin	2013
A25	3-008.01	Los Osos Basin	2015
A26	6-044	Antelope Valley	2015
A27	6-012.01	Inyo County Basins	1991

Map ID	Basin Numbers	Adjudicated Area Name	Court Judgment Date
A28	3-012.01	Nipomo Mesa Management Area	2014
A29	3-012.01	Northern Cities Management Area	2015
A30	8-002.06	Lytle Creek Basin	1924

Table 4-1 note: Five basins are covered by two or more adjudications (3-012.01, 4-013, 6-044, 8-002.06, and 8-005)

Special Act Districts

Special acts have been used since the 1870s to create, by legislation, the rules for various types of districts such as irrigation, water storage, reclamation, and many others. Many of these initial special act districts, established by the Legislature, consist of various authorities, which may include groundwater management.

In response to specific local groundwater management concerns over the years, the Legislature has granted a greater level of authority to manage groundwater to a few local agencies or districts referred to as groundwater management special act districts. Refer to Table 4-9 for a complete list of groundwater management special act districts.

The specific authority of each agency varies, but they are generally able to do the following activities:

- Develop a groundwater management plan.
- Control groundwater-related exports.
- Collect fees or taxes on groundwater pumping or for other groundwater-related activities.
- Regulate or require the reporting of groundwater pumping.
- In some situations, special act districts have authority for other groundwater management activities such as recharge and conjunctive use.

Groundwater Management Plans

Prior to 1992, groundwater management authority was generally granted through some of the more than 20 types of local agencies created by the Legislature to address various aspects of water resource management. At that time, as is still the case today, local governments such as cities and counties also had the authority to adopt ordinances to regulate groundwater.

In 1992, the State promoted voluntary groundwater management efforts at the local level with the enactment of Assembly Bill (AB) 3030, the Groundwater Management Act (California Water Code [Water Code] Section 10750 et seq. Part 2.75). AB 3030 outlined the procedure and recommended content for a local agency to develop a groundwater management plan (GWMP) for a groundwater basin. AB 3030 (1992) superseded AB 255 (1991), which authorized local agencies overlying basins subject to critical conditions of overdraft, as defined in *California's Groundwater* (CalGW) *Update 1980* to levy fees and establish programs for groundwater management within their service areas. AB 3030 also established a systematic process for developing a GWMP for all groundwater basins defined in CalGW Update 1980, not just those with conditions of critical overdraft.

In 1999, the California Budget Act authorized the California Department of Water Resources (DWR) to update CalGW (also known as Bulletin 118), including updating the inventory of groundwater basins, develop criteria for the evaluation of GWMPs, and develop a model groundwater ordinance.

In 2002, Senate Bill (SB) 1938 was signed into law, modifying Water Code Section 10750 et seq. Part 2.75 to require public agencies seeking grant funding for construction of groundwater projects to prepare a GWMP with additional required components. The SB 1938 requirements include both basin and non-basin areas, depending on groundwater management responsibilities of the agency drafting the GWMP.

The Water Conservation Act of 2009 (SB X7-6) and AB 1152 established the California Statewide Groundwater Elevation Monitoring (CASGEM) Program, which allows local agencies and other entities to voluntarily create a monitoring program and upload groundwater level data they collected to the CASGEM website, with the focus being on spring (seasonal high) and fall (seasonal low) measurements. The monitoring entities participating in CASGEM were at an advantage if they had an existing GWMP for their basin and could use wells in their existing monitoring program for their CASGEM monitoring network.

To encourage local agency participation in developing GWMPs and participation in CASGEM monitoring, the Legislature authorized various grants to be made available to local agencies. This funding was intended to assist local agencies in water resource management through a series of propositions and legislation, including AB 303 (2003) and Propositions 50 (2002), 84 (2006), 1E (2006), 1 (2014), and 68 (2018).

A portion of these funds was dedicated to grants for groundwater-related projects and GWMP development. In addition, a much larger amount of grant funding was available for integrated regional water management (IRWM) implementation, which could include groundwater-related projects. The grants provided as part of the programs were generally intended to assist with developing and submitting a compliant GWMP as well as reporting semi-annual groundwater level information to the State.

In 2011, AB 359 was signed into law, directing local agencies to identify and define groundwater recharge areas. The legislation also required that GWMPs be submitted to DWR where they are required to be publicly available.

In *California's Water Plan – Groundwater Update 2013*, DWR reports the results of an inventory and content review of GWMPs submitted prior to January 1, 2012. This analysis provided an overall view of the level of groundwater management efforts being implemented throughout the state.

Groundwater Ordinances

Groundwater ordinances (laws) are another tool that local agencies, such as municipalities and counties, can use to manage groundwater. Many groundwater-related ordinances have been adopted by local governments. Counties and cities are not required to submit groundwater ordinance updates to DWR.

During or immediately after each drought, counties have enacted new rules to secure the groundwater resources with the county. As of January 2021, all 58 counties in the state have ordinances in place regulating groundwater. Ordinances cover topics ranging from well construction, abandonment, and destruction to groundwater exports, recharge, and management. Since the beginning of the 2012-2016 drought, 36 of 58 counties have updated existing ordinances or passed new groundwater ordinances.

Groundwater and Other Related Local and Regional Plans

Because groundwater is a key water source for urban and agricultural users, groundwater information is also presented in other statutorily required or voluntary local and regional plans as summarized below. There may also be other local or regional plans, efforts, or projects that may have a nexus to water resources.

Urban Water Management Plans

Urban water management plans (UWMPs) are prepared by California's urban water suppliers every five years. These plans support the suppliers' long-term resource planning to ensure that adequate water supplies are available to meet existing and future water needs. The requirements for UWMPs are found in Water Code Sections 10610–10656 and 10608. Every urban water supplier that provides more than 3,000 acre-feet of water annually, or serves more than 3,000 urban connections, is required to submit an UWMP.

The groundwater information collected from the submitted UWMPs is useful for local, regional, and statewide groundwater planning. Further information regarding urban water management and UWMPs can be found on DWR's Urban Water Management Plans webpage.

Agricultural Water Management Plans

The Water Conservation Act of 2009 (SB X7-7), Part 2.55, Chapter 4, Section 10608.48, requires agricultural water suppliers serving more than 25,000 irrigated acres (excluding recycled water deliveries) to adopt and submit to DWR an agricultural water management plan (AWMP). The AWMP must be adopted by April 1, 2021, updated every five years thereafter, and submitted electronically to DWR no later than 30 days after adoption.

AWMPs are developed by water and irrigation districts to advance the efficiency of agricultural water management while benefitting the environment. Because agriculture accounts for approximately 80 percent of all applied water use in California, AWMPs provide an important tool for local groundwater management. Some of the water efficiency practices currently being implemented include controlling drainage problems through alternative use of lands, using recycled water that otherwise would not be used beneficially, improving on-farm irrigation systems, and lining or piping ditches and canals that will reduce current levels of groundwater recharge. Additional information regarding agriculture water management and AWMPs can be found on DWR's Agricultural Water Use Efficiency webpage.

Integrated Regional Water Management Plans

IRWM plans are voluntary and comprehensive planning documents prepared on a region-wide scale that identify priority water resource projects and programs. There are 48 defined IRWM regions that cover approximately 87 percent of the state and 99 percent of the population (California Department of Water Resources 2015). IRWM plans are prepared for each region by individual IRWM groups. Groundwater

management tied to IRWM processes and plans can deliver higher value for investments by considering all interests, providing multiple benefits, and working across jurisdictional boundaries.

IRWM improves resource management and supports economic stability, environmental stewardship, and public safety. IRWM plans involve multiple agencies and interested parties, individuals, and groups that cross jurisdictional, watershed, and political boundaries. The methods used in IRWM planning include developing water management strategies that relate to water supply and water quality, water use efficiency, operational flexibility, stewardship of land and natural resources, and groundwater resources.

IRWM plans address groundwater management, when relevant, in the form of regional goals, objectives, and strategies and contain information about current and future groundwater use. Additional information regarding Integrated Regional Water Management and IRWM plans can be found online at the DWR's Integrated Regional Water Management webpage.

State Agencies Supporting Groundwater Management

Several State agencies play major roles in supporting local agencies as they develop and implement GWMPs and projects. Some of these roles may not be self-evident or immediately recognized, but because they work toward the goal of maintaining a reliable groundwater supply, they are closely related to groundwater management. The many ways DWR is involved in supporting and promoting groundwater management activities are described below in this chapter, along with various funding opportunities. The section below describes programs available through other State agencies that assist local agencies in managing groundwater resources. For more information on the roles of various agencies in protecting groundwater resources, see the individual agency website links in Appendix D, "Citations, Reference Materials, and Links."

State Water Resources Control Board and Regional Water Quality Control Boards

The mission of the State Water Board is "to preserve, enhance, and restore the quality of California's water resources and drinking water for the protection of the environment, public health, and all beneficial uses, and to ensure proper water resource allocation and efficient use for the benefit of present and future generations." In alignment with this vision, the nine regional water quality control

boards (RWQCBs) develop and enforce water quality objectives and implement plans to protect the beneficial uses of the state's waters, recognizing differences in climate, topography, geology, and hydrology. The State Water Board has specific authority and responsibility with respect to sustainable groundwater management, which will be discussed later in this chapter.

State Water Board Division of Drinking Water

The State Water Board's Division of Drinking Water (DDW) has the primary enforcement authority to implement federal and State safe drinking water acts, as well as California statutes and regulations related to drinking water. As part of this responsibility, DDW inspects and provides regulatory oversight of 7,403 public water systems (State Water Resources Control Board 2019) to assure delivery of safe drinking water to California consumers. DDW is also responsible for developing and implementing the Safe Drinking Water Plan, which includes an overview of drinking water regulations, reviews and plans for drinking water quality monitoring and threats, treatment technologies, and funding and financial assistance (State Water Resources Control Board 2015).

Other State Water Board Groundwater Management Activities

The State Water Board has many other responsibilities related to the protection of groundwater resources. One of the more notable is the Groundwater Ambient Monitoring and Assessment (GAMA) Program. The GAMA Program was established in 2000 to provide a comprehensive assessment of water quality in wells throughout the state. GAMA was subsequently expanded by the Groundwater Quality Monitoring Act of 2001 (AB 599, Water Code Section 10780 et seq.), which requires the State Water Board to develop a comprehensive monitoring program in a report to the Legislature. The GAMA Program is based on interagency collaboration among the State Water Board and RWQCBs, DWR, California Department of Pesticide Regulation, California Department of Toxic Substances Control, California Department of Food and Agriculture, U.S. Geological Survey, and Lawrence Livermore National Laboratory. It is also based on cooperation with local water agencies and well owners.

To facilitate effective information sharing and communication among interested parties, groundwater quality data are made available on the State Water Board's GeoTracker system. GeoTracker is a geographic information system that provides access to environmental data for sites that require cleanup, such as leaking underground storage tank sites, Department of Defense sites, and cleanup program sites. GeoTracker contains records for various unregulated projects, facilities,

irrigated lands, oil and gas production, operating underground storage tanks, and land disposal sites. For more information about GeoTracker, refer to Appendix D, "Citations, Reference Materials, and Links."

Other State Water Board and RWQCB activities related to groundwater protection include:

- Developing basin plans (also called water quality control plans) that identify existing and potential beneficial uses of marine water, groundwater, and surface water and provide the framework for regulating discharge of wastes that may affect water quality in California.
- Monitoring landfills and hazardous waste facilities.
- Establishing standards for the construction and monitoring of underground storage tanks.
- Establishing management plans for control of nonpoint source pollutants.
- Issuing cleanup and abatement orders that require corrective actions by the responsible party for a surface water or groundwater pollution problem or nuisance.

Responsibilities related to drinking water were previously held by the California Department of Health Services but were transitioned to the State Water Board's DDW on July 1, 2014.

California Department of Pesticide Regulation

The California Department of Pesticide Regulation (DPR) protects human health and the environment through the regulation of pesticide sales and use and through the promotion of reduced-risk pest management. DPR plays a significant role in monitoring for the presence of pesticides in groundwater and in preventing further contamination of water resources.

DPR has a designated Groundwater Protection Program that evaluates samples for pesticides to determine whether they may contaminate groundwater, identifies areas sensitive to pesticide contamination, and develops mitigation measures to minimize pesticide movement. DPR adopts regulations and performs outreach to carry out the mitigation measures. The measures are designed to prevent the continued movement of pesticides and related compounds to groundwater in contaminated areas and to prevent problems before they occur in other areas (California Department of Pesticide Regulation 2020). For more information about DPR and its databases, refer to Appendix D, "Citations, Reference Materials, and Links."

California Department of Toxic Substances Control

The California Department of Toxic Substances Control (DTSC) has two programs related to groundwater resources protection: the Hazardous Waste Management Program and the Site Mitigation Program. These programs are authorized under Division 20 of the California Health and Safety Code; implementing regulations are codified in Title 22 of the California Code of Regulations.

A critical element of both programs is maintaining environmental quality and economic vitality through the protection of groundwater resources. This is accomplished through hazardous waste facility permitting and design; oversight of hazardous waste handling, removal, and disposal; oversight of remediation of hazardous substances releases; funding of emergency removal actions involving hazardous substances, including the cleanup of illegal drug labs; cleanup of abandoned hazardous waste sites; oversight of the closure of military bases; and pollution prevention.

If groundwater is threatened or affected by a hazardous substance release, DTSC provides technical oversight for the characterization and remediation of soil and groundwater contamination. DTSC and the nine RWQCBs coordinate regulatory oversight of groundwater remediation. To ensure site-specific groundwater quality objectives are met, DTSC consults with RWQCB staff and appropriate basin plans.

California Department of Fish and Wildlife

As trustee for California's fish and wildlife resources, the California Department of Fish and Wildlife (CDFW) has jurisdiction over the conservation, protection, and management of fish, wildlife, native plants, and the habitat necessary for biologically sustainable populations of such species (Fish and Game Code Sections 711.7 and 1802).

In response to the passage of SGMA, CDFW developed a Groundwater Program to ensure fish and wildlife resources reliant on groundwater are addressed in groundwater sustainability plans (GSPs) and to support compliance with regulatory requirements on CDFW-owned lands and facilities in groundwater basins currently required to implement a GSP (California Department of Fish and Wildlife 2020). Information for local groundwater planners regarding the needs of fish and wildlife under SGMA is provided in the *Fish & Wildlife Groundwater Planning Considerations* document (California Department of Fish and Wildlife 2019).

California Department of Food and Agriculture

The mission of the California Department of Food and Agriculture (CDFA) is "to serve the citizens of California by promoting and protecting a safe, healthy food supply and enhancing local and global agricultural trade through efficient management, innovation, and sound science, with a commitment to environmental stewardship." Groundwater is an integral part of California's agricultural trade, and the CDFA works with other State agencies on a variety of groundwater-related efforts to advance their mission.

One such partnership includes DWR and the Flood-Managed Aquifer Recharge (Flood-MAR) program (see section below in this chapter). Flood-MAR is an integrated and voluntary resource management strategy that uses flood water resulting from rainfall or snow melt for managed aquifer recharge on agricultural lands and working landscapes, including but not limited to refuges, floodplains, and flood bypasses. CDFA management and staff work with DWR to host workshops, develop pilot programs, and make recommendations to the Legislature and the Governor's Office.

Federal Agencies Supporting Groundwater Management

Several federal agencies supply studies, data, and funding supporting local agencies in developing and implementing GWMPs and projects. This section below describes programs available through federal agencies that provide data to assist local agencies in managing groundwater resources. For more information on the activities of various agencies in protecting groundwater resources, see the individual agency website links in Appendix D, "Citations, Reference Materials, and Links."

U.S. Environmental Protection Agency

The U.S. Environmental Protection Agency's (EPA's) Office of Ground Water and Drinking Water protects public health by ensuring safe drinking water and protecting groundwater. The EPA oversees implementation of the Safe Drinking Water Act, including, but not limited to, developing and implementing national drinking water standards, overseeing funding of State drinking water programs and source water protection programs, protecting groundwater sources for potable uses, and providing information about drinking water quality to the public. The EPA's role in California groundwater is primarily related to protection of the resource and comes in the form of administering several federal programs in close coordination with State agencies such as the State Water Board, RWQCBs, and DTSC.

U.S. Geological Survey

The U.S. Geological Survey (USGS) is a federal agency involved in extensive groundwater research, studies, modeling, and data collection. It has published numerous studies and reports on California groundwater basins. USGS maintains an extensive groundwater level and groundwater quality monitoring network and has compiled the data in the National Water Information System and the National Groundwater Monitoring Network. USGS's Southwest Region is working on cooperative programs with local, State, and other federal agencies. The most notable programs include three regional studies of the San Joaquin-Tulare River Basin (1995), the Sacramento River Basin (2000), and the Santa Ana Basin (2004) under the National Water Quality Assessment Program. These studies were revisited between 2002 and 2012 to provide a synthesis report of major water quality topics of national priority using continued monitoring and assessments completed in the first assessment.

The USGS California Water Science Center maintains an extensive land subsidence monitoring network in an effort to understand and manage the cause, extent, and potential effects of land subsidence in California. Subsidence detection and mapping conducted by USGS is needed to manage land and water resources in areas where subsidence is a problem or may be in the future, especially in critically overdrafted basins where the undesirable effects of subsidence result from extensive groundwater withdrawal. Subsidence data are used to update numerical models of groundwater flow and aquifer-system compaction and to project subsequent effects on groundwater storage and availability (U.S. Geological Survey 2020a).

The USGS also developed and maintains MODFLOW, its open-source groundwater-flow-model code. MODFLOW is described in the "SGMA Technical Assistance Activities" section of this chapter. In addition to developing and maintaining the model code, the USGS has developed numerous local and regional groundwater flow models throughout the state. These models are public domain and hosted by the USGS's California Water Science Center. The model files, publications, and web resources associated with each file are available to download from USGS. For more information regarding USGS models, refer to Appendix D, "Citations, Reference Materials, and Links."

U.S. Bureau of Reclamation

The U.S. Bureau of Reclamation's (Reclamation's) Mid-Pacific Region office operates the Central Valley Project (CVP), an extensive network of dams, canals, and related

facilities that delivers approximately 7 million acre-feet of water during normal years for agricultural, urban, and wildlife use in California (Congressional Research Service 2020). Reclamation's role with respect to groundwater is generally limited to monitoring for effects to the groundwater systems adjacent to its CVP facilities. Through the cooperative efforts of Reclamation, DWR, irrigation districts, farmers, and other local entities, groundwater level data have been collected continuously since project conception in the 1930s and 1940s.

Reclamation also administers the Sustain and Manage America's Resources for Tomorrow (WaterSMART) program. Through this program, Reclamation works cooperatively with States, Tribes, and local entities as they plan for increasing their water supply. This is done through investments to modernize existing infrastructure and attention to local water conflicts. (U.S. Bureau of Reclamation 2020).

The WaterSMART program offers two funding opportunities specific to groundwater activities. The WaterSMART basin studies, which are collaborative studies, cost-shared with non-federal partners, to evaluate water supply and demand and help ensure reliable water supplies by identifying strategies to address imbalances in water supply and demand, including groundwater supplies. The WaterSMART program also supports groundwater management through water marketing strategy grants. Through these grants, Reclamation assists States, Tribes, and local governments in conducting planning activities to develop water marketing strategies that establish or expand water markets or water marketing activities between willing participants, in compliance with State and federal laws.

U.S. Fish and Wildlife Service

The U.S. Fish and Wildlife Service (USFWS) has the primary responsibility of managing fish and wildlife. USFWS helps ensure a healthy environment for people by providing opportunities to enjoy the outdoors and a shared natural heritage. Several functions of USFWS that relate to groundwater include the conservation and restoration of wildlife habitats, such as wetlands and groundwater dependent ecosystems, restoration of nationally significant fisheries, and management of national wildlife refuges and areas.

The National Wildlife Refuge System is a diverse network of lands and waters dedicated to conserving America's rich fish and wildlife heritage. Many of the refuges and wildlife areas under this program are managed through groundwater extractions or are located along the state's largest interconnected surface water courses (such as the San Joaquin River). USFWS has a fishery program called National Fish Hatchery

System, that operates more than 70 national fish hatcheries and 65 fishery resource offices. USFWS also has an Ecological Services Program, that has 86 field stations nationwide.

U. S. Forest Service (under U.S. Department of Agriculture)

The U.S. Forest Service serves as a steward of groundwater resources together with local communities, States, and other partners. Their goal is to maintain and enhance groundwater-fed streams, springs, wells, and wetlands, which supply healthy watersheds and communities with much-needed water.

Bureau of Land Management

The Bureau of Land Management's Soil, Water, Air Program leads efforts to assess and restore water quality condition and to manage water resources on public lands. Clean and adequate supplies of water are necessary to promote healthy watersheds, provide safe habitat for fish and wildlife, maintain drinking water sources, allow for safe recreational use of our surface water, and maintain healthy plant communities. The quality of water generated on public lands is just as important as the quantity and is integral to successful management of water resources.

National Oceanic and Atmospheric Administration Fisheries

National Oceanic and Atmospheric Administration (NOAA) Fisheries is responsible for the stewardship of the nation's ocean resources and their habitats by providing productive and sustainable fisheries, safe sources of seafood, the recovery and conservation of protected resources, and healthy ecosystems. Under the Endangered Species Act (ESA), NOAA Fisheries is responsible for the conservation, protection, and recovery of more than 150 endangered and threatened marine species, including salmon, steelhead, and green sturgeon that inhabit streams and rivers throughout California. Under ESA Policy (Section 2[c][2] of the ESA), NOAA Fisheries "shall cooperate with State and local agencies to resolve water resource issues in concert with conservation of endangered species."

Evolving State Agency Roles in Increasing Water Resiliency

Many State agencies have long-established roles in groundwater management, and it is important to acknowledge the evolving role of State agencies in supporting implementation of California's 2020 *Water Resilience Portfolio* (WRP). The WRP was developed in response to Executive Order N-10-19 and contains a series of proposals and actions for increasing water resiliency by improving groundwater management,

including streamlining permitting processes to facilitate proliferation of groundwater markets. Action 3 of the WRP states its purpose is to "help regions secure groundwater supplies by supporting the transition to sustainable use." Table 4-2 identifies the applicable WRP actions for increasing water resiliency by improving groundwater management.

Table 4-2 Water Resilience Portfolio Actions

Action Number	Water Resilience Portfolio Action	Responsible Agency
3.1	Continue implementation of SGMA, including reviewing Groundwater Sustainability Plans submitted in January 2020 and 2022 and assuring basin-wide alignment across the state's more than 250 new groundwater sustainability agencies. Support local implementation however possible, and where basin managers are unable or unwilling to implement the law, exercise appropriate enforcement.	DWR, State Water Board, CDFW
3.2	Create a state interagency team to work with stakeholders to identify tools and strategies to address the economic, environmental, and social effects of changing land use and agricultural production as local water managers implement sustainable groundwater management.	Administration
3.3	Provide targeted support to local planning efforts to address potential land-use changes in regions implementing SGMA.	Administration
3.4	Explore ways to further streamline groundwater recharge and banking efforts that do not exacerbate water quality issues and provide technical assistance to facilitate the redirection of water during periods of extended high flows to allow water to sink into aquifers, including on agricultural land. Ensure diversions are protective of native fish and wildlife.	State Water Board, DWR
3.5	Make funding available for groundwater recharge and storage projects with multiple benefits.	DWR, State Water Board
3.6	Create flexibility for groundwater sustainability agencies to trade water within basins by enabling and incentivizing transactional approaches, including groundwater markets, with rules that safeguard natural resources, small- and medium-size farms, and water supply and quality for disadvantaged communities.	DWR, State Water Board, CDFW

Action Number	Water Resilience Portfolio Action	Responsible Agency
3.7	Support use of aerial electromagnetic surveys, groundwater quality conditions, and well completion reports to identify optimal areas for enhanced recharge and critical connections in aquifer systems so that local governments may protect those lands from development and utilize for managed aquifer recharge.	DWR, State Water Board, CDFA
3.8	Explore streamlined permitting for low-hazard dams that are not across a stream channel or watercourse and are used principally for agricultural and groundwater recharge purposes.	DWR
3.9	Help regions prevent contamination of groundwater basins, including through seawater intrusion, and remediate contaminated groundwater basins that will enable large-scale water recycling and conjunctive use.	State Water Board, DWR

Table 4-2 notes: Administration = Governor and California Legislature, DWR = California Department of Water Resources; CDFA = California Department of Food and Agriculture, CDFW = California Department of Fish and Wildlife, SGMA = Sustainable Groundwater Management Act, State Water Board = State Water Resources Control Board

Groundwater Management Since Enactment of SGMA

SGMA Enactment

SGMA was signed into law in 2014 during the middle of a five-year drought that exacerbated groundwater conditions and demonstrated the perilous threats faced by California's water resources. During the 2012–2016 drought groundwater levels declined throughout the state, overdraft continued in many basins, land subsidence damaged infrastructure, seawater intrusion threatened freshwater aquifers, and degraded groundwater quality posed health risks to the state's most vulnerable and economically disadvantaged populations.

SGMA is comprised of three separate bills: AB 1739 (Dickinson), SB 1168 (Pavley), and SB 1319 (Pavley). These bills fundamentally changed the course of California's groundwater management history by creating a new regulatory framework for sustainable groundwater management while recognizing and preserving the authority of cities and counties to manage groundwater according to their existing powers. SGMA was enacted on the premise that groundwater is best managed at the local level and that the State's primary role is to provide technical, planning, and financial assistance. SGMA also gives the State regulatory oversight and intervention

responsibilities if local agencies fail to develop and implement collaborative plans and management actions to achieve sustainability.

The legislative intent of SGMA is to:

- Provide for the sustainable management of groundwater basins.
- Enhance local management of groundwater consistent with the rights to use or store groundwater.
- Establish minimum standards.
- Establish groundwater sustainability agencies (GSAs) and provide them with the necessary authority and assistance.
- Avoid or minimize subsidence.
- Improve data collection and understanding about groundwater.
- Increase groundwater storage and remove impediments to groundwater recharge.
- Manage groundwater basins through the actions of GSAs while minimizing State intervention.
- Provide a more efficient and cost-effective groundwater adjudication process.

While SGMA applies to all 515 groundwater basins, participation is mandatory only for high- and medium-priority groundwater basins. Basin priority is defined by DWR through the basin prioritization process discussed below in this chapter. These high- and medium-priority groundwater basins are required to form GSAs and develop and implement GSPs to achieve sustainability within 20 years.

DWR's Role in SGMA

DWR has three roles in implementing SGMA: (1) a regulatory role, which includes development and implementation of the regulations governing basin boundaries and GSP development and evaluation, annual progress reports, and five-year updates; (2) a technical assistance role, which includes providing technical information and models, planning tools, and data; and (3) a financial support role for local agencies and GSAs.

State Water Board's Role in SGMA

The State Water Board's Groundwater Management Program oversees the responsibilities assigned to the State Water Board by SGMA. In areas where groundwater users and local agencies are unable or unwilling to sustainably manage their groundwater basins, SGMA allows for State Water Board intervention.

Current SGMA Groundwater Management

Since the passage of SGMA, groundwater management in California has fundamentally changed in a short period of time. Some of the major changes are the formation of GSAs by local agencies, the development and submission of GSPs or alternative GSPs, and increased reporting requirements for adjudicated areas.

Figure 4-2 provides a timeline of the key activities related to SGMA implementation to date. The timeline for future SGMA-related activities can be found in Figure 4-6.

Figure 4-3 shows the status of SGMA groundwater management in groundwater basins arranged as follows:

- Basins that have submitted GSPs by January 31, 2020.
- Basins that are required to submit GSPs over the next two to four years depending on when the basin was designated as high or medium priority.
- Approved or pending approval of an alternative.
- Adjudicated areas.
- Basins with the option of forming a GSA and developing a GSP.

Figure 4-2 SGMA Implementation Activities (2014–2020)

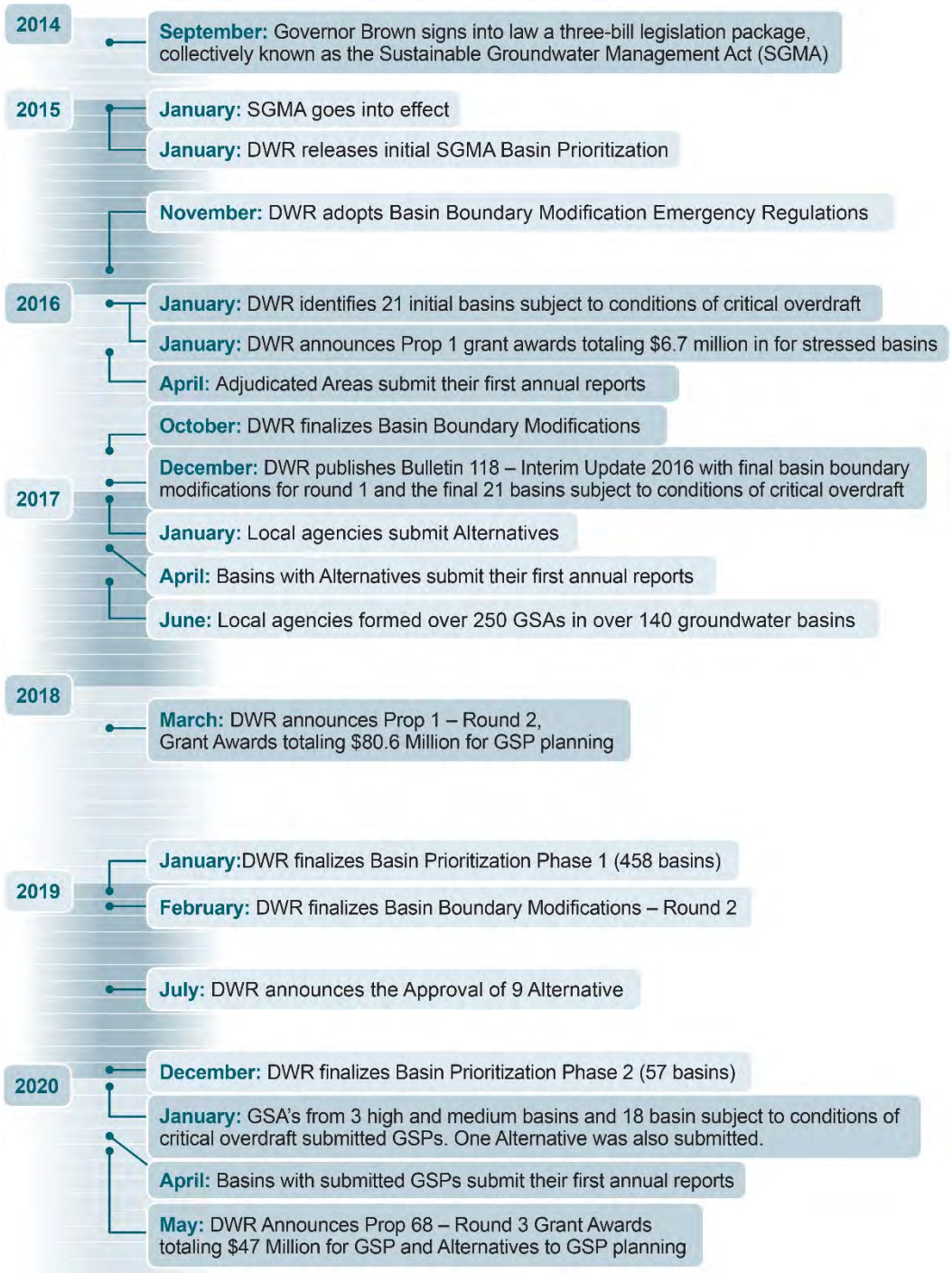


Figure 4-3 Status of SGMA Groundwater Management (January 31, 2020)



SGMA Implementation Activities

Basins Subject to Critical Conditions of Overdraft

Overdraft and Basins Subject to Critical Conditions of Overdraft Before SGMA

Overdraft is "the condition of a groundwater basin or subbasin in which the amount of water withdrawn by pumping exceeds the amount of water that recharges the basin over a period of years, during which the water supply conditions approximate average conditions. Overdraft can be characterized by groundwater levels that decline over a period of years and never fully recover, even in wet years.

Moreover, groundwater overdraft can cause adverse effects including chronic decline of groundwater levels, loss of stored groundwater, intrusion of seawater into coastal basins, land subsidence, degradation of water quality, stream flow depletion, degradation of groundwater-dependent ecosystems, and increased pumping costs.

Starting around the 1930s, groundwater resources were increasingly exploited to meet agricultural, domestic, and industrial water needs. California's continued growth has increased the demand for all water resources, including groundwater. In 1978, an amendment to the Water Code directed DWR to investigate the state's groundwater basins, define their boundaries, and identify basins "subject to critical conditions of overdraft" (Water Code Section 12924).

In CalGW 1980, DWR stated that "[a] basin is subject to critical conditions of overdraft when continuation of present water management practices would probably result in significant adverse overdraft-related environmental, social, or economic impacts." As a result of the analysis, DWR identified 11 groundwater basins as being subject to critical conditions of overdraft (California Department of Water Resources 1980). At the time, there were no follow-up statutes or regulations that required action for the critically overdrafted basins.

Overdraft and Basins Subject to Critical Conditions of Overdraft After SGMA

As required by SGMA, DWR evaluated groundwater basins for adverse effects of overdraft in 2015. If one or more adverse effects of overdraft were documented in a portion of a groundwater basin during the hydrologic base period (Water Years 1989 through 2009), that groundwater basin was identified as subject to critical conditions of overdraft. In January 2016, DWR released a list of 21 groundwater basins identified as subject to critical conditions of overdraft that included the 11 basins identified in 1980. In June 2016, following the basin boundary modification that occurred shortly

afterward, DWR released an updated list of groundwater basins subject to critical conditions of overdraft (California Department of Water Resources 2016a).

The 21 groundwater basins designated as subject to critical conditions of overdraft are depicted in the Figure 4-4 and listed in Table 4-3. Six of the groundwater basins are in the Tulare Lake Hydrologic Region, six are in the Central Coast Hydrologic Region, five are in the San Joaquin River Hydrologic Region, two are in the South Coast Hydrologic Region, one is in the South Lahontan Hydrologic Region, and one is in the Colorado River Hydrologic Region. Additional information on basins subject to critical conditions of overdraft can be obtained on DWR's Groundwater Management webpage.

Figure 4-4 Locations of Groundwater Basins Subject to Critical Conditions of Overdraft



Table 4-3 Groundwater Basins Subject to Critical Conditions of Overdraft

Basin Number	Basin Name
3-001	Santa Cruz Mid-County
3-002.01	Pajaro Valley
3-004.01	180/400 Foot Aquifer
3-004.06	Paso Robles Area
3-008.01	Los Osos Area
3-013	Cuyama Valley
4-004.02	Oxnard
4-006	Pleasant Valley
5-022.01	Eastern San Joaquin
5-022.04	Merced
5-022.05	Chowchilla
5-022.06	Madera
5-022.07	Delta-Mendota
5-022.08	Kings
5-022.09	Westside
5-022.11	Kaweah
5-022.12	Tulare Lake
5-022.13	Tule
5-022.14	Kern County
6-054	Indian Wells Valley
7-024.01	Borrego Springs

Basin Boundary Modifications

Water Code Section 12924 provides DWR the authority to revise (modify) groundwater basin boundaries. Earlier CalGW reports include findings on the state's groundwater basins and include some modifications to basin boundaries in response to improved knowledge of local conditions gained through additional data collection or special studies.

With the passage of SGMA in 2014, Section 10722.2 was added to the Water Code allowing local agencies, or an entity directed by the court in a groundwater adjudication, to request that DWR revise the boundaries of a basin, including the establishment of new subbasins. Water Code Section 10722.2 also required that by

January 1, 2016, DWR must adopt regulations regarding the information required for the submittal and consideration of basin boundary modification requests. Basin boundary regulations (California Code of Regulations, Title 23, Division 2, Chapter 1.5, Subchapter 1 [Title 23 section 340 et seq.]) were adopted on October 21, 2015; the provisions of the regulations became effective November 16, 2015.

DWR provided two online tools to support the submittal of boundary modification requests and provide access to the public. DWR established the online Basin Boundary Assessment Tool to support local agencies during their basin boundary modification efforts by providing online map-based information about the existing CalGW basins and other relevant geologic and geographic data. This tool can be found on DWR's website under Groundwater Management and the tab for Data and Tools.

DWR also established an interactive web application called the Basin Boundary Modification Request System (BBMRS) to enable local agencies to submit groundwater basin boundary modification requests online and for interested parties to review those requests and provide comments. The system provides an interactive map that allows users to view submitted modifications. All the basin boundary modification requests, supporting information, and public comments for the 2016 and 2018 basin boundary modification rounds were submitted through BBMRS and can be viewed online at DWR's Basin Boundary website.

2016 Basin Boundary Modifications

The final 2016 Basin Boundary Modifications (approved by DWR on October 16, 2016) were the first round of basin boundary modifications corresponding to the basin boundary regulations of California Code of Regulations, Title 23, Section 340 et seq. The final 2016 Basin Boundary Modifications were developed through DWR's technical review of modification requests and public comments made during the submission period, which was January 1, 2016, through March 31, 2016. DWR received 54 basin boundary modification requests. Of these, 39 requests were approved, 12 were denied, and three were not accepted because they were incomplete. Details of the final 2016 Basin Boundary Modifications are documented in *California's Groundwater – Interim Update 2016* (California Department of Water Resources 2016a). At the conclusion of the boundary adjustments there were 517 basins, up from the 515 identified in 2003.

2018 Basin Boundary Modifications

A second round of basin boundary modifications was released by DWR on February 11, 2019. In this round, DWR received 43 basin boundary modification requests, of which 35 were approved, four were denied, and four were partially approved. Partially approved requests are those for which some portions of the basin boundary modification request were adequately supported by the information provided and were approved, while other portions were not adequately supported and were denied. At the conclusion of the boundary adjustments, there were 515 basins, down from the 517 identified in 2016.

Post Basin Boundary Modification Implications

Some basins designated as subject to critical conditions of overdraft were affected by the 2016 and 2018 approved basin boundary modifications. For basins subject to critical conditions of overdraft that requested basin boundary modifications, DWR considered the applicability of overdraft status based on the magnitude of the boundary modification. Each affected basin was evaluated; 21 basins remain designated as subject to critical conditions of overdraft (Figure 4-4 and Table 4-2).

Under SGMA, basin boundaries define the geographical area included in each groundwater basin. SGMA requires DWR to reassess basin prioritization any time that DWR updates CalGW basin boundaries (Water Code Section 10722.4[c]). Reprioritization of basins was conducted after the 2016 and 2018 basin boundary modification rounds were completed.

Basin Prioritization

Basin prioritization is a technical process that uses the best available data and information to classify California's groundwater basins into one of four categories: high, medium, low, or very low priority. DWR is required to prioritize basins using a technical process based on eight components that are identified in Water Code Section 10933(b).

History of Basin Prioritization

Basin prioritization was first required as part of California's 2009 Comprehensive Water Package (California Department of Water Resources 2009), which established Part 2.11, "Groundwater Monitoring," of the Water Code. Part 2.11 added general provisions that require DWR to identify the extent of groundwater elevation monitoring undertaken within each basin and directed DWR to prioritize basins for that purpose. In response to the new requirements, DWR established the CASGEM

Program and began prioritizing groundwater basins. In June 2014, DWR released the first prioritization for the state's groundwater basins as CASGEM 2014 Basin Prioritization (California Department of Water Resources 2014).

In September 2014, SGMA was signed into law. SGMA requires DWR to update basin priority for each groundwater basin no later than January 31, 2015. The law also requires DWR to reassess basin prioritization any time groundwater basin boundaries are changed and added the evaluation of adverse effects on local habitat and local stream flows to the ranking criteria. Because of the short time between the passage of SGMA and the deadline for updating basin prioritization, DWR applied the CASGEM 2014 Basin Prioritization results as the initial SGMA 2015 Basin Prioritization, which categorized 127 of the 515 groundwater basins in the state as high or medium priority.

In the fall of 2016, DWR completed and released groundwater basin boundary modifications. As a result of these modifications, updated basin prioritizations were required for the 517 groundwater basins identified after the 2016 Basin Boundary Modifications. In May of 2018, DWR released the draft basin prioritization results for the 517 basins and held a 94-day public comment period. Simultaneously, local agencies requested a subsequent round of basin boundary modifications described above as the 2018 Basin Boundary Modifications. This required DWR to prioritize the basins in two phases (referred to as SGMA 2019 Basin Prioritization Phases 1 and 2), which is described below.

The technical process for basin prioritization used the best available data and information to assess the state's groundwater basins. DWR has uploaded all the relevant data from the SGMA 2019 Basin Prioritization effort to the California Natural Resources Agency's (CNRA's) Open Data platform. For more information on the technical process used during SGMA 2019 Basin Prioritization and links to the relevant data, see the Basin Prioritization website and the SGMA Basin Prioritization webpage.

Basin prioritization is a technical process only for the purpose of ranking groundwater basins. The results are not a judgment of existing groundwater management in a basin or the local importance of groundwater.

Results of the SGMA 2019 Basin Prioritization

The completion of the SGMA 2019 Basin Prioritization effort marked an important milestone for SGMA. SGMA requires basins categorized as high or medium priority to

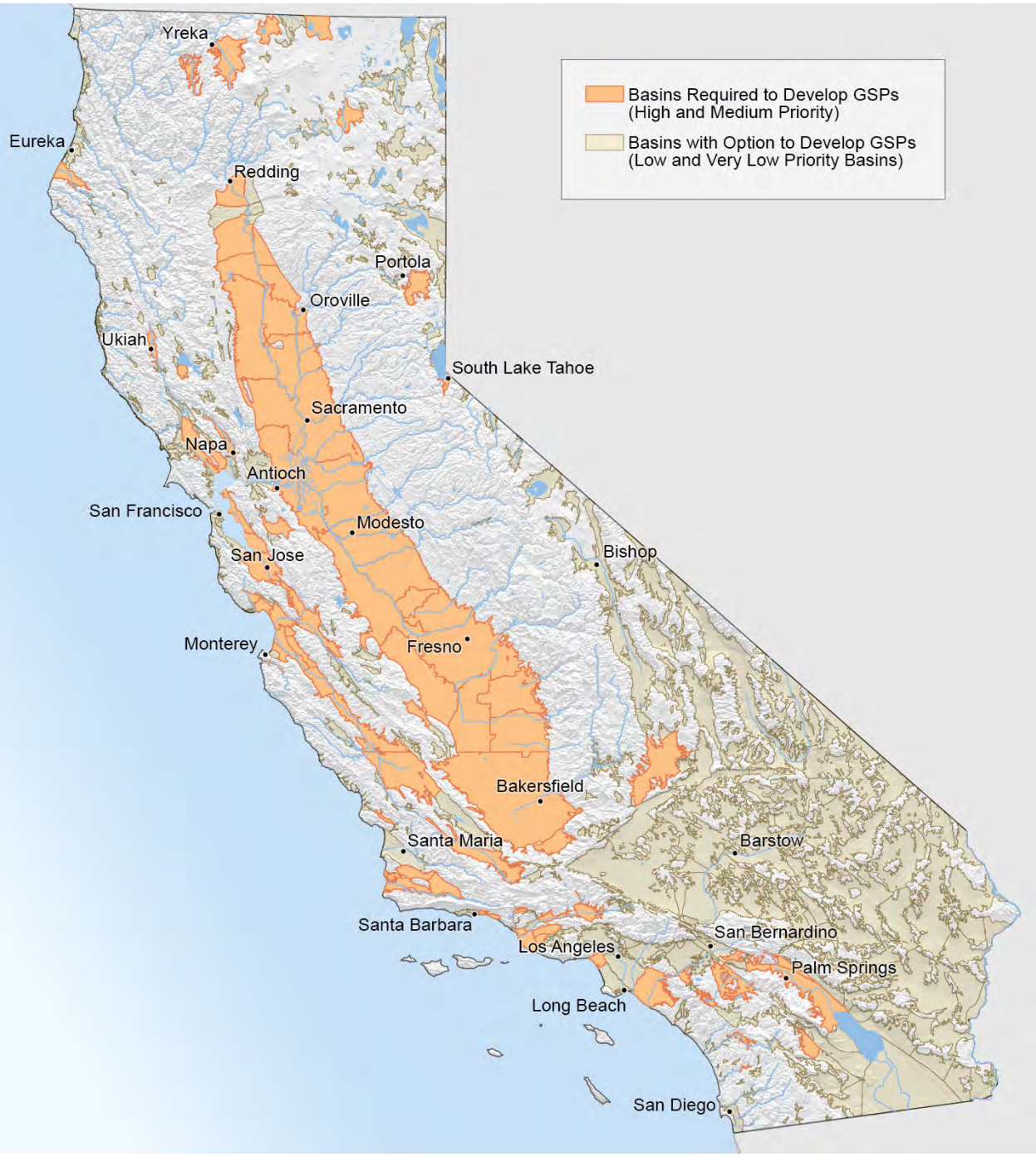
form GSAs, develop GSPs, and sustainably manage groundwater in the basin. The completion of basin prioritization is also important because knowing which provisions of SGMA are applicable to a basin provides stability and certainty for water managers throughout California.

A summary of the results of the SGMA 2019 Basin Prioritization by phase and priority are included in Table 4-4 (California Department of Water Resources 2019). A map of the results is included in Figure 4-5.

Table 4-4 Results of the SGMA 2019 Basin Prioritization

Basin Priority	Basins Prioritized in Phase 1	Basins Prioritized in Phase 2	Total Basins Prioritized
Very Low	393	17	410
Low	9	2	11
Medium	31	17	48
High	25	21	46
Total	**458**	**57**	**515**

Figure 4-5 Results of the SGMA 2019 Basin Prioritization



Phase 1 of the SGMA 2019 Basin Prioritization effort was completed on January 4, 2019. It identifies 56 high- and medium-priority basins in the state. Phase 2 was completed on December 18, 2019, identifies an additional 38 high- and medium-priority basins in the state. The combined results of Phases 1 and 2 of the SGMA 2019 Basin Prioritization effort identifies 94 high- and medium-priority basins in the state. These 94 basins plus adjudicated areas account for 98 percent of the groundwater extraction (20 million acre-feet), 83 percent of the population (25 million Californians), and 88 percent of all irrigated agricultural acres (6.7 million acres) in the state.

During SGMA 2019 Basin Prioritization Phase 1, Pleasant Valley (Groundwater Basin ID 5-022.10) was newly identified as medium priority. During Phase 2, Carpentaria (Groundwater Basin ID 3-018) was newly identified as high priority and Montecito (Groundwater Basin ID 3-049) was newly identified as medium priority. SGMA allows basins that are newly identified as high or medium priority two years to form a GSA and five years to submit a GSP from the finalization date of basin prioritization. The GSP due dates for these three basins can be found in Table 4-7.

DWR has created an interactive web application, the Basin Prioritization Dashboard, to allow easy access to view the results of the project. To view the results using the interactive map, refer to the Basin Prioritization website that can be found in the "Useful Web Links" section of Appendix D, "Citations, Reference Materials, and Links." The list of high- and medium-priority groundwater basins identified during SGMA 2019 Basin Prioritization is included in Table 4-5.

Table 4-5 High- and Medium-Priority Groundwater Basins

Groundwater Basin ID	Groundwater Basin Name	Final Priority	Groundwater Basin ID	Groundwater Basin Name	Final Priority
1-002.01	Tulelake	Medium	5-015	Big Valley	Medium
1-003	Butte Valley	Medium	5-021.50	Red Bluff	Medium
1-004	Shasta Valley	Medium	5-021.51	Corning	High
1-005	Scott River Valley	Medium	5-021.52	Colusa	High
1-010	Eel River Valley	Medium	5-021.54	Antelope	High
1-052	Ukiah Valley	Medium	5-021.56	Los Molinos	Medium
1-055.01	Santa Rosa Plain	Medium	5-021.57	Vina	High

Groundwater Basin ID	Groundwater Basin Name	Final Priority	Groundwater Basin ID	Groundwater Basin Name	Final Priority
2-001	Petaluma Valley	Medium	5-021.60	North Yuba	Medium
2-002.01	Napa Valley	High	5-021.61	South Yuba	High
2-002.02	Sonoma Valley	High	5-021.62	Sutter	Medium
2-009.01	Niles Cone	Medium	5-021.64	North American	High
2-009.02	Santa Clara	High	5-021.65	South American	High
2-009.04	East Bay Plain	Medium	5-021.66	Solano	Medium
2-010	Livermore Valley	Medium	5-021.67	Yolo	High
3-001	Santa Cruz Mid-County	High-COD	5-021.69	Wyandotte Creek	Medium
3-002.01	Pajaro Valley	High-COD	5-021.70	Butte	Medium
3-003.01	Llagas Area	High	5-022.01	Eastern San Joaquin	High-COD
3-003.05	North San Benito	Medium	5-022.02	Modesto	High
3-004.01	180/400 Foot Aquifer	High-COD	5-022.03	Turlock	High
3-004.02	East Side Aquifer	High	5-022.04	Merced	High-COD
3-004.04	Forebay Aquifer	Medium	5-022.05	Chowchilla	High-COD
3-004.05	Upper Valley Aquifer	Medium	5-022.06	Madera	High-COD
3-004.06	Paso Robles Area	High-COD	5-022.07	Delta-Mendota	High-COD
3-004.09	Langley Area	High	5-022.08	Kings	High-COD
3-004.10	Salinas Valley-Monterrey	Medium	5-022.09	Westside	High-COD
3-007	Carmel Valley	Medium	5-022.10	Pleasant Valley	Medium
3-009	San Luis Obispo Valley	High	5-022.11	Kaweah	High-COD

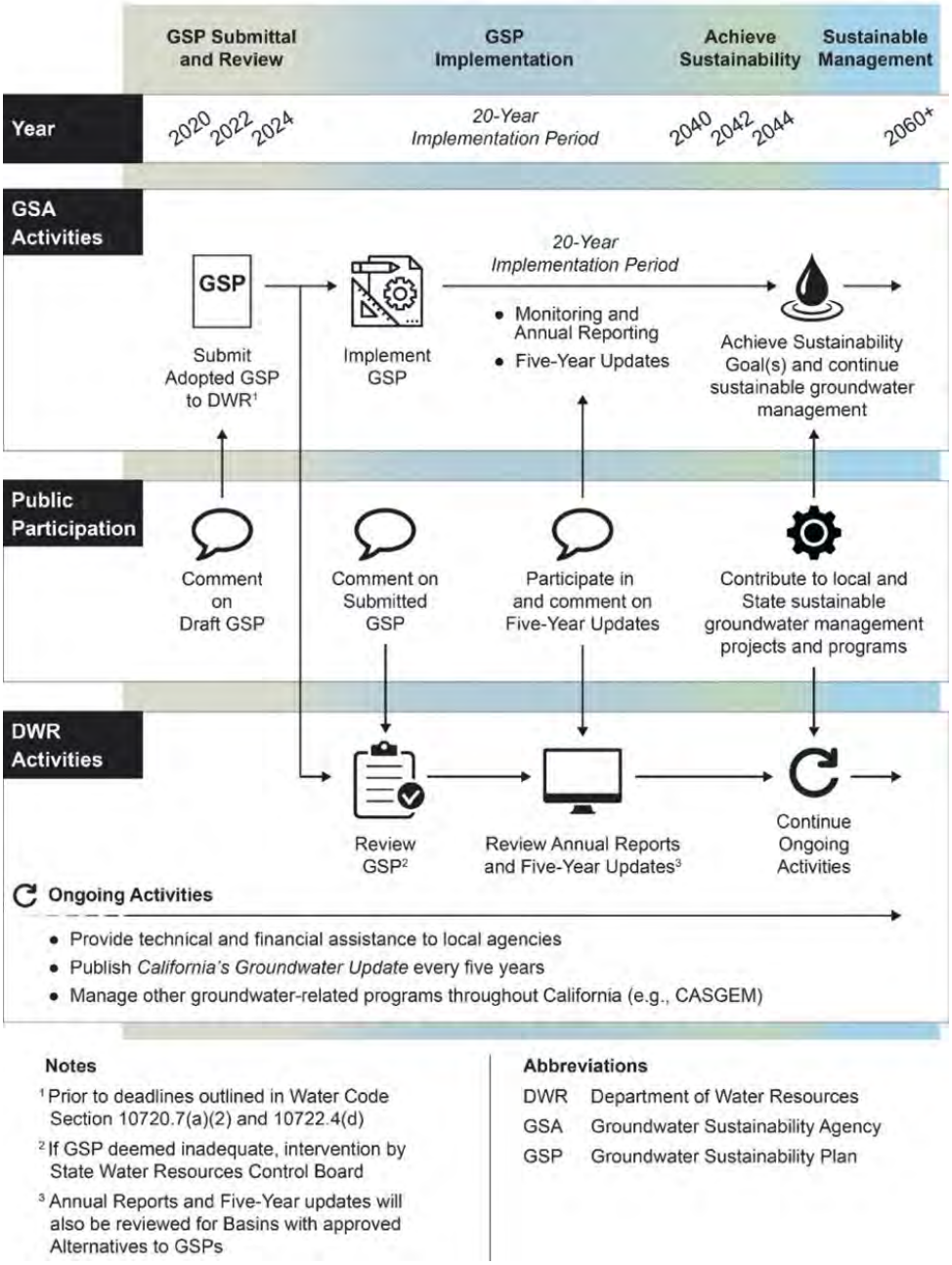
Groundwater Basin ID	Groundwater Basin Name	Final Priority	Groundwater Basin ID	Groundwater Basin Name	Final Priority
3-013	Cuyama Valley	High-COD	5-022.12	Tulare Lake	High-COD
3-014	San Antonio Creek Valley	Medium	5-022.13	Tule	High-COD
3-015	Santa Ynez River Valley	Medium	5-022.14	Kern County	High-COD
3-018	Carpinteria	High	5-022.15	Tracy	Medium
3-027	Santa Margarita	Medium	5-022.16	Cosumnes	Medium
3-049	Montecito	Medium	5-022.18	White Wolf	Medium
4-002	Ojai Valley	High	5-022.19	East Contra Costa	Medium
4-003.01	Upper Ventura River	Medium	6-005.01	Tahoe South	Medium
4-004.02	Oxnard	High-COD	6-054	Indian Wells Valley	High-COD
4-004.03	Mound	High	7-021.01	Indio	Medium
4-004.05	Fillmore	High	7-021.02	Mission Creek	Medium
4-004.06	Piru	High	7-021.04	San Gorgonio Pass	Medium
4-004.07	Santa Clara River Valley East	High	7-024.01	Borrego Springs	High-COD
4-006	Pleasant Valley	High-COD	8-001	Coastal Plain of Orange County	Medium
4-008	Las Posas Valley	High	8-002.07	Yucaipa	High
4-011.01	Santa Monica	Medium	8-002.09	Temescal	Medium
5-004	Big Valley	Medium	8-004.01	Elsinore Valley	Medium
5-006.03	Anderson	Medium	8-005	San Jacinto	High
5-006.04	Enterprise	Medium	9-007.01	Upper San Luis Rey Valley	Medium
5-012.01	Sierra Valley	Medium	9-010	San Pasqual Valley	Medium

Table 4-5 note: COD refers to basins subject to critical conditions of overdraft.

Future SGMA Activities

Figure 4-6 shows the upcoming timelines described above and the interaction along the way with the GSAs, the public, and DWR. Additional details concerning the timeline and interactions are described in the following sections.

Figure 4-6 Timeline of SGMA Implementation Activities and the Interaction of GSAs, the Public, and DWR



Notes

[1] Prior to deadlines outlined in Water Code Section 10720.7(a)(2) and 10722.4(d)

[2] If GSP deemed inadequate, intervention by State Water Resources Control Board

[3] Annual Reports and Five-Year updates will also be reviewed for Basins with approved Alternatives to GSPs

Abbreviations

DWR	Department of Water Resources
GSA	Groundwater Sustainability Agency
GSP	Groundwater Sustainability Plan

Underrepresented Communities

SGMA requires GSAs to consider all beneficial uses and all users of groundwater in a basin when developing and implementing GSPs. This requirement includes identifying communities that traditionally have been underrepresented in local groundwater management processes and encouraging the active involvement of basin populations and their diverse social, cultural, and economic elements. Tribes, disadvantaged communities (DACs), severely disadvantaged communities (SDACs), and the importance of ecosystems generally have been underrepresented in groundwater management discussions in California. The expertise and experiences shared by these communities reliant on groundwater can help provide important information about groundwater basin conditions and responses, and related effects on ecosystems.

To improve the level of engagement and representation of these underrepresented groundwater users, DWR developed guidance and made facilitation support services and written translation services available to help GSAs with outreach and engagement. The guidance materials developed include *Guidance Document for Groundwater Sustainability Plan Stakeholder Communication and Engagement* and *Guidance Document for the Sustainable Management of Groundwater Engagement with Tribal Governments*. DWR, with the engagement of California Department of Fish and Wildlife and The Nature Conservancy, developed a database application on natural communities commonly associated with groundwater to aid in identifying potential groundwater dependent ecosystems (GDE) to be included in their GSP planning. The Natural Communities Dataset is discussed below.

Prior to these guidance and assistance efforts, DWR established the SGMA Nongovernmental Organization Advisory Group and the SGMA Tribal Advisory Group to obtain underrepresented community and Tribal input during GSP regulation development.

Disadvantaged Communities

Water Code Section 75005 defines DAC as a community with a median household income less than 80 percent of the statewide average. SDAC is defined as a community with a median household income less than 60 percent of the statewide average. DWR has an online DAC mapping tool to identify California's DAC and SDAC communities using the most recent census data.

Based on the *U.S. Census American Community Survey (ACS) 5-Year Data: 2012–2016*, the statewide median household income is $63,783; as a result, the calculated DAC and SDAC thresholds are $51,026 and $38,270, respectively.

Figure 4-7 depicts the DAC and SDAC communities in groundwater basins and non-basin areas.

Tribal Governments and Communities

California Native American Tribal governments and Tribal communities have sovereign authority over their members and territory and a unique relationship with California's resources. California Tribes and Tribal communities, whether they are federally recognized, have distinct cultural, spiritual, environmental, economic, and public health interests and valuable traditional cultural knowledge about California resources, including groundwater.

DWR is committed to open, inclusive, and regular communication with Tribal governments and communities to recognize and understand their needs and interests. DWR strives to ensure effective communication and government-to-government consultation, creating a channel for Tribal governments to provide input at all levels into the development of regulations, rules, policies, programs, projects, plans, property decisions, and activities that may impact Tribal communities. DWR's Sustainable Groundwater Management Office continues to communicate and engage with Tribal representatives through DWR's Tribal Advisory Group.

Figure 4-8 depicts the Tribal land overlying the groundwater basins and non-basin areas in California. Most of the mapped Tribal lands are in the non-basin areas of the State. The Tribal reservation and Tribal trust land boundaries can be found in all 10 hydrologic regions with the largest areas occurring in the North Coast, Tulare Lake, South Coast, and Colorado River hydrologic regions.

Figure 4-7 Disadvantaged Communities

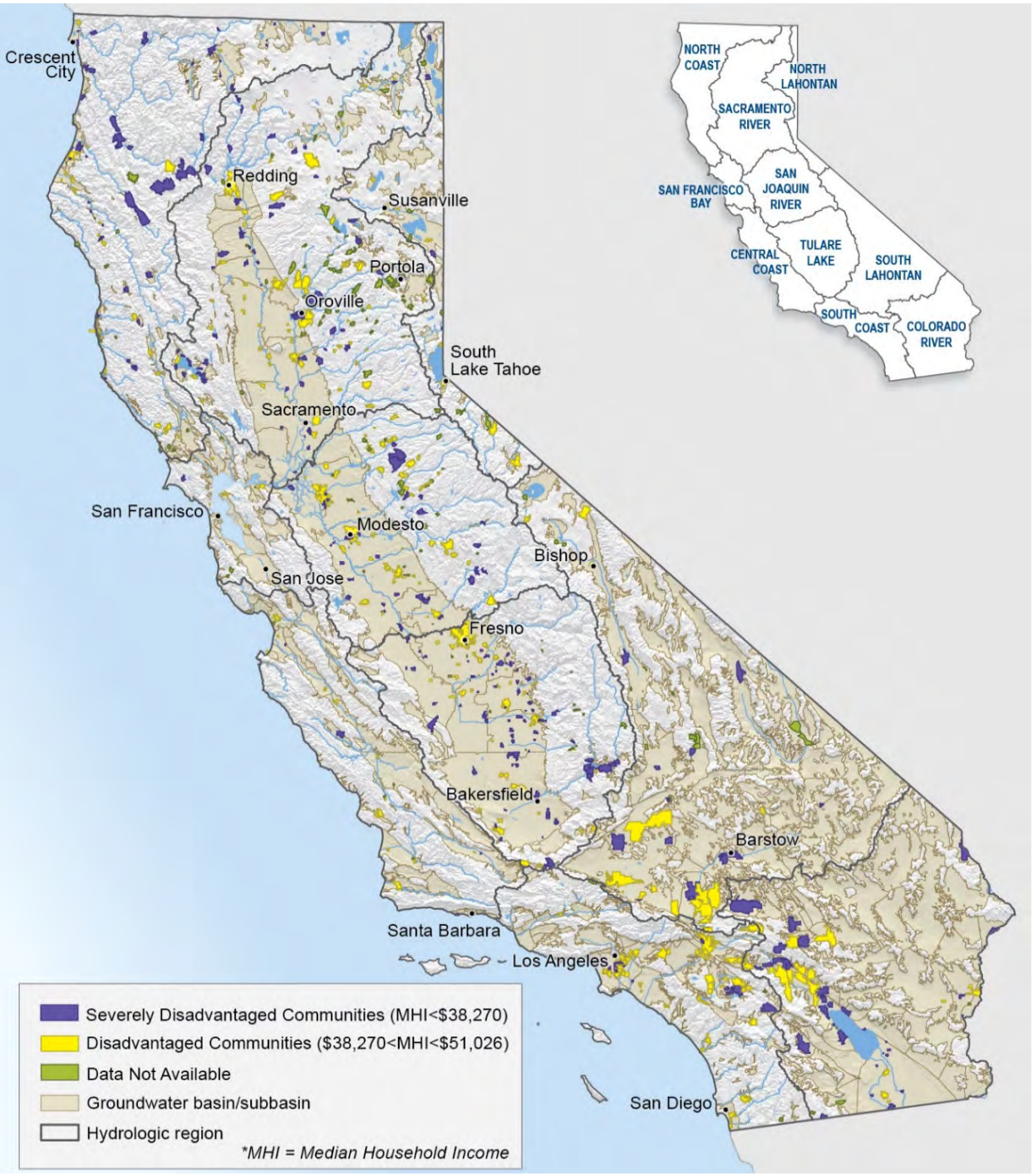
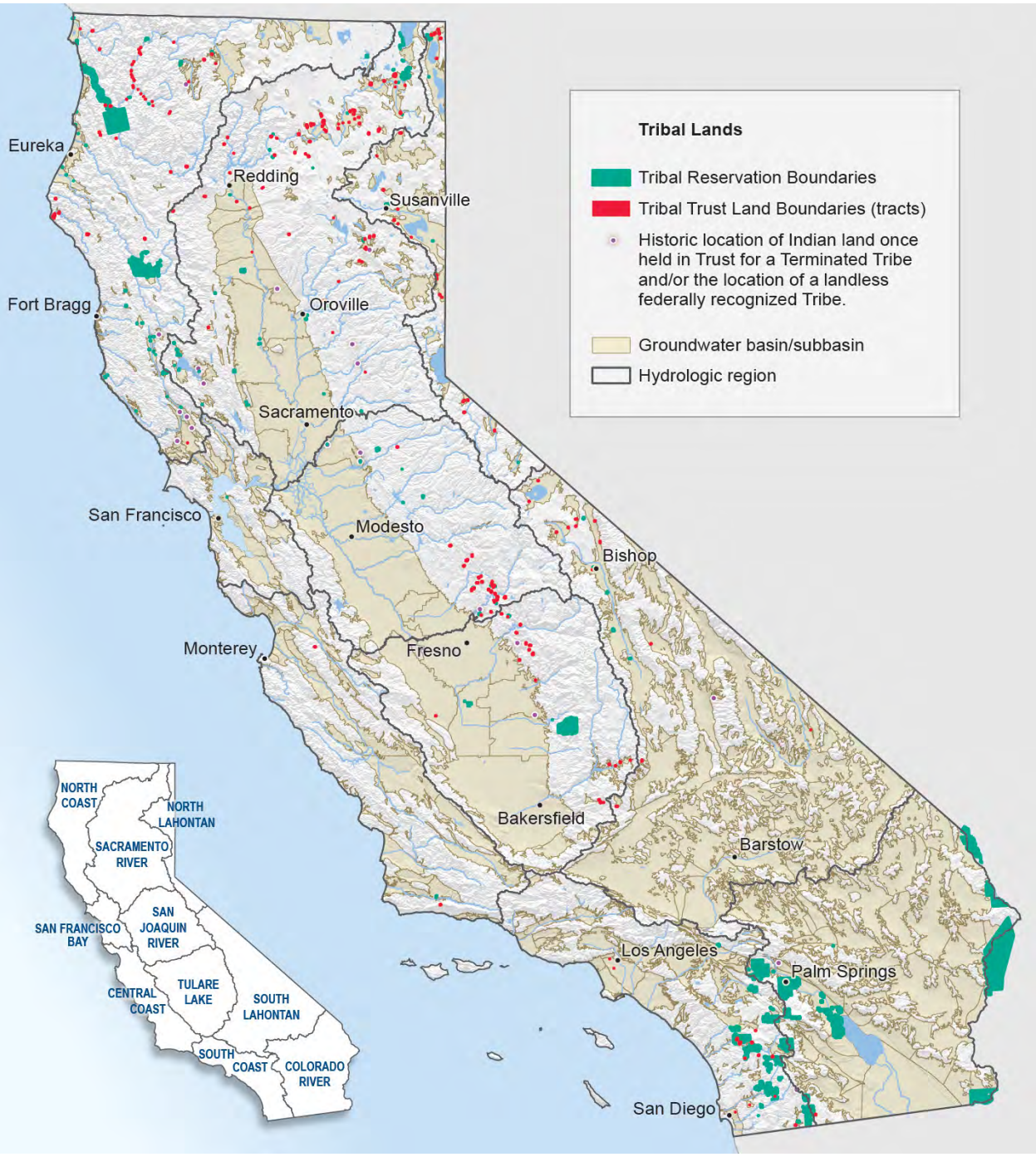


Figure 4-8 Tribal Lands



Ecosystems

Groundwater dependent ecosystems (GDEs) are defined in California Code of Regulations, Title 23, Section 351(m) as ecological communities or species that depend on groundwater emerging from aquifers or on groundwater occurring near the ground surface. GDEs include seeps, springs, and the riverine, palustrine, and lacustrine habitats supported by them. GDEs also include deep-rooted plants or plant communities that obtain water from the water table (called phreatophytes). GDEs provide habitat for numerous plant and wildlife species, including rare, threatened, and endangered species. In addition, GDEs can provide flood mitigation, water quality improvement, carbon capture, and recreational opportunities.

SGMA defines sustainable groundwater management as the management and use of groundwater in a manner that can be maintained during the planning and implementation horizon without causing undesirable results. Two undesirable results – the chronic lowering of groundwater levels and the depletion of interconnected surface water (with groundwater) – have the potential to affect GDEs.

GSP regulations (California Code of Regulations, Title 23, Section 354.16[g]) require GSAs in their GSPs to identify GDEs within their basin using data available from DWR or the best available information. SGMA (Water Code Section 10727.4[l]) requires GSPs to address impacts to GDEs. SGMA (Water Code Section 10933[b][8]) also requires DWR to consider adverse effects to local habitat and local streamflows during the basin prioritization process. As part of the SGMA 2019 Basin Prioritization, DWR coordinated with subject matter experts from the California Department of Fish and Wildlife and The Nature Conservancy to develop a statewide Natural Communities Commonly Associated with Groundwater (Natural Communities) Dataset. To access the database, refer to the "Useful Web Links" section of Appendix D, "Citations, Reference Materials, and Links."

The Natural Communities Dataset assembles information on the location of seeps, springs, natural wetlands, perennial streams, and phreatophytic vegetation within California's groundwater basins based on 48 publicly available State and federal agency datasets. Mapped natural communities within the dataset are commonly associated with groundwater and are considered potential indicators of GDEs. The Natural Communities Dataset Viewer was developed to allow users to query the screened vegetation and wetland datasets, as well as the source datasets. Figure 4-9 shows the mapped natural communities within groundwater basins throughout the state that are potential indicators of GDEs.

Figure 4-9 Natural Communities Dataset Wetland and Vegetation Mapping

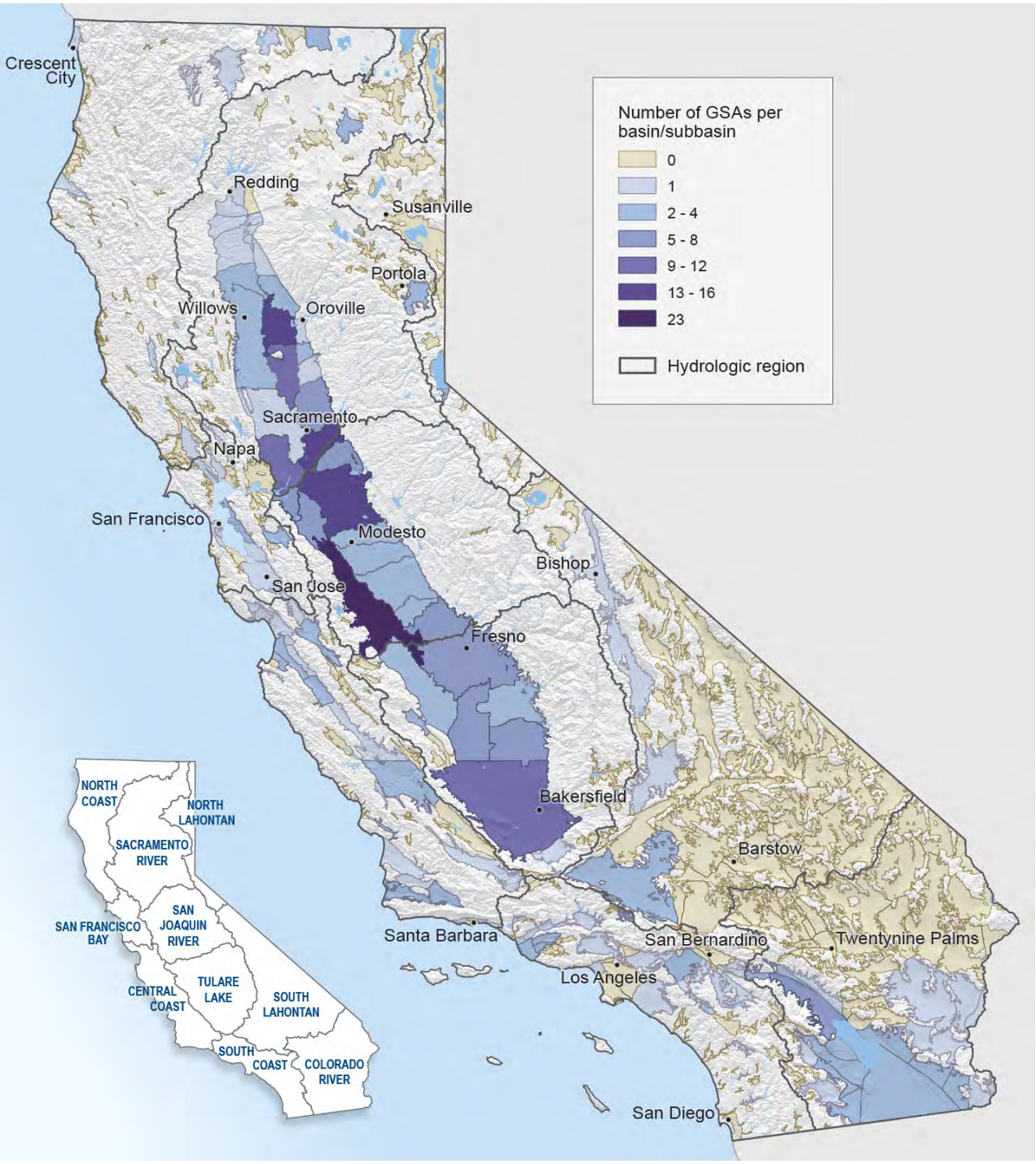


Groundwater Sustainability Agencies

SGMA incorporated the existing 2014 Basin Prioritization determinations established by the CASGEM Program as the initial SGMA Basin Prioritization. All 127 high- and medium-priority basins at that time were required to form GSAs by June 30, 2017, or submit an alternative plan to DWR by January 1, 2017.

By the June 30, 2017, deadline, approximately 260 GSAs were formed in 140 basins. Some GSAs were formed by one local agency in a small portion of a single basin, while other GSAs were formed by one or more local agencies that covered all or portions of multiple basins. To account for data reporting purposes, the GSAs that covered more than one basin were separated into basin-specific GSAs by DWR in July 2019. As of June 30, 2020, there were 347 basin-specific GSAs formed in 143 basins; many GSAs have groundwater management responsibilities in multiple basins. As SGMA implementation continues, and as the priorities and boundaries of some basins may change, new GSAs may be formed, and existing GSAs may reorganize, consolidate, or withdraw from managing all or part of a basin. Figure 4-10 is a statewide map showing the numbers of GSAs in each basin.

Figure 4-10 Number of GSAs in Each Groundwater Basin (June 30, 2020)



Governance by GSAs

Under SGMA, any local public agency that has water supply, water management, or land use responsibilities in a basin is eligible to form a GSA (Water Code Sections 10721[n] and10723[a]). A basin may be governed by one GSA or multiple GSAs, provided that all entities agree to collaboratively manage the basin and that GSA jurisdictions do not overlap. One local agency can assume the GSA responsibilities and authorities for an entire basin, or a combination of local agencies can form a GSA by establishing a joint powers authority or entering into a memorandum of agreement or other legal agreement (Water Code Section 10723.6).

Local agencies are required to collaborate and coordinate their GSA formations on a basin-wide scale to sustainably manage groundwater at a local level and implement SGMA. A local agency that forms a GSA is required to perform the duties and exercise the necessary powers of a GSA when developing, implementing, and enforcing a basin's groundwater sustainability program.

GSA Formation Methods and Timeline

Local agencies must hold a public hearing in the county or counties overlying the basin before deciding to form a GSA (Water Code Section 10723[b]). Within 30 days of deciding to form a GSA, local agencies must inform DWR of its decision and its intent to undertake sustainable groundwater management and provide the information required by SGMA. The decision to form a GSA takes effect 90 days after DWR posts the initial notice, unless another local agency has filed an overlapping notice, in which case the decision to form a GSA shall not take effect until the overlap is resolved by the GSAs.

All GSA formation notifications are posted on DWR's GSA Formation Notification System on the SGMA Portal. A GSA may withdraw from managing a basin by notifying DWR in writing of its intent to withdraw and withdrawing its notification in the SGMA Portal (Water Code Section 10723.8).

For further information on GSA formation methods, refer to DWR's GSA Formation Notification System website. To access the website, refer to the "Useful Web Links" section of Appendix D, "Citations, Reference Materials, and Links."

County's Role in GSA Formation

If an area overlying a high- or medium-priority basin is not within the jurisdiction of a GSA, the county in which that unmanaged area is found will be presumed to be the GSA for that area (Water Code Section 10724[a]). Counties are required to provide

notification to DWR of the intent to oversee the unmanaged area unless the county notifies DWR in writing that it will not be the GSA for the area.

DWRs Role in GSA Formation

DWR is tasked with reviewing the GSA formation notices for completeness and posting them on its website within 15 days of receipt (Water Code Section 10723.8[b]). To assist with the GSA formation process, DWR implemented a Facilitation Support Services Program that aids local agencies in working through challenging institutional and technical issues surrounding GSA formation. The Facilitation Support Services Program provides professional facilitators to attend meetings and build consensus among the attendees regarding GSA issues.

GSA Participation and Public Engagement

GSAs must engage the public in the GSP development process. Each GSA is expected to make SGMA-related information publicly available on the GSA's website and to develop and maintain a list of persons interested in receiving notices (Water Code Section 10723.4). GSAs are also required to encourage the active involvement of diverse social, cultural, and economic groups of the population within the groundwater basin prior to, and during, the development and implementation of the GSP. In accordance with Water Code Section 10723.2, GSAs are also required to consider all beneficial uses and users of groundwater as part of the development of the GSP for the basin.

Groundwater Sustainability Plans

In accordance with Water Code Section 10727, SGMA requires GSAs in high- and medium-priority basins to develop and implement GSPs, or alternatives to GSPs (alternatives), that cover a 50-year planning horizon with a goal to achieve sustainability within a 20-year implementation period. Although local public agencies in basins designated as low or very low priority are not required to develop GSPs, SGMA states that local public agencies may voluntarily form GSAs and develop GSPs in those basins.

GSPs must be developed in accordance with the GSP regulations made final by DWR in May 2016 (California Department of Water Resources 2016b). These regulations are codified in the California Code of Regulations, Title 23, Division 2, Chapter 1.5, Subchapter 2, Section 350 et seq.

The GSP regulations specify the required components of GSPs, submittal of an alternative, and coordination agreements, as well as the methods and criteria used by

DWR to evaluate the GSP, including information required by DWR to facilitate the evaluation. Coordination agreements are required for any basin with multiple GSAs planning to submit more than one GSP for the basin.

Sustainable groundwater management is the "management and use of groundwater in a manner that can be maintained during the planning and implementation horizon without causing undesirable results" (Water Code Section 10721[v]). "Undesirable results" are defined in SGMA (Water Code Section 10721 [x]) and are summarized here as any of the six following effects caused by groundwater conditions occurring throughout the basin:

- Chronic lowering of groundwater levels indicating a significant and unreasonable depletion of supply if continued over the planning and implementation horizon. Overdraft during a period of drought is not sufficient to establish a chronic lowering of groundwater levels if extractions and groundwater recharge are managed as necessary to ensure that reductions in groundwater levels or storage during a period of drought are offset by increases in groundwater levels or storage during other periods.
- Significant and unreasonable reduction of groundwater storage.
- Significant and unreasonable seawater intrusion.
- Significant and unreasonable degraded water quality, including the migration of contaminant plumes that impair water supplies.
- Significant and unreasonable land subsidence that substantially interferes with surface land uses.
- Depletions of interconnected surface water that have significant and unreasonable adverse effects on beneficial uses of the surface water.

The deadline for the submittal of GSPs varies by basin. The deadline is dependent on basin prioritization and whether a basin was designated as being subject to critical conditions of overdraft. Table 4-6 summarizes the dates GSPs are due and the number of basins that must adhere to this date.

Forty-three GSPs from basins designated as subject to critical conditions of overdraft were submitted to DWR prior to the required submittal date of January 31, 2020. Three additional basins, Las Posas Valley (Groundwater Basin ID 4-008), North Yuba (Groundwater Basin ID 5-021.60), and South Yuba (Groundwater Basin ID 5-021.61), also submitted their plans earlier than the due date of January 31, 2022. Borrego Springs Subbasin (Groundwater Subbasin ID 7-024.01) submitted an alternative.

Figure 4-11 is a statewide map showing the number of submitted GSPs by groundwater basin.

Table 4-6 Groundwater Sustainability Plan Due Dates for Critically Overdrafted and High- and Medium-Priority Basins

GSP Categories	Number of Basins	GSP Due Date[a]
High or Medium Priority in SGMA 2015 Basin Prioritization and Critically Overdrafted Basins	20[b]	January 31, 2020
High or Medium Priority in SGMA 2015 Basin Prioritization	71	January 31, 2022
Elevated to High or Medium Priority in SGMA 2019 Basin Prioritization Phase 1	1	January 4, 2024
Elevated to High or Medium Priority in SGMA 2019 Basin Prioritization Phase 2	2	December 18, 2024

Table 4-6 notes: GSP = groundwater sustainability plan, SGMA = Sustainable Groundwater Management Act

[a] This list assumes GSPs and not alternatives. Several GSAs have already submitted alternatives that were approved. Refer to Table 4-6 for more details on alternatives.

[b] Los Osos Area (Groundwater Subbasin ID 3-008.01) has been identified as a basin subject to conditions of critical overdraft. The subbasin is also adjudicated, and as a result the priority has been established as very low, and thus, not required to submit a GSP.

Figure 4-11 Number of Submitted GSPs by Groundwater Basin

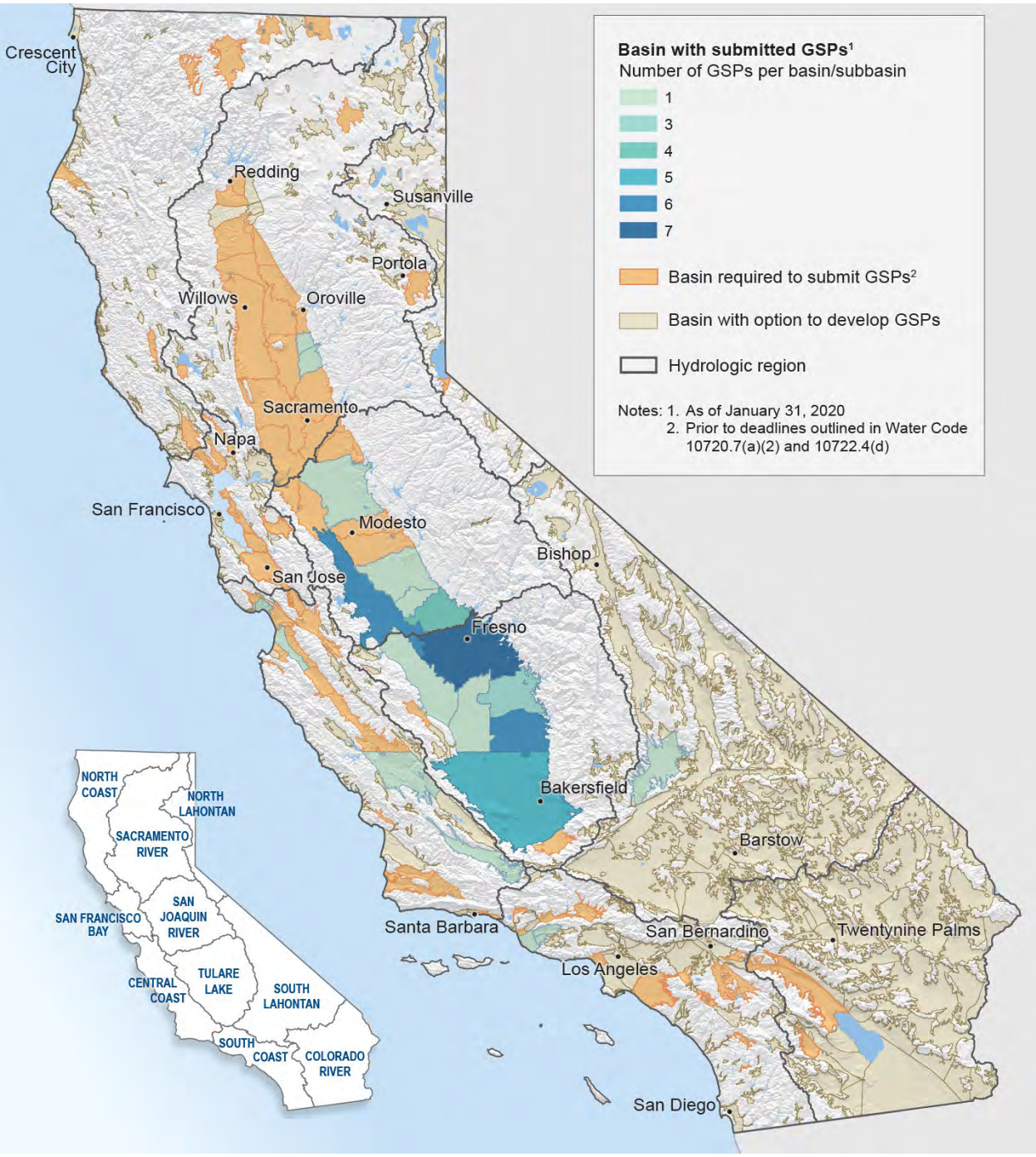


Figure 4-11 note: GSP = groundwater sustainability plan

A full list of the high- and medium-priority groundwater basins identified during SGMA 2019 Basin Prioritization is found in Table 4-7. The table includes the due dates for the submittal of a GSP or alternative, the submittal date, and its approval status. More than one GSP has been submitted for six basins. They are identified in Table 4-7 with the number of plans submitted.

Table 4-7 High- and Medium-Priority Groundwater Basins with GSP and Alternative Status (June 30, 2020)

Groundwater Basin ID	Groundwater Basin Name	Final Priority	GSP Alternative Due Date	Submittal Date	GSP Alternative Status
1-002.01	Tulelake	Medium	Jan. 31, 2022	-	-
1-003	Butte Valley	Medium	Jan. 31, 2022	-	-
1-004	Shasta Valley	Medium	Jan. 31, 2022	-	-
1-005	Scott River Valley	Medium	Jan. 31, 2022	-	-
1-010	Eel River Valley	Medium	Jan. 31, 2022	-	-
1-052	Ukiah Valley	Medium	Jan. 31, 2022	-	-
1-055.01	Santa Rosa Plain	Medium	Jan. 31, 2022	-	-
2-001	Petaluma Valley	Medium	Jan. 31, 2022	-	-
2-002.01	Napa Valley	High	Jan. 31, 2022	-	-
2-002.02	Sonoma Valley	High	Jan. 31, 2022	-	-
2-009.01	Niles Cone	Medium	Jan. 1, 2017	Dec. 31, 2016	Approved Alternative
2-009.02	Santa Clara	High	Jan. 1, 2017	Dec. 21, 2016	Approved Alternative
2-009.04	East Bay Plain	Medium	Jan. 31, 2022	-	-
2-010	Livermore Valley	Medium	Jan. 1, 2017	Dec. 29, 2016	Approved Alternative
3-001	Santa Cruz Mid-County	High-COD	Jan. 31, 2020	Jan. 30, 2020	Approved GSP
3-002.01	Pajaro Valley	High-COD	Jan. 31, 2020	Dec. 31, 2016	Approved Alternative
3-003.01	Llagas Area	High	Jan. 1, 2017	Dec. 21, 2016	Approved Alternative

Groundwater Basin ID	Groundwater Basin Name	Final Priority	GSP Alternative Due Date	Submittal Date	GSP Alternative Status
3-003.05	North San Benito	Medium	Jan. 31, 2022	-	-
3-004.01	180/400 Foot Aquifer	High-COD	Jan. 31, 2022	Jan. 23, 2020	Approved GSP
3-004.02	East Side Aquifer	High	Jan. 31, 2022	-	-
3-004.04	Forebay Aquifer	Medium	Jan. 31, 2022	-	-
3-004.05	Upper Valley Aquifer	Medium	Jan. 31, 2022	-	-
3-004.06	Paso Robles Area	High-COD	Jan. 31, 2020	Jan. 20, 2020	GSP Submitted
3-004.09	Langley Area	High	Jan. 31, 2022	-	-
3-004.10	Salinas Valley -Monterey	Medium	Jan. 31, 2022	-	-
3-007	Carmel Valley	Medium	Jan. 31, 2022	-	-
3-009	San Luis Obispo Valley	High	Jan. 31, 2022	-	-
3-013	Cuyama Valley	High-COD	Jan. 31, 2022	Jan. 28, 2020	GSP Submitted
3-014	San Antonio Creek Valley	Medium	Jan. 31, 2022	-	-
3-015	Santa Ynez River Valley	Medium	Jan. 31, 2022	-	-
3-018	Carpinteria	High	Dec.18, 2024	-	-
3-027	Santa Margarita	Medium	Jan. 31, 2022	-	-
3-049	Montecito	Medium	Dec.18, 2024	-	-
4-002	Ojai Valley	High	Jan. 31, 2022	-	-
4-003.01	Upper Ventura River	Medium	Jan. 31, 2022	-	-
4-004.02	Oxnard	High-COD	Jan. 31, 2020	Jan. 13, 2020	GSP Submitted
4-004.03	Mound	High	Jan. 31, 2022	-	-
4-004.05	Fillmore	High	Jan. 31, 2022	-	-
4-004.06	Piru	High	Jan. 31, 2022	-	-

Groundwater Basin ID	Groundwater Basin Name	Final Priority	GSP Alternative Due Date	Submittal Date	GSP Alternative Status
4-004.07	Santa Clara River Valley East	High	Jan. 31, 2022	-	-
4-006	Pleasant Valley	High-COD	Jan. 31, 2020	Jan. 13, 2020	GSP Submitted
4-008	Las Posas Valley	High	Jan. 31, 2022	Jan. 31, 2020	GSP Submitted
4-011.01	Santa Monica	Medium	Jan. 31, 2022	-	-
5-004	Big Valley	Medium	Jan. 31, 2022	-	-
5-006.03	Anderson	Medium	Jan. 31, 2022	-	-
5-006.04	Enterprise	Medium	Jan. 31, 2022	-	-
5-012.01	Sierra Valley	Medium	Jan. 31, 2022	-	-
5-015	Big Valley	Medium	Jan. 31, 2022	-	-
5-021.50	Red Bluff	Medium	Jan. 31, 2022	-	-
5-021.51	Corning	High	Jan. 31, 2022	-	-
5-021.52	Colusa	High	Jan. 31, 2022	-	-
5-021.54	Antelope	High	Jan. 31, 2022	-	-
5-021.56	Los Molinos	Medium	Jan. 31, 2022	-	-
5-021.57	Vina	High	Jan. 31, 2022	-	-
5-021.60	North Yuba	Medium	Jan. 31, 2022	Jan. 31, 2020	GSP Submitted
5-021.61	South Yuba	High	Jan. 31, 2022	Jan. 31, 2020	GSP Submitted
5-021.62	Sutter	Medium	Jan. 31, 2022	-	-
5-021.64	North American	High	Jan. 31, 2022	-	-
5-021.65	South American	High	Jan. 31, 2022	-	-
5-021.66	Solano	Medium	Jan. 31, 2022	-	-
5-021.67	Yolo	High	Jan. 31, 2022	-	-
5-021.69	Wyandotte Creek	Medium	Jan. 31, 2022	-	-
5-021.70	Butte	Medium	Jan. 31, 2022	-	-
5-022.01	Eastern San Joaquin	High-COD	Jan. 31, 2020	Jan. 29, 2020	GSP Submitted
5-022.02	Modesto	High	Jan. 31, 2022	-	-

Groundwater Basin ID	Groundwater Basin Name	Final Priority	GSP Alternative Due Date	Submittal Date	GSP Alternative Status
5-022.03	Turlock	High	Jan. 31, 2022	-	-
5-022.04	Merced	High-COD	Jan. 31, 2020	Jan. 28, 2020	GSP Submitted
5-022.05	Chowchilla	High-COD	Jan. 31, 2020	Jan. 29, 2020	GSP Submitted
5-022.06	Madera	High-COD	Jan. 31, 2020	Jan. 31, 2020	4 GSPs Submitted
5-022.07	Delta-Mendota	High-COD	Jan. 31, 2020	Jan. 23, 2020	6 GSPs Submitted
5-022.08	Kings	High-COD	Jan. 31, 2020	Jan. 28, 2020	7 GSPs Submitted
5-022.09	Westside	High-COD	Jan. 31, 2020	Jan. 23, 2020	GSP Submitted
5-022.10	Pleasant Valley	Medium	Jan. 4, 2024	-	-
5-022.11	Kaweah	High-COD	Jan. 31, 2020	Jan. 31, 2020	3 GSPs Submitted
5-022.12	Tulare Lake	High-COD	Jan. 31, 2020	Jan. 29, 2020	GSP Submitted
5-022.13	Tule	High-COD	Jan. 31, 2020	Jan. 31, 2020	6 GSPs Submitted
5-022.14	Kern County	High-COD	Jan. 31, 2020	Jan. 31, 2020	5 GSPs Submitted
5-022.15	Tracy	Medium	Jan. 31, 2022	-	-
5-022.16	Cosumnes	Medium	Jan. 31, 2022	-	-
5-022.18	White Wolf	Medium	Jan. 31, 2022	-	-
5-022.19	East Contra Costa	Medium	Jan. 31, 2022	-	-
6-005.01	Tahoe South	Medium	Jan. 1, 2017	Dec. 29, 2016	Approved Alternative
6-054	Indian Wells Valley	High-COD	Jan. 31, 2020	Jan. 31, 2020	GSP Submitted
7-021.01	Indio	Medium	Jan. 1, 2017	Dec. 29, 2016	Approved Alternative
7-021.02	Mission Creek	Medium	Jan. 1, 2017	Dec. 29, 2016	Approved Alternative
7-021.04	San Gorgonio Pass	Medium	Jan. 31, 2022	-	-

Groundwater Basin ID	Groundwater Basin Name	Final Priority	GSP Alternative Due Date	Submittal Date	GSP Alternative Status
7-024.01	Borrego Springs	High-COD	Jan. 31, 2020	Jan. 31, 2020	Alternative Submitted
8-001	Coastal Plain of Orange County	Medium	Jan. 1, 2017	Dec. 22, 2016	Approved Alternative
8-002.07	Yucaipa	High	Jan. 31, 2022	-	-
8-002.09	Temescal	Medium	Jan. 31, 2022	-	-
8-004.01	Elsinore Valley	Medium	Jan. 31, 2022	-	-
8-005	San Jacinto	High	Jan. 31, 2022	-	-
9-007.01	Upper San Luis Rey Valley	Medium	Jan. 31, 2022	-	-
9-010	San Pasqual Valley	Medium	Jan. 31, 2022	-	-

Table 4-7 notes: GSP = groundwater sustainability plan, COD = basin subject to critical conditions of overdraft.
Castac Lake Valley (Groundwater Basin ID 5-029), a very low-priority basin, submitted a GSP on November 4, 2020.

GSPs Online: Notification Submittals and Public Access

DWR developed the SGMA Portal's GSP Reporting System for the electronic submittal of GSPs (Water Code Section 353.4[a]). DWR is required to post the adopted GSP, associated materials, and the GSP submittal date to the SGMA Portal within 20 days of receiving the electronic submittal (Water Code Section 355.2 [b]). Once a GSP is posted to the SGMA Portal the public may view the GSP and associated materials on the GSP Reporting System.

DWR's Role and Potential Actions Related to GSPs

Water Code Section10733 assigns DWR with the responsibility to review and evaluate GSPs for the following:

- Will achieve the sustainability goals established for the groundwater basin.
- Will avoid adversely affecting the ability of an adjacent groundwater basin to implement its GSP or achieve its sustainability goals.
- Will ensure that the GSPs are developed and implemented using the same data and methodologies, and that the elements of the GSPs are based upon consistent groundwater basin-wide interpretations for GSAs choosing to

submit multiple GSPs in a single groundwater basin (California Code of Regulations Sections 357.4).

Article 6 of the GSP regulations, "Department Evaluation and Assessment," describes the methods and criteria used by DWR to evaluate and assess a GSP, periodically evaluate and assess the implementation of a GSP, and to evaluate and assess amendments to a GSP.

- DWR is required to evaluate a GSP within two years of its submittal date and issue a written assessment of that GSP.
- DWR must approve the GSP, determine that the GSP is incomplete and provide the GSA with an opportunity to correct the identified deficiencies, or consult with the State Water Board after DWR has determined that the GSP is inadequate (California Code of Regulation Section 355.2). A groundwater basin with an inadequate GSP is subject to regulatory intervention by the State Water Board.

Alternatives to GSPs

SGMA allows local agencies to submit an alternative to a GSP. For basins designated high or medium priority by January 31, 2015, an alternative must be submitted by January 1, 2017, and approved by DWR as an alternative to a GSP. There are options for alternatives to be submitted in the future that results from a new adjudication or if a basin was reprioritized to be medium or high priority after January 31, 2015. For basins reprioritized to be high or medium priority after January 31, 2015, as an option, the local agency has two years to submit an alternative (Water Code 10722.4[d][1]).

An alternative, per Water Code Section 10733.6 (b), may be any of the following:

- An existing groundwater management plan.
- Groundwater management pursuant to an adjudication.
- An analysis of basin conditions that demonstrates the basin has operated within its sustainable yield over a period of at least 10 years.

Alternatives Submitted and Reviewed

Local agencies submitted 15 alternatives to DWR to be evaluated by DWR by the January 1, 2017, due date. DWR conducted extensive technical review of these alternatives to determine if they met the following:

- Alternatives must have been submitted by January 1, 2017, cover the entire groundwater basin, and be complete. Basins covered by an alternative must also comply with CASGEM groundwater monitoring requirements.
- Alternatives based on a 10-year sustainable yield analysis must demonstrate the absence of undesirable results.
- Alternatives based on an existing groundwater management plan must demonstrate that implementation of the plan is likely to achieve sustainability within 20 years in the groundwater basin.

Of the 15 submitted alternatives for review, nine were approved by DWR, as shown in Figure 4-3 and listed in Tables 4-8a and 4-8b. One alternative was submitted by January 31, 2020, under the option of management pursuant to an adjudication action. DWR had not completed evaluation of this alternative as of August 31, 2020.

Table 4-8a Approved Alternatives as of August 31, 2020 (Groundwater Management Plan)

Groundwater Basin ID	Basin	Submitting Agency
2-009.01	Niles Cone	Alameda County Water District
2-009.02	Santa Clara	Santa Clara Valley Water District
3-002.01	Corralitos	Pajaro Valley Water Management Agency
3-003.01	Llagas Area	Santa Clara Valley Water District
6-005.01	Tahoe South	South Tahoe Public Utility District
7-021.01	Indio	Coachella Valley Water District
7-021.02	Mission Creek	Coachella Valley Water District

Table 4-8b Approved Alternatives as of August 31, 2020 (10-Year Sustainable Yield Analysis)

Groundwater Basin ID	Basin	Submitting Agency
2-010	Livermore Valley	Zone 7 Water Agency
8-001	Coastal Plain of Orange County	Orange County Water District

Alternative Submittal, Annual Reporting, Public Access, and DWR Review

Alternatives were submitted to DWR through the Alternative Reporting System module on the SGMA Portal. The Alternative Reporting System module enables the public to view the submitted alternatives and supporting information. The SGMA Portal also allows the public to submit comments on the GSPS and view public comments submitted.

Groundwater basins with approved alternatives are required to submit updates to their alternatives every five years following submittal of alternatives (Water Code 10733.6 [c]). Annual reports documenting implementation of the alternative toward meeting a sustainability goal or functionally equivalent goal, or documenting continued conditions of sustainability, are also submitted to DWR through the SGMA Portal.

The public can view and download alternatives, DWR's written assessments of the submitted alternatives, annual reports, and five-year updates of approved alternatives through the Alternatives tab on the SGMA Portal.

DWR is required to evaluate approved alternatives and issue an assessment at least every five years. The review is based on information provided by the local agencies in annual reports and the periodic evaluation prepared by the local agencies implementing the alternatives.

Groundwater Adjudicated Areas and Reporting Requirements

In 2014, SGMA legislation identified 29 groundwater adjudicated areas. One adjudicated area was divided into two management areas bringing the total adjudicated areas to 30. For the purposes of SGMA, all 30 areas listed in Water Code Section 10720.8 are considered adjudicated areas. Table 4-1 provides additional information. The watermaster or water manager for each of these adjudicated areas is required to submit an annual report to DWR starting April 1, 2016, but is not required to develop a GSP if the basin is considered low or very low priority. These 30 adjudicated areas cover all, or portions, of 42 groundwater basins listed in Table 4-1.

Two basins out of the 42, Scott River Valley (Groundwater Basin ID 1-005) and San Jacinto (Groundwater Basin ID 8-005), have adjudicated area within the boundaries of the two basins. Both basins have been prioritized high or medium priority and both are required to develop and implement a GSP per the timelines listed in Table 4-6.

SGMA requires the watermaster or local agency managing groundwater adjudicated areas to report the following information to DWR:

- Groundwater elevation data.
- Annual aggregated data identifying groundwater extraction.
- Surface water supply used, or available for use, for groundwater recharge or in-lieu use.
- Total water use.
- Change in groundwater storage.
- The annual report submitted to the court.

DWR's Role and Potential Actions Related to Groundwater Adjudication

SGMA addresses new basin-wide adjudications and establishes the processes and timelines that must be followed by a local agency or GSA if it opts for groundwater adjudication instead of developing and implementing a GSP required for all high- and medium-priority basins. If a local agency or GSA can submit a proposed stipulated judgment approved by the court to DWR by the applicable statutory submittal deadline, then that judgment must be reviewed by DWR as an alternative rather than as a GSP.

It is the responsibility of the local agency or GSA to follow the process established in the Code of Civil Procedure (Part 2, Title 10, Chapter 7, Section 850) before it can submit the proposed stipulated judgment to DWR for review and assessment as an alternative to GSP. DWR is required to submit its assessment directly to the court for judicial review and approval. If a proposed stipulated judgment is not submitted by the applicable statutory deadline, State Water Board intervention would apply just as it would if an adopted GSP was not submitted by the applicable statutory deadline.

There are several groundwater basins that have filed court actions and are currently working through the courts. In 2020, the major groundwater pumpers in Borrego Valley filed a comprehensive groundwater rights adjudication. The Borrego Springs Subbasin (Groundwater Basin ID 7-024.01) stipulated agreement is the basis for their submittal of an alternative to GSP (Borrego Water District 2020). It was submitted by the applicable statutory deadline of January 31, 2020, for basins subject to critical conditions of overdraft.

State Water Board Intervention

SGMA authorizes State Water Board intervention to manage a groundwater basin on an interim basis to ensure continued progression of the groundwater basin toward sustainability when groundwater management efforts of the GSAs in the groundwater basin have not met, or will likely not meet, sustainability goals.

Intervention can only occur for high- and medium-priority groundwater basins when specific trigger events, as listed below, occur:

- A high- or medium-priority groundwater basin is not covered by a GSA after June 30, 2017.
- A high- or medium-priority groundwater basin does not have an adopted GSP (or an approved alternative) under implementation by these statutory deadlines:
  - January 31, 2020, for groundwater basins designated as subject to critical conditions of overdraft.
  - January 31, 2022, for all other high- and medium-priority groundwater basins, or four years after being designated a high- or medium-priority groundwater basin from a basin prioritization process.
- DWR determines a GSP is inadequate at the conclusion of its review process.
  - Basin is designated as subject to critical conditions of overdraft and DWR, in consultation with the State Water Board, disapproves a plan or determines a plan is not being implemented in a manner likely to achieve sustainability.
  - A basin that is not designated as subject to critical conditions of overdraft but is in long-term overdraft (State Water Board determination) and DWR, in consultation with the State Water Board, disapproves a plan or determines a plan is not being implemented in a manner likely to achieve sustainability.
- During the 20-year implementation horizon of a GSP and after January 31, 2025, DWR determines the GSP is not being implemented in a manner that is likely to achieve sustainability.
  - A basin is neither designated as subject to critical conditions of overdraft nor is in long-term overdraft (State Water Board finding), but there are significant depletions of interconnected surface waters (State Water Board determination), and DWR, in consultation with the State Water Board, disapproves a plan or determines a plan is not being implemented in a manner likely to achieve sustainability.

When one of the triggering events occurs, the State Water Board may designate a basin "probationary" after providing notice and holding a public hearing where the deficiencies and potential remedies are discussed. While a basin is on probationary status, the State Water Board may:

- Require groundwater extractors within the basin to install meters and report all groundwater extractions.
- Conduct investigations and collect data necessary for sustainable groundwater management.
- Develop and implement an interim plan to help meet the basin's sustainability goal if a GSA is unable to fix the deficiencies that resulted in probationary status within a specified time frame.
- Assess fees to cover its enforcement activities.

To end State Water Board management of a probationary groundwater basin, GSAs will have to demonstrate to the State Water Board (which will consult with DWR) their ability and willingness to manage groundwater sustainably and address the issues that caused State intervention. This may require changes to the GSPs, revision of coordination agreements among the GSAs, pumping restrictions, or other measures to provide assurances that ongoing local management will be effective. Additional information on State Water Board intervention can be found on the State Water Board's webpage for State Intervention.

Additional Changes to Existing Groundwater Management Resulting from SGMA

Water Rights

SGMA does not give GSAs the authority to modify existing water rights. But GSAs do have the authority to manage resource use (e.g., by limiting pumping within a basin). In doing so, existing groundwater rights need to be acknowledged.

Special Act Districts

As part of SGMA, under Water Code Section 10723(c)(1), 18 special act districts are recognized as having the ability to manage groundwater by statute and, as a result, were deemed "exclusive local agencies" with authority to form a GSA and manage groundwater basins within their statutory boundaries. Of the 18 exclusive local agencies, 13 elected to become GSAs in high- and medium-priority basins underlying their service area. Table 4-9 provides of list of the special act districts, the priority of the applicable basins, and SGMA participation status.

Table 4-9 Special Act Districts with SGMA Priority and Status, by Basin

Special Act District	Groundwater Basin (Basin ID)	Final Priority	GSA Formed	GSP Submitted	Approved Alternative
Alameda County Flood Control and Water Conservation District, Zone 7	Livermore Valley (2-010)	Medium	Yes	-	Yes
Alameda County Water District	Niles Cone (2-009.01)	Medium	Yes	-	Yes
Desert Water Agency	Indio (7-021.01)	Medium	Yes	-	Yes
Desert Water Agency	Mission Creek (7-021.02)	Medium	Yes	-	Yes
Fox Canyon Groundwater Management Agency	Oxnard (4-004.02)	High	Yes	Yes	-
Fox Canyon Groundwater Management Agency	Pleasant Valley (4-006)	High	Yes	Yes	-
Fox Canyon Groundwater Management Agency	Las Posas (4-008)	High	Yes	Yes	-
Fox Canyon Groundwater Management Agency	Arroyo Santa Rosa Valley (4-007)	Very Low	Yes	Yes	-
Honey Lake Valley Groundwater Management District	Honey Lake (6-004)	Low	No	-	-
Kings River East Groundwater Sustainability Agency	Kings (5-022.08)	High - COD	Yes	Yes	-
Long Valley Groundwater Management District	Long Valley (6-104)	Low	No	-	-
Mendocino City Community Services District	Fort Bragg Terrace Area (1-021)	Very Low	No	-	-
Mono County Tri-Valley Groundwater Management District	Fish Slough (6-012.02)	Very Low	Yes	-	-

Special Act District	Groundwater Basin (Basin ID)	Final Priority	GSA Formed	GSP Submitted	Approved Alternative
Mono County Tri-Valley Groundwater Management District	Owens Valley (6-012.02)	Low	Yes	-	-
Monterey Peninsula Water Management District	Carmel Valley (3-007)	Medium	Yes	-	-
North Fork Kings Groundwater Sustainability Agency	Kings (5-022.08)	High - COD	Yes	Yes	-
Ojai Groundwater Management Agency	Ojai Valley (4-002)	High	Yes	-	-
Orange County Water District	Coastal Plain of Orange County (8-001)	Medium	No	-	Yes
Pajaro Valley Water Management Agency	Pajaro Valley (3-002.01)	High - COD	Yes	-	Yes
San Joaquin River Exchange Contractors GSA	Delta-Mendota (5-022.07)	High - COD	Yes	Yes	-
Santa Clara Valley Water District	Santa Clara (2-009.02)	High	Yes	-	Yes
Santa Clara Valley Water District	Llagas (3-003.01)	High	Yes	-	Yes
Sierra Valley Groundwater Management District	Sierra Valley (5-012.01)	Medium	Yes	-	-
Willow Creek Groundwater Management Agency	Willow Creek (6-003)	Very Low	No	-	-

Table 4-9 notes: COD = designated subject to critical conditions of overdraft, GSA = groundwater sustainability agency, GSP = groundwater sustainability plan, SGMA = Sustainable Groundwater Management Act

Groundwater Ordinances

GSPs submitted to DWR are required to identify all ordinances affecting groundwater in the basin. Ordinances may be an effective tool for counties, cities, and GSAs to sustainably manage their basins. Since SGMA was signed into law, several local ordinances have come into effect, including:

- Merced County (2015) restricts the mining and export of groundwater from the Merced Groundwater Subbasin (Groundwater Basin ID 5-022.04).
- Indian Wells Groundwater Authority (2019) requires the registration of all facilities used to extract groundwater from the Indian Wells Valley groundwater basin (Groundwater Basin ID 6-054).
- Indian Wells Valley Groundwater Authority (2020) requires groundwater extraction facilities, except for registered de minimis extractors to meter and report extractions from the Indian Wells Valley groundwater basin (Groundwater Basin ID 6-054).
- Monterey County (2018) extended through May 2020 a moratorium on new wells in the 180/400-Foot Aquifer Subbasin (Groundwater Basin ID 3-004.01).

Relation of SGMA Implementation to Other Local and Regional Water Resource Planning Efforts

Few IRWM plans actively manage groundwater. Typically, have deferred implementation of groundwater management and planning to local agencies through GWMPs. DWR anticipates that this practice will continue with SGMA implementation. SGMA requires (Water Code Section 10723.2) communication and outreach with interested parties, such as IRWM groups.

GSAs can also coordinate with the UWMPs and AWMPs within their basins to assist with their groundwater sustainability planning efforts. These efforts can leverage each other's data and information for mutually beneficial outcomes. It should be noted that final adoption of regulations for GSPs was not finalized before the 2015 UWMPs were due to DWR on July 1, 2016. As a result, new requirements for groundwater management under SGMA did not apply to the 2015 UWMPs. Alignment between the two should occur in future UWMP updates.

SGMA Activities

California Well Standards

California Well Standards, also known as DWR's Bulletin 74, sets the minimum standards for construction, maintenance, and destruction of water supply, cathodic

protection, monitoring, and geothermal heat exchange wells, with the purpose of protecting California's groundwater. The California Well Standards help prevent wells from acting as conduits for contaminant movement into groundwater. Proper well construction helps prevent the introduction and spread of contaminants in the aquifer system.

In California, regulatory authority over well construction, alteration, and destruction activities is given to local jurisdictions (cities, counties, or water agencies) who have the authority to adopt a local well ordinance that meets or exceeds the California Well Standards. Permitting and enforcement are carried out by the local enforcing agency, such as cities and counties, and when authorized by counties GSAs.

Historically, the California Well Standards have included minimum separation distances, or setbacks, from potential sources of pollution to reduce the risk of groundwater contamination. Spacing wells to prevent groundwater or surface water depletion, as described in SGMA, is outside the scope of California Well Standards. SGMA requires GSAs to consider well interference (well spacing in relation to other wells) and stream depletion (well proximity to streams), which are also outside of the scope of California Well Standards.

DWR is developing an update to the 1991 California Well Standards to reflect the changes in standards of practice. The revised California Well Standards will reflect the current state of knowledge, be based on current standards of practice, and further protect groundwater resources. The updated California Well Standards will also formally incorporate geothermal heat exchange well standards. To achieve these goals, an interdisciplinary team of DWR staff is coordinating with members of the public, industry experts, and other State and local agencies to review and provide input for proposed changes. For more information, visit DWR's Well Standards webpage.

Airborne Electromagnetic Surveys

DWR is working to improve data collection and characterization of groundwater basins across the state. Airborne electromagnetic (AEM) is a geophysical technology used to collect data of hydrogeologic characteristics of aquifer systems. AEM surveying uses geophysical instruments that are secured on a large hoop frame. A helicopter carries this measuring device and flies in a pre-defined pattern approximately 100 feet above the ground. The electromagnetic field of the instrument, attached to a helicopter, induces conductivity creating an induced

magnetic field in the ground that is affected by the subsurface deposits. A receiver on the helicopter measures changes in the field and records the field as data.

The changes in magnetic field strength and position are interpreted to better understand the hydrogeology of the basin. Collected data is processed by inversion techniques into cross sections and three-dimensional images to develop a resistivity model of the subsurface. When combined with known hydrogeology the results can provide improved understanding of the aquifers and aquitards that comprise the groundwater system.

The advantages of AEM surveys over ground-based geophysical surveys is that they can cover large areas in a short period of time and are usually more cost effective than ground-based field studies and well drilling. AEM surveys capture changes in electrical resistivity associated with lithology, saturation, and water quality. Data from wells at the field scale can be used to verify the source of changes in resistivity that would otherwise appear similar. The resolution of AEM survey results varies by depth but is generally on the order of 3 feet near the surface to tens of feet at depth. Spatial resolution varies depending on the flight paths taken during the survey. Along the flight line, data density is approximately every 10 feet.

In 2017, the State of California signed an agreement with the Kingdom of Denmark to share the latest technology, research, and techniques for water resources management. One outcome of this agreement was the Groundwater Architecture Project, a pilot study conducted by Stanford University and Danish groundwater companies to collect AEM data and design supporting geophysical and computational infrastructure for data analysis, interpretation, and archiving.

The data and tools developed as part of this study are meant to serve as a foundation for hydrogeological conceptual models, which are required components of GSPs. As part of this effort, numerous pilot AEM surveys have been conducted in California including areas of the Kaweah Subbasin (Basin ID 5-022.11), Indian Wells Valley Basin (Basin ID 6-054), Vina Basin (Groundwater Subbasin ID 5-021.57), and the Paso Robles Basin (Basin ID 3-004.06).

AEM surveys in the northern Sacramento Valley (Butte and Glenn counties) are being conducted to delineate major aquifers and aquitards to improve the hydrogeologic conceptual model, assess the distribution of clay-rich units, examine the connectivity among aquifers, and identify hydrostratigraphic layers for groundwater model development. An example of the lithological interpretation from the AEM flights in

Vina Basin (Groundwater Subbasin ID 5-021.57) is shown in Figures 4-12a through 4-12c. Figure 4-12a shows the approximate flight paths within the study area (black lines) and the locations of the wells (dots) with logs that were used to correlate the AEM data (Figure 4-12b). The results can be seen in Figure 4-12c.

Figure 4-12a Vina Basin AEM Flight Paths and Locations of Wells Used for Lithological Interpretation

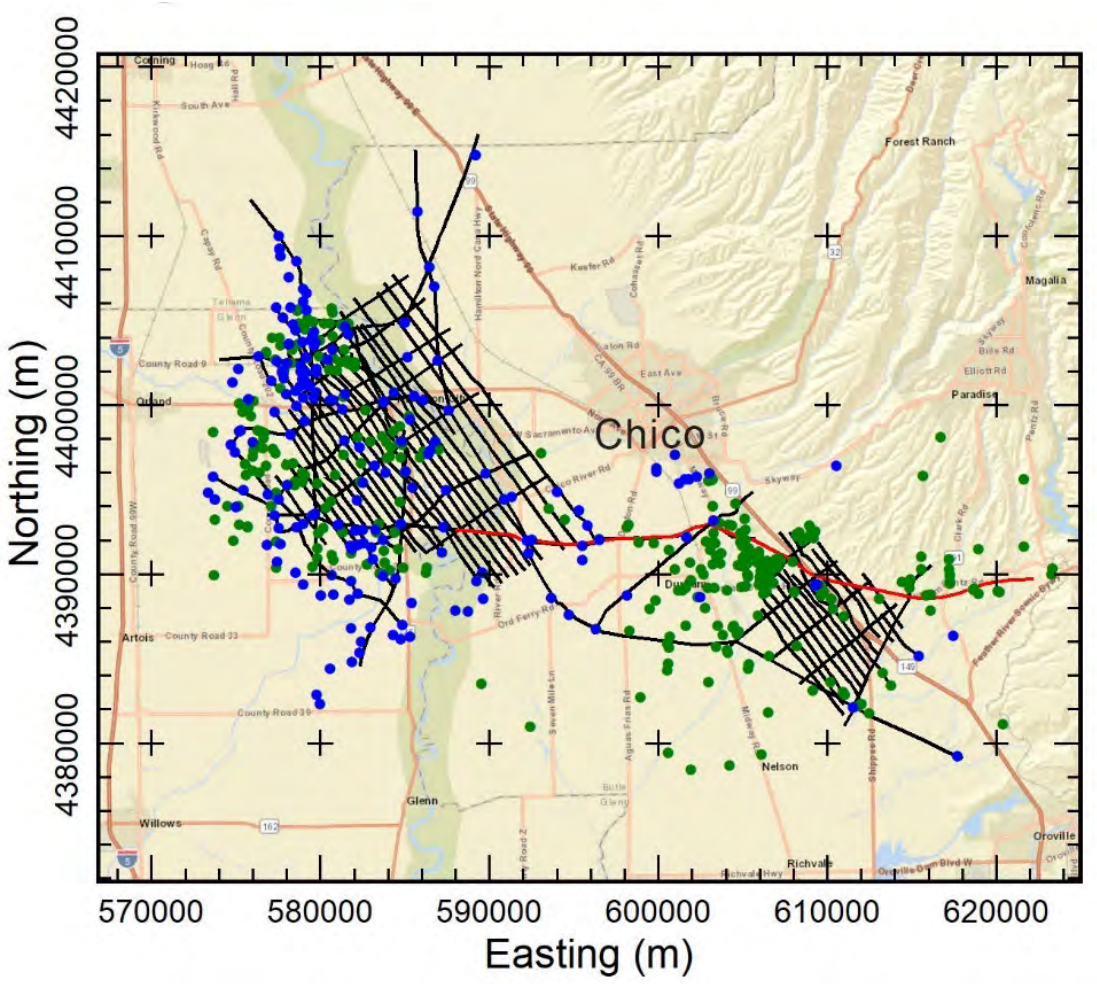


Figure 4-12a note: AEM = airborne electromagnetic

Figure 4-12b Vina Basin AEM Subsurface Inversion Resistivity

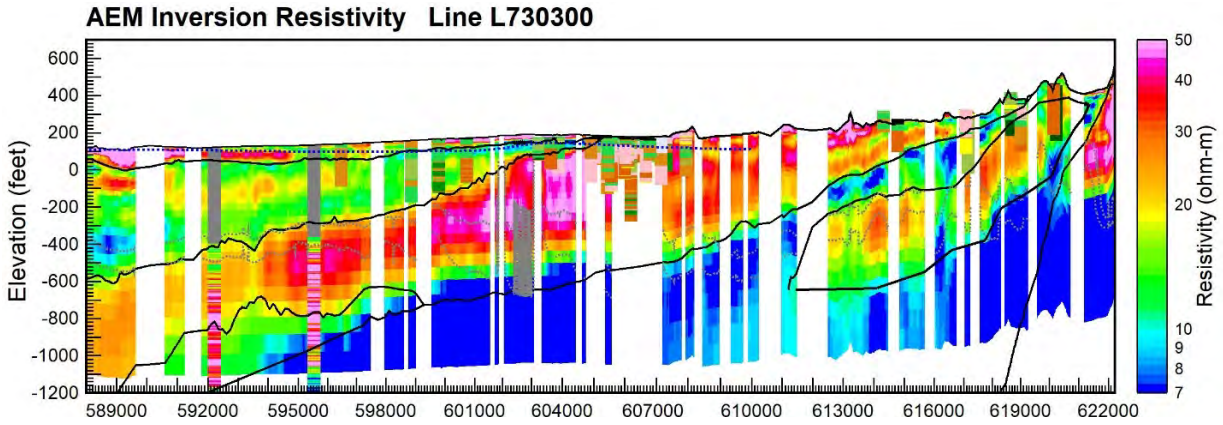


Figure 4-12b note: AEM = airborne electromagnetic

Figure 4-12c Butte County AEM Subsurface Interpretation

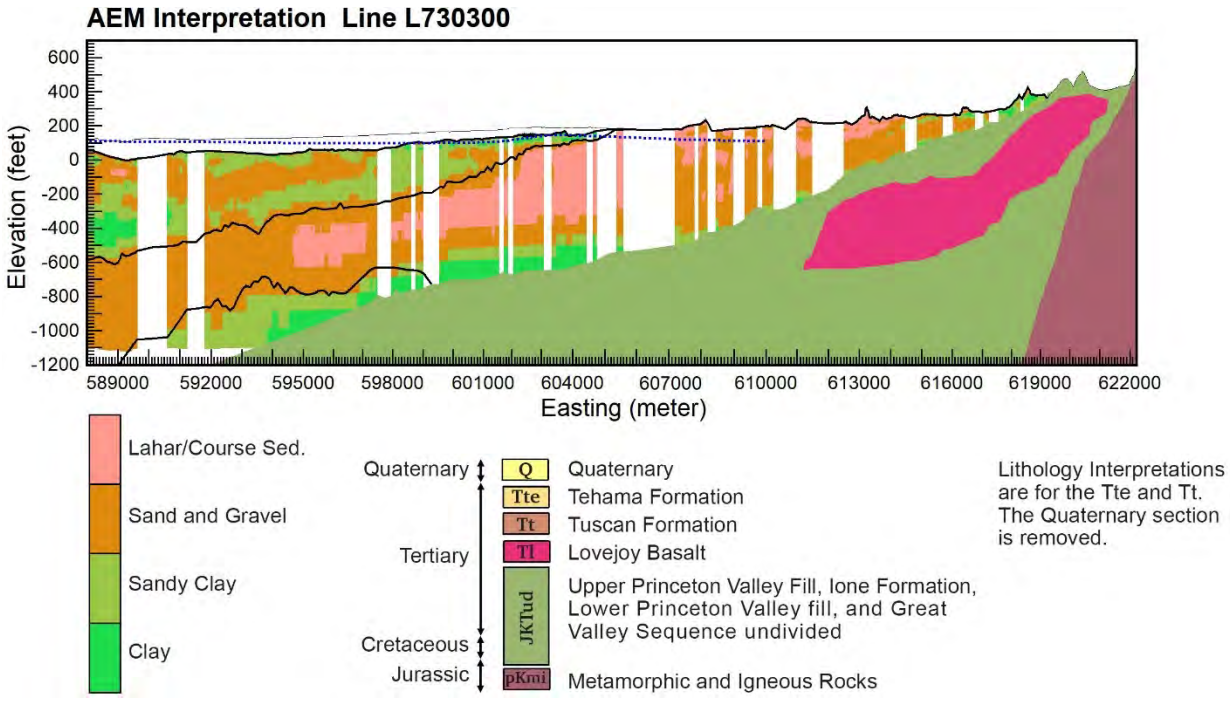


Figure 4-12c note: AEM = airborne electromagnetic

AEM surveys can provide supporting, foundational information on subsurface hydrogeologic characteristics of aquifer systems. The surveys can establish a framework to aid in reducing uncertainty, provide supporting information for models, and improve the potential for successful development and implementation of GSPs and groundwater recharge projects. AEM surveys are multi-benefit projects and have

been successfully implemented at local and regional scales in groundwater basins in California through the Groundwater Architecture Project.

With Proposition 68 funding, DWR is leading an AEM survey project aimed at providing GSAs, interested parties, and the public with basin-specific geophysical data, tools, and analysis aligned to the technical requirements of the GSP regulations and SGMA. The project will generate a coarse-grid subsurface map that will provide informative aquifer data to GSAs. The resulting information will provide standardized, statewide data and reporting, and will have many uses in support of sustainable groundwater management, including development of a hydrogeologic conceptual model and identification of candidate groundwater recharge areas.

SGMA Data Support Activities

DWR provides a variety of technical assistance services to local agencies through its four regional offices and a suite of online services. These services include data and tools, modeling platforms, communications, outreach and engagement, facilitation, technical assistance and field activities, and financial assistance. These services are described below.

New Datasets

DWR has a long history of data collection, monitoring, and reporting. DWR's Sustainable Groundwater Management Office (SGMO) is supplementing existing data collection efforts with advanced data collection methods intended not only to benefit sustainable groundwater management efforts in California, but also water resource programs of various local, State, and federal agencies. These data collection efforts will create new datasets to support development of GSPs and other groundwater management activities, augmentation of data to monitor progress toward sustainability goals, and development of web-based data visualization tools.

New datasets developed by DWR to support GSP development include climate change, ecosystems, and interferometric synthetic aperture radar (InSAR), which are briefly described below. For information on accessing these datasets, see Appendix D, "Citations, Reference Materials, and Links."

Climate Change

The Sustainable Groundwater Management Program (SGMP) has several releases of models and data going back to August 2016 and it continues through to present for

climate change datasets related to climatology, hydrology, and water operations to assist GSAs in calculating projected water budgets during GSP development.

- Modeling and data development were completed and made available as part of the Water Storage Investment Program (referred to as WSIP) in August 2016. The data were originally developed by DWR's Climate Change Program for the California Water Commission's Water Storage Investment Program.
- Data, guidance documents, and tools were released in 2018.
- The Climate Change Program at DWR released data for extreme scenarios in 2020.

The information described above was made available for download on the SGMA Data Viewer.

Ecosystems

GSP regulations require GSAs to identify groundwater dependent ecosystems and the potential effects of groundwater use and management on them. DWR released the Natural Communities Commonly Associated with Groundwater dataset in 2018 to assist GSAs in addressing this requirement in their GSPs. The dataset is a compilation of 48 publicly available State and federal agency datasets that map vegetation, wetlands, springs, and seeps in California. DWR collaborated with the California Department of Fish and Wildlife and The Nature Conservancy to review the compiled dataset. The dataset was made available so that it can be used by GSAs to help identify groundwater dependent ecosystems within a basin. DWR developed the Natural Communities Dataset Viewer to allow users to query the screened vegetation and wetland datasets, as well as the source datasets.

The information described here is available for viewing and downloading on the Natural Communities Dataset Viewer.

Annual InSAR Subsidence Imagery

This dataset represents measurements of vertical ground surface displacement in 164 of the high-use and populated groundwater basins across California between January of 2015 and September of 2019. Vertical displacement estimates are derived from InSAR data that are collected by the European Space Agency Sentinel-1A satellite and processed by TRE ALTAMIRA Inc., under contract with the DWR as part of DWR's SGMA technical assistance to provide important SGMA-relevant data to GSAs for GSP development and implementation. Sentinel-1A InSAR data coverage began in late 2014 for parts of California. Coverage for the entire study area began

June 13, 2015. Included in this dataset are point data that represent average vertical displacement values for 100-meter by 100-meter areas, as well as GIS rasters that were interpolated from the point data; rasters for total vertical displacement relative to June 13, 2015, and rasters for annual vertical displacement rates with earlier coverage for some areas, both in monthly time steps. DWR will continue to make annual InSAR imagery available to improve the subsidence monitoring network.

The information described here is available for viewing and downloading on the SGMA Data Viewer.

Planned Data Collection and Monitoring Efforts

The need for water-related data and easy access has been increasing. The need for this data has moved beyond the scientists and State agencies to include a greater number of local agencies, organizations, and the public. The data are needed to make informed management decisions. With the passage of SGMA came an even greater need for more water-related data. DWR and other State agencies have been expanding the current data and improving access and fill the gaps. Planned data collection and monitoring efforts by DWR include:

- **Conducting AEM Surveys**: AEM surveys are being planned to collect hydrogeologic characteristics and water quality information. The resulting dataset will be provided to GSAs and the public to inform GSP development.
- **Enhancing the Groundwater Elevation Monitoring Network**: Dedicated groundwater monitoring wells will be strategically installed based on hydrogeologic knowledge about the basin, lack of monitoring data, and in some basins, the subsurface knowledge gained from AEM surveys. These monitoring wells will support GSAs and the public by providing fast and reliable groundwater level data that can support GSP development, implementation, and evaluation and support groundwater recharge projects that may develop from DWR's flood-managed aquifer recharge (Flood-MAR) effort.
- **Installing New and Maintaining Existing Stream Gages**: New stream gages are being installed in high- and medium-priority basins to support GSAs and the public in their need for real-time surface water data. Existing stream gages in these basins will continue to be operated and maintained for similar uses. These new and existing gages will provide fast and reliable data to support GSP development, implementation, and evaluation, and will support groundwater recharge projects that may be developed through DWR's Flood-MAR Program. The new surface water data will provide multiple benefits

beyond groundwater management, such as surface water delivery management and flood management.

- **Statewide Land Use Data**: SGMO collaborated with the DWR Land and Water Use Program to acquire and make public the 2014 and 2016 statewide land use data prepared by Land IQ, LLC. These datasets are accessible on the California Land Use Viewer, described below. Future statewide land use datasets will be acquired and made public as they become available. The 2018 statewide land use data are expected in late 2020. DWR is working with USGS on developing the 2017 land use data that are planned to be released in the summer of 2021.

DWR Web-Based Data and Data Visualization Tools

The Sustainable Groundwater Management Office worked with a variety of DWR divisions and other entities to create the following new, web-based mapping applications that integrate decades of data and make the information easier to access. For information on accessing these mapping applications, see Appendix D, "Citations, Reference Materials, and Links."

SGMA Portal

DWR developed the SGMA Portal to provide local agencies, GSAs, and water masters with a platform where they can submit information required by SGMA on GSA formation, annual reporting, alternative submittals, basin boundary modification requests, and GSP initial notifications. The SGMA Portal enables interested parties and the public to view submitted information and, when applicable, provide comments. The SGMA Portal is organized around information topics; GSAs, GSPs, alternative plans, adjudications, and basin boundary modifications. Within the various information topics, a variety of reports, map viewers, submitted plans and annual report information are available.

SGMA Data Viewer

Data related to SGMA and useful for GSP development are managed and stored by a variety of local, State, and federal agencies, thereby making the data difficult to find and use. The SGMA Data Viewer was developed by the SGMO to provide GSAs and the public ease of access to query, visualize, and download data. The SGMA Data Viewer provides map views that can be overlain with information on groundwater levels, land subsidence, interconnected surface water, water budget information, hydrogeologic conceptual models, and spatial boundaries. As new data become available, information will be updated or added to the SGMA Data Viewer.

DWR Land Use Viewer

DWR has been surveying land use since 1950. Land-use surveys were originally performed using aerial photos and USGS 7.5-feet quadrangle maps as base maps for delineating field boundaries and recording land uses. As large format printing of aerial photographs became available, plotted aerial photos were used as field sheets for recording land-use information. Most of the land-use survey data was entered directly into a digital map by using geographic information system (GIS) software on a laptop computer. Georeferenced, orthorectified images is used as a backdrop, and the land-use boundaries are visible on top of the images. DWR staff visited more than 95 percent of the developed agricultural areas within each survey area to visually identify land uses within them.

During the third quarter of 2017, DWR released the DWR Land Use Viewer that presented, for the first time, a single year (2014) of remote sensed agricultural land use data for the entire state. Since the release of the 2014 data, 2016 statewide remote sensed agricultural land use data was added. Statewide 2018 remote sensed agricultural land use is expected to be added soon and will include multi-cropping data.

The viewer allows GSAs, interested parties, and the public to easily access existing statewide and county land-use data, including crop data, that have been collected by DWR since 1950. DWR will augment the Land Use Viewer with new annual statewide land-use data derived from a combination of remote sensing, agronomic analysis, and ground verification.

DWR Well Completion Report Map Application

Water Code Section 13751 requires that anyone who constructs, alters, or destroys a water well, cathodic protection well, groundwater monitoring well, or geothermal heat exchange well must file a report of completion with DWR within 60 days of the completion of the work. Well drillers submit their well completion reports using the Online System of Well Completion Reports (OSWCR). Water Code Section 13752 allows for the release of copies of well completion reports to governmental agencies and to the public. The California DWR Well Completion Report Map Application spatially displays well statistics and general locations.

CASGEM Online System

The CASGEM Online System is a portal that provides public access to the State's groundwater elevation and monitoring well data. Since 2009, CASGEM has tracked seasonal and long-term groundwater elevation trends in groundwater basins

statewide. The program's purpose is to establish a permanent, locally managed program of regular and systematic monitoring in all of California's alluvial groundwater basins. The CASGEM Online System provides descriptive information on monitoring wells, groundwater levels collected for CASGEM, and historical groundwater levels collected pre-CASGEM.

Water Data Library

An easy-to-use viewer of water data is the Water Data Library. This viewer will not only present the data found in other databases, such as CASGEM, it also provides site water quality data that has been collected by DWR and the continuous groundwater time-series data from automated recorders at sites operated by DWR. The Water Data Library includes the following datasets:

- **Groundwater Level Data**: This dataset contains seasonal and long-term groundwater level measurements collected by DWR and cooperating agencies in groundwater basins statewide. Most measurements are collected manually from wells twice per year to capture the peak high and low groundwater elevations. But the dataset includes measurements recorded more frequently.
- **Water Quality Data**: This dataset contains DWR-collected, historical chemical and physical parameters found in drinking water, groundwater, and surface water statewide.
- **Continuous Data**: This dataset contains continuous time-series data from automated recorders at sites operated by DWR. Readings are taken at 15-minute to one-hour intervals. Most of the monitoring sites are visited once every month or two, when readings are downloaded from data recorders, reviewed, and published. The published data are formatted and displayed as daily averages, but the raw data, taken at 15-minute to one-hour intervals, can be made available on request.

California Data Exchange Center

The California Data Exchange Center (CDEC) provides a centralized database to store, process, and exchange real-time hydrologic information gathered by various cooperators throughout the state. CDEC disseminates this information to the cooperators, public and private agencies, news media, and the public. The data collected by CDEC enable forecasters to prepare flood forecasts and water supply forecasts, reservoir and hydroelectric operators to schedule reservoir releases, and water suppliers to anticipate water availability.

Real-time data are collected from remote data stations via the State microwave radio network and GOES satellite system. Real-time data include river stage, precipitation, snow water content, temperature, water quality, and full weather data.

CDEC operates a data exchange program with various federal and State agencies and other public agencies. This data exchange program involves the automated transfer and receipt of data and information via network connections. This data include precipitation, snow water content, reservoir operations, reservoir summary reports, weather forecasts, river bulletins, full weather data, river gage data, and river flow rating tables and shifts. Value added information is created from the data and presented in a variety of formats including maps, plots, charts, and publications.

Other Groundwater Databases and Tools

DWR and other State and federal agencies collect and share data related to California's groundwater. Some of the more commonly accessed databases and tools are described below. These databases are sometimes connected to the web-based visualization tools described above. For information on accessing these databases and tools, see Appendix D, "Citations, Reference Materials, and Links."

Open Data Portal

CNRA created and maintains the Open Data portal website, as a part of the open data initiative for California, that hosts a variety of water datasets available for download. The Open Data portal stores data from numerous State agencies, including DWR, the State Water Board, and the California Department of Fish and Wildlife. Some of the available groundwater datasets include groundwater level monitoring stations and measurements, general site monitoring stations and measurements, GSP Annual Report water use data, natural communities, SGMA 2019 Basin Prioritization, groundwater basin boundaries, geologic provinces, water quality, and water-balance subregions. The CNRA Open Data portal includes modeling tools such as the IWFM, California Central Valley Groundwater-Surface Water Simulation Model (C2VSim), and the Sacramento Valley Groundwater-Surface Water Simulation Model (SVSim) (described below). The CNRA Open Data portal will also contain downloadable versions of this report and the data that was used.

Groundwater Exchange

The Groundwater Exchange is a central, collaborative, and publicly accessible online resource center connecting water managers, water users, and community members with tools and resources to support the design and implementation of effective

Groundwater Sustainability Plans under California's Sustainable Groundwater Management Act. The Groundwater Exchange is a program of the California Water Library and is a project of the Multiplier, a 501(c)3 nonprofit organization that helps protect and foster a healthy, sustainable, resilient, and equitable world.

GAMA Online Tools

The Groundwater Ambient Monitoring and Assessment Program (GAMA) presents online tools created by the State Water Board and the USGS to help users understand groundwater quality in California. The GAMA online mapping tools display information on water quality, public water system wells, and groundwater age. Most of these datasets can only be viewed within the GAMA tools and cannot be downloaded.

One such tool featured in the GAMA online tools is the Groundwater Information System tool that allows for information downloads related to water quality data and public water system wells. The system integrates and displays groundwater quality data from several different sources on an interactive map interface. This system provides access to groundwater sampling results from more than 300,000 wells in California. Analytical tools and reporting features help users assess groundwater quality and identify potential groundwater issues in California.

GeoTracker

GeoTracker is the State Water Board's data management system for sites in California that have affected, or have the potential to affect, groundwater. This includes cleanup sites and permitted facilities. GeoTracker provides records and data from State Water Board programs and other agencies through their search engine or the geographic information system interface map. Data on groundwater quality, elevation, and depth, which is submitted under State Water Board regulations, is available for download.

Human Right to Water Portal

The State Water Board maintains this portal for the implementation of the human right to water recognized under Water Code Section 106.3. The portal includes mapping tools on the exceedance and compliance status of public water systems, water systems' drinking water data, and potential funding opportunities for drinking water projects.

Drinking Water Watch

The State Water Board has a public web portal to view public water systems' locations, facilities, sources, and samples. The portal includes downloadable data for

all public water systems, all water source facilities, and all sample points. The data on the web portal is sourced from the U.S. Environmental Protection Agency (EPA) database Safe Drinking Water Information System as well as the Drinking Water Quality results hosted on the Electronic Data Transfer Library.

Household Water Supply Shortage Reporting System

This website collects data from individuals, not served by a public water system, experiencing problems with their water supply and from agencies receiving calls from those individuals. This information system is intended to inform State and local agencies about drought impacts on household water supplies. It was created as part of the State's emergency response efforts to previous droughts and is being continued to gather information relating to shortages of household water from private well or surface water sources. Participation in this website is voluntary.

Water Quality Portal Data Discovery Tool

The Data Discovery Tool, which is powered by the Water Quality Portal is a federal cooperative data management site sponsored by USGS, EPA, and the National Water Quality Monitoring Council. Data are available from more than 400 State, federal, Tribal, and local entities. This website allows users to search and download publicly available water quality data from the USGS National Water Information System (NWIS), EPA Storage and Retrieval (STORET) Data Warehouse, and the U.S. Department of Agriculture's Sustaining the Earth's Watersheds-Agricultural Research Database System (STEWARDS).

U.S. Geological Survey's National Water Information System

The USGS NWIS website is a data management system that provides access to water resources data collected from approximately 1.9 million sites across the United States and its territories. This website provides groundwater quality and water level data from wells. It is available for download.

Modeling Tools

Model codes are used to develop specific modeling applications. There are many existing model codes and model applications being used throughout California for various groundwater management and planning activities. DWR and USGS have coordinated and compiled a table of available model codes and interactive maps displaying a select number of model applications in California that can be found in Appendix D, "Citations, Reference Materials, and Links." The modeling codes and applications described below were generally developed for regional-scale

groundwater analysis; use of a model for local-scale analysis should be done with an understanding of the limitations and assumptions of the model.

Modeling Platforms

DWR and USGS have developed generic modeling platforms to support water management in California. These are briefly described below.

- **Integrated Water Flow Model (IWFM)**: DWR's Modeling Support Branch of the Bay-Delta Office developed and provides ongoing support for the IWFM. It calculates groundwater flows, soil moisture movement in the topsoil, stream flows, land surface flows and flow exchange between the groundwater, streams and land surface as generated by rainfall, agricultural irrigation, and municipal and industrial water use. IWFM also calculates agricultural water demands based on crop types, crop acreages, soil types, irrigation methods and rainfall rates, as well as the municipal and industrial water demands based on population and per-capita water use rates. IWFM is a powerful tool that can help water managers understand the historical evolution of the surface and subsurface water flows within their basin, and to plan the use of groundwater and surface water to meet future agricultural, municipal, and industrial water demands.

- **MODFLOW**: MODFLOW is the USGS's open-source groundwater flow model code. MODFLOW simulates groundwater conditions and groundwater surface-water interactions. Originally developed and released solely as a groundwater-flow simulation code when first published in 1984, MODFLOW's modular structure has provided a robust framework for integration of additional simulation capabilities that build on and enhance its original scope. The family of MODFLOW-related programs includes capabilities to simulate coupled groundwater/surface-water systems, solute transport, variable-density flow (including saline water), aquifer-system compaction and land subsidence, parameter estimation, and groundwater management. The modular structure of MODFLOW allows for the use of different packages to support a variety of model configurations for different applications. Hydrologic budget component outputs are separated by packages and will vary based on the specific model configuration (U.S. Geological Survey 2020b).

Modeling Applications

DWR, USGS, and others have developed numerous modeling applications to support water management statewide and in the Central Valley. Some of the modeling

applications more commonly used for groundwater management efforts are described below; several others are listed in Appendix D, "Citations, Reference Materials, and Links," as additional references for interested parties. Additional information on groundwater modeling and available resources can be found in DWR's *Modeling Best Management Practices* (California Department of Water Resources 2016c).

- **C2VSim**: DWR developed, maintains, and regularly updates the C2VSim, a model application based on the IWFM platform. The model area covers the entire Central Valley of California. C2VSim has been used for several large-scale Central Valley studies.

DWR has developed two versions of C2VSim: C2VSim-Coarse Grid (CG), which includes 1,392 elements, and C2VSim-Fine Grid (FG), which includes 32,537 elements. The elements are grouped into 21 water budget subregions.

- **C2VSim-CG**: The C2VSim-CG model includes monthly historical stream inflows, surface water diversions, precipitation, land use, and crop acreage data from October 1921 through September 2009. The model simulates the historical response of the Central Valley's groundwater and surface-water flow system to historical stresses and can be used to simulate response to projected future stresses. Hydrologic parameters in C2VSim-CG were calibrated to match observed surface water flows, groundwater heads, groundwater head differences between well pairs, and stream-groundwater flows from October 1975 through September 2009.

  The C2VSim-CG model is being used as the basis for the groundwater flow component of the CalSim 3 model application. It has also been used to investigate how Sacramento Valley water transfers may affect flows in the Sacramento-San Joaquin Delta (Delta) and how an extended drought may affect groundwater levels (California Department of Water Resources 2016c).

  C2VSim-CG is a useful tool for supporting integrated regional water management plans, planning studies, and groundwater storage investigations; assessing infrastructure improvements; evaluating ecosystem enhancement scenarios; conducting climate change studies; and assessing the effects of changes to water operations.

- **C2VSim-FG**: C2VSim-FG was updated using IWFM Version 2015. C2VSim-FG contains estimates of monthly historical stream inflows, surface water

diversions, precipitation, evapotranspiration, and land use acreages for October 1973 through September 2015, with data available in input files for 1922 through 2015. C2VSim-FG dynamically calculates crop water demands, allocates contributions from precipitation, soil moisture, and surface water diversions, and calculates the amount of groundwater pumping required to meet the remaining demand.

The input data have been refined to provide GSAs an optional tool to perform analysis during development and implementation of their GSPs. GSAs can review and verify the input data in C2VSim-FG and update the model further using local knowledge and information. This creates a more refined estimate of the total water budget in a groundwater basin as well as more closely simulates the local hydrogeologic response to management actions and use.

- **SVSim**: SVSim is a model application based on IWFM platform; it covers the Sacramento Valley and select adjacent areas. SVSim supports multiple DWR programs. It has two main purposes: (1) serve as a tool that meets essential modeling requirements for evaluating stream depletion effects from groundwater pumping, and (2) serve as a tool for evaluating water budgets, surface water-groundwater interactions, and sustainable groundwater management scenarios. The intended users of SVSim are DWR, water transfer proponents, GSAs, local agencies, and interested parties.

  SVSim is based on DWR's C2VSim-FG model. SVSim provides an updated analysis of geologic and hydrogeologic data for the Sacramento Valley. The model domain includes the Sacramento Valley Groundwater Basin, the Redding Area Groundwater Basin, and the Delta. The southern model boundary lies between the Mokelumne and Calaveras rivers. SVSim includes nine layers of variable thickness that span the entire groundwater system. The base period of the model simulates conditions from October 1973 through September 2015.

- **CVHM**: The CVHM is a three-dimensional numerical groundwater flow model developed by USGS and documented in *Groundwater Availability of the Central Valley Aquifer, California* (U.S. Geological Survey 2009). The CVHM application simulates groundwater and surface water flow, irrigated agriculture, and other key hydrologic processes over the Central Valley at a uniform grid-cell spacing of 1 mile on a monthly basis using data from April 1961 through September 2003. CVHM simulates surface water flows,

groundwater flows, and land subsidence in response to stresses from water use and climate variability throughout the Central Valley. USGS is working on an updated version of CVHM (CVHM2).

Additional information regarding the above discussed modelling tools can be found in Appendix D, "Citations, Reference Materials, and Links."

Best Management Practices

Water Code Section 10729(d) directed DWR to publish best management practices (BMPs) for sustainable groundwater management on its website by January 1, 2017. Two categories of information were developed to meet these statutory requirements: BMPs and guidance documents. The information provided in these documents will assist GSAs in developing GSPs. BMPs and guidance documents do not substitute for GSP regulations or the statutory provisions of SGMA.

Table 4-10 lists the BMPs developed as of 2020 and briefly describes each BMP. Additional BMPs and guidance documents, or revisions to the existing publications, may be developed. Links to the BMPs and guidance documents are available in Appendix D, "Citations, Reference Materials, and Links."

Guidance Documents

In addition to BMPs, DWR developed guidance documents to address topics unique to SGMA. The documents cover areas in the water management industry that do not have established practices and areas that may not have been specifically identified in the GSP regulations. Table 4-11 lists the guidance documents that DWR has developed as of 2020.

Table 4-10 Published Best Management Practices (BMPs)

BMP #	BMP	Summary of BMP
1	Monitoring Protocols Standards and Sites	Provides guidance on the establishment of consistent data collection processes and procedures that can be used by GSAs to adopt a set of sampling and measuring procedures that will yield similar data regardless of the monitoring personnel.
2	Monitoring Networks and Identification of Data Gaps	Provides information to aid in the development of a monitoring network that is capable of providing sustainability indicator data of sufficient accuracy and quantity to demonstrate that the basin is being sustainably managed.
3	Hydrogeologic Conceptual Model	Provides information to support GSAs in developing a hydrogeologic conceptual model (HCM). HCMs also serves as a foundation for understanding potential uncertainties of the physical characteristics of a basin, which can be useful for identifying data gaps necessary to further refine the understanding of the hydrogeologic setting.
4	Water Budget	Describes the individual water budget components necessary to support water resource management decision making and meet the requirements outlined in the GSP regulations.
5	Modeling	Provides information to assist with the development and use of groundwater and surface water models. Models can be useful tools for estimating the potential hydrologic effects of proposed water management activities.
6	Draft Sustainable Management Criteria	Describes activities, practices, and procedures for defining the sustainable management criteria required by the GSP regulations. Also characterizes the relationship between the different sustainable management criteria — the sustainability goal, undesirable results, minimum thresholds, and measurable objectives — and describes best management practices for developing these criteria as part of a GSP.

Table 4-10 notes: GSA = groundwater sustainability agency, GSP = groundwater sustainability plan

Table 4-11 Guidance Documents for Sustainable Management of Groundwater and GSP Development

Guidance Document	Summary of Content
GSP Annotated Outline	Can be used by GSAs, in conjunction with the preparation of checklist for the GSP submittal guidance document, to develop a GSP and determine if the GSP (or coordinated GSPs) meets the minimum requirements of the GSP regulations and statutory provisions of SGMA.
Checklist for GSP Submittal	Provides GSAs and other interested parties with a checklist of GSP content requirements for the purpose of verifying whether a GSP is complete and is ready for submission to DWR. The checklist includes references to applicable GSP regulation sections and Water Code sections, as well as a brief description of the required GSP information.
Communication and Engagement	Provides GSAs with information to aid in communication and engagement for GSP preparation and provides examples and existing resources related to public engagement and effective communication for SGMA implementation.
Engagement with Tribal Governments	Conveys information provided by California's Tribal governments that local agencies can use to engage Tribal governments in their efforts to identify interested persons and consider the interests of beneficial users of groundwater, including those users on Tribal lands not subject to SGMA.
Resource Guide for Climate Change Data and Guidance	Provides a high-level overview of climate change resources including datasets provided by DWR, tools for working with the DWR-provided datasets, and guidance for using DWR-provided data and tools in developing GSPs. The datasets and methods can be used by GSAs to develop projected water budgets.
Guidance for Climate Change Data Use During Sustainability Plan Development	Contains information on the climate change data and related tools provided by the DWR for use in developing GSPs. The data and methods provided can aid in the development of projected water budgets.
Draft Handbook for Water Budget Development: With or Without Models	A technical reference that systematically presents the existing, but previously uncompiled, information on various methods and data sources for developing water budgets. It is not intended to be used as a prescriptive method for water budget analysis but rather a tool and inventory of information to aid in the development of water budgets.

Table 4-11 notes: DWR = California Department of Water Resources, GSA = groundwater sustainability agency, GSP = groundwater sustainability plan, SGMA = Sustainable Groundwater Management Act

SGMA Planning Assistance

DWR's roles and responsibilities under SGMA include a suite of planning assistance services for GSAs, and cooperating entities. DWR provides communications assistance, outreach and engagement assistance, facilitation services, and translation services to GSAs and cooperating entities participating in sustainable groundwater management. For information on how to access or apply for the following services, see Appendix D, "Citations, References Materials, and Links."

Communications Assistance

Successful implementation of SGMA necessitates timely, forthright, and consistent communication among all cooperating entities and interested parties. DWR promotes consistent internal and external messaging on sustainable groundwater management, local control, and DWR's role. The SGMP website is, and will remain, the primary source for up-to-date and accurate information from DWR regarding SGMA and available resources. Other forms of statewide communications about SGMA from DWR include information provided through periodic email updates that are posted to the SGMP listserv, and development of frequently asked questions, white papers, and other guidance.

Outreach and Engagement Assistance

Proactive outreach to, and engagement of, cooperating entities and interested parties is essential to achieving sustainable groundwater management at the local and regional levels. Local and regional agencies, in turn, must reach out to include local citizens, groundwater users, Tribal entities, and underrepresented communities. DWR engages with interested parties such as State, federal, and local agencies; Tribal governments, affiliated associations, nongovernmental organizations, and the public to provide SGMA information and updates on program implementation. DWR has organized and conducted numerous public meetings, regional workshops, and webinars. Some of these outreach and engagement efforts are highlighted below. Upcoming DWR events are posted on the SGMP Assistance and Engagement webpage. There is also contact information, guidance resources, and how to sign up for notifications and news associated with SGMP (see Appendix D, "Citations, References Materials, and Links").

- **DWR Events**: In addition to public meetings hosted by DWR to solicit comments, DWR has hosted informational workshops, meetings, and webinars to inform GSAs and interested parties about the roles and responsibilities

authorized by SGMA, GSP regulations, and DWR's technical and financial assistance offerings.

- **DWR Region Office Engagement**: DWR provides a variety of IRWM-related resources to assist water management groups and the public. DWR utilizes these established regional resources for communication and outreach related to the implementation of SGMA. Regional coordinators serve as primary points of contact (POCs) for communication and outreach with local interested parties. Geology leads in each of the DWR region offices serve as regional technical experts. Additionally, all basins that are required to implement SGMA are assigned a DWR region office staff POC. POCs assist GSAs and interested parties in the basin with SGMP coordination and local DWR staff for assistance. POCs attend local meetings to understand specific regional issues and to ensure communication throughout the implementation of SGMA.

Facilitation Support Services

Facilitation Support Services helps local agencies work through challenging water management situations. Under SGMA, GSAs must encourage the active involvement of diverse social, cultural, and economic interests and consider all beneficial uses and users of groundwater when developing and implementing GSPs. DWR provides professional facilitators to help GSAs and interested parties foster discussions among diverse water management interests and local agencies to support and encourage the consideration of all beneficial uses and users of groundwater. DWR has made available $2.5 million in facilitation services since SGMA was enacted to support the formation of GSAs and development of GSPs in 39 basins and subbasins.

Translation Services

DWR's Written Translation Service is available to help GSAs, or other groups assisting in local SGMA implementation efforts, to communicate the groundwater planning activities with their non-English speaking constituents. GSAs or other associated groups may submit written notices, letters, forms, presentations, fact sheets, pamphlets, leaflets, and brochures to DWR for translation into the following languages: Chinese, Hmong, Korean, Laotian, Punjabi, Spanish, Tagalog, and Vietnamese.

Technical Assistance

The SGMP Technical Support Services (TSS) Program provides education, data, and tools to GSAs at both regional and statewide scales to build the capacity needed to achieve sustainability. TSS, is available to GSAs through DWR's region offices or

contractors, pending funding availability. In 2019, DWR began providing technical support to GSAs through the coordination and installation of 24 single- and multi-completion groundwater monitoring wells and 13 downhole camera surveys of existing wells. By the end of 2019, technical support for an additional 59 monitoring wells had been requested by GSAs. Field support activities that are offered include monitoring well installation, borehole video logging, monitoring training, geologic and geophysical logging, groundwater level monitoring training, and other groundwater related field activities.

Financial Assistance

Through the Sustainable Groundwater Management (SGM) Grant Program, DWR provides funding for sustainable groundwater planning and implementation projects using a competitive grant solicitation process. State funding for groundwater planning and implementation projects is made available through the passage of statewide propositions by California voters. Funded projects may include the development and implementation of GSPs; investments in groundwater recharge with surface water, stormwater, or recycled water; and the prevention and remediation of groundwater contamination. The recent funding solicitations related to sustainable groundwater management are described below are as of 2015. Additional information regarding funding opportunities for groundwater planning and implementation projects is included in "Appendix D, Citations, Reference Materials, and Links."

Propositions 1 and 68 Grant Awards

Proposition 1, Round 1, Counties with Stressed Basins Grants

In 2015, DWR received 23 applications requesting $7 million in grant funding under Proposition 1. The projects under this round of funding were primarily to support GSP development and consisted of five categories: (1) ordinance development, (2) GSA formation efforts, (3) data collection, (4) groundwater modeling, and (5) monitoring well installation. The final grant awards list was released in March 2016, awarding a total of $6.7 million in grant funding.

Proposition 1, Round 2, Sustainable Groundwater Planning Grant Program

In 2017, DWR received 78 applications requesting $86.3 million in grant funding under Proposition 1. DWR awarded 78 grants totaling $85.8 million. The grants included $16.2 million for Category 1 projects, which provide benefits to severely disadvantaged communities, and $69.6 million for Category 2 projects, which

support GSP development. The final grant awards list was released in March 2016, awarding a total of $80.6 million in grant funding.

Propositions 1 and 68, Round 3, Sustainable Groundwater Management Grant Program Planning Grants

In 2019, DWR opened the proposal solicitation (Planning – Round 3) under Propositions 1 and 68 to award funding on a competitive basis to high- and medium-priority basins, including basins subject to critical conditions of overdraft (COD), for tasks and activities that help develop and implement a GSP(s), or provide updates to approved alternatives to a GSP. Projects had to support groundwater sustainability planning and management within high- and medium-priority basins and assist in the development and implementation of a GSP(s) or provide updates to approved alternatives to a GSP. DWR received 54 applications requesting a total of $52.6 million in grant funding. The final grant awards list was released on March 13, 2020, awarding a total of $47.45 million in grant funding ($46.25 million from Proposition 68 funds and $1.25 million from Proposition 1 funds).

Proposition 68, Upcoming Sustainable Groundwater Management Grants

Proposition 68 provides a minimum of $103 million for drought and groundwater investments to achieve regional sustainability. The investments could include groundwater recharge with surface water, stormwater, recycled water, and other conjunctive use projects, and projects to prevent or clean up contamination of groundwater that serves as a source of drinking water (Public Resources Code Section 80146[a]).

The grant awards will be broken up into two rounds of grant solicitations. Round 1 is expected to be awarded in 2021 and will include $26 million for grant awards to COD basins only. In 2022, Round 2 will include at least $62 million for grant awards and is open to all medium- and high-priority basins, including COD basins, which meet the eligibility requirements listed in the SGM Grant Program Guidelines and Implementation Proposal Solicitation Package. Additionally, approximately $15 million will be available in Round 2 for projects that solely benefit, and are located within, underrepresented communities.

Other Financial Assistance Programs Related to Groundwater Management

Groundwater planning and implementation projects are also eligible for financial assistance through other State and federal programs, including some listed below.

Each funding opportunity may only be used for specific purposes and each program should be contacted to verify applicant eligibility, program funding deadlines, available funds, and requirements. Table 4-12 summarizes the funding opportunities. Refer to Appendix D, "Citations, Reference Materials, and Links" for additional details on each of the funding programs.

Table 4-12 Summary of Financial Assistance Programs Related to Groundwater Management

Funding Program	Funding Entity	Funding Purpose
Infrastructure State Revolving Funding (ISRF) Program	California Infrastructure and Economic Development Bank	Infrastructure and economic development projects including water treatment, distribution, supply, and flood control.
Household Water Well Loan Program	Rural Community Assistance Corporation	Low-interest rate loans for household water well systems.
Clean Drinking Water Well Replacement Program	Rural Community Assistance Corporation	Grant program for individual households and small water systems for drought emergencies.
Clean Water State Revolving Fund	State Water Resources Control Board and Environmental Protection Agency	Low-cost financing for water quality infrastructure projects.
Cleanup and Abatement Account (CAA) Funding Program	State Water Resources Control Board	Grant funding to clean up or abate waste on source water or address an urgent drinking water need.
Drinking Water State Revolving Fund (DWSRF)	State Water Resources Control Board	Low-cost financing for drinking water infrastructure projects.
Nonpoint Source Pollution (NPS) Control Program	State Water Resources Control Board	Grants for management measures or practices that control non-point source pollution.
Orphan Site Cleanup Fund	State Water Resources Control Board	Grant program for the cleanup of sites with leaking petroleum tanks where there is no financially responsible party.

Funding Program	Funding Entity	Funding Purpose
Proposition 1 Groundwater Sustainability Program	State Water Resources Control Board	Grants to prevent and cleanup contamination of groundwater.
Proposition 1 Storm Water Grant Program	State Water Resources Control Board	Grants for multi-benefit stormwater management projects.
Proposition 68 Groundwater Treatment and Remediation	State Water Resources Control Board	Grants for treatment and remediation of contaminated groundwater sources of drinking water.
Safe and Affordable Funding for Equity and Resilience Drinking Water Program	State Water Resources Control Board	Funding for sustainable solutions for small systems with drinking water standards violations.
Small Community Drinking Water Funding Program	State Water Resources Control Board	Funding for planning, design, and construction of drinking water infrastructure for compliance with federal and State drinking water regulations.
Site Cleanup Subaccount Program	State Water Resources Control Board	Grants to address polluted surface water or groundwater.
Proposition 68 Urban Stormwater and Waterways Improvement Program	California Natural Resources Agency	Funding for multi-benefit projects that address flooding in urbanized areas.
Funding for Drought Response Actions	California Department of Fish and Wildlife	Funding for drought response actions and projects for State wildlife areas and ecological reserves.
Watershed Coordinator Grant Program	California Department of Conservation	Funding for watershed coordinator positions to build coalitions to develop plans and projects to improve watershed health and meet California's groundwater sustainability goals.
State Water Efficiency and Enhancement Program	California Department of Food and Agriculture	Funding to reduce on-farm water use and associated greenhouse gas emissions.

Funding Program	Funding Entity	Funding Purpose
Agricultural Water Enhancement Program	U.S. Department of Agriculture	Funding to promote ground and surface water conservation and improved water quality on agricultural lands.
Water and Waste Disposal Revolving Loan Funds	U.S. Department of Agriculture	Low-cost financing to extend and improve water and waste disposal systems in rural areas.
California Water Security and Environmental Enhancement	U.S. Bureau of Reclamation	Funding to improve water quality, ecosystem health, and levees in the Bay-Delta system.
SECURE Water Act Research Agreements	U.S. Bureau of Reclamation	Funding for water conservation, efficiency, and management.
Sustain and Manage America's Resources for Tomorrow (WaterSMART) — Basin Study Program	U.S. Bureau of Reclamation	Funding to evaluate water demands and supply reliability.
WaterSMART — Cooperative Watershed Management Program Phase 2	U.S. Bureau of Reclamation	Funding to form local solutions to address water management needs.
WaterSMART — Desalination Construction Program	U.S. Bureau of Reclamation	Funding for ocean and brackish water desalination projects.
WaterSMART — Drought Response Program	U.S. Bureau of Reclamation	Funding to develop and update comprehensive plans for drought resiliency.
WaterSMART — Water and Energy Efficiency Grant Program	U.S. Bureau of Reclamation	Funding for water savings, production of hydropower, and broader water reliability benefits.
WaterSMART — Water Marketing Strategy Grants	U.S. Bureau of Reclamation	Funding for State, Tribal, and local governments to develop water markets.
State Underground Water Source Protection	U.S. Environmental Protection Agency	Funding for underground injection control programs to enforce the Safe Drinking Water Act.

Funding Program	Funding Entity	Funding Purpose
Surveys, Studies, Investigations, Demonstrations, and Training Grants and Cooperative Agreements	U.S. Environmental Protection Agency	Funding for studies on causes, effects, extent, prevention, reduction, and elimination of water pollution.

GSP Implementation Funding Needs

Statewide Funding Need for GSP Implementation

GSPs provide a glimpse into the needed funding, projected by GSAs, to help bring their groundwater basins into sustainable management. The "Projects and Management Actions" sections of the GSPs include those projects and actions designed to increase supply or reduce demand and bring the basin into sustainable balance within the planning horizon. The GSAs must identify funding mechanisms to implement their proposed projects and actions, likely some combination of generating the revenue internally and seeking available grant funding.

The total anticipated cost of the projects and actions included in the GSPs submitted as of January 31, 2020, exceeds $6 billion. Any needs that may have been identified in the approved or submitted alternatives are not included in this analysis. The costs expected to bring basins under subject to critical conditions of overdraft into sustainable management are expected to be higher than for basins that are not in critical overdraft. It is expected that the total anticipated cost of the projects and actions will increase once the remaining GSAs submit their GSPs by January 2022.

Most GSAs will include some assortment of projects and actions in their GSPs designed to attain or maintain conditions of sustainable management. The total amount of projects and actions funding is expected to be quite large over the 20-year GSP implementation horizon for achieving sustainable management in all California groundwater basins where SGMA participation is mandatory.

It remains to be seen how the projects and management actions associated with GSP implementation will eventually be funded. These are a part of the total costs of implementing SGMA for GSAs, but in some cases, these projects may greatly exceed the general implementation costs for GSPs. State grant funding, along with other programs such as those listed in Table 4-12, can help defray some of the costs of these projects and actions, but funding a full slate of projects may prove challenging for some GSAs.

Water Transfers and Groundwater Markets: Emerging Tools for Groundwater Sustainability Agencies

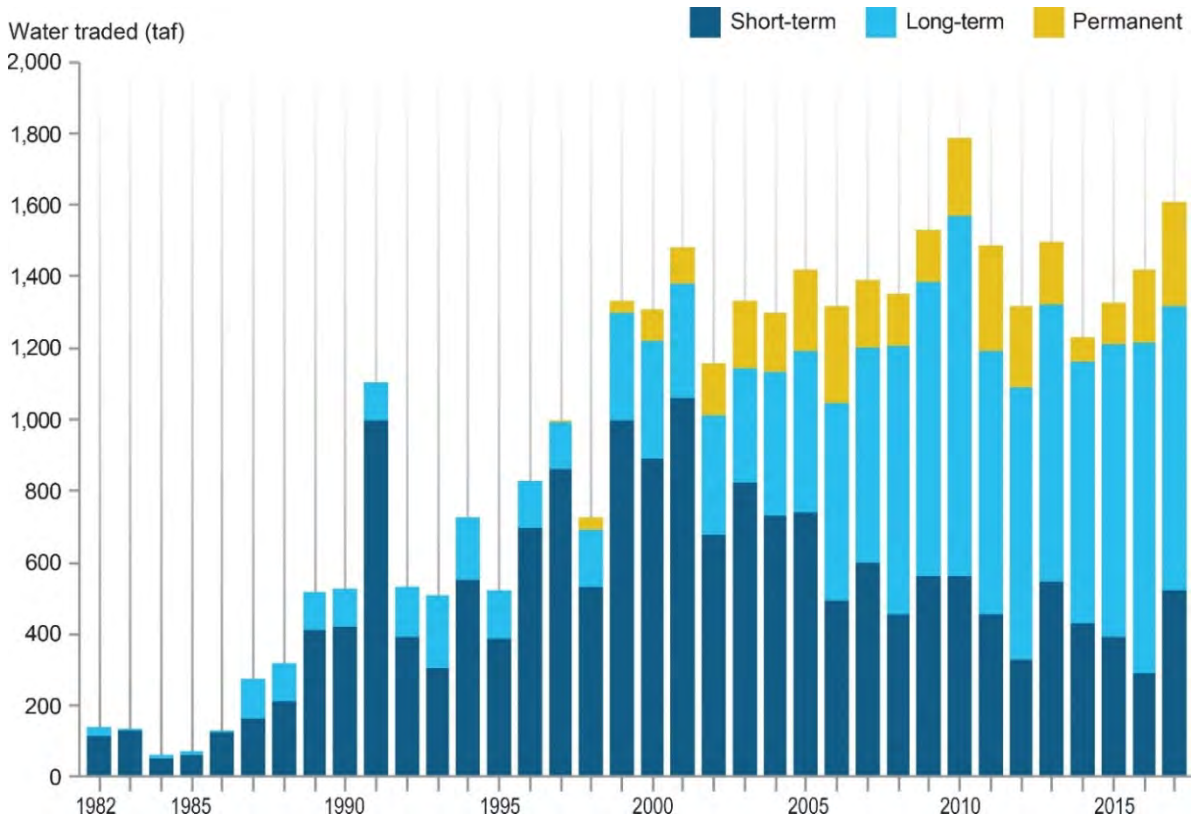
Water markets, along with the related practices of water transfers and groundwater banking, are gaining more importance in California as the State strives to implement a water resilience portfolio to cope with water management challenges, such as more extreme droughts and floods, rising temperatures, declining fish populations, and aging infrastructure. Water markets allow willing sellers to trade their water rights or groundwater pumping allocations with willing buyers through exchanges, one-time purchases, short- and long-term leases, or permanent sale of contract quantities for compensation. Historically, water market transactions in California have primarily involved surface water; transactions involving the physical movement of groundwater or groundwater pumping allocations were limited. For instance, groundwater substitution transfers involve the physical movement of surface water that is made available by replacing that water with groundwater pumping, but the groundwater itself is not physically transferred from one location to another. Today, in response to SGMA, local groundwater markets are emerging as a market-based strategy in some groundwater basins to flexibly manage a scarce resource.

This section summarizes the history and types of water transfers and water markets in California, their driving forces and emerging trends, the opportunities and challenges associated with water market development, and agency recommendations for water market improvement. Water transfers and water markets will be useful tools available to GSAs for inclusion in their GSP planning efforts.

Historical Background

Water markets have existed in California for years. The late 1970s through 1990s saw water markets launch and grow in California, largely driven by the need to move water from one region to another during multi-year droughts. Hanak et al. (2019) compiled more than 25 years of statewide data on surface water trades or transfers between entities that are not members of the same water district or wholesale agency (Figure 4-13). The data shown in Figure 4-13 only include water volumes that were physically transferred; all water volumes committed under long-term lease and permanent-sale contracts, but not physically transferred because of hydrologic conditions or other factors, were excluded.

Figure 4-13 Historical Water Trades in California



Source: Hanak et al. 2019.

In the early 1980s, recorded water trades averaged approximately 100,000 acre-feet per year. During the 1987–1992 drought, water trades increased in California, especially with the introduction of the State-run Drought Water Bank in 1991, when trades exceeded 1 million acre-feet. Today, approximately 1 million to 1.5 million acre-feet of water are traded annually, with more than 40 percent occurring within the same county (Hanak et al. 2019).

Water Market Components

Water transfers or trades involve the mechanisms for permitting and accounting for the movement of water from the place of origin to a new place of use. Conveyance infrastructure is needed to physically move the water from seller to buyer. Water storage, including conjunctive use and groundwater banking, involves storing the water during years of abundant supply in groundwater basins (or surface water reservoirs) for a period until stored water is needed in years of short supply.

Most water trading in California does not occur in a centralized marketplace; federal and State agencies coordinate and permit water transfers in an ad hoc market. There

are no statewide trading platforms or other venues for tracking availability, value, or sales of water, or for connecting willing buyers and sellers. Recently, collaborative efforts have been initiated to develop centralized marketplace platforms for intra-basin groundwater markets in the state (see the "Existing and Emerging Groundwater Markets" section, below).

Water Transfers

Overview

Water transfers can be an effective management tool and provide much needed flexibility in the allocation and use of water in California. Water transfers involve a change in the place of water use from the water's historical point of diversion and use to a new location within or outside the watershed of origin. Water may be transferred from one user to another for a variety of purposes, including agricultural, municipal, and industrial uses. It may also be transferred for environmental purposes such as for in-stream flow augmentation and wildlife refuge water supply.

Historical water transfers in California were primarily executed to meet dry-year demands rather than to obtain a primary, permanent water supply for either agricultural or municipal development. Water transfers are particularly useful for meeting critical needs during droughts but must be carried out in a responsible manner to assure that they do not result in adverse effects to other water users or unreasonable effects to the environment.

Water transfers occurring outside of the watershed of origin may include transfers from northern portions of the state to Central and Southern California. These transfers require conveyance through the Delta. The most common through-Delta transfers to date have been short-term (as much as one year) transfers from agricultural users within the Sacramento Valley to agricultural and urban users south of the Delta to meet critical dry-year demands. The primary facilities used in exporting through-Delta transfer water are the State Water Project's (SWP's) Harvey O. Banks Pumping Plant and the CVP's C.W. "Bill" Jones Pumping Plant. Access to these pumping plants and conveyance canals is essential to accomplishing water transfers from the northern portions of the state to Central and Southern California.

Water Code Section 1810 et seq. encourages reduced impediments to water transfers by requiring any public agency to allow bona-fide transferors the use of available conveyance capacity provided the prospective transferor can show that the transfer will not injure any legal user of water or unreasonably affect fish, wildlife, or

other instream beneficial uses, or unreasonably affect the overall economy or environment of the county from which the water is diverted.

Willing sellers with legal rights to a supply of water can move water through the State's conveyance system to an interested buyer in compliance with all necessary local, State, and federal regulations. The State Water Board approves water transfers that involved water right permits and licenses administered by the board. DWR and Reclamation facilitate and approve water transfers that are conveyed through State Water Project and Central Valley Project facilities, respectively. To ensure that water transfers are carried out in a responsible manner, and do not adversely affect other water users or the environment, DWR and Reclamation have published the draft document *Technical Information for Preparing Water Transfer Proposals* (California Department of Water Resources and U.S. Bureau of Reclamation 2019). Additional guidance documents for water transfers are the *Long-Term Water Transfers Environmental Impact Report/Environmental Impact Statement* prepared in 2019 by Reclamation and the San Luis and Delta-Mendota Water Authority, and the *2021 Tehama-Colusa Canal Authority In-Basin Water Transfers* prepared by Reclamation and the Tehama-Colusa Canal Authority. Water transfers may also be subject to other local, State, and federal regulations or policies.

Water Transfer Types

A water transfer is a reallocation of water from one party to another party through use reduction or storage release. This one-way water movement can be structured as short-term or temporary transfers (one year or less), long-term temporary transfers (more than one year), or permanent transfers. There are also water exchanges composed of multiple transfers in which water is transferred to one party in one year and returned to another party, either in full (even exchange) or in part (uneven exchange), in later year(s). Transfers and exchanges may include some monetary compensation.

The most common types of water transfers are groundwater substitution, reservoir release, and cropland idling and crop shifting. Water conservation measures can also be used to make water available for transfer.

- **Groundwater Substitution**: Groundwater substitution transfers are an option for water users that have access to surface water and groundwater supplies. In a groundwater substitution transfer, a water user that typically uses surface water switches to groundwater pumping for all, or a portion, of its demand and forgo the amount of surface water supply to be delivered to the buyer's service area. No export of actual groundwater occurs.

The amount of water available for transfer is determined by metering the quantity of groundwater pumped beyond the baseline pumping and applying a streamflow depletion factor based on an analysis of the specific wells and hydrogeology of the groundwater basin. The amount and timing of streamflow depletion effects cannot be directly measured but can be estimated using a mathematical model.

- **Reservoir Release**: A reservoir release transfer typically involves sale of excess water (transfer water) stored in a reservoir. The transfer water can be considered water above normal operational or committed use. The transfer water is conveyed downstream to a new point of diversion either within or outside the watershed.
- **Cropland Idling and Crop Shifting**: In a cropland idling and crop shifting transfer, a grower idles a field that otherwise would have been planted or shifts to another crop with lower consumptive use. The amount of water made available for transfer is based on the reduction in consumptive use, which is calculated from evapotranspiration of applied water (ETaw). ETaw is the applied water portion of evapotranspiration of crop through evaporation from the soil and transpiration from plant surfaces.

DWR Water Transfer Database

DWR maintains the Water Transfer Information Management System (WTIMS) to process water transfers that would require use of SWP or CVP facilities. A willing seller can submit an online WTIMS water transfer proposal for DWR and Reclamation to review. Table 4-13 presents the volume of water transferred by groundwater substitution, cropland idling, and reservoir release through DWR facilities from 2008 through 2018, as reported in WTIMS. Figure 4-14 illustrates the magnitude of water transfers by type through DWR facilities for the same time period.

Figure 4-14 Magnitude of Water Transfer by Type as Reported in Water Transfer Information Management System (2008–2018)

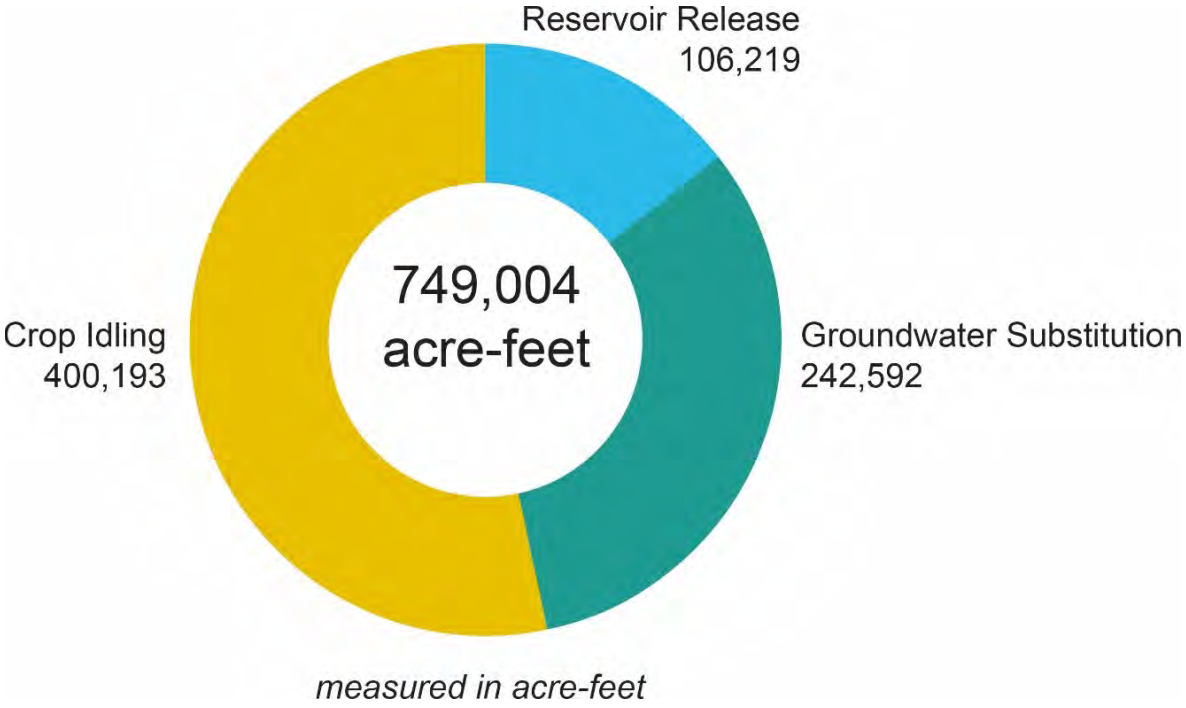


Table 4-13 Water Transfer Data for Groundwater Substitution, Cropland Idling, and Reservoir Release as Reported in Water Transfer Information Management System (2008–2018), in acre-feet

Year	Groundwater Substitution	Crop Idling	Reservoir Release	Annual Total
2008	7,124	45,533	9,999	62,656
2009	59,551	21,045	-	80,596
2010	27,362	74,160	15,000	116,522
2011	409	-	-	409
2012	-	67,712	-	67,712
2013	54,988	2,238	36,754	93,980
2014	29,164	97,502	10,000	136,666
2015	10,863	-	12,000	22,863
2016	-	-	-	-
2017	-	-	-	-
2018	53,131	92,003	22,466	167,600
11-Year Total	**242,592**	**400,193**	**106,219**	**749,004**

The data in Table 4-13 represent only the portion of statewide temporary water transfer volumes that require use of a DWR facility. Refer to DWR's water transfer website for more information on water transfer activities, agency coordination, and frequently asked questions. The link to DWR's water transfer website can be found in Appendix D, "Citations, Reference Materials, and Links."

Disallowed Water Transfers

The draft *Technical Information for Preparing Water Transfer Proposals* identifies types of water transfers that are not considered for approval. Disallowed water transfers include:

- **Direct pumping of groundwater**: The direct pumping of groundwater in the Sacramento River watershed for the purpose of exporting that water is prohibited under Water Code Section 1220 without extensive local review and approval.
- **Transfers that injure legal users of water or cause unreasonable effects on the environment**: Water transfers that reclassify existing stream flows from one category to another, making these flows no longer available to historical downstream users, have the potential to injure other legal users of water and cause harm to the environment.

Groundwater Banking

Groundwater banking is to store water in groundwater basins during wet periods for withdrawal and use in drier periods. Groundwater banking has been in practice for decades throughout California for various purposes, such as supply augmentation, water supply reliability, dry year supply, aquifer replenishment, environmental benefits, and water markets. More details are presented later in this chapter.

During the past 100 years, California has lost more than 100 million acre-feet of groundwater from storage in Central Valley aquifers (Faunt 2019). This has created a large amount of available storage space that can be accessed in the underlying aquifers during wet hydrologic periods through various groundwater recharge mechanisms. Groundwater banking is poised to play a significant role in water markets during SGMA implementation.

Surface storage projects can also be used in water markets, yet storage in reservoirs tends to be devoted to specific agencies or end users ahead of time because of more defined capacity restrictions and initial investments in surface storage infrastructure. Alternatively, groundwater banking can provide greater storage capacity and

accommodate more market participants and project partners over time, allowing for greater market flexibility, and are not subject to the same forfeit principles as surface water sources.

Groundwater in the Water Market

A common-pool resource provides benefits, but is difficult to control access, and can often result in overuse. In the case of groundwater, when pumping is not restricted and other sources of water are not available or are more costly than extraction, there is incentive to use it without consideration of potential effects to other users or before someone else in the basin uses it. The new requirements of SGMA shift groundwater management from unrestricted common-pool resource extraction to a system of collaboratively managed resource stewardship.

Groundwater allocations, allotments, entitlements, or budgets, when coupled with sufficient monitoring, restrict resource extraction to sustainable levels. The removal of the common-pool aspect of groundwater can incentivize a market by defining the number of shares available in the market (in this case the "shares" are the allocations), which leads to the establishment of a more predictable value of the resource. Conversely, a groundwater market can help GSAs with the implementation of SGMA by allowing landowners with a groundwater allocation to decide to use or sell the allocation and alleviate potential financial losses if they determine that an allocation is insufficient to sustain a planned land use. For example, if a landowner has an allocation that cannot financially support cultivation practices for a particular crop, that landowner can be compensated for their groundwater share and alleviate their losses if they have to idle their fields. Without a market, that landowner would likely have to take that loss without compensation for not using the allocation.

Water markets can also help the environment by facilitating environmental water purchases to support wildlife refuges, increase flows for fish, reduce salinity, and address other environmental benefits. During the 1982–2017 period, approximately 17 percent of total water market trades (approximately 6 million acre-feet) were executed for environmental purposes, though these were surface water trades, but exemplify the potential for water trading for environmental purposes.

Water Market Drivers

A brief description of the primary water-market drivers is provided below. These drivers are region-specific and are interconnected to each other; they will influence how a water market develops in a specific region.

Achieving Sustainability

Balancing groundwater basins to achieve sustainability will require increasing water supply and decreasing water demand. Some GSAs are developing plans with fixed allocations of groundwater pumping to farmers, which may include cuts of as much as 35 percent from the existing level of pumping (Heard et al. 2019).

Under a fixed allocation approach, any water that is pumped beyond the allocated limit will have to be purchased in a water market or will be considered a violation subject to steep penalties and regulatory action. The need to achieve sustainability in overdrafted groundwater basins is a major driver for the emergence of a groundwater market in California because it provides the flexibility to operate a groundwater basin by allowing those with unused water allocations to sell to those with unmet demand.

In addition, the empty space available in the aquifers of the overdrafted basins may provide opportunities for storing water from alternative sources within available aquifer space for later use or trade in the water market.

Droughts

Today's water market was more formally initiated at the state level in 1977 during one of the state's driest years on record. Water markets were endorsed through reports from the Governor's Office and the State Legislature as a means of addressing the state's water needs and initiated regulatory changes to facilitate water trading.

The 1986–1992 drought further advanced water market concepts. In 1991, the Drought Water Bank was established, to be administered by DWR, to help meet critical water supply needs across the state. It was activated again in 1992, 1994, and 2009. The Drought Water Bank operated as a voluntary program for water sales and purchases. Sources of water purchases included excess surface water supplies, groundwater substitutions, and, in extremely dry years, crop idling. The Drought Water Bank, while temporary and intermittent in use, demonstrated that a large-scale water market could be used to help move available water to areas with greatest demand.

The water market continued to grow in the 1990s, mainly through increases in purchases of water for the environment and agriculture. Water trading trends have generally leveled off since the early 2000s, with a notable exception in 2009–2010 when the Drought Water Bank was temporarily brought back (Hanak et al. 2019).

Dynamics in the types of trades have evolved since 1977 with a shift from temporary short-term trades to temporary long-term trades and permanent sales.

Economic Value

Groundwater provides economic value from its direct use by farmers, cities, businesses, and individuals (use value), from the benefits generated by the stored groundwater in the aquifer (storage value), and from its conjunctive use within the broader water management system (system value). California can expect groundwater values to increase because of new water management policies and regulations (including SGMA), reservoir operations, climate change, and population and economic growth.

As the economic value of groundwater increases, there may be more incentives for participation in a water market where groundwater allocations can be bought and sold for higher economic value. Allocation holders can make economic decisions on whether to grow crops on their own land or sell allocations to a willing buyer for a higher income than would have been generated from growing their own crops. Markets for trading groundwater pumping allocations can improve flexibility and reduce total costs, but trading should have limits that prevent excessive, localized drawdown that can affect groundwater dependent ecosystems and domestic and agricultural wells. Trading should also account for other potential external costs of groundwater trading and encourage fair and equitable market practices.

Water Resiliency Portfolio and Executive Order

In April 2019, Governor Newsom issued an executive order on the development of the *Water Resilience Portfolio* (WRP) (California Natural Resources Agency 2020) directing all State agencies to incorporate the following principles into water planning in California:

- Prioritize multi-benefit approaches that meet multiple needs at once.
- Utilize natural infrastructure such as forests and floodplains.
- Embrace innovation and new technologies.
- Encourage regional approaches among water users sharing watersheds.
- Incorporate successful approaches from other parts of the world.
- Integrate investments, policies, and programs across State government.
- Strengthen partnerships with local, federal, and Tribal governments, water agencies, irrigation districts, and other interested parties.

The incorporation of the WRP principles in projects creates a supportive environment for creative solutions, such as water markets, to water scarcity. The State recognizes leveraging water markets as a potential tool for achieving sustainability. The WRP identified the following actions, related to water transfers and water markets:

- WRP Action 3.6: Create flexibility for groundwater sustainability agencies to trade water within basins by enabling and incentivizing transactional approaches, including groundwater markets, with rules that safeguard natural resources, small- and medium-size farms, and water supply and quality for disadvantaged communities.
- WRP Action 19.3: Conduct a feasibility analysis for improved and expanded capacity of federal, state, and local conveyance facilities to enhance water transfers and water markets. The analysis must incorporate climate change projections of hydrologic conditions.
- WRP Action 21: Ease movement of water across the state by simplifying water transfers.
    - WRP Action 21.1: Substantially reduce approval time for transfers while providing protections for the environment and communities.
    - WRP Action 21.2: Develop an open and transparent ledger system to allow for improved local and regional participation in the water transfer market.
    - WRP Action 21.3: Develop best practices for inter- and intra-basin groundwater trading programs that protect communities, economies, and the environment, including standards for measuring, reporting, accounting, and monitoring groundwater use and trading.
    - WRP Action 21.4: Explore an expedited process to facilitate transfers between Central Valley Project and State Water Project contractors.
- WRP Action 22.8: Evaluate existing requirements for telemetered diversion data (real-time water use), including potential streamlining opportunities with existing monitoring and reporting requirements. Analyze the costs and benefits of phasing in requirements for telemetered diversion data to diversions of 500 acre-feet or more per year, down from diversions of 10,000 acre-feet a year, to evaluate the potential to help water users coordinate projects, transfers, environmental protection, and other management activities.

To implement the WRP, State agencies will work toward simplifying the approval process and disseminating information on water availability and how much can be safely traded without harming the environment or other legal users.

California Water Action Plan

The *California Water Action Plan 2016 Update* (California Natural Resources Agency 2016) laid out 10 actions that provide a roadmap to put California on a path to sustainable water management. Action 5, "Manage and Prepare for Dry Periods," specifically outlines the need to promote safe and effective water transfers, including legislation to remove barriers to water markets and improving outreach in support of local water transfer programs. Action 6, "Expand Water Storage Capacity and Improve Groundwater Management," also acknowledges the need to improve groundwater management and provides a series of supporting actions. With these actions, the California Water Action Plan identifies and encourages the development of water markets as a tool to help continue moving toward more sustainable water management in California.

Existing and Emerging Groundwater Markets

Groundwater markets in California are evolving with the gradual implementation of SGMA as GSAs explore creative ways to minimize economic impacts in the face of substantial reductions in groundwater pumping to achieve sustainability. Reductions in groundwater pumping could require scaling back production, shifting crops, improving infrastructure, changing operations, and increasing water conservation. As a result, groundwater pumping restrictions will likely affect individual users, the local economy, tax revenues, and the job market.

Groundwater markets are emerging as a cost-effective management strategy to address reduction in groundwater pumping and mitigate some of the anticipated economic impacts. In-basin trading provides flexibility to increase the economic return from the use of groundwater. This optimization of economic value through water market opportunities may also generate funds for expensive multi-benefit projects that may be needed to help achieve sustainability.

Several examples of emerging groundwater markets are described below to illustrate some of the challenges and strategies associated with establishing a groundwater market. Groundwater market mechanics, structures, and oversight can vary based on groundwater basin characteristics and associated governance. The locations example markets are shown in Figure 4-15. Additional markets are in early discussion and development stages and will likely continue to grow in utilization across the state.

Links to additional information on case studies presented below are included in Appendix D, "Citations, Reference Materials, and Links."

Figure 4-15 Location of Water Market Case Studies



Fox Canyon

In the South Coast Hydrologic Region, the Oxnard and Pleasant Valley groundwater basins in western Ventura County are in conditions of critical overdraft. These basins overlie the Fox Canyon aquifer, which is managed by the Fox Canyon Groundwater Management Agency. In response to SGMA GSP requirements for these two basins, the Fox Canyon Groundwater Management Agency became the first GSA to formally develop a groundwater market as a primary tool for implementing a GSP, which was developed concurrently with the groundwater market. The groundwater market provides financial incentives to reduce pumping and economic flexibility by allowing growers to determine the best approach to comply with GSP pumping allocations and sell some, or all, of their allocations to other growers in the basin (Heard et al. 2019). The GSA plans to assign fixed allocations to pumpers based on historical pumping per well and groundwater conditions with respect to sustainable yield. Pumpers can then use those allocations to pump groundwater or sell any portion of those allocations to another pumper in the basin and forgo pumping themselves.

The Fox Canyon Groundwater Management Agency GSA has already implemented two water-market pilot programs in the Oxnard basin to demonstrate the potential for the market and, after testing, plans to open the market to all pumpers in the Oxnard and Pleasant Valley groundwater basins. Through those pilot programs, the Fox Canyon Groundwater Management Agency GSA has established the following rules for the market (Heard et al. 2019):

- **Limited to agricultural water users**: Initially, the market will be limited to agricultural water users but may expand in the future.
- **Temporary (annual) trades only**: Annual trading was chosen because of concerns that permanent sales of agricultural allocations could encourage development projects and conversion of agricultural lands.
- **Restricted trading in two special management areas**: Restricted trading was enacted because of location-specific concerns regarding seawater intrusion and cones of depression caused by over-pumping. In the special management areas, trading is allowed within and outside the areas, but pumping within the areas cannot exceed allocations; groundwater users within the special management areas cannot buy additional allocations from outside the area.

The Fox Canyon Groundwater Management Agency GSA is also implementing a variety of protocols to protect against inadvertent negative effects such as concentrated pumping, effects to drinking water supplies, under-reporting of pumping, and market power inequity (Heard et al. 2019).

- **Monitoring requirements**: A key piece for successfully implementing a groundwater market is accurate groundwater pumping data. Accurate data are needed to track pumped water to verify that only unused allocations are traded and to set annual allocations to meet GSP goals. Metering for agricultural wells has been mandatory in the Oxnard and Pleasant Valley groundwater basins since 1987. The GSA passed an ordinance in 2018 that requires installation of advanced metering infrastructure telemetry on all active wells for automated monthly usage reporting.
- **Third-party administration**: A market administrator is needed to operate the trading platform and keep records of transactions. A third-party administrator was chosen in Fox Canyon based on expertise in water markets and to ensure equitable treatment in the market by an administrator that does not have a direct stake in the water market.
- **Anonymous trading**: The Fox Canyon market participants elected to use an anonymized trading system that keeps the identities of buyers and sellers hidden from each other. An anonymous market can help avoid manipulation

by preventing buyers and sellers from applying external pressures related to pricing or specific bids.

- **Algorithmic matching for trades**: The trading platform for the Fox Canyon water market utilizes an algorithm to match willing buyers and sellers in a manner that maximizes gains, reduces transaction costs, and eliminates market power or inequity. The algorithmic matching, along with anonymous trading, helps prevent market manipulation and ensures equitable treatment of market participants.

The Fox Canyon groundwater market had to overcome several challenges in the development process. The development process was resource-intensive and required significant, dedicated staffing capacity. Funding for the initial planning efforts and pilot projects was assisted by grant support from the Natural Resource Conservation Service. The development process included efforts by agencies, nongovernmental organizations, and local growers. Early support from local growers was also critical for early buy-in by other market participants in the region.

One of the biggest challenges in setting up the market (or otherwise complying with SGMA) is the process of determining groundwater allocations. One approach is to make allocations based on historical pumping trends. One challenge with establishing historical pumping allocations is that it is possible the users that implemented water conservation practices earlier are given lower allocations, while those that continued to use water less efficiently are rewarded with higher allocations. Historical pumping allocations also require good historic data and an agreed-upon base period for establishing historical use. Conversely, a fixed allocation system would allocate the same amount per acre of irrigated land across the basin but would make proportionally larger cuts to higher water-use participants as allocations are ramped down to achieve the GSP goals and could result in larger economic impacts to those users than others in the basin. Ultimately, there are tradeoffs regardless of which method is used.

Rosedale-Rio Bravo Water Storage District

In the Tulare Lake Hydrologic Region, the Rosedale-Rio Bravo Water Storage District embarked on a joint pilot project in 2019 with the Environmental Defense Fund to build an online, open-source groundwater trading platform as a strategy for complying with SGMA in the Kern County subbasin (Environmental Defense Fund 2019).The platform serves as an online exchange where buyers and sellers can connect and negotiate groundwater allocation transfers within the district service area. Transactions can begin anonymously, but as parties get close to an agreement

the identities need to be disclosed to finalize the trade and complete financial transactions outside of the platform.

Through implementation of the basin GSP, landowners and historic groundwater users will be allocated a portion of the overall groundwater available within the basin. The groundwater available for pumping is dependent on existing groundwater levels, final sustainability indicators and thresholds, and climate conditions, and will be set to maintain groundwater levels above thresholds defined in the GSP. Allocations will be tracked by the Rosedale-Rio Bravo Water Storage District and will be adjusted when trades are completed and reported by the relevant parties through the platform. The platform is the first online, open-source groundwater trading platform in the Tulare Lake Hydrologic Region.

The Rosedale-Rio Bravo platform is also being developed and scaled to create an open-source groundwater accounting platform that will be freely available to help GSAs across the state manage the transition to sustainable supplies. DWR, the State Water Board, the California Water Data Consortium, and the Environmental Defense Fund are collaborating on the effort. The new platform is being designed to be compatible with the online electronic portals, such as DWR's Sustainable Groundwater Management Act (SGMA) Portal and the State Water Board's Groundwater Extraction Annual Reporting System, that local agencies use to submit data to the State.

McMullin Area Groundwater Sustainability Agency

In the San Joaquin River Hydrologic Region, the McMullin Area GSA in Fresno is developing a water marketing strategy with financial assistance from Reclamation that allows landowners who do not use their groundwater allocations to sell or trade them, in part or full, with other users within the McMullin Area GSA service area (California Water News Daily 2018). Under sustainability goals, the basin's overall pumping capacity would be distributed among landowners with an existing right to the groundwater as an allocation. Those allocations can be used or sold within the GSA service area based on the landowner's economic decisions. Implementation of this strategy by the McMullin Area GSA is likely to help with SGMA compliance while also reducing financial burden to landowners because of changes to water use requirements and implementation of GSPs.

Water Markets in Australia

Governor Newsom's executive order on water resilience directs State agencies to "Incorporate successful approaches from other parts of the world." A good example

of successful approaches with potential parallels with California water use characteristics could be with the Australian water markets. Australia has been using surface and groundwater markets as a water management strategy involving surface water and groundwater for decades and represents part of a water reform success story, similar to what the governor envisions in his executive order.

Water market development in Australia was driven largely in response to over-allocation of surface water and extraction of groundwater, and the devastating millennium drought (Crase 2019). Like the passage of SGMA, Australia passed a series of legislative reform packages in the 1990s and 2000s to manage the over-allocation and use of water. The reforms set up a cap-and-trade system for the Murray-Darling Basin in eastern Australia, which now accounts for the vast majority of market trades in Australia (Goesch et al. 2019). Markets also exist in other areas, just not on the same scale. In California, some GSAs have been considering, or are in the early stages of developing, a similar water market strategy that would help with implementing their groundwater stainability plans. Fox Canyon is one example that is in the early stages of setting up similar allocation trading systems and leveraging lessons learned from Australia's water markets (Heard et al. 2019).

Trading in the Australian water market includes permanent transfers of water rights, called entitlements, and temporary transfers of allocations that are calculated annually based on a percentage of the entitlements. Prices are driven by several factors including availability of water, conveyance capacities, weather conditions, and demands of various end users. Seasonal carryovers of allocated water are allowed and serve to increase flexibility in the use of water allocations. The carryovers also reduce costs in drier years by storing allocations in wet years for later use. Trading in Australia generates hundreds of millions of dollars annually that may have otherwise been lost under mandated cutbacks or cessation of water use (Australian Government 2019).

Although water markets offer flexibility in the allocation and use of water, the successful implementation of water markets as a water management tool was not an overnight process in Australia. The legislation that initiated the move to water markets has been revisited several times, most recently in 2019 for updates to the water-charge rules regulating how fees are applied and to shift from "caps" to baseline and sustainable diversion limits. The evolution of water market regulations in Australia exemplifies the need for flexible regulation to adapt to changing and new information and advances in water systems understanding.

Ongoing challenges in the Australian markets include addressing interregional trading complexities, refining carryover rules for improved flexibility, and providing consistent market information such as accurate water-pricing information (Goesch et al. 2019). Another challenge for the Australian system dealt with incorporating environmental uses into the market. When initially establishing water markets to include the environmental uses there were barriers in the form of interregional trading regulations and reluctance by the agricultural community, but the barriers were eventually overcome. Environmental buybacks (State, federal, and nongovernmental environmental purchases) were conducted through bids for water sales that were submitted and made publicly available in the process of acquiring the water. Changes to the process in 2015 caused some controversy regarding transparency and potential over-paying for environmental buy-back water (Crase 2019).

These challenges and prior successes represent opportunities for California to leverage lessons learned in Australia when implementing strategies for achieving sustainable groundwater management, such as groundwater markets. The Australian water market experience also underlines the need to be responsive to changing conditions, unforeseen complexities, and advances in the management and science of groundwater.

Opportunities and Challenges

It is expected that water markets allow competing water users to cooperate rather than compete for scarce water resources. By facilitating responsible groundwater trades in an open and transparent marketplace, California can mitigate the economic and environmental effects of water scarcity, in the short term and the long term.

Implementation of Sustainable Groundwater Management

Statewide groundwater overdraft is estimated to be in the range of 2 million to 2.5 million acre-feet per year (California Department of Water Resources 2018a). Some indications are that nearly 14 percent of the current San Joaquin Valley cropland, or 750,000 acres of land, may need to be fallowed or retired to bring the groundwater aquifers into balance. This shift reportedly would have an economic cost of $2 billion per year (Hanak et al. 2019). Generally, there will be substantial costs associated with achieving sustainable groundwater management but some of those costs, such as through land and water use changes or implementation of markets, may be mitigable. But the long-term economic impacts would be considerably greater if groundwater use is not managed sustainably.

Built and Natural Infrastructure

California has significant infrastructure to move water. The CVP and SWP stand as engineering marvels with their large reservoirs; enormous pumps; extensive canals, tunnels, and pipelines; and the use of natural waterways for conveyance. These projects provide the ability to move water from the north to the south. For example, a farmer on the Sacramento River (100 miles north of the city of Sacramento) can sell water to a farmer in Southern California using these delivery systems.

The large amount of available storage space in the Central Valley aquifers offers opportunities for leveraging natural infrastructure for storing water when it is available. For example, capturing and storing flood flows in groundwater aquifers can play an increasingly significant role in the water market through groundwater banking operations. In addition, recaptured stormwater and recycled water can be stored (or exchanged with groundwater as "in lieu") in groundwater aquifers, which can create a buffer to mitigate the potential environmental effects of water trades and promote water market flexibility.

Exploring Groundwater Market Development

The Fox Canyon Groundwater Management Agency GSA identified five enabling conditions to be present for a successful water market to function: water scarcity, fixed allocations, agricultural stakeholder support, market design expertise, and capacity and funding to develop a market (Heard et al. 2019). Many groundwater basins in California are facing water scarcity and are moving toward a fixed allocation model of pumping operation, which satisfies the first two enabling conditions. Obtaining agricultural stakeholder support for an open-water market could offer significant challenges because of lack of data, variability of predictive models, unfamiliarity with water-market concepts, and uncertainties associated with regulations and governmental policies. Several groundwater markets have already been piloted in California, so market design expertise does not pose a significant challenge. Capacity and funding to develop basin-by-basin trading platforms could be challenging unless supplemented by State technical and financial assistance to develop a common platform that can be customized according to the needs of a basin.

Measurement of pumping alone is not adequate for a successful water market; the effects of water exchanges on undesirable results must be evaluated on an ongoing basis such that the primary justification for allowing water exchange markets to achieve sustainability is not undermined for economic gain. It may also be necessary to geographically determine localized areas where there is particular sensitivity to

undesirable results and then develop a management zone that is monitored adequately. These approaches or actions will require data and tools that can be costly to develop without technical and financial assistance from the State.

Developing a groundwater market must ensure the protection of community drinking water sources, especially for disadvantaged communities. Major concerns include reductions of groundwater levels and associated increases in pumping costs; movement of contaminant plumes or the increase of naturally occurring contaminants, such as arsenic; increases in water rates to unaffordable levels; and potential localized economic effects to rural livelihoods.

Water trading in a groundwater market is based on the establishment of well-defined allocations of groundwater, but assigning groundwater pumping allocations can be controversial and there are no easy solutions. The most common approach suggested in GSPs so far has been the acreage-based allocation of allowable pumping to landowners. This approach is fraught with the following challenges:

- It penalizes more concentrated communities and rewards more sprawling communities.
- It doesn't accurately capture and protect the needs of each specific community.

These challenges can be addressed by developing a pumping volume baseline that fully captures the communities' needs and then allocates the remainder of allowable pumping with due consideration for peak historical use and projected growth in population. This may result in two separate allocations – one for agricultural pumpers and one for a community's drinking water.

Developing allocations based on historical amounts of groundwater extraction pumping levels is another approach that may be used as an alternative to an acreage-based allocation (such as in the Fox Canyon water market). This approach has the following problems:

- It requires accurate and detailed historical data on groundwater pumping.
- It requires agreement on a historical baseline for determining allocations, which may present its own difficulties in achieving.
- It may penalize groundwater users that were earlier implementers of water conservation techniques and reward more wasteful users with higher allocations.

The approach to determining allocations will need to be based on the particular circumstances of a basin and should be done in a public and transparent process to promote buy-in and understanding by market participants.

Current groundwater markets are designed to allow transfers or exchanges within the basin; this is a voluntary agreement among the stakeholders in a basin. Out-of-basin and county exports are typically regulated under county ordinances or through the Warren Act, a federal statute passed in 1911 that allows local water agencies to contract with federal agencies to store and convey non-project water in federal reservoirs that have available capacity. As water exchange markets develop further and mature, the relevant county ordinances and federal regulations may need to be revisited to adapt to emerging market trends and rules.

Water transfers are a key tool for the water market and are currently regulated by State and federal laws. Regulatory review of water transfers at the state level are often complex and can be a barrier to participation, particularly if they involve changes to the place of use, purpose of use, or point of diversion. Reviews can be time-consuming and inflexible, creating uncertainty and discouraging market engagement. But regulatory oversight is important to protect against unreasonable harm to other water users and the environment. As a result, changes to the regulatory environment or streamlining approval process surrounding water markets, would require public and legislative support.

As water markets grow and gain acceptance in California, the State should take necessary steps to prevent market failures or inequities that may be caused by external players and speculators. The Australian water market is not without its own problems; corruption has tainted the market as banks and powerful speculators buy up water rights to sell when the price is right. In some cases, these water speculators have allegedly caused price crashes to prompt rapid sales of water. Safeguards need to be in place as preventative measures against similar negative influences.

In summary, water markets offer great opportunities as an effective management strategy for the implementation of SGMA. The challenges are varied and can be broadly categorized into six groups: institutional foundations, economic efficiency, environmental sustainability, equity considerations, reliable and transparent data, and protection against market failures.

Conjunctive Management and Managed Aquifer Recharge

Approaches for achieving groundwater sustainability and water resilience may include increasing the conjunctive use of surface and groundwater resources and promoting aquifer recharge during wet years. Accomplishing these goals requires an understanding of surface and groundwater availability, geologic constraints on surface water infiltration, and the managed aquifer recharge (MAR) strategies already common in many parts of the state. Conjunctive use of surface and groundwater resources at both a basin level and statewide provides opportunities to improve the resiliency of the state's water resources and, in many instances, is implemented by local agencies as part of SGMA implementation. DWR anticipates that many GSPs will incorporate conjunctive water management and MAR strategies as part of their projects and management actions.

Estimates on Water Available for Recharge

An understanding of the amount of surface water available for aquifer recharge projects is critical for local and regional agencies, policy-makers, and permitting agencies in developing water management strategies. In 2018, DWR released the *Water Available for Replenishment* (WAFR) report, the department's best estimate, based on available information, of water available for replenishment of groundwater in the state. The WAFR report estimates 1.5 million acre-feet of surface water may be available statewide for recharging groundwater basins in an average year (California Department of Water Resources 2018b). DWR's estimate of surface water available for recharge is based on a methodology that accounts for instream flows, outflow that can be diverted by the implementation of conceptual projects, and modeled outflows that account for water demands and hydrologic conditions. As a result, DWR's estimate of 1.5 million acre-feet of surface water available for recharge requires new projects and investments in infrastructure (California Department of Water Resources 2018b).

The WAFR report underscores the high variability in the amount of surface water potentially available for recharge in different hydrologic regions of the state (Figure 4-16). Five of the 10 hydrologic regions comprise 90 percent of the estimated water available for recharge. The Sacramento River Hydrologic Region comprises of nearly 45 percent of the estimated water available for recharge in the state. The findings indicate that hydrologic regions with less surface water available for recharge may need to develop a more diversified portfolio of water supply alternatives.

Figure 4-16 DWR Estimate of Average Annual Surface Water Available for Recharge, by Hydrologic Region

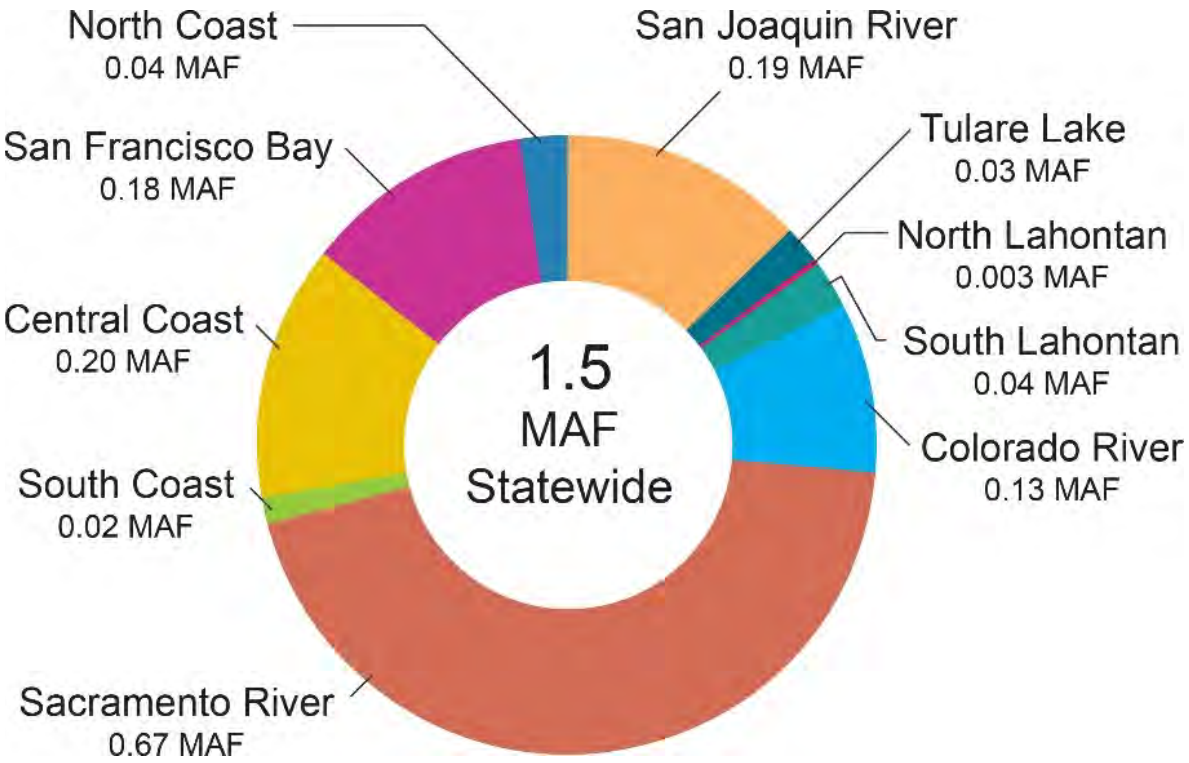


Figure 4-16 note: MAF = million acre-feet

Conjunctive Management

Conjunctive management, broadly defined as the coordinated and combined use of surface and groundwater, is a holistic approach to water resource management that can increase available water for beneficial uses, allow water agencies greater flexibility in scheduling deliveries, and improve drought resiliency (California Department of Water Resources 2003). Conjunctive management often requires an understanding of the availability and connectivity between surface water and groundwater resources. Under conjunctive management scenarios, surface water deliveries can be scheduled to allow for surface water use in lieu of groundwater pumping, or surface water can be intentionally infiltrated into the aquifer using MAR strategies. The strategies for combining surface water and groundwater resources are dictated by the availability of surface water; the depths of groundwater, quality of groundwater, and cost of groundwater extraction; and the suitability of soils to efficiently transmit infiltrated surface water into an aquifer.

Many water providers in California already incorporate elements of conjunctive use into their water management strategies. Early conjunctive use practices often focused

on extracting groundwater to supplement available surface water, or infiltrating surface water to address groundwater quality concerns in the underlying aquifers (Rao et al. 2004). Many modern conjunctive management programs often include the MAR strategies described below.

Managed Aquifer Recharge

MAR is the intentional recharge of surface water into an aquifer. It is often a critical tool for linking surface and groundwater resources under conjunctive management. Two of the most common MAR strategies consist of delivering surface water to spreading basins, where the water naturally percolates into the aquifer, or by directly injecting surface water down wells into the aquifer (i.e., aquifer storage and recovery). Some water managers also take advantage of an emerging strategy called Flood-MAR. These three MAR strategies are described below.

Spreading basins, alternatively referred to as recharge or infiltration basins, represent a common MAR practice in California. The basins are typically engineered facilities designed to facilitate the efficient infiltration of surface water into the aquifer and are often operated with the objectives of recharging the groundwater aquifers and managing stormwater discharge. These basins often consist of either excavated basins or fields surrounded by levees. Spreading basins can be augmented with dry wells, which are vertical pipe structures that provide a conduit through low permeability silt and clay layers, into more permeable sand and gravel materials in the subsurface.

Some of the primary challenges associated with using spreading basins for MAR are site geology, water availability, and existing infrastructure. The rate at which water can infiltrate and recharge the aquifer is controlled by the physical characteristics of underlying soil and unsaturated zone sediments, including depth to the water table. Some soils, such as sands and gravels, allow water to rapidly infiltrate; while other soils, such as silts and clays (i.e., aquitards), can inhibit infiltration. The use of spreading basins in areas with low permeability soils may not be feasible. Also, many spreading basins receive water deliveries through canal networks; a lack of water conveyance infrastructure may limit where spreading basins can be constructed.

Aquifer Storage and Recovery (ASR) is a MAR strategy that uses water wells to directly inject surface water into the aquifer for subsequent withdrawal. Water managers may choose to use ASR over other MAR methods for a variety of reasons, such as desire to recharge deeper aquifers or bypass low permeability layers near the surface that limit infiltration. Water injection is typically performed during periods when surplus surface

water is available. Water can be stored in the aquifer for time periods ranging from months to years before being extracted for subsequent beneficial use. ASR projects can use the same well for injection and withdrawal or use paired wells for injection and pumping.

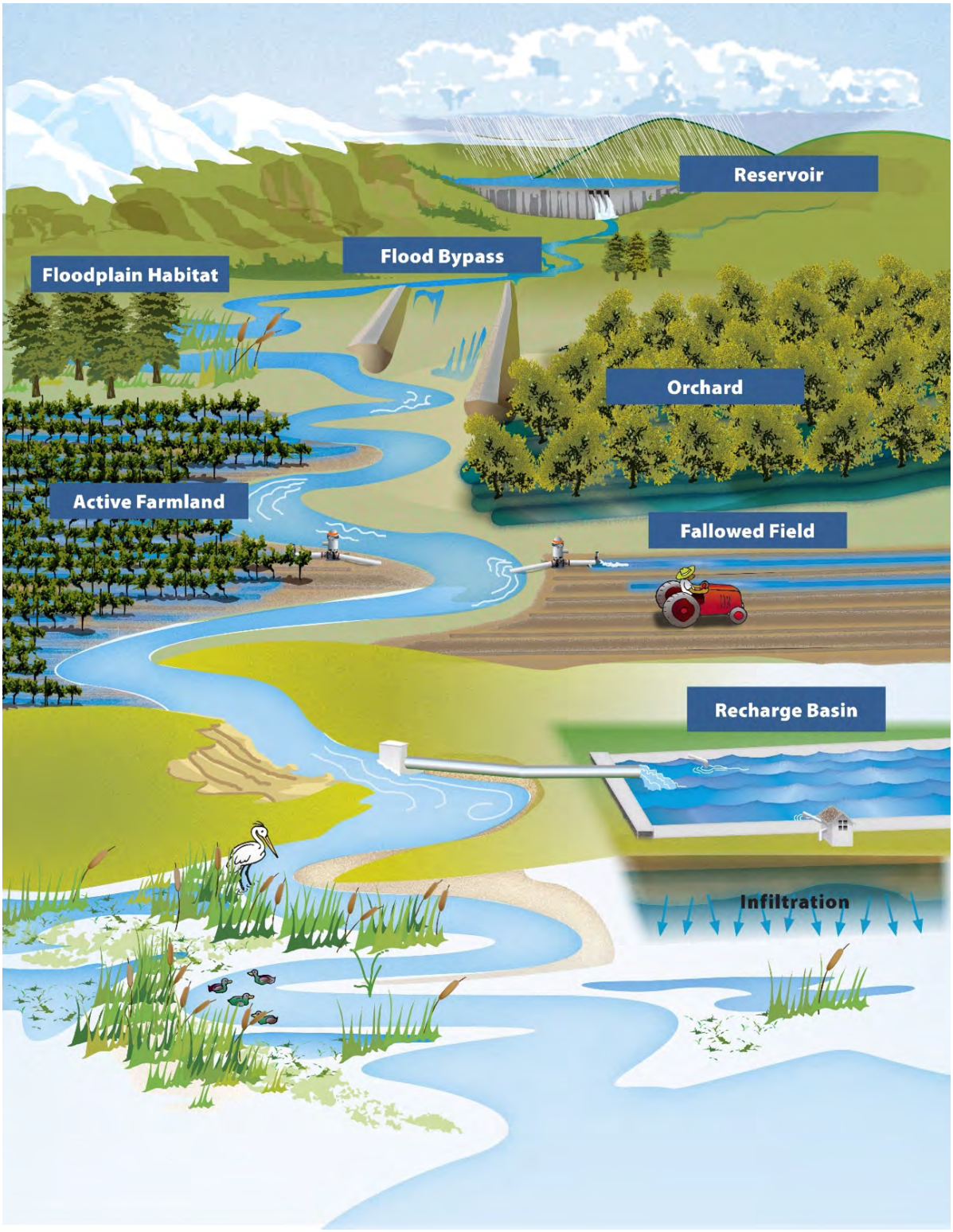
The direct injection of freshwater into groundwater aquifers has been used to supplement other MAR strategies in California since the mid-1950s, starting at the West Coast barrier. ASR strategies were first adopted in California by water providers in the South Coast, South Lahontan, and Colorado River hydrologic regions, with some recent pilot projects completed in the Tulare Lake Hydrologic Region. Another early direct-injection project in California was conducted by the Orange County Water District in the mid-1970s. The district installed a network of injection wells to create a freshwater barrier to counter seawater intrusion in the Talbert Gap (Liles et al. 2001; Luxem 2017).

The Water Replenishment District of Southern California operates a network of injection wells to maintain three seawater barriers in the Los Angeles area. The Water Replenishment District of Southern California injected approximately 9,500 acre-feet of combined surface and recycled water between July and October 2019 (Water Replenishment District 2019). A pilot ASR project was implemented by the Westlands Water District in 2017. Surface water was injected into a confined aquifer with the objective of determining the feasibility of injection and recovery. The project was deemed successful and will likely result in ASR activities being expanded throughout the district (Brown and Caldwell 2018).

Some common challenges associated with ASR implementation include public perception concerns (Rydman 2012), well clogging (Brown et al. 2006), and groundwater quality impacts (Brown et al. 2006). Despite these challenges, ASR is a proven management strategy for improving groundwater storage in California, particularly in areas where recharge by spreading basins is not feasible.

Flood-managed aquifer recharge (Flood-MAR) is an integrated and voluntary resource management strategy that uses floodwater to recharge groundwater aquifers (Figure 4-17). Flood-MAR can be implemented at multiple scales, from individual landowners diverting flood water with their existing infrastructure, to water managers using extensive detention/recharge areas and modernizing flood management infrastructure/operations. An example of a small-scale Flood-MAR

Figure 4-17 Example of the Physical Features of Flood-MAR Projects



Source: California Department of Water Resources 2018c.

project is a single farmer applying available water on farmland (e.g., active farmland, fallowed fields, or designated recharge basins) in excess of crop needs. An example of a large-scale Flood-MAR project is a partnership of landowners, flood management agencies, and water management agencies coordinating operations to achieve flood risk reduction and groundwater benefits through early release of surface storage to large land areas for infiltration into groundwater basins.

The most recent cycle of drought and flood, coupled with the requirements of SGMA, make Flood-MAR an important part of California's portfolio of water resource management strategies, now and in the future, to improve water resources sustainability and climate resiliency. Robust pilot projects and feasibility studies will be required to test and illustrate the potential benefits and effects of Flood-MAR projects at the local level. The Soil Agricultural Groundwater Banking Index is a suitability index for groundwater recharge on agricultural land. The index indicates that approximately 3.6 million acres of farmland in California are suitable for recharging winter water flows without disrupting agricultural activities (O'Geen et al. 2015).

DWR, in coordination with State and local agencies, landowners, Tribes, academia, private researchers, and non-governmental organizations, is conducting ongoing evaluations of Flood-MAR opportunities. DWR's Flood-MAR-related activities include:

- **Research and data development**: In October 2019, DWR completed the Flood-MAR Research and Data Development Plan to support managed aquifer recharge projects with a focus on using floodwater.
- **Watershed-scale technical evaluations**: In March 2020, DWR completed the Merced River Flood-MAR Reconnaissance Study, and a climate change vulnerability analysis for the Tuolumne watershed.
- **Local technical and financial assistance**: In July 2024, DWR will distribute $4.8 million in local assistance funding and provide technical assistance and guidance to project implementors.
- **Communication and engagement**: DWR will provide ongoing communications and engagement on DWR activities, share guidance and information, and facilitate partnerships among project implementors.

To access updated information regarding Flood-MAR activities, refer to Appendix D, "Citations, Reference Materials, and Links."

Chapter 5. Groundwater Monitoring

Introduction

Groundwater monitoring has been conducted in California for more than a century. Early groundwater monitoring efforts included measurement of the groundwater level in a pumping well to ensure effective operation of the well. Groundwater level monitoring is the foundation of groundwater management and is used by local water managers to understand groundwater conditions and make informed decisions.

Groundwater monitoring developed over time to include collecting information on groundwater quality, which gained importance as people began to understand the effects that different chemical constituents had on human health and the environment. In addition to identifying which constituents are in the water, groundwater quality monitoring can be used to detect and track the effects of overlying land use practices (non-point sources), the migration of contaminants and their plumes (point sources), and seawater intrusion.

Other groundwater-related monitoring in California includes land subsidence and groundwater-surface water interaction monitoring. Land subsidence monitoring began in the 1950s by the U.S. Geological Survey (USGS) in response to the localized sinking of land in areas with declining groundwater levels and specific geologic conditions. Land subsidence monitoring is especially important near water conveyance infrastructure because subsidence can damage or affect design performance of these structures. Groundwater-surface water interaction monitoring has been performed in different parts of the state based on local conditions. Groundwater-surface water interaction monitoring typically occurs in areas where streamflow is monitored for environmental reasons including, but not limited to, identifying groundwater discharge locations, streamflow depletion associated with groundwater extractions, potential impacts on groundwater dependent ecosystems (GDEs), or beneficial users.

While groundwater monitoring has occurred voluntarily at the local level for decades, the first legislatively directed statewide groundwater monitoring effort did not begin until 2009 when Senate Bill X7-6 was passed. This legislation required groundwater managers to perform semiannual groundwater level monitoring if they received State groundwater related grants. It also required DWR to develop a centralized system to store groundwater level data. In response, DWR developed the California Statewide Groundwater Elevation Monitoring (CASGEM) Program.

The enactment of the Sustainable Groundwater Management Act (SGMA) in 2014 resulted in the most significant change in groundwater monitoring to date. The groundwater sustainability plan (GSP) regulations (California Code of Regulations, Title 23, Section 354.32), developed pursuant to SGMA, require groundwater sustainability agencies (GSAs) to develop groundwater monitoring networks to "promote the collection of data of sufficient quality, frequency, and distribution to characterize groundwater and related surface water conditions in the basins and evaluate changing conditions that occur through the implementation of the [groundwater sustainability] Plan." GSPs must use a 50-year planning horizon and achieve sustainability within 20 years.

Pursuant to GSP regulations (California Code of Regulations, Title 23, Section 354.34), the 94 high- and medium-priority basins that are currently required to develop and implement GSPs (or an alternative to a GSP) must establish monitoring networks designed to assess each of the following sustainability indicators:

- Chronic lowering of groundwater levels (groundwater level monitoring).
- Reduction of groundwater storage (groundwater level monitoring).
- Degraded water quality (groundwater quality monitoring).
- Land subsidence (land subsidence monitoring).
- Seawater intrusion (seawater intrusion monitoring).
- Depletions of interconnected surface water (groundwater-surface water interaction monitoring).

While many monitoring networks exist in some form within these 94 basins, it is expected that monitoring networks will be enhanced to include more monitoring sites and the collection of additional data. More monitoring sites and data will help to better evaluate groundwater conditions as they relate to the six sustainability indicators and will improve groundwater management within each of the 94 basins and any additional basins that develop GSPs.

A summary of statewide groundwater monitoring data and information for groundwater levels, groundwater quality, land subsidence, and groundwater-surface water interaction are discussed in the following sections. A summary of monitoring occurring in each hydrologic region can be found in Chapter 7, "Groundwater at a Glance: Hydrologic Region Summaries." Information about groundwater conditions based on data collected through 2018 can be found in Chapter 6, "Groundwater Conditions." Basin-specific data used for this report, including the number of groundwater monitoring sites, are available in Appendix H, "Hydrologic Region,

Basin, and County Data." Information regarding the methods, assumptions, and data used in compiling this section are provided in Appendix C, "Methods and Assumptions." Links to the various tools, interactive maps, and datasets discussed in this chapter are included in Appendix D, "Citations, Reference Materials, and Links."

Groundwater Level Monitoring

Groundwater level data are used to assess the SGMA sustainability indicators of chronic lowering of groundwater levels and reduction of groundwater storage. The GSP regulations allow groundwater level monitoring to be used as a proxy to monitor the other four sustainability indicators if a clear, defensible relationship can be demonstrated (California Code of Regulations, Title 23, Section 354.28[d]). The collection of reliable, consistent, high-quality groundwater level data is the cornerstone of data collection for SGMA compliance.

Groundwater level data, including the baseline condition, and the effects of cropping and irrigation changes and groundwater pumping that might affect the measurements or levels, can be used to assess long-term and short-term changes in groundwater conditions in the surrounding area. Long-term records of groundwater level are used to evaluate changes in groundwater elevation and associated changes in storage over time. Short-term records of groundwater level are used to evaluate changes in groundwater elevation caused by groundwater extraction, nearby pumping wells, changes in streamflow, and natural and artificial groundwater recharge efforts.

Groundwater levels can be collected manually or autonomously. Manual groundwater level measurements are collected by a field technician using an instrument, such as an electric sounder or steel tape, to measure the groundwater level in a well. Manual groundwater level measurements give reliable, accurate results and give the recorder an opportunity to observe what is occurring in the surrounding area such as cropping and irrigation changes, nearby pumping, and anything else that might affect the measurements or levels. This process can also be time consuming because it requires visiting each monitoring location.

Autonomous groundwater level measurements are collected by installing a water-level sensing device that automatically measures the groundwater level within a well. The water-level sensing device is paired with a recording device (datalogger) and programmed to collect and record the water level at a set interval defined by the user. Autonomous groundwater level measurements allow for greater monitoring frequency, as measurements can be recorded at a frequency down to minutes. Many

dataloggers can now be paired with telemetry devices to transmit groundwater level data in real-time to a remote user helping better inform groundwater managers about current conditions. Autonomous groundwater level monitoring still requires periodic site visits to extract the data and to ensure the equipment is accurately calibrated and functioning properly.

Only a subset of the total number of monitoring wells are candidates for autonomous groundwater level monitoring and the installation of dataloggers. The two main factors in determining where dataloggers can be installed are well use type and funding. Dataloggers can be easily damaged so typically they are not installed in active irrigation, industrial, or residential wells. Moreover, autonomous groundwater level monitoring is expensive, requiring funding for the initial purchase of equipment and ongoing operation and maintenance.

The California Department of Water Resources' (DWR's) SGMA Technical Support Services (TSS) program is actively working to increase the number of autonomous groundwater level monitoring sites in California. The TSS program is providing local GSAs with funding to construct new monitoring wells and install dataloggers. In addition to the funding, DWR is working with local GSAs to select well locations, manage drilling operations, and design and construct monitoring wells. For more information on the TSS program, refer to Chapter 4, "Groundwater Management."

Groundwater level monitoring data in California can be viewed on many online tools including DWR's SGMA Data Viewer, Water Data Library, CASGEM Online System, SGMA Portal Monitoring Network Module (MNM) and the USGS's National Water Information System (NWIS). Groundwater level data can be downloaded from the following sources:

- DWR's CASGEM Online System: Includes data from wells that are part of a Designated CASGEM network and wells collected on a voluntary basis.
- DWR's SGMA Data Viewer: Includes data from wells that are part of a Designated CASGEM network and wells collected on a voluntary basis.
- DWR's SGMA Portal MNM: Includes data from wells that are part of a submitted GSP monitoring network.
- California Natural Resources Agency's Open Data platform: Includes autonomous groundwater level data from DWR's continuous groundwater-level measurements network.
- USGS's National Water Information System (NWIS): Includes wells measured by the USGS and its cooperators.

Collectively, these sources contain millions of groundwater level measurements from throughout California. Some measurements date back to the 1940s, including several that are still actively being monitored. Over the last decade, the numbers of groundwater level monitoring locations and measurements have increased with the implementation of the CASGEM program. DWR anticipates the implementation of SGMA will continue this trend of increasing groundwater level monitoring into the future.

As SGMA implementation continues, some groundwater level monitoring data at DWR is being migrated from the CASGEM to the MNM. Groundwater level monitoring data for all high- and medium-priority basins will eventually be housed in the MNM, along with groundwater level data for basins with an approved alternative to a GSP and from adjudicated areas. Low- and very-low-priority basins will continue to submit data to the CASGEM database.

Groundwater Level Monitoring Well Summary

The CASGEM and NWIS databases were queried on August 28, 2019, for all active monitoring wells. Active wells are those that were measured at least once between January 1, 2015, and December 31, 2018. At the time, the CASGEM database contained all DWR groundwater level monitoring data because the MNM was still in the development phase. The results of these queries were combined to create a statewide dataset of active groundwater level monitoring wells. The queried dataset includes 11,178 active wells statewide. Data for more than 98 percent (10,967) of these monitoring wells came from the CASGEM database, while data for the remaining 2 percent (211) came from the NWIS database.

Thirty-one percent (3,429) of California's active groundwater level monitoring wells are in the Tulare Lake Hydrologic Region, 19 percent (2,146) are in the Sacramento River Hydrologic Region, and 13 percent (1,450) are in the San Joaquin River Hydrologic Region. The remaining seven hydrologic regions contain between 2 percent (231) and 12 percent (1,369) of the total active monitoring wells in the state (Table 5-1). There are 176 wells being monitored in the non-basin area.

Groundwater Level Monitoring Wells by Program

Groundwater level measurements are collected under three separate programs: Designated CASGEM, Voluntary CASGEM, and NWIS. Figure 5-1 shows the statewide distribution of groundwater level monitoring wells by program. A summary of monitoring wells by program within each hydrologic region is presented in Table 5-1.

Designated CASGEM wells are part of groundwater monitoring networks defined in CASGEM notifications and are required to be measured biannually to maintain compliance with the program. Designated CASGEM wells account for 40 percent (4,509) of monitoring wells in the state. Voluntary CASGEM wells are measured voluntarily at the collecting agency's discretion. Voluntary CASGEM wells represent 58 percent (6,458) of the monitoring wells in the state.

The proportion of wells under each monitoring program varies by hydrologic region. The Tulare Lake Hydrologic Region contains more monitoring wells than any other hydrologic region in the state, but only 14 percent (486) of those wells are Designated CASGEM wells. In contrast, 69 percent (947) of the monitoring wells in the South Coast Hydrologic Region are Designated CASGEM wells, representing the largest number of monitoring wells within this program in any of the state's hydrologic regions.

Groundwater monitoring data in NWIS are collected in coordination with USGS and its local cooperators. NWIS wells account for nearly 2 percent (211) of the wells monitored in the state. The South Coast Hydrologic Region contains the highest percentage of NWIS monitored wells at 43 percent (91).

Table 5-1 Groundwater Level Monitoring Wells by Monitoring Program and Hydrologic Region (2015–2018)

Hydrologic Region	Designated CASGEM	Voluntary CASGEM	NWIS	Total
North Coast	163	290	1	454
San Francisco Bay	277	94	5	376
Central Coast	490	238	17	745
South Coast	947	331	91	1,369
Sacramento River	861	1,273	12	2,146
San Joaquin River	653	773	24	1,450
Tulare Lake	486	2,927	16	3,429
North Lahontan	109	121	1	231
South Lahontan	398	258	18	674
Colorado River	125	153	26	304
Total	**4,509**	**6,458**	**211**	**11,178**

Table 5-1 notes: CASGEM = California Statewide Groundwater Elevation Monitoring, NWIS = National Water Information System

Figure 5-1 Groundwater Level Monitoring Wells by Monitoring Program (2015–2018)

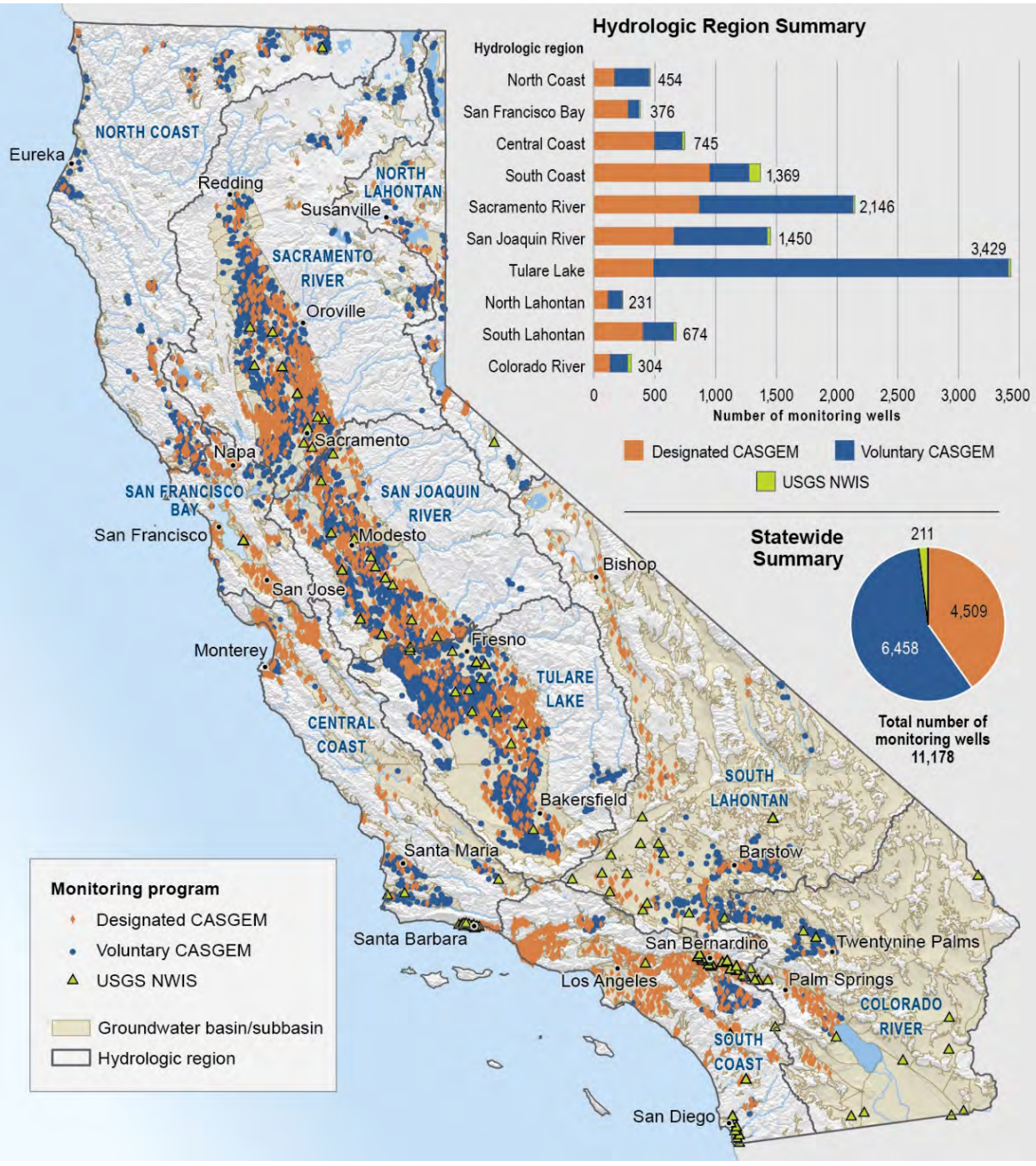


Figure 5-1 notes: CASGEM = California Statewide Groundwater Elevation Monitoring, NWIS = National Water Information System

Groundwater Level Monitoring Wells by Collecting Agency

Groundwater level wells in California are monitored by DWR (28 percent), federal agencies (7 percent), and local agencies (60 percent). Federal agencies include the U.S. Bureau of Reclamation and USGS. Local agencies include counties, water districts, and any organization other than the DWR, U.S. Bureau of Reclamation, or the USGS.

Groundwater level measurements for each monitoring well are usually taken by one agency, but about 5 percent (528) of monitoring wells statewide were measured by more than one agency from 2015 through 2018. The Sacramento River Hydrologic Region has about 45 percent (240) of the wells monitored by multiple agencies, more than any other hydrologic region. Table 5-2 summarizes the number of monitoring wells measured by DWR, federal agencies, local agencies, or multiple agencies in each hydrologic region. Figure 5-2 shows the statewide distribution of groundwater level monitoring wells measured by State, federal, local, and multiple agencies.

Table 5-2 Groundwater Level Monitoring Wells by Collecting Agency and Hydrologic Region (2015–2018)

Hydrologic Region	Measured Only by a Local Agency	Measured Only by DWR	Measured Only by a Federal Agency	Measured by Multiple Agencies	Total
North Coast	237	212	1	4	454
San Francisco Bay	301	70	5	0	376
Central Coast	726	2	17	0	745
South Coast	1,271	0	91	7	1,369
Sacramento River	807	954	145	240	2,146
San Joaquin River	730	547	77	96	1,450
Tulare Lake	1,927	1,281	160	61	3,429
North Lahontan	99	108	19	5	231
South Lahontan	449	0	166	59	674
Colorado River	155	12	81	56	304
Total	**6,702**	**3,186**	**762**	**528**	**11,178**

Table 5-2 note: DWR= California Department of Water Resources

Figure 5-2 Groundwater Monitoring Wells by Collecting Agency (2015–2018)

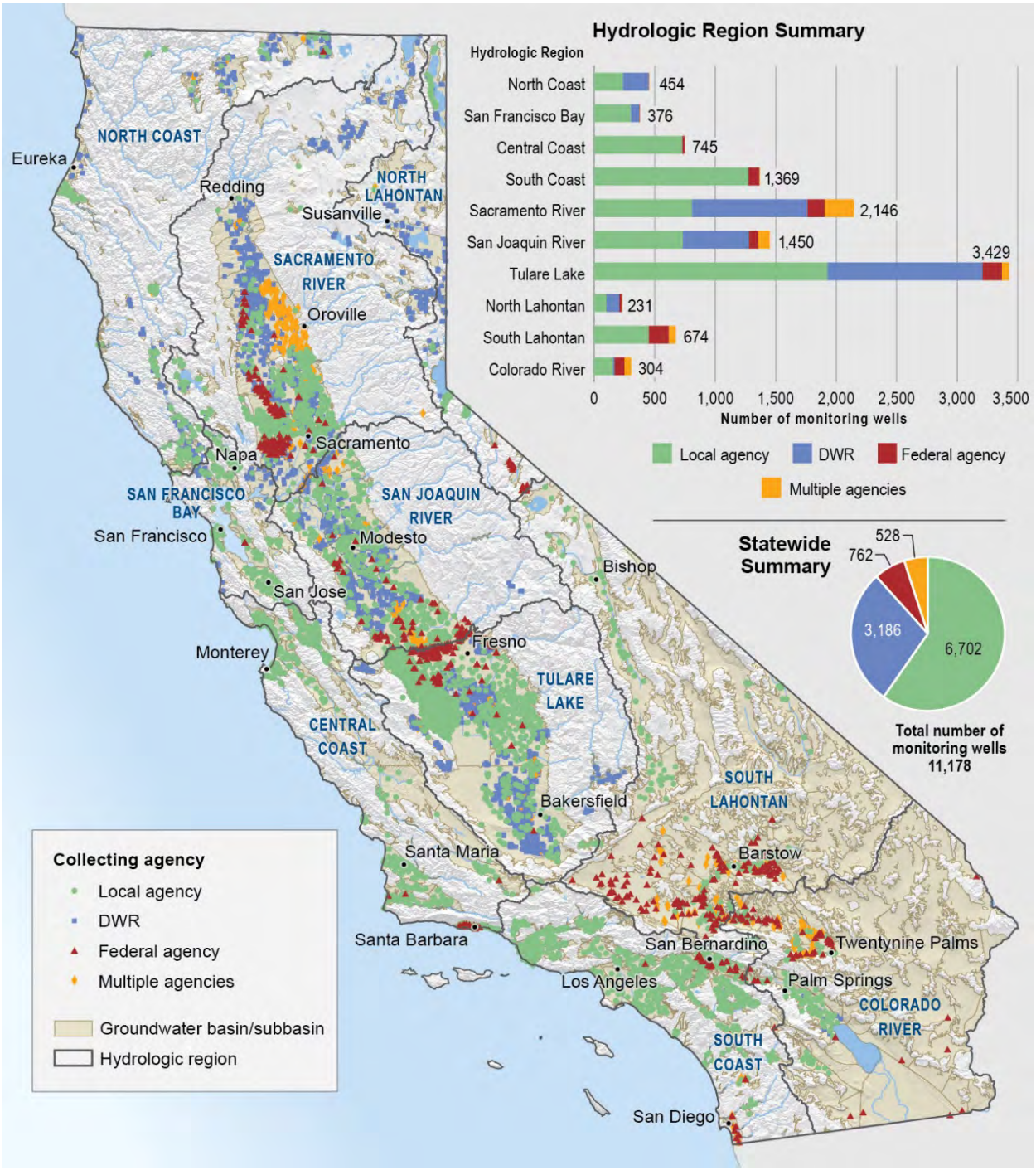


Figure 5-2 note: DWR= California Department of Water Resources

Groundwater Level Monitoring Wells by Well Use Type

Many different types of wells in California are used as groundwater level monitoring wells. This analysis summarizes monitoring wells by well use type. Well use types, as identified in the CASGEM or NWIS databases, include:

- Observation (includes all wells with a "monitoring" or "observation" use type).
- Irrigation.
- Residential (domestic).
- Other (stock wells, test wells, industrial wells and wells that lack sufficient use type information to be classified).
- Unknown (indicates the well use type was left blank in the CASGEM or NWIS databases).

Figure 5-3 displays the statewide distribution of groundwater level monitoring wells by well use type. The most common well use type used for monitoring groundwater levels statewide is irrigation, which accounts for 38 percent (4,208) of total monitoring wells. Observation wells are the second most common well use type for groundwater level observations and measurements, accounting for 30 percent (3,395) of total groundwater level monitoring wells. Wells with an unknown well use type represent 19 percent (2,104). Domestic and other well use types combined account for the remaining 13 percent (1,471).

Forty-four percent (1,866) of the irrigation wells used as monitoring wells are in the Tulare Lake Hydrologic Region; that is more than double the number of irrigation wells used for monitoring in any other hydrologic region. Almost 44 percent (1,488) of the dedicated observation wells used for monitoring are in the South Coast and Sacramento River hydrologic regions. Thirty-two percent (330) of the domestic wells used as monitoring wells are in the Sacramento River Hydrologic Region; that is nearly three times the number of wells used for monitoring in any other hydrologic region. Fifty-nine percent (1,242) of the total monitoring wells with an unknown well use type are in the Tulare Lake Hydrologic Region. A summary of monitoring wells by well use type within each hydrologic region is presented in Table 5-3.

Figure 5-3 Groundwater Level Monitoring Wells by Well Use Type (2015–2018)

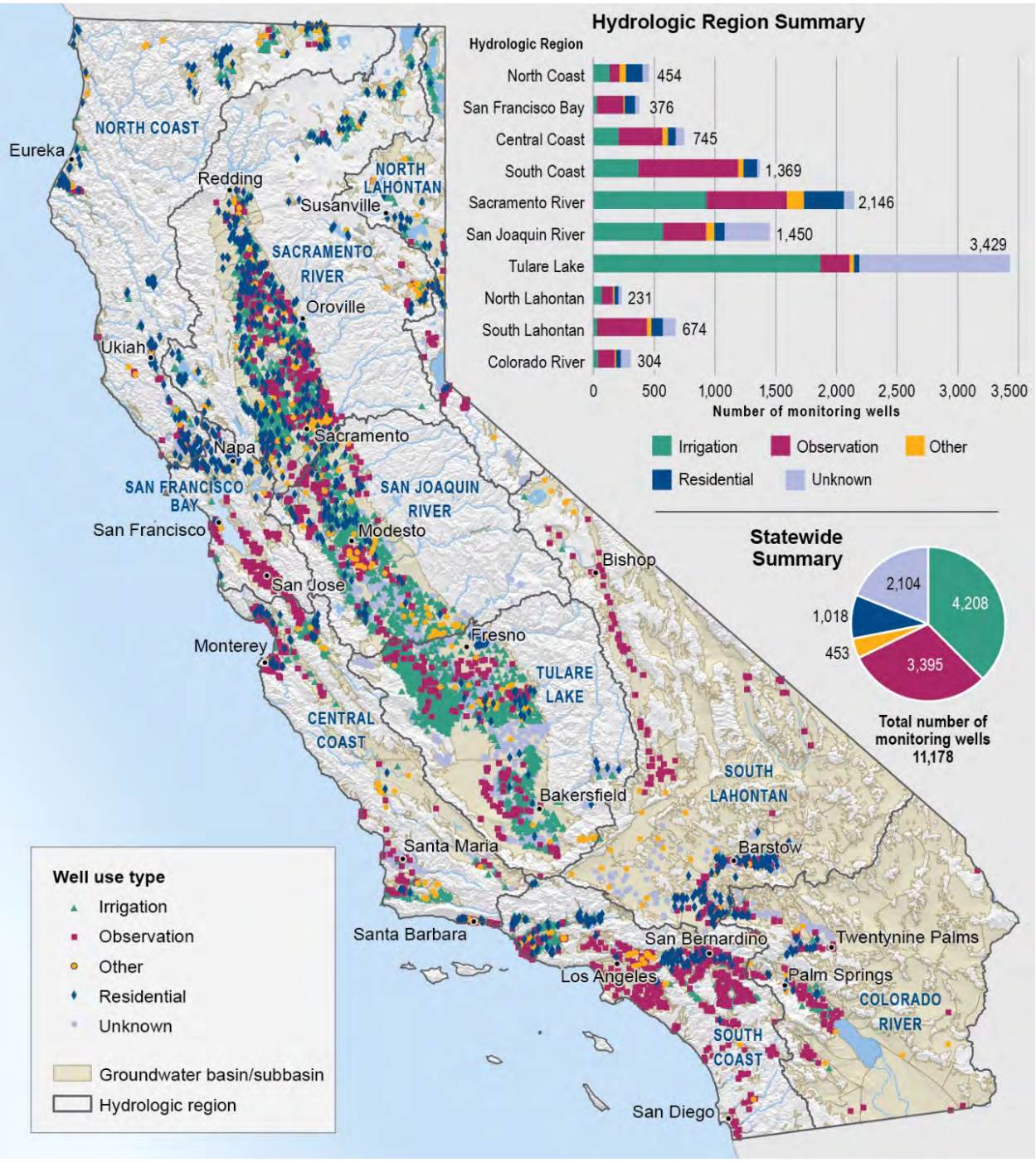


Table 5-3 Number of Groundwater Level Monitoring Wells by Well Use Type and Hydrologic Region (2015–2018)

Hydrologic Region	Dedicated Observation	Irrigation	Domestic	Other Use Types	Unknown Use Type	Total
North Coast	83	129	136	52	54	454
San Francisco Bay	221	23	86	10	36	376
Central Coast	363	202	63	45	72	745
South Coast	825	365	111	45	23	1,369
Sacramento River	663	928	330	140	85	2,146
San Joaquin River	355	570	84	67	374	1,450
Tulare Lake	242	1,866	45	34	1,242	3,429
North Lahontan	94	64	33	11	29	231
South Lahontan	410	28	93	37	106	674
Colorado River	139	33	37	12	83	304
Total	**3,395**	**4,208**	**1,018**	**453**	**2,104**	**11,178**

Groundwater Level Monitoring Wells by Measurement Frequency

Groundwater level measurements in California are collected at various frequencies ranging from one measurement per year to hundreds of measurements per year. Measurement frequencies are influenced by many different factors including legislation (CASGEM), regulations (SGMA), groundwater use (volume and well density), data collection for studies, or local decisions. For this analysis, monitoring wells were grouped into categories based on the number of recorded measurements taken at the well from January 1, 2015, through December 31, 2018. All wells identified within DWR's Continuous Monitoring Network were grouped together in a separate category. The five categories for the measurement frequency analysis are:

- 1 to 7 measurements.
- 8 to 15 measurements.
- 16 to 48 measurements.
- More than 48 measurements.
- DWR continuous monitoring.

Figure 5-4 displays the measurement frequency for each groundwater level monitoring well. Forty percent (4,476) of the groundwater level monitoring wells statewide were measured between 1 and 7 times between 2015 and 2018.

Approximately 33 percent (3,694) of the wells were measured between 8 and 15 times, while 18 percent (1,963) of the wells were measured between 16 and 48 times over the same four-year period. The remaining 9 percent (1,045) of groundwater level monitoring wells were measured more than 48 times over four years. Four percent (450) of the wells are also continuously monitored.

Groundwater level monitoring occurs more frequently in the Sacramento River Hydrologic Region than in other regions, with 58 percent (610) of the wells measured more than 48 times being in the region. Groundwater level monitoring occurs less frequently in the Central Coast, North Lahontan, San Francisco Bay, South Lahontan, and Tulare Lake hydrologic regions, where each region had ten or fewer monitoring wells that were measured more than 48 times from 2015 through 2018. A summary of groundwater level monitoring wells by measurement frequency within each hydrologic region is included in Table 5-4.

Fifty-five percent (6,252) of the groundwater level monitoring wells in California were measured at least two times per year from 2015 through 2018, the monitoring frequency recommended by the CASGEM Program. With the implementation of SGMA, it is anticipated that the number of groundwater level monitoring wells and frequency of groundwater level monitoring will increase to more than two per year in the future.

Table 5-4 Number of Groundwater Level Monitoring Wells by Number of Measurements, Continuous Monitoring and Hydrologic Region (2015–2018)

Hydrologic Region	1 to 7	8 to 15	16 to 48	More than 48	Continuous Monitoring	Total
North Coast	144	212	53	22	23	454
San Francisco Bay	50	136	188	2	0	376
Central Coast	221	316	201	7	0	745
South Coast	27	583	523	236	0	1,369
Sacramento River	215	747	574	202	408	2,146
San Joaquin River	771	534	116	10	19	1,450
Tulare Lake	2,651	743	25	10	0	3,429
North Lahontan	54	173	4	0	0	231
South Lahontan	224	133	233	84	0	674
Colorado River	119	117	46	22	0	304
Total	**4,476**	**3,694**	**1,963**	**595**	**450**	**11,178**

Figure 5-4 Groundwater Level Monitoring Wells by Measurement Frequency (2015–2018)

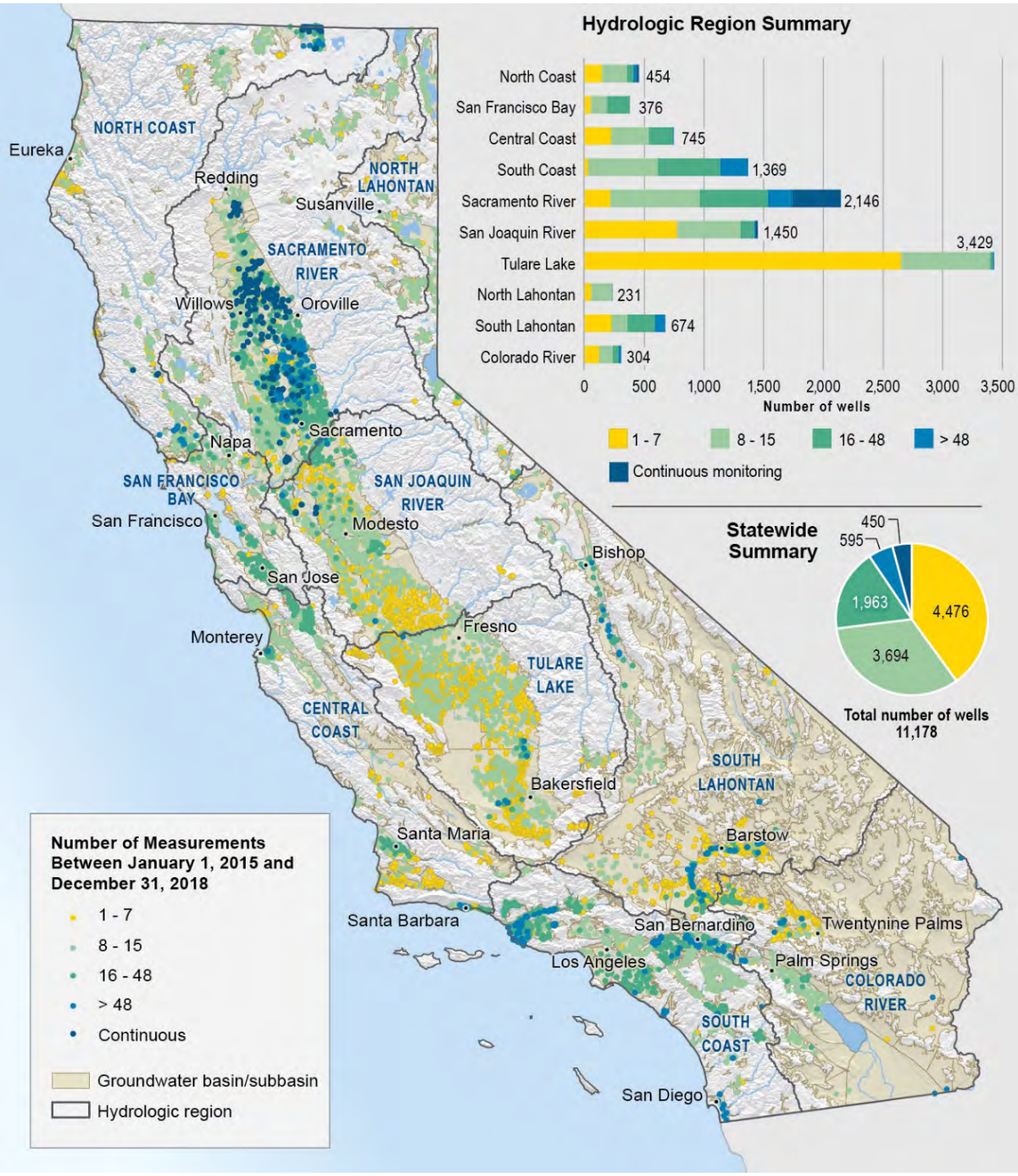


Figure 5-4 note: Bar chart shows the number of wells by their frequency of measurements during the four-year period for each hydrologic region.

Groundwater Level Monitoring Wells by Well Depth

The characteristics and extent of aquifers within the state's groundwater basins and non-basin areas are highly variable. To effectively manage the basin aquifer systems, groundwater level measurements are collected from monitoring wells with variable depths ranging from less than 100 feet to more than 1,000 feet below the ground surface. The following analysis is based on the "monitoring well depth" data field in the CASGEM and NWIS databases. Groundwater level measurements were classified into five categories based on the total depth of the well:

- Unknown well depths.
- Less than 200 feet.
- 200 to 600 feet.
- 601 to 1,000 feet.
- 1,001 to 1,500 feet.
- More than 1,500 feet.

Figure 5-5 displays the location of groundwater level monitoring wells according to the defined well-depth categories. The most commonly monitored well-depth range for groundwater levels is 200 to 600 feet, accounting for 30 percent (3,373) of all wells monitored. Monitoring wells with recorded depths ranging from 1 to 199 feet account for 22 percent (2,494), monitoring wells with depths ranging from 601 to 1,000 feet account for 10 percent (1,145), and monitoring wells with depths ranging from 1,001 to 1,500 feet account for 7 percent (756) of all wells monitored. Wells with depths of 1,501 feet or more represent approximately 5 percent (499) of all wells monitored statewide. These reported percentages could vary greatly if all monitoring well depths were known because 26 percent (2,911) of the monitoring wells statewide have an unknown well depth.

The Tulare Lake Hydrologic Region has the largest number of deep monitoring wells in the state. Almost 70 percent (878) of monitoring wells with a depth of 1,001 feet or more are in the Tulare Lake Hydrologic Region. By contrast, the Central Coast, Colorado River, North Coast, North Lahontan, San Francisco Bay, and San Joaquin River hydrologic regions all have 20 or fewer monitoring wells with depths of 1,001 feet or more. The Tulare Lake Hydrologic Region has the highest number of monitoring wells with unknown well depths (1,775) in the state, more than all other hydrologic regions combined. Table 5-5 provides a summary of monitoring wells by well depth and hydrologic region.

Figure 5-5 Groundwater Level Monitoring Wells by Well Depth, in Feet (2015–2018)

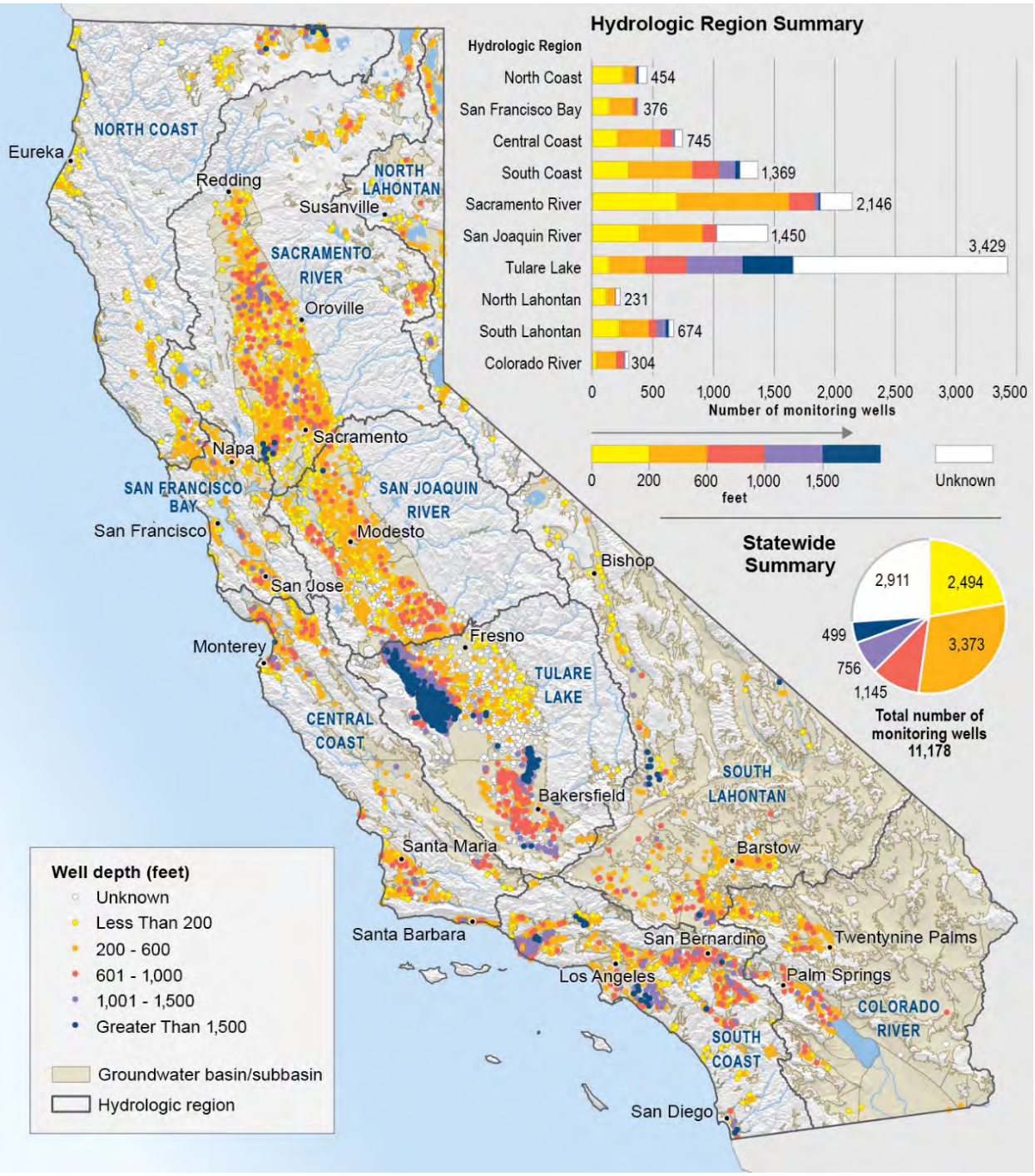


Table 5-5 Number of Groundwater Monitoring Wells by Well Depth in each Hydrologic Region (2015–2018)

Hydrologic Region	1 to 199 feet	200 to 600 feet	601 to 1,000 feet	1,001 to 1,500 feet	1,501+ feet	Unknown Depth	Total
North Coast	253	97	7	9	11	77	454
San Francisco Bay	140	193	25	6	0	12	376
Central Coast	206	355	100	13	1	70	745
South Coast	295	525	222	137	36	154	1,369
Sacramento River	699	923	207	37	11	269	2,146
San Joaquin River	386	522	111	3	1	427	1,450
Tulare Lake	140	295	341	463	415	1,775	3,429
North Lahontan	116	65	5	3	0	42	231
South Lahontan	224	240	65	75	24	46	674
Colorado River	35	158	62	10	0	39	304
Total	**2,494**	**3,373**	**1,145**	**756**	**499**	**2,911**	**11,178**

Groundwater Quality Monitoring

Groundwater quality monitoring is necessary to detect and evaluate chemical levels in groundwater. Groundwater quality monitoring is performed for many reasons and at thousands of locations throughout California. Both anthropogenic (those originating from human activities) and naturally occurring chemicals can be found in groundwater. Climate change, drought, and excessive groundwater extraction can influence groundwater quality by mobilizing and exacerbating the anthropogenic and naturally occurring chemical concentration levels.

Degrading groundwater quality can lead to many challenges for water managers in California, including the need to install treatment systems, blend water sources, abandon wells, and even seek alternative water sources. In areas where groundwater is used as a potable water source, monitoring chemical levels is especially important because some chemicals can be harmful to human health if consumed above certain levels. Elevated chemical levels in groundwater can also lead to changes in irrigation practices and crop productivity, reductions in groundwater available for urban and domestic users, and affect other beneficial uses of groundwater. Degraded groundwater quality can also introduce harmful chemicals into the interconnected surface waters and cause catastrophic harm to groundwater dependent ecosystems.

The State Water Resources Control Board (State Water Board) has largely been tasked with monitoring and regulating groundwater quality in the state. It operates various programs to detect, evaluate, and remediate groundwater. Groundwater quality monitoring data collected by the State Water Board are stored in the Groundwater Ambient Monitoring Assessment (GAMA) database, the largest groundwater- quality-monitoring repository in California. GAMA includes groundwater-quality data from numerous regulatory and non-regulatory programs throughout California. Figure 5-6 is a statewide map showing the locations of monitoring stations in GAMA. Water quality monitoring stations include dedicated monitoring wells as well as domestic, irrigation, municipal, and other supply wells that take water quality measurements.

As of July 2020, the GAMA database contains more than 21 million individual records from nearly 310,000 unique stations. The South Coast Hydrologic Region contains more stations (96,221) than any other hydrologic region, which amounts to 31 percent of the groundwater stations in GAMA. The San Francisco Bay and Tulare Lake hydrologic regions have the second and third most stations in the state, each with approximately 42,000 stations. Table 5-6 displays the number of groundwater quality monitoring stations in GAMA by hydrologic region.

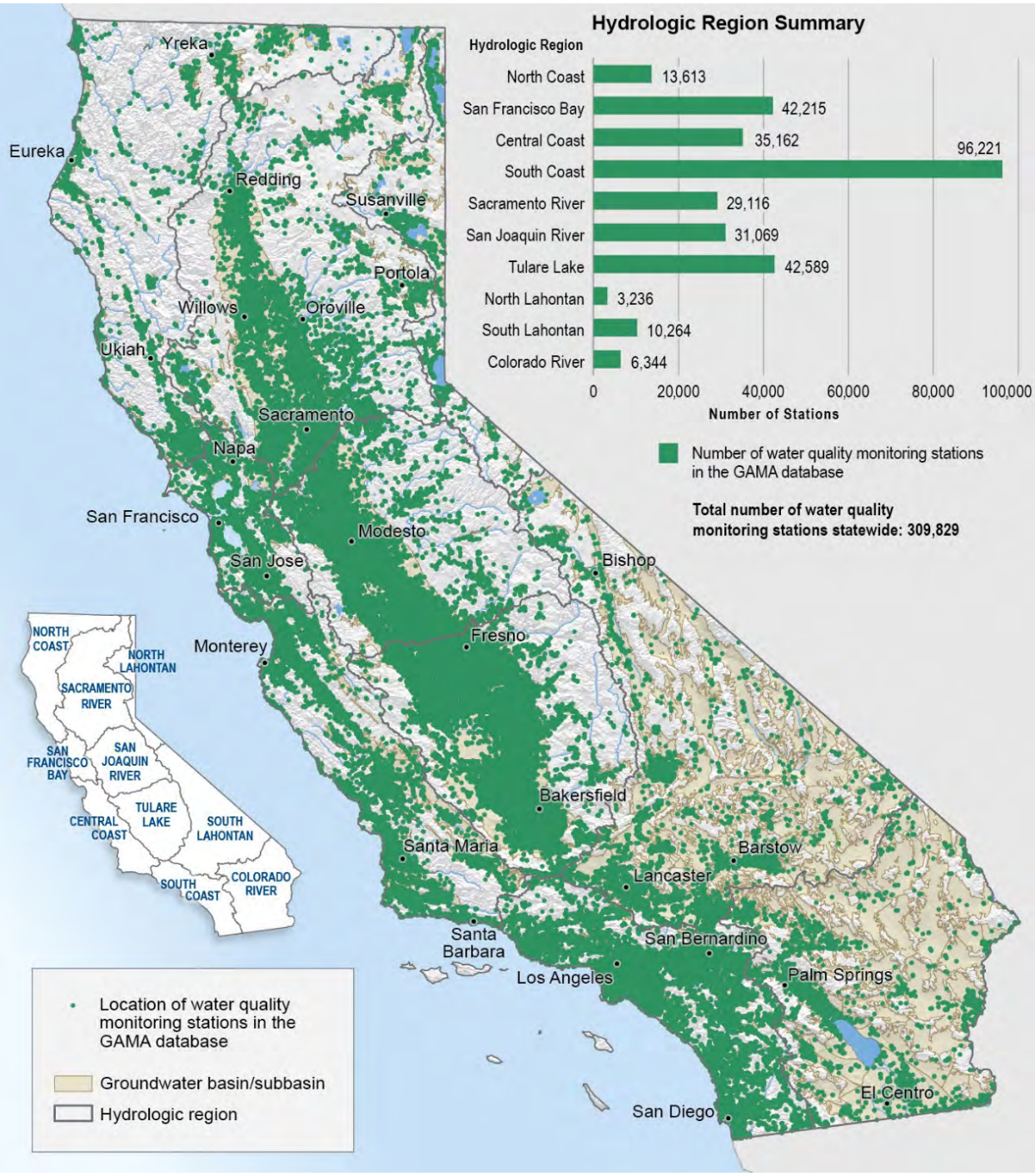
Table 5-6 Number of Groundwater Quality Monitoring Stations in GAMA by Hydrologic Region (as of July 2020)

Hydrologic Region	Total
North Coast	13,613
San Francisco Bay	42,215
Central Coast	35,162
South Coast	96,221
Sacramento River	29,116
San Joaquin River	31,069
Tulare Lake	42,589
North Lahontan	3,236
South Lahontan	10,264
Colorado River	6,344
Total	**309,829**

Table 5-6 note: GAMA = Groundwater Ambient Monitoring Assessment

Table 5-6 and Figure 5-6 include all the stations in GAMA from various programs that may or may not currently be in operation. For more information about water quality monitoring data stored in GAMA, visit the State Water Board's GAMA Groundwater Information System.

Figure 5-6 Groundwater Quality Monitoring Stations in the Groundwater Ambient Monitoring Assessment (GAMA) Database (as of July 2020)



Land Subsidence Monitoring

Land subsidence is a gradual settling or sudden sinking of the Earth's surface resulting from removal or displacement of subsurface earth materials. Land subsidence in California can be caused by compaction associated with groundwater level decreases, oil and gas withdrawals, and the drainage of organic soils. In parts of the state, tectonics can also play a role by raising or lowering the ground surface. When groundwater is extracted from some aquifers in excess quantities the groundwater level is lowered, and water pressure decreases, causing more of the weight of the overlying sediments to be supported by the aquifer formation skeleton (the remaining sediment configuration after the removal of water). If these remaining skeleton sediments have not previously been stressed, such as by a previous lowering of groundwater levels, the overlying sediments will compact the aquifer skeleton and cause subsidence at the land surface. The magnitude and permanence (elasticity or inelasticity) of subsidence can vary depending on the extraction parameters, sediment type, and extent of the sediment beds. Subsidence can cause damage to existing surface and subsurface infrastructure, cause groundwater wells to fail, reduce available groundwater storage, change the natural flow of water, and affect groundwater dependent ecosystems.

Subsidence monitoring has occurred sporadically since the 1950s in select locations of the state. Because of advances in technology, such as satellite and remote sensing, land subsidence monitoring and coverage has expanded since the 1990s. Initially, there were two primary methods for detecting and monitoring subsidence, spirit-level surveying and borehole extensometers. Spirit-level surveying measures changes in the land surface elevation based on established locations called benchmarks. Borehole extensometers measure aquifer compaction by installing a special well casing that compresses vertically as land subsidence occurs. In the 1980s, the total station, which combined an electronic distance measuring device with an electronic theodolite and computer software, was used to complement spirit-level surveying by measuring horizontal distances between points.

In the 1990s, researchers started using global positioning system (GPS) array monitoring that can be used in small (portions of a basin) or regional (many basins) areas. During this time, satellite-based remote sensing using interferometric synthetic aperture radar (InSAR) began to be used to detect deformation of the ground surface and has been found to be useful for basin analysis and monitoring. InSAR studies provided by DWR are based on data collected by the European Space Agency's Sentinel satellites on a 12-day measurement period.

Repeated light detection and ranging (LiDAR) is also employed to measure ground surfaces changes. LiDAR measurements have a lower vertical resolution compared to other methods of measuring the elevation of land surface (Borchers and Carpenter 2014).

Satellites and remote-sensing-based monitoring cannot always differentiate between subsidence and changes to ground surface elevation resulting from activities such as farming practices or construction. Field verification may be needed to verify that the reported subsidence is occurring.

Subsidence monitoring data are publicly available from non-profit organizations including the Scripps Orbit and Permanent Array Center, UNAVCO (a non-profit university-governed consortium for geosciences research using geodesy), and public agencies including DWR, USGS, and other State and federal agencies.

This section discusses the publicly available statewide DWR InSAR subsidence datasets, select regional subsidence monitoring networks, continuous global positioning system (CGPS) stations, and borehole extensometer stations. Figure 5-7 displays the distribution of the GPS stations, InSAR data coverage, borehole extensometers, and regional subsidence networks. A more comprehensive description of subsidence networks in operation throughout the state was compiled in the 2014 report, *Subsidence from Groundwater use in California* (Borchers and Carpenter 2014).

Figure 5-7 Distribution of Continuous GPS Stations, Borehole Extensometers, InSAR Data Coverage, and Regional Subsidence Networks



Figure 5-7 notes: GPS = global positioning system, InSAR = interferometric synthetic aperture radar

Continuous Global Positioning System Monitoring

CGPS monitoring stations record horizontal and vertical ground surface displacement with high frequency. Scripps Orbit and Permanent Array Center and UNAVCO maintain statewide networks of CGPS stations that record the real-time GPS data, which is available online. As of December 2019, these networks include 345 CGPS stations within California groundwater basins. Table 5-7 shows the number of CGPS stations in each hydrologic region and the stations located inside and outside basin areas.

Table 5-7 Continuous Global Positioning System Stations in Each Hydrologic Region (as of December 2019)

Hydrologic Region	Number of Stations in Basins	Number of Stations Outside of Basins	Total Number of Stations
North Coast	16	62	78
San Francisco Bay	22	38	60
Central Coast	48	78	126
South Coast	72	133	205
Sacramento River	17	39	56
San Joaquin River	18	16	34
Tulare Lake	34	28	62
North Lahontan	0	6	6
South Lahontan	52	95	147
Colorado River	66	45	111
Total	**345**	**540**	**885**

Many organizations, including the National Science Foundation (NSF), USGS, the California Department of Transportation (Caltrans), and DWR, help fund CGPS stations in California. In an open letter dated June 2019, the NSF announced a divestment of about 10 percent of CGPS stations in the state. DWR is working with UNAVCO to help retain CGPS stations that are of interest for land subsidence monitoring in California. DWR is also coordinating with USGS, Caltrans, and GSAs to ensure that statewide subsidence monitoring at CGPS stations remain largely unaffected by any funding divestment.

Satellite Based Remote Sensing Studies using Interferometric Synthetic Aperture Radar

InSAR is a remote sensing technique that uses satellite radar images taken at different times to measure the deformation of the Earth's surface at a high degree of spatial detail and measurement resolution (U.S. Geological Survey 2000). DWR contracted with TRE Altamira to evaluate InSAR data collected by the European Space Agency's Sentinel remote sensing satellites from January 2015 through June 2018 for 164 basins. The TRE Altamira InSAR dataset has a horizontal resolution of 100 meters and provides land subsidence measurements in monthly timesteps. InSAR's data quality is influenced by changes at the land surface over time, including agricultural cropping practices. Low-quality data were removed from the dataset by TRE Altamira; areas associated with the low-quality data appear as blank areas in Figure 5-7.

InSAR datasets correspond to the water year (October 1–September 30) and are released to the public the following spring on the California Natural Resources Agency's Open Data platform and on the data viewer of the SGMA Portal. As of June 2020, DWR's statewide InSAR coverage is through September 2019. Coverage will be increased through October 2020 and will be available in spring of 2021. DWR will evaluate the future use of InSAR datasets for local agencies as an additional tool to monitor subsidence.

Borehole Extensometer Monitoring

A borehole extensometer records compaction within a portion of the aquifer by measuring changes in the distance from the ground surface to the depth in the aquifer where the extensometer is anchored. Many of the borehole extensometers in California were constructed in the 1950s and 1960s during the planning and construction of State and federal water projects. After completion of the water projects, it was commonly thought that the threat of subsidence had largely been eliminated. As a result, subsidence monitoring became less of a priority and borehole extensometer sites fell into disrepair or were abandoned.

During the drought in 2009, the USGS evaluated 12 of the existing borehole extensometers in the San Joaquin Valley for potential repair and reuse. Since 2009, four extensometers have been rehabilitated. Rehabilitation included repairs and improvements of existing extensometer systems, new reference tables, and installation of dataloggers.

As of June 2020, 18 active DWR and USGS borehole extensometers record daily compaction measurements in the Sacramento River (11 extensometers), San Joaquin River (one extensometer), and Tulare Lake (six extensometers) hydrologic regions. For locations of these active borehole extensometers, see Figure 5-7.

Regional Monitoring

Three regional monitoring networks with publicly available data are discussed below.

GPS Survey of the Sacramento Valley Land Subsidence Network

In 2008, DWR developed a series of survey monuments (markers that define a geographic position) in the Sacramento Valley to create a regional land subsidence monitoring network. The network encompasses all or part of 11 counties, from Shasta County at the north end of the valley to Solano and Sacramento counties on the south end. The network includes more than 300 monuments with an average spacing of 4.3 miles (7 kilometers). During the spring and summer of 2008, DWR, along with 25 local, State, and federal cooperators, performed an initial GPS survey of the network to establish a measurement baseline.

DWR resurveyed the regional subsidence monitoring network in 2017 with assistance from 19 State, county, and local agencies, and one private entity. The methods and equipment were similar to those used in the 2008 survey. The results were analyzed by comparing the measured height of each monument in the grid recorded in 2008 with the measured height of the same monuments in 2017 and reporting the detected differences. The results released in 2019 reported the change in height from 2008 to 2017 at each of the monuments and are included in the *Sacramento Valley GPS Subsidence Network Report* (California Department of Water Resources 2019).

California Aqueduct Land Subsidence Monitoring Network

DWR conducts periodic elevation surveys along the California Aqueduct to measure land subsidence. Repeated surveys compare elevations along specific portions of the aqueduct in Fresno and Kings counties to the 1967 baseline survey. Fifteen surveys occurred from 1968 through 2015 on approximately three-year intervals. DWR's California Aqueduct survey results are reported after each survey. The most recent results are available in the 2017 *California Aqueduct Subsidence Study* and the 2019 *California Aqueduct Subsidence Study: Supplemental Report*.

San Joaquin River Restoration Program Land Subsidence Monitoring Network

The U.S. Bureau of Reclamation surveys a network of more than 70 control points for land subsidence across the San Joaquin Valley as part of the San Joaquin River Restoration Program. Under the existing program, each control point is measured every July and December to monitor for land subsidence. Results are reported biannually.

Groundwater-Surface Water Interaction Monitoring

Groundwater and surface water interactions occur when there is a hydraulic connection between a stream and the underlying aquifer system. The hydraulic connection may change over time depending on the conditions of the groundwater table adjacent to, and below, the streambed. The mechanics of groundwater-surface water interaction is described, along with various methods of computing interactions, in the draft *Handbook for Water Budget Development: With or Without Models* (California Department of Water Resources 2020). A summary is presented below.

The rate of water exchange between a stream and an aquifer is dependent on the hydraulic gradient and the streambed permeability. If the stream is overlain on a low permeability layer, such as peat or a clay layer, it may be hydraulically disconnected from the aquifer regardless of groundwater levels or stream stage. Three general scenarios of groundwater and surface water interactions may occur.

1. When the stream stage (elevation of the water surface in the stream) is lower than the surrounding groundwater levels, the groundwater system will lose water to the stream proportional to the hydraulic gradient between the stream stage and the surrounding groundwater levels (Figure 5-8a).
2. When the surrounding groundwater levels are higher than the bottom elevation of streambed sediments and lower than the stream stage, the groundwater gain from the stream is proportional to difference between stream stage and the surrounding groundwater elevation (Figure 5-8b).
3. When the surrounding groundwater levels are lower than the bottom elevation of streambed sediments, the groundwater gain is proportional to difference between stream stage and bottom elevation of streambed sediments. In this situation, the stream is not hydraulically connected to the groundwater system, and the net groundwater gain from stream is independent of the surrounding groundwater levels as the stream and aquifer are not directly in contact (Figure 5-8c). It should be noted that the exact condition when a stream is disconnected from the groundwater system is still a research topic.

Figure 5-8a Groundwater-Surface Water Interaction Scenarios – Gaining Stream

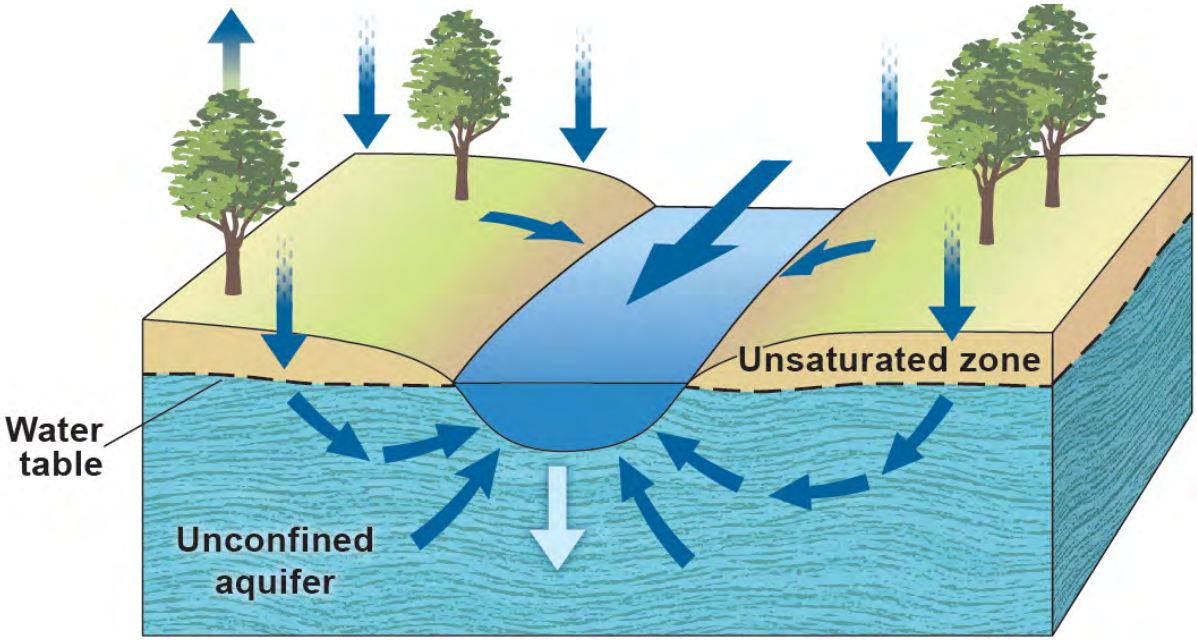


Figure 5-8b Groundwater-Surface Water Interaction Scenarios – Losing Stream

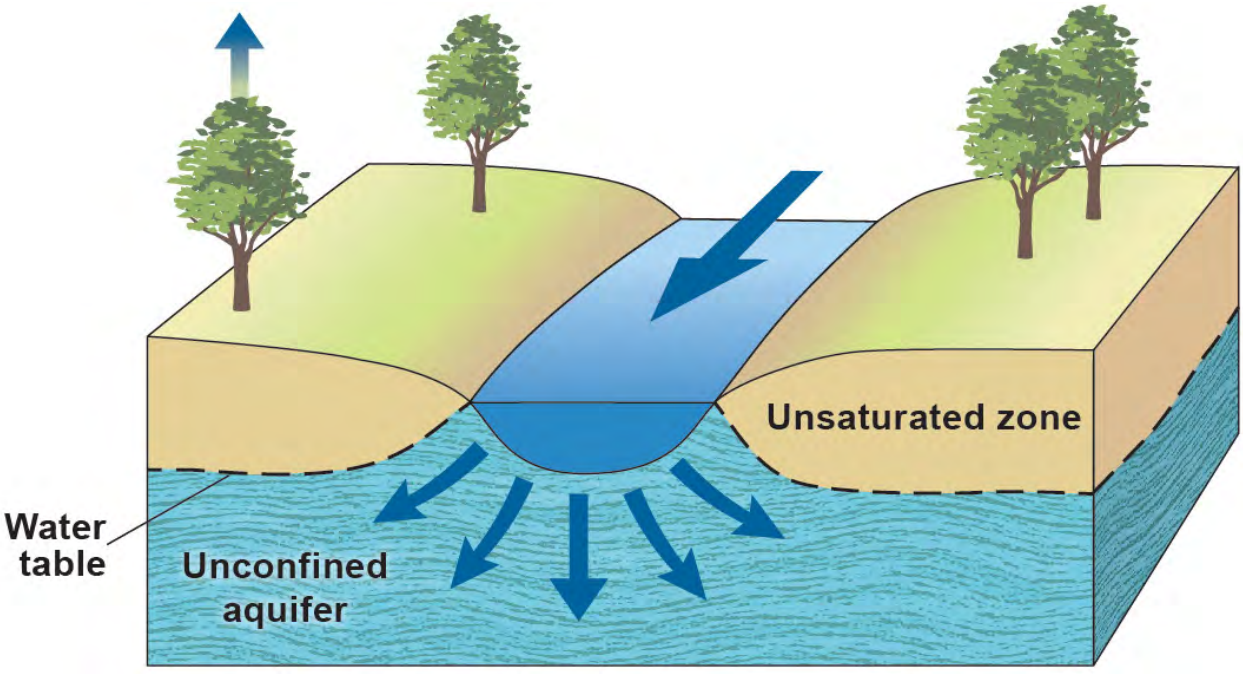
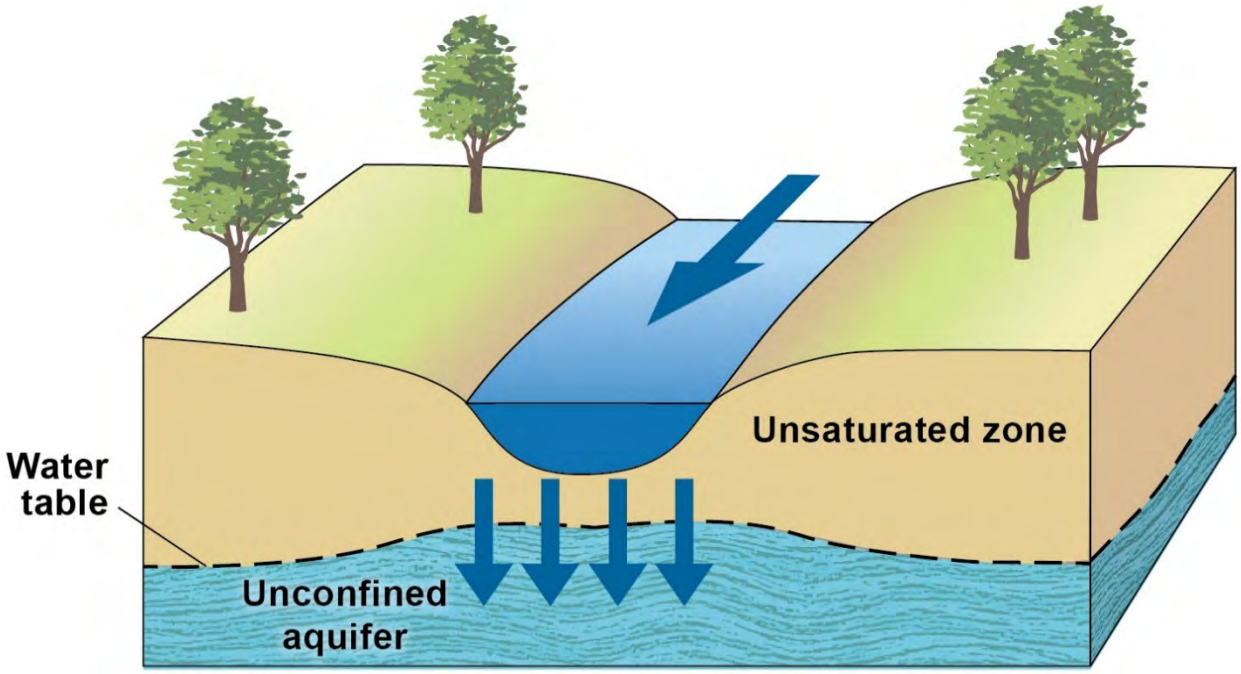


Figure 5-8c Groundwater-Surface Water Interaction Scenarios – Disconnected Stream



Streams can be losing or gaining at different locations depending on the corresponding hydraulic gradient between the stream and the surrounding groundwater levels at those locations. Streams can also be losing or gaining at different times, depending on changing conditions (such as dry or wet periods).

Monitoring

Groundwater-surface water interaction monitoring efforts are increasing throughout California in response to SGMA and other regional and statewide initiatives. Monitoring and management of groundwater-surface water interaction is complex and requires shallow groundwater level monitoring, extensive surface water monitoring networks, and use of hydrologic models to estimate the stream depletions associated with groundwater extraction and to identify groundwater discharge locations. Increased monitoring and future modeling efforts will help improve the understanding of interconnected surface water and groundwater and associated groundwater dependent ecosystems that are reliant on these interconnected systems.

According to DWR's *Best Management Practices for the Sustainable Management of Groundwater Monitoring Networks and Identification of Data Gaps* (Monitoring BMP),

the following components should be included when establishing a monitoring network for groundwater-surface water interaction:

- Use existing stream gaging and groundwater level monitoring networks to the extent possible.
- Establish stream gaging along sections of known surface water-groundwater connections.
- Establish a shallow groundwater monitoring well network to characterize groundwater levels adjacent to connected streams and hydrogeologic properties.
- Identify and quantify the timing and volume of groundwater pumping within approximately 3 miles of the stream or as appropriate for the flow regime.
- Establish qualitative monitoring with the use of GPS surveys to determine the timing and position along ephemeral or intermittent streams where they cease to flow. The surveys should be conducted annually or as appropriate to capture stream flow change.

Because of the natural variation of each stream and groundwater basin, summarizing statewide monitoring for groundwater-surface water interaction is a complex task. While local monitoring networks have been developed using a combination of the tools listed above, historically there has been no statewide repository for local agencies to submit groundwater-surface water interaction monitoring plans and data. The SGMA Portal's MNM online application was developed by DWR to allow GSAs to submit the required groundwater-surface water interaction monitoring plans and data.

A discussion about the stream gaging network in the state is provided below to facilitate an understanding of the extent of stream flow data that can be used, in conjunction with available statewide groundwater monitoring discussed earlier, to monitor groundwater-surface water interaction.

Statewide Stream Gaging Network

In addition to helping monitor groundwater-surface water interaction, stream gages are used for many other purposes in California. The need to operate and maintain a robust statewide stream gaging network was reinforced by the California State Legislature in 2019 through the passage of Senate Bill 19. The legislation requires DWR to develop a plan to operate and maintain a statewide network of stream gages, as well as determine where there is need for installing new stations and reactivating inactive stations where necessary.

In California, stream gages are operated by many organizations, including DWR. For organizational and display purposes, stream gages were categorized as either DWR stream gages or non-DWR stream gages. An active station is defined as a stream gage that transmitted data from January 1, 2018, through July 1, 2019, to one or more of the following databases: DWR California Data Exchange Center, USGS National Water Information System, and the National Weather Service.

Inactive stations are gages that have previously submitted stream flow data but did not transmit data from January 1, 2018, through July 1, 2019. Figure 5-9 presents a statewide summary of stream gage stations in California showing active DWR stream gages, active non-DWR stream gages, and inactive stream gages.

There are 2,870 stream gage stations in California. Forty-five percent (1,295) are active, with 237 operated by DWR and 1,058 operated by other organizations. The remaining 55 percent (1,575) are currently inactive. Table 5-8 summarizes the number of active, inactive, and total stream gages in each hydrologic region.

Table 5-8 Stream Gage Stations by Hydrologic Region (as of March 2020)

Hydrologic Region	Active DWR	Active Non-DWR	Inactive	Total
North Coast	26	105	145	276
San Francisco Bay	15	98	91	204
Central Coast	5	65	128	198
South Coast	6	121	270	397
Sacramento River	96	239	402	737
San Joaquin River	77	195	209	481
Tulare Lake	4	98	108	210
North Lahontan	7	37	77	120
South Lahontan	2	37	93	132
Colorado River	0	63	52	115
Total	**237**	**1,058**	**1,575**	**2,870**

Table 5-8 note: DWR = California Department of Water Resources

Figure 5-9 Stream Gaging Stations (as of March 2020)

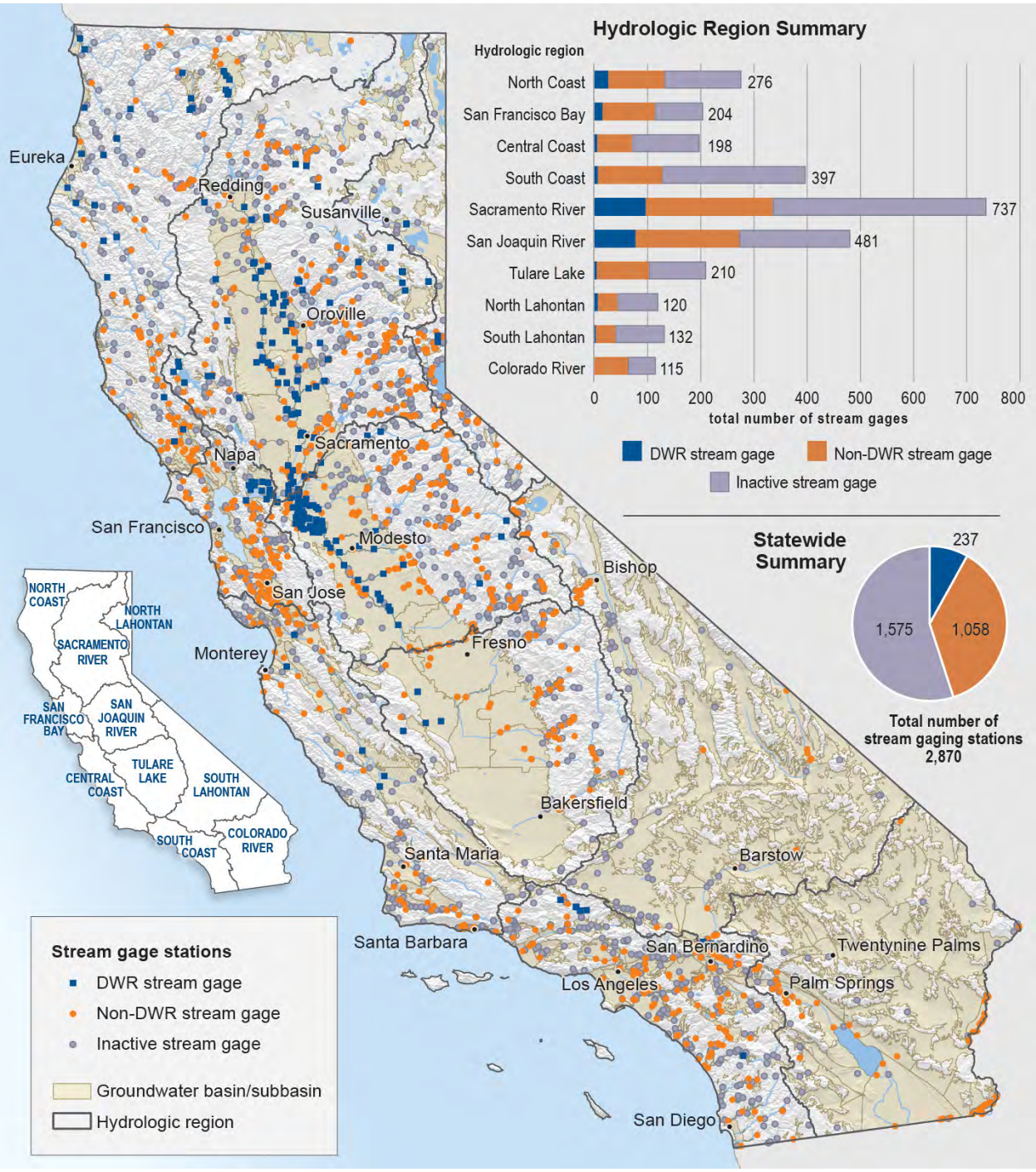


Figure 5-9 note: DWR = California Department of Water Resources

The Sacramento River Hydrologic Region has the largest number of active stream gages in California with 26 percent (335) of the statewide total. DWR (96) and non-DWR (239) organizations each operate more active stream gages in the Sacramento River Hydrologic Region than any other hydrologic region. The San Joaquin River Hydrologic Region has the second-largest number of active stream gages in state with 21 percent (272). DWR operates 77 while non-DWR organizations operate 195 of these stream gages. These two regions combined represent 47 percent of the active stream gages in the state.

Inactive stream gages may have some, or all, of the infrastructure required to collect streamflow measurements at the site, but the site is not currently transmitting data, usually because of a lack of funding. As outlined in Senate Bill 19, inactive stream gage stations are an important resource to quantify because reactivation of stations is typically much less expensive and easier than installing new stations.

Of the 1,575 inactive gages in the state, the largest number (402) is in the Sacramento River Hydrologic Region, representing 26 percent of the total inactive stream gages. The South Coast Hydrologic Region has the second-most inactive stream gages (270), and the San Joaquin River Hydrologic Region has the third-most inactive stations (209) in the state. There are inactive stream gages in all 10 hydrologic regions.

Seawater Intrusion Monitoring

Seawater intrusion is the process of the natural seawater-freshwater interface migrating landward within a groundwater basin because of changes in the hydraulic gradient in the basin caused by groundwater extraction. Monitoring for seawater intrusion has been conducted locally in many coastal basins to track changes in water quality conditions associated with the dynamic seawater-freshwater interface along coastal aquifers.

According to DWR's Monitoring BMP, the following practices should be considered, at a minimum, to provide data supporting the assessment of seawater intrusion:

- Monitoring groundwater elevation in all seawater intrusion-specific monitoring locations.
- Monitoring groundwater-quality data from each principal aquifer in the basin that is currently, or may be in the future, affected by seawater intrusion.
- Collecting groundwater-quality data from each principal aquifer in the basin that is currently, or may be in the future, affected by degraded water quality.

- Defining the three-dimensional extent of any existing seawater intrusion or degraded water quality.
- Sampling should be sufficient for mapping movement of seawater or degraded water quality and assessing groundwater quality effects on beneficial uses and users.

Because of the hydrogeologic variation of each groundwater basin, summarizing statewide monitoring for seawater intrusion is challenging. Historically, local monitoring networks have been developed using a combination of the methods listed above, but a statewide repository summarizing these local seawater intrusion monitoring efforts has not yet been developed.

As GSAs work to develop and implement GSPs, the GSAs will utilize the SGMA Portal's MNM online application to collect, store, and disseminate seawater-intrusion data. Future updates of CalGW will include a summary of seawater-intrusion monitoring data that are collected and reported in GSPs and submitted to the SGMA Portal's MNM online system. For more information on local efforts to monitor seawater intrusion, contact local water management agencies in coastal areas.

Chapter 6. Groundwater Conditions

Introduction

Evaluating conditions using groundwater data provides important information and insight about the state of groundwater at a local or regional scale. This chapter presents the results of a series of analyses performed using available data to evaluate groundwater and subsidence conditions.

Groundwater Levels

The depth to, or elevation of, the water surface measured in a monitoring well (i.e., groundwater level) is one of the most basic indicators of groundwater conditions. When groundwater elevations decrease over time it is a condition referred to as the chronic declining of groundwater levels, which is one of the six sustainability indicators addressed in the Sustainable Groundwater Management Act (SGMA). The following discussion provides an analysis of groundwater level conditions by analyzing the statewide groundwater level data collected from monitoring wells.

Groundwater level data are presented in two ways (Figure 6-1), (1) as depth to groundwater, which measures the distance from the ground surface at the monitoring well to the water surface in the well, and (2) as groundwater surface elevation, which is calculated by subtracting the depth to water surface from the elevation (i.e., the distance above mean sea level) of the ground surface at the well.

Groundwater maps and figures in this section were developed using groundwater level data from the California Statewide Groundwater Elevation Monitoring (CASGEM) Program as of October 2019. Data from the SGMA Portal Monitoring Network Module were not used because the interface was still in development.

Depth to Groundwater

Groundwater levels reflect the balance between the amount of groundwater discharge (or extraction) compared to recharge. When the amount of discharge exceeds that of recharge, depth to groundwater increases (i.e., groundwater levels drop). Conversely, when the amount of recharge exceeds that of discharge, depth to water decreases (i.e., groundwater levels rise).

Figure 6-1 shows how groundwater measurements are interpreted and used in the following conditions sections. The depth to groundwater is the distance from the

ground surface to the top of the water level in a well (reference A in Figure 6-1) and is expressed as a positive number. Groundwater level data collected over time provide valuable information about seasonal and long-term groundwater fluctuations and trends. Knowledge of changes in the local depth to groundwater can provide a better understanding of the interaction between groundwater and surface water, the potential for land subsidence, the availability of groundwater storage, and the potential costs associated with well installation and groundwater extraction.

Figure 6-1 Groundwater Level Schematic

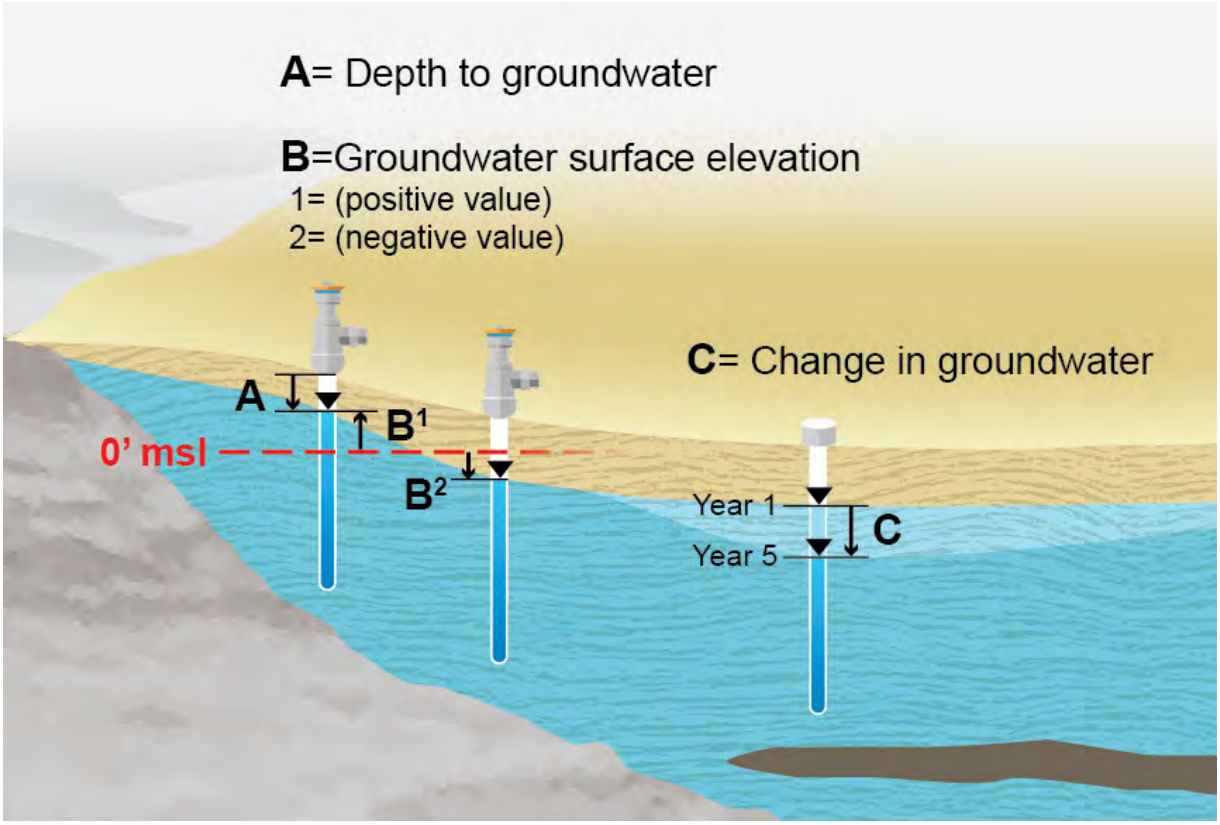


Figure 6-1 note: msl = mean sea level

Figure 6-2 displays the spring 2018 depth to groundwater as measured in wells throughout the state and reported to the California Department of Water Resources (DWR) through the California Statewide Groundwater Elevation Monitoring (CASGEM) Program. Data from all available wells were included and represent water levels from a range of well use types, well depths, and screened intervals, including wells with unknown construction. For more information about the well monitoring, see Chapter 5, "Groundwater Monitoring."

Figure 6-2 Depth to Groundwater with Summary by Hydrologic Region (Spring 2018)

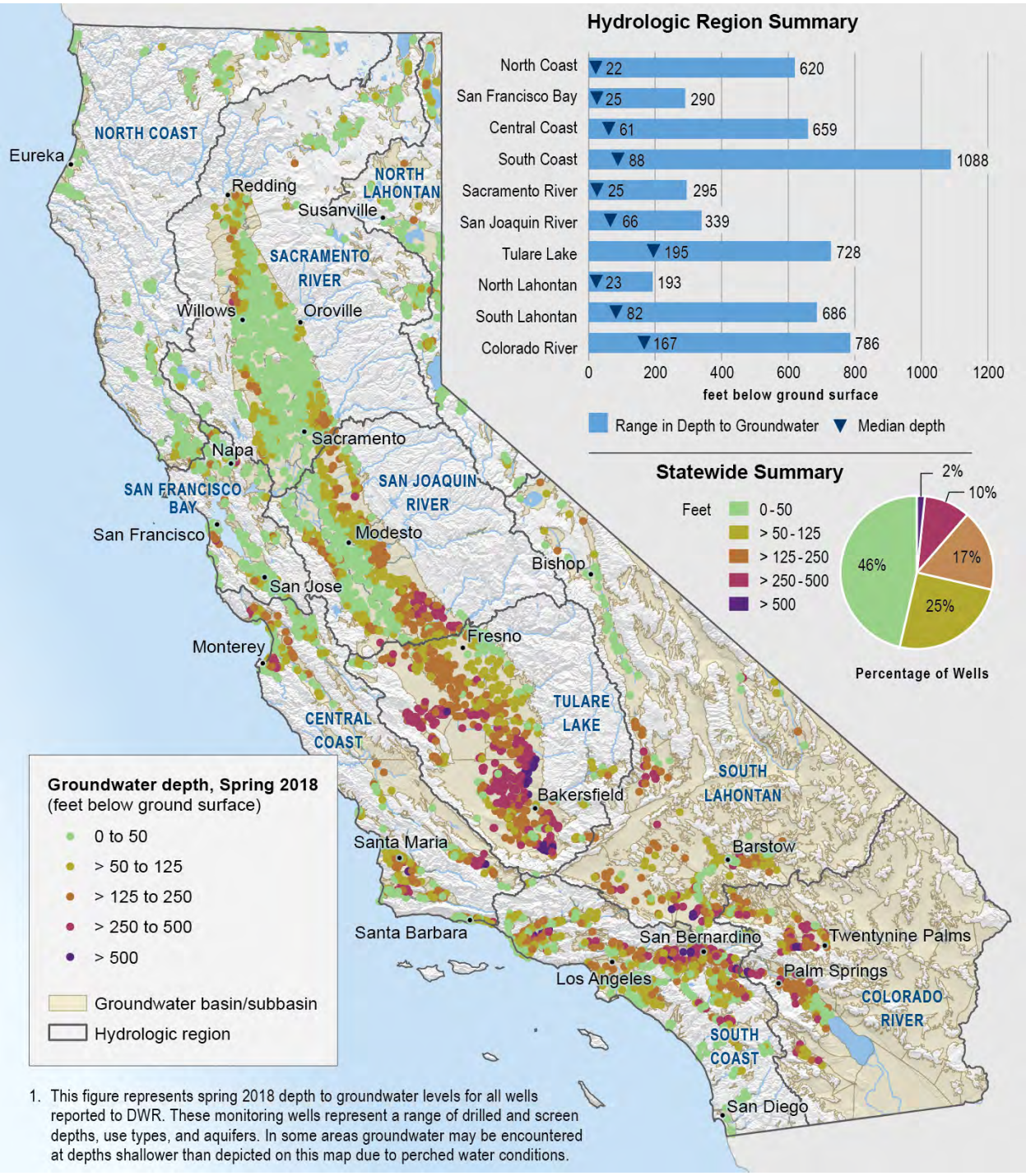


Figure 6-2 note: DWR = California Department of Water Resources

Spring groundwater level data, shown in Figure 6-2, correspond to the time period before the typical irrigation season begins. Figure 6-2 displays conditions at a time of year when groundwater elevation is at the highest level (i.e., depth to groundwater is shallowest). The data from January 1 through May 31 for each well was reviewed. For each year, the measurement nearest March 15 was used to represent the spring groundwater level.

Figure 6-3 displays the spring 2018 depth-to-groundwater contour map (a map showing lines of equal groundwater depths) for the Central Valley groundwater basins. The contour lines were created using wells with screened intervals that intersect the unconfined to semi-confined aquifers (typically 100 to 400 feet below ground surface (bgs) and only include areas where data were sufficient to interpret contours. Areas with insufficient data to interpret contours, along the edges of the Central Valley, in the Sacramento–San Joaquin Delta west and north of Stockton, and along the southwestern part of the Central Valley, are shown in Figure 6-3.

Figure 6-3 shows that spring 2018 depth to groundwater in the Central Valley's unconfined to semi-confined aquifers gradually increases from north to south. Shallower depths to groundwater tend to occur near large water features, such as the Sacramento and San Joaquin rivers. Depth to groundwater increases near the Sierra foothills and where land surface elevation increases.

In the northern portion of the Sacramento River Hydrologic Region, spring 2018 depth to groundwater levels ranged from less than 5 feet bgs to approximately 20 feet bgs in areas west of the Sacramento River and east of the Feather River, to a maximum depth of approximately 160 feet bgs east of the city of Sacramento.

Spring 2018 depth-to-groundwater contours are more variable in the southern Central Valley than in the Sacramento Valley. The depth to groundwater in the western half of the southern Central Valley is shallowest along the valley floor adjacent to the San Joaquin River and tributaries, and deepest along the eastern side of the valley where it abuts the foothills of the Sierra Nevada. Depth to groundwater ranges from 100 to 280 feet bgs along the eastern side of the valley near Visalia. In the southern areas of the Central Valley, groundwater levels continued to deepen southward to depths ranging from 300 to 600 feet bgs north of Bakersfield.

Figure 6-3 Depth-to-Groundwater Contour Map for the Central Valley (Spring 2018)

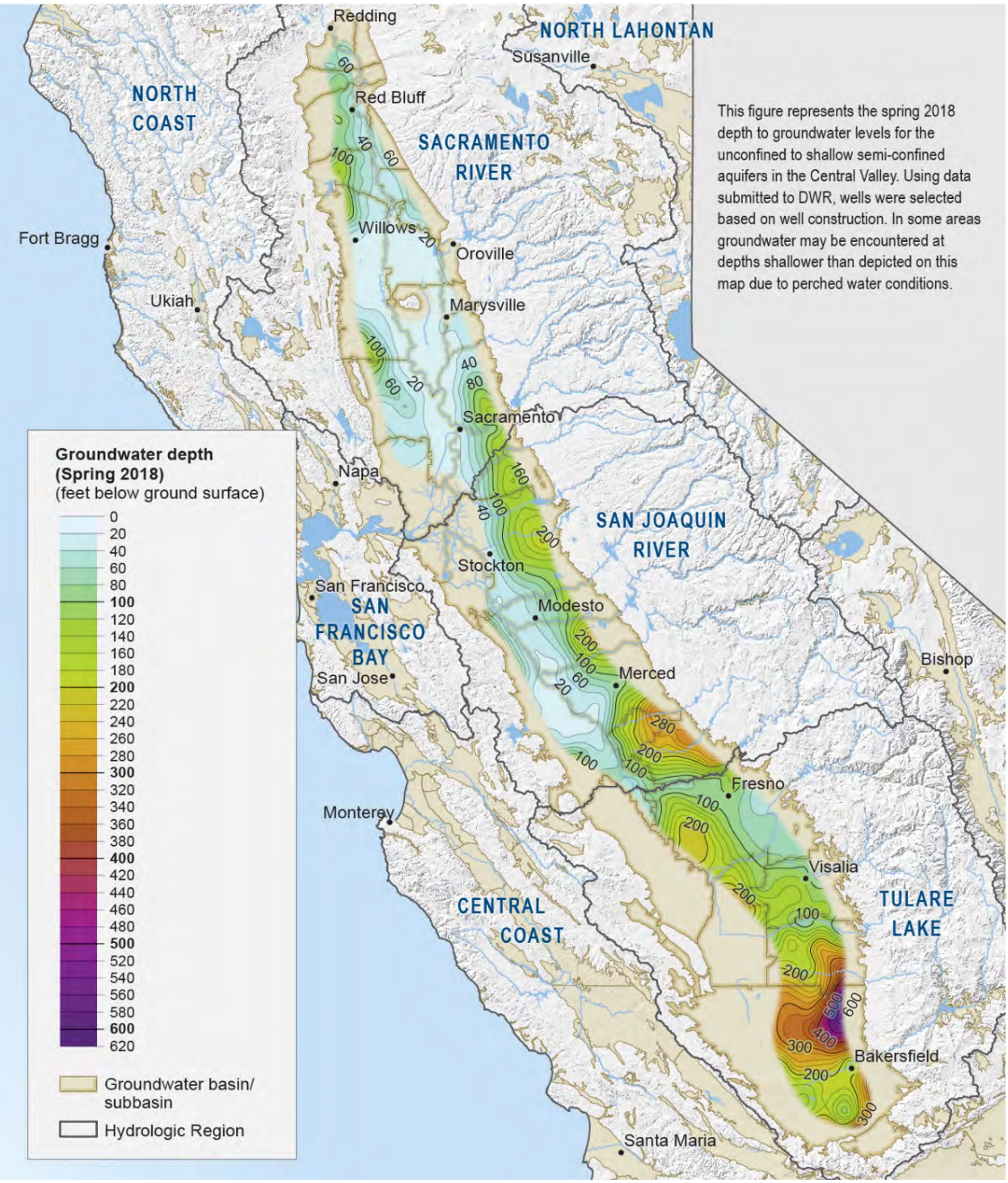


Figure 6-3 note: DWR = California Department of Water Resources

Depth to groundwater is more variable in the southern Central Valley because of local effects such as groundwater recharge activities along the eastside drainages, seepage from the Friant-Kern Canal, extensive groundwater extraction, variable imported surface water availability, and large groundwater banking projects (Kings River Conservation District 2012).

Groundwater Surface Elevations

Groundwater elevations denote the position of the groundwater level with respect to mean sea level instead of the surface of the ground. This is important when determining the flow of water through the earth. As with surface water, groundwater tends to flow from higher elevations to lower elevations. Maps depicting lines of equal groundwater elevation (i.e., groundwater elevation contours) allow interpretation of the changes in elevation of the groundwater surface and the direction of groundwater flow. These contours generally follow the relief of the land surface but are locally affected by groundwater pumping, geology, and hydrologic conditions.

Groundwater elevation contour maps can be used to identify the regional groundwater flow direction, groundwater, discharge areas where groundwater leaves the aquifer system (e.g., streams, lakes, and wetlands), areas of high and low water use, potential flow directions of contaminant plumes, and, along the coast, the potential for seawater intrusion. The direction of groundwater flow follows a path is perpendicular to the groundwater contour lines, along a hydraulic gradient, moving from areas of higher to lower piezometric pressure (which is generally from higher to lower elevation in unconfined and semi-confined aquifers).

In aquifer discharge areas, or in areas characterized by pumping depressions in the groundwater surface, groundwater flow lines tend to converge toward the center of the discharge or pumping area. In aquifer recharge areas, groundwater flow lines tend to diverge from the source area in a radial flow pattern. Groundwater elevation contours that increase in elevation toward a water body indicates the water body is losing water to the groundwater system. Contours that decrease in elevation toward a water body indicate that the water body is gaining water from the groundwater system.

Figure 6-4 represents the spring 2018 groundwater elevation contours for the unconfined to shallow semi-confined aquifers within the Central Valley. The contours shown depict the elevation of the groundwater surface. The arrows show the general

Figure 6-4 Groundwater Elevation Contour Map for the Central Valley (Spring 2018)

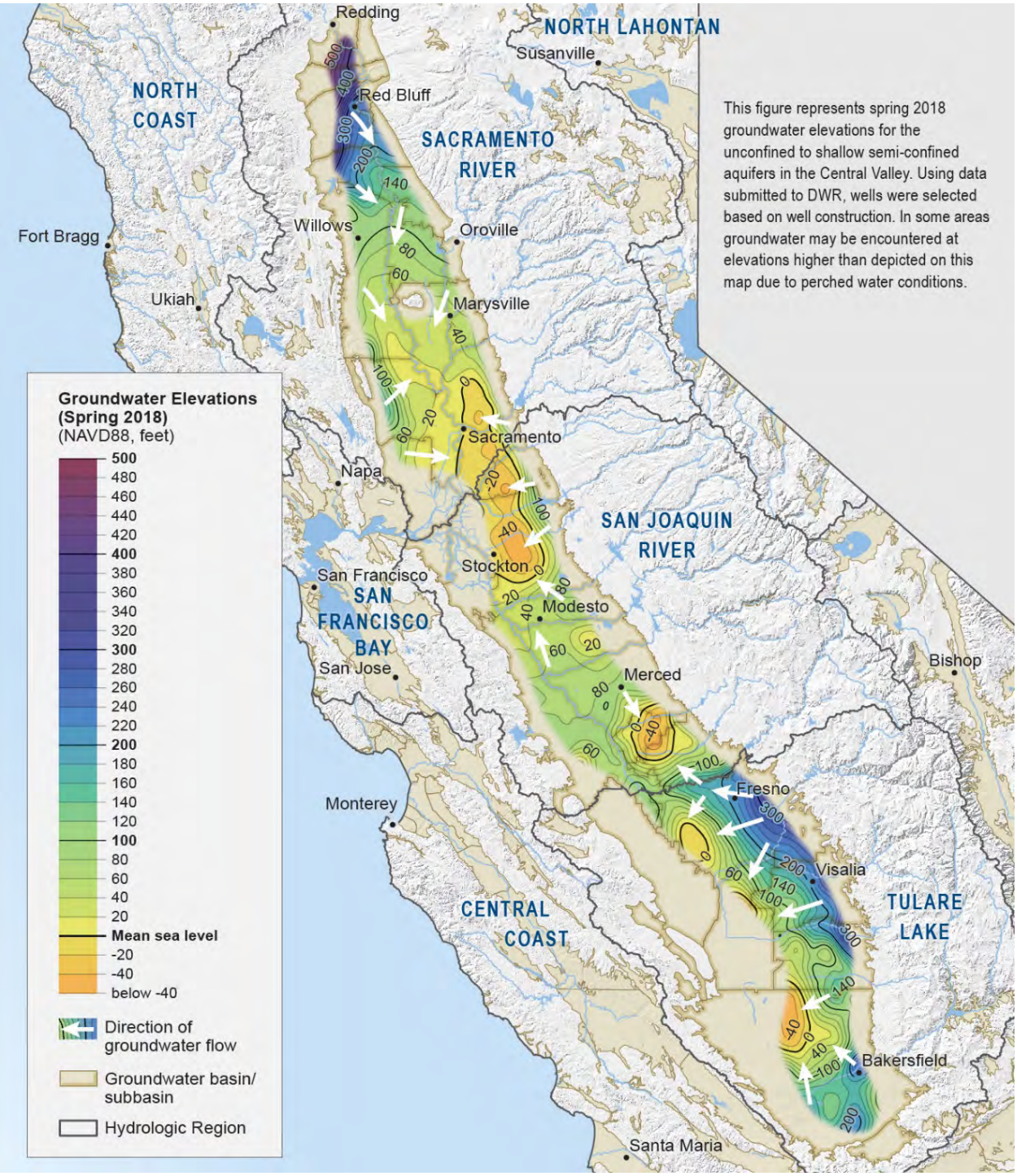


Figure 6-4 notes: DWR = California Department of Water Resources, NAVD88 = National Vertical Datum 1988

direction of horizontal movement along a groundwater flow path or the gradient (the vertical movement of groundwater is not indicated in the figure).

The contour lines were created using spring 2018 groundwater level measurements from wells screened in the unconfined to semi-confined aquifers (typically 100 to 400 feet) and only include areas where data were sufficient to interpret contour lines. Additional information regarding the assumptions and methods associated with groundwater elevation contours are provided in Appendix C, "Methods and Assumptions."

In the northernmost part of the Sacramento Valley near Red Bluff and Redding, the spring 2018 groundwater elevations were greater than 500 feet above mean sea level (National Vertical Datum 1988). The regional groundwater movement is generally from the edges of the valley (where groundwater elevations are higher) toward the Sacramento River and nearby drainages (where groundwater elevations are lower) and then southward toward the Sacramento area. Groundwater flow in the Sacramento Valley is ultimately directed toward the Sacramento-San Joaquin Delta, and out to the Pacific Ocean through the San Francisco Bay.

Areas where groundwater elevations are lower in the center of closed groundwater contours are known as cones of depression. These areas generally indicate places where the rate of groundwater pumping exceeds the rate of recharge. The groundwater gradient, and groundwater flow, is directed toward the center of these cones of depression. In spring 2018, groundwater cones of depression reaching depths of 40 feet below mean sea level extended from the southern part of the Sacramento River Hydrologic Region into the northern part of the San Joaquin River Hydrologic Region, roughly from Sacramento to Stockton. Large cones of depression were also documented in the southern portions of San Joaquin River Hydrologic Region southeast of Merced, southwest of Fresno, and northwest of Bakersfield.

Groundwater Level Trends

Groundwater levels vary seasonally and with climate cycles. It can be difficult to assess whether water levels in individual groundwater monitoring wells have exhibited significant declines or increases over specific time periods. Trend analysis allows for a statistical assessment of presence and estimated magnitude of groundwater level trends over time for many monitoring wells at once. This analysis method allows for graphing and mapping of the results and displaying spatial patterns in groundwater level changes. As such, trend analysis is a simple but powerful method for interpreting the status of groundwater conditions at local to

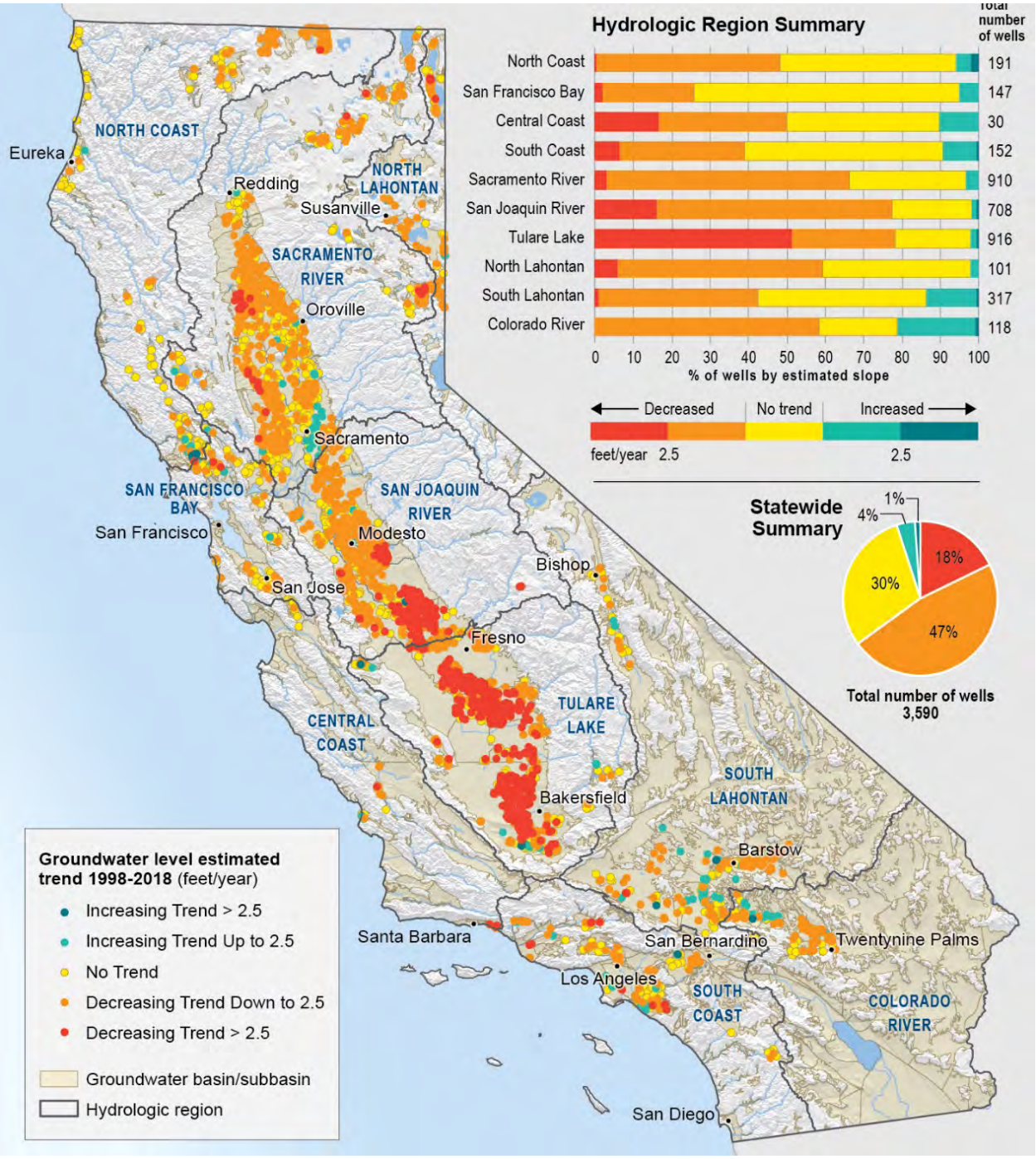
regional scales and complements the more labor-intensive visual interpretation of individual hydrographs.

Groundwater levels at selected wells were analyzed using the Mann-Kendall non-parametric test to determine whether a statistically significant trend (declining trend, no trend, or increasing trends in groundwater levels) was present during the specified period. A 21-year analysis period (1998 through 2018) was selected. The data used came only from wells that have at least 10 years of data within the 1998–2018 period. This period includes the dry periods of 2001–2002, 2007–2009, and 2012–2016; and wet periods of 1998–2000, 2005–2006, 2011, and 2017 that were as defined by water year types according to Sacramento River and San Joaquin River indices. If a statistically significant trend was observed, the Theil-Sen method was used to calculate the estimated slope of the trend line to quantify the decline or increase. The results of the analysis are presented in Figure 6-5. Appendix C, "Methods and Assumption," has more details.

The results of the 1998–2018 analysis were categorized by the slope and slope direction. Approximately 65 percent of wells statewide demonstrated a trend of declining groundwater levels. In the Central Valley, declining groundwater level trends were more prevalent and steeper in the south and less prevalent and gentler in the north.

There are several clusters of wells with steep declines of groundwater levels across the state during this period. Prominent declines occurred in the southeastern basins of the San Joaquin River Hydrologic Region, in the majority of the basins in the Tulare Lake Hydrologic Region, and along the western edge of the basins in the Sacramento River Hydrologic Region. In contrast, there is a notable increase in groundwater levels in the basins in the southeastern portion of the Sacramento River Hydrologic Region, in an area roughly overlying Sacramento County.

Figure 6-5 Statewide and Hydrologic Region Groundwater Level Trend Analysis Results (1998–2018)



Groundwater Level Changes

Groundwater level changes in a well, over a time period, are calculated by subtracting the measurement of an earlier time from that of a later time. Positive changes calculated in this manner indicate an increase or rise in groundwater levels, negative changes indicate a decrease or decline. When these calculated changes are displayed from many wells, they can show the regional recovery or depletion of an aquifer over a time period, such as a season, year, or several years.

Two different periods of spring data are used for analysis of the three-year (spring 2015–spring 2018) and eight-year (spring 2010–spring 2018) periods. These three-year and eight-year comparisons show the change in groundwater levels in wells across different hydrologic conditions. Figure 6-6 shows the difference in groundwater levels measured in spring 2015 and spring 2018 from 5,213 wells throughout the state. Figure 6-7 shows the difference in groundwater levels measured in spring 2010 and spring 2018 from 2,725 wells throughout the state.

Both maps include bar charts displaying the percentage of wells that experienced rises or declines in groundwater levels in each hydrologic region. The pie charts on the figures summarize groundwater level changes statewide. Table 6-1 provides a summary of the number and percentage of wells with groundwater level changes for 2015–2018 and 2010–2018).

Table 6-1 Summary of Groundwater Level Changes (2015–2018 and 2010–2018)

Period	Total wells compared	Wells with a decline of greater than 50 feet	Wells with a decline of 10–50 feet	Wells with a change of +/- 10 feet	Wells with a rise of 10–50 feet	Wells with a rise greater than 50 feet
2015–2018	5,213	0.8%	8.7%	72.9%	15.5%	2.1%
2010–2018	2,725	3.8%	21.3%	67.3%	6.8%	0.8%

Figure 6-6 Changes in Groundwater Levels (Spring 2015–Spring 2018)

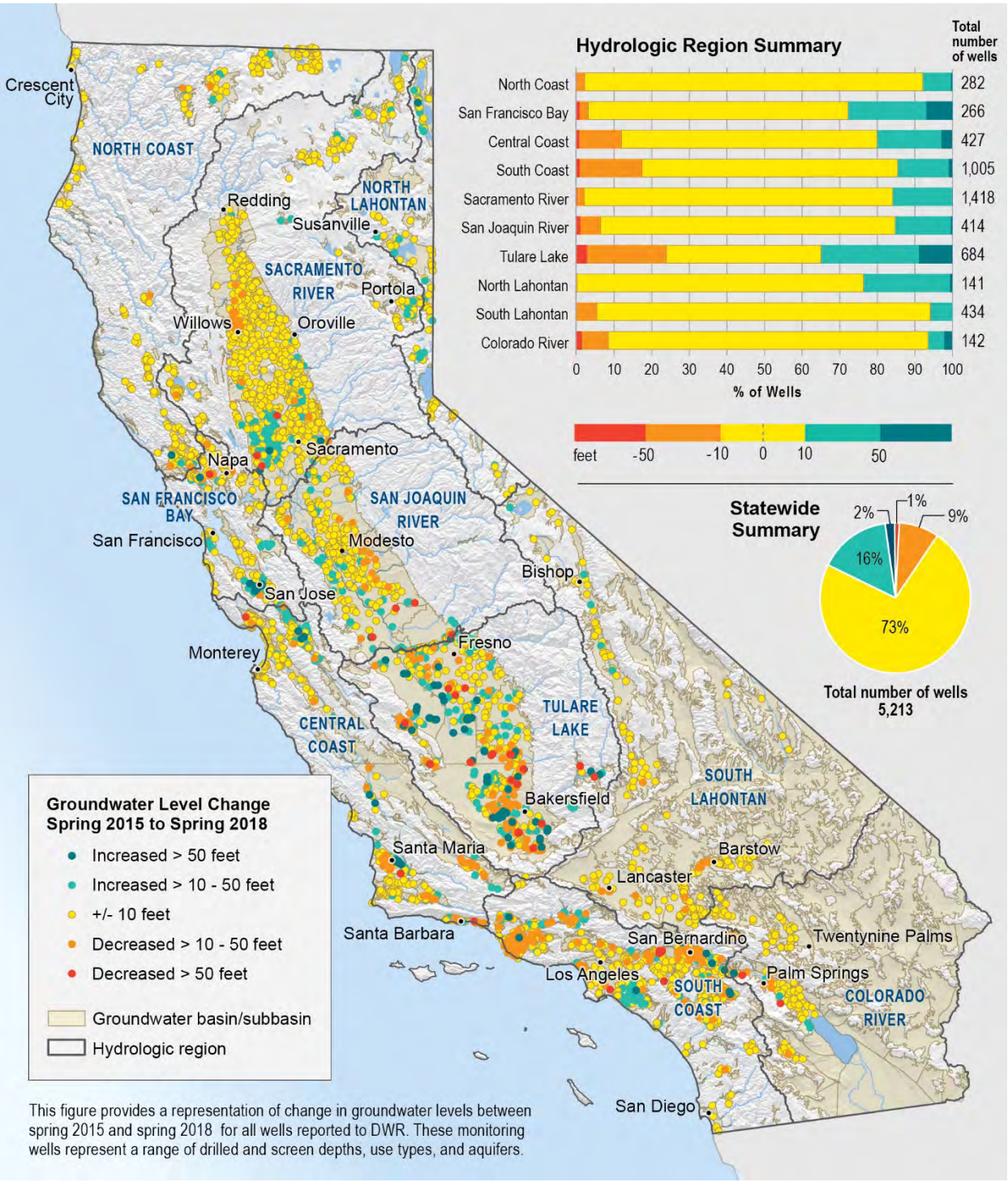


Figure 6-6 note: DWR = California Department of Water Resources

Figure 6-7 Changes in Groundwater Levels (Spring 2010–Spring 2018)

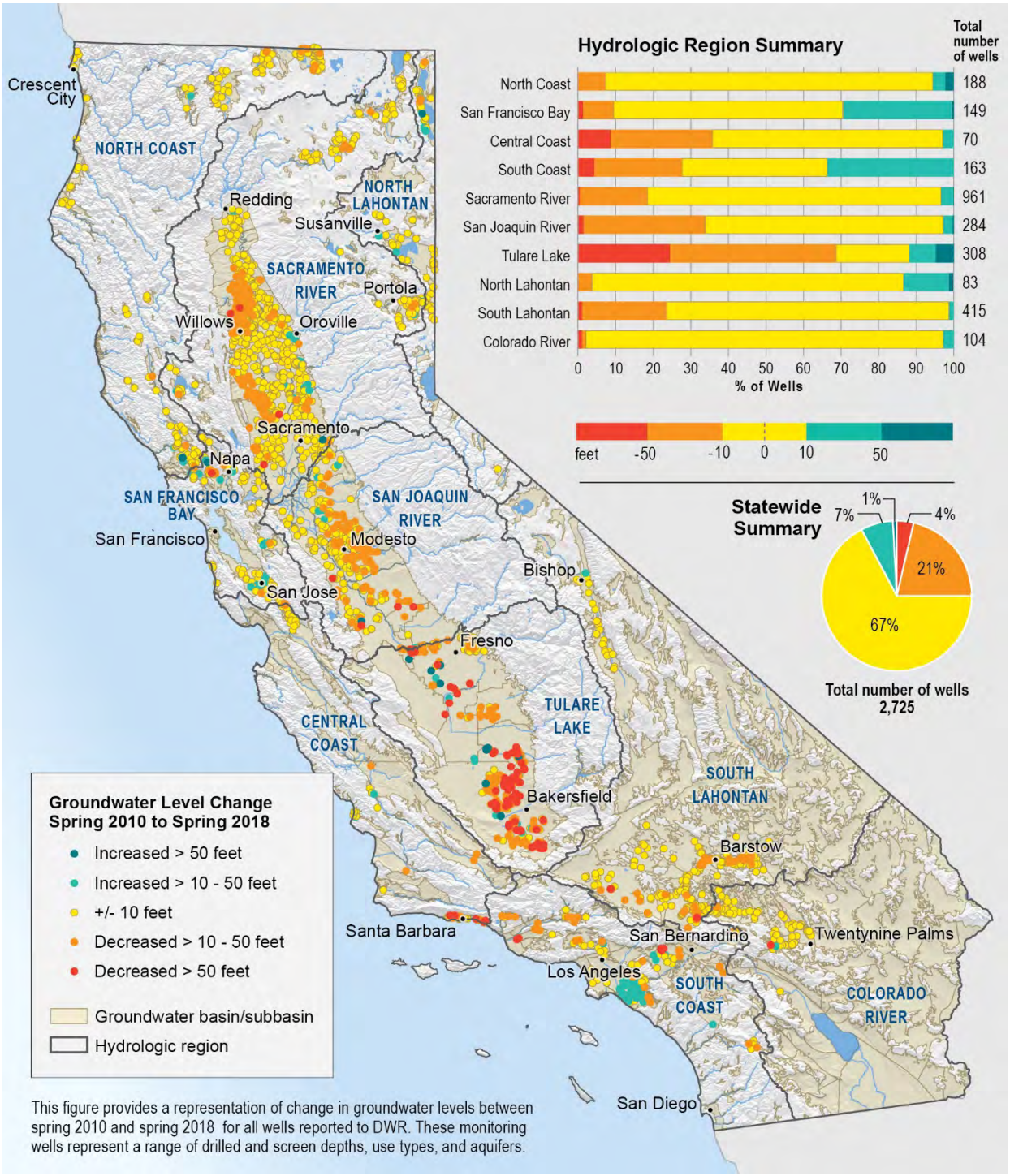


Figure 6-7 note: DWR = California Department of Water Resources

Figure 6-6 and Table 6-1 show that from 2015 through 2018, a period that included the 2012–2016 drought, 73 percent of monitoring wells showed little to moderate change (from -10 feet to +10 feet). Groundwater level rises of more than 10 feet occurred in nearly 16 percent of wells, with areas of recovering groundwater levels in the Sacramento River and San Francisco Bay hydrologic regions and recoveries within the Tulare Lake Hydrologic Region. Approximately 9 percent of wells showed groundwater level declines of more than 10 feet in wells in the Tulare Lake, South Coast, and Central Coast hydrologic regions.

Figure 6-7 and Table 6-1 shows that from 2010 through 2018, which covers the entire 2011–2016 drought, approximately 67 percent of monitoring wells show little (from -10 feet to +10 feet). The number of wells available to analyze for this period is fewer than the 2015–2018 period. The Tulare Lake Hydrologic Region shows the most groundwater level decline during the 2010–2018 period with approximately 68 percent of wells showing declines in groundwater levels. Most of the rises of groundwater levels, of as much as 50 feet, occurred along the coast, especially in the San Francisco Bay and South Coast hydrologic regions.

The three-year groundwater level analysis (2015–2018), spring 2018 groundwater levels generally show recovery from 2015, when most of the state experienced above average precipitation. The eight-year groundwater level changes (2010–2018) show a different story; data indicate that groundwater basins did not fully recover to levels measured in 2010 throughout most of the state.

Change in Stored Groundwater

Change in stored groundwater in a basin can be estimated using a broad range of techniques and tools. Some examples include numerical models, such as DWR's California Central Valley Groundwater-Surface Water Simulation Model (C2VSim) or the U.S. Geological Survey's (USGS's) Central Valley Hydrologic Model (CVHM); remote sensing, such as NASA's Gravity Recovery and Climate Experiment Program (also known as GRACE); or spreadsheet water balance accounting methods. The method described in this section uses groundwater level changes, the specific yield of the aquifer (the portion of a volume of unconfined aquifer that may store and release water to a well), and the use of geospatial tools to estimate the volumetric change in stored groundwater based on changes in groundwater levels. More details are provided in Appendix C, "Methods and Assumptions."

The change in stored groundwater estimates presented in this section represent the change in stored groundwater in the unconfined aquifer between two time periods in the three hydrologic regions within the Central Valley.

The change in groundwater level values were calculated for one-year periods from 2005 to 2018 using spring groundwater level measurements. For each time period, the groundwater elevation from the spring of earlier year was subtracted from the groundwater elevation of the spring of the subsequent year for each well. The values of groundwater elevation change were plotted spatially for each well. A geographic information system (GIS) program was used to interpolate a surface representing the change in groundwater elevation for the basin. This "change surface," along with the estimated specific yield, were used to estimate the change in stored groundwater.

Change in stored groundwater values were determined for each annual period from 2005 to 2018 by multiplying the area below the change surface area with two estimates of specific yield values, 0.07 and 0.17. This broad range of specific yield values is used to show a potential minimum and maximum annual change in groundwater volume. The specific yield values (0.07 and 0.17) are an approximation of the range of aquifer storage parameter for the unconfined aquifers in the Central Valley, based on aquifer-texture data from the DWR 2013 C2VSim and the USGS 2009 CVHM models.

The change in stored groundwater results provide insights into changes in aquifer conditions relating to recharge and discharge over time and are not meant to be used as an indicator of groundwater management practices. Change in stored groundwater estimates presented in this section are limited to the unconfined aquifer in the data reporting area within the Central Valley. Areas of the Central Valley without enough data to perform the calculations are considered non-reporting areas as shown in Figure 6-8.

Figure 6-8 displays the 2005 to 2018 change in stored groundwater reporting area used for this analysis. The reporting area includes 62 percent of the Central Valley (approximately 8.1 million acres). The reporting area represents the extent of the available groundwater-level-change data for the 2005–2018 annual datasets.

Figure 6-8 Central Valley Change in Stored Groundwater Reporting Area



Central Valley Change in Stored Groundwater Results

Table 6-2 provides the reporting area details for the Central Valley and each of the three hydrologic regions that cover the Central Valley. Annual change in stored groundwater results for the reporting area within the Central Valley, and the three hydrologic regions that cover the Central Valley, are presented in Table 6-3. Figure 6-9 displays the annual and cumulative change in stored groundwater for the reporting area within the Central Valley for Water Years 2006–2018. Although the

range of the changes in stored groundwater is broad, it is useful in comparing regional differences and trends over years.

On average, results for the Central Valley reporting area indicate an annual reduction in stored groundwater in the unconfined aquifer between 900 thousand acre-feet (taf) and 2,100 taf from 2006 to 2018. The largest annual recovery in stored groundwater occurred from 2016 to 2017, with an estimated recovery of 2,500 to 6,000 taf. The largest annual reduction in stored groundwater occurred from 2013 to 2014, with an estimated reduction of 3,600 to 8,700 taf. The total cumulative reduction in stored groundwater volume from 2006 to 2018 is between 11,200 and 27,200 taf.

Table 6-2 Reporting Area

Study Area	Central Valley Portion of HR (acres)	Reporting Area (acres)	Percentage of HR Area	Non-Reporting Area (acres)	Percentage of HR Area
Sacramento River HR	4,138,227	3,288,690	79%	849,538	21%
San Joaquin River HR	3,693,189	2,350,019	64%	1,343,170	36%
Tulare Lake HR	5,091,305	2,435,032	48%	2,656,272	52%
Central Valley	12,922,722	8,073,741	62%	4,848,980	38%

Table 6-2 notes: HR = hydrologic region
Only the Redding Area, Sacramento Valley, and San Joaquin Valley basins are included in the Central Valley area.

Table 6-3 Estimated Annual Change in Stored Groundwater for Reporting Area (2005–2018) (in thousand acre-feet)

Period: Spring–Spring	Sacramento River HR SY=0.07	Sacramento River HR SY=0.17	San Joaquin River HR SY=0.07	San Joaquin River HR SY=0.17	Tulare Lake HR SY=0.07	Tulare Lake HR SY=0.17	Central Valley (Total of 3 HRs) SY=0.07	Central Valley (Total of 3 HRs) SY=0.17
2005–2006	540	1,310	180	420	1,190	2,890	1,900	4,620
2006–2007	-1,000	-2,420	-450	-1,100	190	470	-1,250	-3,040
2007–2008	No Change	No Change	-70	-170	-2,620	-6,370	-2,690	-6,540
2008–2009	-400	-980	-560	-1,370	-1,310	-3,170	-2,270	-5,520
2009–2010	110	270	-80	-190	-420	-1,030	-390	-950
2010–2011	460	1,110	-120	-300	1,230	2,980	1,560	3,780
2011–2012	-500	-1,220	-220	-530	380	910	-350	-840
2012–2013	-430	-1,040	-540	-1,320	-2,190	-5,320	-3,160	-7,680
2013–2014	-430	-1,060	-850	-2,070	-2,280	-5,530	-3,560	-8,650
2014–2015	-280	-690	-840	-2,050	-1,460	-3,550	-2,590	-6,290
2015–2016	190	460	-650	-1,580	-590	-1,440	-1,060	-2,560

Period: Spring–Spring	Sacramento River HR SY=0.07	Sacramento River HR SY=0.17	San Joaquin River HR SY=0.07	San Joaquin River HR SY=0.17	Tulare Lake HR SY=0.07	Tulare Lake HR SY=0.17	Central Valley (Total of 3 HRs) SY=0.07	Central Valley (Total of 3 HRs) SY=0.17
2016–2017	1,080	2,620	740	1,790	650	1,570	2,460	5,980
2017–2018	-690	-1,690	-180	-440	1,070	2,610	200	480
Total	**-1,380**	**-3,340**	**-3,660**	**-8,880**	**-6,170**	**-14,980**	**-11,200**	**-27,210**
Annual Average	**-110**	**-260**	**-280**	**-680**	**-470**	**-1,150**	**-860**	**-2,090**

Table 6-3 notes: SY = specific yield
Some columns may not add up precisely because of numbers being rounded to the nearest 10 thousand acre-feet.

Figure 6-9 Central Valley Reporting Area Annual and Cumulative Change in Stored Groundwater (Water Years 2006–2018)



Figure 6-9 notes: SY = specific yield, TAF = thousand acre-feet

Change in Groundwater Volume Results in the Central Valley, by Hydrologic Region

Changes in stored groundwater are governed by the inputs and outputs of the groundwater budget for a basin. On a regional scale, many of the inputs and outputs of large groundwater basins, such as the Sacramento Valley and San Joaquin Valley, are often not measured or are difficult to calculate or obtain. But precipitation and surface water deliveries in a region provide insights into the changes of stored groundwater in a region.

Figures 6-10 through 6-12 display the annual and cumulative changes in groundwater volume estimates along with annual precipitation and surface water deliveries, respectively for the Sacramento River, San Joaquin River, and Tulare Lake hydrologic regions. Precipitation values were obtained from DWR's Sierra Nevada precipitation indices (California Department of Water Resources 2019a and 2019b), Water Year Hydrologic Classification Indices are provided by the California Cooperative Snow Surveys program. Surface water delivery values were obtained from the California Water Plan but are only available through Water Year 2015 (California Department of Water Resources 2018).

Figure 6-10A shows the Sacramento River Hydrologic Region precipitation (in inches), the average precipitation, water year type for each year, and the annual surface water supply for the region. As shown in Figure 6-10A, the precipitation ranged from approximately 30 to 95 inches, and surface water deliveries ranged from approximately 4,200 to 5,700 taf, for Water Years 2006–2015.

Figure 6-10B shows the water year type and the annual cumulative change in stored groundwater. The Sacramento River Hydrologic Region average annual change in stored groundwater ranges from -110 taf to -260 taf (Table 6-3 and Figure 6-10B). For Water Years 2006–2018, the Sacramento River Hydrologic Region's cumulative change in stored groundwater result is between -1,380 taf and -3,340 taf.

Figure 6-10 Sacramento River Hydrologic Region Reporting Area Annual Precipitation, Surface Water Deliveries, and Annual and Accumulated Change in Stored Groundwater (Water Years 2006–2018)



Figure 6-10 notes: SY = specific yield
Water year type is based on DWR's unimpaired runoff for the Sacramento Valley.
Surface water deliveries are only available for Water Years 2005–2015.
The 2006 change in stored groundwater results are calculated from 2005.

Figure 6-11A shows the San Joaquin River Hydrologic Region precipitation (in inches), the average precipitation, water year type for each year, and the annual surface water supply for the region. As shown in Figure 6-11A, the precipitation ranged from approximately 20 to 60 inches, and surface water deliveries ranged from approximately 1,900 to 4,500 taf, for Water Years 2006–2015.

Figure 6-11B shows the water year type and the annual cumulative change in stored groundwater. The San Joaquin River Hydrologic Region average annual change in stored groundwater ranges from -300 taf to -700 taf (Table 6-3 and Figure 6-11B). For Water Years 2006–2018, the San Joaquin River Hydrologic Region's cumulative change in stored groundwater result is between -3,660 taf and -8,880 taf.

Figure 6-12A shows the Tulare Lake Hydrologic Region precipitation (in inches), the average precipitation, water year type for each year, and the annual surface water supply for the region. As shown in Figure 6-12A, the precipitation ranged from approximately 12 to 48 inches, and surface water deliveries ranged from approximately 1,200 taf to 8,400 taf, for Water Years 2006–2015.

Figure 6-12B shows the water year type and the annual cumulative change in stored groundwater. The Tulare Lake Hydrologic Region average annual change in stored groundwater ranges from -470 taf to -1,150 taf (Table 6-3 and Figure 6-12B). From Water Years 2006–2018, the Tulare Lake Hydrologic Region's cumulative change in stored groundwater result is between -6,170 taf and -14,980 taf.

Figure 6-11 San Joaquin River Hydrologic Region Reporting Area Annual Precipitation, Surface Water Deliveries, and Annual and Accumulated Change in Stored Groundwater (Water Years 2006–2018)



Figure 6-11 notes: SY = specific yield
Water year type is based on the California Department of Water Resources' unimpaired runoff for the San Joaquin Valley.
Surface water deliveries are only available for Water Years 2005–2015.
The 2006 change in stored groundwater results are calculated from 2005.

Figure 6-12 Tulare Lake Hydrologic Region Annual Precipitation, Surface Water Deliveries, and Annual and Accumulated Change in Stored Groundwater (Water Years 2006–2018)

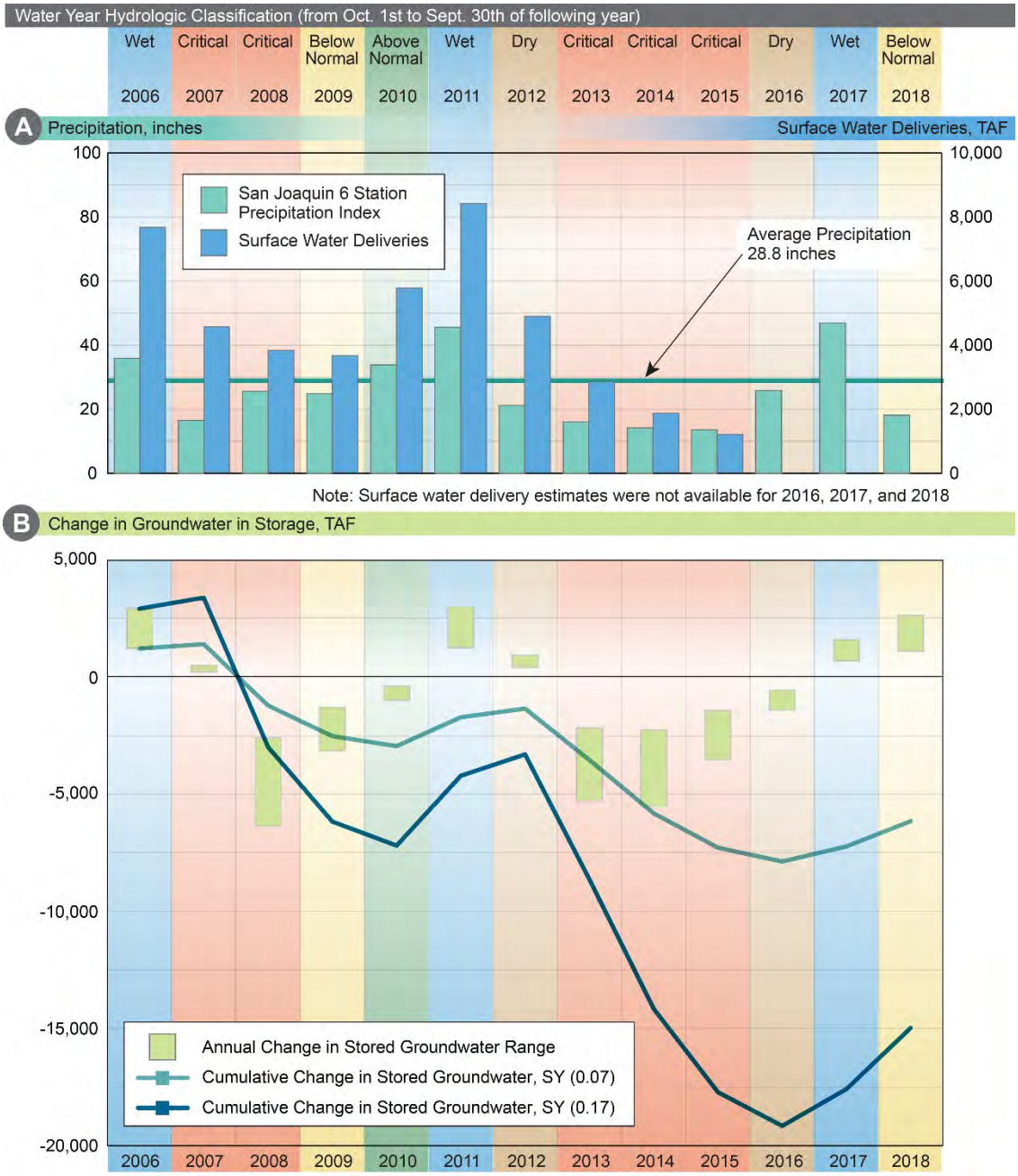


Figure 6-12 notes: SY = specific yield
Water year type is based on the California Department of Water Resources' unimpaired runoff for the San Joaquin Valley.
Surface water deliveries are only available for Water Years 2005–2015.
The 2006 change in stored groundwater results are calculated from 2005.

Groundwater Quality

Groundwater quality varies greatly in California's groundwater basins because of a broad range of natural and anthropogenic influences. Groundwater quality conditions can be assessed by collecting groundwater samples and comparing the results to a set of drinking water standards, such as the maximum contaminant level (MCL) set by the U.S. Environmental Protection Agency (EPA) and the California Office of Environmental Health Hazard Assessment (OEHHA). Groundwater quality trends can be assessed by comparing the data from one well to those of nearby wells, or by comparing the data over time from a single well. This report includes groundwater quality conditions information based on comparison of sample data with MCLs and secondary maximum contaminant levels (SMCLs).

Groundwater quality information is available from several sources, such as online data repositories for regulatory and voluntary programs, technical reports, or online tools. Links to many of these resources are provided in Appendix D, "Citations, Reference Materials, and Links."

Overall Groundwater Quality Conditions

The groundwater quality information available from the State Water Resources Control Board's (State Water Board's) Groundwater Ambient Monitoring and Assessment (GAMA) Program's groundwater information system is used to summarize groundwater quality conditions in California. As described in Chapter 5, "Groundwater Monitoring," the GAMA database includes raw groundwater quality sampling results (i.e., samples taken prior to treatment) from nearly 310,000 locations in the state. For this analysis, the State Water Board queried data from GAMA geographic information system. All data from water quality monitoring stations with water quality data from January 1, 2009, through December 31, 2018, was compiled into a dataset named "Statewide Groundwater Quality Data" (WQ Conditions dataset). Water quality monitoring stations in the GAMA system include dedicated monitoring wells as well as domestic, irrigation, municipal, and other supply wells that take water quality measurements. To conduct the water quality analysis based on baseline groundwater conditions, stations tagged as active contaminant investigations, active cleanup sites, or monitoring wells for permitted discharge sites such as gas station cleanups, hazardous site cleanups, and similar projects, were omitted from the dataset and analysis.

The WQ Conditions dataset contains groundwater quality sampling results from 28,006 water quality monitoring stations (Figure 6-13). Although the source dataset

Figure 6-13 Location of the Water Quality Monitoring Stations Statewide and by Hydrologic Region (2009–2018)

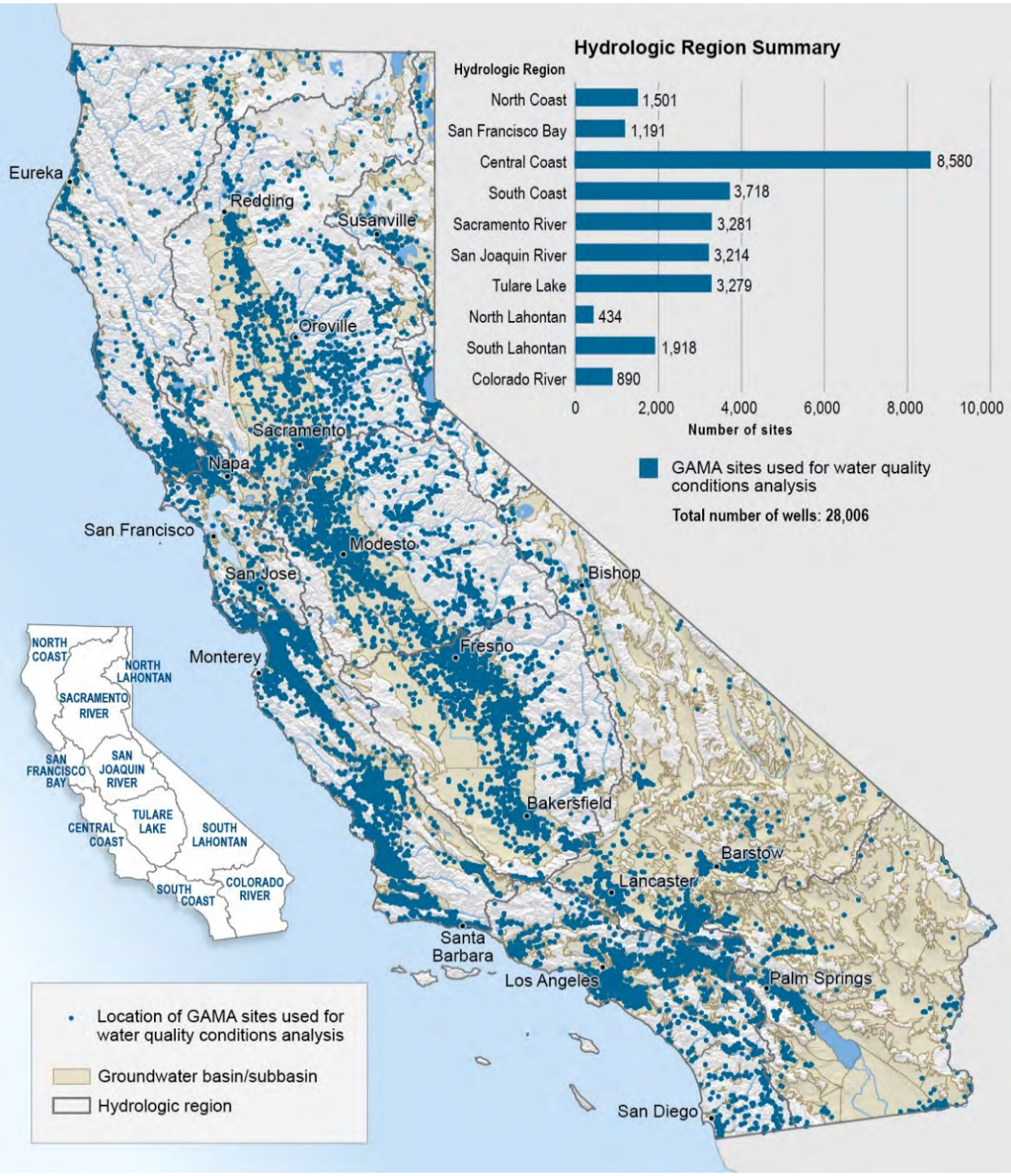


Figure 6-13 note: GAMA = State Water Resources Control Board's Groundwater Ambient Monitoring and Assessment Program

provides the most comprehensive statewide coverage available, the locations tend to be biased toward urban settings. This analysis reports on the quality of raw groundwater and does not indicate or predict the quality of water delivered as the water may be treated prior to delivery and use. For the groundwater quality sampling results, see the WQ Conditions dataset posted on the California Natural Resources Agency Open Data platform.

The results of the WQ dataset query are summarized below to provide a snapshot of overall groundwater quality conditions in California. Sampling results from the water quality monitoring stations were organized into three categories with reference to the corresponding MCL of the constituent:

- Low (results greater than 0 and up to half of the [S]MCL).
- Medium (results more than half the [S]MCL and up to the [S]MCL).
- High (results greater than [S]MCL).

Concentrations for Constituents of Concern

Five constituents of concern were selected for individual analysis to highlight statewide groundwater quality trends: 1,2,3-trichloropropane (1,2,3-TCP), nitrate as nitrogen (NO_3N), arsenic (As), uranium (U), and total dissolved solids (TDS).

- 1,2,3-TCP is a synthetic organic compound that was primarily used as a cleaning and degreasing agent. It was historically blended into pesticides. 1,2,3-TCP exposure has been demonstrated to cause cancer in laboratory animals. In 2009, OEHHA established a California-specific MCL of 0.005 micrograms per liter (State Water Resources Control Board 2019).
- Nitrate as nitrogen is an inorganic, water-soluble compound that is often associated with potentially fatal human health effects, such as methemoglobinemia (a cause of blue baby syndrome) (World Health Organization 2011). In 2009, OEHHA established a California-specific MCL of 10 milligrams per liter.
- Arsenic is an inorganic semi-metalloid that is present in the environment naturally and as a result of certain human activities, is a known human carcinogen (State Water Resources Control Board 2017a). OEHHA established a California-specific MCL of 10 micrograms per liter.
- Uranium is a radionuclide that occurs naturally in many geologic formations. In California, it is often associated with the granitic rocks of the Sierra Nevada and the Peninsular Ranges and their detritus. The most common uranium isotope, U-238, is only weakly radioactive; it is not considered to be a hazardous

radioactive substance but can function as a weak chemical poison in high concentrations (World Health Organization 2004a; State Water Resources Control Board 2017b). Uranium may also be associated with other radionuclides, such as gross alpha and gross beta radiation. OEHHA established a California-specific MCL of 20 picocuries per liter of air.

- TDS is the measure of all dissolved organic and inorganic substances in water, primarily minerals and salts. TDS is often used as a proxy for measuring water salinity and detecting seawater intrusion. Low TDS concentrations can give water a flat taste, which most people would dislike. Even though high TDS concentrations are not usually harmful to human health, they may limit the beneficial uses of groundwater by giving it a sour, bitter, or metallic taste, or by staining household fixtures and corroding pipes. A secondary MCL (SMCL) of 1,000 milligrams per liter was established for TDS based on these aesthetic effects. OEHHA established a California-specific secondary MCL (SMCL) of 1,000 milligrams per liter.

These constituents were selected based on known toxicity (1,2,3-TCP, NO_3N, As, and U), known effects to beneficial water use (TDS), and the geographic extent.

Table 6-4 lists the number of water quality monitoring stations tested for each constituent listed above within each hydrologic region and statewide. Table 6-5 provides the percentage of water quality monitoring stations with the same list of constituents detected at a maximum value greater than the MCL, out of the total number of stations sampled within each hydrologic region and statewide. In a separate analysis reviewing all constituents, Table 6-6 shows the five most frequently detected constituents for each hydrologic region and statewide that is determined by the highest percent of results that are above the MCL or SMCL.

Tables 6-7 through 6-11 provide the testing results of five selected constituents in terms of low, medium, and high categories, defined above, in each region and statewide. The percentage of high measurements was calculated by taking the number of water quality monitoring stations with measurements above the MCL or SMCL within the region divided by the number of water quality monitoring stations sampled in the region. The statewide percentage of high measurements is calculated the same way by using the statewide total of high measurements divided by the total number of statewide measurements.

Table 6-4 Number of Water Quality Monitoring Stations Tested by Constituent in Each Hydrologic Region and Statewide (2009–2018)

Hydrologic Region	1,2,3-TCP	NO_3N	As	U	TDS
North Coast	859	1,470	1,049	169	949
San Francisco Bay	800	1,170	926	234	885
Central Coast	1,597	7,458	2,043	692	7,538
South Coast	2,744	3,630	3,307	1,981	3,316
Sacramento River	1,836	3,257	2,307	694	2,177
San Joaquin River	1,856	3,191	2,240	1,038	2,088
Tulare Lake	2,266	3,242	2,557	1,115	2,618
North Lahontan	188	421	304	75	287
South Lahontan	939	1,845	1,629	624	1,477
Colorado River	504	835	711	320	735
Statewide	**13,589**	**26,519**	**17,073**	**6,942**	**22,070**

Table 6-4 notes: 1,2,3-TCP = 1,2,3-trichloropropane, As = arsenic, NO_3N = nitrate as nitrogen, TDS = total dissolved solids, U = uranium

Table 6-5 Percentage of Water Quality Monitoring Stations Exceeding Maximum Contaminant Level in Each Hydrologic Region and Statewide (2009–2018)

Hydrologic Region	1,2,3-TCP	NO_3N	As	U	TDS
North Coast	19%	1%	7%	0%	1%
San Francisco Bay	11%	3%	7%	0%	4%
Central Coast	12%	23%	8%	1%	15%
South Coast	11%	12%	3%	5%	7%
Sacramento River	16%	3%	10%	1%	1%
San Joaquin River	15%	7%	16%	17%	8%
Tulare Lake	23%	13%	12%	12%	2%
North Lahontan	17%	2%	14%	9%	0%
South Lahontan	12%	2%	15%	11%	3%
Colorado River	11%	2%	7%	7%	3%
Statewide	**15%**	**11%**	**9%**	**8%**	**8%**

Table 6-5 notes: 1,2,3-TCP = 1,2,3-trichloropropane, As = arsenic, NO_3N = nitrate as nitrogen, TDS = total dissolved solids, U = uranium

Table 6-6 Five Most Frequently Detected Constituent in Each Hydrologic Region and Statewide (2009–2018)

Hydrologic Region	1	2	3	4	5
North Coast	Mn	Fe	1,2,3-TCP	DBCP	As
San Francisco Bay	Mn	Fe	ClO_2	1,2,3-TCP	BRO_3
Central Coast	Fe	Mn	NO_3N	SC	DBCP
South Coast	Fe	Mn	NO_3N	1,2,3-TCP	ClO_4
Sacramento River	Mn	Fe	1,2,3-TCP	As	BRO_3
San Joaquin River	Mn	Fe	1,2,3-TCP	As	U
Tulare Lake	1,2,3-TCP	Fe	NO_3N	U	As
North Lahontan	DBCP	1,2,3-TCP	As	Fe	U
South Lahontan	As	Radon-222	Fe	1,2,3-TCP	Alpha
Colorado River	Fe	1,2,3-TCP	DBCP	Alpha	F
Statewide	**Fe**	**Mn**	**1,2,3-TCP**	**NO_3N**	**As**

Table 6-6 notes: 1,2,3-TCP = 1,2,3-trichloropropane, Alpha = gross alpha radionuclides, As = arsenic, BRO_3 = bromate, ClO_2 = chlorite, DBCP = dibromo chloropropane, F = fluorine, Fe = iron, ClO_4 = perchlorate, Mn = manganese, NO_3N = nitrate as nitrogen, SC = scandium

1,2,3-Trichloropropane

From January 1, 2009, through December 31, 2018, 13,589 water quality monitoring stations were tested for 1,2,3-TCP, of which 11,563 (approximately 85 percent) had concentrations of 1,2,3-TCP at or below the MCL of 0.005 micrograms per liter; 2,026 (15 percent) had detected concentrations of 1,2,3-TCP at levels above the MCL.

Water quality monitoring stations with 1,2,3-TCP concentrations above the MCL were identified in all hydrologic regions. Most of the affected monitoring stations are in the Tulare Lake, San Joaquin River, Sacramento River, and South Coast hydrologic regions. Figure 6-14 depicts the categorization, from high to low, of 1,2,3-TCP in wells throughout California. Table 6-7 depicts the categorization, from high to low, the number of water quality monitoring stations tested for 1,2,3-TCP within each hydrologic region and statewide.

Figure 6-14 1,2,3-TCP Concentrations Detected in Groundwater Based on Reported Water Quality Results from Water Quality Monitoring Stations (2009–2018)

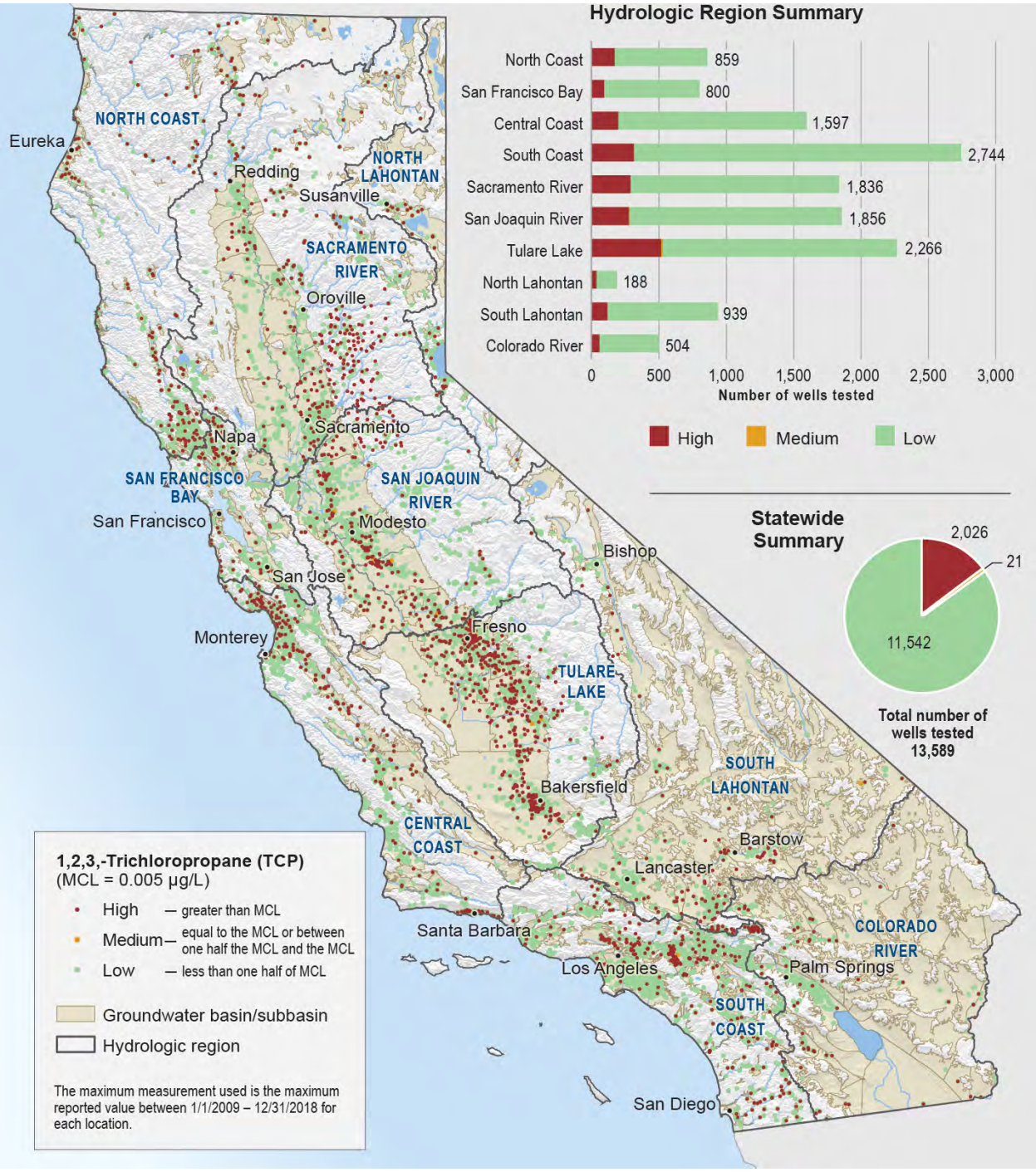


Figure 6-14 notes: µg/L = micrograms per liter, MCL = maximum contaminant level

Table 6-7 1,2,3-TCP Testing Results from Water Quality Monitoring Stations in Each Hydrologic Region and Statewide (2009–2018)

Hydrologic Region	Low	Medium	High	Percent High
North Coast	692	0	167	19.4%
San Francisco Bay	710	2	88	11.0%
Central Coast	1,403	0	194	12.1%
South Coast	2,433	2	309	11.3%
Sacramento River	1,551	0	285	15.5%
San Joaquin River	1,578	6	272	14.7%
Tulare Lake	1,743	10	513	22.6%
North Lahontan	156	0	32	17.0%
South Lahontan	825	1	113	12.0%
Colorado River	451	0	53	10.5%
Statewide	**11,542**	**21**	**2,026**	**14.9%**

Table 6-7 notes: 1,2,3-TPC = 1,2,3-Trichloropropane
Maximum contaminant level (MCL) = 0.005 micrograms per liter.
Low is less than half the MCL.
Medium is between half the MCL and the MCL.
High is more than the MCL.

Nitrate as Nitrogen

From January 1, 2009, through December 31, 2018, 26,519 water quality monitoring stations were tested for nitrate as nitrogen, of which 23,516 (88.7 percent) had concentrations of nitrate as nitrogen at or below the MCL of 10 milligrams per liter; 3,003 (11.3 percent) reported nitrate as nitrogen above the MCL.

Water quality monitoring stations with nitrate as nitrogen concentrations above the MCL were identified in all hydrologic regions. Most of the affected monitoring stations are in the Tulare Lake, San Joaquin River, Central Coast, and South Coast hydrologic regions. Figure 6-15 depicts the high, medium, and low concentration of nitrate as nitrogen detected in water quality monitoring stations throughout California. Table 6-8 depicts the categorization, from high to low, the number of water quality monitoring stations tested for nitrate as nitrogen within each hydrologic region and statewide.

Figure 6-15 Nitrate as Nitrogen Concentrations Detected in Groundwater Based on Reported Water Quality Results from Water Quality Monitoring Stations (2009-2018)

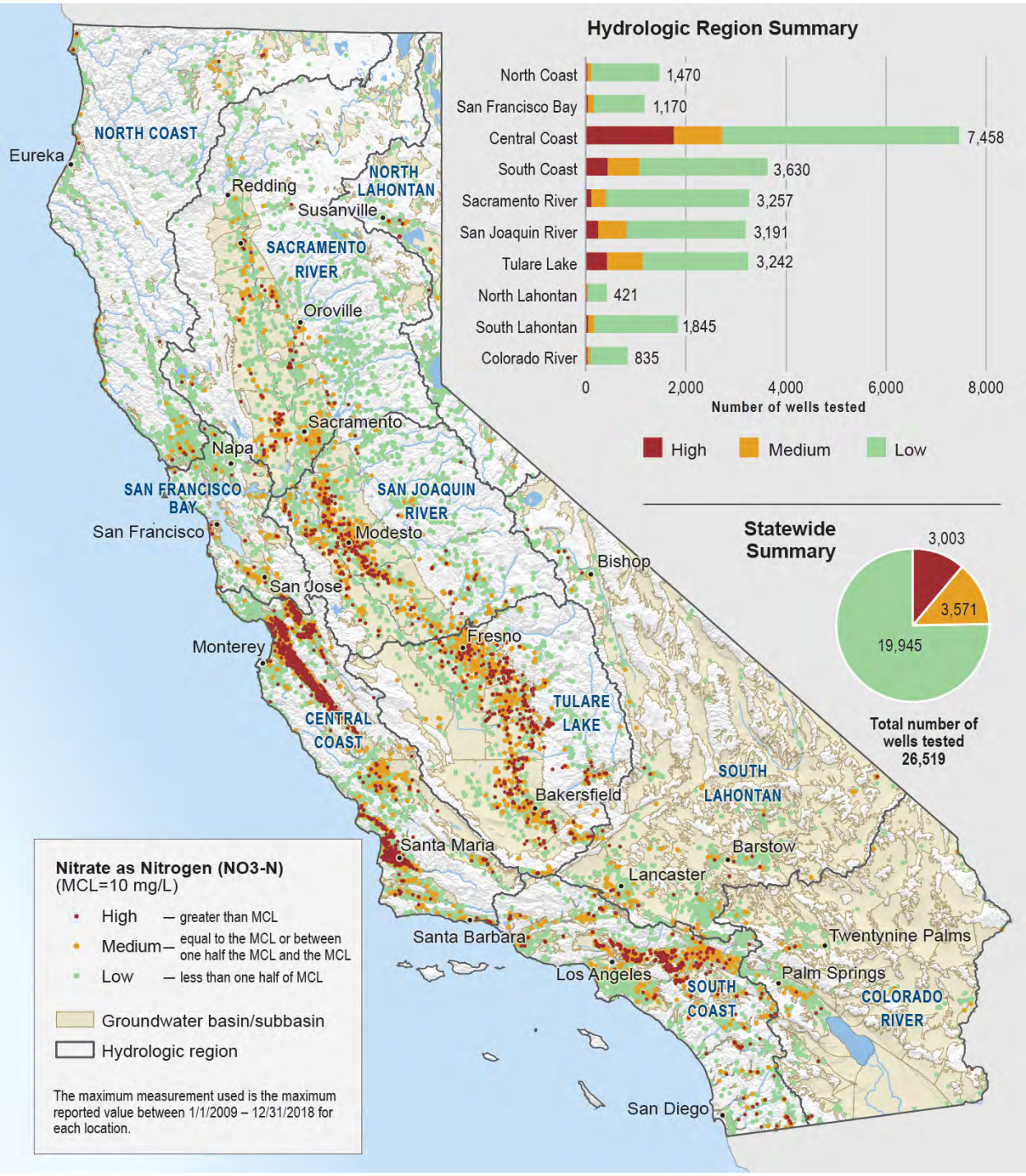


Figure 6-15 notes: MCL = maximum contaminant level, mg/L = milligrams per liter

Table 6-8 Nitrate as Nitrogen Testing Results from Water Quality Monitoring Stations in Each Hydrologic Region and Statewide (2009–2018)

Hydrologic Region	Low	Medium	High	Percent High
North Coast	1,379	73	18	1.2%
San Francisco Bay	1,025	116	29	2.5%
Central Coast	4,736	979	1,743	23.4%
South Coast	2,574	634	422	11.6%
Sacramento River	2,865	299	93	2.9%
San Joaquin River	2,393	564	234	7.3%
Tulare Lake	2,119	715	408	12.6%
North Lahontan	400	13	8	1.9%
South Lahontan	1,690	123	32	1.7%
Colorado River	764	55	16	1.9%
Statewide	**19,945**	**3,571**	**3,003**	**11.3%**

Table 6-8 notes: Maximum contaminant level (MCL) = 10 milligrams per liter.
Low is less than half the MCL.
Medium is between half the MCL and the MCL.
High is more than the MCL.

Arsenic

From January 1, 2009, through December 31, 2018, 17,073 water quality monitoring stations were tested for arsenic, of which 15,466 (approximately 91 percent) had concentrations of arsenic at or below the MCL of 10 micrograms per liter; 1,607 (approximately 9 percent) had detected concentrations of arsenic at levels above the MCL.

Water quality monitoring stations with arsenic concentrations above the MCL were identified in all hydrologic regions. Most of the affected monitoring stations are in the Sacramento River, San Joaquin River, Tulare Lake, and South Lahontan hydrologic regions. Figure 6-16 depicts the categorization, from high to low, of arsenic in water quality monitoring stations throughout California, while Table 6-9 depicts the categorization, from high to low, the number of water quality monitoring stations tested for arsenic within each hydrologic region and statewide.

Figure 6-16 Arsenic Concentrations Detected in Groundwater Based on Reported Water Quality Results from Water Quality Monitoring Stations (2009–2018)

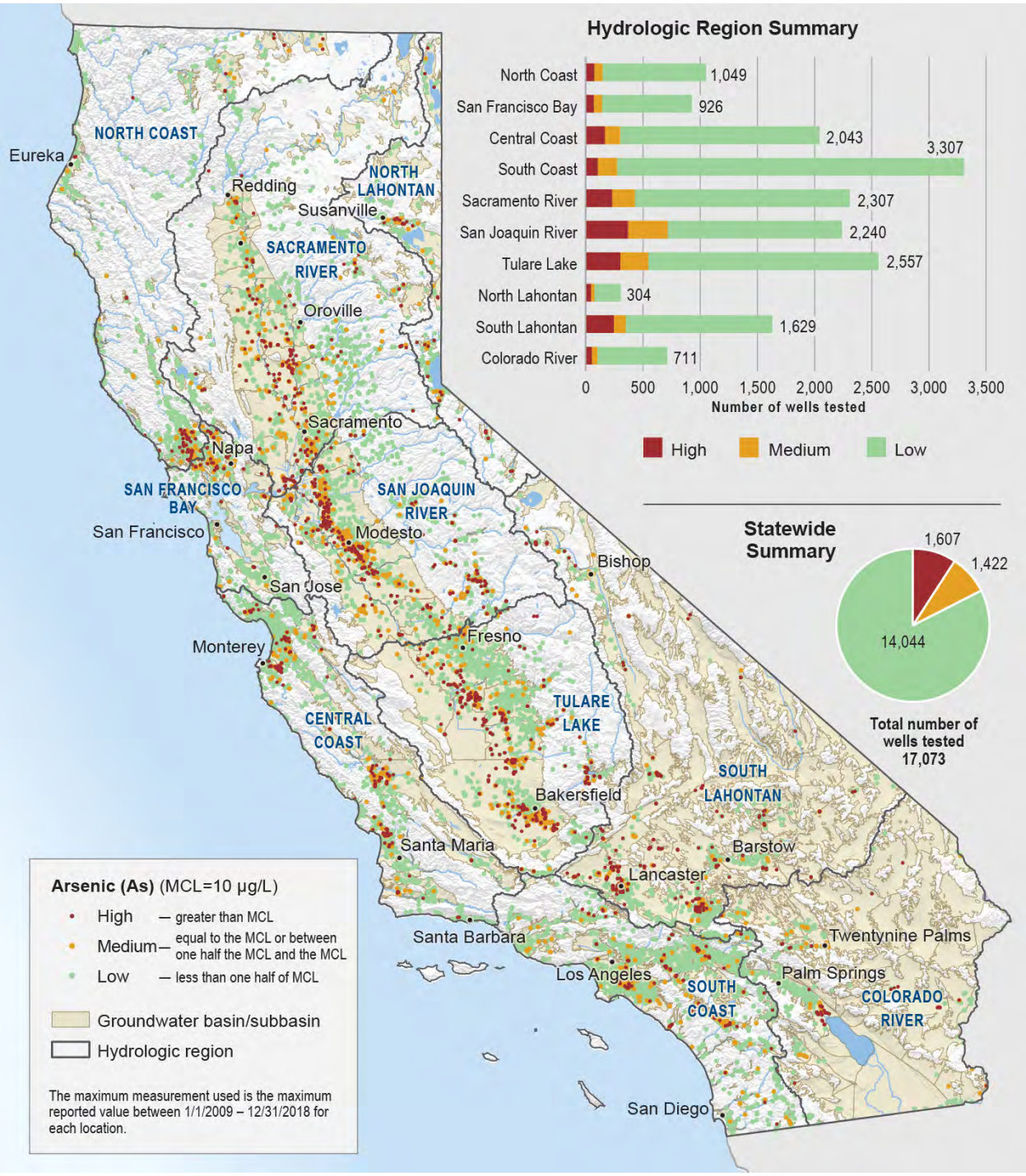


Figure 6-16 notes: µg/L = micrograms per liter, MCL = maximum contaminant level

Table 6-9 Arsenic Testing Results from Water Quality Monitoring Stations in Each Hydrologic Region and Statewide (2009–2018)

Hydrologic Region	Low	Medium	High	Percent High
North Coast	908	72	69	6.6%
San Francisco Bay	790	72	64	6.9%
Central Coast	1,743	138	162	7.9%
South Coast	3,039	169	99	3.0%
Sacramento River	1,883	199	225	9.8%
San Joaquin River	1,531	345	364	16.3%
Tulare Lake	2,015	246	296	11.6%
North Lahontan	233	30	41	13.5%
South Lahontan	1,286	103	240	14.7%
Colorado River	616	48	47	6.6%
Statewide	**14,044**	**1,422**	**1,607**	**9.4%**

Table 6-9 notes: Maximum contaminant level (MCL) = 10 micrograms per liter.
Low is less than half the MCL.
Medium is between half the MCL and the MCL.
High is more than the MCL.

Uranium

From January 1, 2009, through December 31, 2018, 6,942 water quality monitoring stations were tested for uranium, of which 6,409 (approximately 92 percent) contained no or detected concentrations of uranium at or below the MCL of 20 picocuries per liter of air; 533 (approximately 8 percent) had detected concentrations of uranium at levels above the MCL.

Water quality monitoring stations with uranium concentrations above the MCL were identified in all hydrologic regions. Most of the affected monitoring stations are in the South Coast, San Joaquin, and Tulare Lake hydrologic regions. Figure 6-17 depicts the categorization, from high to low, of uranium in water quality monitoring stations throughout California. Table 6-10 depicts the categorization, from high to low, of the number of water quality monitoring stations tested for uranium within each hydrologic region and statewide.

Figure 6-17 Uranium Concentrations Detected in Groundwater Based on Reported Water Quality Results from Water Quality Monitoring Stations (2009–2018)

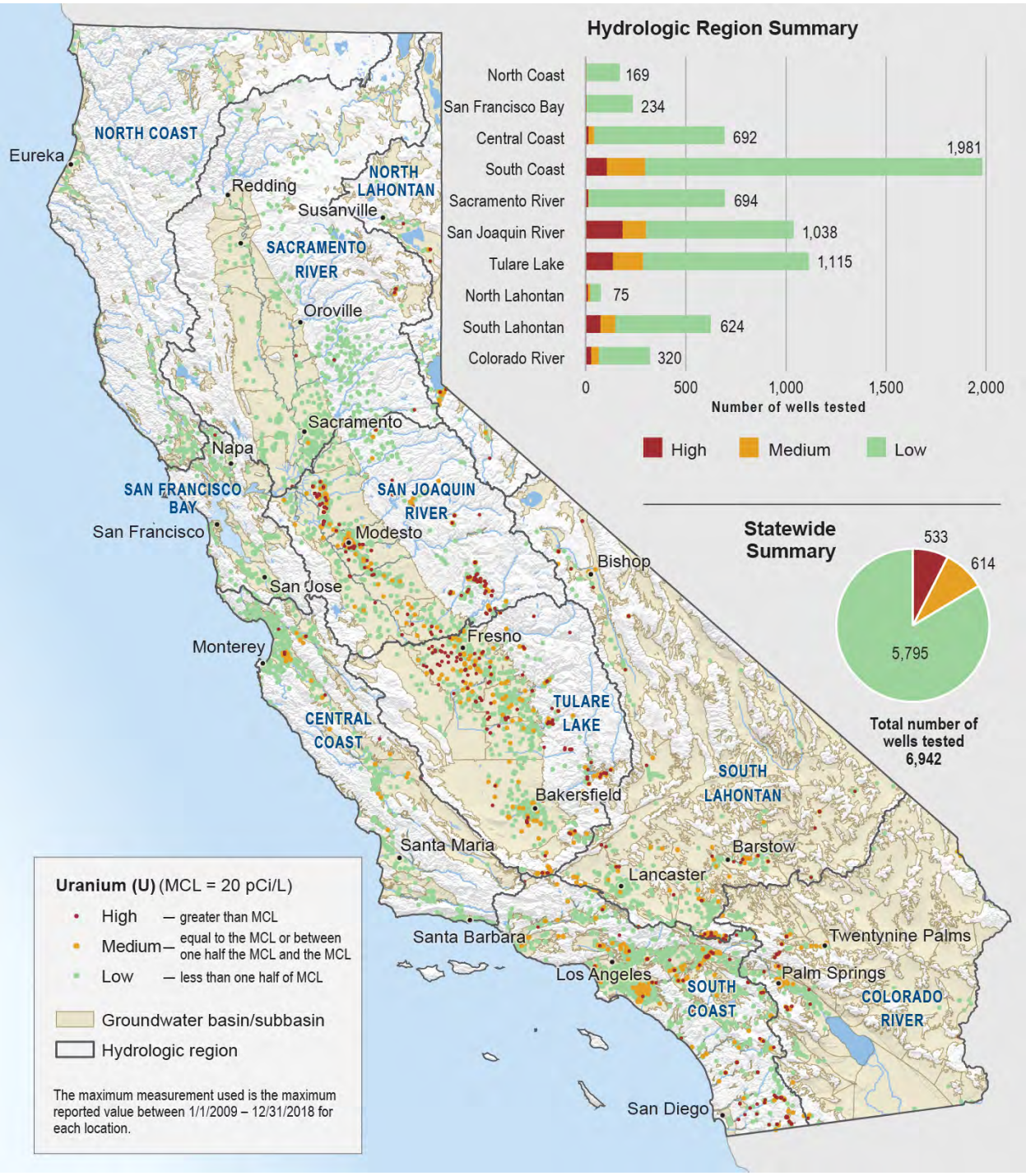


Figure 6-17 notes: pCi/L = picocuries per liter of air, MCL = maximum contaminant level

Table 6-10 Uranium Testing Results from Water Quality Monitoring Stations in Each Hydrologic Region and Statewide (2009–2018)

Hydrologic Region	Low	Medium	High	Percent High
North Coast	169	0	0	0.0%
San Francisco Bay	233	0	1	0.4%
Central Coast	651	31	10	1.4%
South Coast	1,689	191	101	5.1%
Sacramento River	683	3	8	1.2%
San Joaquin River	741	117	180	17.3%
Tulare Lake	833	149	133	11.9%
North Lahontan	56	12	7	9.3%
South Lahontan	481	73	70	11.2%
Colorado River	259	38	23	7.2%
Statewide	**5,795**	**614**	**533**	**7.7%**

Table 6-10 notes: Maximum contaminant level (MCL) = 20 picocuries per liter of air.
Low is less than half the MCL.
Medium is between half the MCL and the MCL.
High is more than the MCL.

Total Dissolved Solids

From January 1, 2009, through December 31, 2018, 22,070 water quality monitoring stations were tested for TDS, of which 20,321 (approximately 92 percent) contained no detected concentrations of TDS at or below the SMCL of 1,000 milligrams per liter; 1,749 (approximately 8 percent) had detected concentrations of TDS at levels above the SMCL.

Water quality monitoring stations with TDS concentrations above the SMCL were identified in all hydrologic regions. Most of the affected monitoring stations are in the Central Coast, South Coast, San Joaquin River, and Tulare Lake hydrologic regions. Figure 6-18 depicts the categorization, from high to low, of TDS in water quality monitoring stations throughout California. Table 6-11 depicts the categorization, from high to low, of the number of water quality monitoring stations tested for uranium within each hydrologic region and statewide.

Figure 6-18 Total Dissolved Solids Concentrations Detected in Groundwater Based on Reported Water Quality Results from Water Quality Monitoring Stations (2009–2018)

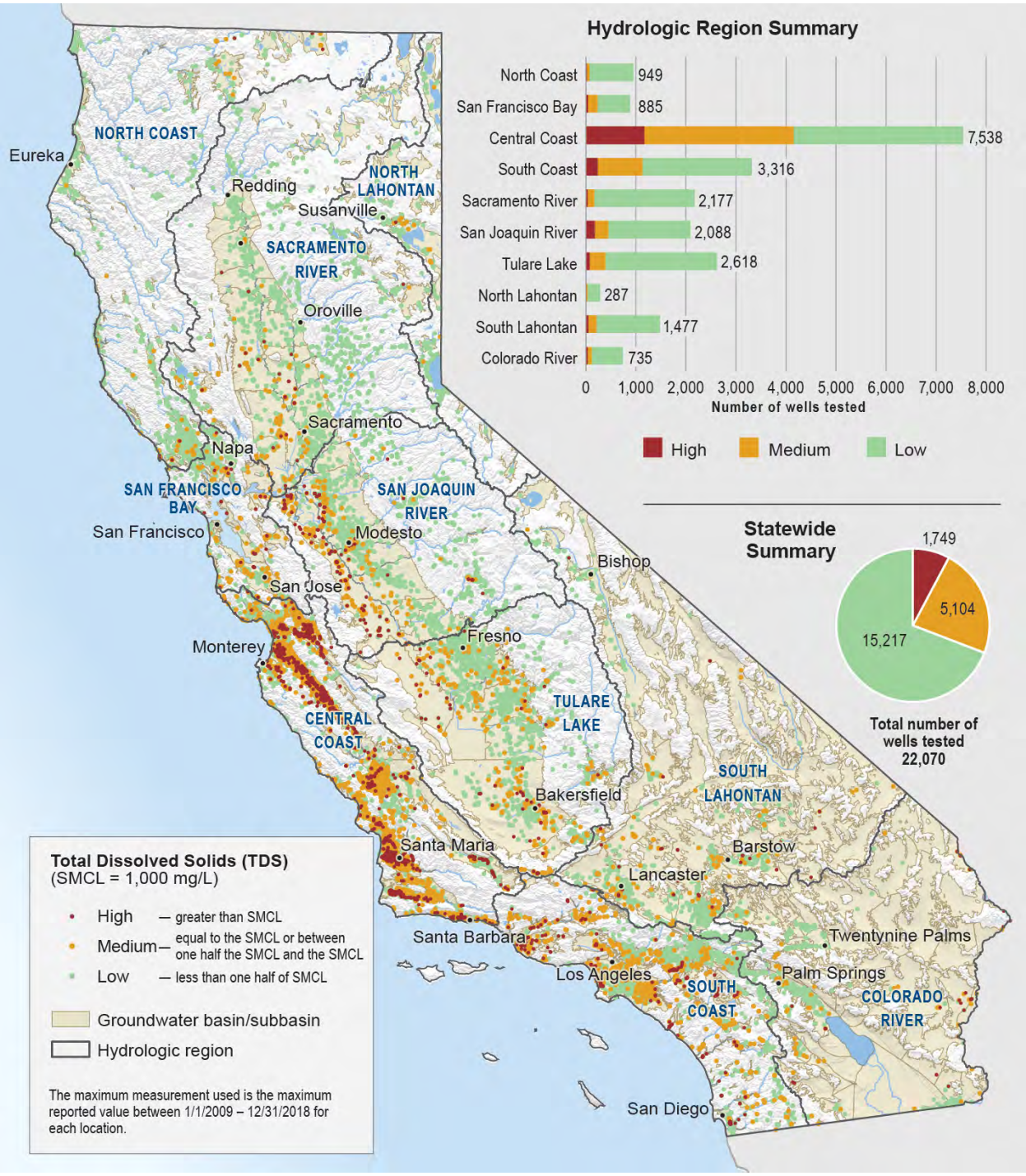


Figure 6-18 notes: mg/L = milligrams per liter, SMCL = secondary maximum contaminant level

Table 6-11 Total Dissolved Solids Testing Results from Water Quality Monitoring Stations in Each Hydrologic Region and Statewide (2009–2018)

Hydrologic Region	Low	Medium	High	Percent High
North Coast	888	52	9	0.9%
San Francisco Bay	663	190	32	3.6%
Central Coast	3,388	2,991	1,159	15.4%
South Coast	2,198	891	227	6.8%
Sacramento River	2,020	131	26	1.2%
San Joaquin River	1,650	270	168	8.0%
Tulare Lake	2,239	315	64	2.4%
North Lahontan	267	19	1	0.3%
South Lahontan	1,276	163	38	2.6%
Colorado River	628	82	25	3.4%
Statewide	**15,217**	**5,104**	**1,749**	**7.9%**

Table 6-11 notes: Secondary maximum contaminant level (SMCL) = 1,000 milligrams per liter.
Low is less than half the SMCL.
Medium is between half the SMCL and the SMCL.
High is more than the SMCL.

Land Subsidence

Recent instances of land subsidence have occurred primarily in the Tulare Lake and San Joaquin hydrologic regions with the largest areas of negative elevation change measured in the Tulare Lake Hydrologic Region. Interferometric synthetic aperture radar (InSAR) data gathered from June 2015 through June 2018 show that more than 2,000 square miles in the Tulare Lake Hydrologic Region experienced a decrease in elevation ranging from 0.25 foot (3 inches) to 3 feet (TRE Altamira Inc 2019). In contrast to the widespread land subsidence observed in the Tulare Lake Hydrologic Region, approximately 7 square miles of area experienced an increase in elevation ranging from 0.25 foot (3 inches) to 0.5 foot (6 inches).

The second-largest area of land subsidence was measured in the San Joaquin River Hydrologic Region, where nearly 900 square miles experienced a decrease in elevation ranging from 0.25 foot (3 inches) to 2.25 feet (TRE Altamira Inc 2019). Subsidence was also observed over 25 square miles of area in the Sacramento River Hydrologic Region, with decreases in elevation ranging from 0.25 foot (3 inches) to 0.75 foot (9 inches). In the Central Coast Hydrologic Region, approximately 1-square-mile experienced 0.25 foot (3 inches) to 0.5 foot (6 inches) of subsidence.

The remaining six hydrologic regions did not experience subsidence of more than 0.25 foot (3 inches) from June 2015 through June 2018 (TRE Altamira Inc 2019). The InSAR data are summarized in Table 6-12 and Figure 6-19.

The results of the InSAR study are consistent with data collected by the continuous global positioning system (CGPS) stations from 2015 through 2018. Two CGPS stations located in the Tulare Lake Hydrologic Region (CRCN and LEMA stations) recorded subsidence values of as much as 3 feet during this period. These two stations have also measured large subsidence values over the last decade. At the north end of the city of Corcoran, the CRCN station recorded 6.0 feet of subsidence from 2010 through 2018, while the LEMA station, west of the city of Hanford, recorded 5.6 feet of subsidence from 2005 through 2018.

Three other CGPS stations, CHOW (southeast of the city of Chowchilla), MULN (southeast of the city of San Joaquin), and P-056 (city of Porterville) recorded more than 2 feet of subsidence during the last 15 years. Figure 6-19 shows the total observed subsidence at each CGPS station during each station's period of record and highlights stations with 1 foot or more of observed subsidence.

Figure 6-19 Summary of InSAR and CGPS Station Land Subsidence Data (2015-2018)

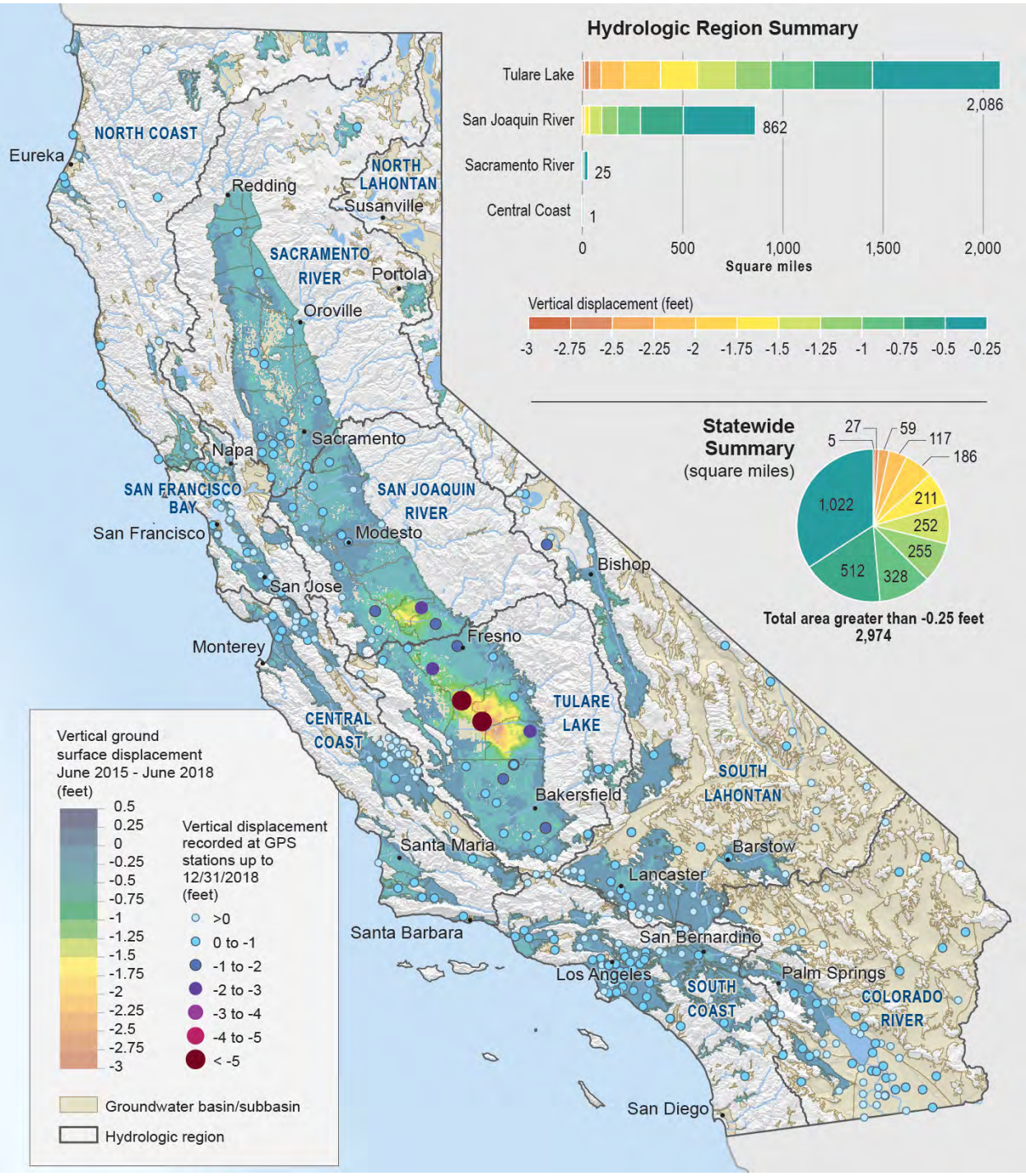


Figure 6-19 notes: CGPS = continuous global positioning system, GPS = global positioning system, InSAR = interferometry synthetic aperture radar

Table 6-12 Land Subsidence – InSAR Coverage in Square Miles by Hydrologic Region (HR) and Measured Vertical Displacement (2015–2018)

Vertical Displacement (feet)	Central Coast HR	Sacramento River HR	San Joaquin River HR	Tulare Lake HR
< -0.5 to -0.25	1	22	360	639
< -0.5 to -0.75	-	3	215	294
< -0.75 to -1.0	-	-	114	214
< -1.0 to -1.25	-	-	79	176
< -1.25 to -1.5	-	-	61	191
< -1.5 to -1.75	-	-	27	184
< -1.75 to -2.0	-	-	5	181
< -2.0 to -2.25	-	-	1	116
< -2.25 to -2.5	-	-	-	59
< -2.5 to -2.75	-	-	-	27
< -2.75 to -3.0	-	-	-	5
Square Miles Greater than -0.25 feet	**1**	**25**	**862**	**2,086**

Table 6-12 notes: InSAR = Interferometric Synthetic Aperture Radar
Total data coverage varies by hydrologic region and does not cover all basins.

Groundwater and Surface Water Interaction

Groundwater and surface water interaction in every basin is unique. The evaluation of the interaction is done at the local level with data collection and models. Because many of the past studies and monitoring have been done locally, statewide information is not available to DWR for inclusion in this 2020 update.

Seawater Intrusion

As with groundwater and surface water interaction, every basin is unique. The evaluation of seawater intrusion can only be done with local studies involving data collection, monitoring, and modeling. Because many of the past studies and monitoring are done locally, statewide information is not available to DWR for inclusion in this 2020 update.

Chapter 7
Groundwater at a Glance: Hydrologic Region Summaries

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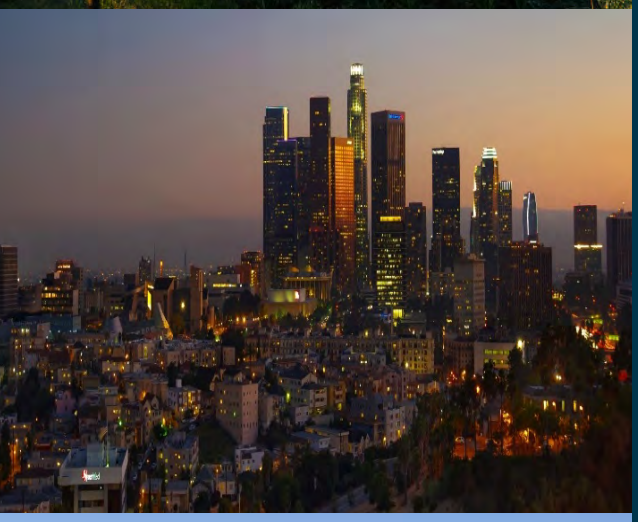
Colorado River 7-94

Figure 7-1: *California Hydrologic Regions*











Introduction

Chapter 7 provides groundwater information for each of California's 10 hydrologic regions (HR). The goal of the regional summaries is to provide "groundwater at a glance," a snapshot of data, figures, and information at the HR scale. These regional summaries include an overview of demographics, groundwater and land use, groundwater management, well infrastructure, groundwater levels, groundwater quality, local assistance and local projects. Each summary concludes with a map of each HR and list of basins required and with the option to develop a groundwater sustainability plan (GSP) under the Sustainable Groundwater Management Act (SMGA). The Summaries include information presented in Chapters 1 through 6 along with additional region-specific information. For more information about the datasets or methods used in this chapter please see Appendix C, Methods and Assumptions.

The summaries include a series of infographics, figures and data that were designed for informational purposes only. For example, each summary explores groundwater quality using sampling results submitted to the State Water Resources Control Board. These sample results are presented in relation to regulatory limits such as maximum contaminant levels (MCLs) or secondary MCLs (SMCLs) but are not a summary of any ongoing regulatory actions. Additionally, each summary includes two region-specific pages which highlight one of the six SGMA sustainability indicators and a local project. Information included on the region-specific pages was chosen through coordination with DWR's Regional Offices to highlight interesting and unique activities occurring in each region. Inclusion of a sustainability indicator is not judgment on the sustainability of any groundwater basin and inclusion of a specific project is not an endorsement by DWR.

While the regional summaries include a lot of information, some topics such as climate change, water available for recharge, and water markets are not included. Information on these topics can be found in Chapters 1 through 6. For information on potential climate change effects in each HR please see the recently released *California Water Resilience Portfolio*.

Groundwater at a Glance:
North Coast Hydrologic Region



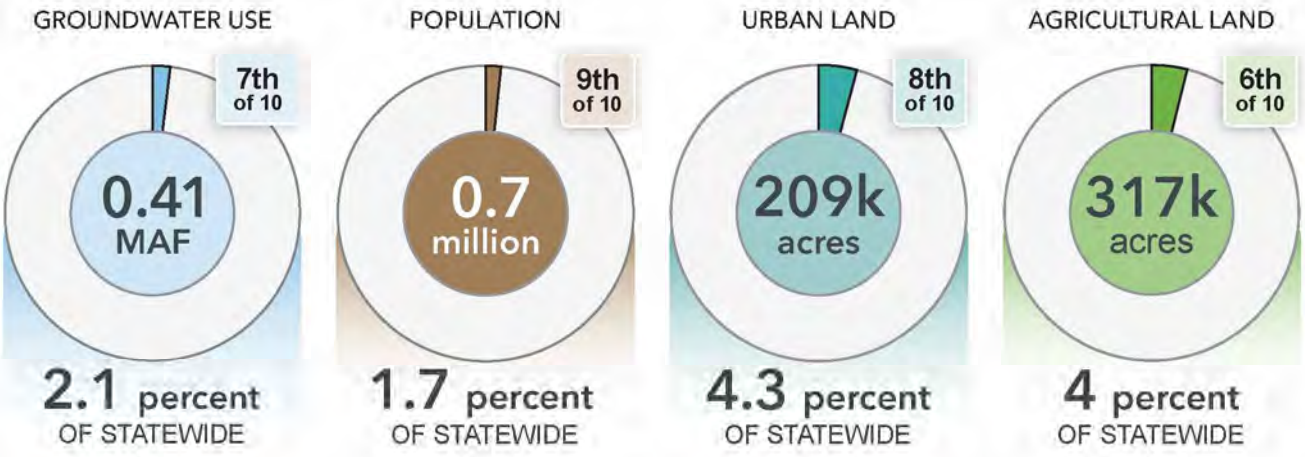
The North Coast Hydrologic Region (HR) encompasses approximately 19,000 square miles, including 340 miles of scenic coastline and remote wilderness areas. The region includes coastal areas, redwood forests, inland mountain valleys, and the semi-desert-like Modoc Plateau. About half of the region is protected federal lands including the Klamath, Modoc, and Six River national forests and Lava Beds and Redwood national parks. The region is the wettest in California, with some areas averaging more than 100 inches of precipitation per year. The average annual runoff is 29 million acre-feet (maf), which amounts to 40 percent of the state's total natural runoff. The region is home to 690,000 people and many tribal lands.



The Van Duzen River in Humboldt County.

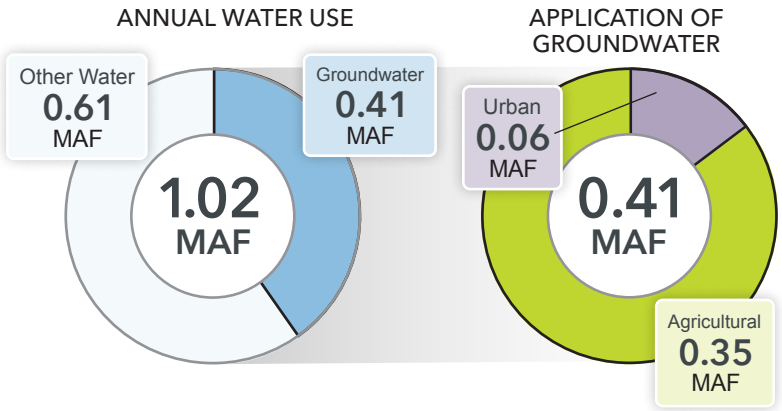
The North Coast Hydrologic Region accounts for two percent of all groundwater use in the state, averaging approximately 0.41 maf annually for agricultural and urban use. Overall water supplies in the region are almost evenly split between groundwater and surface water sources.

There are 65 groundwater basins in the region, seven of which are required to submit a GSP under SGMA.



North Coast Hydrologic Region Land and Water Use

The North Coast HR uses an average of 1.02 maf of water annually, 2 percent of California's total water use. Groundwater accounts for 40 percent of the region's water supply and 2 percent of statewide groundwater use.



Map of General Land Use



Groundwater Use

Groundwater use in the region is largely driven by agriculture. About 85 percent (0.35 maf) of the groundwater applied in the region is used for agricultural purposes. The remaining 15 percent of groundwater (0.06 maf) supports urban water demands from the 690,000 residents who live in the region.

Land Use

The region is largely rural and undeveloped. It has one of the smallest urban footprints in the state with only 210,000 acres of developed land. The four largest cities in the region are Eureka, Ukiah, Fortuna, and Yreka. About 4 percent of the state's agricultural lands are located in the region, totaling about 320,000 acres.

Did you know? The North Coast HR receives more precipitation than any other region in the state. Climate change may increase the likelihood of extreme weather events, yielding shorter wet seasons with more intense storms. These events may decrease the reliability of surface water supplies.

Total Urban Area: 208,823 Acres

Top 4 Cities by Population (2010):
- Santa Rosa (167,000)
- Rohnert Park (41,000)
- Eureka (27,000)
- Windsor (27,000)

Total Agricultural Area: 317,203 Acres

Top 4 Crops by Acreage (2016):
- Mixed Pasture (128,000)
- Alfalfa and Alfalfa Mix (66,000)
- Grapes (63,000)
- Miscellaneous Grain and Hay (29,000)

North Coast Hydrologic Region Groundwater Management

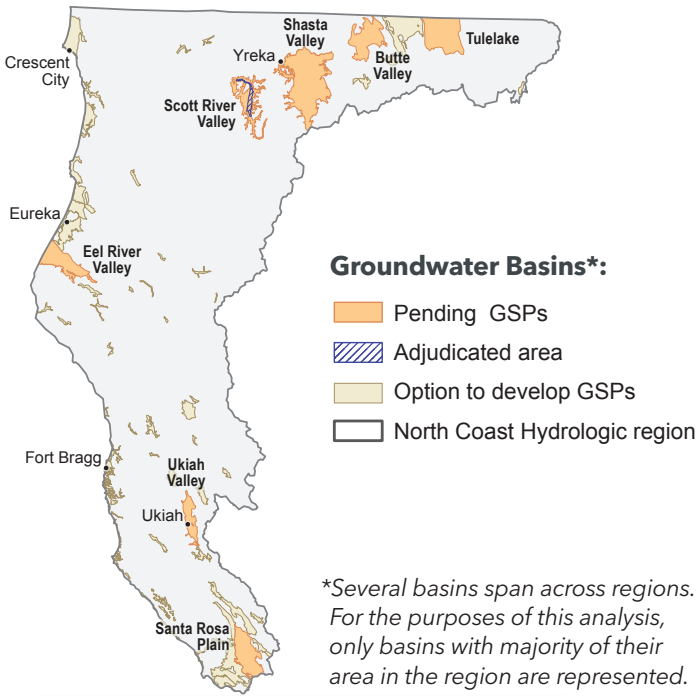
BASINS REQUIRING GSPs	BASINS WITH ADJUDICATED AREAS	APPROVED ALTERNATIVE GSPs
7	1	0
CRITICALLY OVERDRAFTED BASINS	**GROUNDWATER SUSTAINABILITY AGENCIES**	**GSPs SUBMITTED BY 01/31/2020**
0	11	0

Groundwater Management

Seven basins within the North Coast Hydrologic Region are required by SGMA to submit Groundwater Sustainability Plans (GSPs) by January 31, 2022. Eleven Groundwater Sustainability Agencies have been formed within these seven basins. As of January 31, 2020, no GSPs have been submitted to DWR for review. There are no approved Alternative GSPs in the region.

No basins in the region have been designated as critically overdrafted. One adjudicated area is located in the Scott River Valley Basin.

SGMA Groundwater Management Status



**Several basins span across regions. For the purposes of this analysis, only basins with majority of their area in the region are represented.*

CASGEM Monitoring

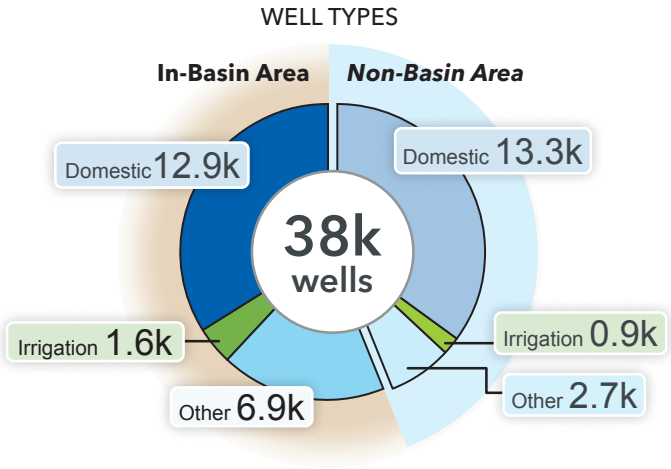
Twenty-seven (27) basins in the region not required to develop GSP are actively participating in the California Statewide Groundwater Elevation Monitoring (CASGEM) program. Within these basins, biannual groundwater level measurements are collected and posted on the CASGEM online system. Measurements are collected voluntarily by private individuals, academic institutions, conservation districts and local, state, and federal entities.

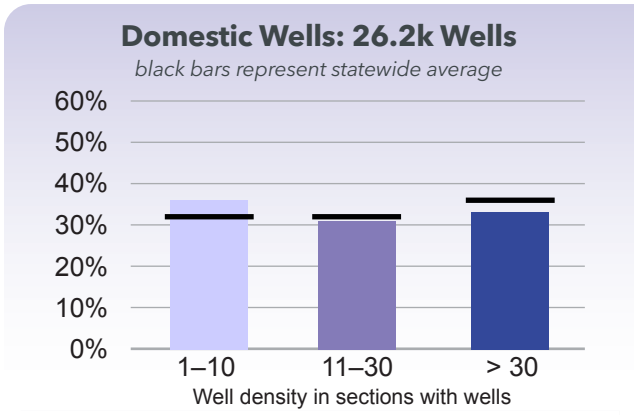


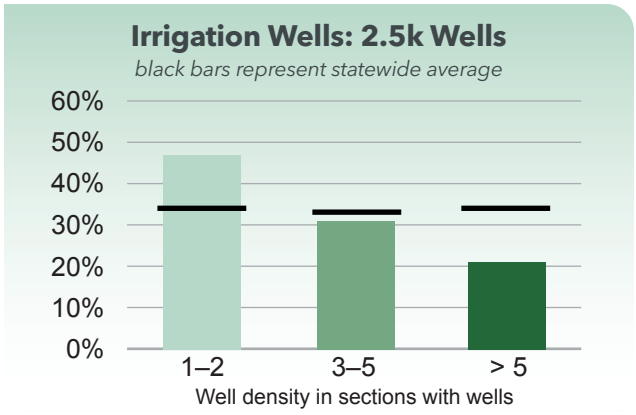
Agricultural well used for groundwater level monitoring in the North Coast HR.

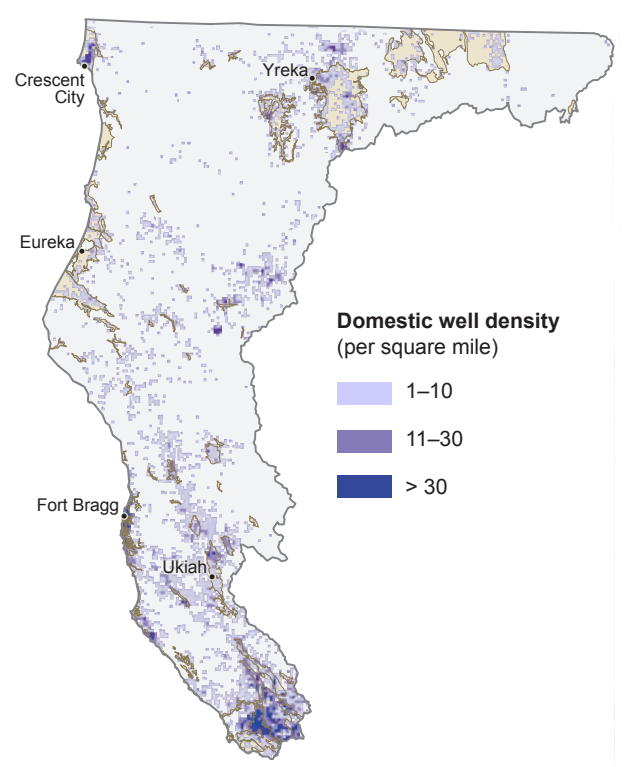
North Coast Hydrologic Region Well Infrastructure

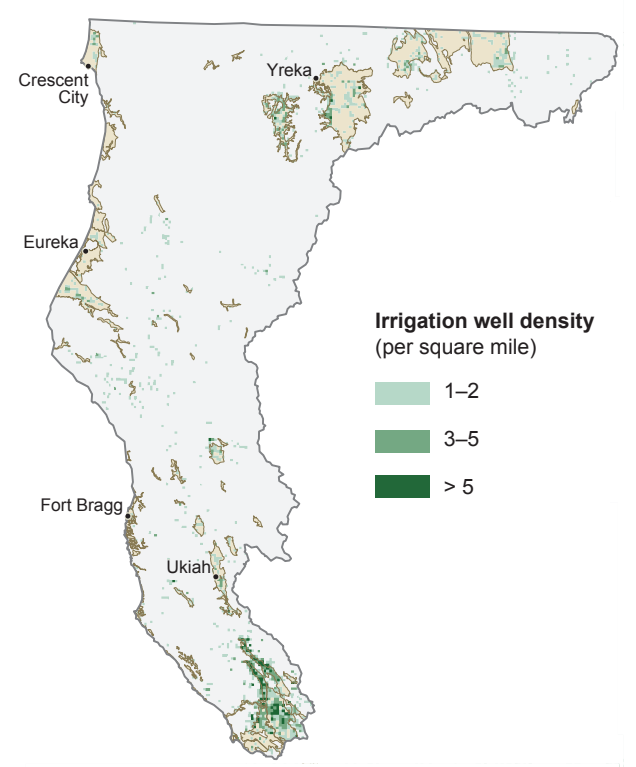
There have been more than 38,000 groundwater wells installed in the North Coast HR since 1977. Groundwater basins contain 56 percent of wells, and non-basin areas contain 44 percent of wells. Sixty-eight percent of wells in the region have been drilled for domestic uses). There are more domestic wells drilled in the non-basin area than basin area. Of the wells drilled since 1977, 8 percent have been within the North Coast HR.









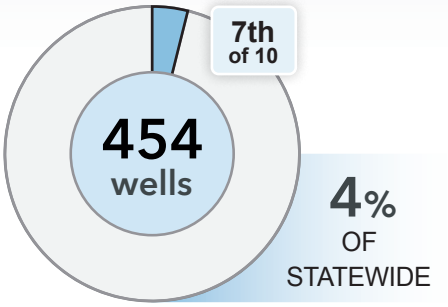


North Coast Hydrologic Region Groundwater Levels

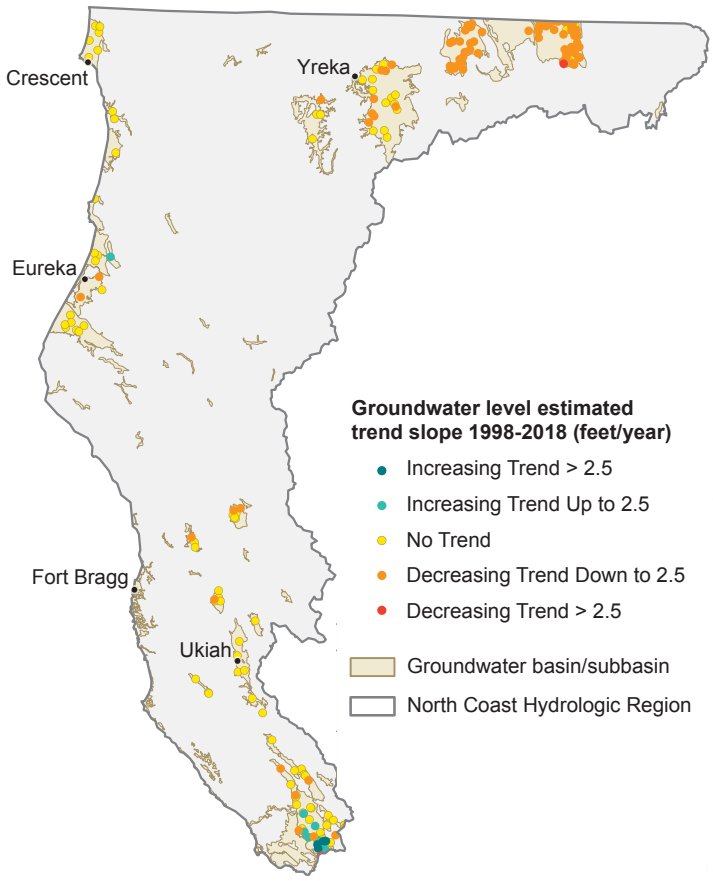
Monitoring

The North Coast HR has 4 percent of all groundwater level monitoring wells in the state (454 wells). This ranks the North Coast HR seventh among HRs for number of groundwater level monitoring wells. Most monitoring wells are located within groundwater basins near the Oregon border and in the southernmost portion of the region. In the region, groundwater level monitoring activities are split almost evenly between local agencies and by DWR. Nearly two thirds of wells (64 percent) are measured voluntarily and the majority of wells (56 percent) are less than 200 feet deep.

GW LEVEL MONITORING WELLS

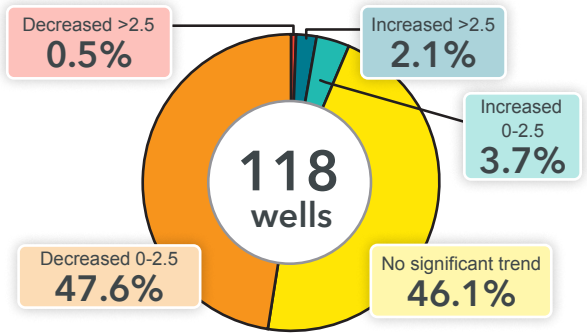


Conditions



Groundwater levels in much of the region are dropping with nearly half the monitoring wells recording a declining trend between 1998 and 2018. Specifically, 48 percent showed a declining trend as much as 2.5 feet per year over this period. One percent showed a faster trend of decline at a rate of more than 2.5 feet per year. Most of the other monitoring wells in the region (46 percent) displayed no significant trend over this period. The remaining 6 percent of wells showed an increasing trend.

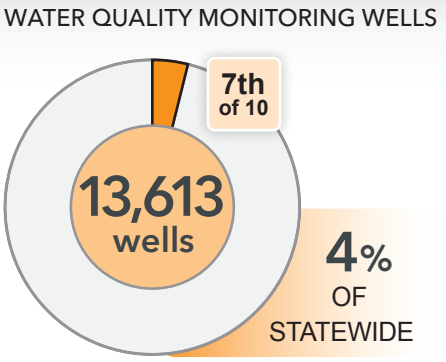
GROUNDWATER WELL LEVEL TREND



North Coast Hydrologic Region Groundwater Quality

Monitoring

The North Coast HR has the seventh most groundwater quality monitoring stations among the ten regions with 13,613 unique locations in the Groundwater Ambient Monitoring and Assessment (GAMA) Groundwater Information System. The region has 4 percent of all groundwater quality monitoring stations in the state.



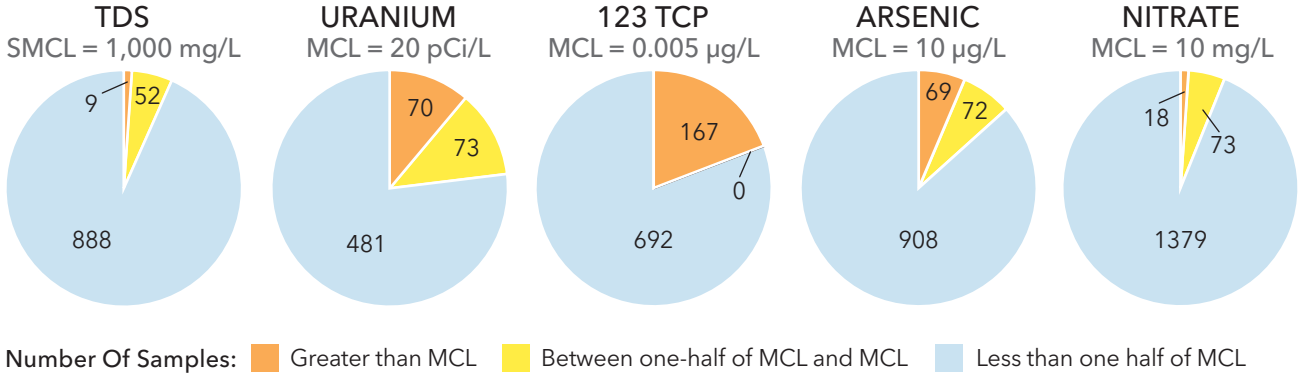
Conditions

Over one-third (33.9 percent) of all water quality stations in the North Coast HR were reported at levels above the secondary maximum contaminant level (SMCL) for manganese between 2009 and 2018. This amount is the highest proportion of wells exceedances for any individual chemical of any HR. Iron, was detected above the SMCL in more than 25 percent of the wells tested in the region over the same time period. The chemical 1,2,3, TCP was detected above the MCLin 19.4 percent of wells in the region over this period, the second highest percentage in the state after the Tulare Lake HR.

Top 10 Chemicals in Hydrologic Region by Percentage of Wells with Detections Above an MCL or SMCL:

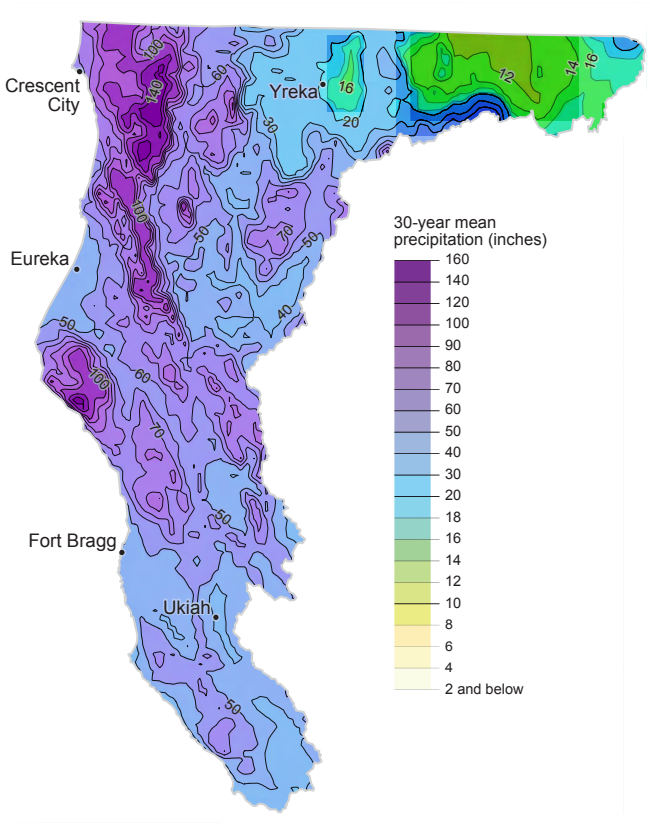
33.9% Manganese
25.6% Iron
19.4% 1,2,3 Trichloropropane (1,2,3 TCP)
16.8% 1,2-Dibromo,3-Chloropropane (DBCP)
6.6% Arsenic
1.9% Ethylene Dibromide (EDB)
1.7% Aluminum
1.2% Nitrate
1.2% Fluoride
1.0% Total Dissolved Solids (TDS)

Regional Water Quality Summaries for 5 Chemicals of Statewide Concern



North Coast Hydrologic Region Groundwater-Surface Water Interaction

The North Coast HR is unique because of the abundance of precipitation that falls in the region. Some cities in the region receive 70 inches of rainfall per year (Crescent City) which is more than the average annual precipitation of Los Angeles, San Diego, San Francisco, Long Beach, and Bakersfield combined. The abundance of precipitation recharges many groundwater basins in the region, resulting in water levels near the surface and creating a strong connection between surface water and groundwater. This strong connection is important because groundwater extraction resulting in a decrease in water level may lead to stream depletion in the region. Any reduction in streamflow is especially important in the North Coast HR where three federally listed salmonids use coastal rivers for migratory spawning purposes.



Scientific studies have identified the linkage between groundwater pumping and a decrease in streamflow in areas of the North Coast region (U.S. Geological Survey 1975). Groundwater managers in the region must consider stream depletion among other factors when extracting and managing groundwater


Photo of a juvenile salmonid

Did you know?

The North Coast HR is historically home to some of the most prolific anadromous fisheries in the state. These fisheries, including the Smith, Klamath, Mad, and Russian rivers have supported many California Native American Tribes for millennia. Today, 42 California Native American Tribes are known to have tribal homelands, trust lands, rancherias, and reservations in the region. These fisheries are critical for the cultures and livelihoods of tribes in the region. These fisheries have been affected over the last century by dams, land use changes, and flow reductions, but efforts are underway to help restore them. In-stream flow requirements are now in place to help provide adequate flows to sensitive species. Additionally, millions of dollars in State and federal funding have been invested in the Tulelake area to reduce reliance on surface water and provide a reliable, affordable water source to the local agricultural community.

North Coast Hydrologic Region Groundwater Assistance

TECHNICAL SUPPORT

Monitoring Wells
16 Installed at 13 Sites
18 Planned at 10 Sites

Statewide Datasets
878 mi^2 of Land Use
935 mi^2 of Land Subsidence Monitoring

FACILITATION SUPPORT

FSS Contracts
Awarded in 5 Basins

Points of Contact (POCs)
7 POCs in 7 Basins

GRANT FUNDING

Grants Awarded
12 Grants since 2010

Total Funding
$10.4 Million Awarded

Note: Assistance summaries are from Department of Water Resources' Groundwater Program. Many other local, state and federal entities also provide assistance in this region

Local Project Spotlight: Ranney Collectors

The North Coast HR is home to multiple "Ranney" collectors, a special type of well used to extract water from an aquifer that has a direct connection to a surface water source like a river or lake. Ranney wells within these collectors typically have horizontal screens from the collectors to nearby surface water bodies where they pump water from the saturated sediments underneath the waterbody. While the water pumped by a Ranney well is beneath the ground, it is often not considered groundwater as the amount of water available from the collector is typically related more to the surface water source than to the groundwater level of the aquifer.

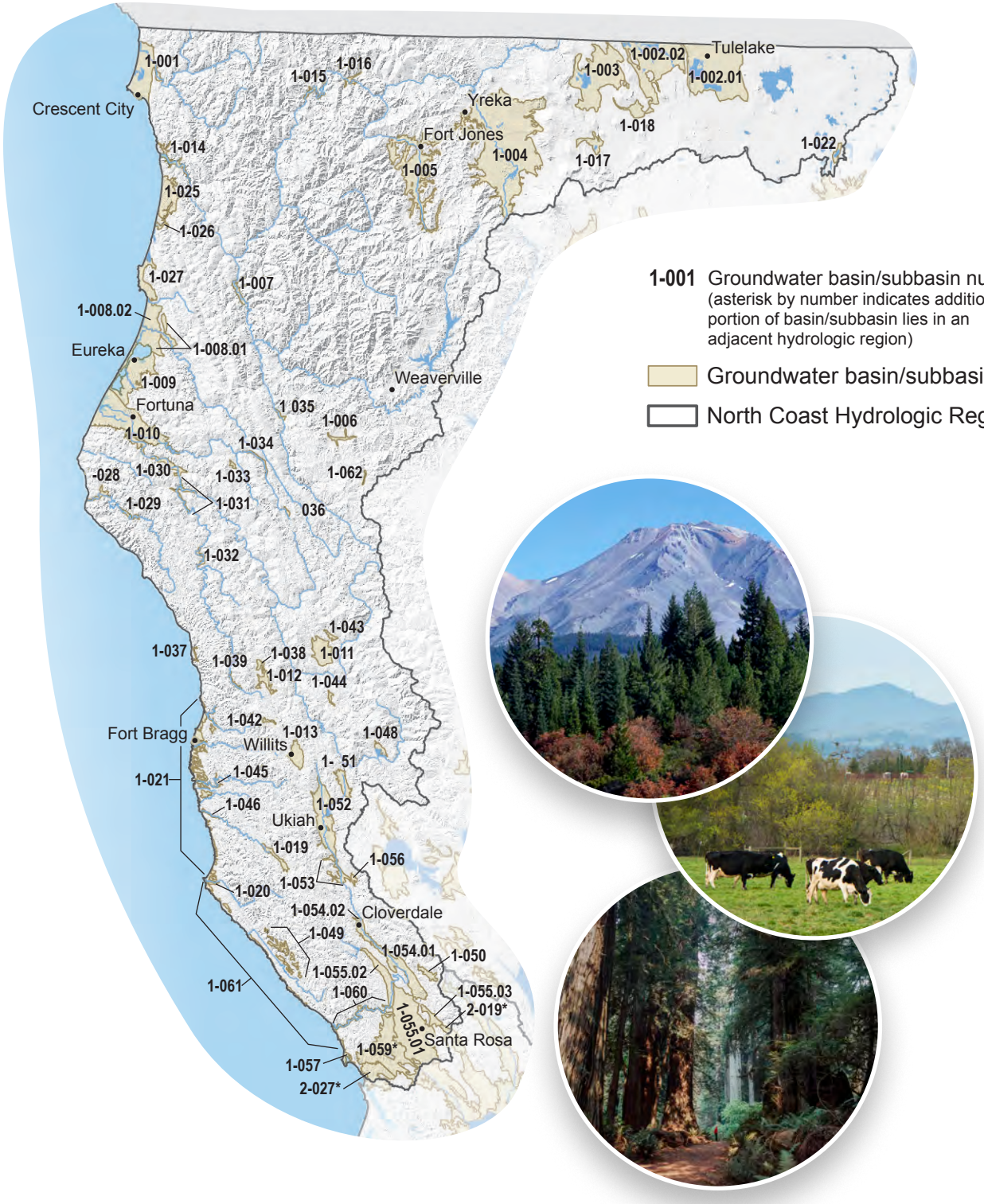
Ranney collectors provide local communities with a consistent source of water from local rivers without directly diverting surface water and potentially affecting sensitive species. The State Water Board has recognized the strong connection between Ranney wells and surface water by issuing water rights permits for Ranney wells as a surface water diversion.

Ranney collectors are found throughout the North Coast HR including near the coastal cities of Crescent City and Eureka as well as the southern portion of the region near Healdsburg. The Ranney collector shown in the photo is located on the Mad River northeast of Arcata. This particular Ranney collector is operated by the Humboldt Bay Mutual Water District and provides drinking water to residents near Humboldt Bay.



Ranney Collector located on the Mad River northeast of Arcata, California.

North Coast Hydrologic Region Basin Map



North Coast Hydrologic Region Basin List

Basins (7) Required to Submit Groundwater Sustainability Plans

Basin Number	Basin Name	GSP Status	Critically Overdrafted
1-003	Butte Valley	Due 2022	No
1-010	Eel River Valley	Due 2022	No
1-002.01	Klamath River Valley - Tulelake	Due 2022	No
1-055.01	Santa Rosa Valley - Santa Rosa Plain	Due 2022	No
1-005	Scott River Valley	Due 2022	No
1-004	Shasta Valley - Shasta Valley	Due 2022	No
1-052	Ukiah Valley	Due 2022	No

Basins (58) with Option to Develop Groundwater Sustainability Plans (GSP)

Basin Number	Basin Name	Basin Number	Basin Name
1054.01	Alexander Valley - Alexander Area	1-033	Larabee Valley
1054.02	Alexander Valley - Cloverdale Area	1-012	Laytonville Valley
1-019	Anderson Valley	1-013	Little Lake Valley
1-049	Annapolis Ohlson Ranch Fm Highlands	1-041	Little Valley
1-027	Big Lagoon Area	1-014	Lower Klamath River Valley
1-045	Big River Valley	1-038	Lower Laytonville Valley
1-057	Bodega Bay Area	1-060	Lower Russian River Valley
1-039	Branscomb Town Area	1-008.02	Mad River Valley - Dows Prairie School Area
1-017	Bray Town Area	1-008.01	Mad River Valley - Mad River Lowland
1-037	Cottoneva Creek Valley	1-028	Mattole River Valley
1-011	Covelo Round Valley	1-056	Mcdowell Valley
1-034	Dinsmores Town Area	1-046	Navarro River Valley
1-044	Eden Valley	1-030	Pepperwood Town Area
1-009	Eureka Plain	1-051	Potter Valley
1-022	Fairchild Swamp Valley	1-025	Prairie Creek Area
1-021	Fort Bragg Terrace Area	1-018	Red Rock Valley
1-061	Fort Ross Terrace Deposits	1-026	Redwood Creek Area
1-032	Garberville Town Area	2-027*	Sand Point Area
1-020	Garcia River Valley	1-053	Sanel Valley
1-048	Gravelly Valley	1-055.02	Santa Rosa Valley - Healdsburg Area
1-015	Happy Camp Town Area	1-055.03	Santa Rosa Valley - Rincon Valley
1-006	Hayfork Valley	1-016	Seiad Valley
1-036	Hettenshaw Valley	1-042	Sherwood Valley
1-029	Honeydew Town Area	1-001	Smith River Plain
1-007	Hoopa Valley	1-040	Ten Mile River Valley
1-035	Hyampom Valley	1-031	Weott Town Area
2-019*	Kenwood Valley	1-043	Williams Valley
1-002.02	Klamath River Valley - Lower Klamath	1-059*	Wilson Grove Formation Highlands
1-050	Knights Valley	1-062	Wilson Point Area

Basins (1) with Adjudicated Areas

Basin Number	Basin Name
1-005	Scott River Valley

Basins with Approved Alternative GSPs

Basin Number	Basin Name
none	

**Basin partially located in adjacent hydrologic region*

Groundwater at a Glance:
San Francisco Bay Hydrologic Region

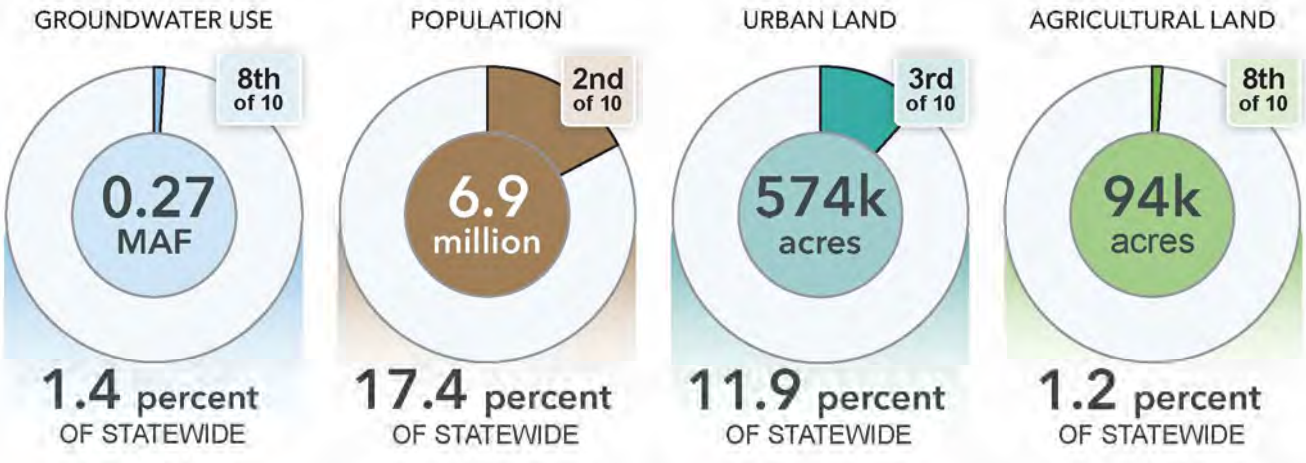
The San Francisco Bay HR is the smallest hydrologic region in California, covering approximately 4,500 square miles. Though it is the smallest region, it is home to the second largest population with 6.9 million people. The region HR is known for its microclimates, which often result in large temperature differences in areas only a short distance apart. Average precipitation in the region ranges from 15 to 20 inches per year with increasing precipitation in the northern portions of the HR. Highlights of the region include the world-renowned vineyards of Napa and Sonoma Counties, technology mecca Silicon Valley, and the cities of San Francisco, San Jose, and Oakland.





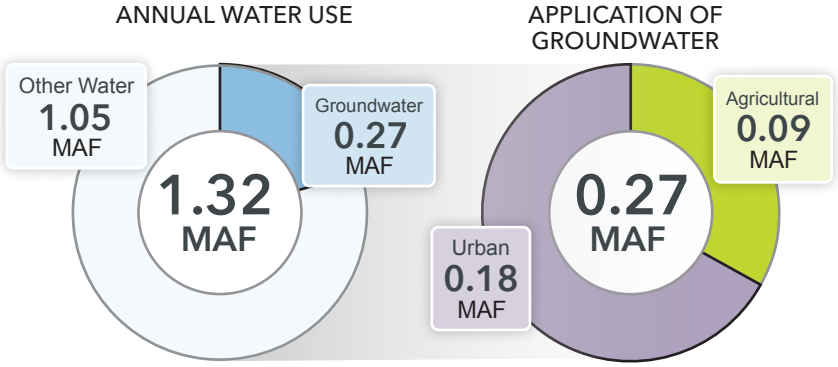
A View of the San Francisco Skyline at Dusk.

The HR averages 0.27 maf per year in groundwater use. Groundwater accounts for one-fifth of the region's total water supply, which largely relies on imported water. There are 34 groundwater basins in the region, seven of which are required by SGMA to submit GSPs.

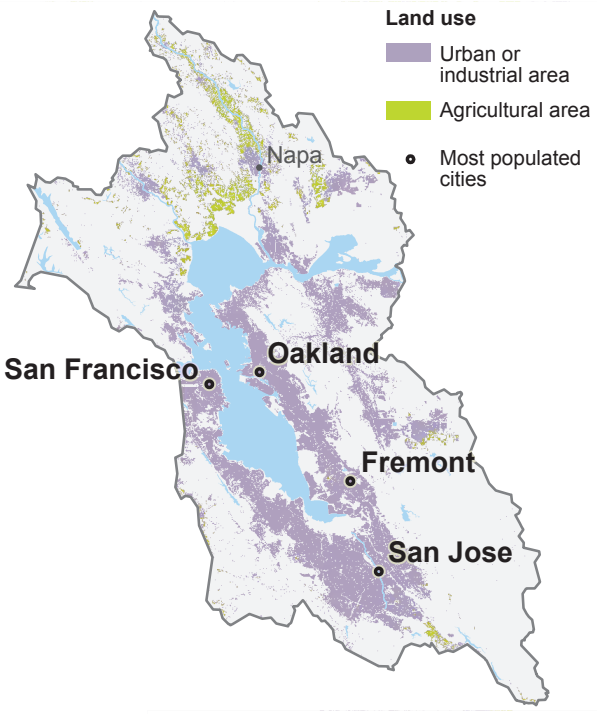


San Francisco Bay Hydrologic Region Land and Water Use

The San Francisco Bay HR uses 3 percent of California's total water use, averaging 1.32 maf each year. Groundwater accounts for 20 percent of the water supply in the region and 1 percent of statewide groundwater use.



Map of General Land Use



Groundwater Use

The region ranks eighth of the ten regions for groundwater use, averaging 0.27 maf annually. Groundwater is primarily used to meet urban water demands in the region with 0.18 maf of groundwater extracted annually. The remaining 33 percent of groundwater (0.09 maf) is used for agricultural purposes.

Land Use

The region has the second largest population and the third largest urban footprint in the state with over 570,000 acres of urban area. Agricultural lands comprise roughly 1.2 percent of the area in the region with almost 94,000 acres. The majority of those agricultural acres are in the northern part of the region.

Did you know? The main water sources for many Bay Area residents are located hundreds of miles away in the Sierra Nevada. Hetch Hetchy Reservoir, located in Yosemite National Park, is the main water source for San Francisco and other cities on the peninsula. Camanche and Pardee reservoirs are located in the Sierra Nevada foothills and provide water to the East Bay area.

Total Agricultural Area: 93,829 Acres

Top 4 Crops by Acreage (2016):
- Grapes (63,000)
- Miscellaneous Grain and Hay (2,000)
- Miscellaneous Grasses (7,000)
- Mixed Pasture (6,000)

Total Urban Area: 574,189 Acres

Top 4 Cities by Population (2010):
- San Jose (946,000)
- San Francisco (805,000)
- Oakland (391,000)
- Fremont (214,000)

San Francisco Bay Hydrologic Region Groundwater Management

BASINS REQUIRING GSPs	BASINS WITH ADJUDICATED AREAS	APPROVED ALTERNATIVE GSPs
7	0	3*

CRITICALLY OVERDRAFTED BASINS	GROUNDWATER SUSTAINABILITY AGENCIES	GSPs SUBMITTED BY 01/31/2020
0	16	0

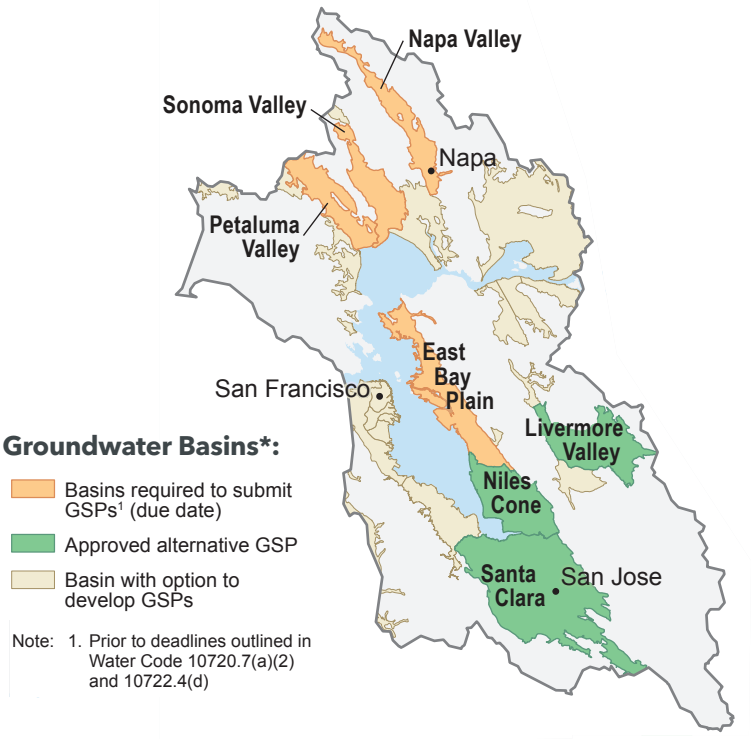
** Livermore Valley basin has an approved 10-Year Sustainable Yield Analysis, not a full Alternative GSP.*

Groundwater Management

There are seven basins within the San Francisco Bay Region required by SGMA to develop GSPs. Sixteen Groundwater Sustainability Agencies have been formed within these seven basins. Three of these seven basins have approved Alternative GSPs. There are no critically overdrafted basins or adjudicated areas in the region.

**Several basins span across regions. For the purposes of this analysis, only basins with majority of their area in the region are represented.*

SGMA Groundwater Management Status



CASGEM Monitoring

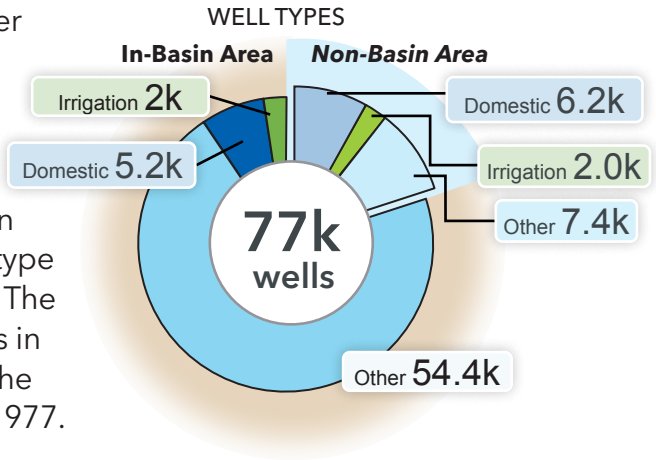
Eighteen (18) basins in the region that are not required to develop GSPs are actively participating in the CASGEM program. Within these basins, biannual groundwater level measurements are collected and posted to the CASGEM online system. These measurements are collected voluntarily by private individuals, academic institutions, conservation districts, and other local, state, and federal entities.

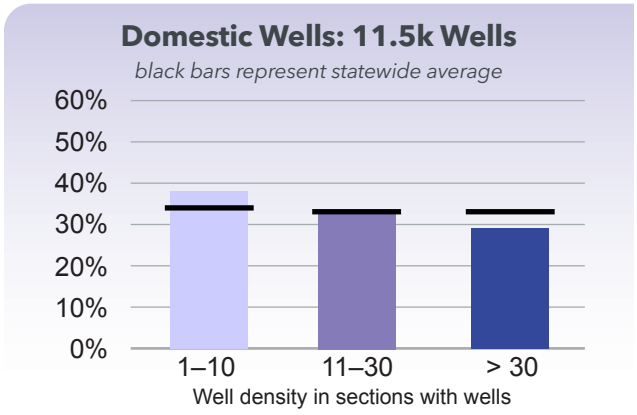


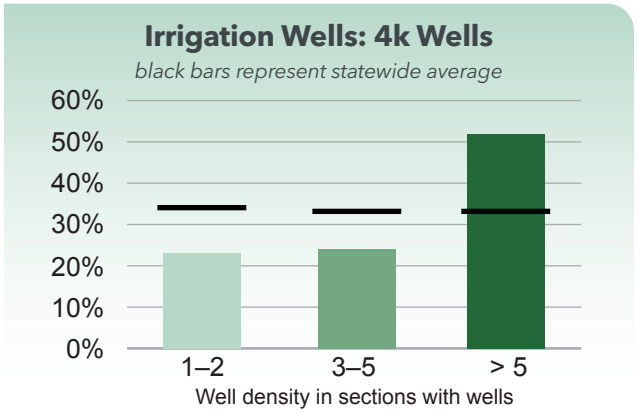
A groundwater level monitoring well is installed in the San Francisco Bay HR in 2020.

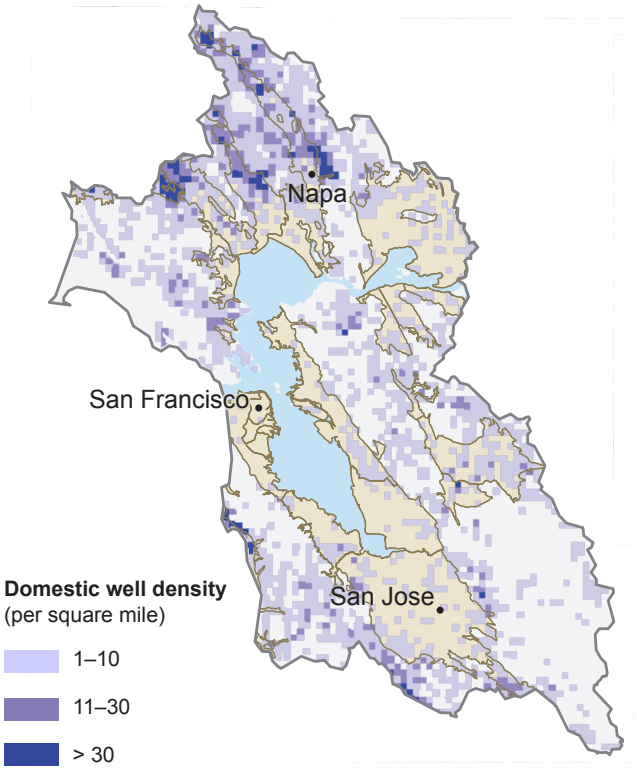
San Francisco Bay Hydrologic Region Well Infrastructure

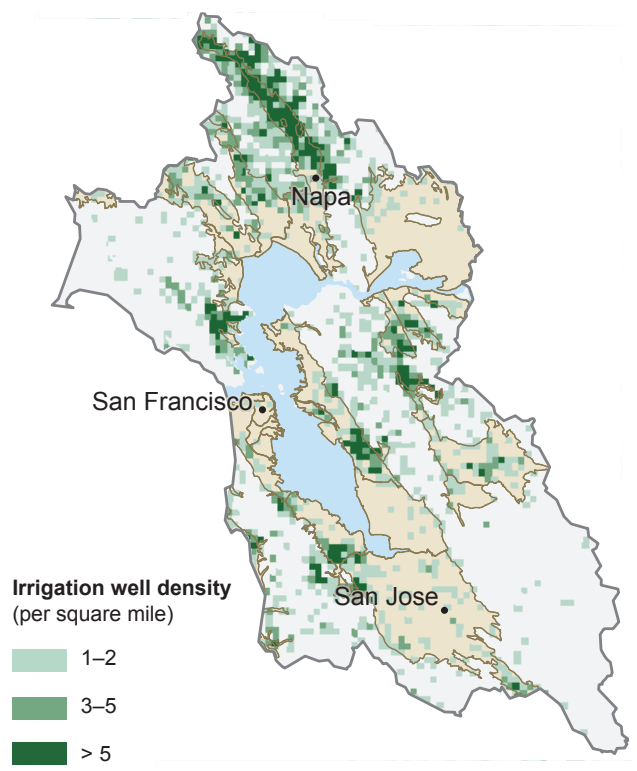
There have been more than 77,000 groundwater wells drilled in the San Francisco Bay HR since 1977, second most among HRs. Eighty percent of the wells (61,700) have been drilled within groundwater basins and the remaining 20 percent of the wells (15,600) in the non-basin area. Within the region the most common well type is monitoring, selected on 61 percent of WCRs. The region has the highest density of irrigation wells in the state. In total, the region has 17 percent of the groundwater wells installed in California since 1977.







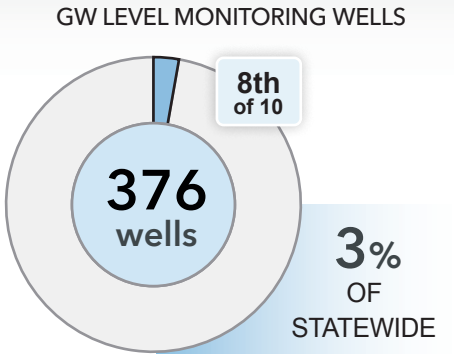




San Francisco Bay Hydrologic Region Groundwater Levels

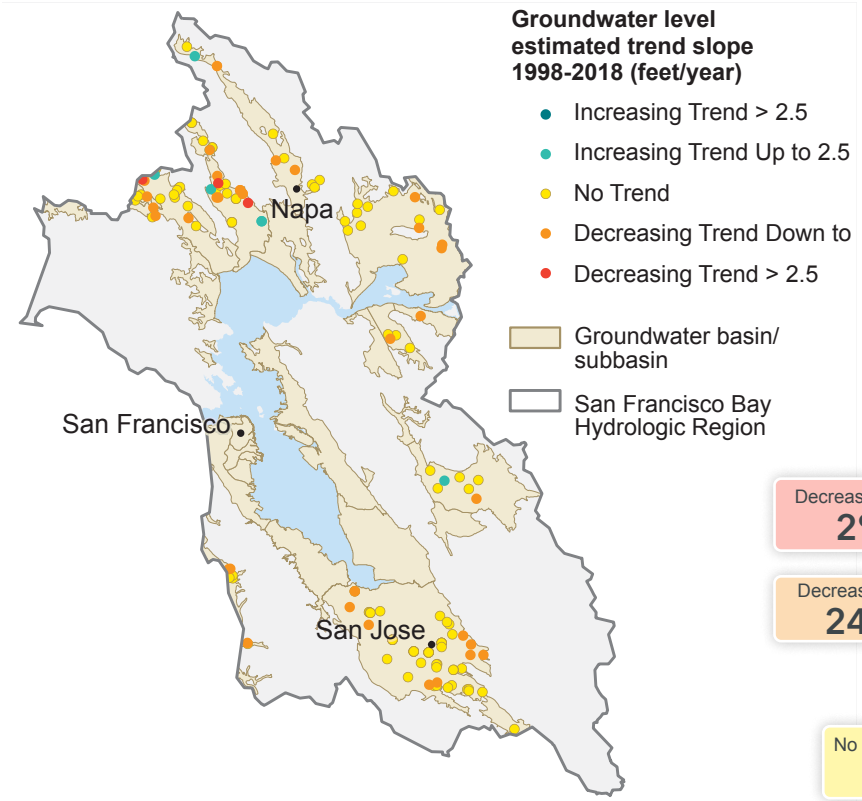
Monitoring

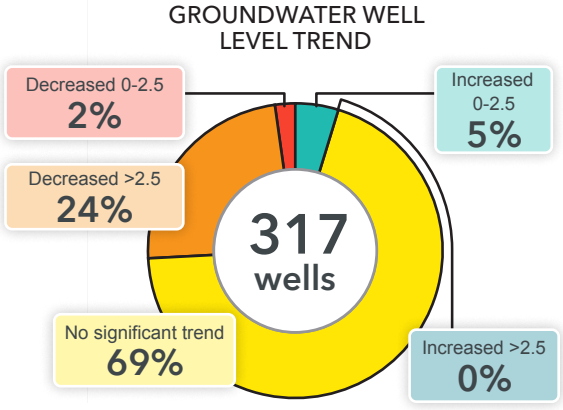
The San Francisco Bay HR has the eighth most groundwater level monitoring wells in the state with 376 sites. Currently, 3 percent of all groundwater level monitoring wells in the state are in the San Francisco Bay HR. Local agencies perform most of the groundwater level monitoring in the region, collecting data from 80 percent of the monitoring wells (310). Most of the groundwater level monitoring wells are clustered in the northern and southern ends of the region.



Conditions

Groundwater levels in much of the San Francisco Bay HR are stable, with 69 percent of monitoring wells in the region reflecting that trend between 1998 and 2018. Approximately one quarter of monitoring wells (26 percent) experienced a declining trend over the same time period. Most of these wells (24 percent) experienced a declining trend of less 2.5 feet per year, with 2 percent of all wells experiencing a more rapid trend of more than 2.5 feet of decline per year. The remaining 5 percent of monitoring wells experienced an increasing trend of up to 2.5 feet per year over this 20-year period.



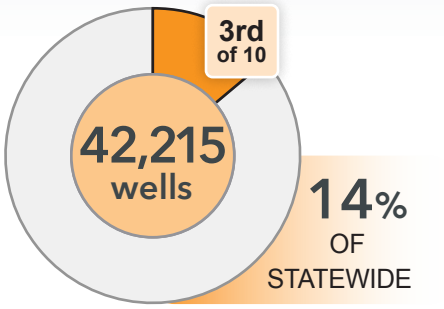


San Francisco Bay Hydrologic Region Groundwater Quality

Monitoring

The San Francisco Bay HR has the third most groundwater quality monitoring stations among the ten regions with 42,215 unique locations in the GAMA Groundwater Information System. The region has 14 percent of all groundwater quality monitoring stations in the state.

WATER QUALITY MONITORING STATIONS



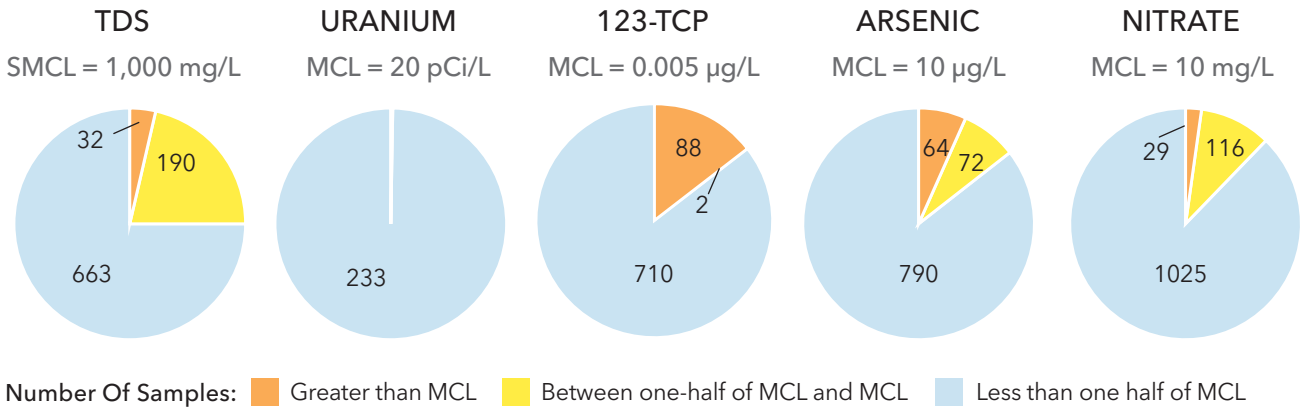
Conditions

The most common chemical detected above a regulatory limit between 2009 and 2018 in the region was manganese, with 28.9 percent of water quality stations in the region above the SMCL. The second most commonly detected chemical above a regulatory limit over this period was iron, detected in 28.3 percent of wells above the SMCL. Four chemicals were detected above their MCL or SMCL in 10 percent or more of wells tested in the region over the ten year period from 2009 to 2018.

Top 10 Chemicals in Hydrologic Region by Percentage of Wells with Detections Above an MCL or SMCL:

28.9% Manganese
28.3% Iron
12.5% Chlorite
11.0% 1,2,3-Trichloropropane (1,2,3-TCP)
9.7% Bromide
7.2% 1,2-Dibromo,3-Chloropropane (DBCP)
6.9% Arsenic
3.7% Standard Conductivity
3.6% Total Dissolved Solids (TDS)
2.5% Nitrate

Regional Water Quality Summaries for 5 Chemicals of Statewide Concern



San Francisco Bay Hydrologic Region Land Subsidence

Monitoring

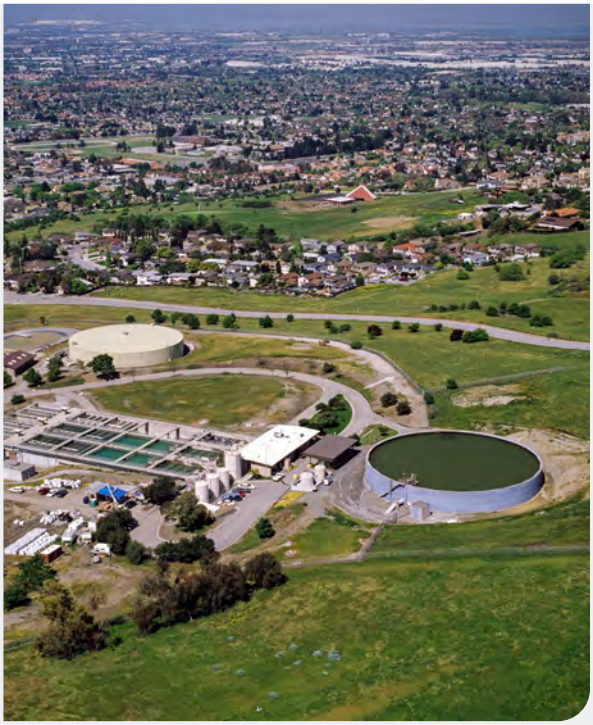
Land subsidence monitoring in the region includes satellite-based remote sensing (InSAR), Continuous GPS (CGPS) stations, and a regional subsidence monitoring network. The statewide InSAR dataset includes 970 square miles of land subsidence monitoring coverage in the San Francisco Bay HR. A total of 60 CGPS sites are operated in the region and it is home to a local subsidence monitoring network maintained by the Santa Clara Valley Water District (Valley Water). The Valley Water network features hundreds of survey benchmarks measured annually and two borehole extensometers, and ten subsidence index wells (Santa Clara Valley Water District, 2020).

Conditions

Subsidence has been documented in areas within the region throughout the 20th century. Between the 1900s and 1970s, areas of Santa Clara County experienced up to 13 feet of subsidence caused by groundwater pumping (Santa Clara Valley Water District, 2020). When compared to other areas in California subjected to significant land subsidence, the San Francisco Bay Region is unique because much of it is no longer experiencing subsidence. CGPS data has recorded less than 0.25 feet of subsidence in the region over the last decade and InSAR data has recorded less than 0.25 feet of subsidence since its inception in 2015.

Management Actions

In response to land subsidence in the southern portion of the region during the first half of the 20th century, DWR and local agencies constructed the South Bay Aqueduct (completed in 1965) as a part of the State Water Project. The project provided an alternative water source to groundwater-dependent areas in the region experiencing overdraft and groundwater pumping-related land subsidence. Local agencies immediately began using this imported water to supplement existing water supplies and recharge local aquifers. Over time, groundwater levels have stabilized and even increased in many areas and recent data show land subsidence has effectively ceased in the southern part of the region.



Terminal Reservoir, the Last Facility on the South Bay Aqueduct located East of San Jose.

San Francisco Bay Hydrologic Region Groundwater Assistance

TECHNICAL SUPPORT

Monitoring Wells
9 Installed at 9 Sites
0 Planned at 0 Sites

Statewide Datasets
1,341 mi^2 of Land Use
970 mi^2 of Land Subsidence Monitoring

FACILITATION SUPPORT

FSS Contracts
Awarded in 2 Basins

Points of Contact (POCs)
7 POCs in 7 Basins

GRANT FUNDING

Grants Awarded
22 Grants since 2010

Total Funding
$14.5 Million Awarded

Note: Assistance summaries are from Department of Water Resources' Groundwater Program. Many other local, state and federal entities also provide assistance in this region

Regional Project Spotlight: Conjunctive Use Projects

In the San Francisco Bay Region, many water managers have historically relied on imported surface water to meet local demands. Sustained drought and climate change have forced local water managers to develop and implement programs to diversify local supplies.

Valley Water uses conjunctive management of groundwater and surface water resources near San Jose. In an area historically impacted by land subsidence, Valley Water now uses in-lieu and direct recharge of imported, local, and recycled water to manage groundwater resources. This conjunctive management approach has resulted in stable groundwater levels and mitigated land subsidence and seawater intrusion.

The San Francisco Public Utilities Commission (SFPUC) has recently reduced their dependence on imported surface water by developing local groundwater resources. The SFPUC also plans to conjunctively use groundwater and surface water to meet local needs. They are working with other local partners to develop a regional dry year groundwater bank. The project, located in San Mateo County, will store 20 billion gallons of water in the groundwater basin to provide water supplies during droughts. Other conjunctive use programs are also actively managed in the region near Fremont and Livermore.



Did you know? Local water managers in the region are working collaboratively to solve ongoing challenges. The Bay Area Regional Reliability project involves the largest water managers in the Bay Area working together to create more reliable water sources for the region. Another project called the North Bay Water Reuse Program includes 11 different partners in the region with the goal of expanding recycled water supplies to improve reliability.

San Francisco Bay Hydrologic Region Basin Map



San Francisco Bay Hydrologic Region Basin List

Basins (4) Required to Submit Groundwater Sustainability Plans

Basin Number	Basin Name	GSP Status	Critically Overdrafted
2-002.01	Napa-Sonoma Valley - Napa Valley	Due 2022	No
2-002.02	Napa-Sonoma Valley - Sonoma Valley	Due 2022	No
2-001	Petaluma Valley	Due 2022	No
2-009.04	Santa Clara Valley - East Bay Plain	Due 2022	No

Basins (27) with Option to Develop Groundwater Sustainability Plans (GSP)

Basin Number	Basin Name
2-031	Arroyo Del Hambre Valley
2-008	Castro Valley
2-005	Clayton Valley
2-040	Downtown
2-022*	Half Moon Bay Terrace
2-033	Islais Valley
2-019*	Kenwood Valley
2-038	Lobos
2-039	Marina
2-002.03	Napa-Sonoma Valley - Napa-Sonoma Lowlands
2-030	Novato Valley
2-026	Pescadero
2-004	Pittsburg Plain
2-028	Ross Valley
2-024	San Gregorio Valley
2-036	San Pedro Valley
2-029	San Rafael Valley
2-007	San Ramon Valley
2-027*	Sand Point Area
2-009.03	Santa Clara Valley - San Mateo Plain
2-037	South San Francisco
2-003	Suisun-Fairfield Valley
2-011	Sunol Valley
2-032	Visitacion Valley
1-059*	Wilson Grove Formation Highlands
2-035	Westside
2-006	Ygnacio Valley

Basins with Adjudicated Areas

Basin Number	Basin Name
none	

Basins with Approved Alternative GSPs

Basin Number	Basin Name
2-009.01	Santa Clara Valley - Niles Cone
2-009.02	Santa Clara Valley - Santa Clara
2-010	Livermore Valley

Basin partially located in adjacent hydrologic region

Groundwater at a Glance:
Central Coast Hydrologic Region

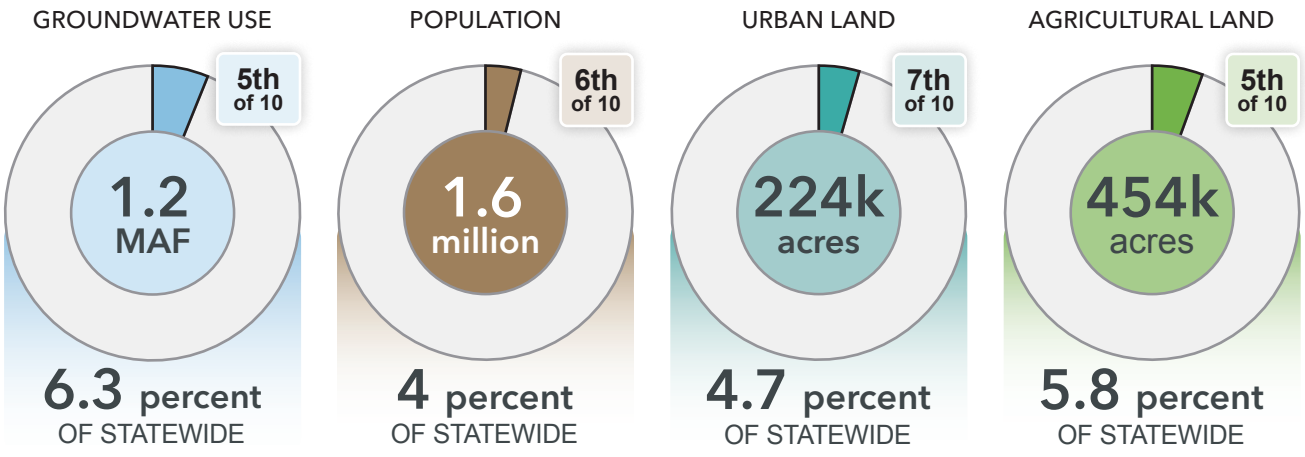
The Central Coast HR covers approximately 11,300 square miles along the Pacific coast in central California. The region is home to an estimated population of 1.6 million people and some of the state's most prominent agricultural areas outside of the Central Valley. The region averages 11 to 36 Inches of annual precipitation. Some of the region's most well-known areas include Salinas the "World's Salad Bowl," Gilroy the "Garlic Capital of the World," Big Sur, Pinnacles National Park, and many coastal tourist destinations including Monterey, Pismo Beach, and Santa Barbara.





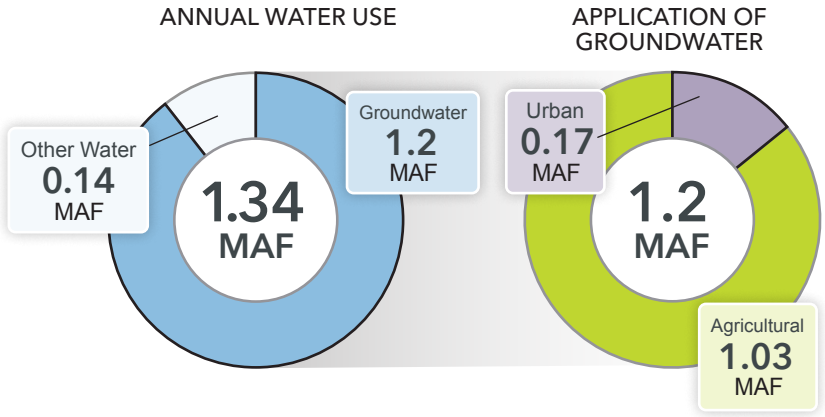
Sprinklers Irrigate a Lettuce Field in an area known as the "World's Salad Bowl" near Salinas.

The Central Coast Region is the fifth largest user of groundwater in the state, using an average of 1.2 maf each year. Groundwater accounts for more than 90 percent of the region's total water supply, the highest proportion of all the regions. The region contains 60 groundwater basins, 19 of which are required by SGMA to submit GSPs.

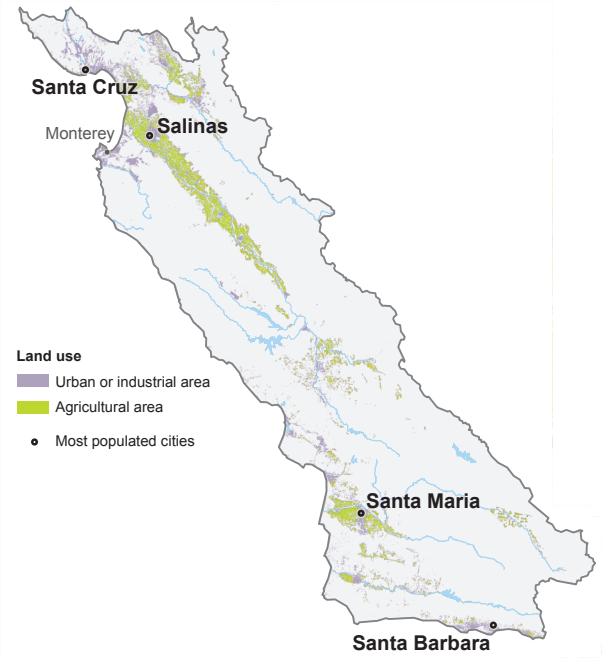


Central Coast Hydrologic Region Land and Water Use

The Central Coast HR uses an average of 1.34 maf of water annually, 3 percent of California's total water use . Groundwater accounts for 90 percent of the region's water supply and 6 percent of statewide groundwater use.



Map of General Land Use



Groundwater Use

The Central Coast Region ranks fifth out of the ten regions for groundwater use, averaging 1.2 maf annually. Groundwater is primarily used to meet agricultural water demands in the region with 1.03 maf of groundwater extracted annually. The remaining 10 percent of groundwater (0.17 maf) is used for urban purposes. The region uses the highest proportion of groundwater out of all hydrologic regions.

Did you know? Conjunctive use of surface water and groundwater is a long-standing practice in the region. Several reservoirs including Hernandez, Twitchell, Lake San Antonio, and Lake Nacimiento are operated primarily for groundwater recharge.

Land Use

The region encompasses 6 percent of the agricultural area in the state with almost 454,000 acres, including some of the most well-known farmlands in the state. The region has the sixth largest urban footprint in the state with approximately 225,000 acres of urban area, mostly located along the Pacific coast.

Total Urban Area: 224,490 Acres

Top 4 Cities by Population (2010):
- Salinas (150,000)
- Santa Maria (100,000)
- Santa Barbara (88,000)
- Santa Cruz (60,000)

Total Agricultural Area: 453,544 Acres

Top 4 Crops by Acreage (2016):
- Miscellaneous Truck Crops (128,000)
- Grapes (127,000)
- Miscellaneous Grain and Hay (55,000)
- Lettuce/Leafy Greens (48,000)

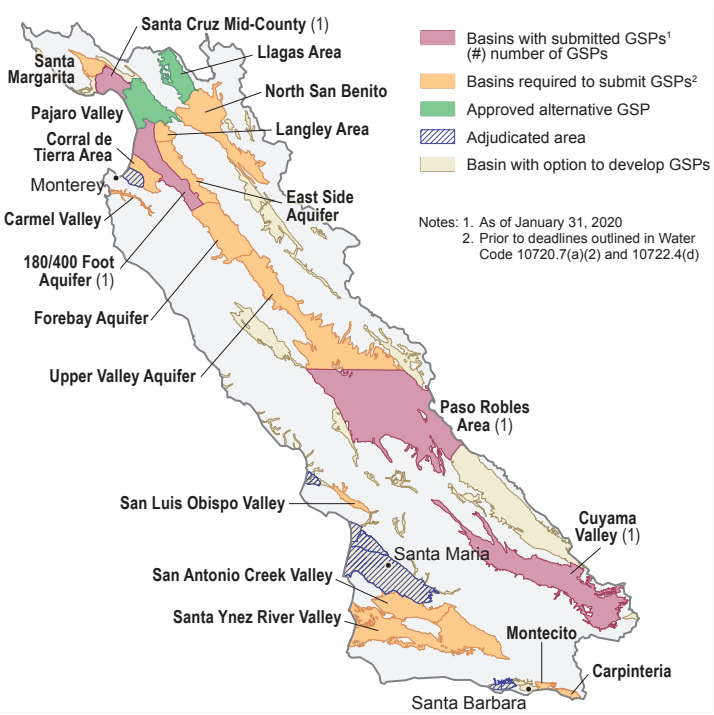
Central Coast Hydrologic Region Groundwater Management

BASINS REQUIRING GSPs	BASINS WITH ADJUDICATED AREAS	APPROVED ALTERNATIVE GSPs
19	4	2
CRITICALLY OVERDRAFTED BASINS	**GROUNDWATER SUSTAINABILITY AGENCIES**	**GSPs SUBMITTED BY 01/31/2020**
6	40	4

Groundwater Management

There are 19 groundwater basins within the Central Coast HR required by SGMA to submit GSPs. Forty Groundwater Sustainability Agencies have been formed within these 19 basins. Four basins have submitted GSP(s) as of January 2020 and two basins have approved Alternative GSPs. There are six adjudicated areas in the region covering all or portions of four basins.

SGMA Groundwater Management Status



CASGEM Monitoring

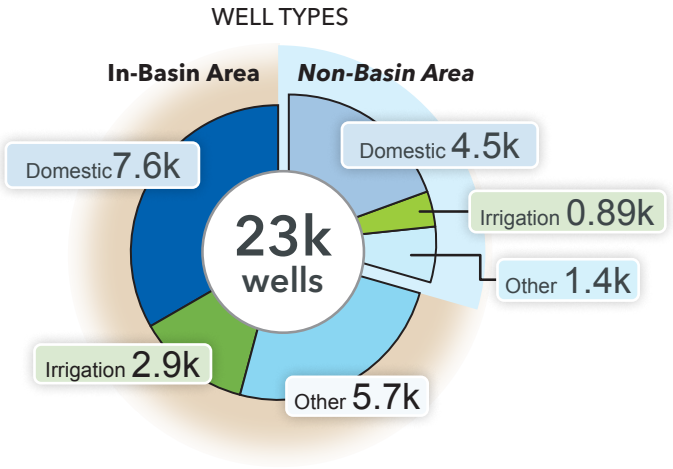
Thirteen basins in the region that are not required to develop GSPs are actively participating in the CASGEM program. Within these basins, biannual groundwater level measurements are collected and posted to the CASGEM online system. These measurements are collected voluntarily by private individuals, academic institutions, conservation districts, and other local, state, and federal entities.

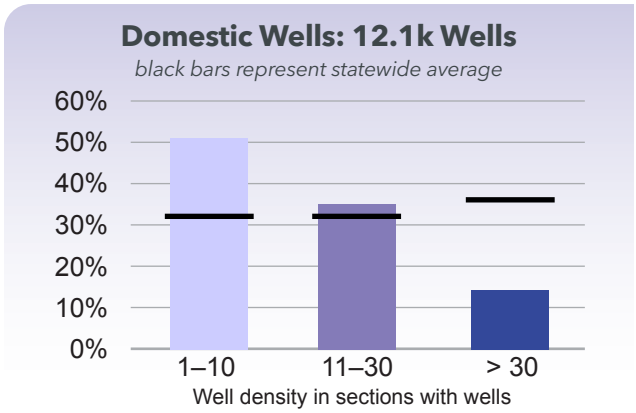


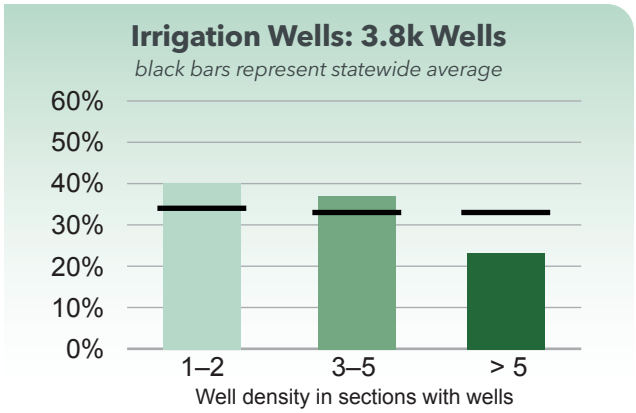
A Groundwater Level Monitoring Well located near Soquel.

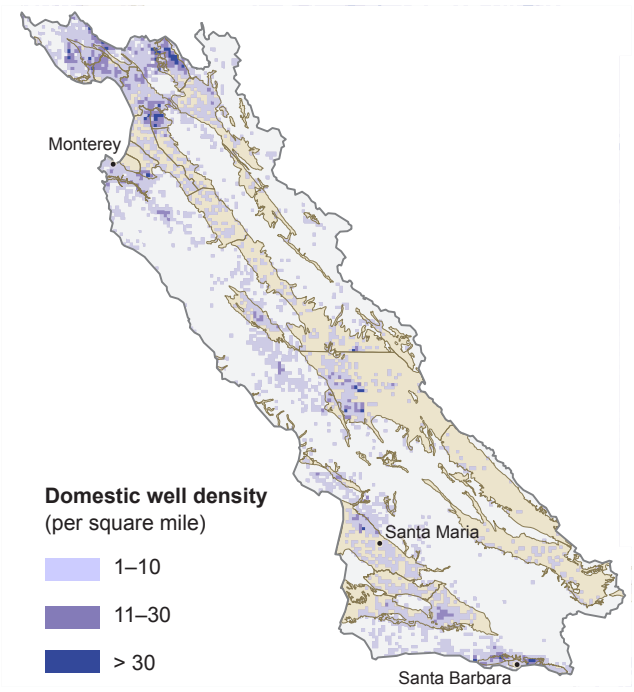
Central Coast Hydrologic Region Well Infrastructure

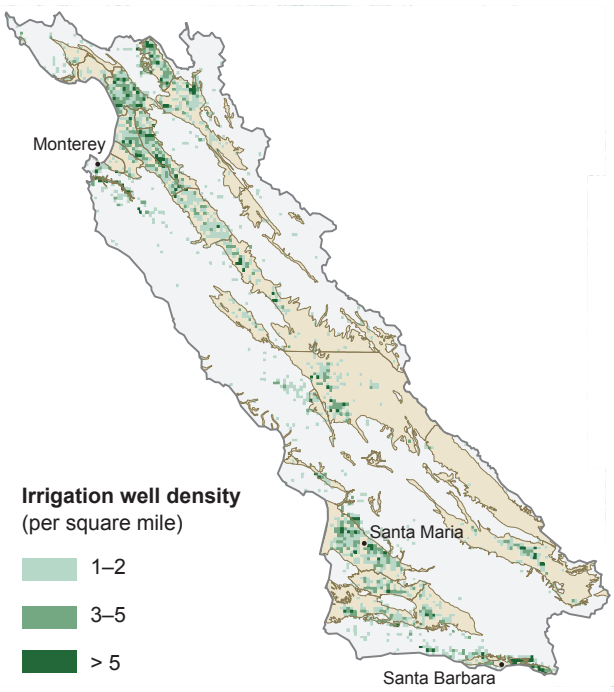
Since 1977, almost 23,000 groundwater wells have been installed in the Central Coast Region. Seventy one percent of the wells (16,200) have been drilled within groundwater basins and the remaining 29 percent (6,760) drilled in the non-basin area. Most wells in the region in the both the basin area (47 percent) and non-basin area (66 percent) are used for domestic purposes. In total, the Central Coast HR has 5 percent of the groundwater wells installed in California since 1977.









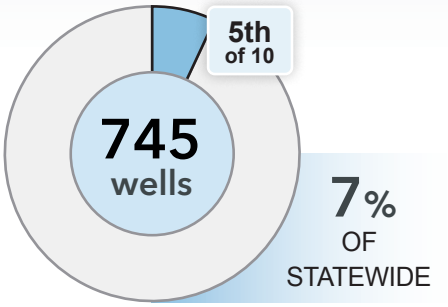


Central Coast Hydrologic Region Groundwater Levels

Monitoring

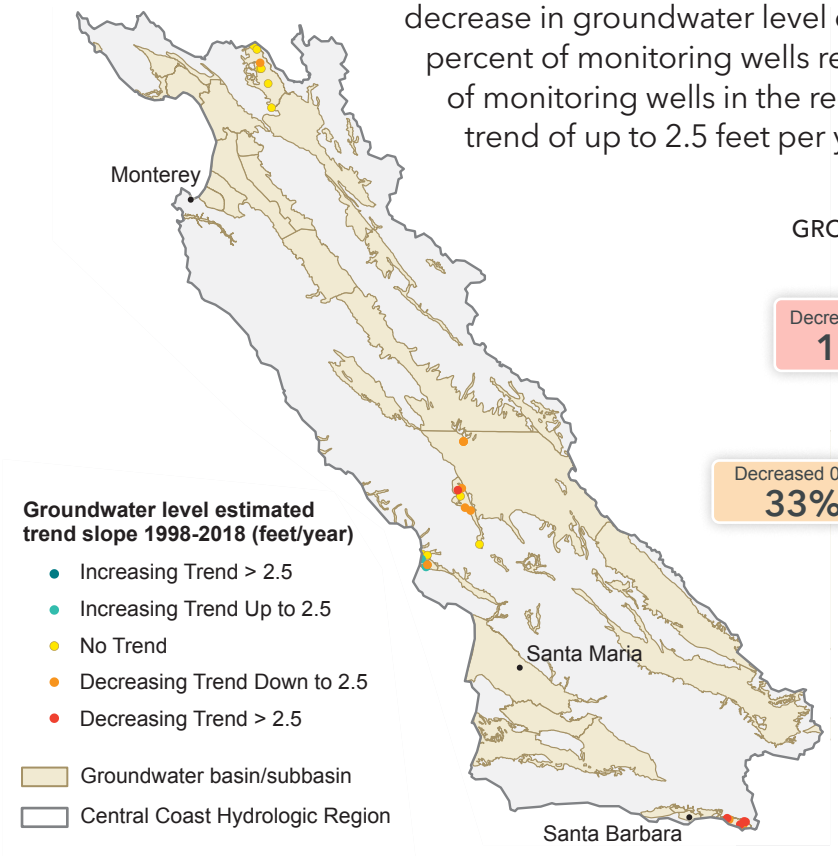
The Central Coast HR has the fifth most groundwater level monitoring wells in the state with 745 sites. Seven percent of all groundwater monitoring wells in California are in the Central Coast HR. Local agencies perform nearly all of the groundwater level monitoring in the region, collecting data from 97 percent of the monitoring wells (726). This is the highest percentage of monitoring done by local agencies of any HR in the state. Nearly half the groundwater level monitoring wells in the region are dedicated observation wells. Unlike other regions, most of the groundwater level monitoring wells in the region have a relatively short period of record of ten years or less, coinciding with the inception of DWR's CASGEM program.

GW LEVEL MONITORING WELLS

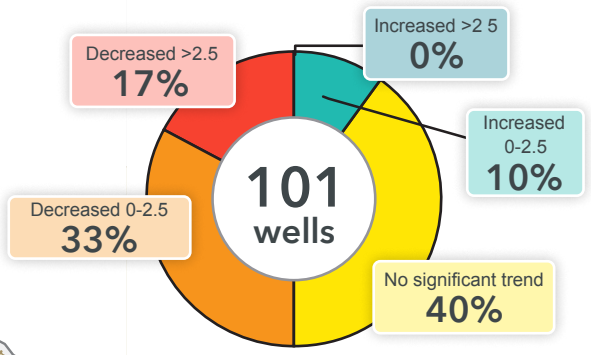


Conditions

Nearly 50 percent of the limited number of monitoring wells in the region showed a decreasing trend between 1998 and 2018. One-third of these wells experienced a declining trend of up to 2.5 feet per year. Seventeen percent experienced a more rapid decline averaging more than 2.5 feet of decline per year, an overall decrease in groundwater level of 50 feet or more. About 40 percent of monitoring wells remained stable while 10 percent of monitoring wells in the region experienced an increasing trend of up to 2.5 feet per year.



GROUNDWATER WELL LEVEL TREND

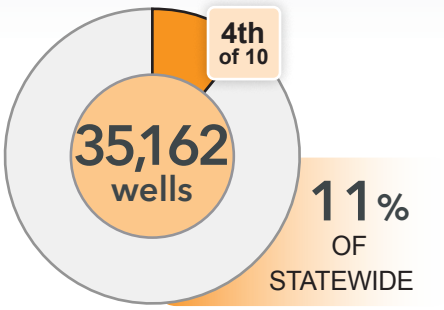


Central Coast Hydrologic Region Groundwater Quality

Monitoring

The Central Coast HR has the fourth most groundwater quality monitoring stations of the ten regions with 35,162 unique locations in the GAMA Groundwater Information System. The region has 11 percent of all groundwater quality monitoring stations in the state.

WATER QUALITY MONITORING WELLS



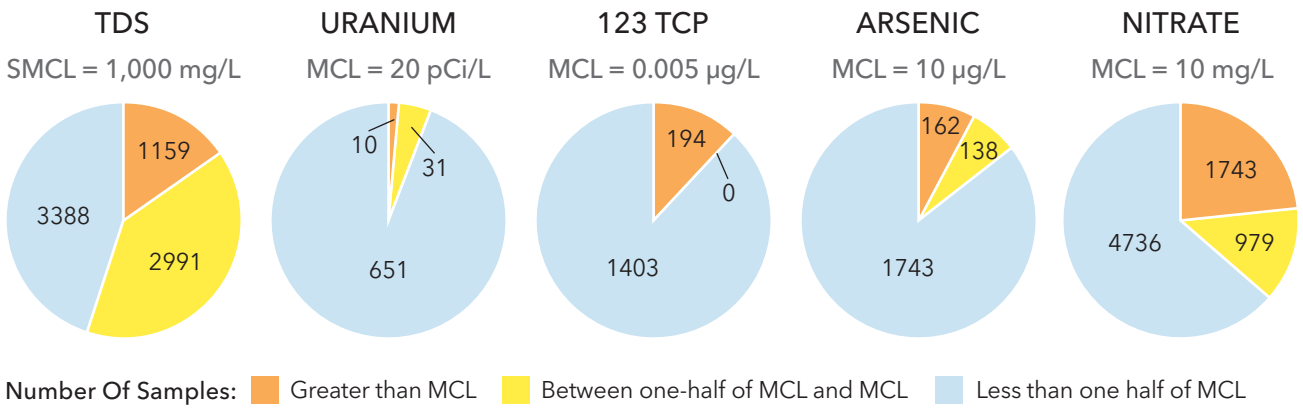
Conditions

The most common chemical detected above a regulatory limit in the region between 2009 and 2018 was iron, with 26.7 percent of wells in the region reporting above the SMCL. The second most commonly detected chemical over this period was manganese, detected in 26.4 percent of wells above the SMCL. The third most commonly detected chemical above its MCL between 2009 and 2018 was nitrate, detected higher in 23.4 percent of wells tested. This is the highest percentage of wells testing above the MCL for nitrate of any region in the state.

Top 10 Chemicals in Hydrologic Region by Percentage of Wells with Detections Above an MCL or SMCL:

26.7% Iron
26.4% Manganese
23.4% Nitrate
18.3% Standard Conductivity
17.8% 1,2-Dibromo,3-Chloropropane (DBCP)
15.4% Total Dissolved Solids (TDS)
12.2% 1,2,3-Trichloropropane (1,2,3-TCP)
7.9% Arsenic
7.8% Sulfate
4.7% Gross BETA Radioactivity

Regional Water Quality Summaries for 5 Chemicals of Statewide Concern



Central Coast Hydrologic Region Seawater Intrusion

Many coastal areas in the Central Coast HR were developed with groundwater as the main water source and some areas experienced overdraft in the 20th century. For some coastal areas, overdraft and declining groundwater levels allowed seawater to intrude into freshwater aquifers. In areas that have experienced seawater intrusion near Monterey Bay, local water managers have been working to mitigate it by passing local ordinances and providing alternative water sources to local farmlands.

Areas at Risk of Seawater Intrusion Near Monterey Bay



Local Groundwater Ordinances Related to Seawater Intrusion

Local water managers and elected officials in Monterey County have taken legislative steps to address ongoing seawater intrusion. In 1993, the first local ordinance (3709) was passed in the area restricting groundwater extraction and new well installation in areas impacted by seawater intrusion. Another local ordinance (3790) was passed in 1994 to manage wells within areas impacted by seawater intrusion. Each of these ordinances are still in effect today and have helped shape how local managers are addressing the issue. Recently, the Monterey County Board of Supervisors adopted more local ordinances (5302 and 5303) to address ongoing seawater intrusion. These ordinances established a temporary moratorium on new well installation in impacted areas for two years. The moratorium expired in May 2020, yet local water managers recommend extending and expanding the moratorium on new wells.

Alternative Agricultural Water Sources

In the two areas most impacted by seawater intrusion, Pajaro Valley and Castroville, local water managers have been working to provide alternative water sources to agricultural users for decades. These water managers face the challenge that the region lacks the infrastructure to tap into external water supply sources. Instead, local water managers have turned to reuse and water recycling. In both Pajaro Valley and Castroville, projects have been constructed to provide recycled water to local growers as an alternative water source. Since the inception of these projects, local seawater intrusion rates have declined.

Central Coast Hydrologic Region Groundwater Assistance

TECHNICAL SUPPORT

Monitoring Wells
0 Installed at 0 Sites
18 Planned at 6 Sites

Statewide Datasets
1,228 mi^2 of Land Use
3,115 mi^2 of Land Subsidence Monitoring

FACILITATION SUPPORT

FSS Contracts
Awarded in 6 Basins

Points of Contact (POCs)
21 POCs in 21 Basins

GRANT FUNDING

Grants Awarded
39 Grants since 2010

Total Funding
$29.4 Million Awarded

Note: Assistance summaries are from Department of Water Resources' Groundwater Program. Many other local, state and federal entities also provide assistance in this region

Local Project Spotlight: Recycled Water

In the Central Coast HR, water managers are actively developing projects to reduce reliance on groundwater. Multiple water recycling projects have been completed to do so, especially in areas impacted by seawater intrusion.

The Pajaro Valley Water Management Agency (PV Water) manages a recycled water project near Watsonville, the Coastal Distribution System (CDS). The CDS supplies recycled water to 5,500 acres of agriculture through more than 21 miles of pipeline. A recent study by Stanford University concluded the CDS has decreased seawater intrusion (Goedbel, 2017). An expansion of the CDS is currently underway to add more miles of pipeline to deliver to 700 more acres of farmland.

Another recycled water project located near Castroville, the Castroville Seawater Intrusion Project (CSIP), delivers a combination of recycled water and surface water to over 12,000 acres of farmland through more than 45 miles of pipeline. The CSIP has been in operation for over 20 years and has also decreased the rate of seawater intrusion.



A Recycled Water Turnout within the Coast Distribution System near Watsonville.

Did you know? Local efforts to irrigate crops with recycled water along the Central Coast has been ongoing for over 30 years. A Monterey Wastewater Reclamation Study for Agriculture concluded in 1986 that crops grown with recycled water were safe for human consumption. After the study was finalized, local water managers began the framework for what is now the CSIP.

Central Coast Hydrologic Region Basin Map



Central Coast Hydrologic Region Basin List

Basins (17) Required to Submit Groundwater Sustainability Plans

Basin Number	Basin Name	GSP Status	Critically Overdrafted
3-007	Carmel Valley	Due 2022	No
3-018	Carpinteria	Due 2024	No
3-013	Cuyama Valley	Submitted 2020	Yes
3-003.05	Gilroy-Hollister Valley - North San Benito	Due 2022	No
3-049	Montecito	Due 2024	No
3-004.01	Salinas Valley - 180/400 Foot Aquifer	Submitted 2020	Yes
3-004.10	Salinas Valley - Corral De Tierra Area/Monterey	Due 2022	No
3-004.02	Salinas Valley - East Side Aquifer	Due 2022	No
3-004.04	Salinas Valley - Forebay Aquifer	Due 2022	No
3-004.09	Salinas Valley - Langley Aquifer	Due 2022	No
3-004.06	Salinas Valley - Paso Robles Area	Submitted 2020	Yes
3-004.05	Salinas Valley - Upper Valley Aquifer	Due 2022	No
3-014	San Antonio Creek Valley	Due 2022	No
3-009	San Luis Obispo Valley	Due 2022	No
3-001	Santa Cruz Mid-County	Submitted 2020	Yes
3-027	Santa Margarita	Due 2022	No
3-015	Santa Ynez River Valley	Due 2022	No

Basins (37) with Option to Develop Groundwater Sustainability Plans (GSP)

Basin Number	Basin Name
3-020	Ano Nuevo Area
3-034	Arroyo De La Cruz Valley
3-047	Big Spring Area
3-030	Bitter Water Valley
3-019*	Carrizo Plain
3-038	Cayucos Valley
3-005	Cholame Valley
3-042	Chorro Valley
3-002.02	Corralitos - Purisima Highlands
3-029	Dry Lake Valley
3-053	Foothill
3-031	Hernandez Valley
3-045	Huasna Valley
3-006	Lockwood Valley
4-017*	Lockwood Valley
3-008.02	Los Osos Valley - Warden Creek
3-051	Majors Creek
3-041	Morro Valley
3-052	Needle Rock Point

Basin Number	Basin Name
3-039	Old Valley
3-032	Peach Tree Valley
3-044	Pozo Valley
3-024	Quien Sabe Valley
3-046	Rafael Valley
3-043	Rinconada Valley
3-004.11	Salinas Valley - Atascadero Area
3-028	San Benito River Valley
3-033	San Carpoforo Valley
3-035	San Simeon Valley
3-022	Santa Ana Valley
3-017	Santa Barbara
3-012.02	Santa Maria River Valley - Arroyo Grande
3-036	Santa Rosa Valley
3-040	Toro Valley
3-023	Upper Santa Ana Valley
3-037	Villa Valley
3-026	West Santa Cruz Terrace

Basins (2) with Approved Alternative GSPs

Basin Number	Basin Name
3-002.01	Corralitos - Pajaro Valley
3-003.01	Gilroy-Hollister Valley - Llagas Area

**Basin partially located in adjacent hydrologic region*

Basins (4) with Adjudicated Areas

Basin Number	Basin Name
3-016	Goleta
3-008.01	Los Osos Valley - Los Osos Area
3-004.08	Salinas Valley - Seaside
3-012.01	Santa Maria River Valley - Santa Maria

Groundwater at a Glance:
South Coast Hydrologic Region

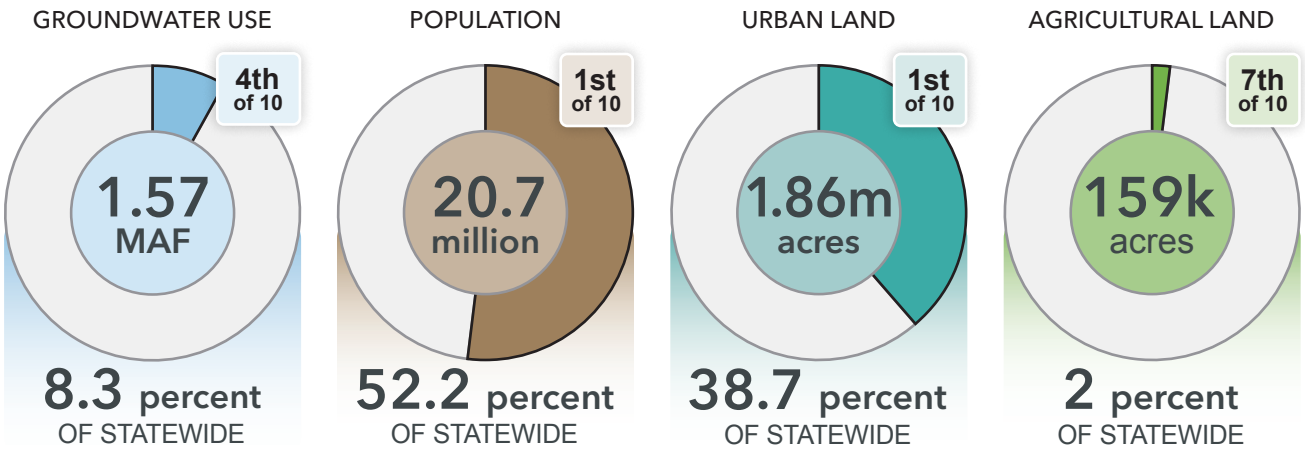
The South Coast HR encompasses almost 11,000 square miles from the Pacific Ocean to Riverside County and from Ventura County south to San Diego County. Though the region covers just seven percent of the state's total area, it is home to over 20 million people, more than half of the state's population. Annual precipitation ranges from more than 40 inches in the mountains to less than 10 inches in some valleys, with an overall average of 17.6 inches for the region. The two largest cities in California, Los Angeles and San Diego, are located in the region.





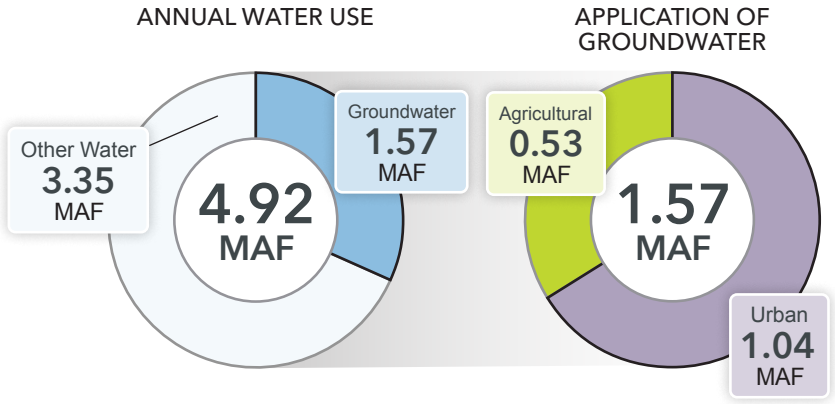
The sun sets over Los Angeles, California's largest city.

The South Coast Region is the fourth largest user of groundwater in the state, averaging more than 1.6 maf annually. Groundwater accounts for one-third of the region's water supply. The region has 15 adjudicated areas, more than any other region. Of the region's 74 groundwater basins, 17 are required to submit GSPs.

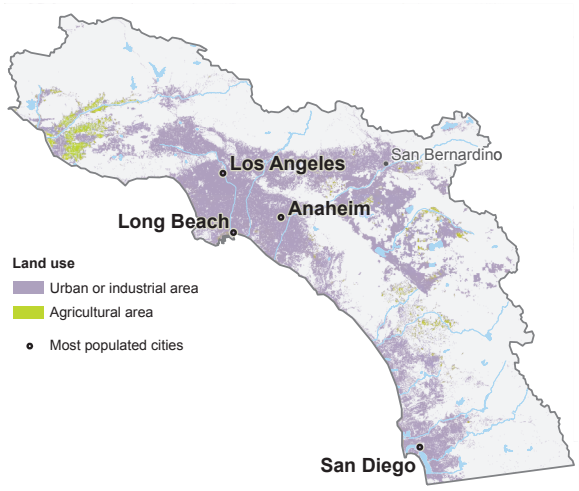


South Coast Hydrologic Region Land and Water Use

The South Coast Region ranks fourth in total water use among the ten regions, averaging 4.9 maf each year. Groundwater supplies approximately 33 percent of the total water use in the region. This accounts for 12 percent of all water use in California and 8 percent of statewide groundwater use.



Map of General Land Use



Land Use

The South Coast Region has the largest urban footprint in the state. About 1.86 million acres, 40 percent of the state's urban lands, are within the region. In contrast, the land designated for agricultural production is relatively small, totaling less than 160,000 acres, which ranks seventh out of the ten regions.

Groundwater Use

The South Coast Region ranks fourth of the ten regions for groundwater use, averaging 1.6 maf annually. Groundwater is primarily used to meet urban water demands in the region with 1 maf of groundwater extracted annually. The remaining 34 percent of groundwater (0.53 maf) is used for agricultural purposes.

Did you know? While the South Coast Region is home to over half of the state's population, it only accounts for 36 percent of the state's urban groundwater use. In contrast, the regions that comprise the Central Valley are home to only 20 percent of the state's population, yet account for 37 percent of the state's urban groundwater use. The South Coast HR has been able to reduce reliance on groundwater to meet urban demand through a combination of increasing water imports and improvements to desalination and water recycling technology.

Total Urban Area: 1,861,073 Acres

Top 4 Cities by Population (2010):
• Los Angeles (3,800,000) • San Diego (1,300,000) • Long Beach (462,000) • Anaheim (336,000)

Total Agricultural Area: 158,679 Acres

Top 4 Crops by Acreage (2016):
• Avocados (47,000) • Citrus (41,000)
• Miscellaneous Truck Crops (19,000)
• Strawberries (12,000)

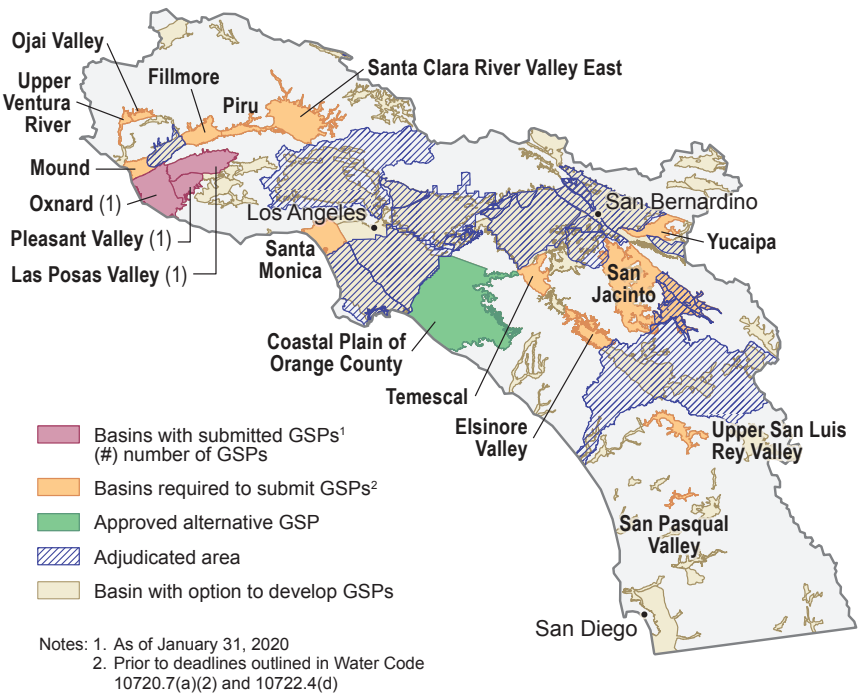
South Coast Hydrologic Region Groundwater Management

BASINS REQUIRING GSPs	BASINS WITH ADJUDICATED AREAS	APPROVED ALTERNATIVE GSPs
17	16	1
CRITICALLY OVERDRAFTED BASINS	**GROUNDWATER SUSTAINABILITY AGENCIES**	**GSPs SUBMITTED BY 01/31/2020**
2	37	3

Groundwater Management

There are 17 basins within the South Coast Hydrologic Region that are required by SGMA to submit GSPs. A total of 37 Groundwater Sustainability Agencies have been formed in these 17 basins. Three basins have submitted GSPs as of January 2020, including two critically overdrafted basins. One basin in the region has an approved Alternative GSP. There are 15 adjudicated areas in the region, more than any other region in the state. These adjudicated areas cover all or part of 16 basins and over 1 million acres.

SGMA Groundwater Management Status



**Several basins span across regions. For the purposes of this analysis, only basins with majority of their area in the region are represented.*

CASGEM Monitoring

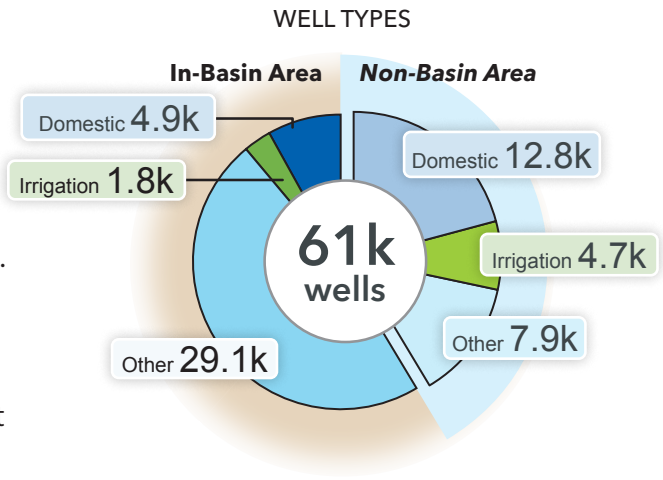
Forty basins in the region that are not required to develop GSPs are actively participating in the CASGEM program. Within these basins biannual groundwater level measurements are collected and posted to the CASGEM online system. These measurements are collected voluntarily by private individuals, academic institutions, conservation districts, and other local, state, and federal entities.

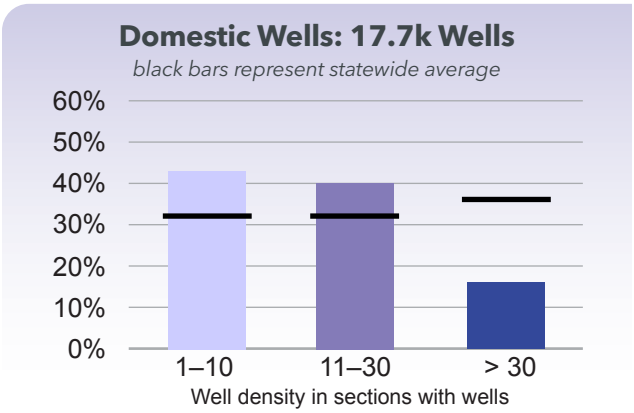


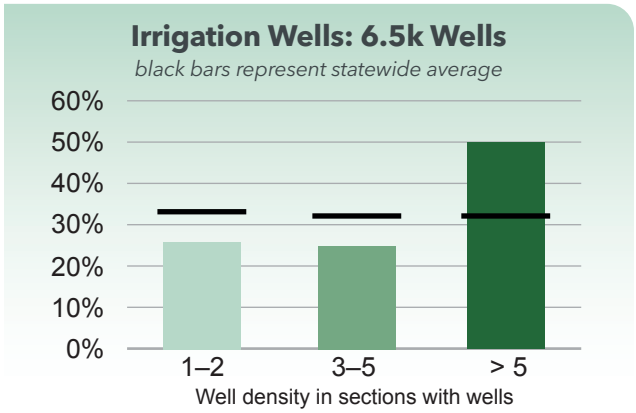
A desiccant attached to an automatic water level measuring device in the South Coast HR.

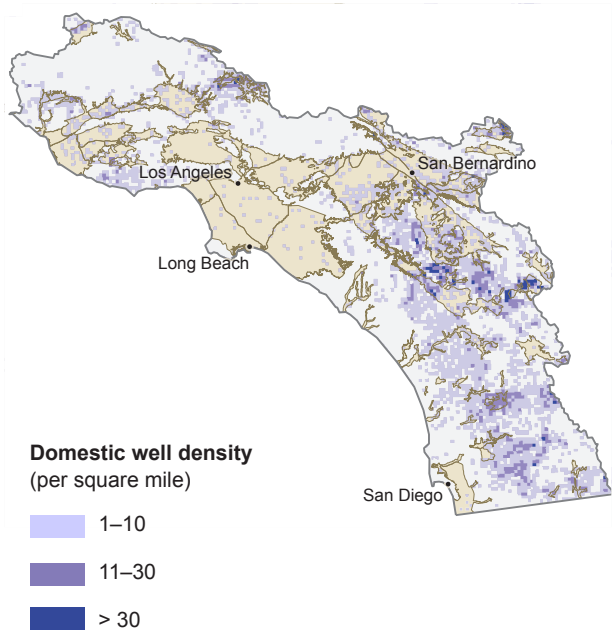
South Coast Hydrologic Region Well Infrastructure

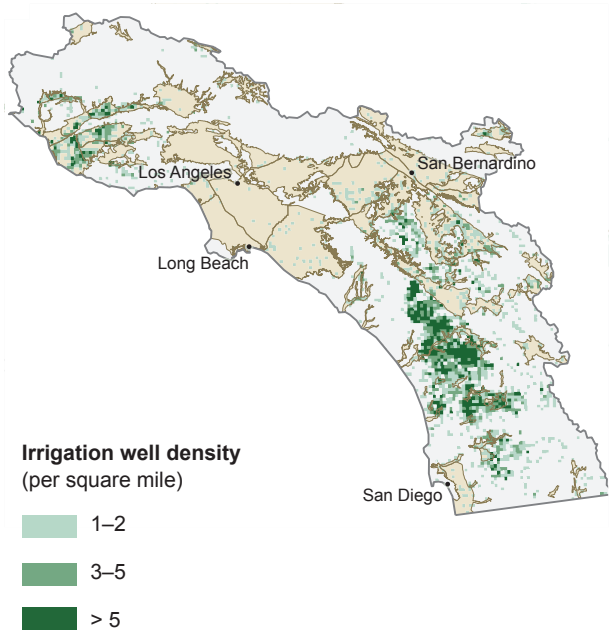
There are more than 61,000 groundwater wells in the South Coast Region. Fifty-nine percent of the wells (35,900) have been drilled within groundwater basins and approximately 41 percent (25,400) have been drilled in the non-basin area. Wells installed within the basins are primarily for monitoring (55 percent). In the non-basin area, wells are mainly for domestic use (50 percent). More domestic and irrigation wells have been installed in the non-basin area than within basins in the South Coast HR. Of the wells drilled since 1977, 13 percent have been within the South Coast HR.









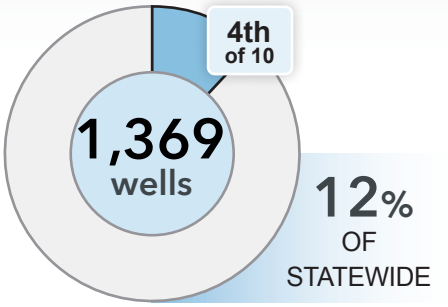


South Coast Hydrologic Region Groundwater Levels

Monitoring

The South Coast HR has the fourth most groundwater level monitoring wells in the state with 1,369 sites. This amount to 12 percent of all groundwater level monitoring wells in the state being in the South Coast HR. Local agencies perform most of the groundwater level monitoring in the region, collecting data from 93 percent of the monitoring wells (1,279). The region has the most dedicated observation wells in the state with 852 wells. These wells make up more than 60 percent of all monitoring wells in the region. Most of the monitoring wells in the region, or 60 percent (820), are 600 feet deep or shallower.

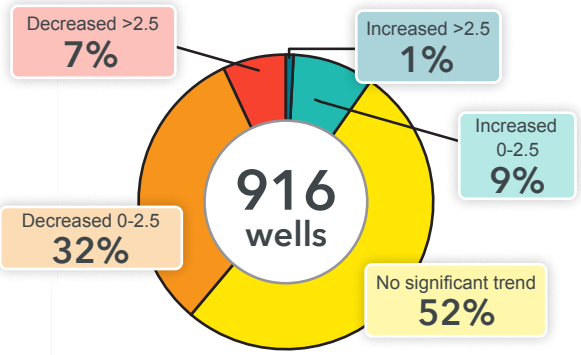
GW LEVEL MONITORING WELLS

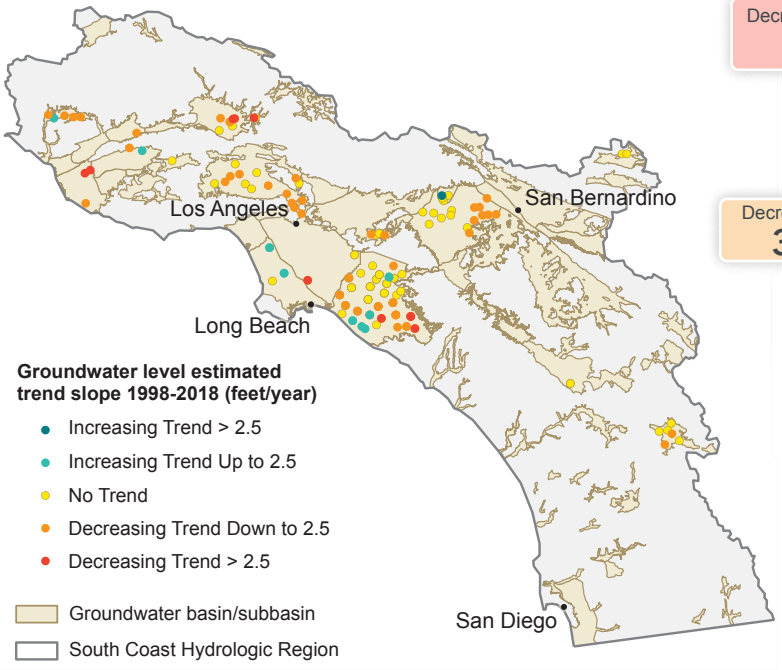


Conditions

Groundwater levels in the South Coast HR are generally stable with over 50 percent of monitoring wells showing no changing trend between 1998 and 2018. A declining trend was found in 39 percent of monitoring wells, with seven percent experiencing a declining trend of more than 2.5 feet per year over this period and 32 percent showing a declining trend of up to 2.5 feet per year. Approximately 10 percent of monitoring wells in the region experienced an increasing trend.

GROUNDWATER WELL LEVEL TREND

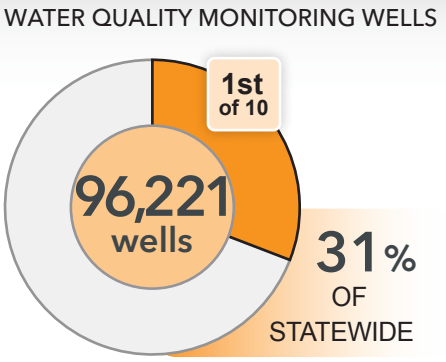




South Coast Hydrologic Region Groundwater Quality

Monitoring

The South Coast HR has more groundwater quality monitoring stations in the GAMA Groundwater Information System than any other region with 96,221 unique locations. Nearly one-third (31 percent) of all groundwater quality monitoring stations in California are in the South Coast HR.



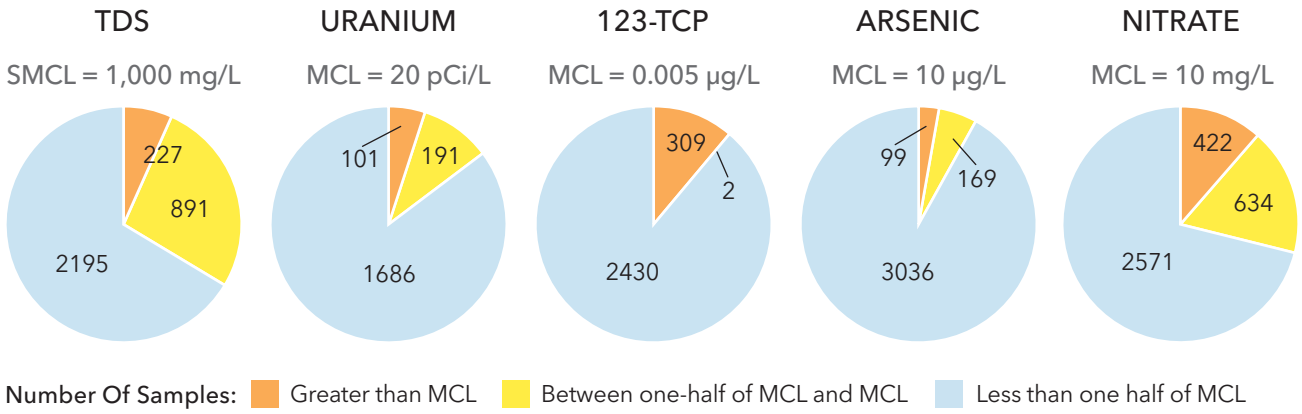
Conditions

The most common chemical detected above a regulatory limit in the South Coast HR between 2009 and 2018 was iron, with 17 percent of water quality stations reporting above the SMCL. The second most commonly detected chemical above its MCL or SMCL over this period was manganese, detected in 15.6 percent of wells above its SMCL. Notably, perchlorate was detected above its MCL in 7.7 percent of wells tested between 2009 and 2018, the highest detection level for perchlorate in any HR.

Top 10 Chemicals in Hydrologic Region by Percentage of Wells with Detections Above an MCL or SMCL:

17.0% Iron
15.6% Manganese
11.6% Nitrate
11.3% 1,2,3-Trichloropropane (1,2,3-TCP)
7.7% Perchlorate
7.2% Gross ALPHA Radioactivity
7.0% Trichloroethylene (TCE)
6.9% Total Dissolved Solids (TDS)
6.3% 1,2-Dibromo,3-Chloropropane (DBCP)
6.2% Tetrachloroethylene (PCE)

Regional Water Quality Summaries for 5 Chemicals of Statewide Concern

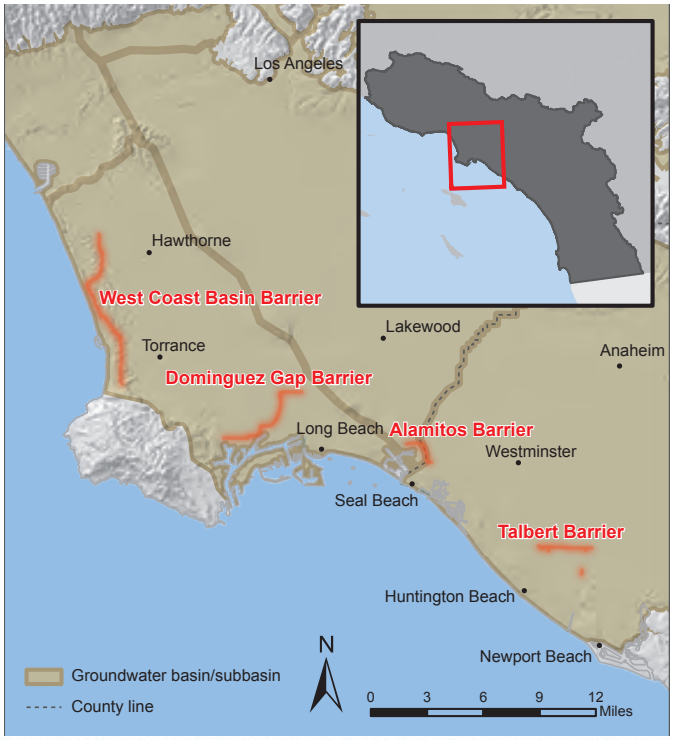


South Coast Hydrologic Region Seawater Intrusion

The South Coast HR includes all the watersheds that drain to the Pacific Ocean from Ventura County to Mexico. Groundwater has been an important water supply source throughout development of the region and many areas experienced overdraft during the 20th century. For some coastal basins, overdraft and declining groundwater levels allowed seawater to intrude into freshwater aquifers. Local water managers have worked to mitigate this by importing water for in-lieu use, implementing water reuse and desalination, conserving water, and utilizing seawater intrusion barriers.

Seawater intrusion barriers were first developed in the region in the 1950s. Currently, four large seawater intrusion barrier projects are ongoing: West Coast Basin Seawater Barrier, Dominguez Gap Barrier, Talbert Seawater Intrusion Barrier, and Alamitos Seawater Intrusion Barrier. These barriers consist of a series of wells that inject water into the aquifer to maintain the seawater-freshwater interface. The continued operation of these barriers in conjunction with augmentation of local water supply have prevented substantial impacts of seawater intrusion in the South Coast HR.

Seawater Intrusion Barriers





The Orange County Groundwater Replenishment System is Located near Fountain Valley.

Did you know? The four seawater intrusion barriers mentioned above consist of over 400 injections wells using about 58,000 AFY of water to prevent seawater intrusion. The water injected in the barriers consists of recycled water (87 percent) and imported water (13 percent). One barrier, the Talbert Barrier, uses 100 percent recycled water from the Orange County Groundwater Replenishment System (GWRS). The GWRS is one of the largest potable reuse projects in the world, supplying 100 million gallons per day of high-quality recycled water.

South Coast Hydrologic Region Groundwater Assistance

TECHNICAL SUPPORT

Monitoring Wells
11 Installed at 4 Sites
0 Planned at 0 Sites

Statewide Datasets
3,710 mi^2 of Land Use
2,962 mi^2 of Land Subsidence Monitoring

FACILITATION SUPPORT

FSS Contracts
Awarded in 6 Basins

Points of Contact (POCs)
22 POCs in 22 Basins

GRANT FUNDING

Grants Awarded
61 Grants since 2010

Total Funding
$114.9 Million Awarded

Note: Assistance summaries are from Department of Water Resources' Groundwater Program. Many other local, state and federal entities also provide assistance in this region

Local Project Spotlight: Desalination Projects

In the South Coast HR where rainfall is scarce and options to increase water imports are limited, water managers have turned to emerging technology in desalination to augment local water supplies. Desalination facilities convert high-salinity water into potable water. These alternative sources of water help diversify the region's water supply and reduce the reliance on groundwater and imported water.

The Claud "Bud" Lewis Carlsbad Desalination Plant near San Diego produces 50 million gallons of high-quality water per day from seawater. This project has been delivering water to users since 2015.



Goldsworthy Desalter Facility Located near Los Angeles.

Two other projects in the region treat brackish groundwater. The Richards A. Reynolds Groundwater Desalination Facility in Chula Vista began desalinating brackish groundwater in 1999. An expansion in 2017 allows the facility to produce up to 10 million gallons of potable water per day. Another facility located in Torrance, the Goldsworthy Desalter, was recently upgraded and now has the capacity to produce over 42 million gallons per day of high-quality potable water.

Did you know? Desalination projects were highlighted in the Governor's Water Resilience Portfolio (WRP). The WRP recommends "state agencies team with federal and academic partners to develop desalination technologies that treat a variety of water types for various uses, with a goal of enabling manufacturing of energy-efficient desalination technologies in the U.S. at a lower cost, same or better quality, and reduced environmental impact than non-traditional water sources."

South Coast Hydrologic Region Basin Map



4-003.01 Groundwater basin/subbasin number (asterisk by number indicates additional portion of basin/subbasin lies in an adjacent hydrologic region)

Groundwater basin/subbasin

South Coast Hydrologic Region

South Coast Hydrologic Region Basin List

Basins (17) Required to Submit Groundwater Sustainability Plans

Basin Number	Basin Name	GSP Status	Critically Overdrafted
4-011.01	Coastal Plain of Los Angeles - Santa Monica	Due 2022	No
8-001	Coastal Plain of Orange County	Due 2022	No
8-004.01	Elsinore - Elsinore Valley	Due 2022	No
4-008	Las Posas Valley	Submitted 2020	No
4-002	Ojai Valley	Due 2022	No
4-006	Pleasant Valley	Submitted 2020	Yes
9-007.01	San Luis Rey Valley - Upper San Luis Rey Valley	Due 2022	No
8-005	San Jacinto**	Due 2022	No
9-010	San Pasqual Valley	Due 2022	No
4-004.05	Santa Clara River Valley - Fillmore	Due 2022	No
4-004.03	Santa Clara River Valley - Mound	Due 2022	No
4-004.02	Santa Clara River Valley - Oxnard	Submitted 2020	Yes
4-004.06	Santa Clara River Valley - Piru	Due 2022	No
4-004.07	Santa Clara River Valley - Santa Clara River Valley East	Due 2022	No
8-002.09	Upper Santa Ana Valley - Temescal	Due 2022	No
8-002.07	Upper Santa Ana Valley - Yucaipa	Due 2022	No
4-003.01	Ventura River Valley - Upper Ventura River	Due 2022	No

Basins (41) with Option to Develop Groundwater Sustainability Plans

Basin Number	Basin Name
4-005	Acton Valley
4-007	Arroyo Santa Rose Valley
9-002	Batiquitos Lagoon Valley
8-009*	Bear Valley
8-007	Big Meadows Valley
9-028	Campo Valley
4-011.02	Coastal Plain Of Los Angeles - Hollywood
9-033	Coastal Plain Of San Diego
4-010	Conejo
9-027	Cottonwood Valley
9-016	El Cajon Valley
8-004.02	Elsinore - Bedford-Coldwater
9-009	Escondido Valley
8-006*	Hemet Lake Valley

Basin Number	Basin Name
4-016	Hidden Valley
4-018	Hungry Valley
4-017*	Lockwood Valley
4-022*	Malibu Valley
9-014	Mission Valley
9-024	Pamo Valley
9-029	Potrero Valley
9-013	Poway Valley
9-025*	Ranchita Town Area
4-020	Russell Valley
9-015	San Diego River Valley
9-012	San Dieguito Creek
9-023	San Elijo Valley
9-001	San Juan Valley

Basin Number	Basin Name
9-007.02	San Luis Rey Valley - Lower San Luis Rey Valley
9-032	San Marcos Area
9-002	San Mateo Valley
9-003	San Onofre Valley
9-011	Santa Maria Valley
8-008	Seven Oaks Valley
4-009	Simi Valley
4-019	Thousand Oaks Area
4-015	Tierra Rejada
4-001	Upper Ojai Valley
8-002.05*	Upper Santa Ana Valley – Cajon
4-003 02	Ventura River Valley - Lower Ventura River
9-008	Warner Valley

Basins (15) with Adjudicated Areas

Basin Number	Basin Name
9-006*	Cahuilla Valley
4-011 04	Coastal Plain of Los Angeles – Central**
4-011 03	Coastal Plain of Los Angeles - West Coast
4-023	Raymond
4-012	San Fernando Valley
4-013	San Gabriel Valley**
4-004.04	Santa Clara River Valley - Santa Paula
9-004	Santa Margarita Valley
9-005	Temecula Valley
8-002.01	Upper Santa Ana Valley – Chino**

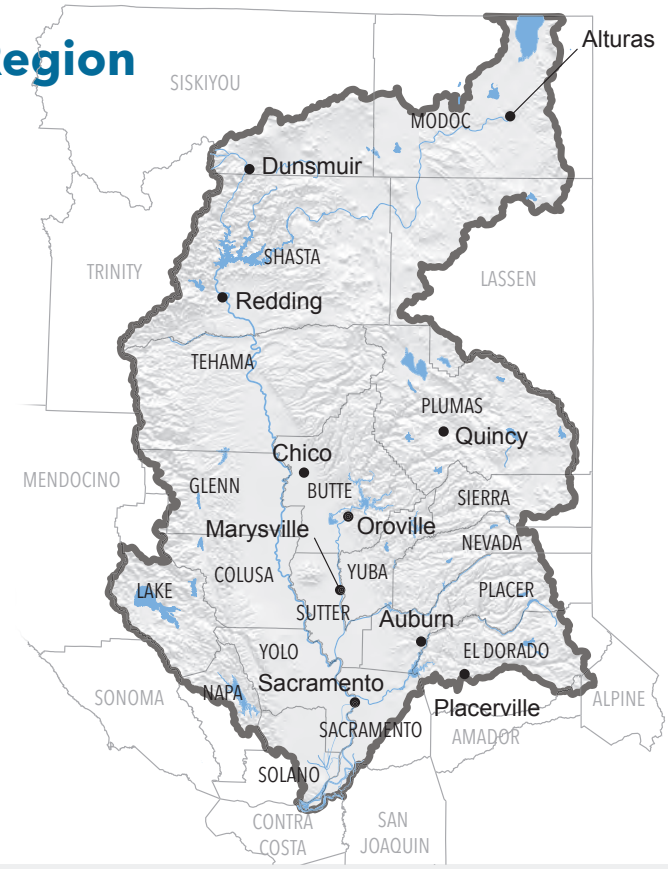
Basin Number	Basin Name
8-002.02	Upper Santa Ana Valley - Cucamonga
8-002.04	Upper Santa Ana Valley - Rialto-Colton**
8-002.03	Upper Santa Ana Valley - Riverside-Arlington**
8-002.06	Upper Santa Ana Valley - San Bernardino
8-002 08*	Upper Santa Ana Valley - San Timoteo**

Basins with Approved Alternative GSPs

Basin Number	Basin Name
8-001	Coastal Plain of Orange County

**Basin partially located in adjacent hydrologic region*
***Basin partially adjudicated*

Groundwater at a Glance:
Sacramento River Hydrologic Region



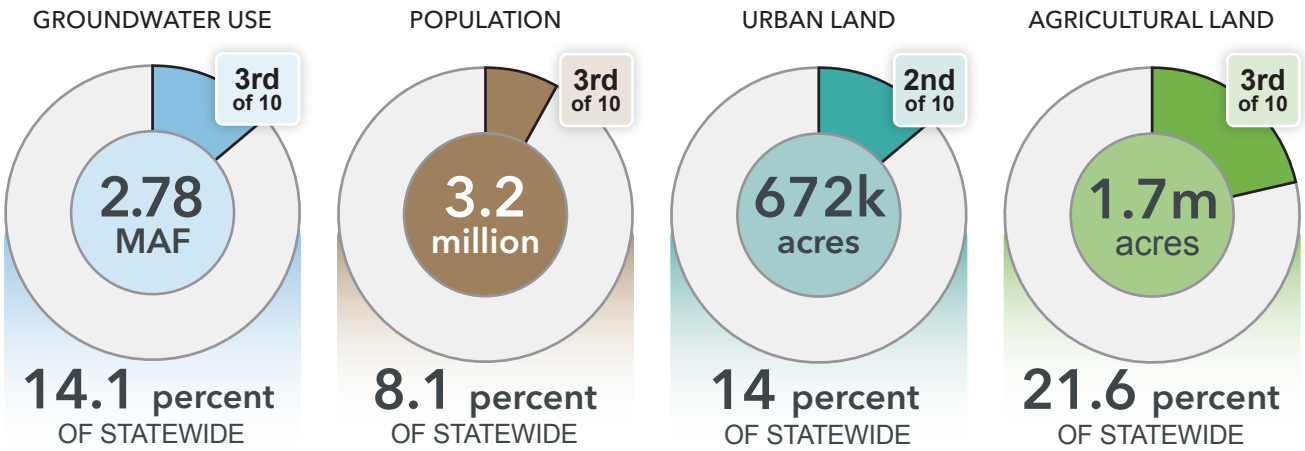
The Sacramento River HR includes the entire drainage basin of the state's largest river, the Sacramento River covering approximately 27,200 square miles. The river is historically home to important anadromous fish species that have ongoing restoration efforts. In 2017, its population was estimated at nearly 3.2 million people. Annual precipitation is highly variable in the region ranging from less than 10 inches in high desert areas, to 18-35 inches in the Central Valley to more than 50 inches in the Sierra foothills. Highlights of the region include the headwaters of the state and federal water projects, Mounts Lassen and Shasta and California's capital Sacramento.



An agricultural groundwater well in Colusa County.

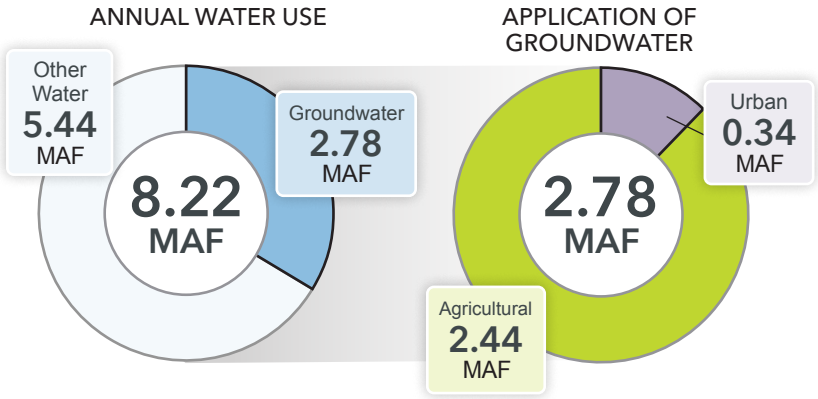
The region accounts for 14 percent of all groundwater use in the state (2.78 maf annually). Groundwater demands account for about one-third of the overall water demands in the region.

There are 85 groundwater basins in the region, 21 of which are required to submit GSPs by SGMA, the most of any hydrologic region in the state.

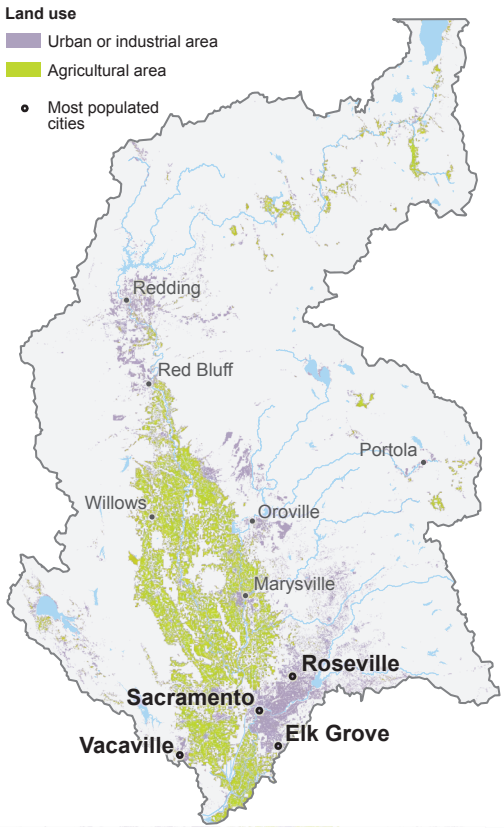


Sacramento River Hydrologic Region Land and Water Use

The Sacramento River HR uses an average of 8.22 maf of water annually, 20 percent of California's total water use . Groundwater accounts for 34 percent of the region's water supply and 14 percent of statewide groundwater use.



Map of General Land Use



Groundwater Use

The Sacramento River HR ranks third of the ten regions for groundwater use, averaging 2.78 maf annually. About 88 percent (2.44 maf) of the groundwater applied in the region is used for agricultural purposes. Eleven percent of groundwater is applied to support the 3.2 million residents in the region, with the remaining 1 percent used to supply water to managed wetlands.

Did you know?

The Sacramento River HR is the main water source for many agricultural and urban users in other HRs. The region has more than 40 major storage reservoirs which provide flood protection in the winter and store spring runoff from the Sierra Nevada and Cascade ranges. The state and federal water projects store and transport water from many of these reservoirs to many other parts of California.

Land Use

Agricultural lands comprise roughly 22 percent of the area in the region with almost 1.7 million acres. The region has the second largest urban footprint in the state with over 670,000 acres of urban land use, mostly located in the greater Sacramento area.

Total Urban Area: 672,030 Acres

Top 4 Cities by Population (2010):

- Sacramento (466,000)
- Elk Grove (153,000)
- Roseville (119,000)
- Vacaville (92,000)

Total Agricultural Area: 1,699,302 Acres

Top 4 Crops by Acreage (2016):

- Rice (539,000)
- Mixed Pasture (210,000)
- Walnuts (206,000)
- Almond (201,000)

Sacramento River Hydrologic Region Groundwater Management

BASINS REQUIRING GSPs	BASINS WITH ADJUDICATED AREAS	APPROVED ALTERNATIVE GSPs
21	0	0

CRITICALLY OVERDRAFTED BASINS	GROUNDWATER SUSTAINABILITY AGENCIES	GSPs SUBMITTED BY 01/31/2020
0	78	2

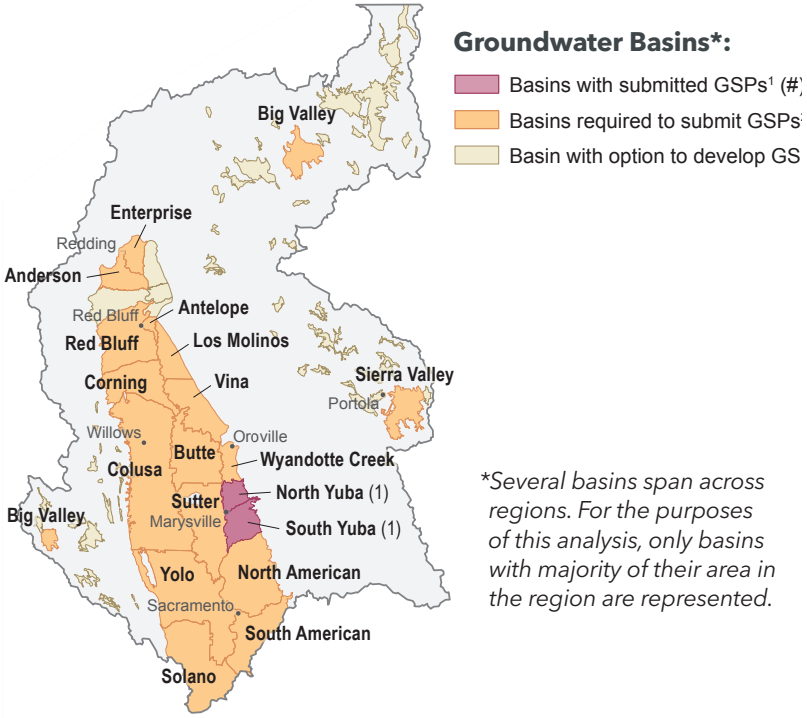
Groundwater Management

Twenty-one basins within the Sacramento River HR are required by SGMA to submit GSPs. Within these 21 basins, 78 Groundwater Sustainability Agencies have been formed as of January 2020.

Two basins have submitted one or more GSPs to DWR for review. The remaining 19 required basins have GSPs due in 2022.

No basins in the region have an approved Alternative GSP and there are currently no adjudicated areas in the Sacramento River HR.

SGMA Groundwater Management Status



Several basins span across regions. For the purposes of this analysis, only basins with majority of their area in the region are represented.

CASGEM Monitoring

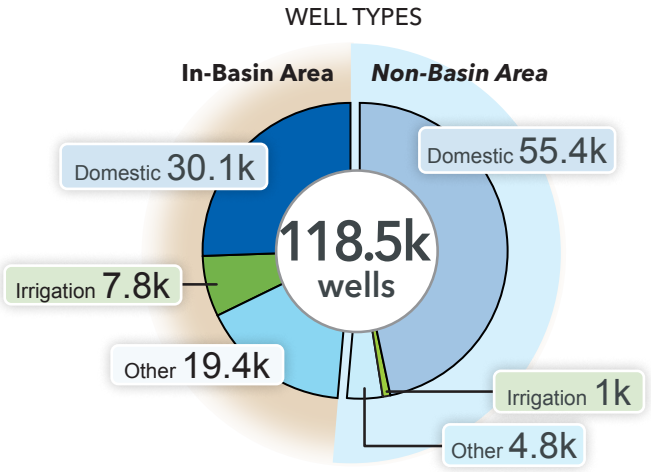
There are 27 basins in the region that are not required to develop GSPs but are actively participating in the CASGEM program. Within these basins, biannual groundwater level measurements are collected and posted to the CASGEM online system. It is important to note these measurements are collected voluntarily by private individuals, academic institutions, conservation districts, and other local, state, and federal entities.

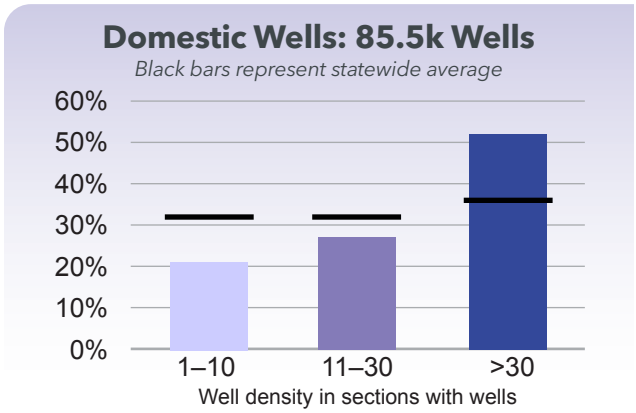


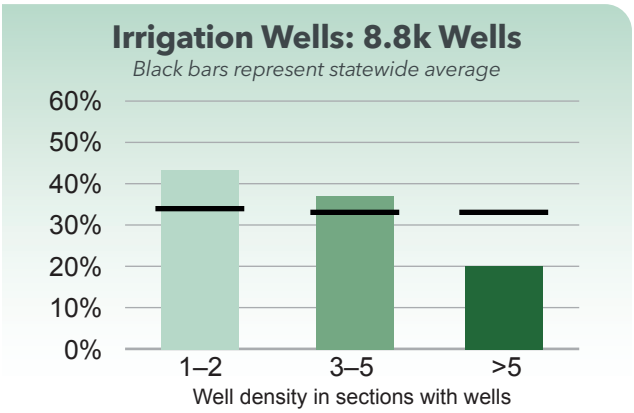
A DWR Engineering Geologist measures the groundwater level in an agricultural well in Colusa County.

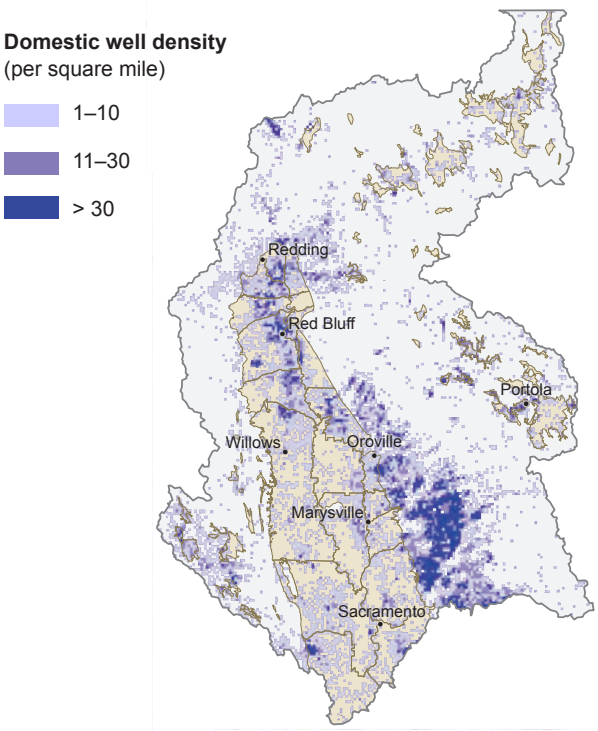
Sacramento River Hydrologic Region Well Infrastructure

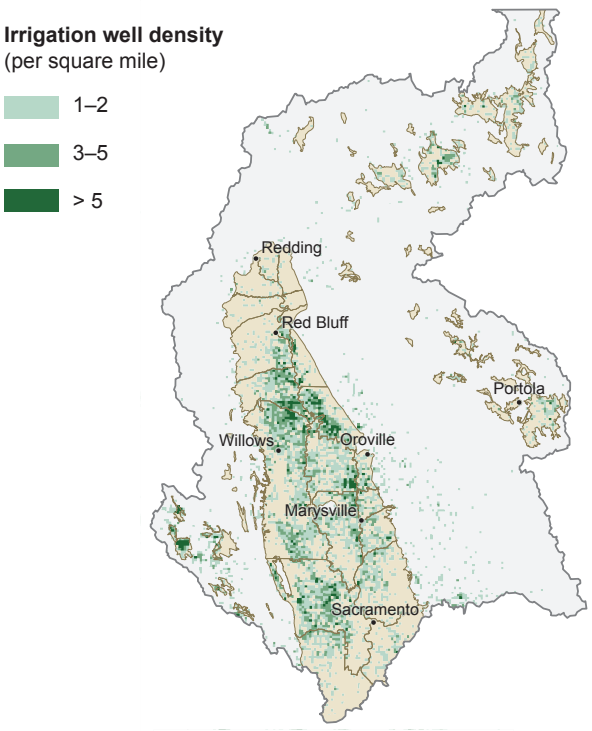
There have been 118,500 groundwater wells drilled in the Sacramento River HR since 1977, more than any other HR. More wells have been drilled in the non-basin area than within groundwater basins in this region. Wells in the basin and non-basin areas are mostly for domestic use, which account for 72 percent of all wells in the region. More than one quarter (26 percent) of all wells drilled since 1977 have been within the Sacramento River HR.





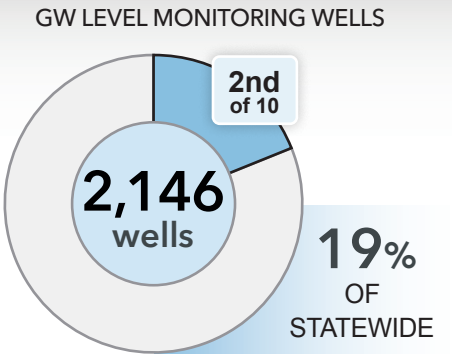






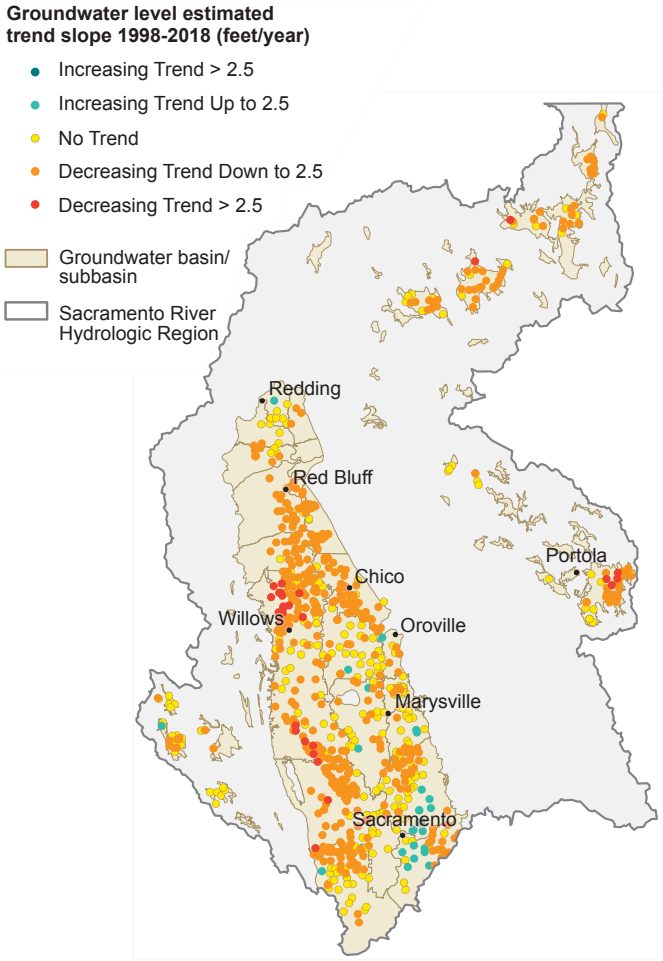
Sacramento River Hydrologic Region Groundwater Levels

Monitoring

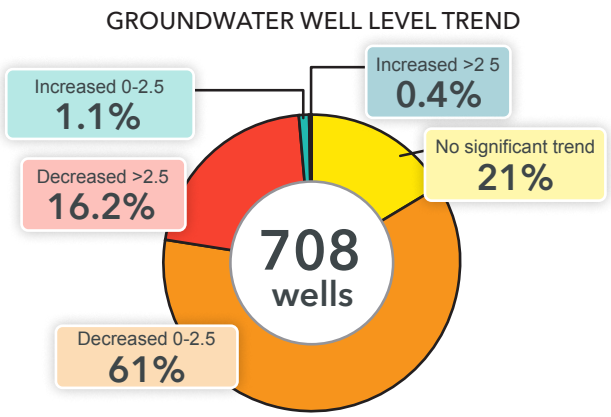


The Sacramento River HR has 2,146 groundwater level monitoring wells, the second most among hydrologic regions. Currently, 19 percent of California's groundwater level monitoring wells are located in the Sacramento River HR. Most groundwater level monitoring wells (75 percent) in the region are less than 600 feet deep. Wells in the region are measured more frequently than any other HR. Fifty eight percent of the wells (610) measured more than 48 times in four years statewide are in this region. Most wells in the DWR Continuous Groundwater Level Monitoring Network (408 of 450 wells) are also in the Sacramento River HR.

Conditions



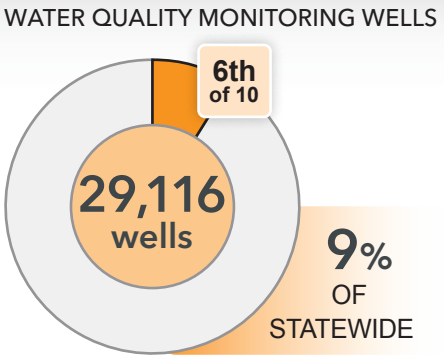
Groundwater levels in the Sacramento River HR are on a declining trend. More than 77 percent of monitoring wells experienced a declining trend for groundwater levels from 1998 to 2018. Most monitoring wells in the region (61 percent) showed a decreasing trend of up to 2.5 feet per year. Sixteen percent of wells showed a greater decreasing trend of more than 2.5 feet of decline per year over this period. Twenty one percent of wells displayed a stable trend. The remaining percent of wells showed an increasing trend.



Sacramento River Hydrologic Region Groundwater Quality

Monitoring

There are 29,116 water quality monitoring sites in the Sacramento River HR in the GAMA Groundwater Information System. This number ranks sixth for most sites among the ten hydrologic regions. Nine percent of all groundwater quality stations in GAMA are located in the Sacramento River HR.



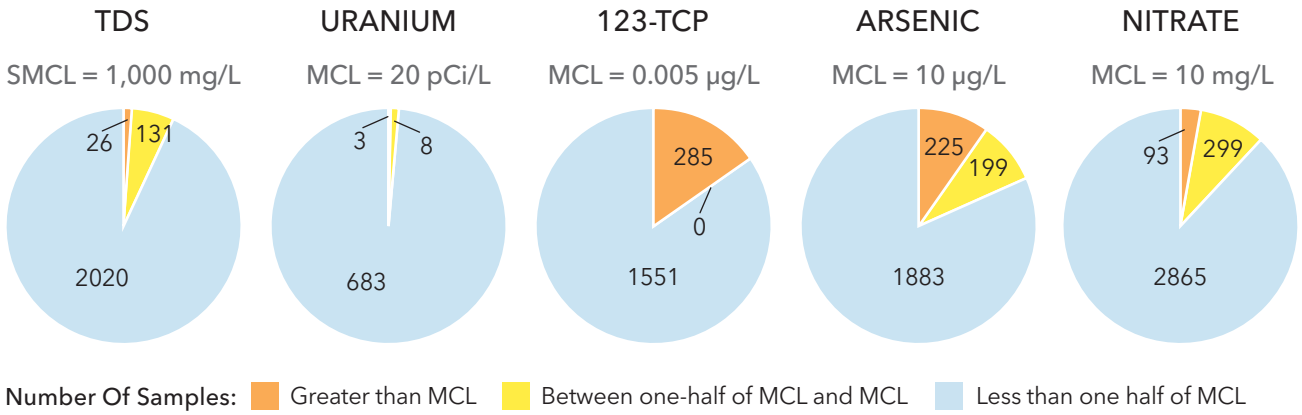
Conditions

The most commonly detected chemical above a regulatory limit in the Sacramento River HR between 2009 and 2018 was Manganese, with 23.9 percent of water quality stations reporting at levels above the SMCL . The second most common chemical detected above a regulatory limit over thid period was iron, detected in approximately 17 percent of wells above its SMCL. Only three chemicals in groundwater in the Sacramento River HR were detected above MCLs or SMCLs in 10 percent or more of water quality stations between 2009 and 2018, tying for the least of any HR.

Top 10 Chemicals in Hydrologic Region by Percentage of Wells with Detections Above an MCL or SMCL:

23.9% Manganese
16.6% Iron
15.5% 1,2,3-Trichloropropane (1,2,3-TCP)
9.8% Arsenic
6.7% Bromide
6.2% 1,2-Dibromo,3-Chloropropane (DBCP)
2.9% Nitrate
1.2% Total Dissolved Solids (TDS)
1.2% Uranium
1.0% Aluminum

Regional Water Quality Summaries for 5 Chemicals of Statewide Concern



Sacramento River Hydrologic Region Land Subsidence

Monitoring

Land subsidence monitoring in the Sacramento River HR includes 5,564 square miles of InSAR coverage, 17 CGPS stations, 11 extensometers and one regional subsidence network. While much of this network has shown little to no land subsidence, localized areas have experienced more than two feet of subsidence based on data collected from the regional subsidence network. The region is a great example of the need to have multiple methods to measure land subsidence, as different datasets may show different results depending on the period or record and location of equipment.

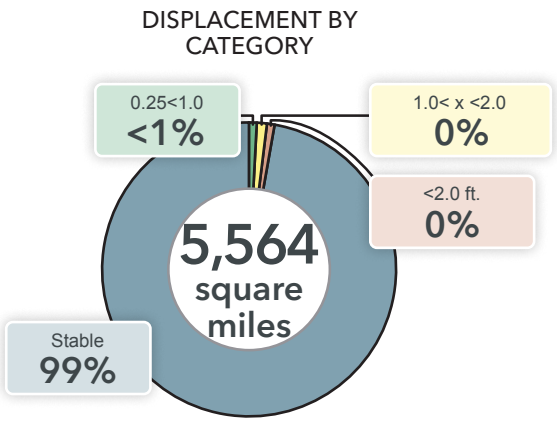
Did you know?

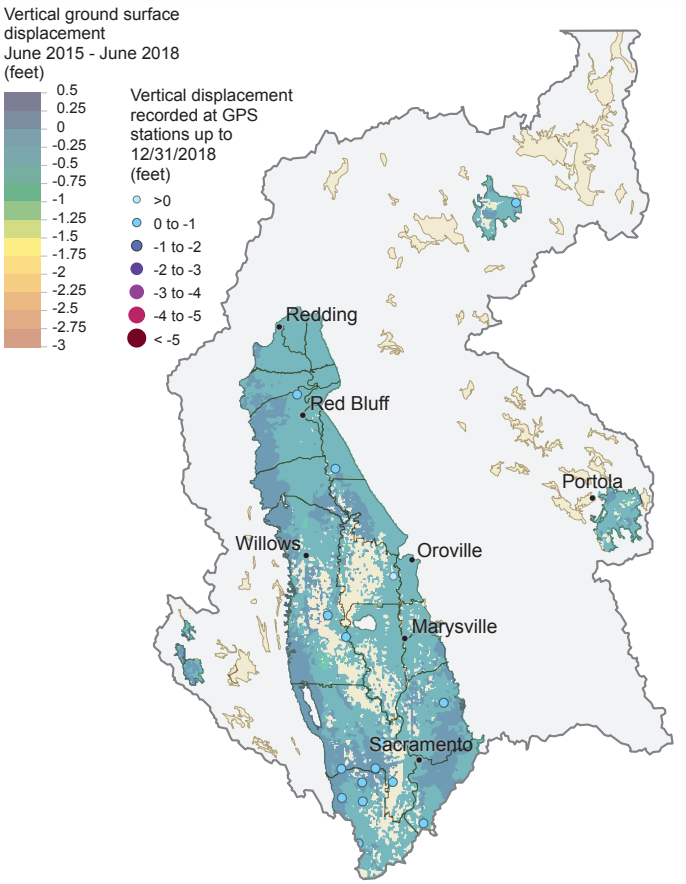
DWR operates the Sacramento Valley GPS Subsidence Monitoring Network in the region. The network includes more than 300 benchmarks across 11 counties. DWR collaborated with 19 state, county, and local entities to resurvey the network in 2017 to determine if any changes had occurred in the ground surface elevation.

The results of the study were released in 2019. The largest recorded elevation drop was just over 2 feet near the city of Arbuckle. The most widespread subsidence was found in Yolo County.

Conditions

Land subsidence has been occurring in localized areas within the region for decades. The southern portion of the Sacramento Valley Basin has been especially affected by land subsidence. Areas within Yolo and Colusa County experienced more than four feet of subsidence between 1950 and 1990. Recently, additional land subsidence has been measured in the same area.





Sacramento River Hydrologic Region Groundwater Assistance

TECHNICAL SUPPORT

Monitoring Wells
12 Installed at 3 Sites
65 Planned at 21 Sites

Statewide Datasets
4,123 mi^2 of Land Use
5,246 mi^2 of Land Subsidence Monitoring

FACILITATION SUPPORT

FSS Contracts
Awarded in 19 Basins

Points of Contact (POCs)
20 POCs in 20 Basins

GRANT FUNDING

Grants Awarded
75 Grants since 2010

Total Funding
$53.4 Million Awarded

Note: Assistance summaries are from Department of Water Resources' Groundwater Program. Many other local, state and federal entities also provide assistance in this region

Local Project Spotlight: Water Transfers

Water transfers can help stretch water supplies in dry times and move water to places of critical need. Water transfers have occurred in California for a number of years and many see well-regulated water transfer markets as a key to the sustainability of California's water portfolio.

Many water transfers occur in the Sacramento River HR due to the routine availability of water and location of conveyance facilities near the Delta. Many types of transfers occur in the region such as crop idling, groundwater substitution, and reservoir storage release. Water transfers are tracked by DWR in the Water Transfer Information Management System.

Groundwater substitution transfers involve someone selling part of their yearly federal or state surface water allocation to a buyer, with the seller pumping groundwater to meet its water needs. Each proposal is reviewed by a multi-agency team to minimize impacts to local resources. Each project includes a specialized monitoring program and metrics where groundwater extraction must stop temporarily if sustained groundwater level declines go beyond a pre-approved level.

Year	Volume(AF)	Year	Volume(AF)
2011	409	2016	-
2012	-	2017	-
2013	53,841	2018	53,153
2014	79,201	2019	-
2015	79,372	2020*	125,529

Below Normal Water Year Type in San Joaquin Valley
**Proposed transfer amount*

Did you know?

In 2020, DWR received the highest volume of groundwater substitution transfer proposals on record, more than 125,000 AF. Transfers were likely fueled by a combination of below average precipitation and a 20 percent water allocation for both federal and state water projects' contractors. In dry years, local water agencies must be creative to meet local water needs through conservation, pumping additional groundwater, or securing imported water through transfers from other areas.

Sacramento River Hydrologic Region Basin Map





5-001.01 Groundwater basin/subbasin number
(asterisk by number indicates additional portion of basin/subbasin lies in an adjacent hydrologic region)

Groundwater basin/subbasin

Sacramento River Hydrologic Region

Sacramento River Hydrologic Region Basin List

Basins (21) Required to Submit Groundwater Sustainability Plans

Basin Number	Basin Name	GSP Status	Critically Overdrafted
5-004	Big Valley	Due 2022	No
5-006.03	Redding Area – Anderson	Due 2022	No
5-006.04	Redding Area – Enterprise	Due 2022	No
5-012.01	Sierra Valley – Sierra Valley	Due 2022	No
5-015	Big Valley	Due 2022	No
5-021.50	Sacramento Valley – Red Bluff	Due 2022	No
5-021.51	Sacramento Valley – Corning	Due 2022	No
5-021.52	Sacramento Valley – Colusa	Due 2022	No
5-021.54	Sacramento Valley – Antelope	Due 2022	No
5-021.56	Sacramento Valley – Los Molinos	Due 2022	No
5-021.57	Sacramento Valley – Vina	Due 2022	No
5-021.60	Sacramento Valley – Nor h Yuba	Submitted 2020	No
5-021.61	Sacramento Valley – South Yuba	Submitted 2020	No
5-021.62	Sacramento Valley – Sutter	Due 2022	No
5-021.64	Sacramento Valley – North American	Due 2022	No
5-021.65*	Sacramento Valley – South American (83%)	Due 2022	No
5-021.66	Sacramento Valley – Solano	Due 2022	No
5-021.67	Sacramento Valley – Solo	Due 2022	No
5-021.69	Sacramento Valley – Wyandotte Creek	Due 2022	No
5-021.70	Sacramento Valley – Butte	Due 2022	No
5-002.16*	San Joaquin Valley – Cosumnes (1%)	Due 2022	No

Basins (64) with Option to Develop Groundwater Sustainability Plans

Basin Number	Basin Name	Basin Number	Basin Name	Basin Number	Basin Name
5-001.01	Goose Lake – Goose Valley	5-020	Berryessa Valley	5-057	Last Chance Creek Valley
5-001.02	Goose Lake – Fandango Valley	5-021.53	Sacramento Valley – Bend	5-058	Clover Valley
5-002.01	Alturas Area – South Fork Pitt River	5-030	Lower Lake Valley	5-059	Grizzly Valley
5-002.02	Alturas Area – Warm Spings Valley	5-031	Long Valley	5-060	Humbug Valley
5-003	Jess Valley	5-035	McCloud Area	5-061	Chrome Town Area
5-005	Fall River Valley	5-036	Round Valley	5-062	Elk Creek Area
5-006.01	Redding Area – Bowman	5-037	Toad Well Area	5-063	Stonyford Town Area
5-006.05	Redding Area – Millville	5-040	Hot Springs Valley	5-064	Bear Valley
5-006.06	Redding Area – South Battle Creek	5-041	Egg Lake Valley	5-065	Little Indian Valley
5-007	Lake Almanor Valley	5-043	Rock Prairie Valley	5-066	Clear Lake Cache Formation
5-008	Mountain Meadows Valley	5-044	Long Valley	5-068	Pope Valley
5-009	Indian Valley	5-045	Cayton Valley	5-086	Joseph Creek
5-010	American Valley	5-046	Lake Britton Area	5-087	Middle Fork Fea her River
5-011	Mohawk Valley	5-047	Goose Valley	5-088	Stony George Reservoir
5-012.02	Sierra Valley – Chilcoot	5-048	Burney Creek Valley	5-089	Squaw Flat
5-013	Upper Lake Valley	5-049	Bry Burney Creek Valley	5-090	Funks Creek
5-014	Scotts Valley	5-050	North Fork Battle Valley	5-091	Antelope Creek
5-015	Big Valley	5-051	Butte Creek Valley	5-092	Blanchard Valley
5-016	High Valley	5-052	Grays Valley	5-094	Middle Creek
5-017	Burns Valley	5-053	Dixie Valley	5-095	Meadow Valley
5-018	Coyote Valley	5-054	Ash Valley		
5-019	Collayomi Valley	5-056	Yellow Creek Valley		

**Basin partially located in adjacent hydrologic region (% represesents percent of basin within the hydrologic region)*
There are no adjudicated basins or basins with approved alternative GSPs in the hydrologic region

Groundwater at a Glance:
San Joaquin River Hydrologic Region

The San Joaquin River HR covers 15,200 square miles in Central California. The region is named after the San Joaquin River, one of the state's longest rivers, which meanders for over 350 miles throughout the region. The river is historically home to important anadromous fish species that have on-going restoration efforts. Annual precipitation in the region varies from up to 40 inches in the foothills to 12-18 inches on the valley floor near Stockton and Merced. The region is home to approximately 2.3 million people. The region includes one of the most well-known places in the world, Yosemite National Park.

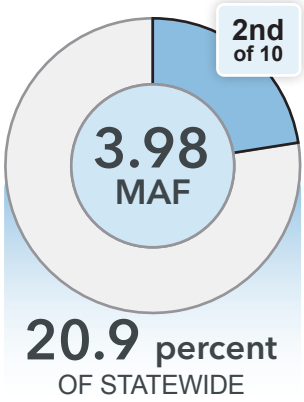




An aerial view of the California Aqueduct and Delta-Mendota Canal near Tracy, California.

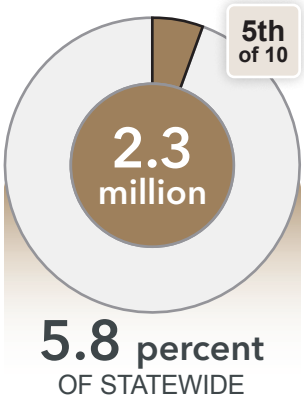
The San Joaquin River HR accounts for more than a fifth of all groundwater use in the state, averaging nearly 4 maf annually. Groundwater accounts for nearly half of the region's total supply. Water supply in the region is supplemented with surface water delivered by the federal Central Valley Project. Of the 14 groundwater basins in the region, 12 are required to submit GSPs under SGMA.

GROUNDWATER USE



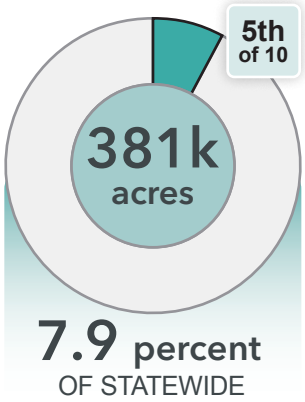
20.9 percent
OF STATEWIDE

POPULATION



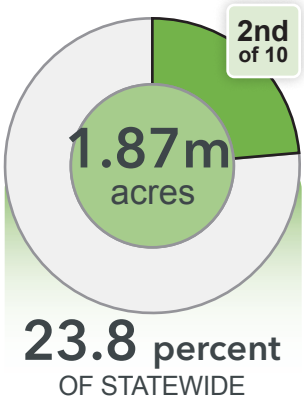
5.8 percent
OF STATEWIDE

URBAN LAND



7.9 percent
OF STATEWIDE

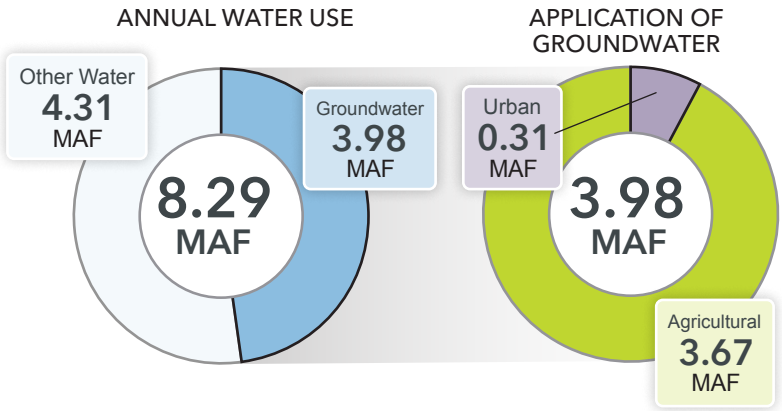
AGRICULTURAL LAND



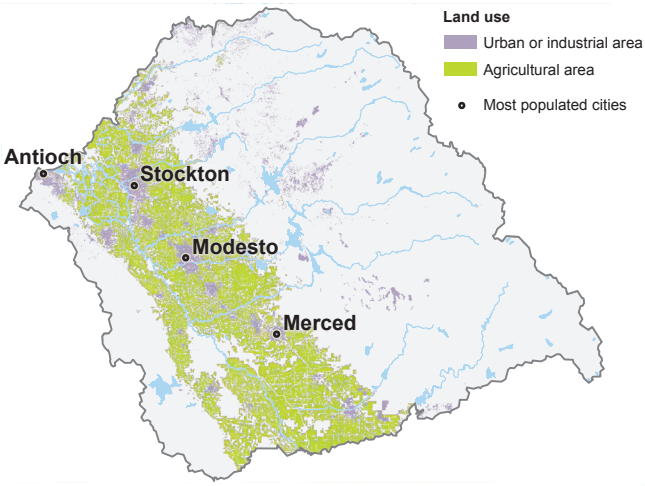
23.8 percent
OF STATEWIDE

San Joaquin River Hydrologic Region Land and Water Use

The San Joaquin River HR uses 20 percent of California's total water use, averaging 8.29 maf each year. Groundwater accounts for 48 percent of the water supply in the region and 21 percent of statewide groundwater use.



Map of General Land Use



Land Use

The region is home to one-quarter of the agricultural area in the state with over 1.9 million acres. Agricultural area covers nearly one-fifth of the entire region. The region has the 5th largest urban footprint in the state with over 380,000 acres of urban area.

Groundwater Use

The San Joaquin River HR uses the second highest volume of groundwater of any HR, averaging 3.98 maf annually. Of the groundwater extracted in the region, 86 percent is used for agricultural purposes (3.67 maf). The remaining groundwater is used to support urban uses and managed wetlands.

Did you know? The San Joaquin River Restoration Program (SJRRP) is a long-term effort that resulted from the 2006 San Joaquin River litigation settlement. The SJRRP aims to restore and maintain the fish populations below Friant Dam, and mitigate water supply impacts to water users as a result of SJRRP's restoration flows. DWR is conducting studies and projects to support successful fish passage conditions. DWR is also supporting the SJRRP by improving levees to allow for higher in-channel flows, improving off-stream recreational opportunities, and isolating gravel pits to reduce juvenile salmon mortality.

Total Urban Area: 381,392 Acres

Top 4 Cities by Population (2010):

- Stockton (292,000)
- Modesto (201,000)
- Antioch (102,000)
- Merced (79,000)

Total Agricultural Area: 1,867,523 Acres

Top 4 Crops by Acreage (2016):

- Almonds (518,000)
- Corn, Sorghum and Sudan (253,000)
- Grapes (216,000)
- Alfalfa and Alfalfa Mixtures (29,000)

San Joaquin River Hydrologic Region Groundwater Management

BASINS REQUIRING GSPs	BASINS WITH ADJUDICATED AREAS	APPROVED ALTERNATIVE GSPs
12	0	0

CRITICALLY OVERDRAFTED BASINS	GROUNDWATER SUSTAINABILITY AGENCIES	GSPs SUBMITTED BY 01/31/2020
6	85	12

SGMA Groundwater Management Status



Notes: 1. As of January 31, 2020
2. Prior to deadlines outlined in Water Code 10720.7(a)(2) and 10722.4(d)

Groundwater Management

Twelve basins in the San Joaquin River HR are required by SGMA to submit GSPs. The region has 85 Groundwater Sustainability Agencies within those 12 basins, more than any other region. Six basins in the region have been designated as critically overdrafted by DWR and submitted GSPs in January 2020. There are no approved Alternative GSPs or adjudicated areas in the region.

**Several basins span across regions. For the purposes of this analysis, only basins with majority of their area in the region are represented.*

CASGEM Monitoring

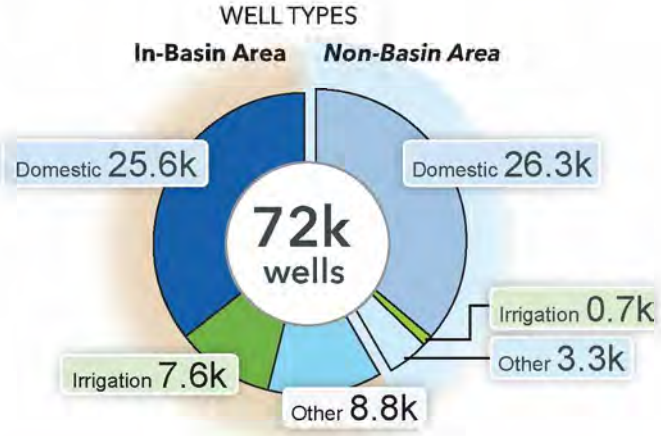
Neither of the two basins in the region not required to develop GSPs are actively participating in the CASGEM program. Local agencies can start participating in the CASGEM program at any time by collecting groundwater level measurements and submitting data to CASGEM. One of these basins, Yosemite Valley, is widely known throughout the world.

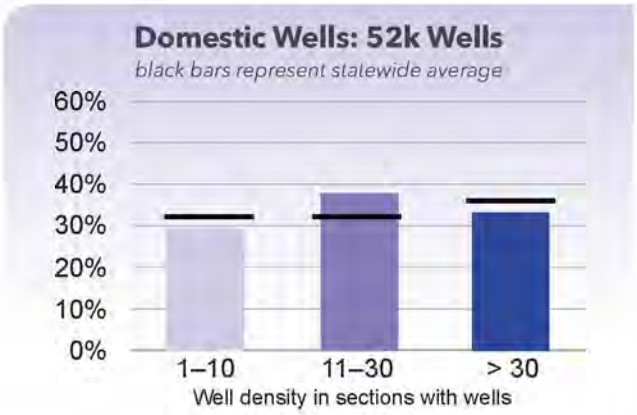


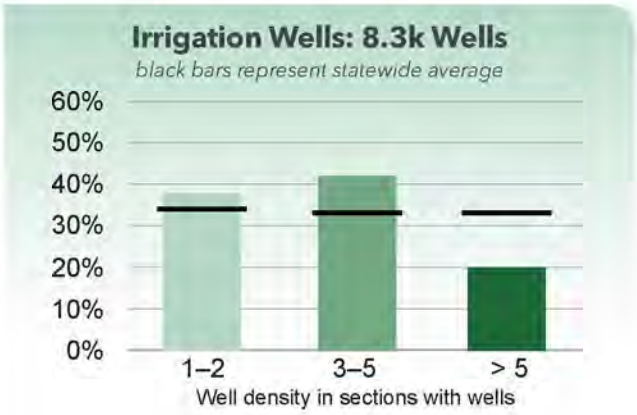
An Aerial View of Yosemite Valley, a very low priority basin in the region.

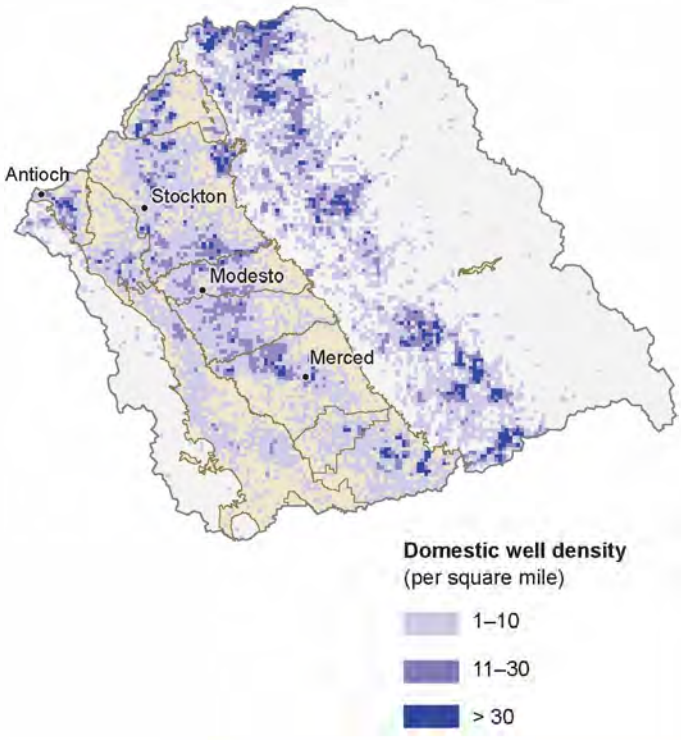
San Joaquin River Hydrologic Region Well Infrastructure

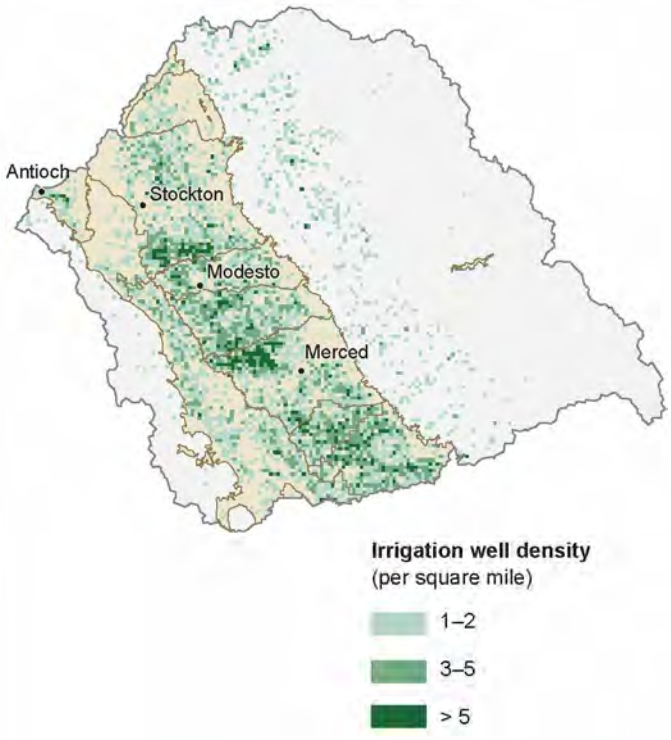
There have been 72,300 groundwater wells installed in the San Joaquin River HR since 1977. Nearly 58 percent of the wells (42,000) have been drilled within groundwater basins and the remaining 42 percent (30,400) are in the non-basin area. Most of the wells that have been installed are for domestic use (61percent within basins and 87 percent in the non-basin area). The region has had the third most wells drilled since 1977, 16 percent of wells statewide.







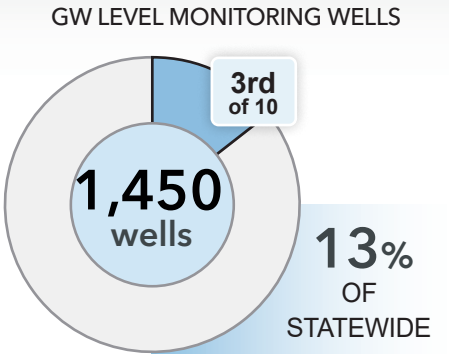




San Joaquin River Hydrologic Region Groundwater Levels

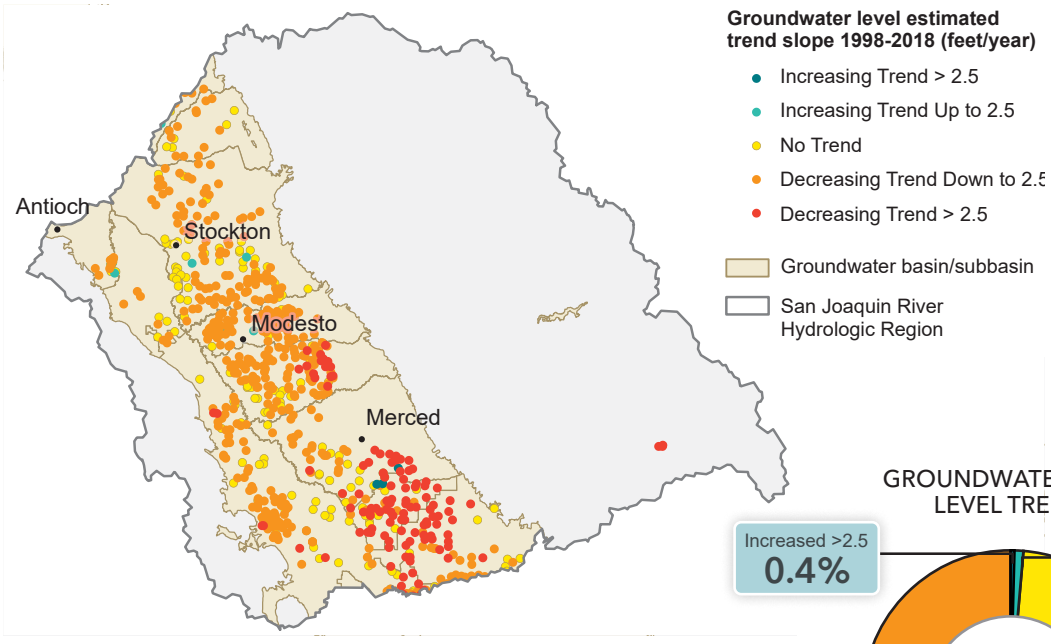
Monitoring

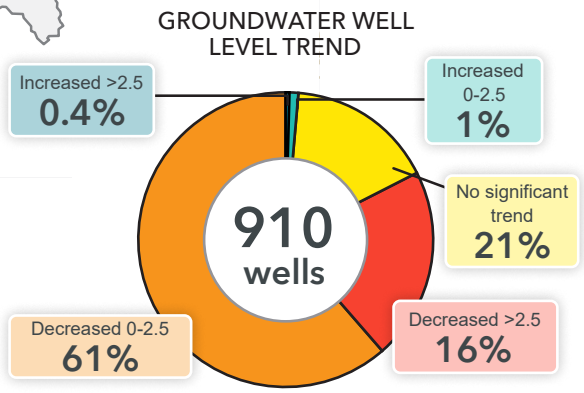
The San Joaquin River HR has the third most groundwater level monitoring wells in the state with 1,450 sites. This amounts to 13 percent of all groundwater level monitoring wells in California. Within the region, most monitoring wells are relatively shallow with only four of 1,450 monitoring wells being deeper than 1,000 feet. Approximately 29 percent of monitoring wells in the region have an unknown well depth.



Conditions

Groundwater levels are trending lower in much of the San Joaquin River HR. Between 1998 and 2018, approximately 77 percent of monitoring wells in the region experienced a declining trend. Approximately 16 percent of monitoring wells experienced a declining trend of more than 2.5 feet per year, which equates to a drop of 50 feet or more in groundwater level over this period. Sixty percent experienced a declining trend of up to 2.5 feet per year over this period. Twenty one percent of wells reported a stable trend while the remaining one percent showed an increasing trend.



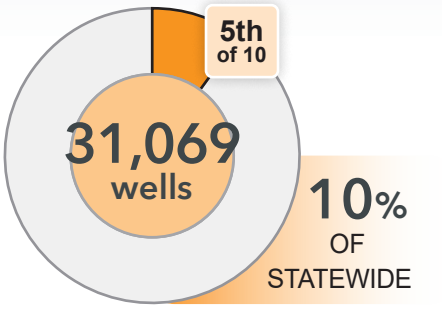


San Joaquin River Hydrologic Region Groundwater Quality

Monitoring

The San Joaquin River HR has the fifth most groundwater quality monitoring stations among regions in the GAMA Groundwater Information System with 31,069 unique locations. The region has approximately 10 percent of all groundwater quality monitoring stations in the state.

WATER QUALITY MONITORING WELLS



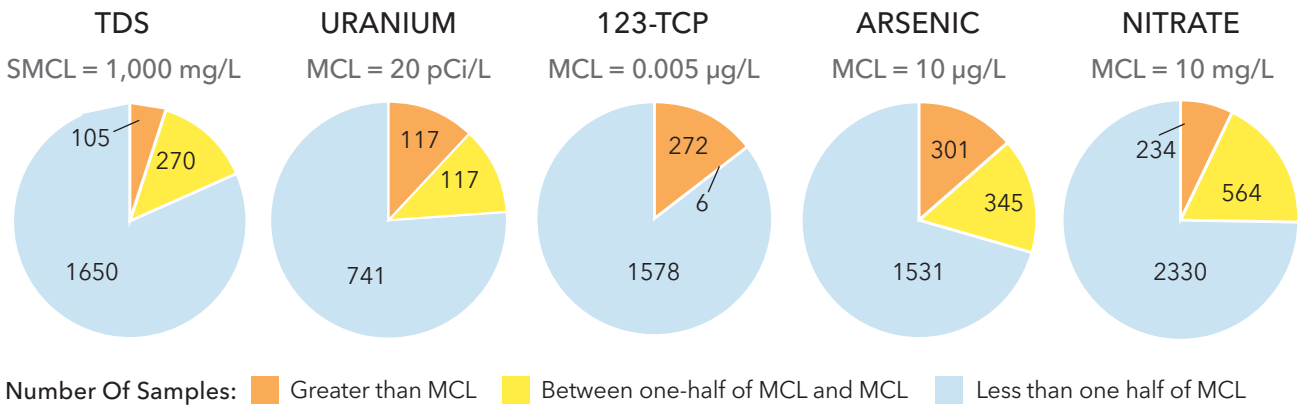
Conditions

The most common chemical detected above a regulatory limit in the San Joaquin HR between 2009 and 2018 was manganese, detected in 22.6 percent of water quality stations above the SMCL. The second most commonly detected chemical over this period was iron, detected in 20.9 percent of wells above its SMCL. The third most commonly detected chemical was 1,2,3-TCP, detected above its MCL in 14.7 percent of wells tested between 2009 and 2018.

Top 10 Chemicals in Hydrologic Region by Percentage of Wells with Detections Above an MCL or SMCL:

22.6% Manganese
20.9% Iron
14.7% 1,2,3-Trichloropropane (1,2,3-TCP)
13.8% Arsenic
12.0% Uranium
11.8% Gross ALPHA Radioactivity
7.5% Nitrate
5.2% Total Dissolved Solids (TDS)
4.1% 1,2-Dibromo,3-Chloropropane (DBCP)
3.8% Standard Conductivity

Regional Water Quality Summaries for 5 Chemicals of Statewide Concern



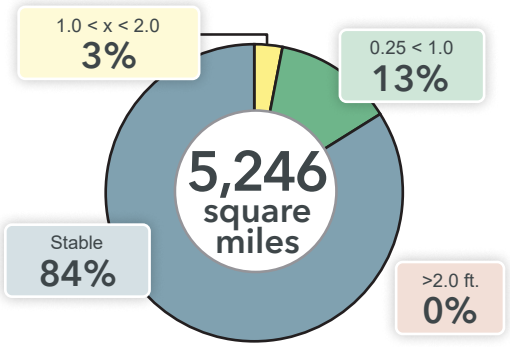
San Joaquin River Hydrologic Region Land Subsidence

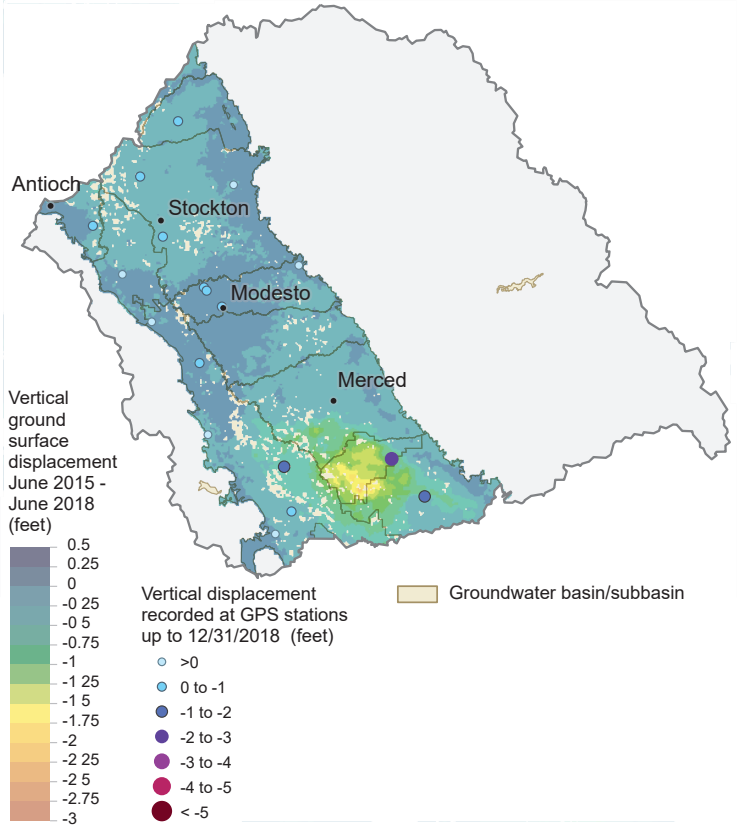
Monitoring

Land subsidence monitoring in the San Joaquin River HR includes satellite-based remote sensing (InSAR), Continuous GPS stations, an extensometer, and two regional subsidence monitoring networks. The statewide InSAR dataset includes 5,246 square miles of coverage in the region, the third largest coverage area in the state. A total of 18 GPS sites and one borehole extensometer monitoring land subsidence are operated in the region. The region is also home to two regional land subsidence monitoring networks, one maintained by DWR and one maintained by the United States Bureau of Reclamation (Reclamation).

Conditions

Land subsidence has been documented in areas of the San Joaquin River HR for decades. Recently, land subsidence has been detected in the southern portions of the region by multiple monitoring networks. Continuous GPS station data indicates 2 to 3 feet of subsidence at three locations since 2010. The InSAR dataset has recorded land subsidence in the region since its inception in 2015. Over the three-year period between 2015 and 2018, more than 500 square miles in the region experienced more than 6 inches of subsidence, an area equivalent to the size of the city of Los Angeles.





Did you know?

Reclamation maintains a regional subsidence network called the San Joaquin River Restoration Subsidence Monitoring Network in the southern portion of the region. The network features more than 70 control points that have been measured bi-annually since 2011. The Reclamation network has recorded areas with land subsidence rates of 3 to 6 inches per year and cumulative land subsidence of 3 to 5 feet over the last 10 years.

San Joaquin River Hydrologic Region Groundwater Assistance

TECHNICAL SUPPORT

Monitoring Wells
13 Installed at 5 Sites
43 Planned at 14 Sites

Statewide Datasets
4,123 mi^2 of Land Use
5,246 mi^2 of Land Subsidence Monitoring

FACILITATION SUPPORT

FSS Contracts
Awarded in 9 Basins

Points of Contact (POCs)
10 POCs in 10 Basins

GRANT FUNDING

Grants Awarded
33 Grants since 2010

Total Funding
$30.2 Million Awarded

Note: Assistance summaries are from Department of Water Resources' Groundwater Program. Many other local, state and federal entities also provide assistance in this region

Regional Project Spotlight: Groundwater Recharge

There are many efforts underway or in development to provide groundwater recharge in the San Joaquin River HR. Many local areas that rely on groundwater in the region have experienced recent declines in groundwater levels, storage, and even land subsidence. Local water managers are actively seeking creative solutions to solve these challenges.

In the center of the region, near Merced, local water managers are working to enhance groundwater recharge. The Merced Irrigation District operates a series of groundwater recharge basins which collect stormwater during the winter months and allow it to percolate into the ground recharging local aquifers. The basins are conjunctively managed during the spring and summer months when surface water is pumped into the basins to provide additional groundwater recharge and storage. In all, these basins help to recharge up to 140,000 acre-feet of groundwater annually.

In the southern part of the region, Westlands Water District is pursuing a groundwater recharge project called artificial storage & recovery (ASR). The ASR project involves using a series of wells to inject imported surface water directly into the groundwater aquifer in areas where natural groundwater recharge is ineffective. In March 2020, the Central Valley Regional Water Quality Control Board approved a Monitoring and Reporting Program (MRP) for ASR. The MRP allows up to 28,000 acre-feet per year of filtered, treated water to be directly injected as long as it meets the water quality objectives in the MRP. The project will begin with 10 wells with the potential to add up to 20 more wells annually for a total of more than 400 ASR wells by 2040.



Groundwater Recharge Basin near Merced

San Joaquin River Hydrologic Region Basin Map











San Joaquin River Hydrologic Region Basin List

Basins (12) Required to Submit Groundwater Sustainability Plans

Basin Number	Basin Name	GSP Status	Critically Overdrafted
5-021.65*	Sacramento Valley — South American	Due 2022	No
5-022.02	San Joaquin Valley — Chowchilla	Submitted 2020	Yes
5-022.16*	San Joaquin Valley — Cosumnes	Due 2022	No
5-022.07*	San Joaquin Valley — Delta-Mendota	Submitted 2020	Yes
5-022.19	San Joaquin Valley — East Contra Costa	Due 2022	No
5-022.01	San Joaquin Valley — Eastern San Joaquin	Submitted 2020	Yes
5-022.06	San Joaquin Valley — Madera	Submitted 2020	Yes
5-022.04	San Joaquin Valley — Merced	Submitted 2020	Yes
5-022.02	San Joaquin Valley — Modesto	Due 2022	No
5-022.15	San Joaquin Valley — Tracy	Due 2022	No
5-022.03	San Joaquin Valley — Turlock	Due 2022	No
5-022.09*	San Joaquin Valley — Westside	Submitted 2020	Yes

Basins (58) with Option to Develop Groundwater Sustainability Plans

Basin Number	Basin Name
5-070	Los Banos Creek Valley
5-069	Yosemite Valley

Basins with Adjudicated Areas

Basin Number	Basin Name
none	

Basins with Approved Alternative GSPs

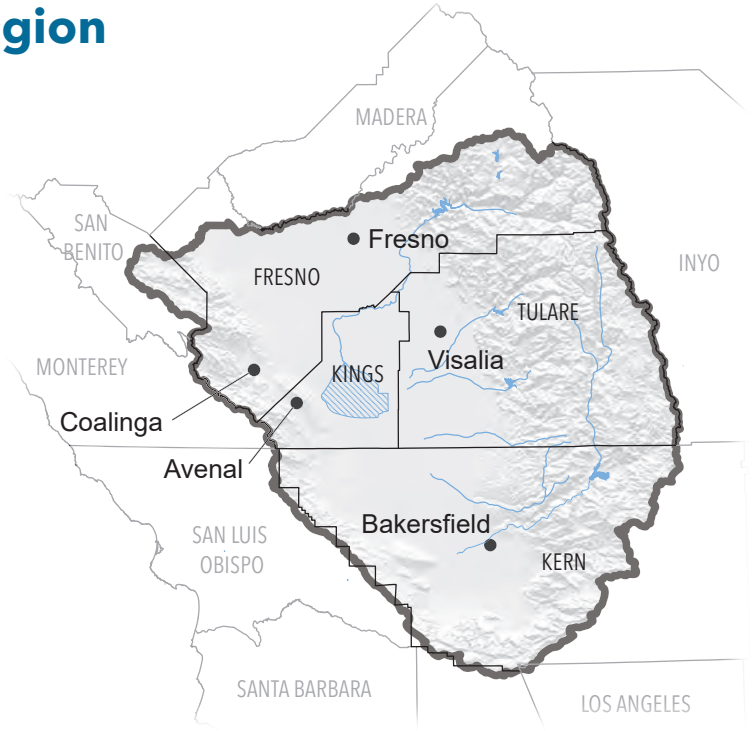
Basin Number	Basin Name
none	

**Basin partially located in adjacent hydrologic region (% represents percent of basin within the hydrologic region)*

There are no adjudicated basins or basins with approved alternative GSPs in the hydrologic region

Groundwater at a Glance:
Tulare Lake Hydrologic Region

The Tulare Lake HR encompasses roughly 17,000 square miles in the southern San Joaquin Valley. The region that historically contained a vast freshwater lake is now home to an estimated 2.4 million people and one-third of the agricultural area in California with over 2.5 million acres. Average annual rainfall ranges from about six to 11 inches on the valley floor to more than 30 inches in the foothills. Kings Canyon and Sequoia National Parks are located in the region.

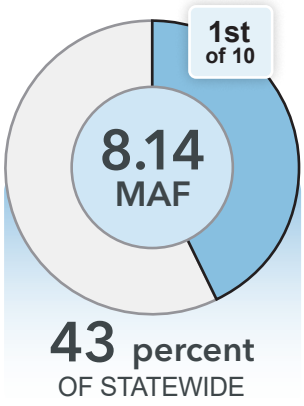




Sprinklers Irrigate an Agricultural Field within the Tulare Lake Hydrologic Region near Bakersfield.

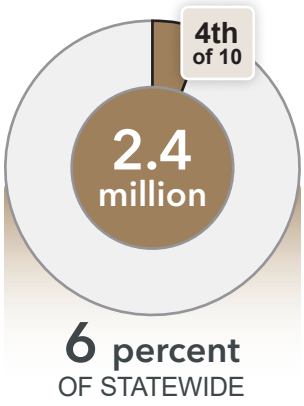
The Tulare Lake HR uses more than twice the volume of groundwater than any other HR in the state, averaging more than 8.1 maf annually. The region is also served by both the Central Valley and State Water projects and has the largest water banking capacity in the state, totaling more than 3 maf. There are 23 groundwater basins in the region including nine basins required by SGMA to submit GSPs.

GROUNDWATER USE



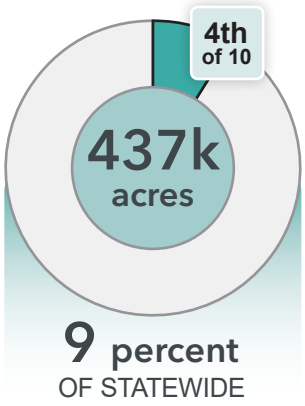
43 percent OF STATEWIDE

POPULATION



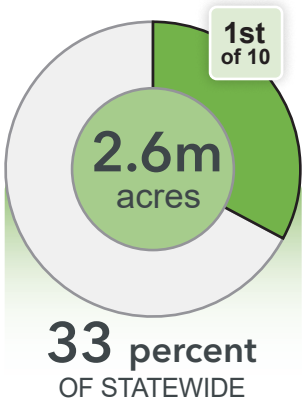
6 percent OF STATEWIDE

URBAN LAND



9 percent OF STATEWIDE

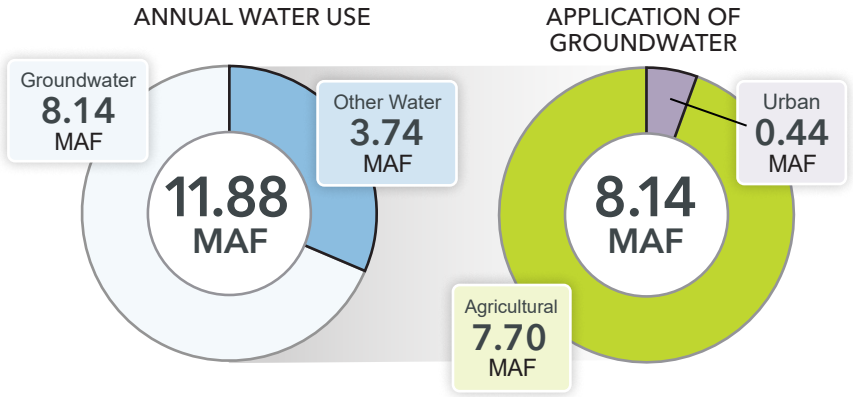
AGRICULTURAL LAND



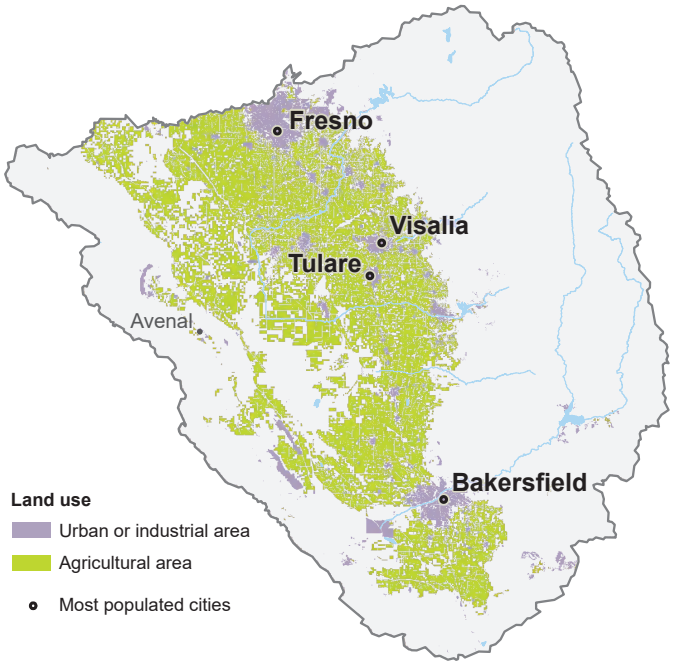
33 percent OF STATEWIDE

Tulare Lake Hydrologic Region Land and Water Use

The Tulare Lake HR has the largest water demand of any HR in the state, using an average of 11.9 maf of water each year, equaling 28 percent of all water use in California. Groundwater accounts for 69 percent of the region's water supply and 43 percent of statewide groundwater use.



Map of General Land Use



Groundwater Use

The Tulare Lake Region uses more groundwater than any other region in the state, averaging 8.1 maf annually. Groundwater is primarily used for agriculture which accounts for 95 percent of the region's annual groundwater use (7.7 maf). Urban and domestic groundwater use equals 0.4 maf to support the region's 2.4 million residents.

Did you know? Some of the largest groundwater banking projects in the state are located in the region. The combined storage of these groundwater banks totals more than 3 maf, comparable to the capacity of Lake Oroville, the second largest storage reservoir in California.

Land Use

One-third of the agricultural area in California is in the region, equaling more than 2.6 million acres and a quarter of the region's total land area. The region has the fourth largest urban footprint in the state with over 430,000 acres of urban area.

Total Urban Area: 437,000 Acres

Top 4 Cities by Population (2010):

- Fresno (495k)
- Bakersfield (347k)
- Visalia (124,000)
- Tulare (59,000)

Total Agricultural Area: 2,616,000 Acres

Top 4 Crops by Acreage (2016):

- Almonds (469,000)
- Grapes (339,000)
- Pistachios (280,000)
- Corn, Sorghum and Sudan (255,000)

Tulare Lake Hydrologic Region Groundwater Management

BASINS REQUIRING GSPs	BASINS WITH ADJUDICATED AREAS	APPROVED ALTERNATIVE GSPs
9	3	0

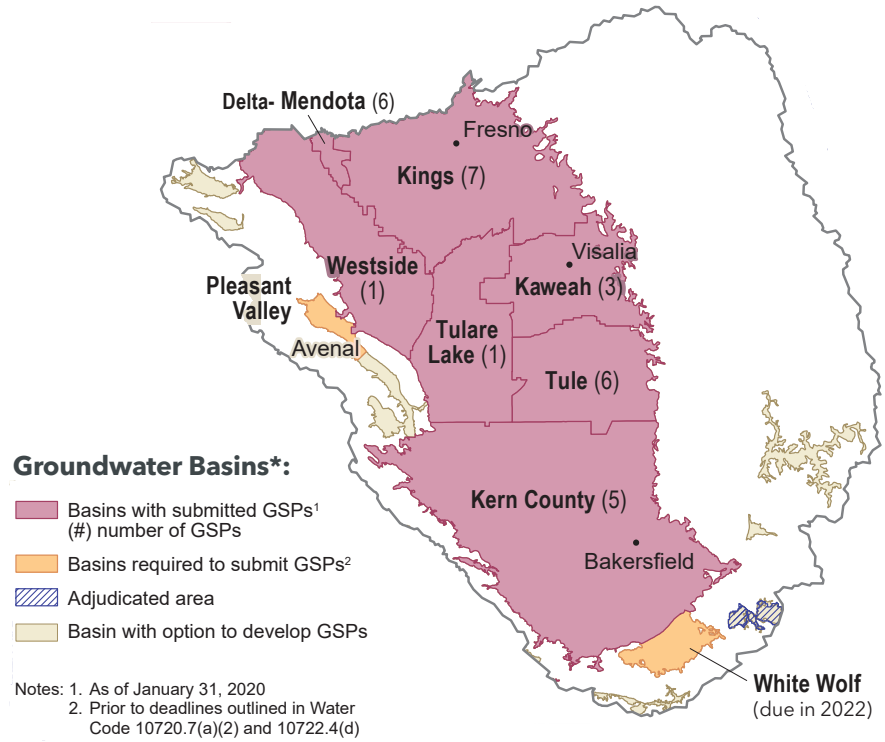
CRITICALLY OVERDRAFTED BASINS	GROUNDWATER SUSTAINABILITY AGENCIES	GSPs SUBMITTED BY 01/31/2020
7	47	28

Groundwater Management

Nine basins within the Tulare Lake HR are required by SGMA to submit GSPs. Within these nine basins, more than 40 Groundwater Sustainability Agencies have been formed. As of January 31, 2020, seven basins have submitted one or more GSP(s) for review.

Seven basins in the region have been designated as critically overdrafted. There are three adjudicated areas within three basins in the region. No Alternative GSPs have been approved in the region.

SGMA Groundwater Management Status



CASGEM Monitoring

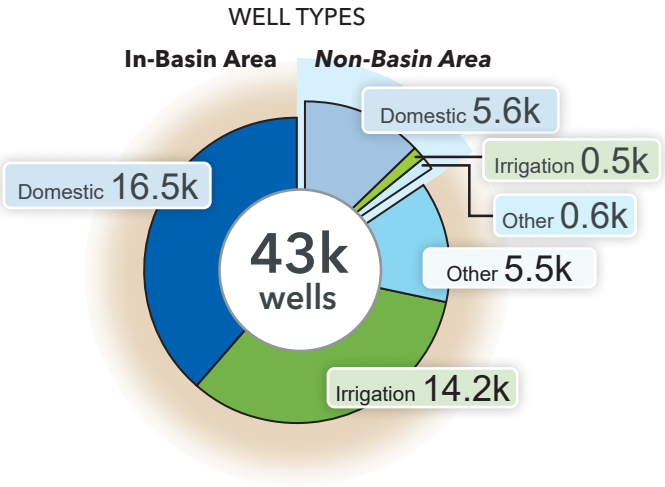
Nine basins in the region not required to develop GSPs are actively participating in the CASGEM program. Within these basins, biannual groundwater level measurements are collected and posted to the CASGEM online system. These measurements are collected voluntarily by private individuals, academic institutions, conservation districts, and other local, state, and federal entities

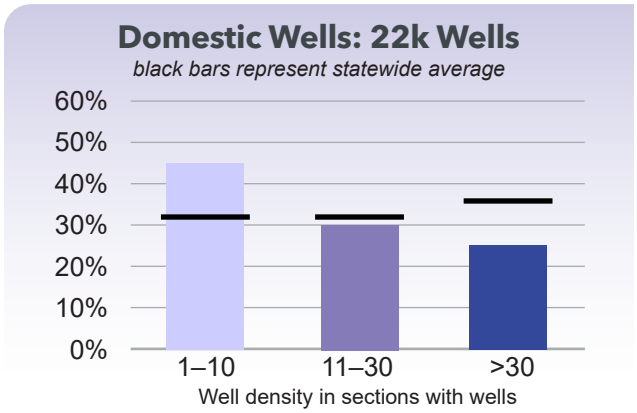


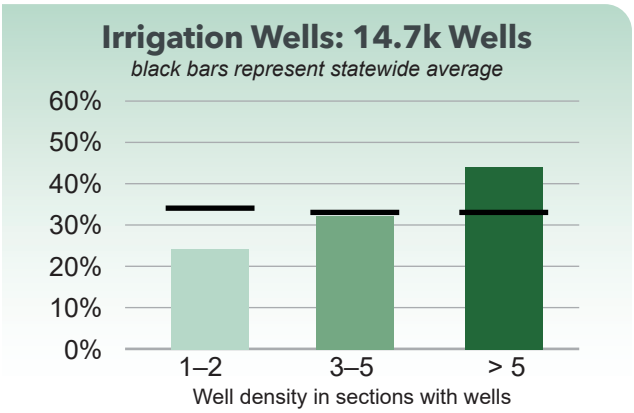
A Drilling Rig Installs a Groundwater Level Monitoring Well in 2015 within the Tulare Lake Hydrologic Region.

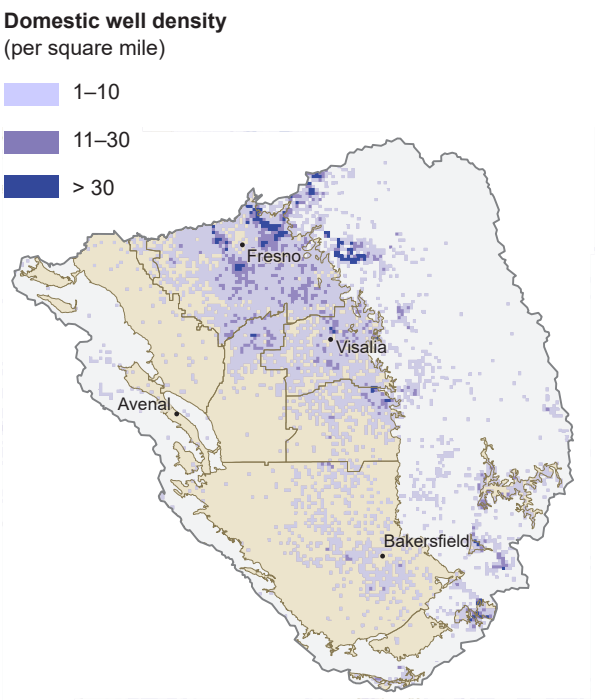
Tulare Lake Hydrologic Region Well Infrastructure

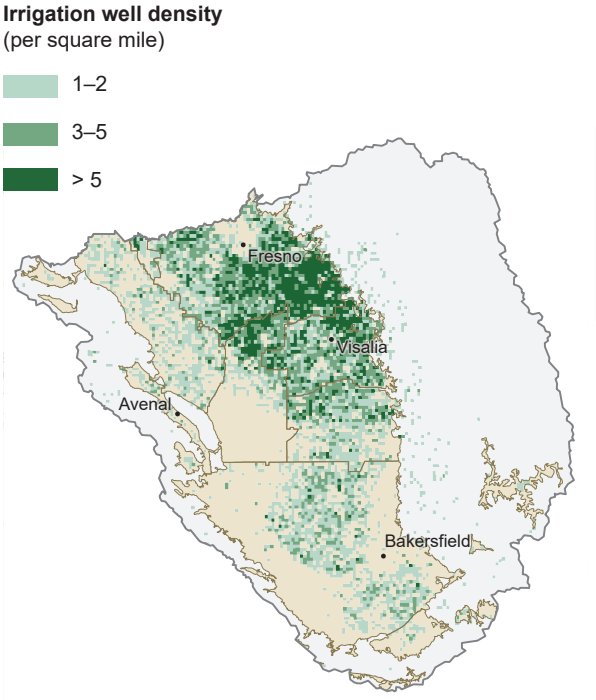
There have been 43,000 groundwater wells drilled in the Tulare Lake HR since 1977. Eighty-four percent of the wells (36,100) are located within groundwater basins with sixteen percent (6,700) in the non-basin area. The region has more irrigation wells than any other HR with 29 percent (14,700) of all the irrigation wells in California. Nine percent of all groundwater wells drilled since 1977 are within the Tulare Lake HR.











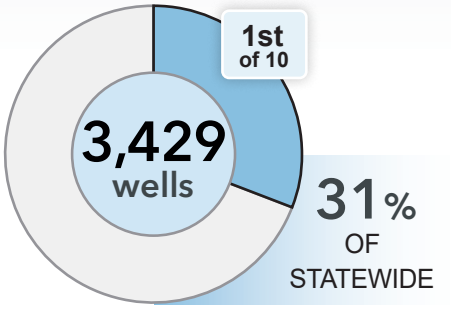
Tulare Lake Hydrologic Region Groundwater Levels

Monitoring

The Tulare Lake HR has 3,429 groundwater level monitoring wells, the highest number among HRs. In total, 31 percent of all the groundwater level monitoring wells in California are located in the Tulare Lake HR.

The region has the most deep monitoring wells (greater than 1,500 feet) in the state (415), which equates to 83 percent of the deep monitoring wells statewide. Over half (52 percent) of the monitoring wells (1,775) in the region have an unknown well depth. Local agencies perform most groundwater level monitoring, collecting measurements from 58 percent of monitoring wells (1,988).

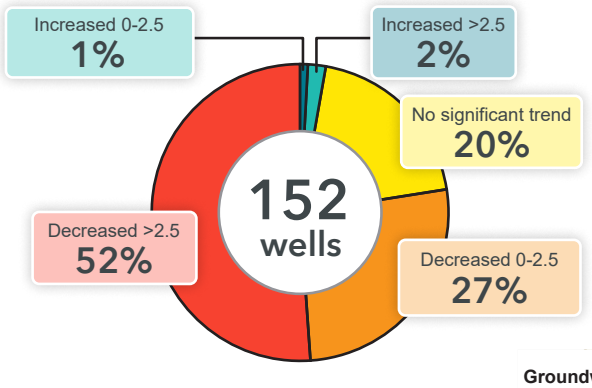
GW LEVEL MONITORING WELLS

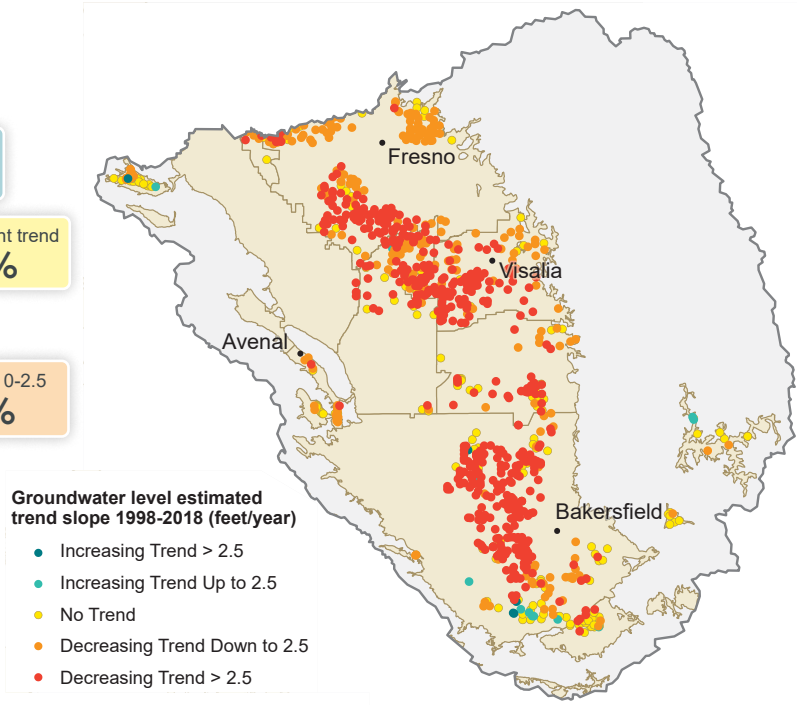


Conditions

Groundwater levels are trending lower than historical levels in much of the Tulare Lake HR. Between 1998 and 2018, about 78 percent of monitoring wells in the region experienced a declining trend. Over 51 percent of all the monitoring wells indicated a declining trend of more than 2.5 feet per year, which is a drop of 50 feet or more in groundwater levels. An additional 27 percent of wells showed a declining trend of up to 2.5 feet per year. A stable trend was observed in 20 percent of monitoring wells and 3 percent of wells indicated an increasing trend over this period.

GROUNDWATER WELL LEVEL TREND

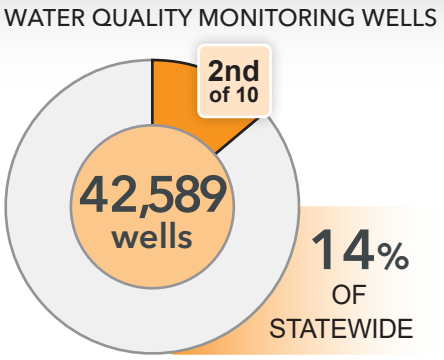




Tulare Lake Hydrologic Region Groundwater Quality

Monitoring

The Tulare Lake HR contains 42,589 groundwater quality stations in the GAMA Groundwater Information System, the second highest number among regions. This value represents 14 percent of all the groundwater quality stations in the state.



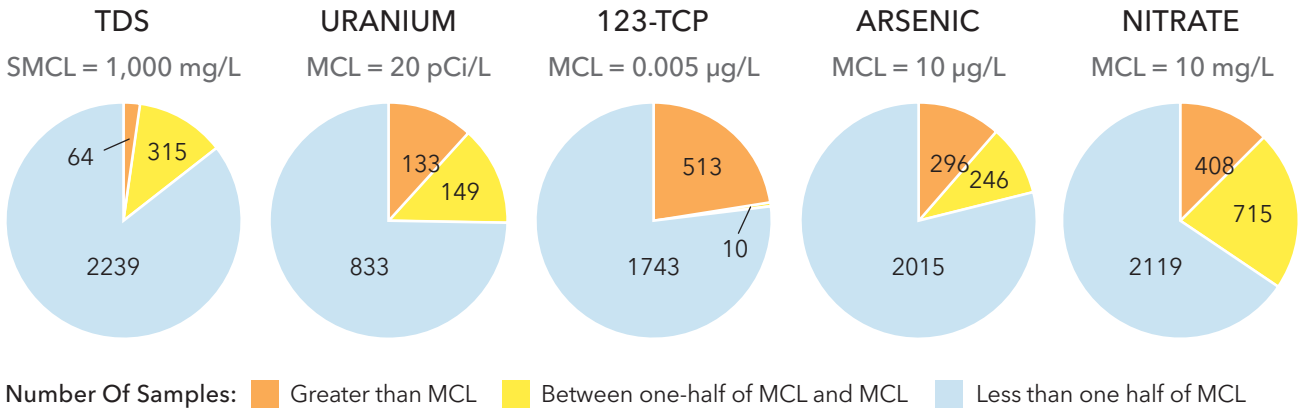
Conditions

The most commonly detected chemical above a regulatory limit in the Tulare Lake HR between 2009 and 2018 was 1,2,3 TCP, with 22.6 percent of the wells reporting above the primary MCL. The region had the highest proportion of wells detecting 1,2,3 TCP above the MCL of any HR in the state. The second most common chemical detected above a regulatory limit over this period was iron, detected in 17.8 percent of wells. Seven chemicals in total were detected above the MCL or SMCL in 10 percent or more wells tested in the region between 2009 and 2018.

Top 10 Chemicals in Hydrologic Region by Percentage of Wells with Detections Above an MCL or SMCL:

22.6% 1,2,3 Trichloropropane (1,2,3 TCP)
17.8% Iron
12.6% Nitrate
11.9% Uranium
11.6% Arsenic
10.5% Manganese
10.2% Gross ALPHA Radioactivity
4.5% 1,2-Dibromo,3-Chloropropane (DBCP)
2.6% Specific Conductivity
2.5% Radon-222

Regional Water Quality Summaries for 5 Chemicals of Statewide Concern



Tulare Lake Hydrologic Region Land Subsidence

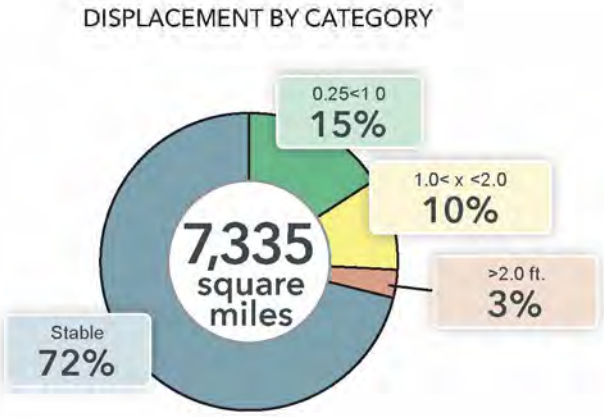
Monitoring

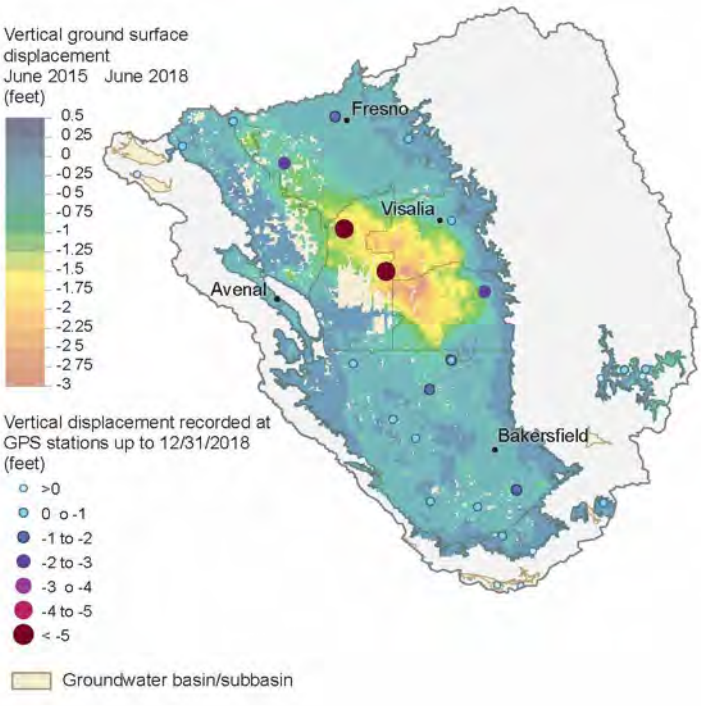
Land subsidence monitoring in the Tulare Lake HR includes satellite based-remote sensing (InSAR), CGPS stations, extensometers, and two regional subsidence monitoring networks. The statewide InSAR dataset includes 7,335 square miles of coverage in the region, more than any other HR in the state. A total of 62 CGPS sites and six borehole extensometers monitoring land subsidence are operated in the region, along with two regional land subsidence monitoring networks, one maintained by DWR and one by Reclamation.

Conditions

The Tulare Lake HR has been experiencing land subsidence for decades. Over the past ten years, the region has experienced more land subsidence than any other HR in the state. CGPS station data shows nearly six feet of subsidence at two locations over this ten-year period. InSAR data collected between 2015 and 2018 outlines more than 2,000 square miles of area in the region experiencing recordable subsidence. InSAR data also recorded an area of 939 square miles experiencing more than 1.0 feet of subsidence over these three years.

Land subsidence has also been detected along water conveyance facilities in the region. Conveyance facilities that rely on gravity to move water face major challenges from land subsidence as capacities of these facilities can be reduced. After the last drought period in 2017, a loss of capacity of 60 percent was recorded in the Friant-Kern Canal due to land subsidence (Friant Water Authority, 2020). Subsidence has also been recorded along other conveyance facilities in the region, including the California Aqueduct (DWR, 2020).





Tulare Lake Hydrologic Region Groundwater Assistance

TECHNICAL SUPPORT

Monitoring Wells
12 Installed at 5 Sites
12 Planned at 6 Sites

Statewide Datasets
5,570 mi^2 of Land Use
7,335 mi^2 of Land Subsidence Monitoring

FACILITATION SUPPORT

FSS Contracts
Awarded in 3 Basins

Points of Contact (POCs)
8 POCs in 8 Basins

GRANT FUNDING

Grants Awarded
48 Grants since 2010

Total Funding
$45.5 Million Awarded

Note: Assistance summaries are from Department of Water Resources' Groundwater Program. Many other local, state and federal entities also provide assistance in this region

Local Project Spotlight: Groundwater Recharge

Many efforts to provide groundwater recharge are underway in the Tulare Lake HR. These recharge efforts are active as many local areas that rely on groundwater have experienced recent declines in groundwater levels, loss of storage, and land subsidence.

Groundwater managers in the region are finding innovative ways to recharge local aquifers. Along the Kings River, a Flood-managed Aquifer Recharge (FloodMAR) project has been built at Terranova Ranch. This FloodMAR project captures excess runoff during high winter flows in the Kings River. Flood waters are conveyed to seasonally idle farmlands where the water percolates into the ground and recharges local aquifers. The project has the capacity to convey water to over 18,000 acres of local farmland providing up to 1,000 acre-feet per day of groundwater recharge.



Headwaters Gate to Terra Nova FloodMAR project along Kings River in Tulare Lake Region.



Groundwater Recharge Basin near Fresno, California.

Did you know?

Near Fresno, local water managers have invested in recharge projects involving municipal stormwater. These multi-benefit projects capture floodwater and stormwater in newly constructed percolation ponds, which reduces flood risk to the local areas, prevents pollutants from entering local waterways, and recharges aquifers. One project located near Fancher Creek removed nearly 700 acres of urban areas from the FEMA flood zone by capturing stormwater runoff. The water is collected in the percolation ponds and recharges local aquifers.

Tulare Lake Hydrologic Region Basin Map





Tulare Lake Hydrologic Region Basin List

Basins (9) Required to Submit Groundwater Sustainability Plans

Basin Number	Basin Name	GSP Status	Critically Overdrafted
5-022.07*	San Joaquin Valley – Delta-Mendota	Submitted 2020	Yes
5-022.08	San Joaquin Valley – Kings	Submitted 2020	Yes
5-022.09*	San Joaquin Valley – Westside	Submitted 2020	Yes
5-022.10	San Joaquin Valley – Pleasant Valley	Due 2024	No
5-022.11	San Joaquin Valley – Kaweah	Submitted 2020	Yes
5-022.12	San Joaquin Valley – Tulare Lake	Submitted 2020	Yes
5-022.13	San Joaquin Valley – Tule	Submitted 2020	Yes
5-022.14	San Joaquin Valley – Kern County	Submitted 2020	Yes
5-022.18	San Joaquin Valley – White Wolf	Due 2022	No

Basins (11) with Option to Develop Groundwater Sustainability Plans (GSP)

Basin Number	Basin Name
5-022.17	San Joaquin Valley – Kettleman Plain
3-019	Carrizo Plain
5-023	Panoche Valley
5-025	Kern River Valley
5-026	Walker Basin Creek Valley
5-029	Castac Lake Valley
5-071	Vallecitos Creek Valley
5-082	Cuddy Canyon Valley
5-083	Cuddy Ranch Area
5-084	Cuddy Valley
5-085	Mil Potrero Area

**Basin partially located in adjacent hydrologic region*

Basins (3) with Adjudicated Areas

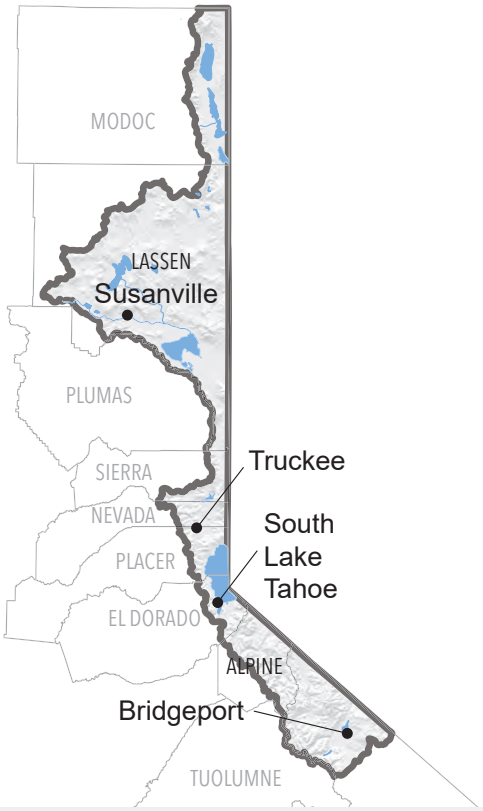
Basin Number	Basin Name
5-027	Cummings Valley
5-028	Tehachapi Valley West
5-029	Brite Valley

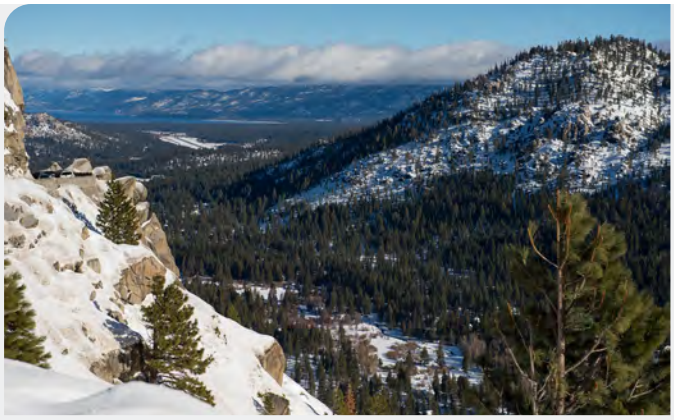
Basins with Approved Alternative GSPs

Basin Number	Basin Name
none	

Groundwater at a Glance:
North Lahontan Hydrologic Region

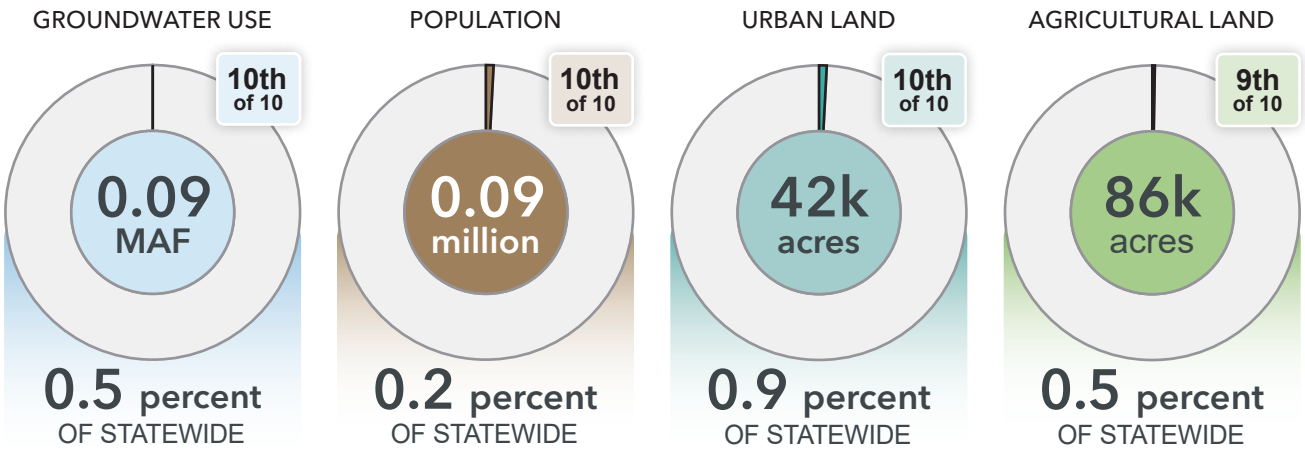
The North Lahontan HR is the second smallest region in the state, encompassing 6,100 square miles in northeastern California. While only 93,000 people live in the region permanently, the region swells with visitors exploring the region in both the summer and winter months. Most of the permanent residents in the region live in the cities of South Lake Tahoe, Susanville, and Truckee. Average annual precipitation in the region is 23 inches, with most precipitation falling as snow. One very recognizable feature in the North Lahontan HR is Lake Tahoe, the largest freshwater lake in California.





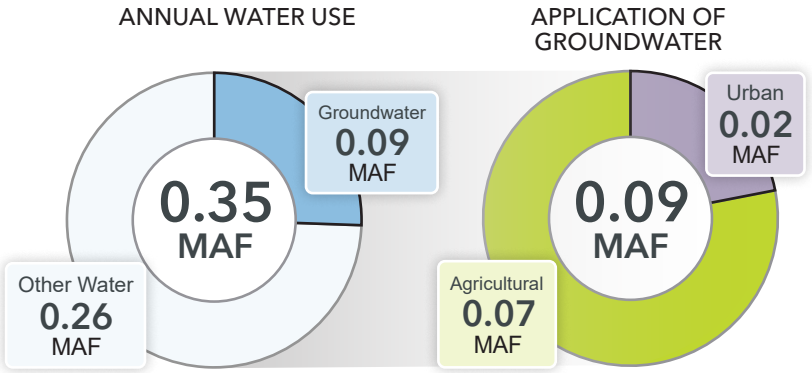
A View of Christmas Valley and Lake Tahoe in the North Lahontan Hydrologic Region.

The region uses less groundwater than any other region in the state, with an average of 0.09 maf each year. Groundwater accounts for one-quarter of the region's total water supply. There are 27 groundwater basins in the region, one of which is required to develop a GSP under SGMA but has an approved Alternative GSP.

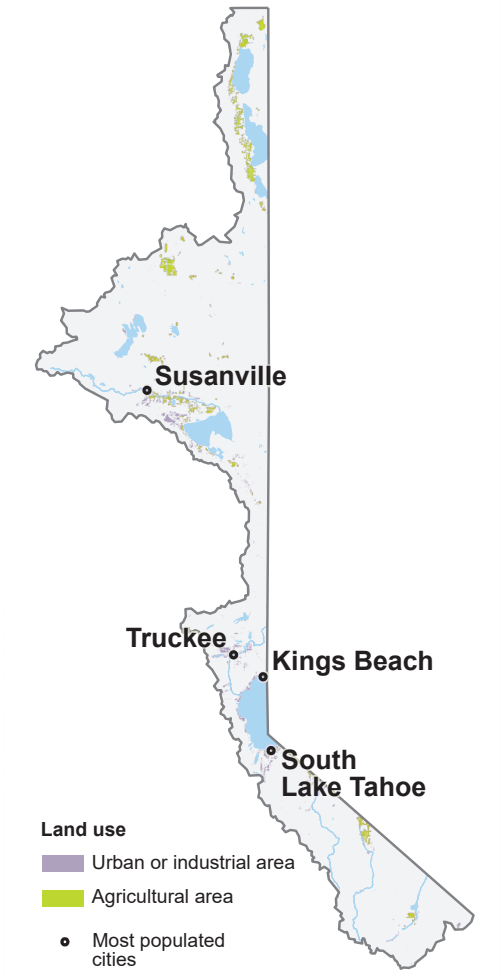


North Lahontan Hydrologic Region Land and Water Use

The North Lahontan HR uses less than one percent of California's total water use, averaging 0.35 maf each year. Groundwater accounts for 27 percent of the water supply in the region and less than one percent of statewide groundwater use. The HR use less total water and groundwater than any other HR.



Map of General Land Use



Groundwater Use

The region ranks last of the ten regions for groundwater use, averaging 0.09 maf annually. About 0.07 maf of groundwater is extracted annually to meet agricultural water demands. The remaining 0.02 maf of groundwater is used for urban and domestic purposes.

Land Use

The North Lahontan HR is primarily rural. The region has the smallest urban footprint and second smallest agricultural footprint in the state. The region includes approximately 1 percent of the urban and agricultural areas in the state.

Did you know?

Lake Tahoe is one of the deepest and clearest lakes in the United States. While the water in the lake is incredibly pure, the residents in the South Lake Tahoe area are supplied 100 percent by groundwater, not lake water.

Total Urban Area: 42,080 Acres

Top 3 Cities by Population (2010):

- South Lake Tahoe (21,000)
- Susanville (18,000)
- Truckee (16,000)

Total Agricultural Area: 86,062 Acres

Top 4 Crops by Acreage (2016):

- Mixed Pasture (74,000)
- Alfalfa and Alfalfa Mixtures (34,000)
- Miscellaneous Grasses (6,000)
- Miscellaneous Grain and Hay (3,000)

North Lahontan Hydrologic Region Groundwater Management

BASINS REQUIRING GSPs	BASINS WITH ADJUDICATED AREAS	APPROVED ALTERNATIVE GSPs
1	0	1

CRITICALLY OVERDRAFTED BASINS	GROUNDWATER SUSTAINABILITY AGENCIES	GSPs SUBMITTED BY 01/31/2020
0	2	0

**Some adjudicated areas include multiple basins.*

Groundwater Management

One basin in the region is required by SGMA to submit a GSP. This basin, Tahoe Valley – Tahoe South, opted to submit an Alternative GSP, which was approved in 2019. Two Groundwater Sustainability Agencies have been formed in the region. There are no critically overdrafted basins or adjudicated areas in the region.

SGMA Groundwater Management Status



CASGEM Monitoring

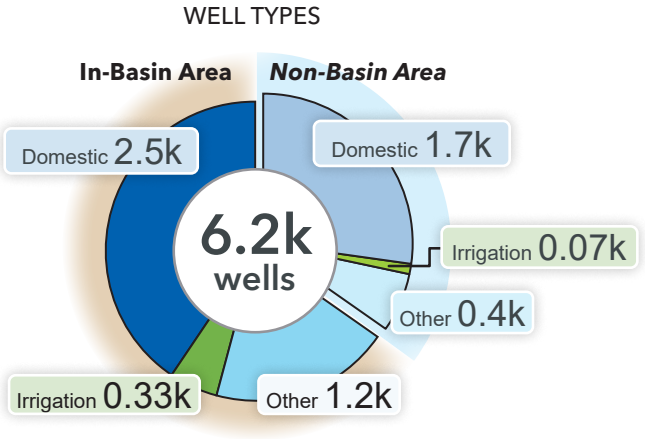
Seven basins in the region that are not required to develop GSPs are actively participating in the CASGEM program. Within these basins biannual groundwater level measurements are collected and posted to the CASGEM online system. These measurements are collected voluntarily by private individuals, academic institutions, conservation districts, and other local, state, and federal entities.

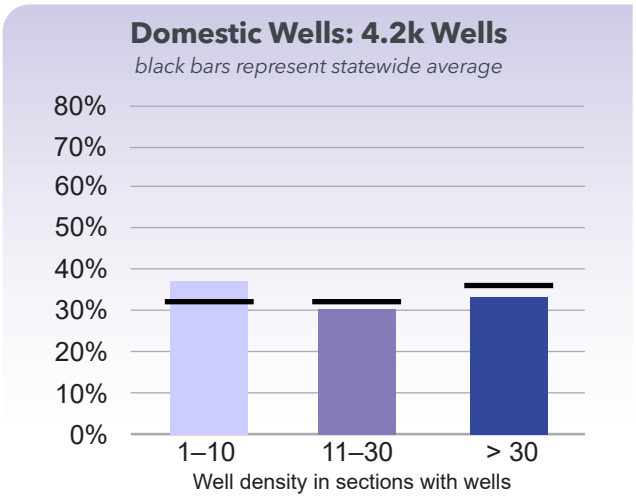


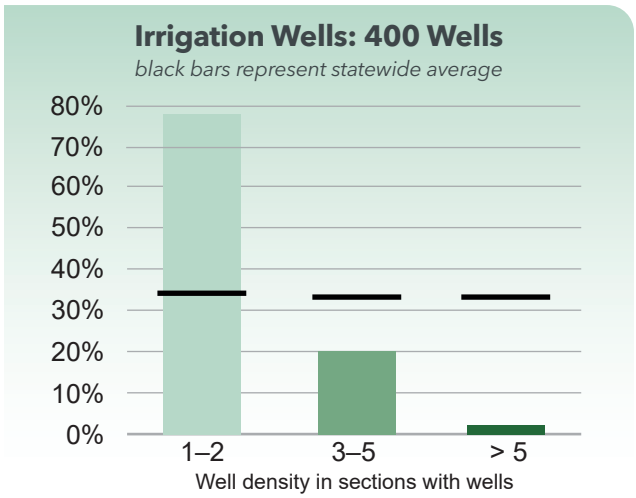
A wheel-line irrigation system operates in the HR near Cedarville.

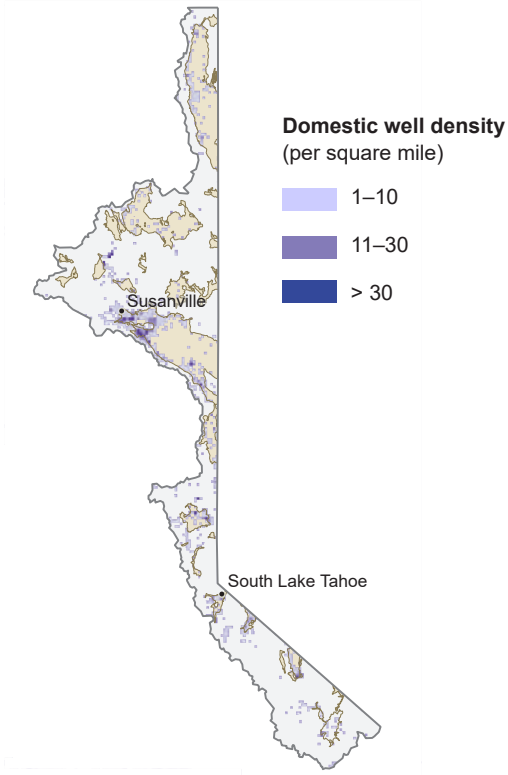
North Lahontan Hydrologic Region Well Infrastructure

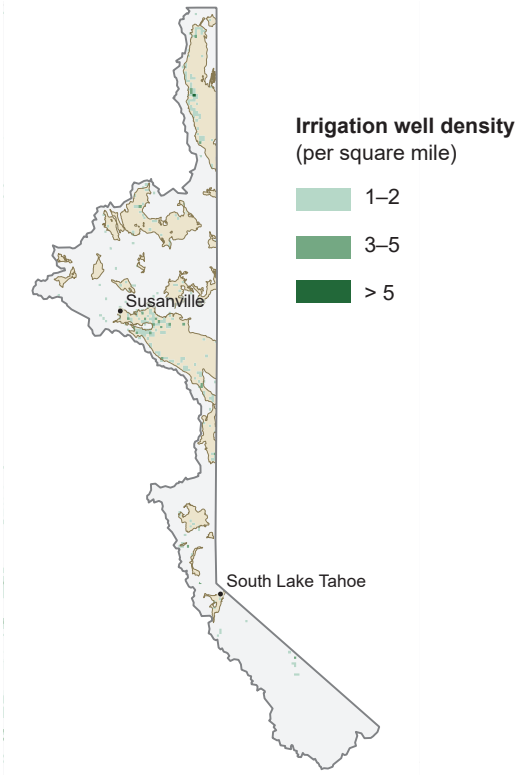
The North Lahontan HR has fewer groundwater wells than any other region, with approximately 6,200 wells installed since 1977. Sixty-five percent of the wells (4,000) have been installed within groundwater basins and about 35 percent (2,100) in the non-basin area. Within basins and the non-basin area, wells are primarily for domestic use. In total, the North Lahontan HR has approximately 1 percent of the state's groundwater wells.









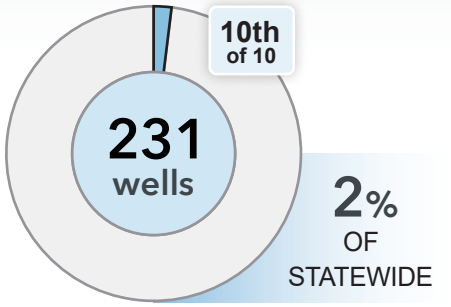


North Lahontan Hydrologic Region Groundwater Levels

Monitoring

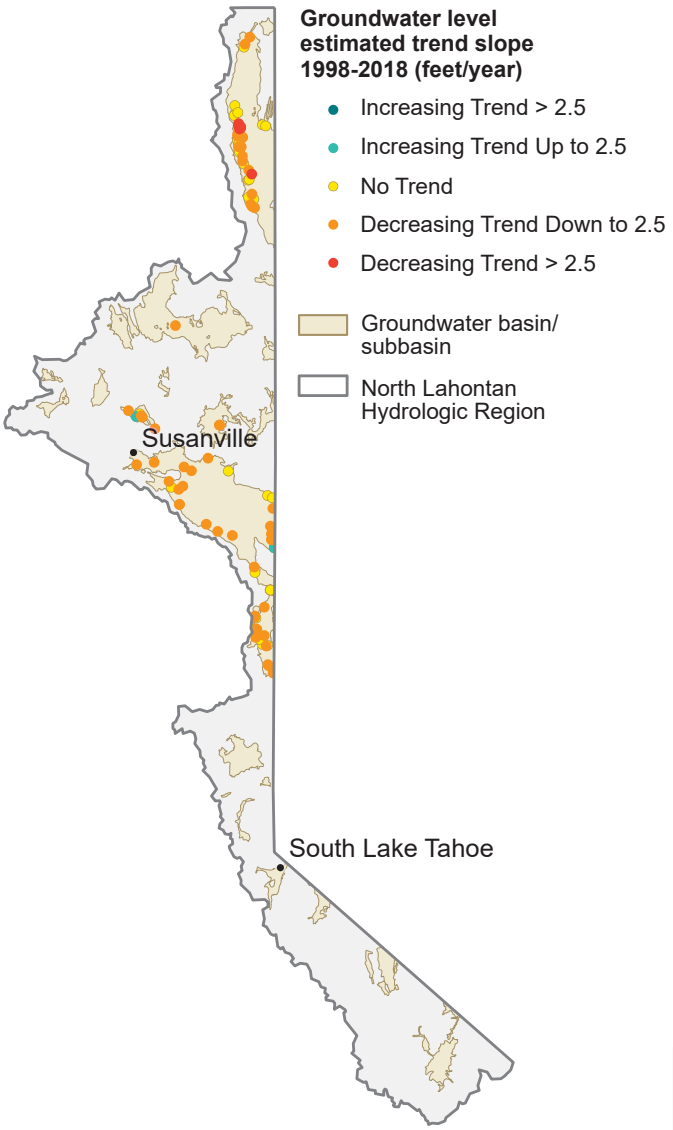
The North Lahontan HR has 231 groundwater level monitoring wells, less than any other region. Currently, 2 percent of all the groundwater level monitoring wells in the state are in the North Lahontan HR. DWR performs the most groundwater level monitoring in the region, collecting measurements from 48 percent of monitoring wells (113). Local agencies collect data from 44 percent of the wells (104) in the region. There are currently no groundwater level monitoring wells located in the southern half of the HR.

GW LEVEL MONITORING WELLS

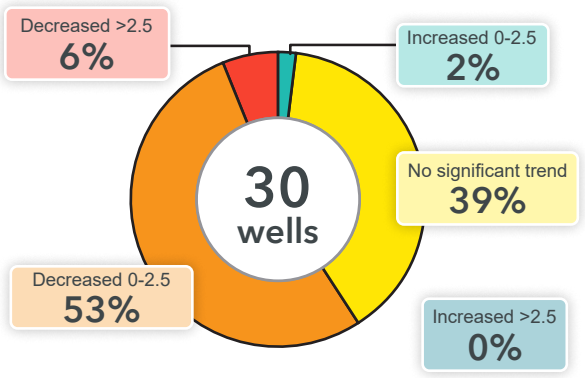


Conditions

In areas with available groundwater data, groundwater levels in many wells are declining. Overall, 59 percent of monitoring wells in the region showing a decreasing trend between 1998 and 2018. Over half of the wells in the region (53 percent) experienced a decreasing trend of up to 2.5 feet per year over this period. Six percent of wells displayed a more intense declining trend of more than 2.5 feet per year over this time. The remaining monitoring wells showed a stable trend (39 percent) with a small portion (2 percent) showing a slight increasing of up to 2.5 feet per year between 1998 and 2018.



GROUNDWATER WELL LEVEL TREND

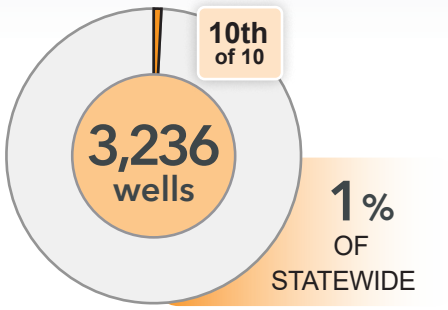


North Lahontan Hydrologic Region Groundwater Quality

Monitoring

The North Lahontan HR has the fewest groundwater quality monitoring stations among the ten regions with over 3,236 unique locations in the GAMA Groundwater Information System. The region has 1 percent of all groundwater quality monitoring stations in the state.

WATER QUALITY MONITORING STATIONS



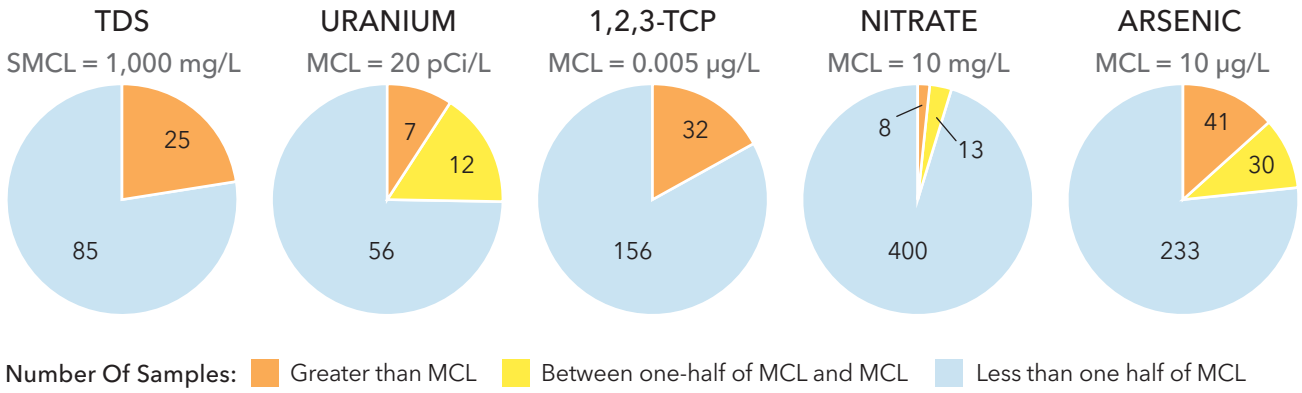
Conditions

The most common chemical detected above a regulatory limit between 2009 and 2018 in the North Lahontan HR was 1,2-dibromo,3- chloropropane (DBCP), reported in 22.9 percent of water quality stations. This percentage is the highest among wells testing above the MCL for DBCP of any HR in the state. The second most commonly detected chemical above a regulatory limit over this period was 1,2,3-TCP, detected in 17.0 percent of wells. Only three chemicals were detected above MCL or SMCL in 10 percent or more of water quality stations in the North Lahontan HR between 2009 and 2018, tying for the lowest of any region.

Top 10 Chemicals in Hydrologic Region by Percentage of Wells with Detections Above an MCL or SMCL:

22.9% 1,2-Dibromo,3-Chloropropane (DBCP)
17.0% 1,2,3-Trichloropropane (1,2,3-TCP)
13.5% Arsenic
9.7% Iron
9.3% Uranium
9.1% Gross ALPHA Radioactivity
8.5% Manganese
3.7% Radon-222
3.5% Tetrachloroethylene (PCE)
1.9% Nitrate

Regional Water Quality Summaries for 5 Chemicals of Statewide Concern

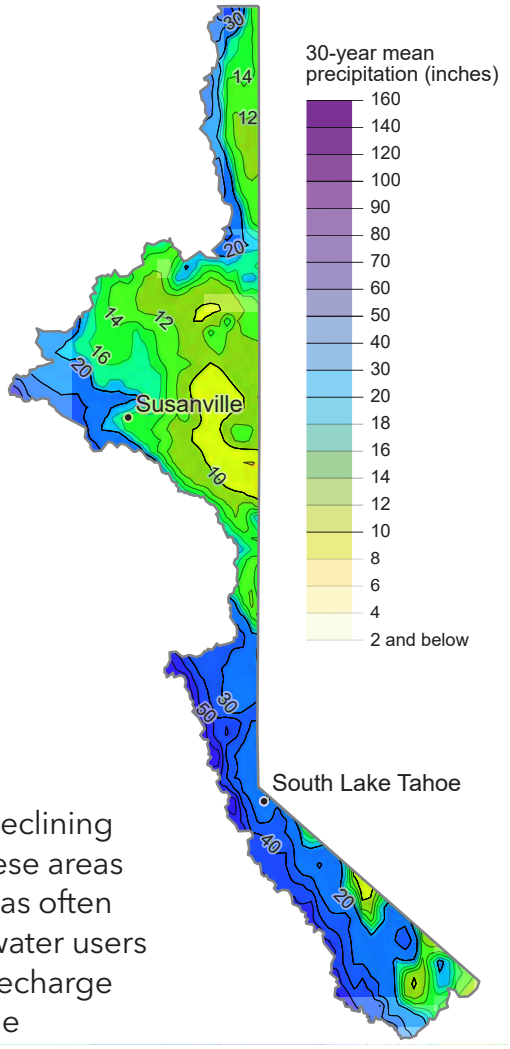


North Lahontan Hydrologic Region Groundwater Storage

The North Lahontan HR is unique as most precipitation falls as snow and all runoff from the region flows east and terminates in the high desert areas of northern California and Nevada. Similar to other regions located in eastern California, local groundwater managers face a unique challenge as minimal groundwater recharge occurs after the snowpack melts each year. Groundwater managers must balance groundwater extraction with groundwater recharge and storage to maintain balance in the system.



Map of Average Precipitation



Areas near Standish and Cedarville have experienced declining groundwater levels over the past 20 years. Although these areas are home to sparse populations, rural users in these areas often rely entirely on groundwater. It is important for groundwater users to understand the timing and amount of groundwater recharge occurring each year in the region to maintain sustainable groundwater use.

Did you know? While the population of South Lake Tahoe and Truckee combined is less than 40,000 people, it is estimated the area receives nearly 3 million visitors each year. This influx of people creates a challenge for local water managers as the water demand vastly increases during times when little to no groundwater recharge is occurring. Ensuring groundwater storage is adequate is essential to both permanent residents and visitors to the area.



North Lahontan Hydrologic Region Groundwater Assistance

TECHNICAL SUPPORT

Monitoring Wells
0 Installed at 0 Sites
0 Planned at 0 Sites

Statewide Datasets
290 mi^2 of Land Use
74 mi^2 of Land Subsidence Monitoring

FACILITATION SUPPORT

FSS Contracts
Awarded in 0 Basins

Points of Contact (POCs)
1 POCs in 1 Basins

GRANT FUNDING

Grants Awarded
5 Grants since 2010

Total Funding
$0.9 Million Awarded

Note: Assistance summaries are from Department of Water Resources' Groundwater Program. Many other local, state and federal entities also provide assistance in this region

Regional Project Spotlight: Restoration Projects

The North Lahontan HR is one of the most preserved and least developed areas of the state. Many local efforts are underway to maintain and restore areas to natural conditions. Some projects aim to restore meadows, streams, and habitat impacted by road building, fire suppression, and historic grazing and logging activities. Other restorations projects to decrease sedimentation and improve water quality are also underway. Many of these multi-benefit projects also help to improve groundwater conditions.

The US Forest Service is actively working on a meadow restoration project near the south shores of Lake Tahoe in Baldwin Meadow. This project will remove invasive species from the meadow by thinning and understory burning. The goal of the project is to allow native vegetation to flourish and raise groundwater levels in the meadow. Wet meadows play an important role in storing runoff in the spring and slowly releasing the water throughout the summer to maintain stable baseflows and water temperatures in many High Sierra streams.

Hope Meadow in 2014 Prior to Restoration Work.



Another important ongoing restoration project in the region is the Environmental Improvement Program in the Lake Tahoe Area. This program, initiated in 1997, has secured more than $400 million to improve environmental conditions. A large portion of the program focuses on water quality and stormwater in the region. The stormwater program aims to install best management practices to capture stormwater and allow it to infiltrate into the ground rather than flowing directly into Lake Tahoe. The program helps restore water clarity in Lake Tahoe, but also recharges local aquifers.

North Lahontan Hydrologic Region Basi



North Lahontan Hydrologic Region Basin List

Basins Required to Submit Groundwater Sustainability Plans

Basin Number	Basin Name	GSP Status	Critically Overdrafted
None	See Alternative GSPs		

Basins (26) with Option to Develop Groundwater Sustainability Plans

Basin Number	Basin Name	Basin Number	Basin Name
6-007	Antelope Valley	6-002	Madeline Plains
6-008	Bridgeport Valley	6-067	Martis Valley
6-101	Bull Flat	6-108	Olympic Valley
6-006	Carson Valley	6-099	Painters Flat
6-091	Cow Head Lake Valley	6-092	Pine Creek Valley
6-095	Dry Valley	6-100	Secret Valley
6-096	Eagle Lake Area	6-105	Slinkard Valley
6-094	Grasshopper Valley	6-001	Surprise Valley
6-093	Harvey Valley	6-107	Sweetwater Flat
6-004	Honey Lake Valley	6-005.03	Tahoe Valley - Tahoe North
6-097	Horse Lake Valley	6-005.02	Tahoe Valley - Tahoe West
6-106	Little Antelope Valley	6-098	Tuledad Canyon Valley
6-104	Long Valley	6-003	Willow Creek Valley

Basins (0) with Adjudicated Areas

Basin Number	Basin Name
none	

Basins (1) with Approved Alternative GSPs

Basin Number	Basin Name
6-005.01	Tahoe Valley - Tahoe South

**Basin partially located in adjacent Hydrologic Region*

Groundwater at a Glance:
South Lahontan Hydrologic Region

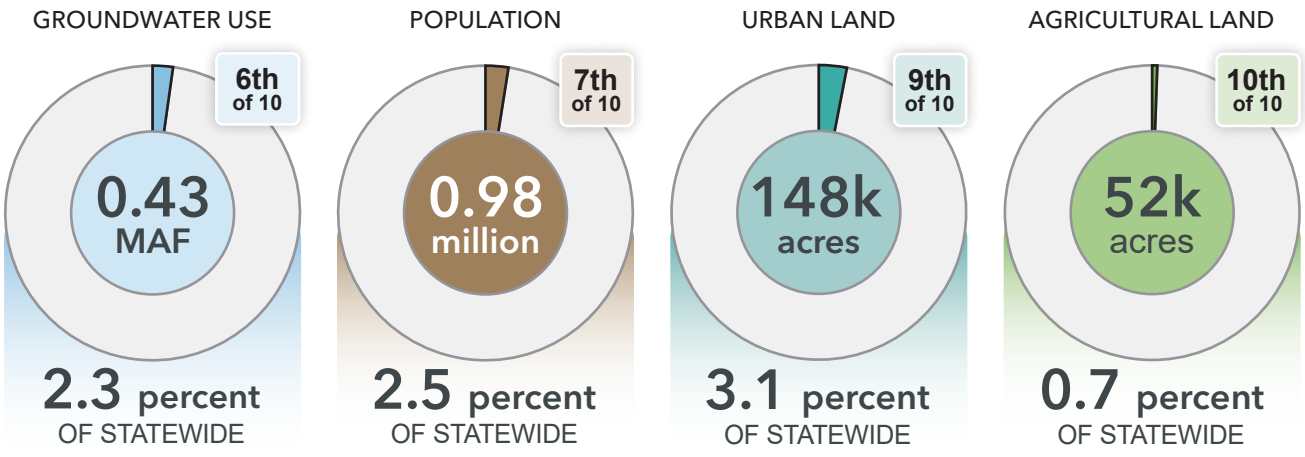
The South Lahontan HR covers nearly 27,000 square miles in eastern California. An estimated 980,000 people live in the region. Annual rainfall averages 10 inches or less for most of the region. The region is home to multiple national parks and forests, including Death Valley National Park, Inyo National Forest, and Mojave National Preserve. The region also includes the lowest and highest points in the conterminous United States: Mount Whitney at an elevation of 14,495 feet above sea level, and Death Valley at 282 feet below sea level.





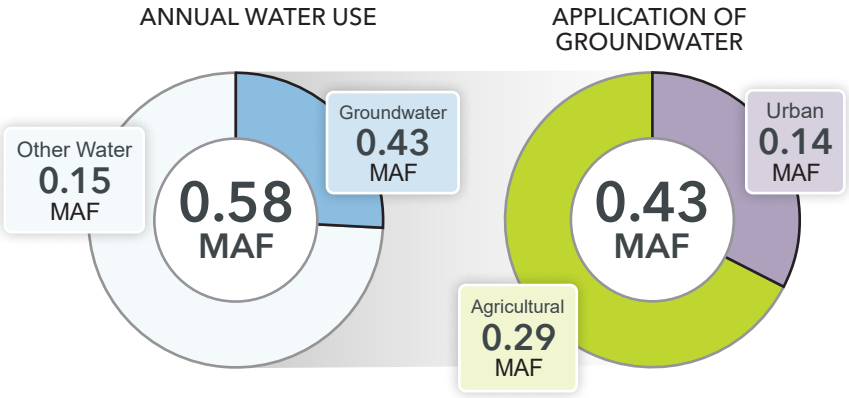
A Meadow of California poppies bloom in the Antelope Valley of the South Lahontan HR.

The region uses 0.43 maf of groundwater annually, which accounts for 74 percent of the total water supply in the region. There are 81 groundwater basins in the region including one basin required by SGMA to submit a GSP. This basin, Indian Wells Valley, has also been designated as critically overdrafted.

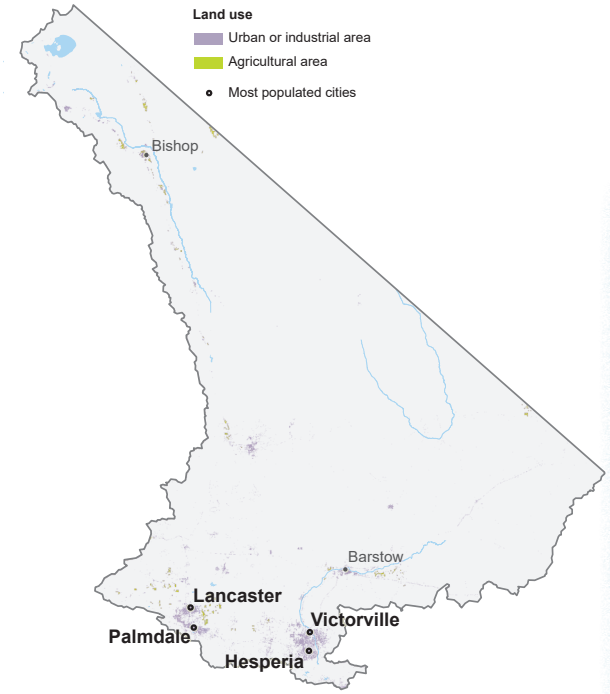


South Lahontan Hydrologic Region Land and Water Use

The South Lahontan HR uses an average of 0.58 maf of water annually, one percent of California's total water use. Groundwater accounts for 74 percent of the region's water supply and 2 percent of statewide groundwater use.



Map of General Land Use



Groundwater Use

Average groundwater use in the region is 0.43 maf, ranking sixth of ten HRs. More than two-thirds of groundwater (68 percent) is used for agricultural purposes with the remaining 32 percent is used to meet urban and domestic water demands.

Did you know? Several water banking projects operate in the region to store imported water and increase water supply reliability. The Antelope Valley- East Kern Water Agency operates the Westside Water Bank and the Eastside Water Banking and Blending Program. Collectively, these groundwater banks can store up to 125,700 AFY. The Southern California Water Bank Authority is also in the process of expanding the Willow Springs Water Bank to provide 1 million AFY of storage in the Antelope Valley Groundwater Basin.

Land Use

The region has about 52,000 acres of agricultural land. This area is less than 1 percent of the agricultural lands in the state and the least of all the regions. The region also has the second smallest urban footprint of all the regions with 148,000 acres of urban land and 980,000 residents.

Total Urban Area: 148,292 Acres

Top 4 Cities by Population (2010):

- Lancaster (157,000)
- Palmdale (153,000)
- Victorville (116,000)
- Hesperia (90,000)

Total Agricultural Area: 52,185 Acres

Top 4 Crops by Acreage (2016):

- Alfalfa and Alfalfa Mixtures (27,000)
- Mixed Pasture (11,000)
- Miscellaneous Grasses (5,000)
- Pistachios (3,000)

South Lahontan Hydrologic Region Groundwater Management

BASINS REQUIRING GSPs	BASINS WITH ADJUDICATED AREAS	APPROVED ALTERNATIVE GSPs
1	14*	0

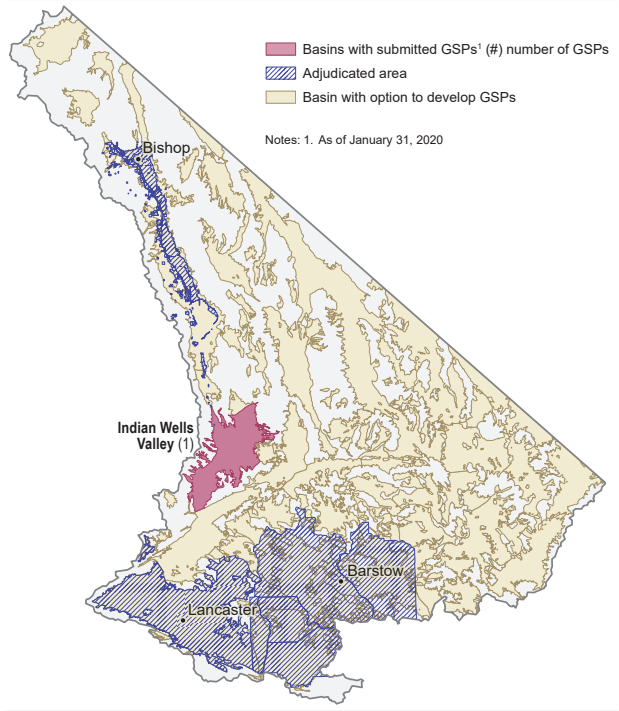
CRITICALLY OVERDRAFTED BASINS	GROUNDWATER SUSTAINABILITY AGENCIES	GSPs SUBMITTED BY 01/31/2020
1	5	1

**Some adjudicated areas include multiple basins.*

There is one basin in the South Lahontan HR that is required to submit a GSP. There are five Groundwater Sustainability Agencies that have formed in the region. As of January 31, 2020, one basin has submitted one or more GSPs for review.

There are 14 basins affected by four adjudicated areas in the region. This is the second highest number of basins with adjudicated areas of the ten regions. DWR has designated one basin in the region as critically overdrafted.

SGMA Groundwater Management Status



CASGEM Monitoring

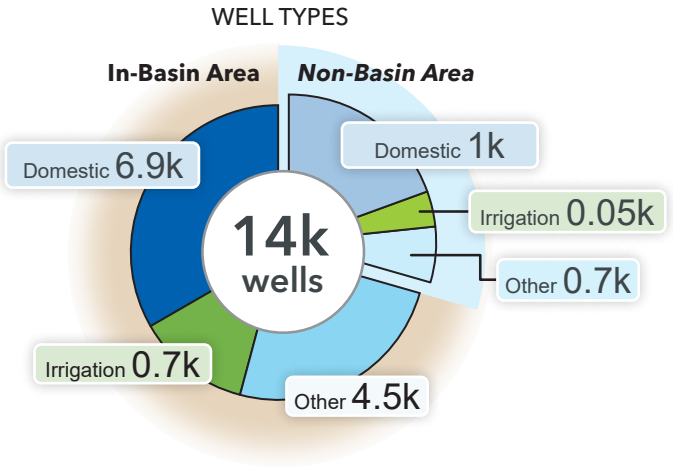
Forty-one basins in the region that are not required to develop GSPs are actively participating in the CASGEM program. Within these basins, biannual groundwater level measurements are collected and posted to the CASGEM online system. These measurements are collected voluntarily by private individuals, academic institutions, conservation districts, and other local, state, and federal entities.

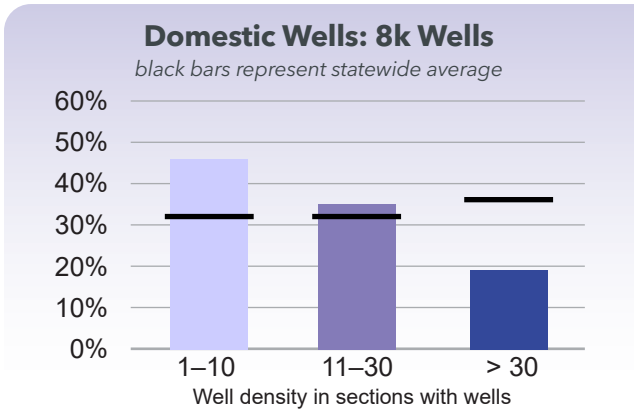


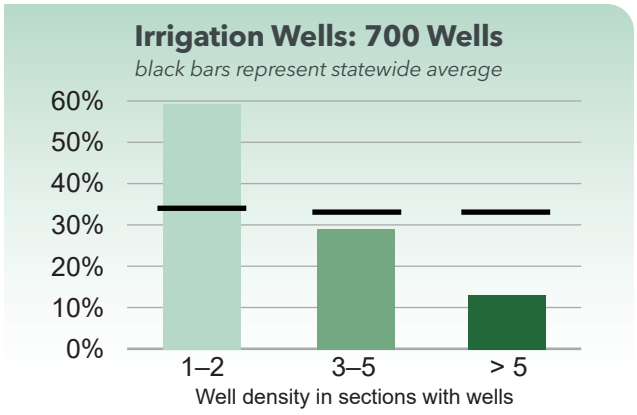
Rainbow Basin Natural Area located north of Barstow.

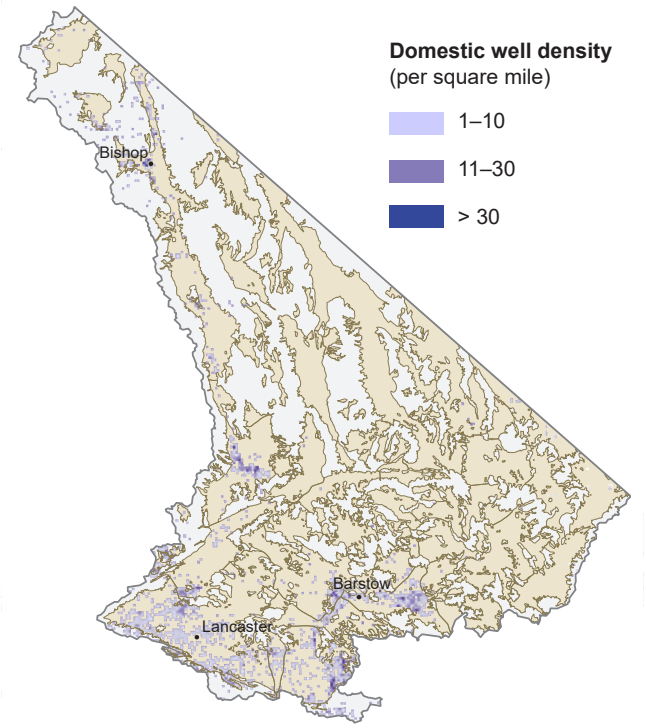
South Lahontan Hydrologic Region Well Infrastructure

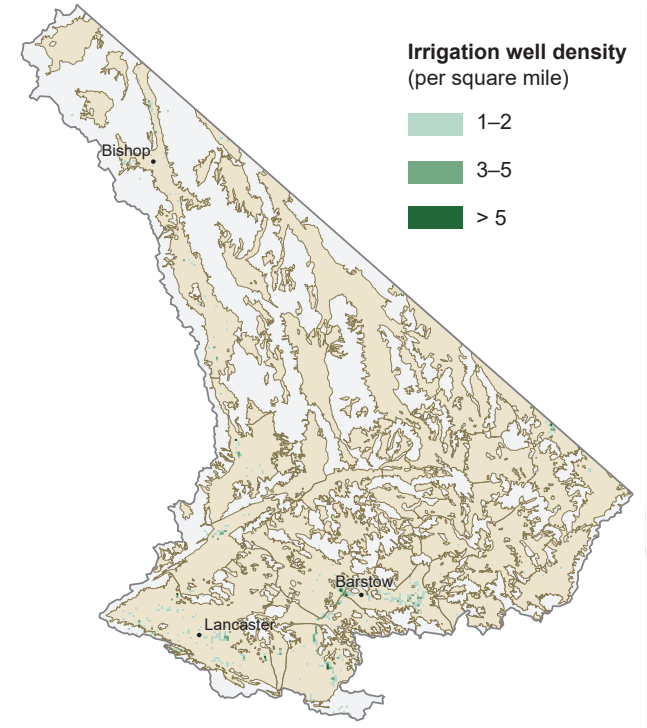
There have been 13,800 wells drilled in the South Lahontan HR since 1977. Eighty-seven percent of the wells (12,000) are located within groundwater basins and 13 percent (1,800) are in the non-basin area. Well type distribution in groundwater basins and the non- basin area are very similar, with most wells (58 percent) used for domestic purposes. Three percent of the wells drilled since 1977 are within the South Lahontan HR.









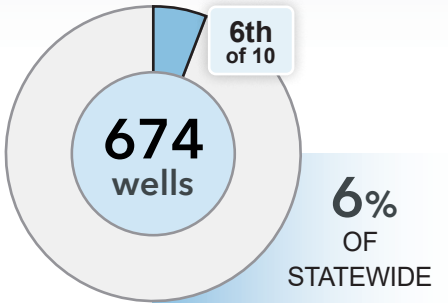


South Lahontan Hydrologic Region Groundwater Levels

Monitoring

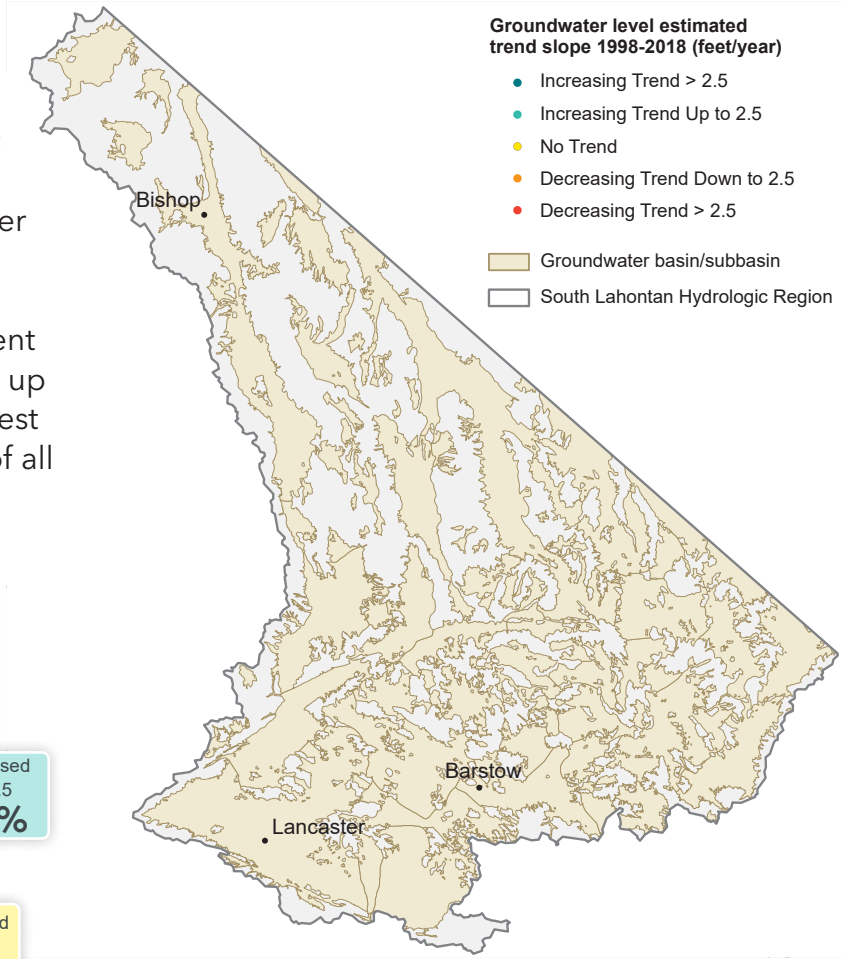
The South Lahontan HR has the sixth most groundwater level monitoring wells of the ten regions with 674 stations. This amounts to six percent of all groundwater level monitoring wells in California. Local agencies perform most of the groundwater level monitoring in the HR, collecting data from 69 percent of the monitoring wells (508). The remaining 31 percent of monitoring wells (225) are measured by federal agencies. Many areas in the HR do not currently have groundwater level monitoring.

GW LEVEL MONITORING WELLS

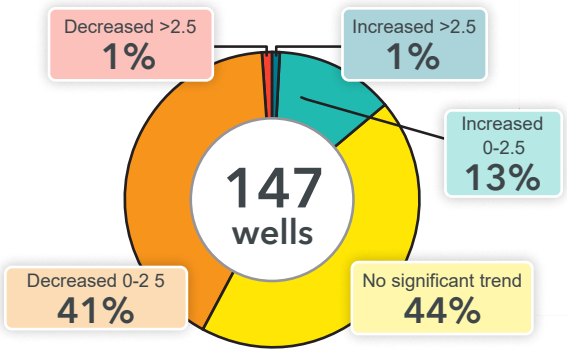


Conditions

Groundwater level trends in areas with groundwater data in the South Lahontan HR are a mix of declining trends and stable conditions. About 41 percent of wells indicated a decreasing trend of up to 2.5 feet per year between 1998 and 2018, while 44 percent of wells reflected stable groundwater levels. Nearly 13 percent of wells showed increasing levels of up to 2.5 feet per year, the second largest percentage with increasing trends of all regions during this time period.



GROUNDWATER WELL LEVEL TREND

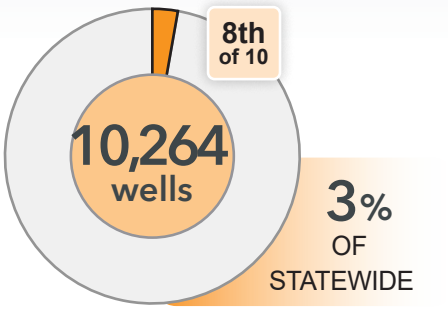


South Lahontan Hydrologic Region Groundwater Quality

Monitoring

The South Lahontan HR accounts for 3 percent of all the water quality monitoring stations in the state with than 10,264 different monitoring stations. The region has 3 percent of all groundwater quality monitoring stations in the state.

WATER QUALITY MONITORING WELLS



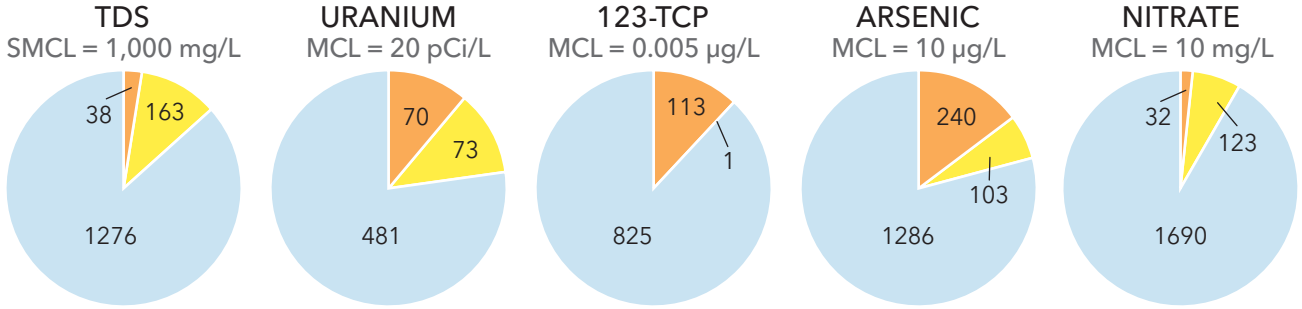
Conditions

The most commonly detected chemical above a regulatory limit in the South Lahontan HR between 2009 and 2018 was arsenic, detected above its MCL in 14.7 percent of wells. The region had the highest percentage of wells detecting arsenic above its MCL of any HR. The second most commonly detected chemical above a regulatory limit over this period was radon-222, detected in 12.6 percent of wells. Six chemicals in total were detected above their MCL or SMCL in 10 percent or more wells tested in the South Lahontan HR between 2009 and 2018.

Top 10 Chemicals in Hydrologic Region by Percentage of Wells with Detections Above an MCL or SMCL:

14.7% Arsenic
12.6% Radon-222
12.1% Iron
12% 1,2,3-Trichloropropane (1,2,3-TCP)
11.4% Gross ALPHA Radioactivity
11.2% Uranium
4.3% Manganese
3.7% 1,2-Dibromo,3-Chloropropane (DBCP)
3.4% Fluoride
2.6% Total Dissolved Solids (TDS)

Regional Water Quality Summaries for 5 Chemicals of Statewide Concern



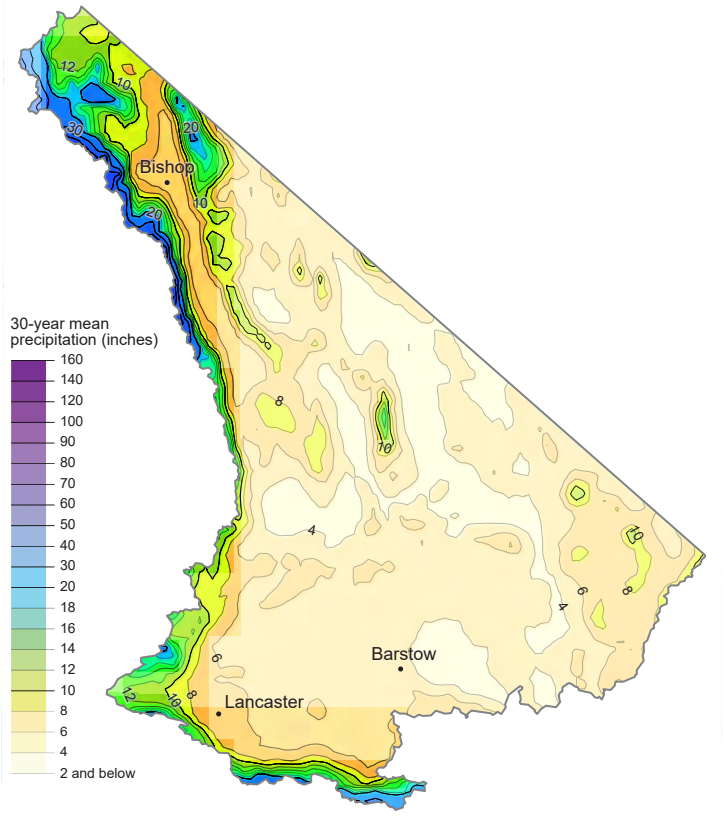
South Lahontan Hydrologic Region Groundwater Storage

The South Lahontan HR's desert climate presents a challenge for groundwater users as natural groundwater recharge occurs less frequently than in other regions due to the lack of precipitation and perennial streams. Managers must balance groundwater extraction with groundwater recharge and storage to maintain system balance.



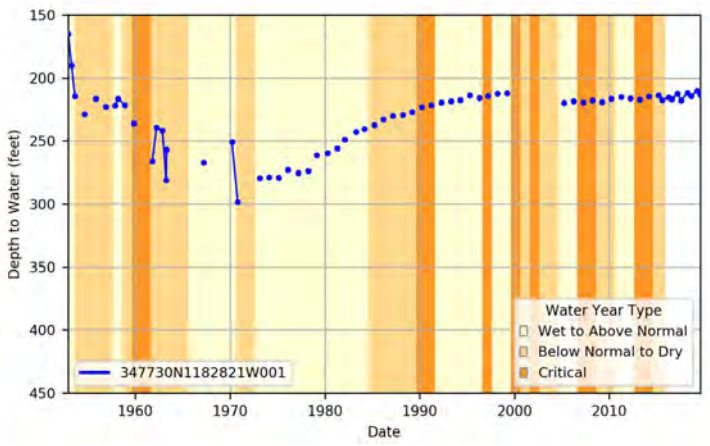
A View of urban development near Victorville.

Map of Average Precipitation



Reduction in groundwater storage has been a problem in various parts of the region for decades. In the Antelope Valley area, loss of groundwater storage resulted in declining groundwater levels and land subsidence. Damage to local infrastructure from subsidence was documented in the area as early as 1951. As a result, litigation efforts began in the area and resulted in a court-ordered adjudication ruling in 2015. Following adjudication, local groundwater data indicates a recovery and increase in overall groundwater storage in 2016.

Did you know? Changes in groundwater use can be visualized on charts showing groundwater level over time called hydrographs. This hydrograph from the South Lahontan HR shows a decrease in groundwater levels in the 1960s and 1970s followed by a recovery and stabilization. This well is located near Lancaster within an area that was adjudicated in 1996.



South Lahontan Hydrologic Region Groundwater Assistance

TECHNICAL SUPPORT

Monitoring Wells
0 Installed at 0 Sites
4 Planned at 1 Sites

Statewide Datasets
538 mi² of Land Use
4,341 mi² of Land Subsidence Monitoring

FACILITATION SUPPORT

FSS Contracts
Awarded in 2 Basins

Points of Contact (POCs)
2 POCs in 2 Basins

GRANT FUNDING

Grants Awarded
7 Grants since 2010

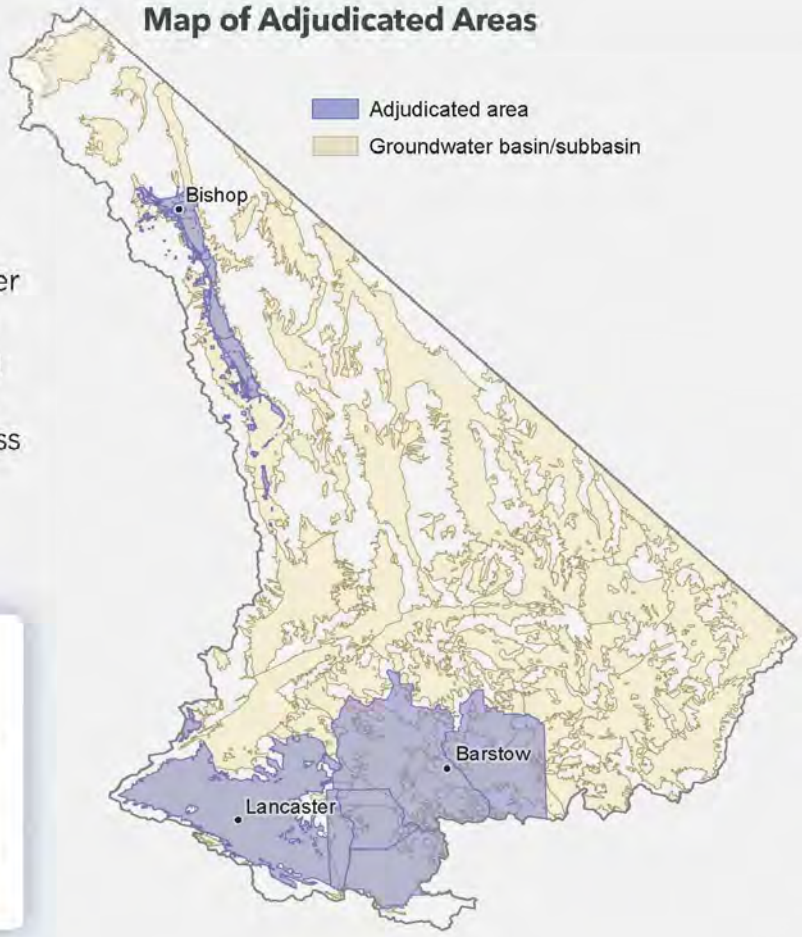
Total Funding
$9 Million Awarded

Note: Assistance summaries are from Department of Water Resource's Groundwater Program. Many other local, state and federal entities also provide assistance in this region

Local Project Spotlight: Groundwater Adjudications

There are four different adjudicated areas covering all or parts of 14 different groundwater basins in the region. Most of the groundwater-producing areas, including the Mojave, Antelope Valley, and Inyo County areas, are covered by an adjudication. Adjudicated areas are subject to local governance, oversight, and management. Groundwater pumping is often limited in these areas with a local governing body, such as a watermaster, ensuring compliance with groundwater extraction allocations. While adjudicated areas are not required to develop GSPs under SGMA, they are subject to annual reporting requirements, including extraction reporting and other data to be submitted to the state. More information on adjudicated areas across the state can be found in the Adjudicated Area Annual Reporting System.

Map of Adjudicated Areas



Did you know? The largest court-ordered groundwater adjudication in California history is located in the Mojave Basin covering over 1.5 million acres. The Mojave Basin court judgement was ruled in 1996 and affected more than 1.1 million acres in the region.

South Lahontan Hydrologic Region Basin Map



6-012.02 Groundwater basin/subbasin number (asterisk by number indicates additional portion of basin/subbasin lies in an adjacent hydrologic region)

Groundwater basin/subbasin

South Lahontan Hydrologic Region

South Lahontan Hydrologic Region Basin List

Basins (1) Required to Submit Groundwater Sustainability Plans

Basin Number	Basin Name	GSP Status	Critically Overdrafted
6-054	Indian Wells Valley	Submitted 2020	Yes

Basins (69) with Option to Develop Groundwater Sustainability Plans (GSP)

Basin Number	Basin Name
6-010	Adobe Lake Valley
6-026	Avawatz Valley
6-025	Bicycle Valley
6-013	Black Springs Valley
7-008*	Bristol Valley
6-032	Broadwell Valley
6-076	Brown Mountain Valley
6-081	Butte Valley
6-070	Cactus Flat
6-090	Cady Fault Area
6-079	California Valley
6-061	Cameo Area
6-072	Coles Flat
6-055	Coso Valley
6-065	Cottonwood Spring Area
6-035	Cronise Valley**
6-050	Cuddeback Valley**
6-057	Darwin Valley
6-018	Death Valley
6-015	Deep Springs Valley
6-078	Denning Spring Valley
6-016	Eureka Valley
6-014	Fish Lake Valley
6-046	Fremont Valley
6-085	Gold Valley
6-048	Goldstone Valley
6-077	Grass Valley
6-084	Greenwater Valley
6-074	Harrisburg FLats
6-063	Hidden Valley
6-030	Ivanpah Valley
6-069	Kelso Lander Valley
6-031	Kelso Valley
7-001*	Lanfair Valley
6-036.02	Langford Valley - Irwin
6-036.01	Langford Valley - Langford Well Lake**
7-014*	Lavic Valley
6-027	Leach Valley
6-066	Lee Flat
6-011	Long Valley
6-071	Lost Lake Valley
6-021	Lower Kingston Valley
6-064	Marble Canyon Area
6-029	Mesquite Valley
6-020	Middle Amargosa Valley
6-080	Middle Park Canyon
6-009	Mono Valley
6-012.02	Owens Valley - Fish Slough
6-088	Owl Lake Valley
6-028	Pahrump Valley
6-058	Panamint Valley
6-051	Pilot Knob Valley
6-062	Race Track Valley
6-024	Red Pass Valley
6-086	Rhodes Hill Area
6-023	Riggs Valley
6-056	Rose Valley
6-017	Saline Valley
6-053	Salt Wells Valley
6-068	Santa Rosa Flat
6-052	Searles Valley
6-034	Silver Lake Valley
6-033	Soda Lake Valley
6-082	Spring Canyon Valley
6-049	Superior Valley**
6-022	Upper Kingston Valley
6-073	Wild Horse Mesa Area
6-075	Wildrose Canyon
6-019	Wingate Valley

Basins (11) with Adjudicated Areas

Basin Number	Basin Name
6-044*	Antelope Valley**
6-038	Caves Canyon Valley
6-037	Coyote Lake Valley
6-043	El Mirage Valley
6-047	Harper Valley
6-089	Kane Wash Area
6-040	Lower Mojave River Valley
6-041	Middle Mojave River Valley
6-012.01	Owens Valley - Owens Valley**
6-045*	Tehachapi Valley East
6-042*	Upper Mojave River Valley

Basins with Approved Alternative GSPs

Basin Number	Basin Name
none	

**Basin partially located in adjacent hydrologic region*
***Basin partially adjudicated*

Groundwater at a Glance:
Colorado River Hydrologic Region

The Colorado River HR covers roughly 20,000 square miles in southeastern California. It has a variety of arid desert terrain that includes many valleys, broad alluvial fans, sandy washes, and mountains. The average annual precipitation is about 6 inches, making it the most arid region of California. An estimated 800,000 people live in the region. The Colorado River defines the eastern boundary of the region and is the main water supply for the region. Regional points of interest include Palm Springs, Joshua Tree National Park, and the Salton Sea.

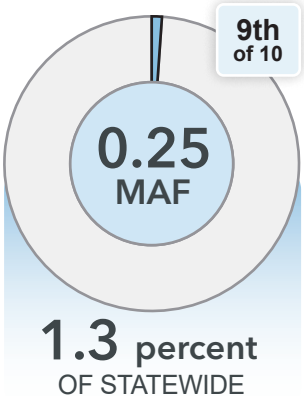




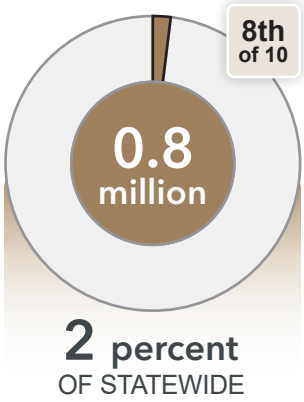
The sunset over Joshua Tree National Park.

The Colorado River HR uses an average of 0.24 maf of annual groundwater use, eighth most among HRs. Groundwater accounts for only six percent of the region's total supply, less than any other HR. Of the 70 groundwater basins in the region, four are required by SGMA to submit GSPs.

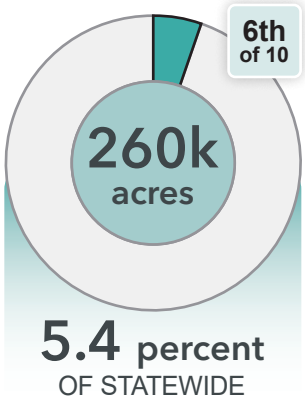
GROUNDWATER USE



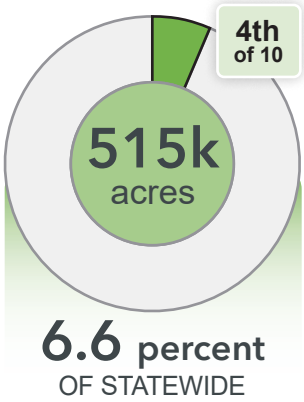
POPULATION



URBAN LAND

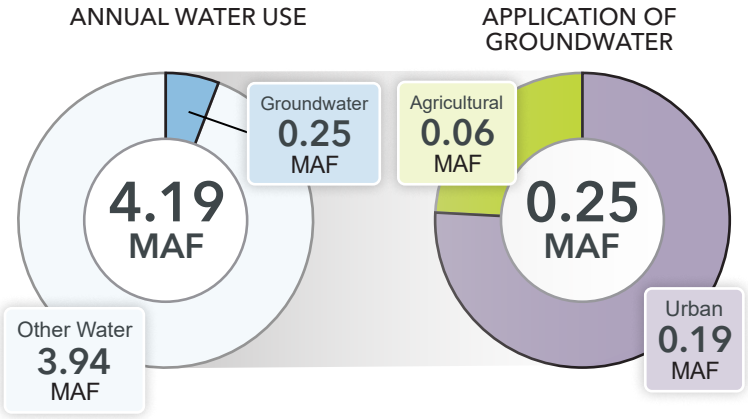


AGRICULTURAL LAND

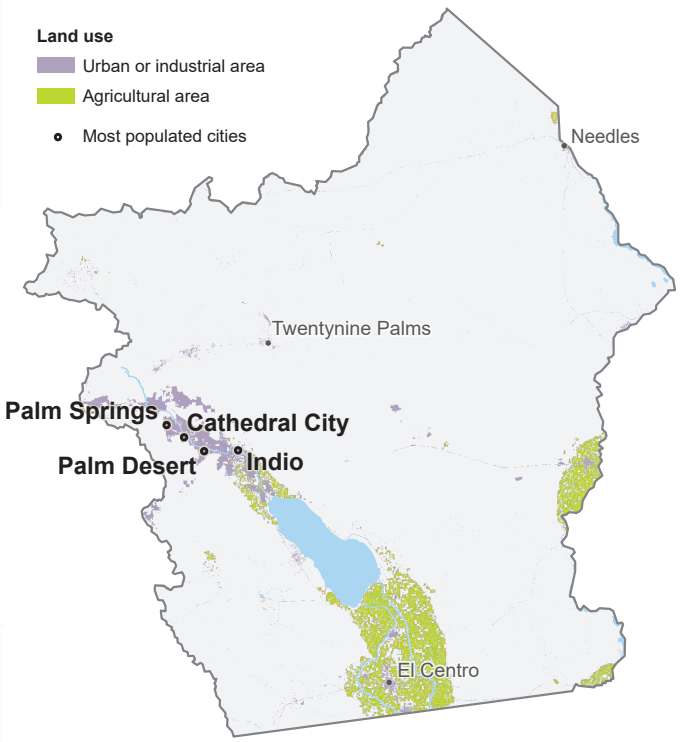


Colorado River Hydrologic Region Land and Water Use

The Colorado River HR uses 10 percent of California's total water use, averaging 4.19 maf each year. Groundwater accounts for 6 percent of the water supply in the region, less than any other HR. The HR accounts one percent of statewide groundwater use.



Map of General Land Use



Groundwater Use

The region uses 0.25 maf of groundwater annually, the second smallest volume among the ten HRs. Of the 0.25 maf of groundwater extracted annually, 78 percent is used by the region's 800,000 residents for urban demands.

Did you know? California's largest lake by area, the Salton Sea, is in the Colorado River Region. The lake has experienced declining water levels and increasing salinity for decades, resulting in the lake being saltier than the ocean. While the lake water cannot be used for agricultural or domestic uses, it does provide habitat and food for fish and migratory birds.

Land Use

The region is home to 7 percent of the agricultural area in the state with over 500,000 acres, ranking fourth among regions. Most of the agricultural water demands are met with water from the Colorado River. The region has the sixth largest urban footprint in the state with over 250,000 acres of urban area.

Total Urban Area: 259,682 Acres

Top 4 Cities by Population (2010):

- Indio (76,000)
- Cathedral City (51,000)
- Palm Desert (48,000)
- Palm Springs (45,000)

Total Agricultural Area: 515,265 Acres

Top 4 Crops by Acreage (2016):

- Alfalfa Mixtures (192,000)
- Miscellaneous Grasses (74,000)
- Leafy Greens (40,000)
- Wheat (28,000)

Colorado River Hydrologic Region Groundwater Management

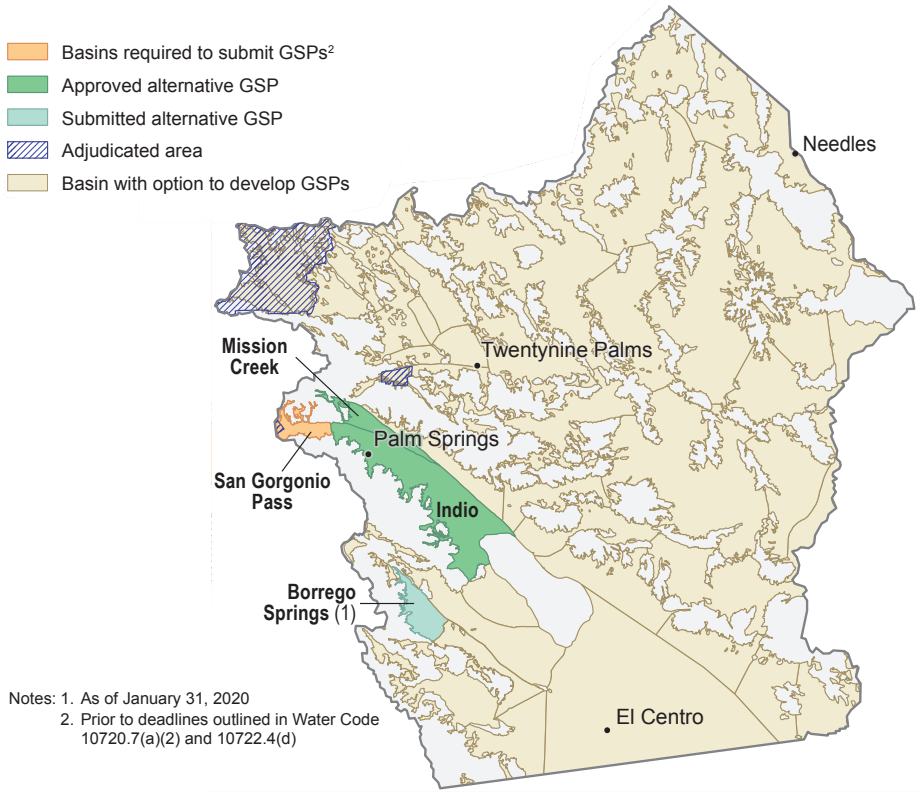
BASINS REQUIRING GSPs	BASINS WITH ADJUDICATED AREAS	APPROVED ALTERNATIVE GSPs
4	6	2

CRITICALLY OVERDRAFTED BASINS	GROUNDWATER SUSTAINABILITY AGENCIES	GSPs SUBMITTED BY 01/31/2020
1	40	0

Groundwater Management

Four groundwater basins within the Colorado River HR are required by SGMA to submit GSPs. Within the region 40 Groundwater Sustainability Agencies have been formed. One basin in the region, Borrego Springs, has been designated as critically overdrafted and submitted an Alternative GSP in January 2020. Two basins in the region have approved Alternative GSPs. There are three adjudicated areas in the region, affecting six groundwater basins.

SGMA Groundwater Management Status



Notes: 1. As of January 31, 2020
2. Prior to deadlines outlined in Water Code 10720.7(a)(2) and 10722.4(d)

CASGEM Monitoring

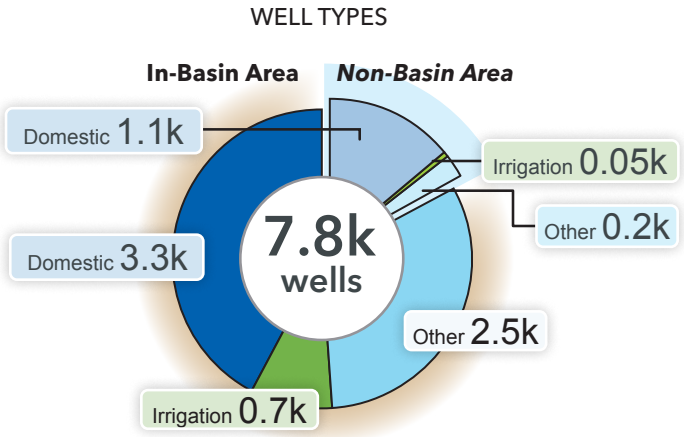
Forty-five basins in the region that are not required to develop GSPs are actively participating in the CASGEM program. Within these basins biannual groundwater level measurements are collected and posted to the CASGEM online system. These measurements are collected voluntarily by private individuals, academic institutions, conservation districts, and other local, state, and federal entities.

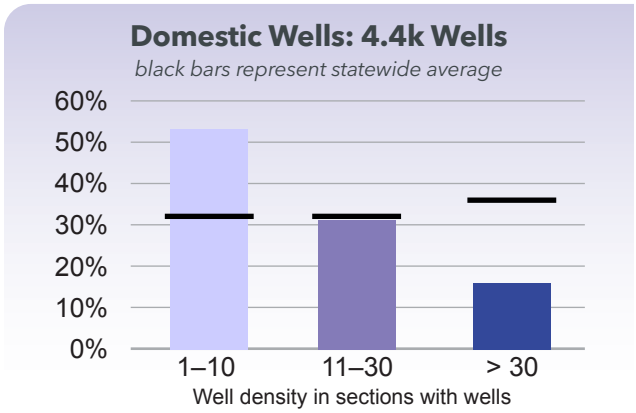


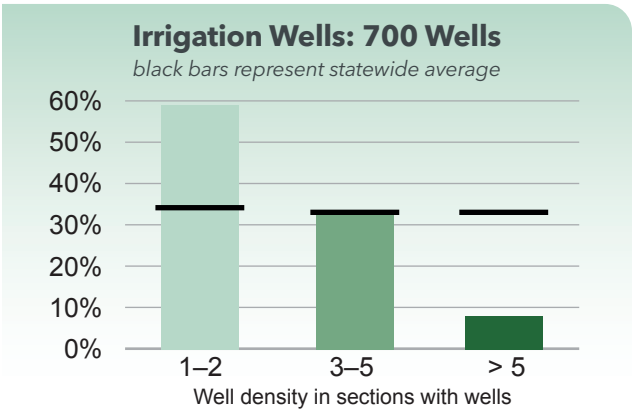
A DWR geologist uses an electric sounder to measure a groundwater level monitoring well.

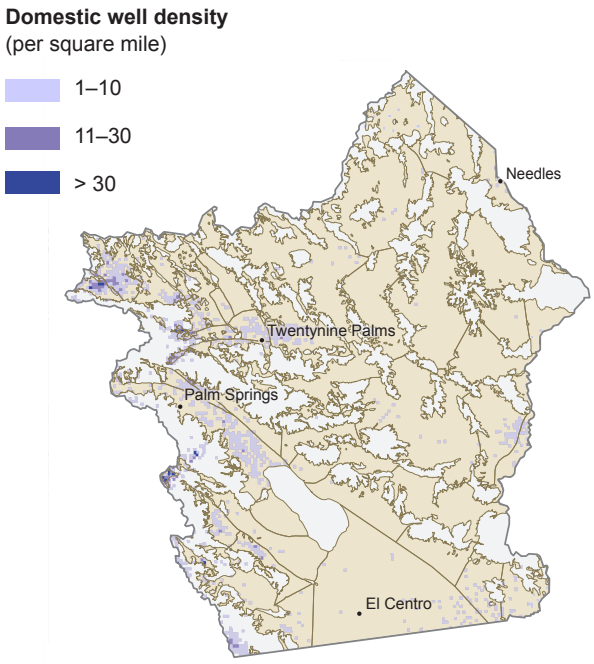
Colorado River Hydrologic Region Well Infrastructure

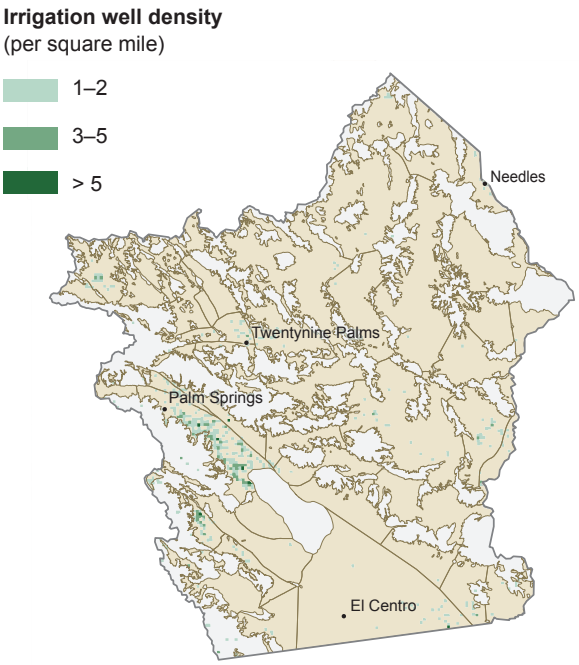
There have been about 7,800 groundwater wells drilled in the Colorado River HR since 1977. Approximately 82 percent of the wells (6,400) have been drilled within groundwater basins and 18 percent (1,400) drilled in the non-basin area. Within basins, 51 percent of wells are for domestic use, while in the non- basin area 79 percent of wells are for domestic use. In total, two percent of the wells drilled since 1977 are within the Colorado River HR.









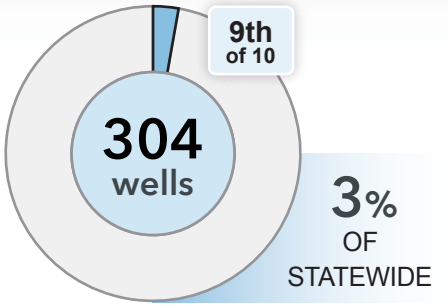


Colorado River Hydrologic Region Groundwater Levels

Monitoring

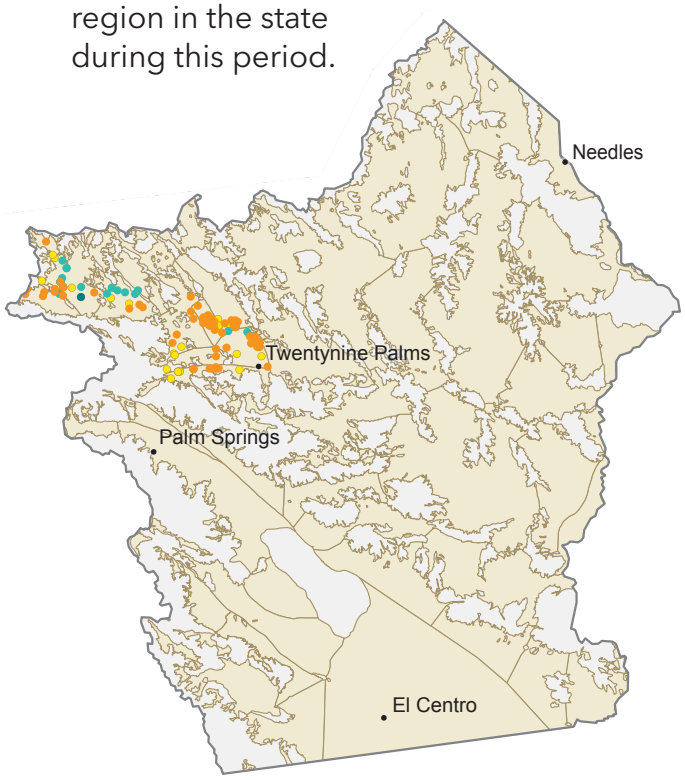
The Colorado River Region has 304 groundwater level monitoring wells, ranking ninth out of the ten HRs. The region is home to 3 percent of all groundwater level monitoring wells in California. Local agencies collect groundwater level measurements from 59 percent of the monitoring wells in the region. Nearly half of the wells monitored for groundwater water levels in the region (46 percent) are observation wells. Many areas in the HR do not currently have groundwater level monitoring wells.

GW LEVEL MONITORING WELLS



Conditions

In areas with available groundwater data, groundwater levels in many wells are declining. In total, 58 percent of groundwater level monitoring wells in the region experienced a declining trend of up to 2.5 feet per year between 1998 and 2018. No monitoring wells in the region indicated a more severe decline than 2.5 feet per year over this period, making the region the only one in the state with no wells showing this level of decline. The remaining wells equally showed a stable trend (21 percent) and increasing trend (21 percent). The region had more wells with an ncreasing g oundwater trend than an region in the state during this period.

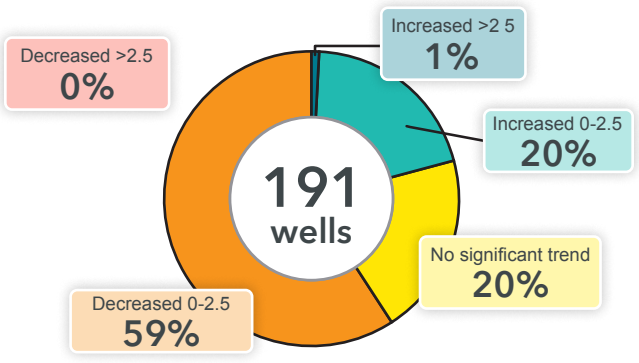


Groundwater level estimated trend slope 1998-2018 (feet/year)

- Increasing Trend > 2.5
- Increasing Trend Up to 2.5
- No Trend
- Decreasing Trend Down to 2.5
- Decreasing Trend > 2.5

- Groundwater basin/subbasin
- Colorado River Hydrologic Region

GROUNDWATER WELL LEVEL TREND

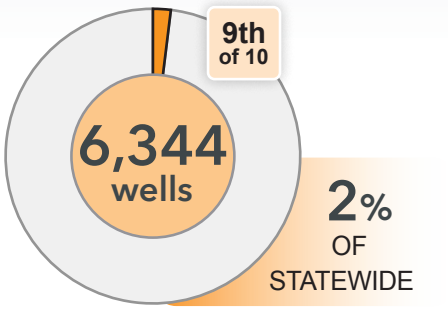


Colorado River Hydrologic Region Groundwater Quality

Monitoring

The Colorado River HR ranks ninth out of the ten regions for most groundwater quality monitoring stations in the GAMA Groundwater Information System, with 6,344 unique locations. This amount accounts for about 2 percent of all groundwater quality monitoring stations in California.

WATER QUALITY MONITORING STATIONS



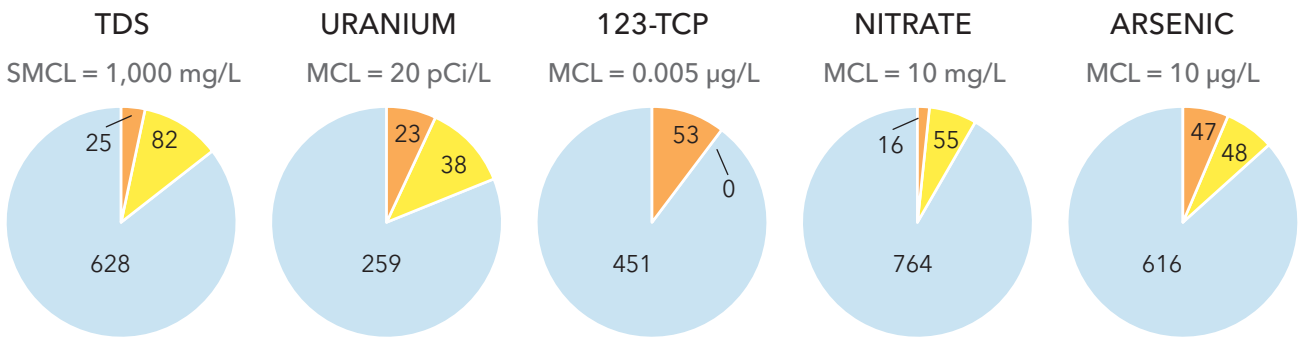
Conditions

The most common chemical detected above a regulatory limit between 2009 and 2018 was iron, with 10.6 percent of water quality stations in the Colorado River HR reporting above the SMCL. The second most commonly detected chemical above the regulatory limit over this period was 1,2,3-TCP, detected above the MCL in 10.5 percent of wells tested. Only three chemicals were detected above their MCL or SMCL in 10 percent or more of water quality stations in the region between 2009 and 2018, tying for the lowest of any region.

Top 10 Chemicals in Hydrologic Region by Percentage of Wells with Detections Above an MCL or SMCL:

10.6% Iron
10.5% 1,2,3-Trichloropropane (1,2,3-TCP)
10.4% 1,2-Dibromo,3-Chloropropane (DBCP)
8.9% Gross ALPHA Radioactivity
7.3% Fluoride
7.2% Uranium
6.6% Arsenic
5.6% Manganese
3.8% Specific Conductivity
3.4% Total Dissolved Solids (TDS)

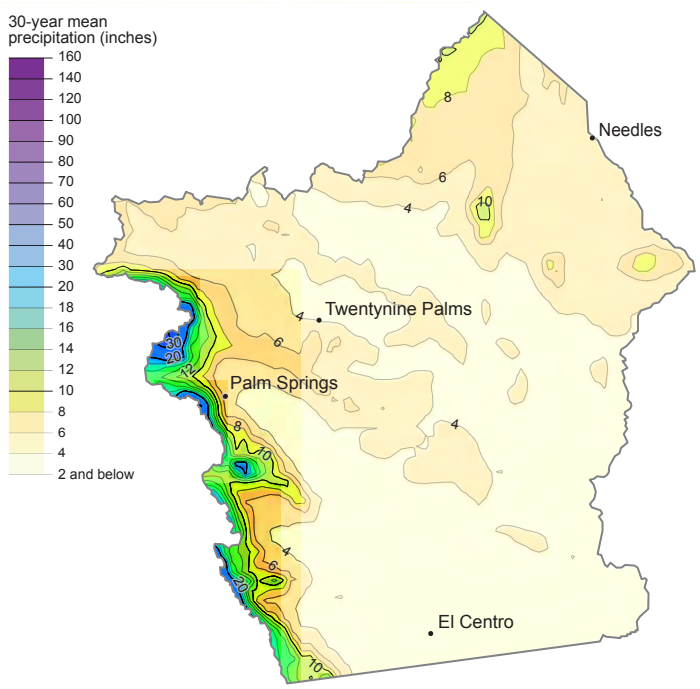
Regional Water Quality Summaries for 5 Chemicals of Statewide Concern



Colorado River Hydrologic Region Groundwater Storage

The Colorado River HR is largely undeveloped due to its arid climate. Most of the region averages less than 4 inches of precipitation annually, less than any other HR. While groundwater is found throughout the region, the lack of precipitation and natural recharge presents a serious challenge to groundwater managers.

Map of Average Precipitation



The lack of a reliable water supply has mostly hindered development in the region with the exception of the Coachella and Imperial Valleys. The Coachella Valley is the most populous area in the region and has been developed with agricultural, recreational, and urban land uses. Development has been good for the local economy but is a challenge for water managers as the area has experienced a steady decline in groundwater levels and loss of storage for decades. In response, local managers have actively sought water transfers and exchanges to supplement supply, constructed groundwater recharge projects, and updated irrigation methods to reduce reliance on groundwater and address overdraft. Groundwater levels have increased or stabilized throughout much of the Coachella Valley as a result.

Did you know? Colorado River water has been diverted into the Imperial Valley for nearly 120 years. Today, an average of 3 maf of water from the Colorado River is delivered annually to support nine cities and over 500,000 acres of farmland in the region. Due to this, the Colorado River Region is the least reliant on groundwater out of the ten regions with groundwater accounting for only 5 percent of total supply, primarily for urban uses. Even with this small reliance on groundwater, the region has historically experienced declining groundwater levels and loss of storage.



A distressed vineyard in the Coachella Valley in the Colorado River Hydrologic Region.

Colorado River Hydrologic Region Groundwater Assistance

TECHNICAL SUPPORT

Monitoring Wells
0 Installed at 0 Sites
0 Planned at 0 Sites

Statewide Datasets
1,190 mi^2 of Land Use
952 mi^2 of Land Subsidence Monitoring

FACILITATION SUPPORT

FSS Contracts
Awarded in 1 Basin

Points of Contact (POCs)
4 POCs in 4 Basins

GRANT FUNDING

Grants Awarded
11 Grants since 2010

Total Funding
$34.3 Million Awarded

Note: Assistance summaries are from Department of Water Resources' Groundwater Program. Many other local, state and federal entities also provide assistance in this region

Local Project Spotlight: Water Transfers

Many areas within the Colorado River HR rely on water transfers and imported water to provide groundwater recharge. In the Coachella and Imperial Valleys, aquifers are artificially replenished with Colorado River water exchanged from State Water Project allocations. Since 1973, more than 4.1 maf of imported water has been delivered to groundwater replenishment facilities in the region.

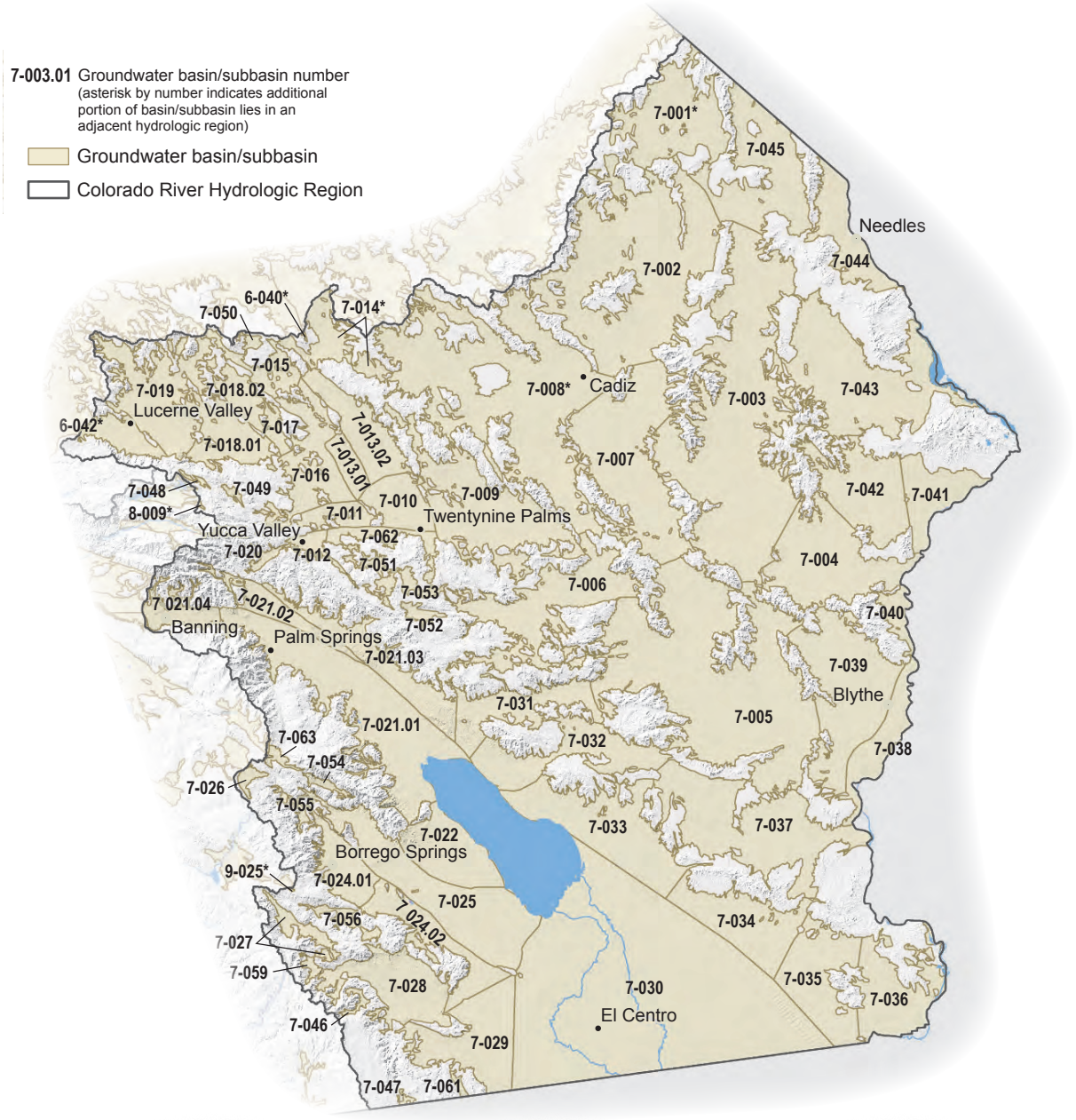
Local water managers also use imported water to irrigate golf courses and green belts in the region. More than 50 golf courses in the Coachella Valley use imported water or an imported-recycled water blend as the primary source for irrigation. An additional 23 golf courses will be connected to these water sources by 2031. The goal is for each golf course to meet its annual irrigation demand using 20 percent or less from groundwater.

The combination of importing and conserving water, recycling wastewater, and recharging groundwater have helped stabilize and improve groundwater levels and associated groundwater storage in the area.



Whitewater Groundwater Replenishment Facility located in Palm Springs, California

Colorado River Hydrologic Region Basin Map









Colorado River Hydrologic Region Basin List

Basins (2) Required to Submit GSPs by 2022

Basin Number	Basin Name	GSP Status	Critically Overdrafted
7-021.04	Coachella Valley - San Gorgonio Pass	Due 2022	No
7-024.01	Borrego Valley - Borrego Springs	Alternative GSP submitted 01/2020	Yes

Basins (1) with Submitted Alternative GSPs

Basin Number	Basin Name
7-024.01	Borrego Valley - Borrego Springs

Basins (63) with Option to Develop Groundwater Sustainability Plans

Basin Number	Basin Name
7-016	Ames Valley
7-034	Amos Valley
7-037	Arroyo Seco Valley
8-009*	Bear Valley
7-015	Bessemer Valley**
7-024.02	Borrego Valley - Ocotillo Wells
7-008*	Bristol Valley
6-032*	Broadwell Valley
7-054	Buck Ridge Fault Valley
7-007	Cadiz Valley
7-041	Calzona Valley
7-046	Canebrake Valley
7-043	Chemehuevi Valley
7-032	Chocolate Valley
7-005	Chuckwalla Valley
7-021.03	Coachella Valley - Desert Hot Springs
7-055	Collins Valley
7-011	Copper Moutain Valley
7-029	Coyote Wells Valley
7-009	Dale Valley
7-061	Davies Valley
7-013.01	Deadman Valley - Deadman Lake
7-013.02	Deadman Valley - Surprise Spring
7-033	East Salton Sea
7-002	Fenner Valley
7-048	Helendale Fault Valley
8-006*	Hemet Lake Valley
7-053	Hexie Moutain Area
7-030	Imperial Valley
7-050	Iron Ridge Area**
7-047	Jacumba Valley
7-018.01	Johnson Valley - Soggy Lake**
7-018.02	Johnson Valley - Upper Johnson Valley
7-062	Joshua Tree
7-001*	Lanfair Valley
7-014*	Lavic Valley
7-051	Lost Horse Valley
7-059	Mason Valley
7-017	Means Valley
7-020	Morongo Valley
7-044	Needles Valley
7-025	Ocotillo-Clark Valley
7-035	Ogilby Valley
7-031	Orocopia Valley
7-039	Palo Verde Mesa
7-038	Palo Verde Valley
7-006	Pinto Valley
7-049	Pipes Canyon Fault Valley
7-045	Piute Valley
7-052	Pleasant Valley
7-040	Quien Sabe Point Valley
9-025*	Ranchita Town Area
7-004	Rice Valley
7-027	San Felipe Valley
7-026	Terwilliger Valley
7-010	Twentynine Palms Valley
7-028	Vallecito-Carrizo Valley
7-063	Vandeventer Flat
7-042	Vidal Valley
7-003	Ward Valley
7-022	West Salton Sea
7-056	Yaqui Well Area
7-036	Yuma Valley

Basins (3) with Adjudicated Areas

Basin Number	Basin Name
7-019	Lucerne Valley
6-042*	Upper Mojave River Valley (10%)
7-012	Warren Valley

Basins (2) with Approved Alternative GSPs

Basin Number	Basin Name
7-021.01	Coachella Valley - Indio
7-021.02	Coachella Valley - Mission Creek

**Basin partially located in adjacent hydrologic region*
***Basin partially adjudicated*




DEPARTMENT OF WATER RESOURCES
STATE OF CALIFORNIA