Water Available for Replenishment

Final Report

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California Department of Water Resources

State of California

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Director's Letter

In September of 2014, Governor Edmund G. Brown Jr. enacted a landmark package of three groundwater management bills, steering California water policy in a new direction. For the first time in the state's history, cities, counties, and water districts have the framework and the authority to work together to prevent long-term overpumping of groundwater basins.

Unseen and often ignored by Californians, groundwater basins support hundreds of billions of dollars of economic activity each year, providing 40 percent of the state's water supply in normal years and up to 60 percent in drought years. Often referred to as a drought buffer, groundwater is a critical component of California's water portfolio, helping to sustain nearly 39 million people and the nation's most robust farm industry.

Getting groundwater basins into a sustainable regime of pumping and recharge will not be easy or painless. Regions that have, for years, pumped more groundwater than is replenished — in some cases to the point of causing land subsidence, sea water intrusion, or other undesirable effects — must either find other sources of supply or do with less. This report, required by the historic Sustainable Groundwater Management Act of 2014, will aid newly formed groundwater sustainability agencies as they determine how much water may be available for replenishment of their local groundwater basin.

But the central takeaway of this first-of-its kind report goes beyond a regional accounting of water availability and use. It goes beyond even the Sustainable Groundwater Management Act. This report makes clear that a diversified water resources portfolio is needed at the local, regional, and state levels. Effective investments will be required in many locations.

Conservation, recycling, desalination, additional storage and conveyance, stormwater capture, and water transfers — all are needed; a single method or project will no longer secure future regional water supply or quality. If California is to simultaneously bring sustainability to its groundwater basins, cope with climate change, and improve the resiliency of its water system, water managers must embrace an "all-of-the-above" approach. Since 2014, state agencies have been moving forward with that approach, guided by the California Water Action Plan, Governor Brown's five-year roadmap for more resilient, reliable water supplies.

Progress since enactment of the Sustainable Groundwater Management Act is substantial, with local agencies meeting key milestones and the state providing ongoing technical and financial assistance. Highlights include adoption of regulations; technical assistance for local agencies; publication of best management practices; and an Interim Update of Bulletin 118, California's Groundwater; formation of groundwater sustainability agencies covering 99 percent of the state's high- and medium-priority groundwater basins by the June 30, 2017 deadline; and grants from the state to assist with planning.

Now comes the truly hard part: developing and implementing plans to bring groundwater basins into balance. As this report makes clear, working at the local and regional scales across jurisdictions and embracing a portfolio approach to water management are key to ensuring that California's groundwater basins are sustained for generations to come.

Karla A. Nemeth

Director, California Department of Water Resources

Executive Summary

In 2014, California enacted three laws, collectively known as the Sustainable Groundwater Management Act (SGMA), to provide a framework for statewide sustainable groundwater management. The SGMA framework provides tools and authorities for local water managers to implement sustainable groundwater management practices through the creation of groundwater sustainability agencies (GSAs) and groundwater sustainability plans (GSPs). SGMA essentially empowers local jurisdictions to work together to determine how best to manage their local groundwater resources.

A critical element of sustainable groundwater management is the replenishment of groundwater basins. SGMA directs the California Department of Water Resources (DWR) to provide assistance to local agencies in estimating the amount of water available for groundwater replenishment. The act directs DWR to prepare a report "that presents the department's best estimate, based on available information, of water available for replenishment of groundwater in the state" (California Water Code Section 10729(c)). This report satisfies that statutory requirement.

DWR has developed planning estimates of surface water available for replenishment (referred to in this report as WAFR estimates) for each of the state's 10 hydrologic regions and 56 planning areas. These estimates and the related water resources information are presented in this report.

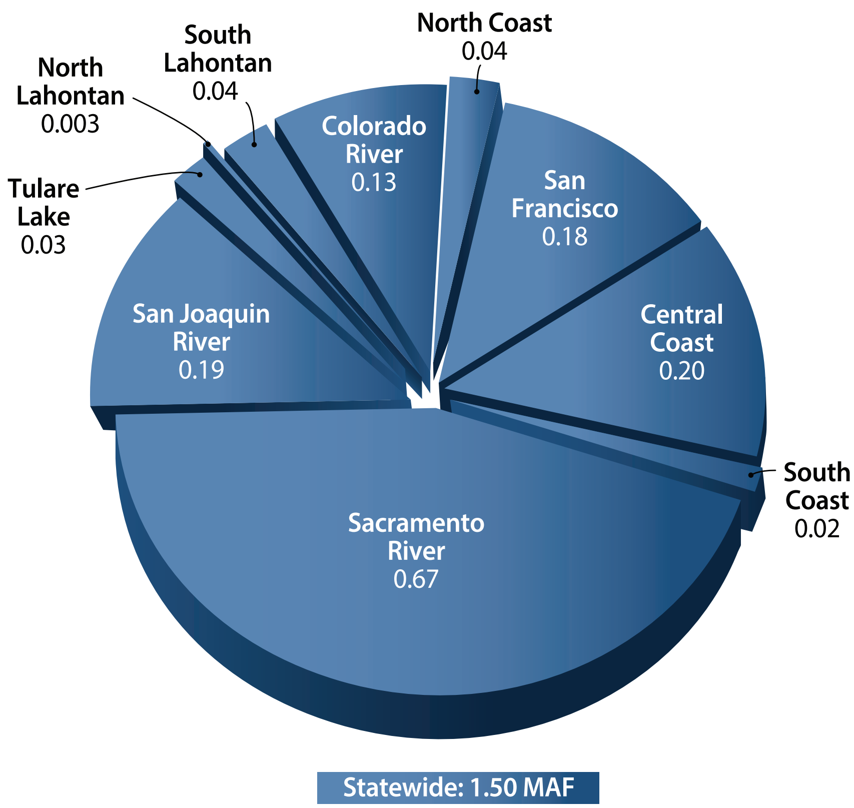
Overview of Findings

- DWR estimates that in total, 1.5 million acre-feet (MAF) of water is available statewide for replenishment of groundwater basins. The estimate is broken down by hydrologic region and the water available for replenishment varies greatly from region to region.
- Getting groundwater basins into a sustainable regime of pumping and recharge will take time and continued commitment on the part of water managers and basin stakeholders. Regions that have for years pumped more groundwater than is replenished — in some cases to the point of causing subsidence, sea water intrusion, or other undesirable effects — must either find other sources of supply or manage with less.
- Effective investments will be required in many locations to produce enough water to meet replenishment needs. Local jurisdictions must take an all-of-the-above approach and develop a diverse water portfolio of conservation, recycling, desalination, additional storage and conveyance, stormwater capture, and transfers. A single method or project will not secure future regional water supply or quality.
- The WAFR estimates in this report indicate a potential range of opportunities, investments, and innovations that may provide a foundation or starting point for local planning. As local planning progresses, analyses will become location- and project-specific, and more comprehensive as entities refine their water available analysis, as required for water right applications, permits, and changes to an existing right. The state and GSAs will need to balance the needs of water users consistent with state law and the need for replenishing groundwater basins.
- Achieving reliability and sustainability requires local, state, and federal agencies to work toward identifying and facilitating appropriate investments in ecosystem restoration, storage, and conveyance, as described in the California Water Action Plan.

Using this Report

- In addition to a "best estimate," this report provides a broader range of WAFR estimates. DWR acknowledges that the water associated with the WAFR estimates shown in this report may be developed for other uses, rather than being dedicated to replenishment, depending on the priorities and needs of water managers and users.
- GSAs should use the information provided in this report and the guidance included in Appendices C and D for direction in developing their description and analysis of the surface water supply used, or available for use, for active groundwater recharge or in-lieu use, as required by California Water Code Section 10727.2 (d)(5).
- WAFR estimates presented in this report can be used to support planning decisions by GSAs, as they consider potential improvements to their water portfolio and water sustainability within their management areas. The estimates indicate that some surface water may be available for replenishment in each of the state's hydrologic regions and many of the planning areas, especially during relatively high-flow events.
- SGMA and GSP regulations specify the requirements of a GSP. The WAFR report does not impose new requirements, but is intended to provide technical assistance for GSAs and/or interested parties to aid in the achievement of sustainable groundwater management. While this report describes methods a GSA may use to identify water available for replenishment, following these methods or any additional guidance in this report does not guarantee approval of the resulting GSP by the Department.

Figure ES-1. DWR's Best Estimate of Average Annual WAFR, by Hydrologic Region (taf)



Methodology

- The WAFR estimates were developed by determining outflow using streamflow data and an integrated water resources planning tool that combines information related to precipitation, runoff, water supplies (groundwater and surface water), and water use. A conceptual project that would divert and convey the water was then applied to the outflow estimate. The conceptual project included a project capacity and an instream flow requirement that determined the amount of outflow that could be developed and made available for groundwater replenishment. Therefore, the 1.5 MAF of water DWR estimates is available for replenishment requires new projects to divert and convey the water.

- To underscore the uncertainty associated with the WAFR estimates in this report, DWR is showing a range of values, including a "Best," a "Sensitivity Range," as well as "Maximum" and "No Project" estimates that illustrate the uncertainty and sensitivity associated with conceptual project assumptions for project capacity and instream flow requirement.

- The methodology used in this report may not fully capture competing needs associated with instream flows to support habitat, species (including endangered or threatened species), water quality, and recreation.

- The analytical approach used for this report will not satisfy the State Water Resources Control Board (SWRCB) requirements of a water availability analysis for a water right application, permit, or changes to an existing right. Additional study and data refinement would likely be necessary for such a determination; this information should be developed for specific proposed projects. More detailed analysis at a local level will need to be conducted by the GSAs as part of their GSPs.

- These estimates of water available for replenishment need to be refined by DWR to provide ongoing support and technical assistance to GSAs, and to assist in the review of the WAFR analysis included in GSPs.

Groundwater recharge ponds, located on the grounds of the Stockton East Water District (SEWD) drinking water treatment plant, provide recharge in Stockton, California, in San Joaquin County.

Introduction: Water Available for Replenishment

Background

In recent years, severe drought has resulted in a lack of adequate surface water supplies. Consequently, water users have increased groundwater pumping. Between 2010 and 2014, numerous wells throughout California experienced declines in groundwater levels in excess of 10 feet. In parts of the state, long-term groundwater use over many decades has had serious effects, including:

- Alarming declines in groundwater levels and storage.
- Degradation in water quality.
- Irreversible land subsidence.
- Ecosystem effects associated with streamflow depletion and reduced connectivity between groundwater and surface water systems.

In response, California enacted three laws, collectively referred to as the Sustainable Groundwater Management Act (SGMA) of 2014, to provide a framework for statewide sustainable groundwater management. The SGMA framework authorizes local water managers, and provides them the tools they need, to implement sustainable groundwater management practices through the creation of groundwater sustainability agencies (GSAs) and groundwater sustainability plans (GSPs).

SGMA directed the California Department of Water Resources (DWR) to provide assistance to local agencies, including the preparation of a report "…that presents the department's best estimate, based on available information, of water available for replenishment of groundwater in the state" (California Water Code section 10729(c)). This report satisfies that statutory requirement. Text Box 1 describes some roles of GSAs, DWR, and SWRCB in WAFR planning.

Purpose of this Report

This report includes DWR's estimates of surface water available for replenishment in the state, by region, based on available information. This report will also help GSAs prepare their GSPs, since GSPs are required to include "a description of surface water supply used or available for use for groundwater recharge or in-lieu use" (California Water Code Section 10727.2 (d)(5)). The estimates provided and the methodologies described in this report will help inform this description and analysis to be completed by GSAs.

Moreover, DWR intends for the information in this report to serve as a resource and as guidance for GSAs, as they plan for sustainability. Achieving groundwater sustainability will depend on implementing sustainable and balanced water budgets, which may require the development of both water and replenishment projects and management actions. A diversified portfolio of solutions, which considers local, regional, and statewide options, will support implementation of SGMA and many of the key actions identified in Governor Brown's California Water Action Plan. Updated in January of 2016, the California Water Action Plan identifies 10 key actions that focus on sustainable management of water resources for California's people, environment, industry, and agriculture, with the overarching goals of improving reliability, restoring key ecosystem functions, and establishing resilient resources that can be relied upon for future generations. This report supports Action 6 of the California Water Action Plan: "Expand water storage capacity and improve groundwater management."

Text Box 1. Roles in Water Available for Replenishment Planning

GSA water managers will need to understand their local water budgets (i.e., a comprehensive accounting of all surface water and groundwater inflows and outflows) and then increase supply or reduce use, or perform both of those actions to improve sustainability. GSAs are responsible for achieving local sustainability, and this DWR report is intended to support GSAs by providing the following:

- **Framework for estimates.** This report provides a framework for estimating water available for groundwater replenishment. The framework includes a discussion about the relationship of water available for replenishment and SGMA, estimates for surface water available for replenishment, specific planning guidance for developing the water available methods as well as the replenishment methods, and a set of recommendations for improving related planning. This framework also supports GSA development of GSPs, including the development of water budgets and projects and management actions to achieve sustainability. (Descriptions of water available and for replenishment can be found in the "Understanding Water Available for Replenishment" section.)

- **Technical assistance.** DWR has developed planning tools to estimate water available from potential surface water projects at the hydrologic region and planning area scales. These tools can be refined for use at the GSA level and could be used by GSAs to estimate water available from surface water for their agency, as required in each GSP. In addition, DWR staff will be available to provide technical guidance related to the use of these tools and methods.

- **Statewide planning assistance.** An important element of GSA planning will be to develop a water budget that includes each GSA's uses and supplies of water, along with all water inflows and outflows. GSAs that receive water supplies from the statewide projects (i.e., Central Valley Project [CVP] and State Water Project [SWP]) will need to present and understand the reliability of these supplies for their water budgets. This report includes a discussion of the water supply reliability of the CVP and the SWP, as well as potential water available from specific statewide projects. A discussion about CVP and SWP uncertainties and vulnerabilities related to reliability is also included.

- **Agency alignment and financial assistance guidance.** Coordination among GSAs, DWR, and the State Water Resources Control Board (SWRCB) is essential for the successful implementation of SGMA. DWR will continue to coordinate with SWRCB to ensure that guidance is consistent with SWRCB's policies and the needs of the State's water rights program. DWR will also coordinate with State financial assistance programs that may provide assistance for water available and replenishment projects or management actions.

- **Interregional assistance.** The framework above acknowledges that GSAs may also consider adding multi-regional planning projects and management actions into their sustainability planning.

During development of the WAFR final report, DWR and others have initiated exploring expanded opportunities to use floodwater for managed aquifer recharge (Flood-MAR), which is introduced in Text Box 2.

Text Box 2. Flood-MAR: Using Flood Water for Managed Aquifer Recharge

Anticipated climate change effects indicate the need for both increased flood risk reduction measures and sustainable water supply solutions. Over the past six years, California endured five years of drought followed by the wettest year on record. Water managers and users recognize the need to further adapt our water management to these dry and wet cycles.

DWR, SWRCB, Department of Food and Agriculture, and federal, regional, and local entities are actively exploring opportunities to determine how flood and groundwater management can be integrated to their mutual benefit. Although integrating flood and groundwater management is not a new concept, the time is ripe for an expanded, integrated program implementation. In addition to water supply benefits, the potential public benefits of flood-MAR include:

- Flood risk reduction.
- Drought preparedness.
- Groundwater replenishment.
- Ecosystem restoration.
- Aquifer remediation.
- Working landscape preservation and stewardship.
- Climate change adaptation.

See Flood-MAR fact sheet and white paper at http://www.water.ca.gov/system_reop/

Understanding Water Available for Replenishment

Understanding DWR's conceptual approach to "water available for replenishment" (WAFR) is fundamental to using this report. The concept is separated into two parts: (1) ***water availablity methods*** and (2) ***groundwater replenishment methods***. An implementing entity (such as a GSA) will need to develop projects or management actions in two parts. First, GSAs will identify and describe the method(s) of making water available, including the timing and amount of water available.

Second, GSAs will determine and describe the location and method(s) for groundwater replenishment, including replenishment timing and limitations. Consequently, in many cases, GSAs will need to develop and implement two projects or management actions to achieve replenishment. In this report, we refer to water available methods and replenishment methods to describe the options available for GSAs.

Water Available

Methods of making water available include a portfolio of water management actions: surface water development (including stormwater), water conservation, recycled water, desalination, and water transfers. All of these methods can help make water available for groundwater replenishment by either increasing water supply directly or reducing demand on existing water supplies.

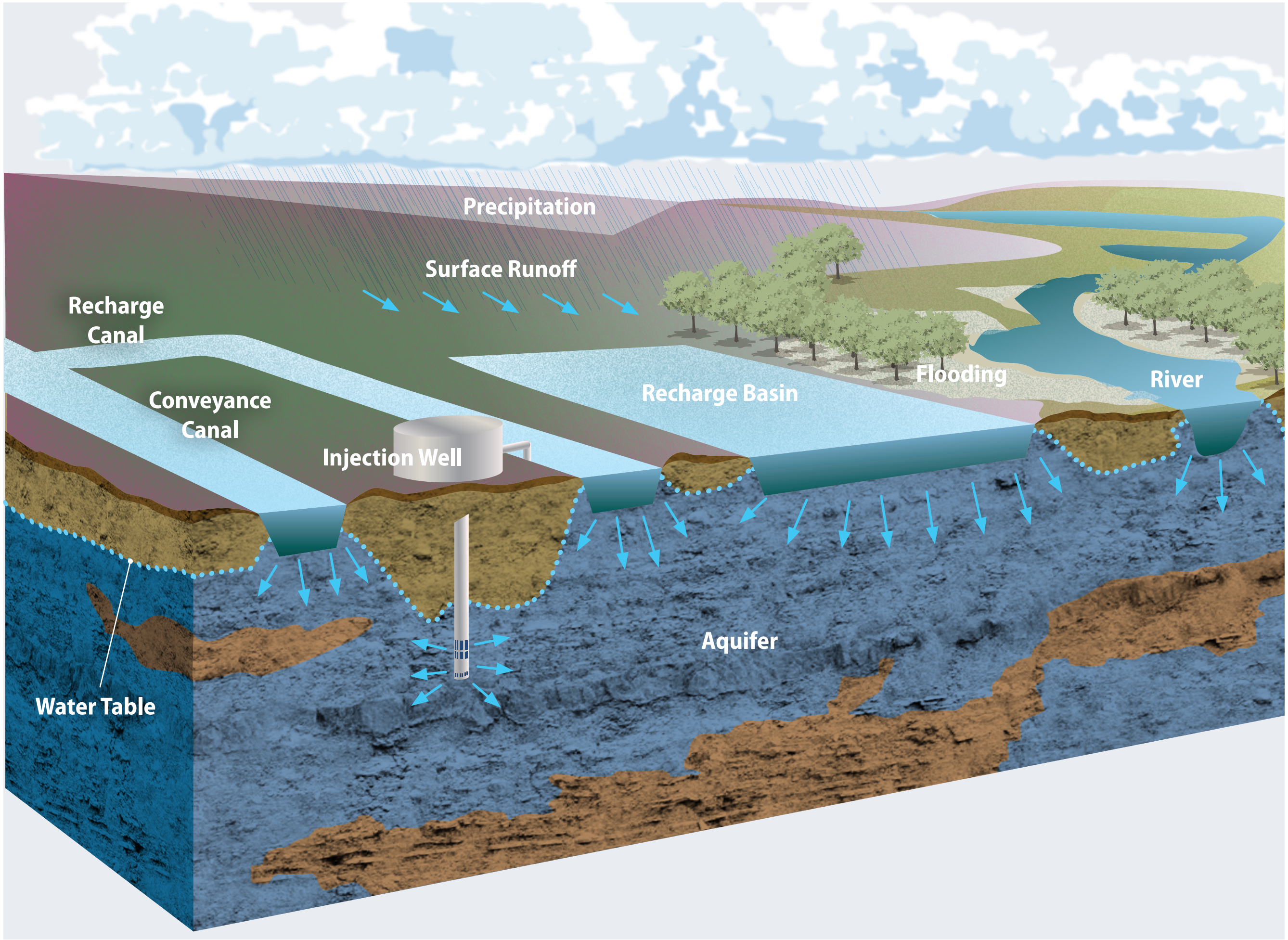
Developing available water can be challenging because of a number of societal and technical factors. Societal factors include laws, regulations, and environmental needs, as well as the characteristics of water demand and use. Technical factors include the capacity to develop, convey, store, and deliver water. Timing and location are additional key technical factors when evaluating water availability. Water developed by a water available method has many potential uses, including traditional uses in such areas as agricultural, urban, and environmental, and may not be dedicated to groundwater replenishment. Nevertheless, this report makes two simplifying assumptions for our surface water available estimates (WAFR estimates): (1) available water can be dedicated to groundwater replenishment, and (2) replenishment capacity is not a limiting factor.

Methods of making water available are described in greater detail in Appendix C. GSAs are required to provide a description of the surface water supply used or available for groundwater recharge or in-lieu use in their GSPs. While this report highlights surface water specifically, the planning approach used here also acknowledges a broader portfolio of methods, consistent with integrated regional water management plans and the California Water Plan updates developed over the past 20 years. GSAs should also consider the full portfolio of methods for making water available.

Replenishment of Groundwater

Replenishment of groundwater can be accomplished using two methods: active recharge and in-lieu recharge. Groundwater recharge occurs naturally as part of the hydrologic cycle, in which precipitation, runoff, and surface water flow infiltrates into the aquifer system. In addition, recharge occurs as a result of agricultural and landscape irrigation.

Figure 1. Example Methods of Replenishing Groundwater



For the purposes of this report, replenishment occurs when a groundwater basin is managed so that groundwater levels are either maintained at or improved above a baseline condition. Active recharge includes direct spreading and aquifer injection. Recharge may also be accomplished by providing an alternative source to users who would normally use groundwater, thereby leaving groundwater in place for later use and increasing the potential to improve groundwater levels. This indirect method of managed recharge is known as in-lieu recharge.

Groundwater replenishment depends on many physical, legal, and institutional factors, including water use, recharge rate, land area available for recharge, surface soil characteristics, hydrogeological and geochemical properties, availability of water for recharge, water rights, and the infrastructure to deliver water to users or into the aquifer system.

Methods for active recharge of groundwater are illustrated in Figure 1. Both active and in-lieu recharge are described in more detail in Appendix D.

Challenges and Uncertainties

Complex technical, legal, and institutional challenges and future uncertainties will affect the planning and estimation of water available for replenishment. The current challenges include institutional and regulatory issues, spatial and temporal connectivity of the water system, data availability, water quality, system operations and capacity, financial feasibility, and environmental sustainability. There is also uncertainty about how water availability may be affected by future institutional and regulatory changes, new infrastructure, climate change, population growth, and land use changes. These factors are described in the next section.

Current Challenges

Institutional and Regulatory

Water infrastructure in California is owned and operated by many federal, state, and local agencies. In addition, private entities, including hydropower operators, manage water throughout the state. These facilities and their operations are subject to numerous regulatory requirements. Flexibility of the system has been reduced over the years as a result of the increasing institutional and regulatory complexity of water management in California. For instance, recent legal decisions and endangered species protections have restricted pumping from the Sacramento-San Joaquin Delta (Delta). Deliveries from the SWP and CVP have become increasingly less reliable as a result of the recent drought and the deterioration of environmental conditions in the Delta, leading to more stringent water quality and environmental requirements. The increasing uncertainties associated with surface water supplies from the SWP and CVP consequently increases uncertainties for local water users as their total water supply reliability is diminished. In many places, less reliable surface water has led to an increase in the use of other water supplies, including groundwater. In addition, crop shifts and land use changes that have responded to changes in farm economics have increased water use in some areas.

Spatial and Temporal Connectivity

The spatial and temporal connectivity between potential water sources and groundwater are important considerations when evaluating or implementing water availability and replenishment projects. Incomplete understanding can lead to an inaccurate assessment of either the water available from a particular method or the potential response of a groundwater basin to replenishment.

Groundwater and surface water bodies are connected physically and interact directly with each other. At some locations or at certain times of the year, groundwater will be recharged through infiltration from, for instance, a streambed. At other locations or at other times of the year, groundwater may discharge to the stream, contributing to its base flow. Despite this interconnection, the water rights system treats surface water and groundwater separately, complicating the ***water availability*** evaluation and implementation of ***replenishment*** projects.

Data Availability

Lack of data can be a significant barrier to accurately quantifying water availability and its potential use for groundwater replenishment. DWR, SWRCB, U.S. Geological Survey (USGS), National Oceanic and Atmospheric Administration (NOAA), and other federal, State, and local entities collect a significant amount of water resources information. Nevertheless, in some locations, climatic, hydrological, and hydro-geological data are either not collected or the collection is inadequate for meaningful analysis. For example, inadequate information on streams, aquifer storage, and recharge capacity may lead to considerable uncertainties associated with water available for replenishment planning.

Accurate information on water use is helpful for quantifying water availability. California Water Plan Update 2013 separates water use into urban (municipal, commercial, and industrial), agricultural, and environmental (refuge and instream flow) sectors. Water use can be difficult to quantify because it can depend on climatic conditions at a specific location. For example, agricultural water use depends on land use (crop type), soil moisture, precipitation, temperature, water delivery and application methods, and other factors.

Water rights are one of the principal pieces of information required for evaluating water availability; however, water rights, diversions, and return flows may be challenging to quantify in some locations and for some users.

Water Quality

Depending on the water source and the intended use of the water, water developed for replenishment will be subject to specific water quality standards, which may limit its use. For example, the SWRCB requires that all recycled water used for groundwater recharge projects or public use be reviewed and permitted on a site-specific basis, following the California Department of Public Health's water quality standards.

In addition, if the water available for replenishment is to be delivered to the groundwater basin via surface water releases to a stream, GSAs should consider the effects of such releases on the pH, turbidity, total dissolved solids, temperature, and pollutants in both the streams used and the groundwater basin.

For aquifer injection, water treatment is again very important. The water for injection must be free of turbidity, organic material, bacteria, and viruses, and the water chemistry of the injected water must be compatible with the water quality in the aquifer system. Concerns with water quality, clogging of well screens, or clogging of the pore space within the aquifer system surrounding the injection well may also present challenges.

System Operations and Capacity

The operations and capacities of water management facilities are important factors when analyzing water availability and potential groundwater replenishment. For example, the conveyance of water will have specific physical characteristics (e.g., conveyance capacity) and system operations that may limit the amount, or affect the timing, of water available at a specific site.

Additionally, for groundwater recharge, capacity constraints can limit the conveyance of water to a groundwater recharge location, the infiltration or injection of water into the basin, and the aquifer's ability to store the water.

Environmental Sustainability

Environmental sustainability concerns related to groundwater replenishment include potential effects on habitat, water quality, and wildlife caused by shifting or increasing patterns of groundwater and surface water use. For example, floodwaters can serve an important ecosystem function; removing or reducing flood flows for groundwater replenishment may cause undesirable ecosystem effects. A key challenge is to balance beneficial uses, including the instream flow and other environmental needs, with water available for groundwater replenishment.

There may also be environmental effects from construction and operation of groundwater recharge basins and new conveyance facilities. Conversely, reconnecting groundwater to streams (or maintaining such connections over the long term) could have significant environmental benefits, and groundwater recharge facilities in some locations may provide important habitat for a variety of wildlife. Consequently, addressing short-term and long- term effects on, and benefits to, the environment may be accomplished in collaboration with environmental resource agencies.

Financial Feasibility

Financial feasibility plays an important role in effectively managing water resources. Although State funds may provide some financial assistance, local entities must have sufficient authority and flexibility to raise the funds needed to carry out sustainable water management programs. Costs will need to be considered for the construction of facilities, environmental mitigation, and operation and maintenance.

Future Uncertainties

Institutional and Regulatory

Institutional and regulatory challenges are likely to change over time. Water managers need to consider how endangered species and associated regulatory requirements may change in the future, including the sustainability of habitat and species, as well as uncertainties associated with a changing climate. As an example, implementation of GSPs may result in reducing reliance on groundwater in areas experiencing extensive overdraft.

Relying more on other water sources may further stress water supply reliability, water quality, ecosystems, or water rights.

Infrastructure

Infrastructure improvements may increase system flexibility with better conveyance, storage, or management of water. These changes could have either positive or negative effects on water availability for groundwater replenishment for specific locations and times. Water managers, including GSAs, will need a fuller understanding of potential infrastructure implementation and its effects on broader water management. GSAs will need to consider potential participation in local, regional, or statewide projects and management actions.

Climate Change

Climate change is already altering the water cycle with increases in extreme events and shifts in seasonal patterns, requiring adaptive water management solutions. These changes are expected to continue into the future, and a greater percentage of precipitation will likely fall as rain instead of snow. The timing and magnitude of a wide range of potential climate change effects may lead water managers to different conclusions and decisions, highlighting the need to consider the effect of climate change on both water budgets and water availability estimates.

Population and Land Use Change

Future water demand will be affected by a number of evolving factors, including land use changes and population growth. Land use changes include agricultural practices and management (e.g., planting decisions by farmers), and the size and type of urban landscapes. A significant factor in recent years has been expansion of permanent crops, as well as changes in irrigation practices for such crops. Also, when estimating future urban water demands, water managers will need to account for future population growth, including planning for when changes occur, as well as uncertainty in population changes and development density. Population and development density will also influence potential land-use changes, such as urban encroachment of agricultural lands.

Text Box 3. Technical Uncertainty Example

DWR has been following an observed technical uncertainty related to precipitation and streamflow in the Sacramento River watershed for several decades. Specifically, an analysis of the relationship between precipitation and streamflow for the Sacramento River indicates that the relationship has changed since 1950. A fuller description and graphic depiction of this analysis is included in Appendix A.

The analysis focuses on the relationship between the Northern Sierra Precipitation 8-Station Index and the streamflow of the Sacramento River from April to September. Two observations have been made:

- Streamflow associated with precipitation has decreased, based on a comparison of the 1950s trend and the 1990–2015 trend.
- During multi-year droughts (e.g., water years, 1976–1977, 1987–1992, 2007–2009, and 2012–2015), streamflow as a result of precipitation is negative, indicating that water use exceeds runoff within the watershed.

The change in trend and decrease in streamflow associated with precipitation indicates a fundamental change for the streamflow of the watershed. Several complex, and sometimes interdependent, factors may contribute to this observed effect:

- Increased diversion from the tributaries and Sacramento River for water uses.
- Increased groundwater withdrawal, including effects on the hydraulic connection between surface water and groundwater.
- Climate change effects to stream hydrologies, including more rain and less snow, as well as increased evaporation effects.
- Increase in frequency and severity of drought periods.

While there is uncertainty regarding the relative importance of these factors associated with the observed changes in the Sacramento River, changes have occurred. A fundamental challenge associated with sustainable groundwater management and water available for replenishment is to better understand how physical or natural changes can influence the hydraulic connection between groundwater and surface water. In particular, understanding the interdependent functionality between groundwater and surface water will assist the development of best management practices at local, regional, and statewide levels, and will also affect opportunities to develop water available for replenishment.

How to use WAFR Estimates and Guidance

This report has been developed to support GSAs as they consider potential opportunities to improve the sustainability of their groundwater basins. DWR has included two pieces of technical support and guidance to assist GSAs in potential project planning: (1) estimates of surface water available for replenishment and (2) general guidance to support potential development of water available and for replenishment. These estimates provide an initial scale and location of where, and how much, surface water may be available in relative proximity to GSA boundaries. In addition, a simplified methodology for estimating available surface water is described and can provide a basis for GSAs as they develop their own analyses of surface water available for replenishment. Also, DWR is including available planning estimates from urban water portfolio actions (i.e., recycled water, desalination, conservation).

Text Box 4. Water Resources Planning

The following general water-resources planning process may be helpful for GSAs, as they consider WAFR solutions.

1. Context

   Defining the context or setting will identify the nature of the problems and needs, as well as the range of potential projects and management actions to consider.

2. Performance Metrics

   Identifying performance metrics allows planners to measure current or future conditions and evaluate the ability of projects or management actions to meet specific objectives.

3. Assessment

   Analysis and assessment provides insights regarding the ability of projects and actions to meet objectives.

4. Investment Priorities

   Determining investment needs and priorities will facilitate selection of specific projects and actions for implementation.

5. Financial Plan

   Laying out a financial plan, with specific funding strategies, assures the financial feasibility of proposed projects or management actions.

6. Implementation

   Setting up a clear path for implementation enables water managers and decision-makers to complete work on time and on budget.

This water resources planning process may be completed in a step-by-step manner, but often requires iterations at various steps.

As directed in SGMA, GSAs should complete their own water available for replenishment planning, in which action- and project-specific concepts that make water available for replenishment in their basin can be considered and compared. DWR staff will be available to assist GSAs and their water available for replenishment planning by providing technical guidance related to the use of the tools and methods developed under this report.

In addition to the estimates, detailed guidance for developing water available methods and for replenishment methods that can be used by GSAs as their planning progresses is provided in Appendices C and D. This guidance describes how to quantify "water available," as well as the potential effectiveness of replenishment, by method. This guidance is intended for general planning considerations, as well as for addressing the potential issues and challenges associated with implementing projects and/or management actions that (1) make water available and (2) manage that water for the purpose of groundwater replenishment. Guidance is included for the following water available methods: surface water, recycling, conservation, desalination, and water transfers. Guidance is also included for the following for replenishment methods: active recharge and in-lieu recharge.

Water Available Estimates and Information

California's water supplies vary spatially, seasonally, and yearly, while the state's water users (urban, agricultural, and environmental) have variable water-use needs associated with the quantity, quality, timing, and place of use. Understanding the relationships between water supply and water use is foundational to estimating the amount of water available for groundwater replenishment.

Recognizing this complexity, a simplified analytical approach to estimating water available for replenishment from surface water was developed, acknowledging the requirement of GSAs in their GSPs. Figure 2 illustrates many of the considerations used in developing WAFR estimates in this report.

Text Box 5. Water Available and California Water Rights

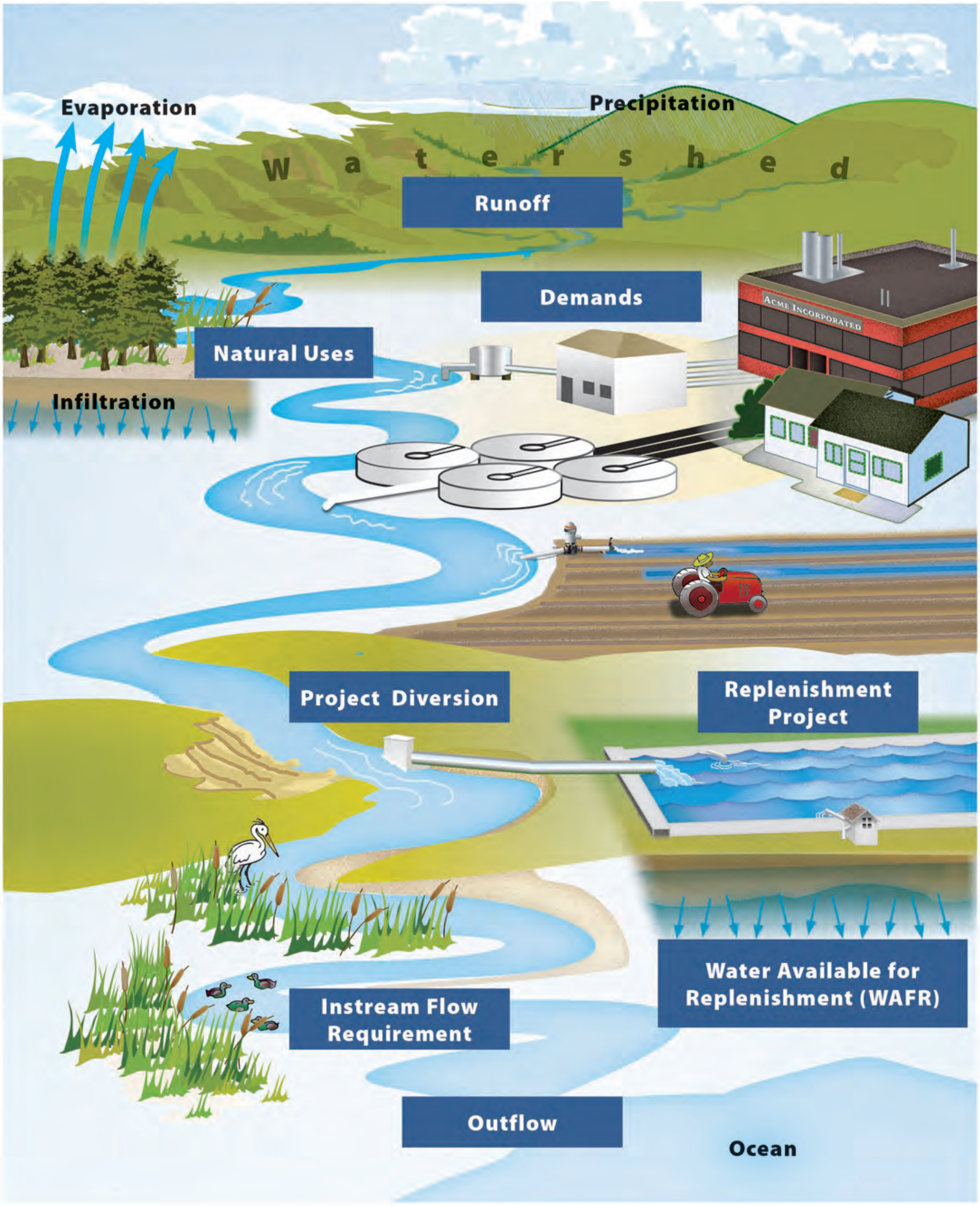
In California, the Water Code and State Water Resources Control Board use the term "water available" to support water right application review and permitting. Specifically, every water right application submitted to the SWRCB must include "sufficient information to demonstrate a reasonable likelihood that unappropriated water is available for appropriation (Water Code section 1260(k))." Additionally, for a permit, the SWRCB must find that there is, "unappropriated water available to supply the applicant (Water Code section 1375(d))." A discussion of water rights as they apply to surface water is presented in Appendix C.

For purposes of this report and water available for replenishment estimates, DWR is employing a simplified estimation methodology. Recognizing this simplification, **the methodology used here will not meet requirements of a Water Availability Analysis (WAA), as required for a water right application, permit, or change to an existing right.** For a more detailed description of WAA and water rights, see Appendix C, "Surface Water Method Guidance."

GSAs can and should consider the water available from other methods. Estimates of potential water development by urban retailers using other methods (recycled water, desalination, and water conservation) are also shown on the Hydrologic Region Results summary pages. These estimates are provided to indicate the scale of planned water development by urban retailers for each region during this decade. Guidance for planning considerations associated with both surface water and the other methods is provided in Appendix C.

Figure 2 illustrates the factors considered to determine surface water available for replenishment.

Figure 2. Factors Considered for the WAFR Estimates



Methodology for WAFR Estimates

WAFR estimates have been calculated at two scales: hydrologic regions and planning areas, as identified in California Water Plan Update 2013. This report summarizes the WAFR estimates for each of the state's 10 hydrologic regions and 56 planning areas. For the purposes of these estimates, water available is assumed to be dedicated to replenishment, and replenishment capacity is assumed to be unlimited. Additional information about the methodology and the WAFR estimates are provided in Appendix A.

WAFR estimates were determined by combining information from monthly simulated Water Evaluation and Planning (WEAP) model outflows and historical daily gage data. The following discussion refers to these two tools, WEAP and gage data.

- The WEAP model simulates historical surface runoff by using 1967 through 2012 precipitation data, existing urban and agricultural demands, and operations information. After meeting demands, the remaining runoff is outflow. Consequently, the WEAP-simulated outflow represents historical hydrologic conditions and a fixed, existing level of demand and operations.

- Historical gage data at a river mouth represents actual outflow conditions that result from changing levels of demand, regulations, and operations over the period when gage data are available.

Both WEAP and gage data have specific advantages and limitations when used individually (Table 1). For these reasons, the tools were combined to capture the advantages of each.

Table 1. Advantages and Limitations of the WEAP model and the historical gage data tools

Tool	Advantages	Limitations
WEAP	• Based on current level of development (demands) and operations. • Incorporates the entire study area.	• Monthly outflow provides limited resolution.
Gage Data	• Daily data provides high resolution.	• Historical record is affected by changing demands and operations. • Incorporates gaged watersheds only.

The WAFR estimates were calculated in two steps:

1. Determine the WAFR fraction — The percentage of gage data outflow that can be diverted by a conceptual project(s). The term conceptual project is used in this report to identify a potential surface water diversion for the purpose of groundwater replenishment, and is described below.
2. Determine the WAFR estimate — The product of the WAFR fraction and the WEAP outflow.

These two steps can be described using the following equations:

$$1.\ \textit{WAFR Fraction} = \frac{\textit{Diversion from Conceptual Project}}{\textit{Gage Data Outflow}}$$

$$2.\ \textit{WAFR Estimate} = \textit{WAFR Fraction} \times \textit{WEAP Outflow}$$

In order to determine the WAFR fraction, the following, more detailed, procedures were used:

1. Flow gage data were collected as close to the outflow location as possible, where streams/rivers leave a hydrologic region.
2. An instream flow requirement was determined to support and maintain water quality and aquatic and riparian species*. These flows provide habitat, species protection, and water quality, and are not available for diversion and replenishment (see Figure 3). The assumed instream flow is based on existing federal, State, or local requirements or studies. If existing federal, State, or local requirements did not exist, the instream flow requirement would be based on the water right, the SWRCB's Policy for Maintaining Instream Flows in Northern California Coastal Streams, or the Tennant method.
3. The conceptual project diversion was determined based on a new conceptual project capacity and the above instream flow requirement (see Figure 3). For the best estimate, the new conceptual project diversion capacity is sized based on the largest existing diversion capacity on the stream/river associated with the watershed. This information was retrieved from the SWRCB's Electronic Water Rights Information Management System (eWRIMS).
4. WAFR fractions were calculated for each of the streams/rivers.
5. The WAFR fractions for all of the gaged streams/rivers were aggregated by hydrologic region. The aggregation process for multiple streams is described in Appendix A.

Figure 3 and Table 1 show an example application of WAFR fraction development for a single stream, using the Best Estimate conceptual project assumptions to determine the conceptual project diversion. For the example stream, using the Best Estimate Conceptual Project, the gage data outflow is 400 taf, the conceptual project diversion is 10 taf, and the WAFR fraction is 2.5 percent (10 taf/400 taf).

Using this procedure, DWR determined the WAFR fractions by acknowledging that the primary factors affecting the WAFR estimates are (1) project diversion capacity and (2) instream flow requirements to maintain ecosystems. Further details can be found in Appendix A.

Figure 3. Best Estimate Conceptual Project Application of Water Available for Replenishment for the Example Stream

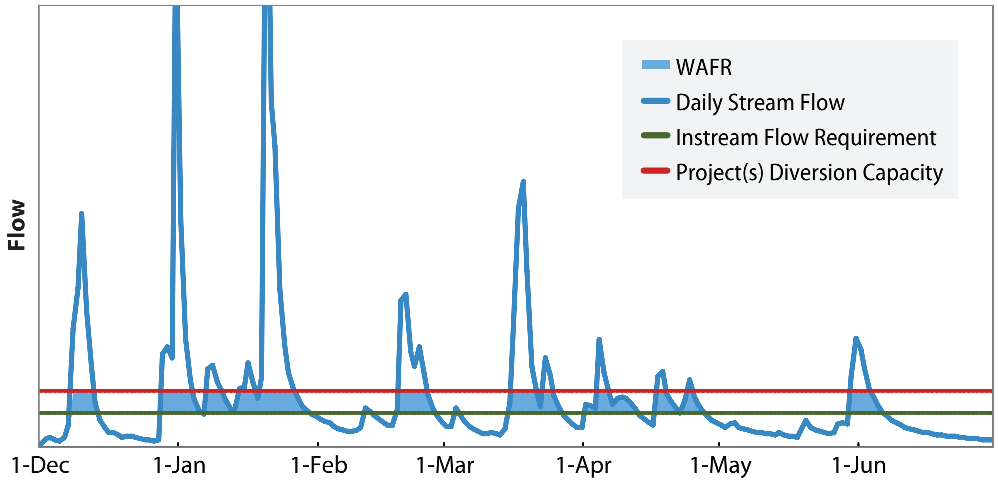


Table 2. Best Estimate Conceptual Project Application of Water Available for Replenishment for the Example Stream

River/Stream	Best Estimate		
	Average Annual Gage Data Outflow (taf)	Conceptual Project Diversion (taf)	WAFR Fraction
Example Stream	400	10	2.5%

Note: taf = thousand acre feet, WAFR = Water Available for Replenishment

To underscore the uncertainty of these evaluations, DWR is also showing an extended array of WAFR estimates that illustrate the sensitivity associated with instream flow requirements and conceptual project assumptions. The array of conceptual project assumptions is described below and shown in Table 2, and contain a range of diversion capacity and instream flow requirement. Each of the other estimates in the array are based upon variations of the best estimate assumptions.

The sensitivity range estimates are based on conceptual projects with capacities of one half to two times the largest existing project diversion capacity, while the instream requirements are up to two times the existing requirement.

The "Maximum Estimate" illustrates a maximum potential diversion or diversions, assuming unlimited project diversion capacity while maintaining existing instream flow requirements. This unlimited diversion capacity assumes technical and/or water management innovation associated with diversions.

The "No Project Estimate" demonstrates that surface water projects must be implemented to develop water that could be used for replenishment. No projects mean no water available and no new water available for replenishment. Figures 3, 4, and 5 and the corresponding tables 1, 3, and 4 show the sensitivity of the conceptual project diversion to diversion capacity and instream flow requirement. The tables also show the WAFR Fraction.

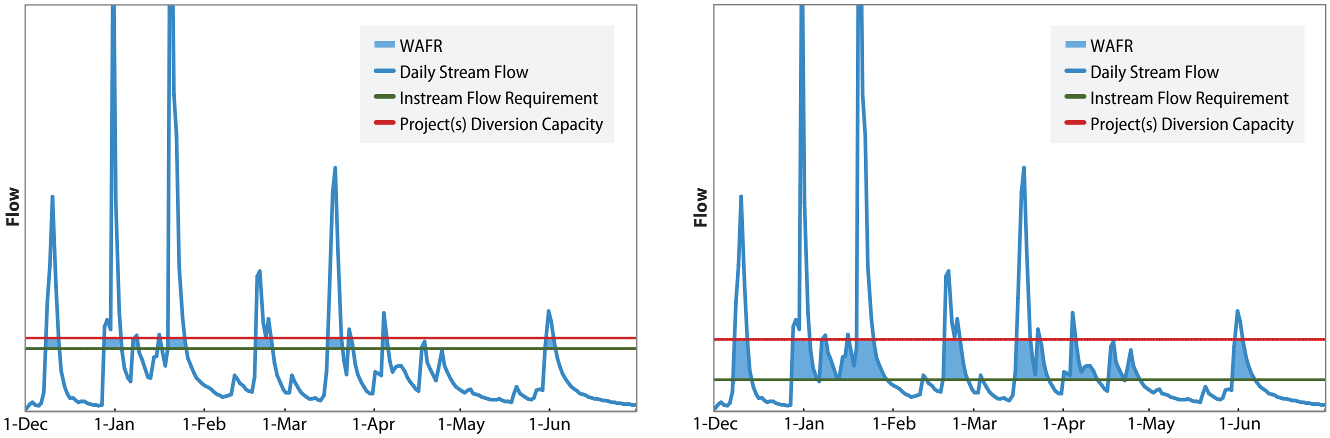
* For these WAFR estimates, the instream flow requirement to maintain aquatic and riparian species is assumed to be constant throughout the year. In most cases, a range of flows, by season, is required and necessary to support the ecological processes needed for a healthy stream.

Table 3. Array of WAFR Estimates and Conceptual Project Characteristics

Estimate Name	Conceptual Project Diversion Capacity	Conceptual Project Instream Flow Requirement	Figure and Table for Example Stream
Best Estimate	Largest existing project diversion capacity	Existing instream flow requirement	Figure 3 and Table 1
Lower Sensitivity Range Estimate	One half the largest existing project diversion capacity	Two times existing instream flow requirement	Figure 4 and Table 3
Upper Sensitivity Range Estimate	Two times the largest existing project diversion capacity	Existing instream flow requirement	Figure 4 and Table 3
Maximum Estimate	Unlimited capacity	Existing instream flow requirement	Figure 5 and Table 4
No Project Estimate	No Project	No Project	Table 4

These cursory estimates of water available for replenishment should not be considered refined values. Project- and location-specific analyses by GSAs will likely yield different results for the same streams because of project sizing, as well as updated and location-specific determinations of instream flow requirements.

Figure 4. Lower Sensitivity Range and Upper Sensitivity Range Conceptual Project Diversion Showing Gage Data Outflow for the Example Stream



Note: The lower sensitivity is on the left and the upper sensitivity range is on the right.

Table 4. Lower and Upper Sensitivity Range Estimate Conceptual Project Diversion and WAFR Fraction for the Example Stream

River/ Stream	Lower Sensitivity Range			Upper Sensitivity Range		
	Average Annual Gage Data Outflow (taf)	Conceptual Project Diversion (taf)	WAFR Fraction	Average Annual Gage Data Outflow (taf)	Conceptual Project Diversion (taf)	WAFR Fraction
Example Stream	400	5	1.2 %	400	18	4.4 %

Note: taf = thousand acre feet WAFR = Water Available for Replenishment

Figure 5. Maximum Estimate Conceptual Project Diversion Showing Gage Data Outflow for the Example Stream

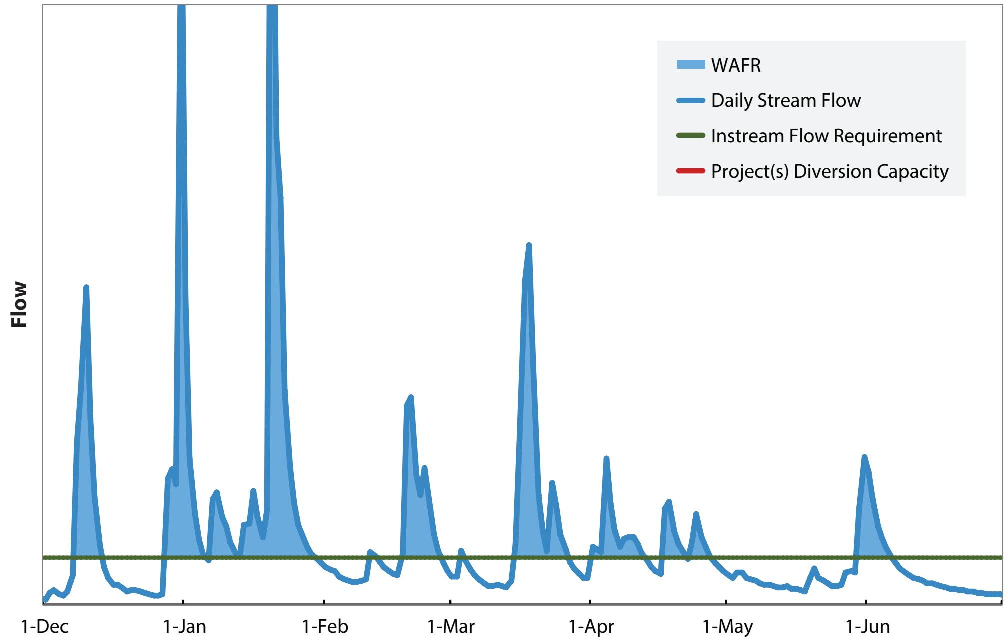


Table 5. No Project and Maximum Estimate Conceptual Project Diversion and WAFR Fraction for the Example Stream

River/ Stream	No Project			Maximum		
	Average Annual Gage Data Outflow (taf)	Conceptual Project Diversion (taf)	WAFR Fraction	Average Annual Gage Data Outflow (taf)	Conceptual Project Diversion (taf)	WAFR Fraction
Example Stream	400	0	0.0 %	400	292	73.0 %

Note: taf = thousand acre feet WAFR = Water Available for Replenishment

The outflow estimate simulated using the WEAP model was then multiplied by the range of WAFR fractions defined by the historical gage data and conceptual project diversion to determine the range of WAFR estimates for the example stream. Table 5 shows the array of WAFR estimates for the example stream, using the water available for replenishment fractions from Tables 1, 3, and 4 above.

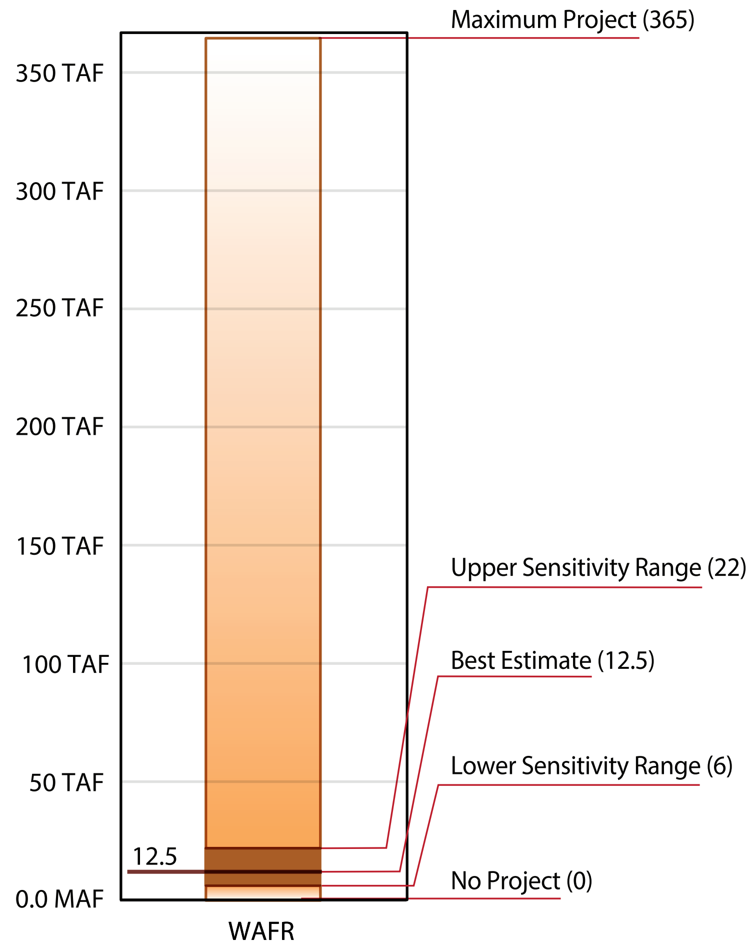
Table 6. Summary Surface Water Available for Replenishment Estimates for the Example Stream

WEAP Outflow (taf)	No Project (taf, WAFR Fraction 0.0 %)	Lower Sensitivity Range Estimate (taf, WAFR Fraction 1.2 %)	Best Estimate (taf, WAFR Fraction 2.5 %)	Upper Sensitivity Range Estimate (taf, WAFR Fraction 4.4 %)	Maximum Estimate (taf, WAFR Fraction 73.0 %)
500	0	6	12.5	22	365

Note: taf = thousand acre feet WAFR = Water Available for Replenishment

Figure 6 presents the "Best Estimate," "Sensitivity Range," "Maximum Project," and "No Project" WAFR estimates for the example stream described above. To determine the WAFR estimates for a region, the estimates for multiple streams are aggregated as described in the methodology section of Appendix A.

Figure 6. Schematic Example of Water Available for Replenishment Array of Estimates



This array of WAFR estimates is made for each hydrologic region of the state featured in this report, and for each planning area discussed in Appendix A.

As noted above, the Example Stream array of estimates illustrates how the various conceptual project assumptions affect the WAFR estimate for a single stream.

Results: Water Available for Replenishment Estimates and Information

DWR is providing both WAFR estimates and additional water resources information that may be helpful for GSAs as they begin and progress with groundwater sustainability planning. Estimate results and information are found on the two-page summaries for each region in the following section. The analytical approach used here provides DWR's best estimate, based on available information, of water available for replenishment of groundwater in California. DWR's estimate of water available for replenishment is shown for each of the state's 10 hydrologic regions and 56 planning areas. The information and models used to estimate the amount of water available for replenishment were developed at a planning estimate level. This analytical approach may not satisfy the SWRCB requirements of a water availability analysis for a water right application, permit, or change to an existing right. Additional study and data refinement would likely be necessary for such a determination. More detailed location- and project-specific analysis will need to be conducted by the GSAs as part of their GSPs.

These estimates indicate a potential range of opportunities, investments, and innovations that may provide a foundation or starting point for local planning. As local planning progresses, analyses will become location- and project-specific, and more comprehensive as entities refine their water available analysis, as required for water right applications, permits, and changes to an existing right. The methodology used here may not fully capture, for example, competing needs, including needs associated with instream flows to support habitat, species (including those endangered or threatened), water quality, and recreation. The State and GSAs will need to balance the needs of water users consistent with State law and the need for replenishing groundwater basins.

Text Box 6. State Water Board and the Bay-Delta Water Quality Control Plan

The State Water Resources Control Board is in the process of developing and implementing updates to the Bay-Delta Water Quality Control Plan and flow objectives for priority tributaries to the Delta to protect beneficial uses in the Bay-Delta watershed. This multi-phased plan will identify the beneficial uses of the Bay-Delta, water quality objectives for the reasonable protection of those beneficial uses, and a program of implementation for achieving the objectives. The State Water Resources Control Board's balancing of the competing uses of water is consistent with the Water Code's coequal goals of providing a more reliable water supply for California, and protecting, restoring, and enhancing the Delta ecosystem. The WAFR estimates provided in this report are for planning purposes only. Comprehensive consideration of balancing competing uses was not included in the WAFR estimations. As noted previously, WAFR estimates provided here will not satisfy SWRCB requirements for a water availability analysis associated with water rights. GSAs will need to follow the SWRCB water availability analysis requirements for their specific projects. Consequently, comparison of the results from these efforts should be made with caution and understanding of the differences between the respective evaluations.

Figure 7. Statewide Outflow and Best Estimate WAFR by Hydrologic Region (MAF)

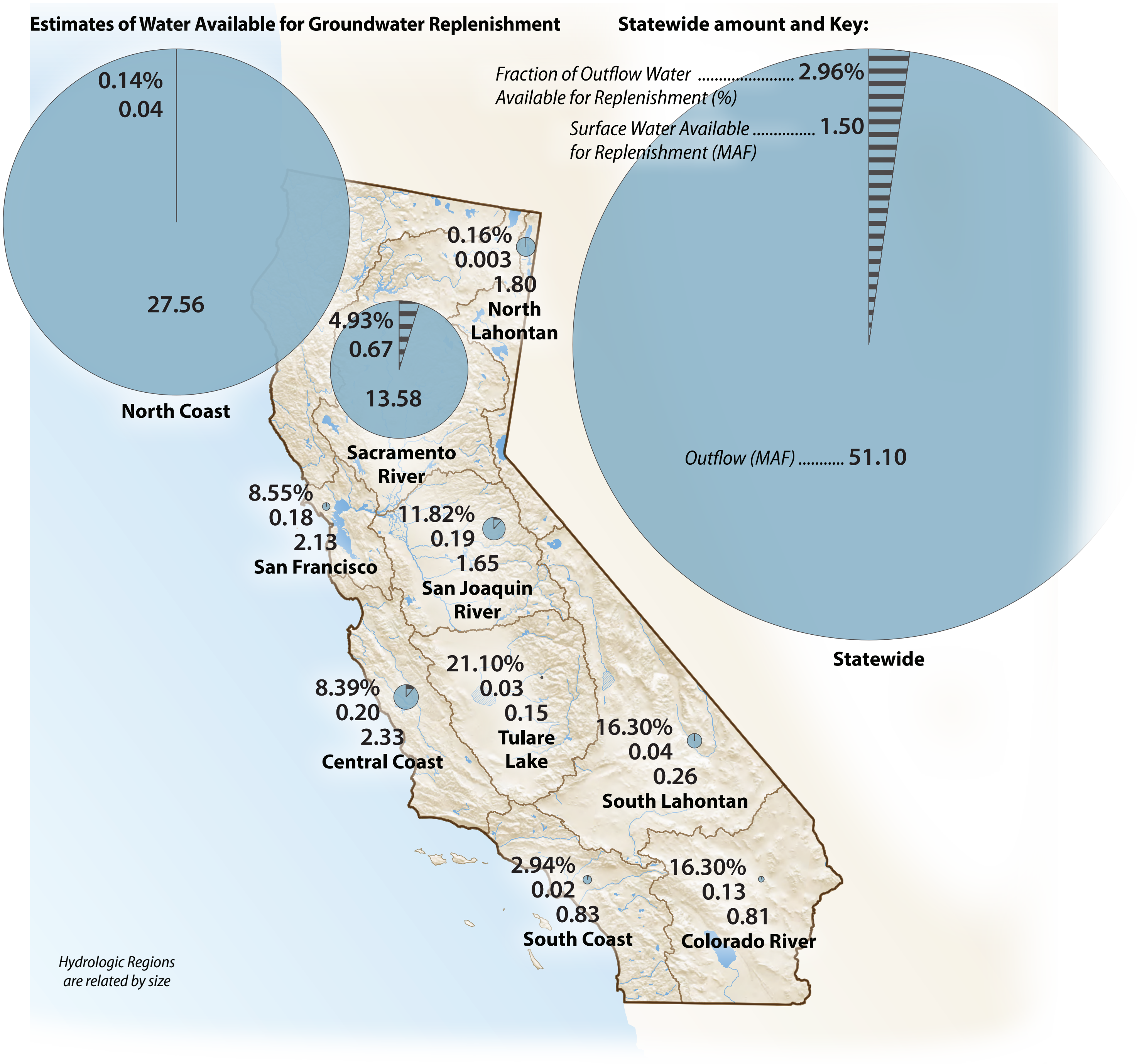
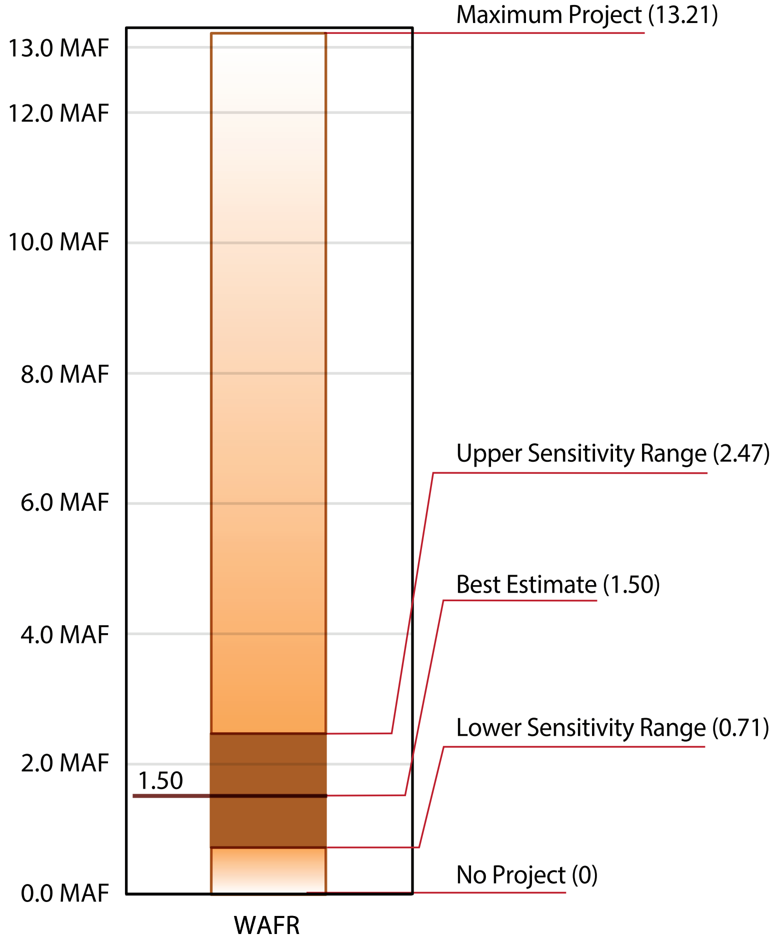
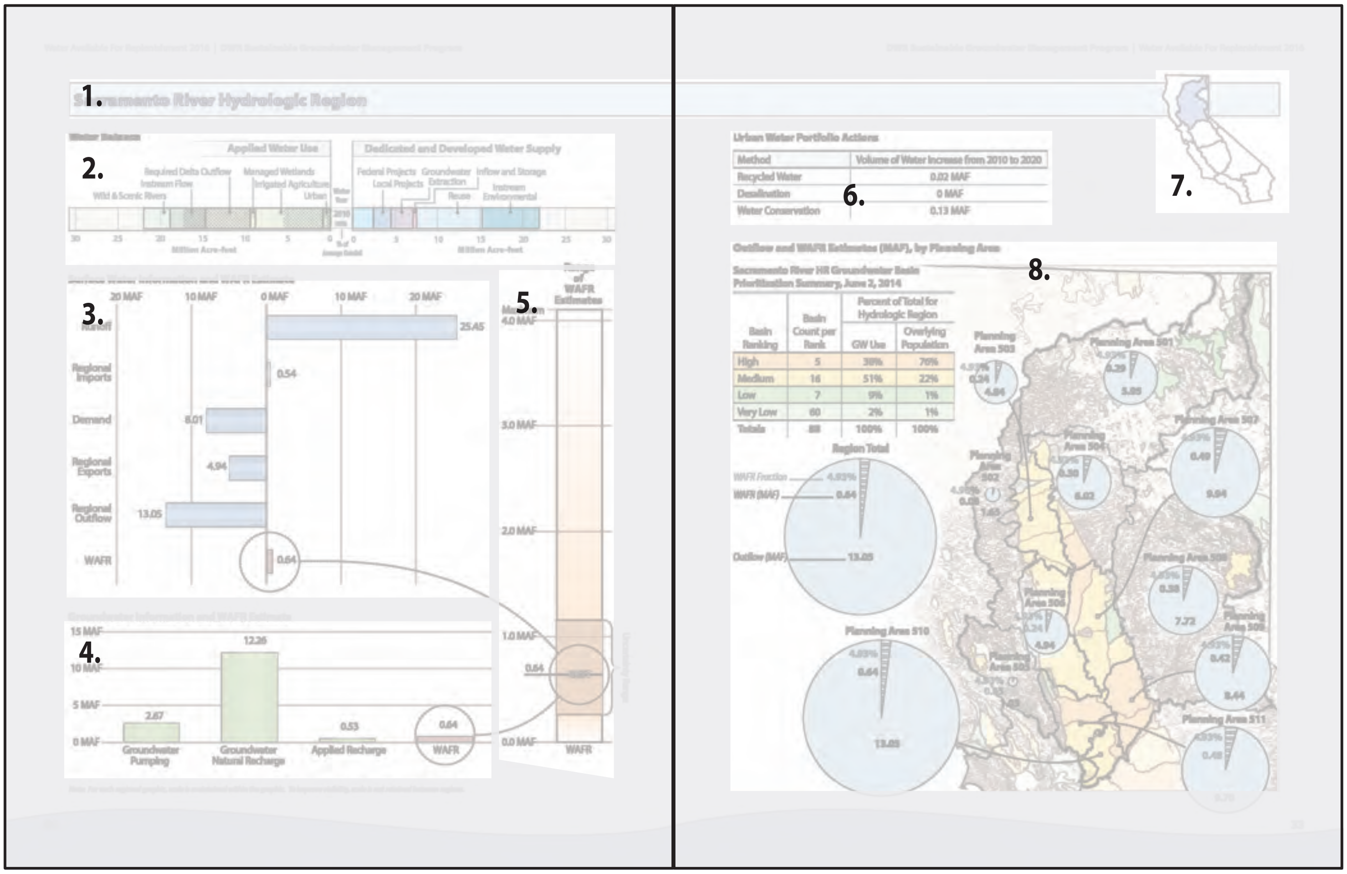


Figure 7 shows both the outflow and best estimate WAFR for each of California's hydrologic regions. Figure 8 shows the array of statewide WAFR estimates, including the no project, lower sensitivity range, best estimate, upper sensitivity range, and maximum estimates of WAFR.

Figure 8. Statewide Array of WAFR Estimates (MAF)



Key to Hydrologic Region Results Summary Pages



1. Hydrologic Region

California is divided into 10 Hydrologic Regions, as described in the California Water Plan Update. Each region includes 2 to 11 planning areas.

2. Water Balance

The hydrologic region water balance is presented here for the water year 2010. For further details, refer to the California Water Plan Update 2013 Volume 5, Technical Guide, and Volume 4, the article "California's Groundwater Update 2013."

Terminology:

Water Balance: Analyses of the total developed/dedicated supplies, uses, and operational characteristics for a region; the analyses show what water was applied to actual uses so that use equals supply.

3. WAFR Estimate and Information Used to Develop the Estimate

The figure presents the data used to determine DWR's estimate of WAFR for the hydrologic region.

Terminology:

Runoff: Rainfall, snowmelt, or irrigation water in excess of what can infiltrate the soil surface and be stored in small surface depressions.

Regional exports: Water conveyed from this hydrologic region to another region.

Regional imports: Water conveyed to this hydrologic region from another region.

Demand: Total demand, including urban indoor, urban outdoor, agricultural, and refuge.

Regional Outflow: The amount of water that flows out of a hydrologic region.

WAFR: Water available for replenishment estimate.

4. Groundwater Information and WAFR Estimate

The figure presents several groundwater data components in comparison to WAFR for the hydrologic region.

Terminology:

Groundwater pumping: The amount of groundwater withdrawn from the groundwater basin (Source: California Water Plan Update 2013).

Groundwater natural recharge: The percolation to groundwater basins from precipitation falling on the land and from flows in rivers and streams (United States Geological Survey, California Basin Characterization Model 2017).

Applied and Artificial Recharge: The sum of the applied and artificial recharge. Applied recharge is the amount of applied agricultural, urban, and wetlands water that percolates through the ground and beyond the root zone into the groundwater. Applied recharge is also referred to as deep percolation of applied water (California Water Plan Update 2013). Artificial recharge is the (intentional) addition of water to a groundwater reservoir by human activity, such as putting surface water into constructed spreading basins or injecting water through wells. Also referred to as intentional recharge or managed recharge (California Water Plan Update 2013).

WAFR: Water available for replenishment estimate.

5. Range of WAFR Estimates

The bar represents the array of estimates for the hydrologic region. The range includes five estimates, the best estimate, sensitivity range estimates (upper and lower), no project estimate, and maximum estimate. A more detailed description of these estimates can be found in the Methodology for WAFR Estimates section.

6. Urban Water Portfolio Actions

Estimates of potential water development by other methods, including recycled water, desalination, and water conservation, between 2010 and 2020. This information is provided to give some context of the type and quantity of actions recently planned by urban water agencies in each of the state's hydrologic regions. Further description of the estimates is presented in Appendix A.

7. Geolocation of the hydrologic region in the State of California.

8. Hydrologic Region Map, Outflow and WAFR Estimates By Planning Area and Groundwater Basin Prioritization

The map illustrates the planning area outflows and WAFR estimates for each planning area in the hydrologic region. The CASGEM groundwater basin prioritizations are shown on the map and indicate the comparative locations of planning areas and groundwater basins. The map also includes a table summarizing the number of basins with high, medium, low, and very low priorities, percentage use of groundwater in those basins, and the percentage of population in each basin for the region.

Terminology:

WAFR Fraction: Ratio of the diversion amount from the conceptual project with gage data and the gage data outflow.

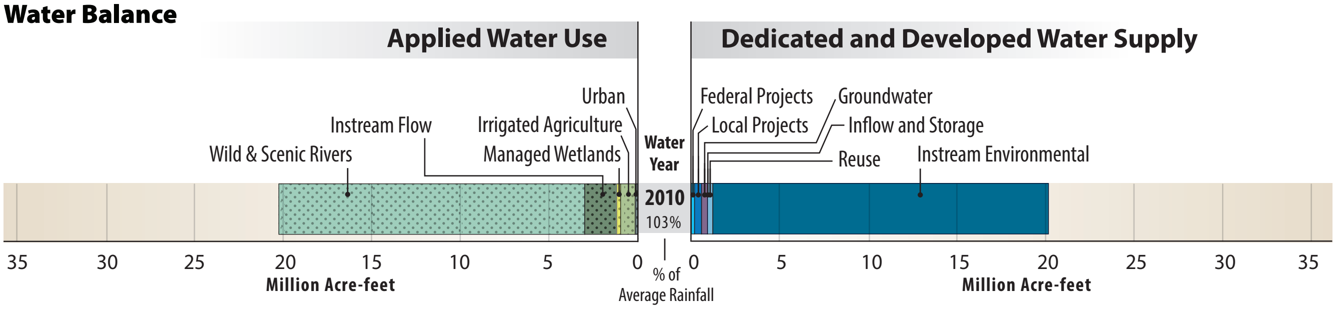
WAFR: Best estimate of water available for replenishment.

Planning area outflow: The amount of water that flows out of the planning area.

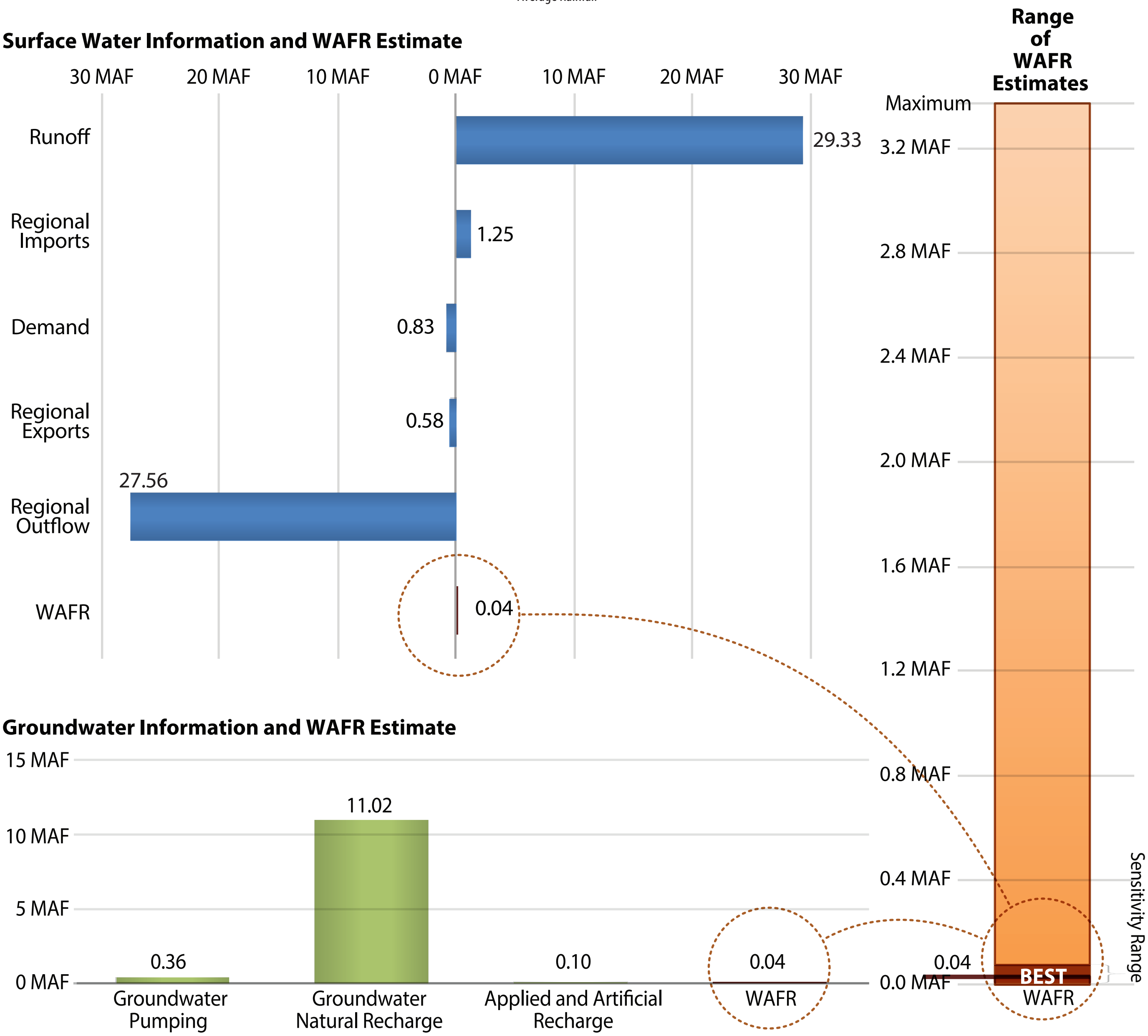
CASGEM Groundwater Basin Prioritization: CASGEM Groundwater basin prioritization is a statewide ranking of groundwater basin importance that incorporates groundwater reliance and focuses on basins producing greater than 90 percent of California's annual groundwater.

North Coast Hydrologic Region

Water Balance



Surface Water Information and WAFR Estimate

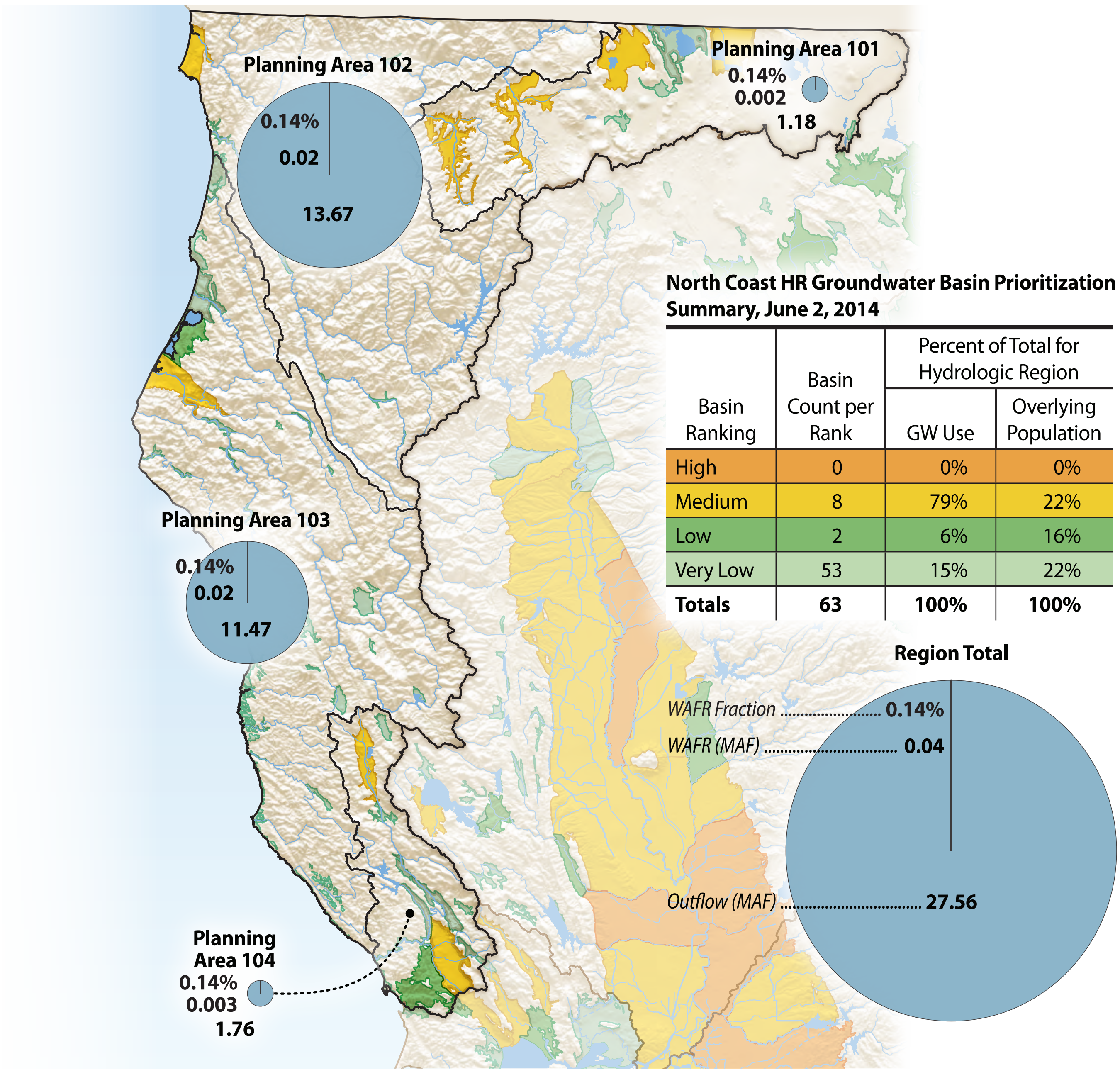


Note: For each regional graphic, scale is maintained within the graphic. To improve visibility, scale is not retained between regions.

Urban Water Portfolio Actions

Method	Volume of Water Increase from 2010 to 2020
Recycled Water	0.01 MAF
Desalination	0 MAF
Water Conservation	0.01 MAF

Outflow and WAFR Estimates (MAF) by Planning Area

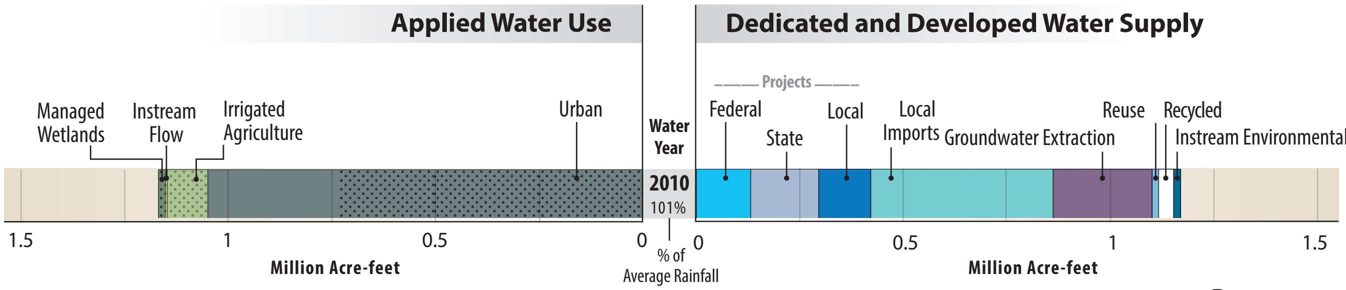


North Coast HR Groundwater Basin Prioritization Summary, June 2, 2014

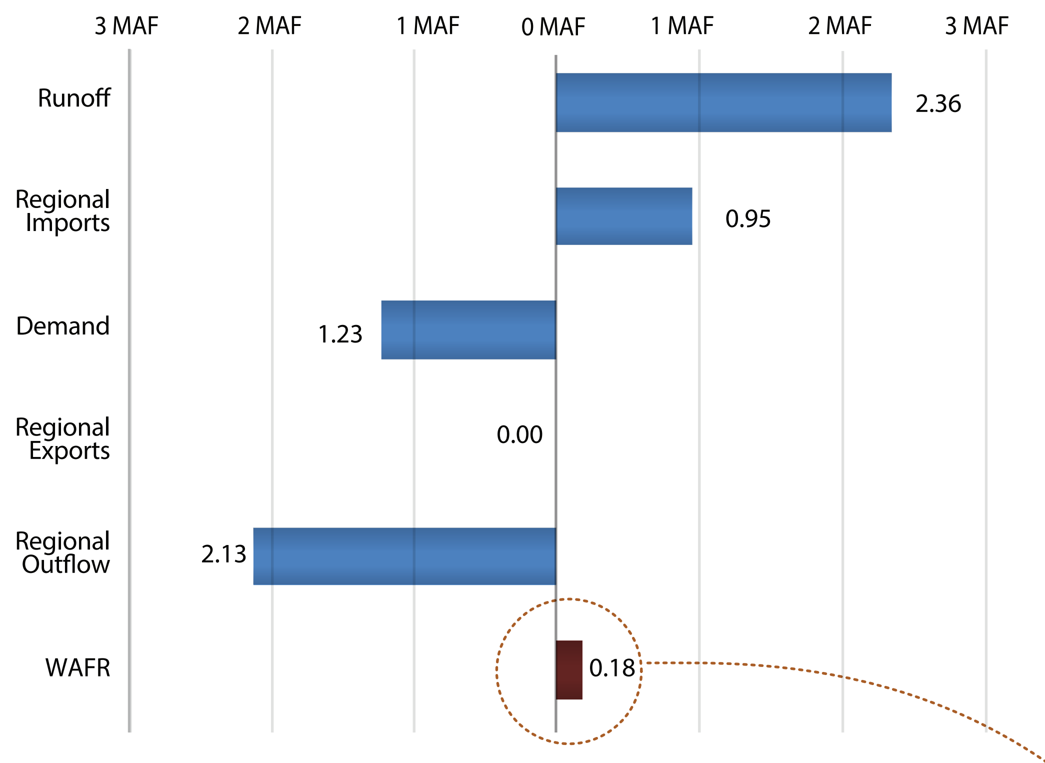
Basin Ranking	Basin Count per Rank	Percent of Total for Hydrologic Region: GW Use	Percent of Total for Hydrologic Region: Overlying Population
High	0	0%	0%
Medium	8	79%	22%
Low	2	6%	16%
Very Low	53	15%	22%
Totals	**63**	**100%**	**100%**

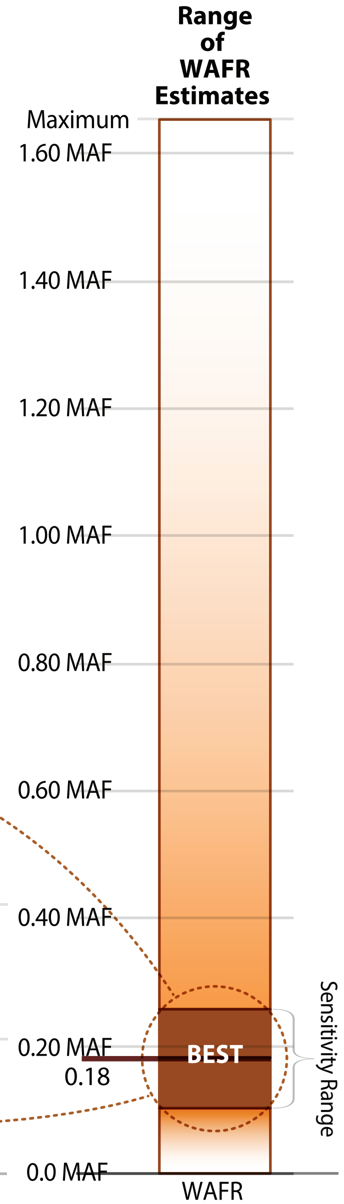
San Francisco Hydrologic Region

Water Balance

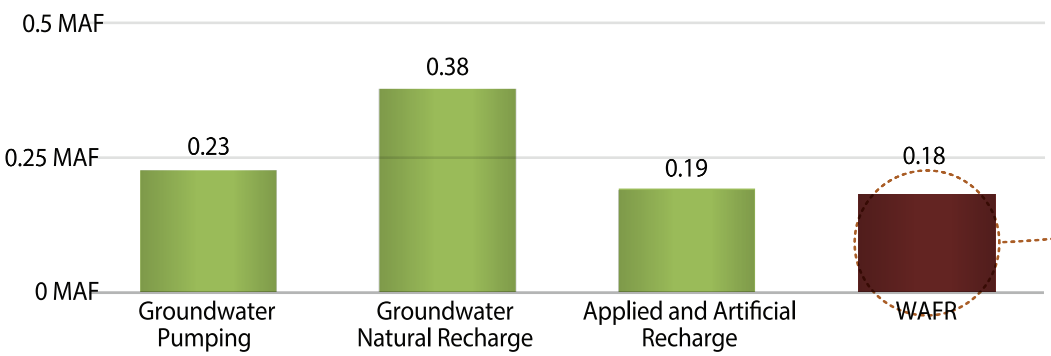


Surface Water Information and WAFR Estimate





Groundwater Information and WAFR Estimate

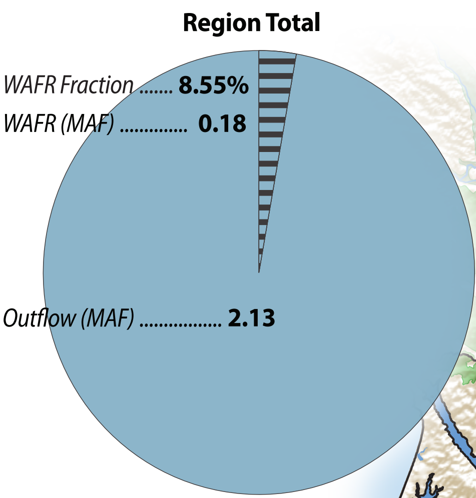


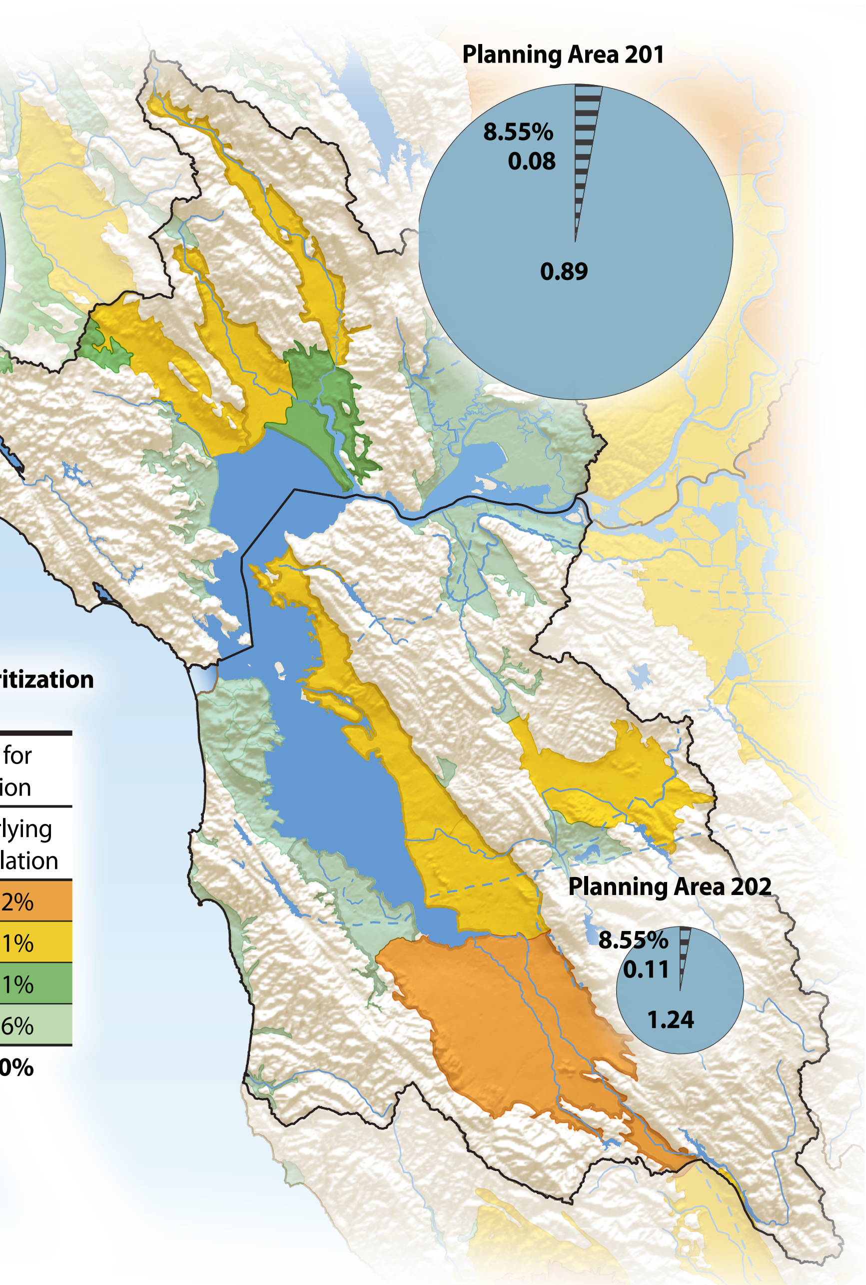
Note: For each regional graphic, scale is maintained within the graphic. To improve visibility, scale is not retained between regions.

Urban Water Portfolio Actions

Method	Volume of Water Increase from 2010 to 2020
Recycled Water	0.02 MAF
Desalination	0 MAF
Water Conservation	0.02 MAF

Outflow and WAFR Estimates (MAF) by Planning Area



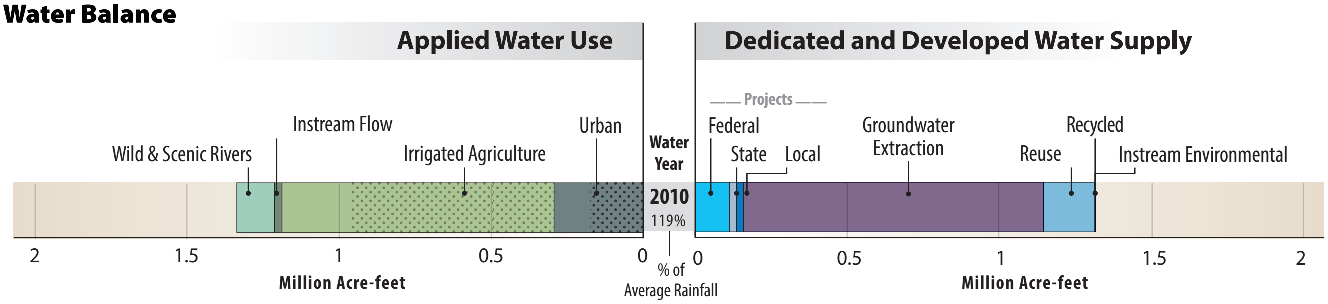


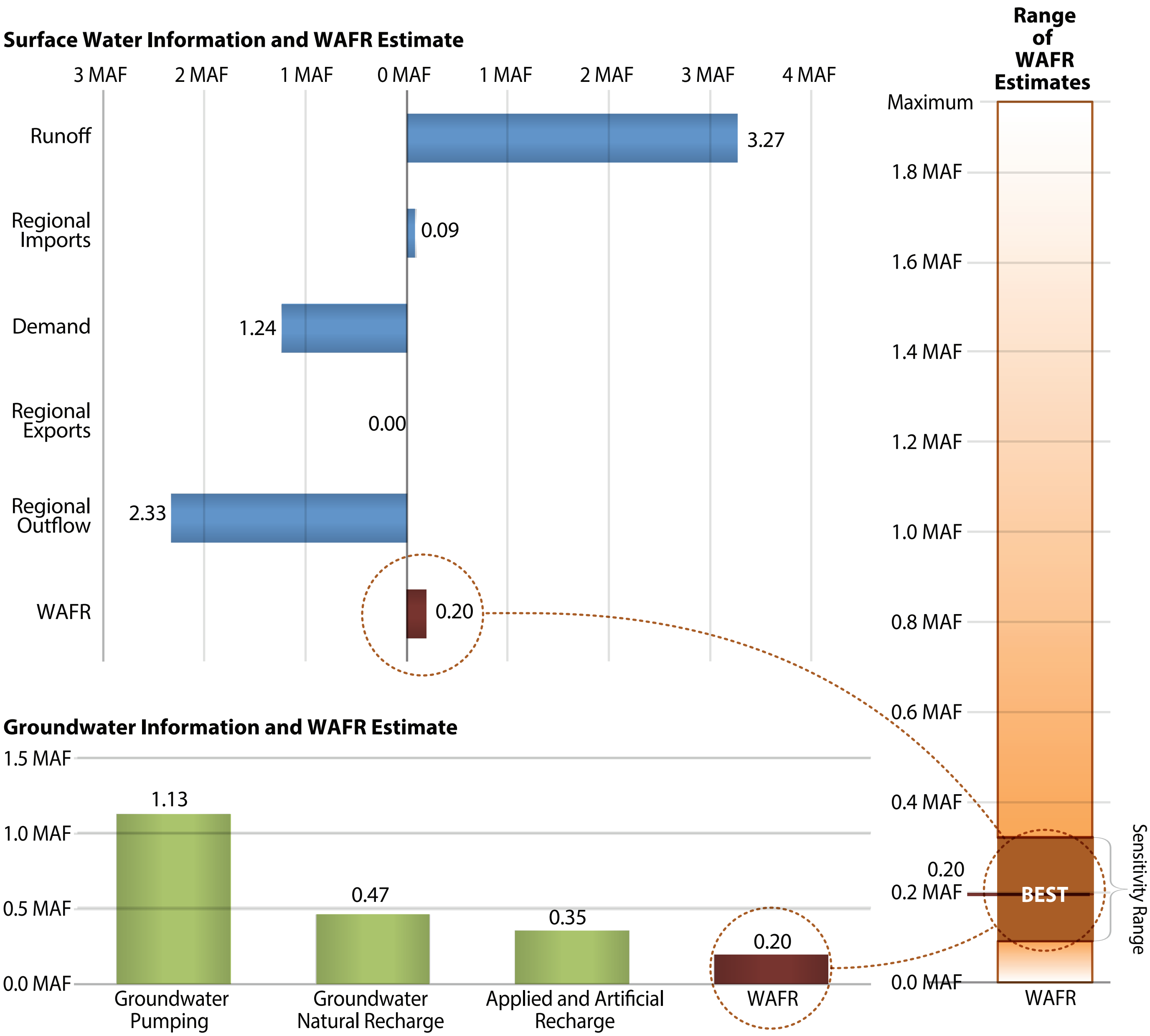
San Francisco HR Groundwater Basin Prioritization Summary, June 2, 2014

Basin Ranking	Basin Count per Rank	Percent of Total for Hydrologic Region	
		GW Use	Overlying Population
High	1	51%	32%
Medium	6	37%	31%
Low	1	4%	1%
Very Low	25	8%	36%
Totals	**33**	**100%**	**100%**

Central Coast Hydrologic Region

Water Balance



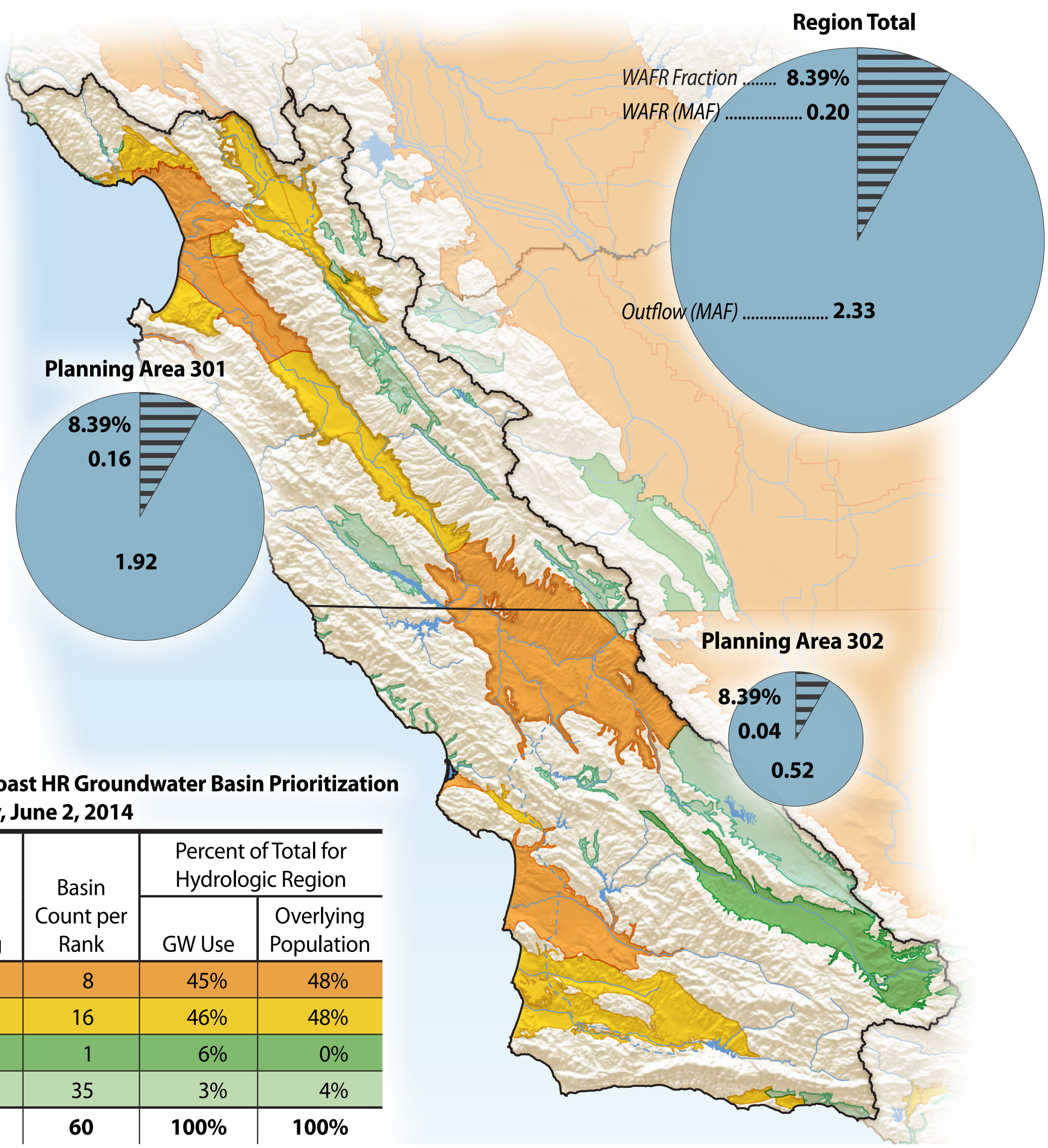


Note: For each regional graphic, scale is maintained within the graphic. To improve visibility, scale is not retained between regions.

Urban Water Portfolio Actions

Method	Volume of Water Increase from 2010 to 2020
Recycled Water	0 MAF
Desalination	0.02 MAF
Water Conservation	0.01 MAF

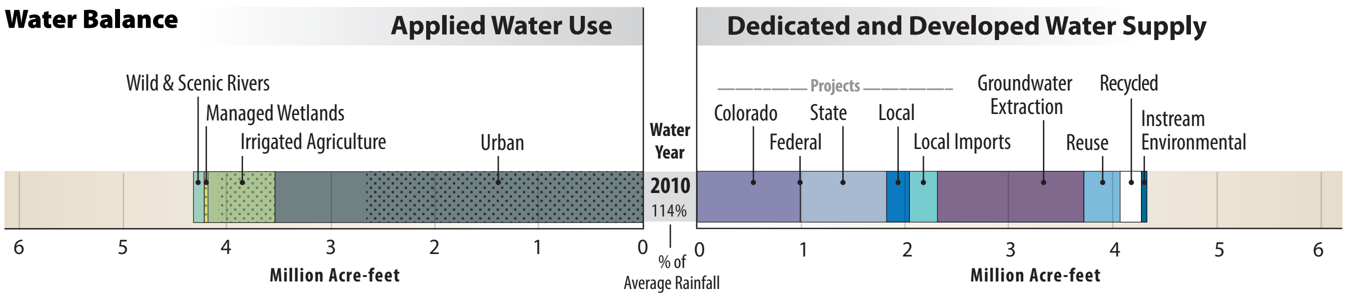
Outflow and WAFR Estimates (MAF) by Planning Area



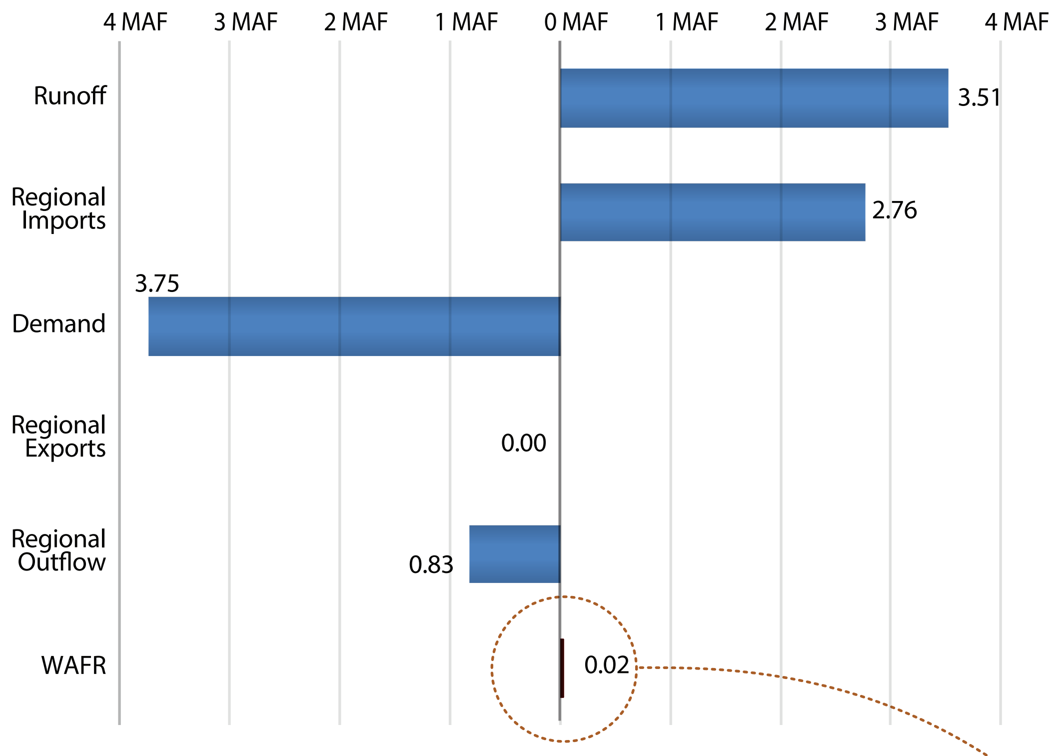
Central Coast HR Groundwater Basin Prioritization Summary, June 2, 2014

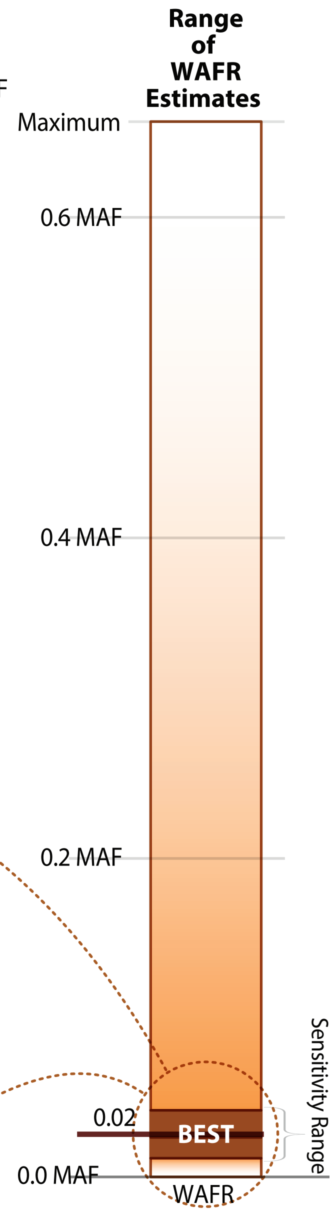
Basin Ranking	Basin Count per Rank	Percent of Total for Hydrologic Region	
		GW Use	Overlying Population
High	8	45%	48%
Medium	16	46%	48%
Low	1	6%	0%
Very Low	35	3%	4%
Totals	**60**	**100%**	**100%**

South Coast Hydrologic Region

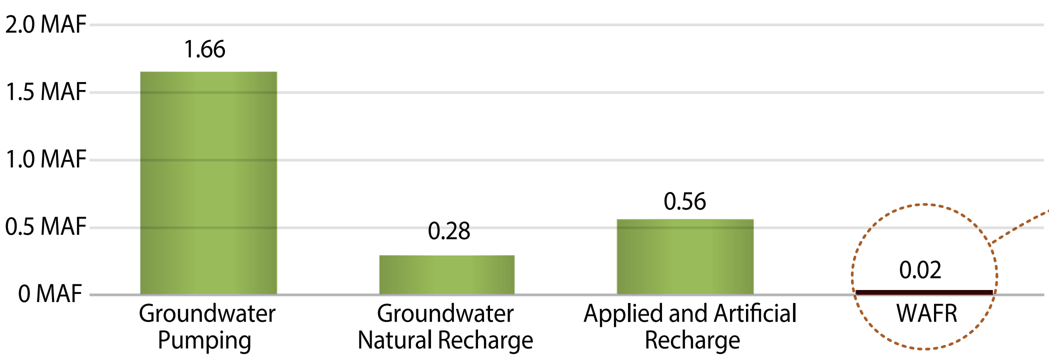


Surface Water Information and WAFR Estimate





Groundwater Information and WAFR Estimate

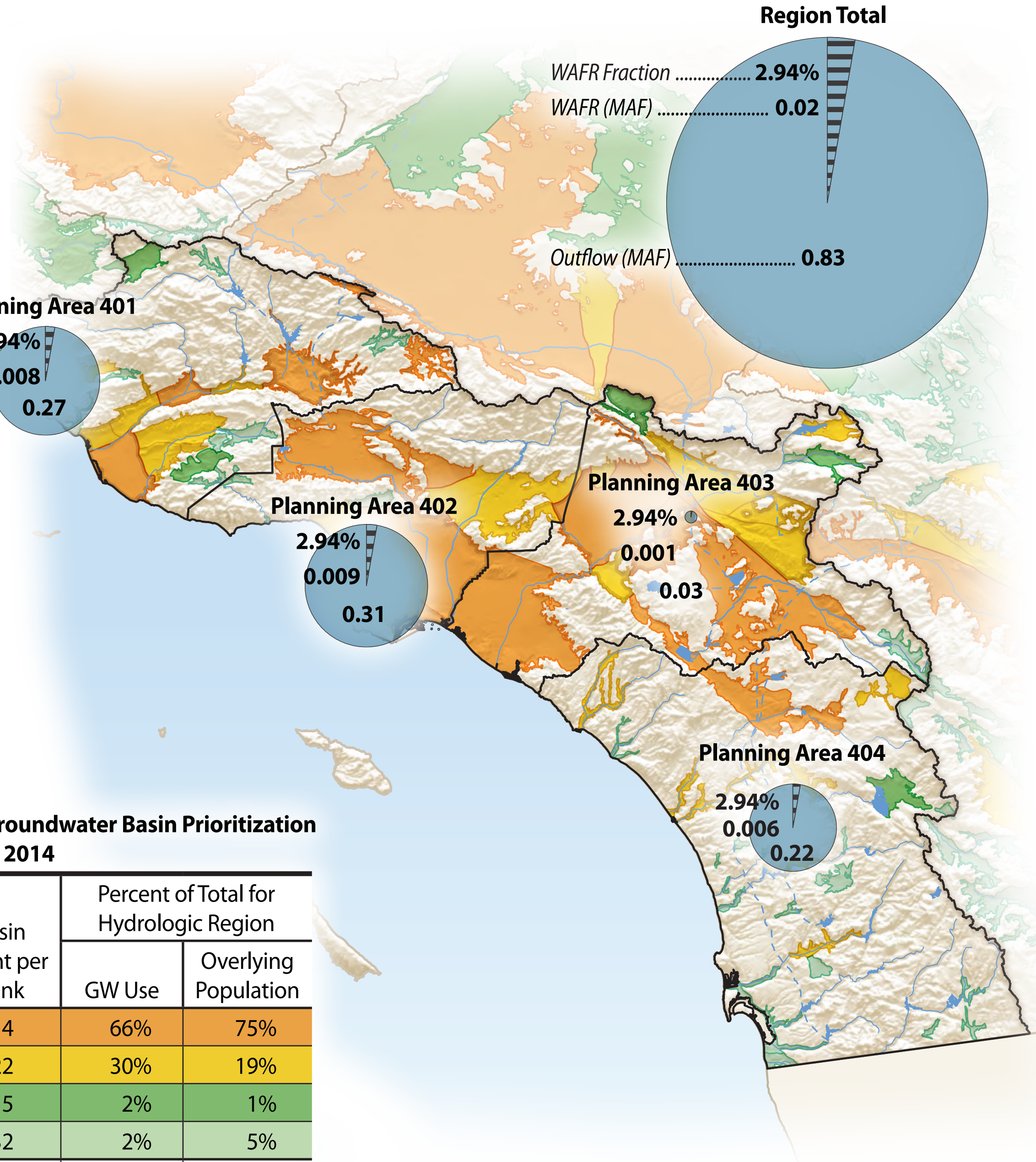


Note: For each regional graphic, scale is maintained within the graphic. To improve visibility, scale is not retained between regions.

Urban Water Portfolio Actions

Method	Volume of Water Increase from 2010 to 2020
Recycled Water	0.10 MAF
Desalination	0.31 MAF
Water Conservation	0.24 MAF

Outflow and WAFR Estimates (MAF) by Planning Area

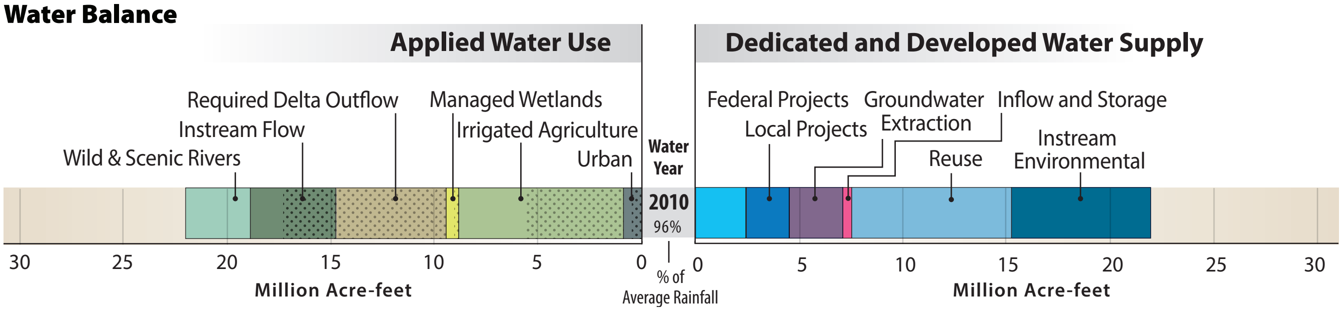


South Coast HR Groundwater Basin Prioritization Summary, June 2, 2014

Basin Ranking	Basin Count per Rank	Percent of Total for Hydrologic Region: GW Use	Percent of Total for Hydrologic Region: Overlying Population
High	14	66%	75%
Medium	22	30%	19%
Low	5	2%	1%
Very Low	32	2%	5%
Totals	**73**	**100%**	**100%**

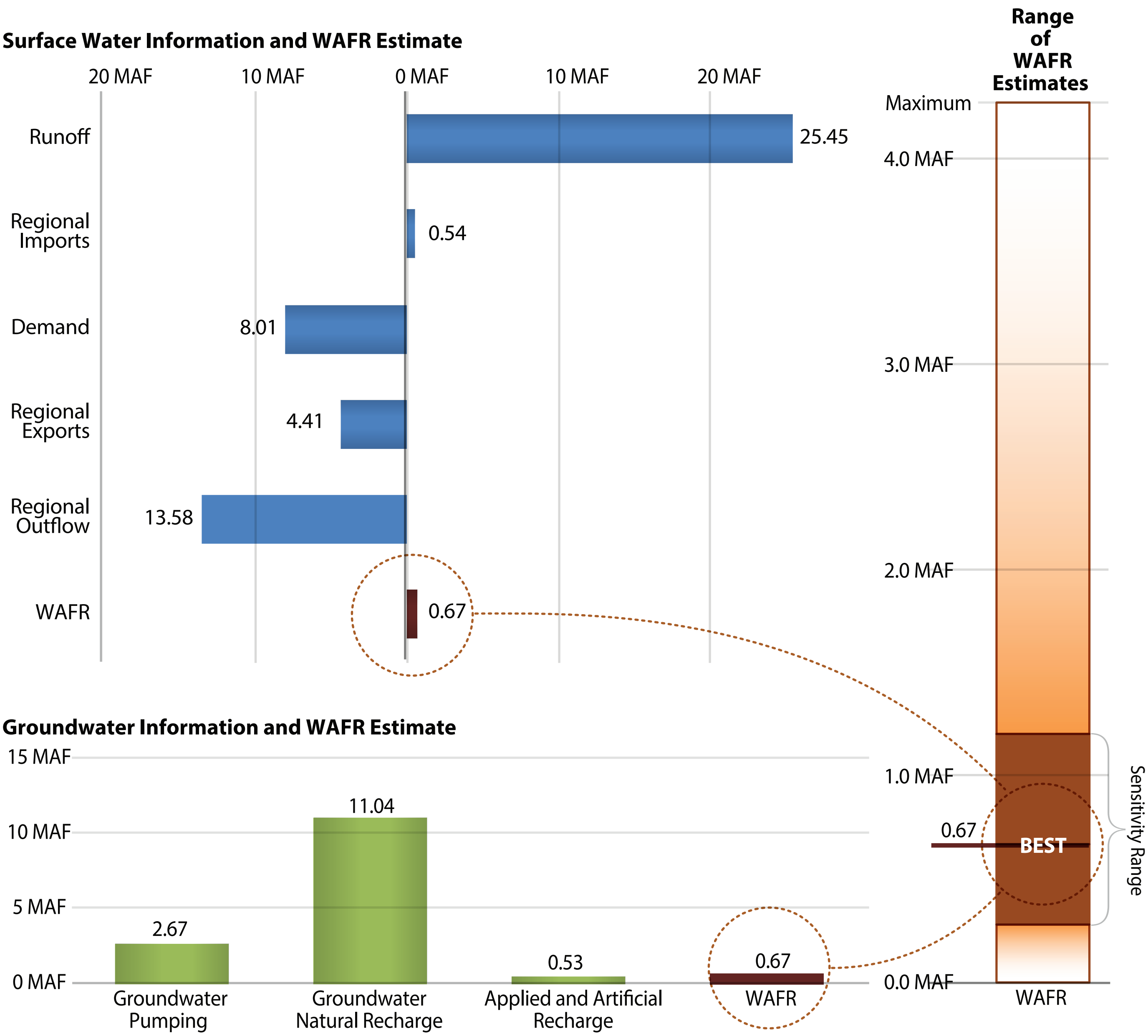
Sacramento River Hydrologic Region

Water Balance



Surface Water Information and WAFR Estimate

Groundwater Information and WAFR Estimate



Note: For each regional graphic, scale is maintained within the graphic. To improve visibility, scale is not retained between regions.

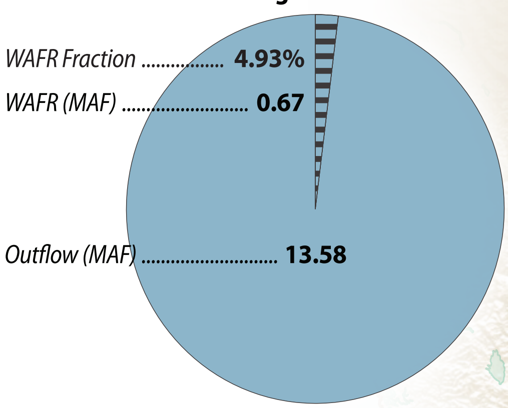
Urban Water Portfolio Actions

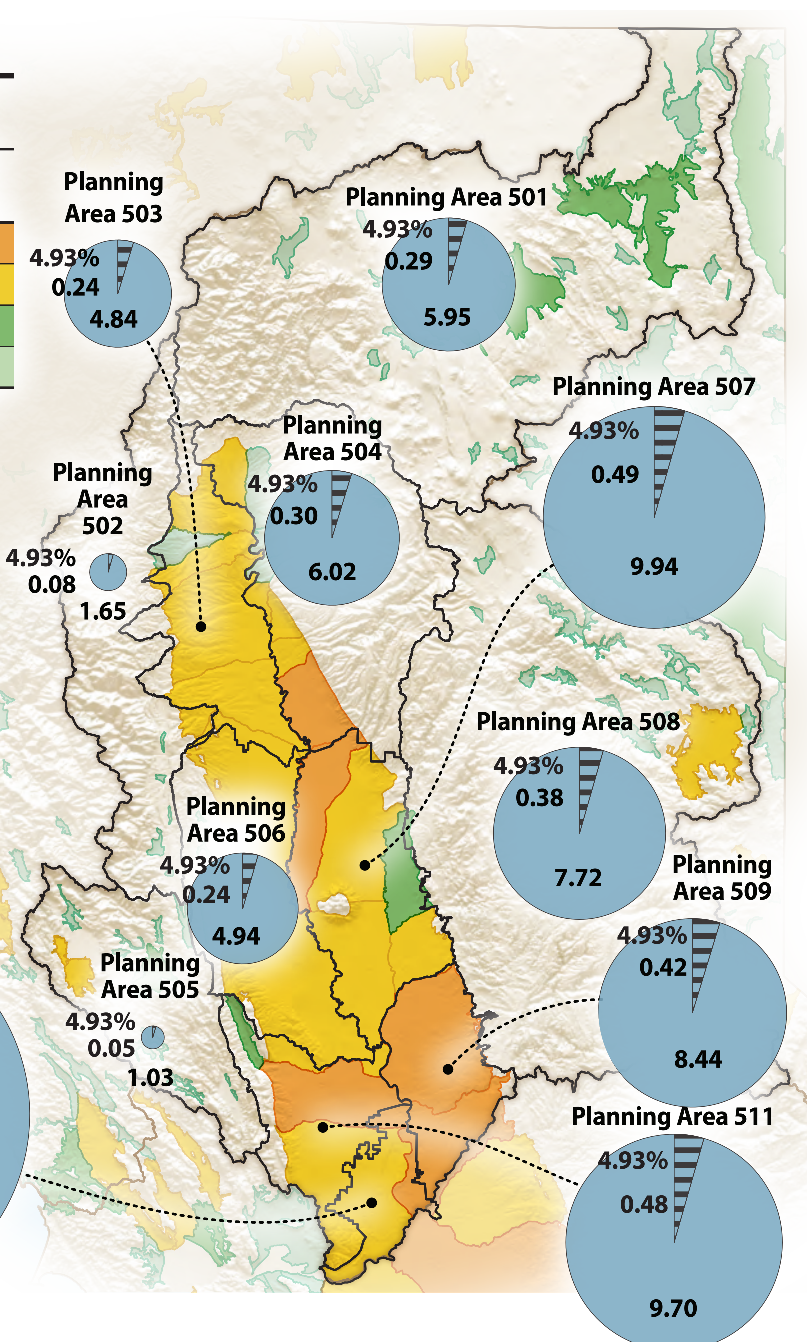
Method	Volume of Water Increase from 2010 to 2020
Recycled Water	0.02 MAF
Desalination	0 MAF
Water Conservation	0.13 MAF

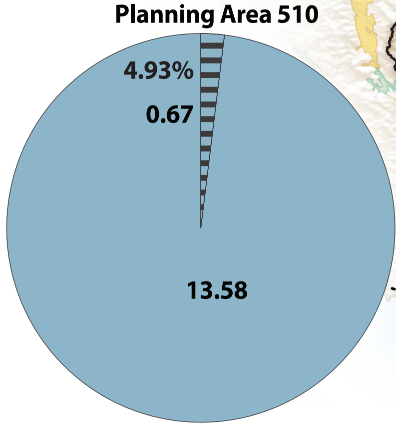
Outflow and WAFR Estimates (MAF) by Planning Area

Sacramento River HR Groundwater Basin Prioritization Summary, June 2, 2014

Basin Ranking	Basin Count per Rank	Percent of Total for Hydrologic Region	
		GW Use	Overlying Population
High	5	38%	76%
Medium	16	51%	22%
Low	7	9%	1%
Very Low	60	2%	1%
Totals	**88**	**100%**	**100%**

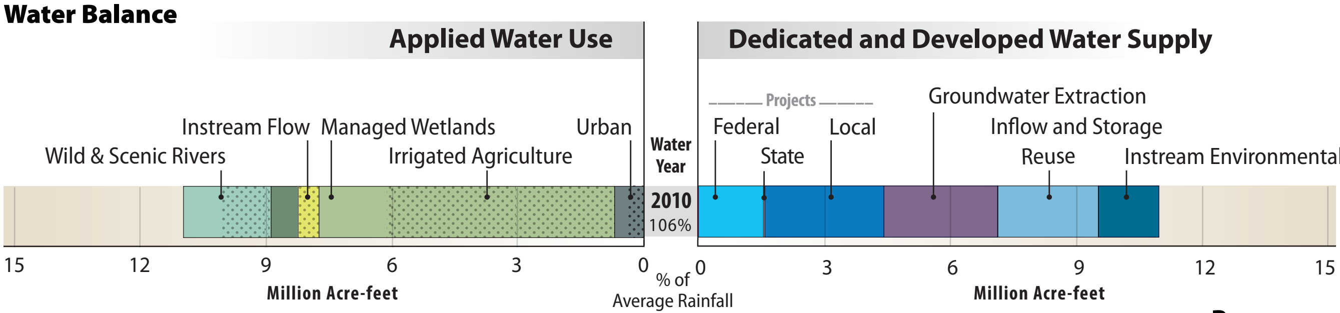




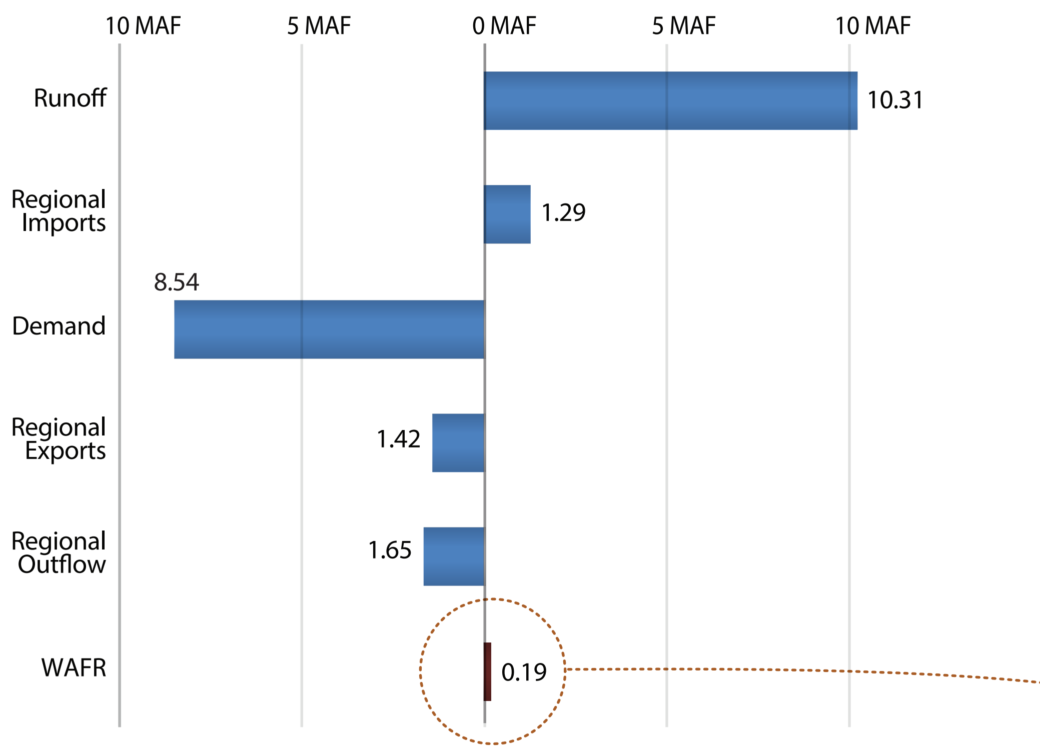


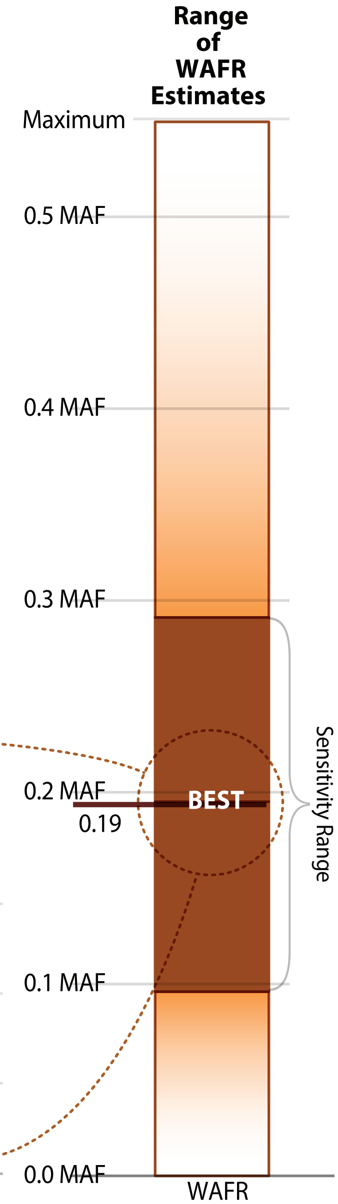
San Joaquin River Hydrologic Region

Water Balance

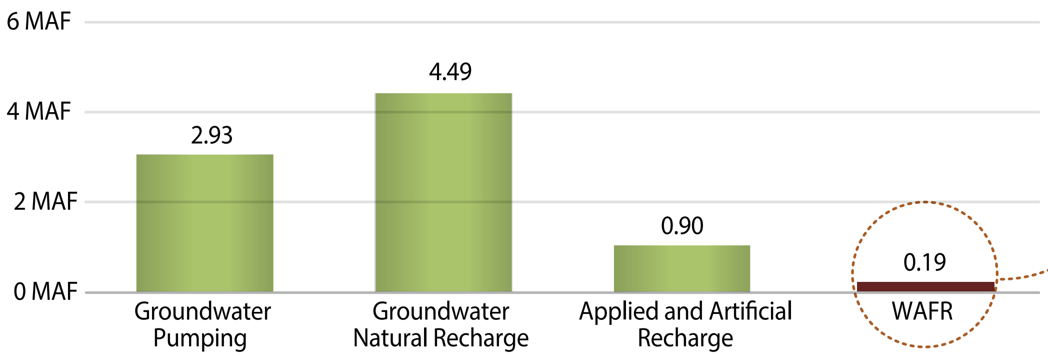


Surface Water Information and WAFR Estimate





Groundwater Information and WAFR Estimate



Note: For each regional graphic, scale is maintained within the graphic. To improve visibility, scale is not retained between regions.

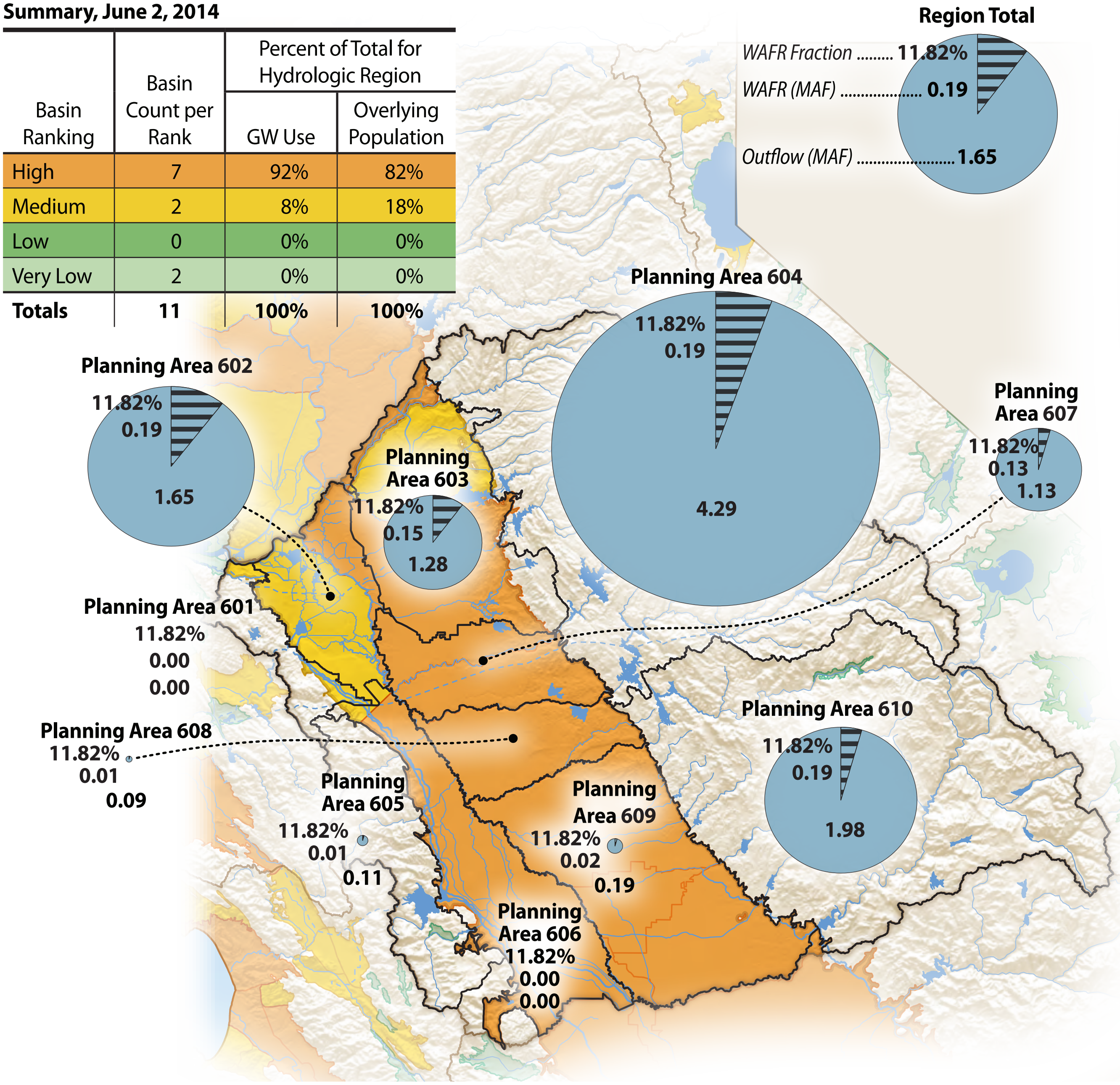
Urban Water Portfolio Actions

Method	Volume of Water Increase from 2010 to 2020
Recycled Water	0.03 MAF
Desalination	0 MAF
Water Conservation	0.11 MAF

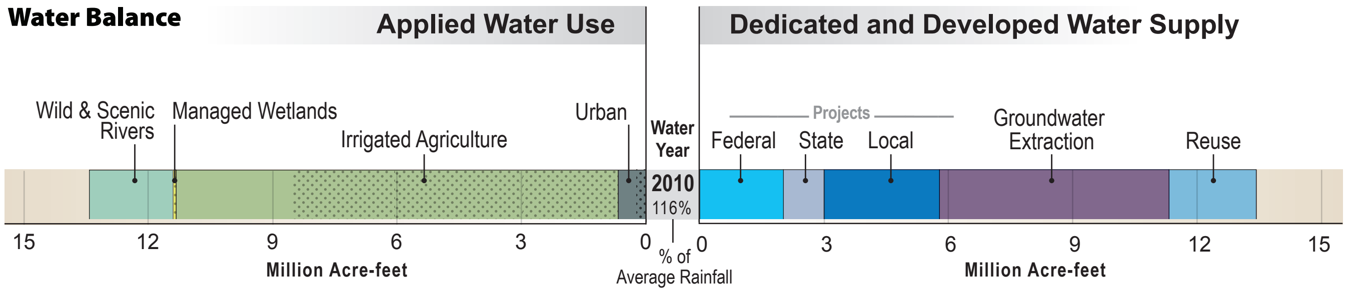
Outflow and WAFR Estimates (MAF) by Planning Area

San Joaquin HR Groundwater Basin Prioritization Summary, June 2, 2014

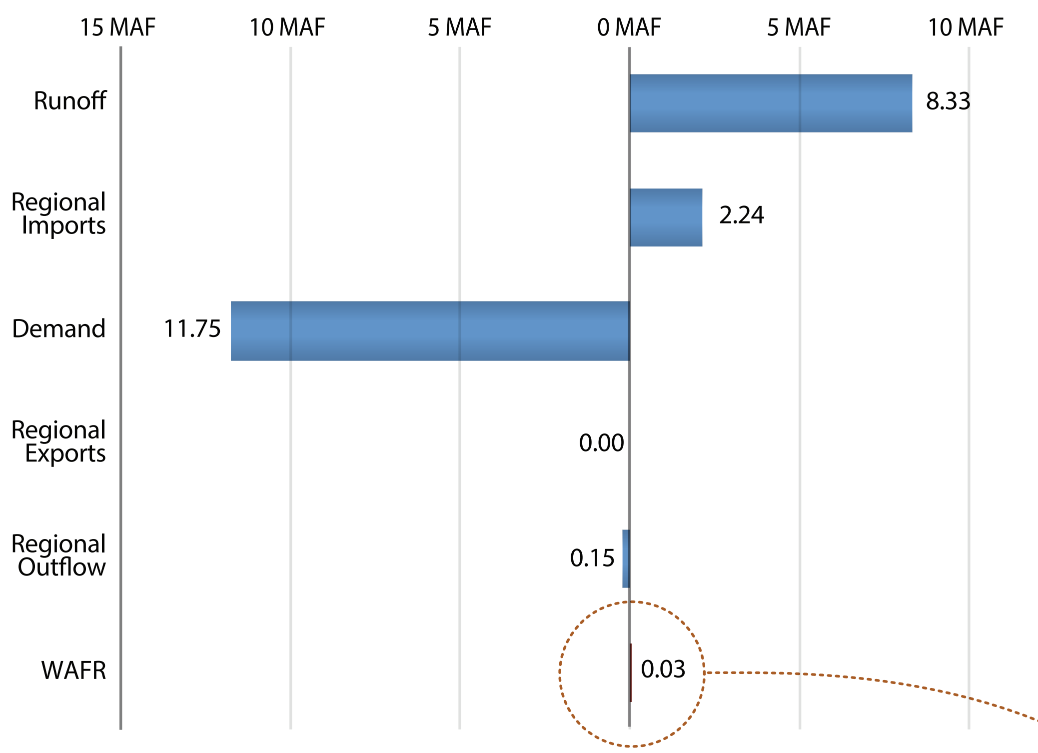
Basin Ranking	Basin Count per Rank	Percent of Total for Hydrologic Region	
		GW Use	Overlying Population
High	7	92%	82%
Medium	2	8%	18%
Low	0	0%	0%
Very Low	2	0%	0%
Totals	**11**	**100%**	**100%**

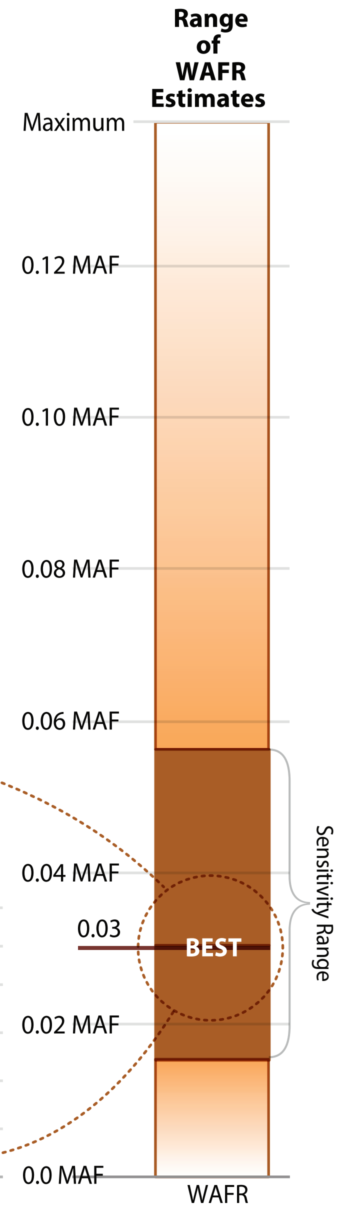


Tulare Lake Hydrologic Region

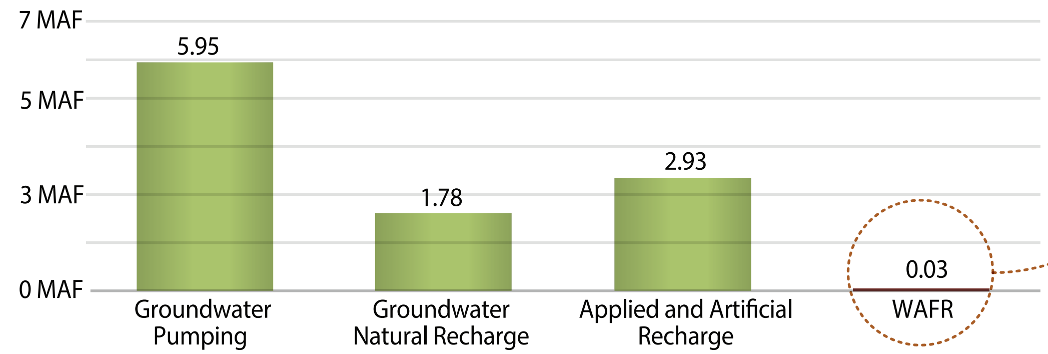


Surface Water Information and WAFR Estimate





Groundwater Information and WAFR Estimate



Note: For each regional graphic, scale is maintained within the graphic. To improve visibility, scale is not retained between regions.

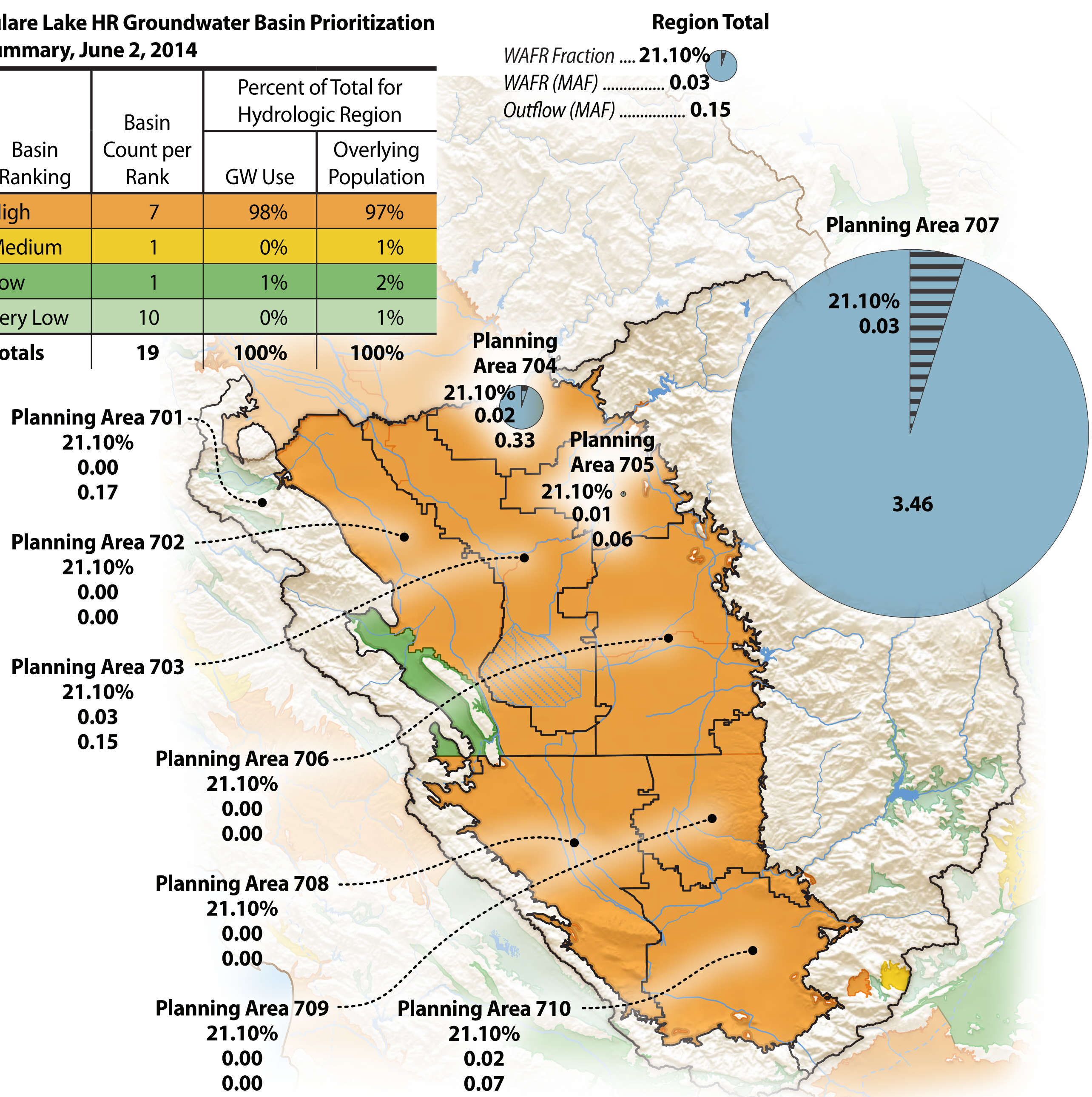
Urban Water Portfolio Actions

Method	Volume of Water Increase from 2010 to 2020
Recycled Water	0.01 MAF
Desalination	0 MAF
Water Conservation	0.05 MAF

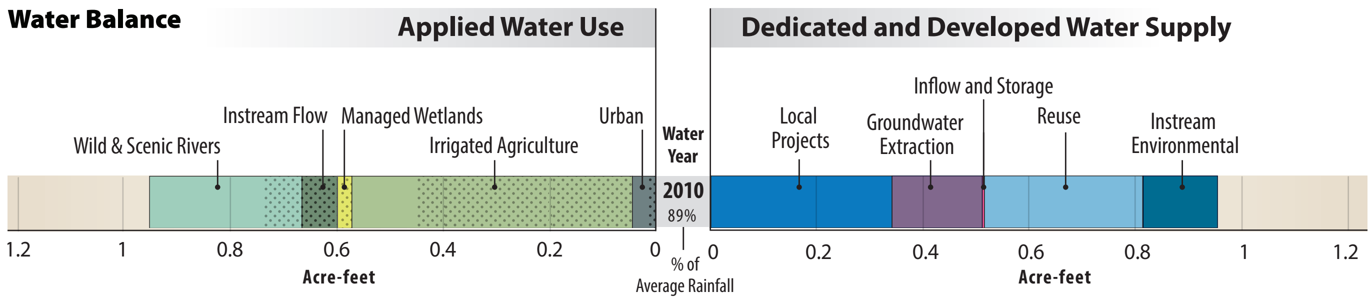
Outflow and WAFR Estimates (MAF) by Planning Area

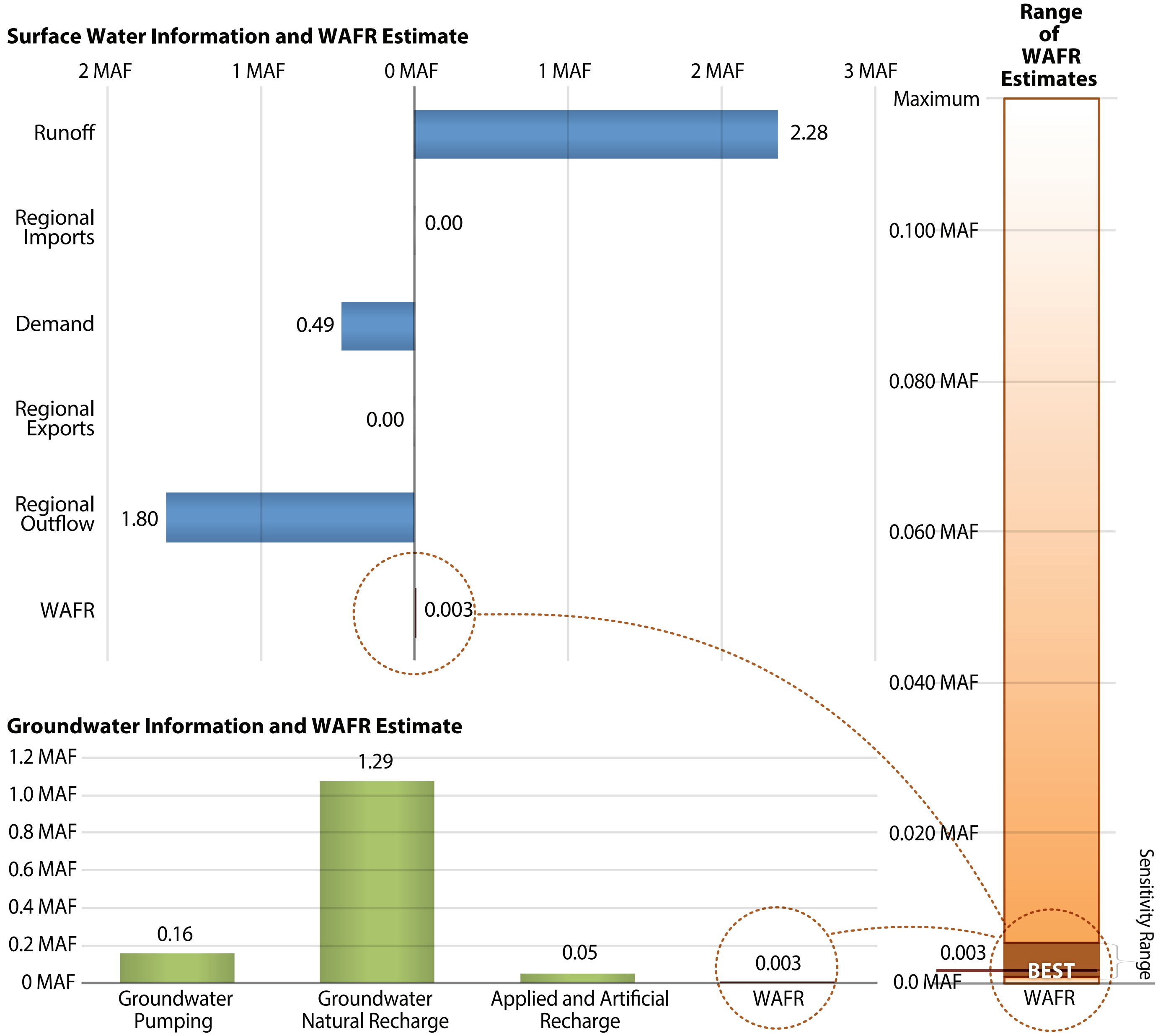
Tulare Lake HR Groundwater Basin Prioritization Summary, June 2, 2014

Basin Ranking	Basin Count per Rank	Percent of Total for Hydrologic Region	
		GW Use	Overlying Population
High	7	98%	97%
Medium	1	0%	1%
Low	1	1%	2%
Very Low	10	0%	1%
Totals	**19**	**100%**	**100%**



North Lahontan Hydrologic Region





Note: For each regional graphic, scale is maintained within the graphic. To improve visibility, scale is not retained between regions.

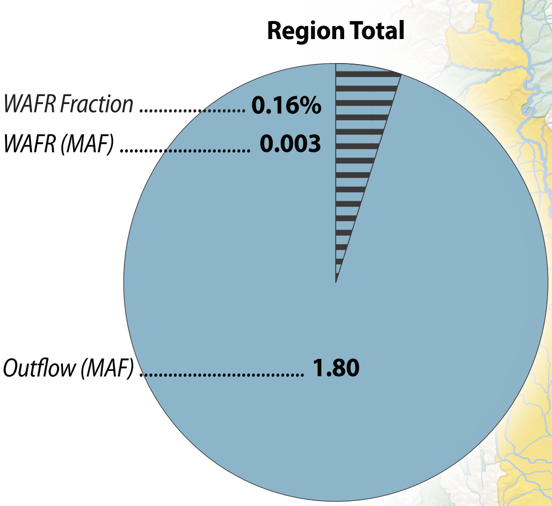
Urban Water Portfolio Actions

Method	Volume of Water Increase from 2010 to 2020
Recycled Water	0.0 MAF
Desalination	0 MAF
Water Conservation	0.0 MAF

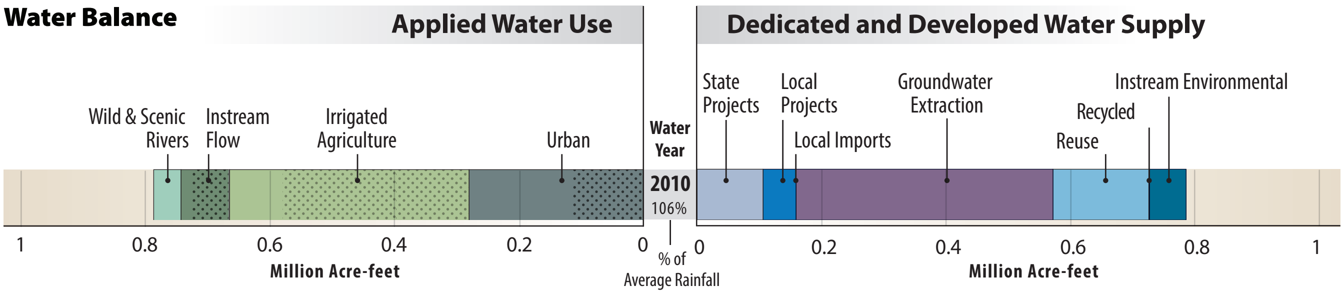
Outflow and WAFR Estimates (MAF) by Planning Area

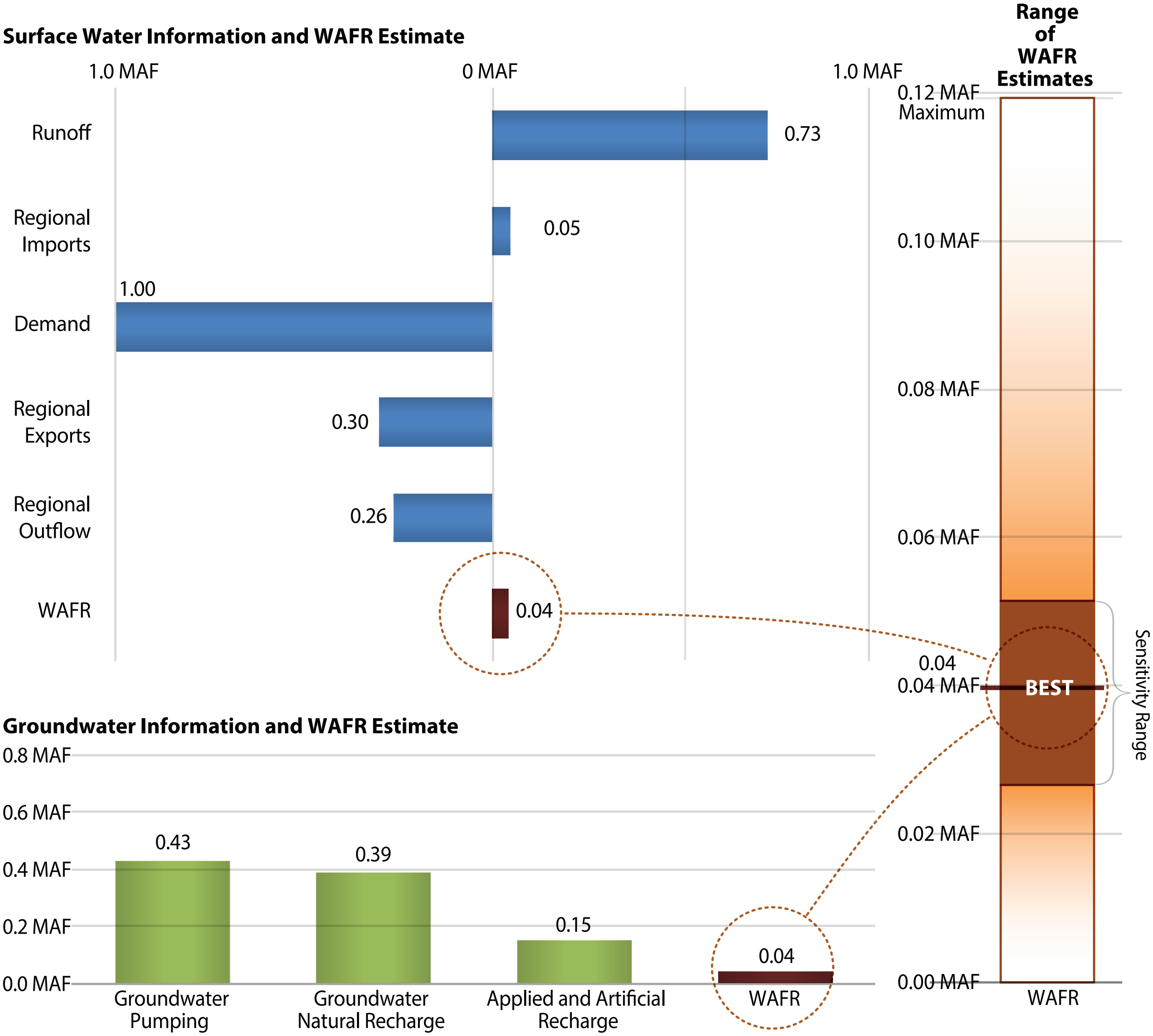
North Lahontan HR Groundwater Basin Prioritization Summary, June 2, 2014

Basin Ranking	Basin Count per Rank	Percent of Total for Hydrologic Region	
		GW Use	Overlying Population
High	0	0%	0%
Medium	2	9%	55%
Low	2	72%	33%
Very Low	23	19%	12%
Totals	**27**	**100%**	**100%**



South Lahontan Hydrologic Region



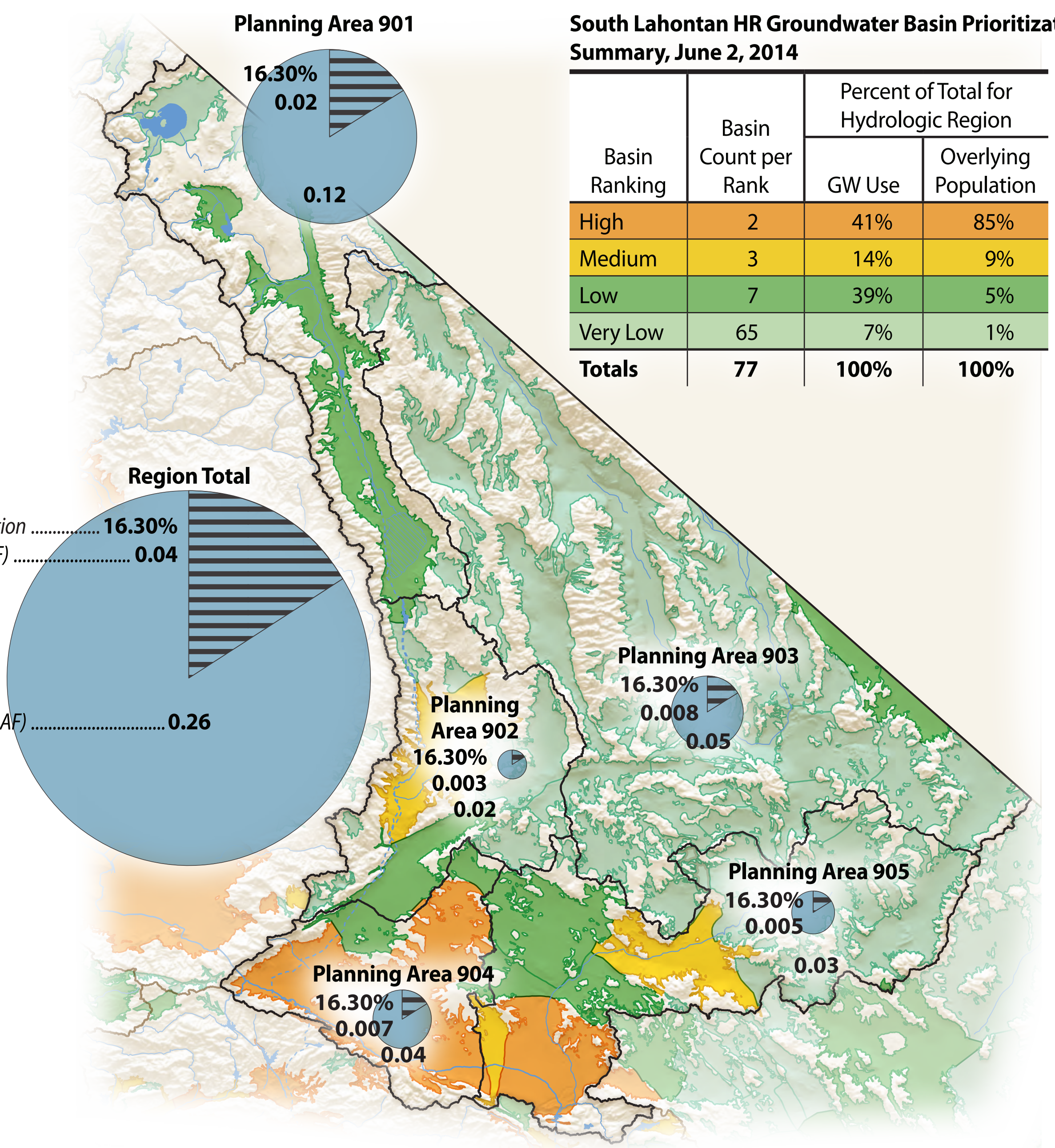


Note: For each regional graphic, scale is maintained within the graphic. To improve visibility, scale is not retained between regions.

Urban Water Portfolio Actions

Method	Volume of Water Increase from 2010 to 2020
Recycled Water	0.01 MAF
Desalination	0 MAF
Water Conservation	0.01 MAF

Outflow and WAFR Estimates (MAF) by Planning Area

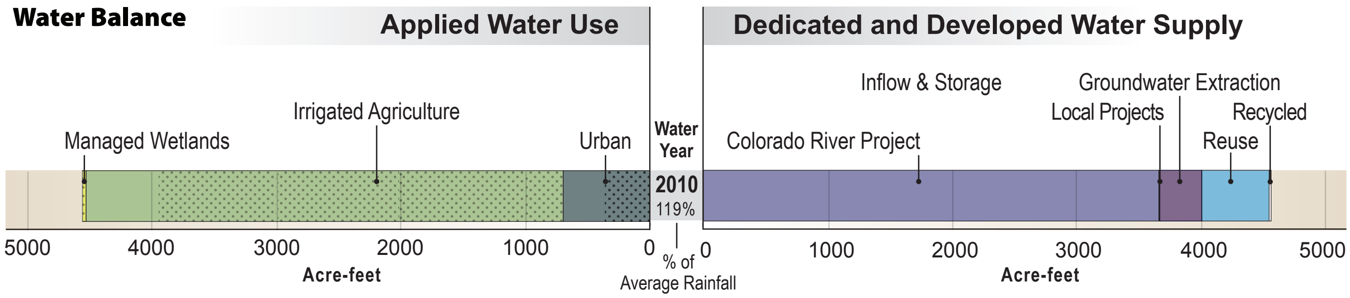


South Lahontan HR Groundwater Basin Prioritization Summary, June 2, 2014

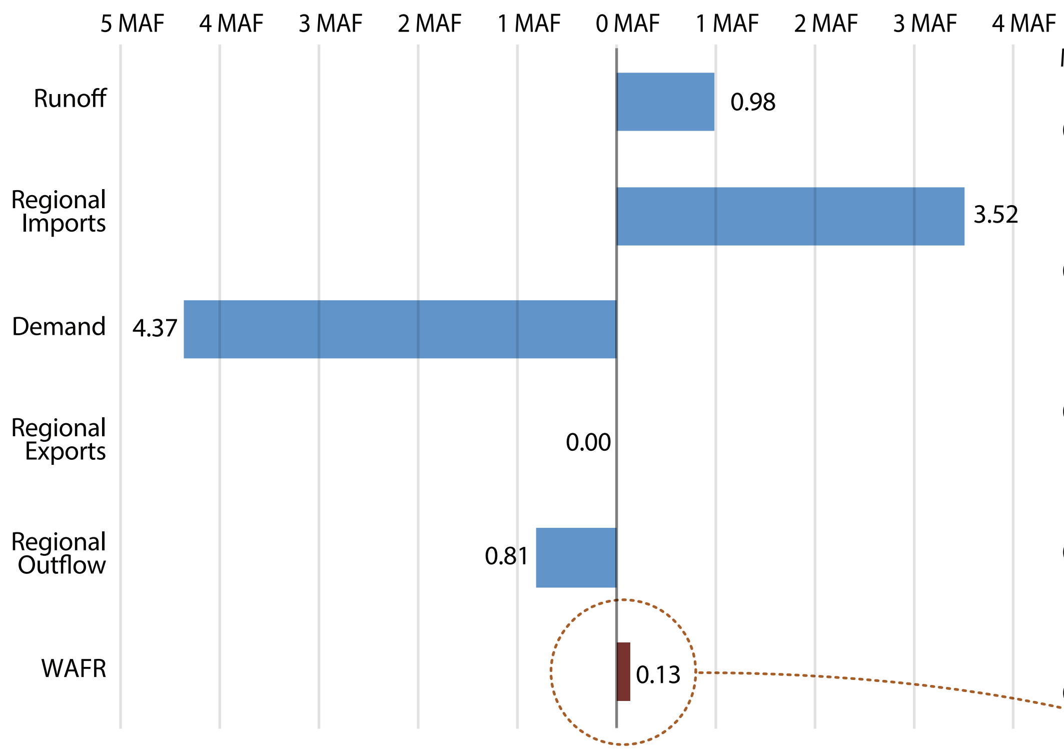
Basin Ranking	Basin Count per Rank	Percent of Total for Hydrologic Region	
		GW Use	Overlying Population
High	2	41%	85%
Medium	3	14%	9%
Low	7	39%	5%
Very Low	65	7%	1%
Totals	**77**	**100%**	**100%**

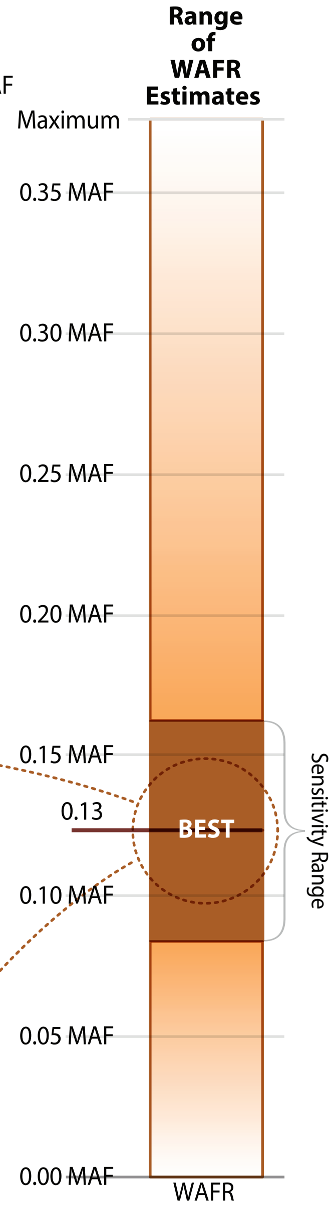
Colorado River Hydrologic Region

Water Balance

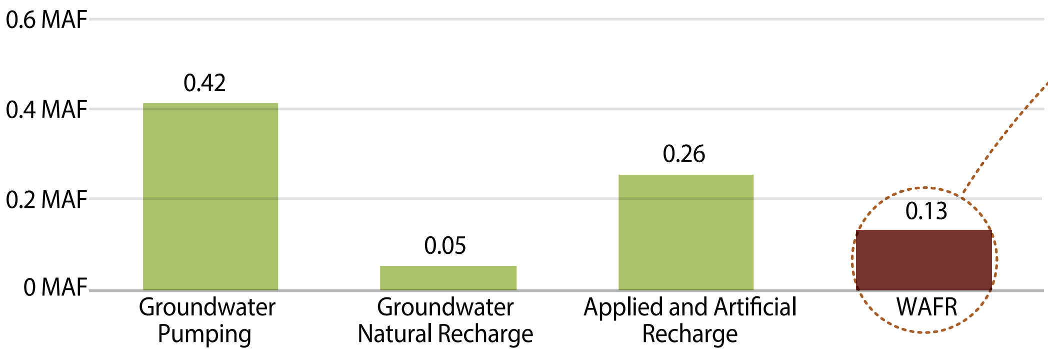


Surface Water Information and WAFR Estimate





Groundwater Information and WAFR Estimate



Note: For each regional graphic, scale is maintained within the graphic. To improve visibility, scale is not retained between regions.

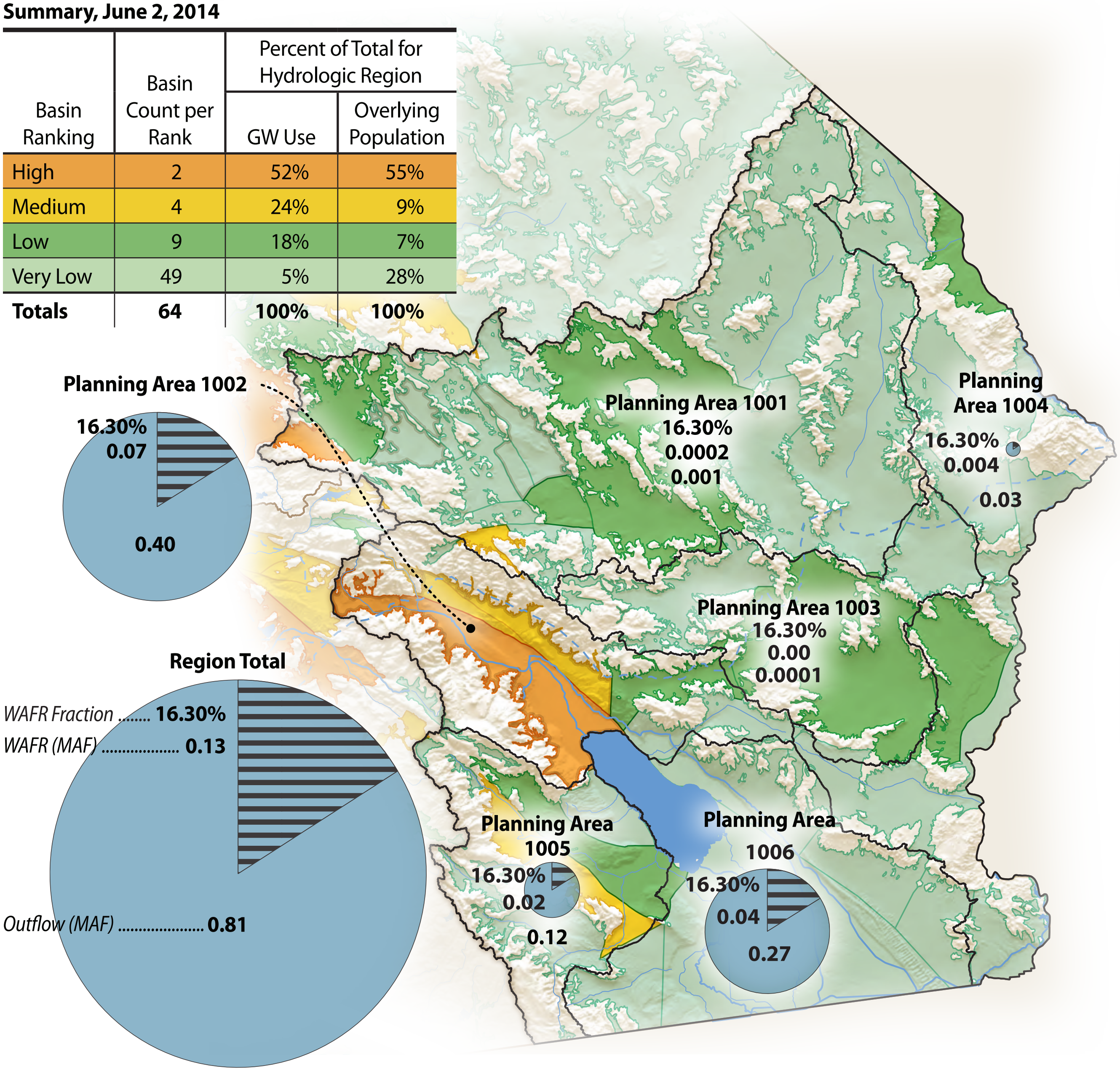
Urban Water Portfolio Actions

Method	Volume of Water Increase from 2010 to 2020
Recycled Water	0.01 MAF
Desalination	0 MAF
Water Conservation	0 MAF

Outflow and WAFR Estimates (MAF) by Planning Area

Colorado River HR Groundwater Basin Prioritization Summary, June 2, 2014

Basin Ranking	Basin Count per Rank	Percent of Total for Hydrologic Region	
		GW Use	Overlying Population
High	2	52%	55%
Medium	4	24%	9%
Low	9	18%	7%
Very Low	49	5%	28%
Totals	**64**	**100%**	**100%**



State Water Project and Central Valley Project: Reliability and Availability

Many regions in California receive part of their supply from the SWP or CVP. As GSAs in these regions plan for their water futures, there is a need to understand the reliability of SWP and CVP deliveries — how reliability has changed through time and how it may change again in the future. Additional detail is provided in Appendix B. This report provides historical information and context for the SWP and the CVP as a background for estimates of the current reliability of surface water deliveries for both projects. GSAs in regions that receive deliveries from either project may find this information useful for developing water budgets for their GSPs. This report also includes a summary of statewide surface water project investigation results that quantify the additional surface water supplies (i.e., water available) that may be developed by enhancing California's statewide infrastructure. In addition, this report includes discussion of how statewide water supplies may be affected by climate change, including such topics as inflow to major reservoirs and sea level rise.

The SWP and CVP were constructed over many decades. The demand for water, recognition of ecosystem needs, the need to balance beneficial uses, and the resulting regulations governing SWP and CVP operations have all steadily increased through time. Figure 9, below, shows a timeline of the almost 40 years of key regulations that have governed or affected the operation of the SWP/CVP system.

Figure 9. Timeline of Major Regulations Affecting Operations of the SWP and CVP

1978 **D-1485:** Decision setting Delta water quality standards

1986 **COA:** CVP-SWP agreement to coordinate operations, including Delta conditions

1990 **WRO 90-5:** Order requiring CVP operations to regulate temperatures in the Upper Sacramento River

1992 **CVPIA:** Improvement act dedicated 800,000 acre-feet of CVP water to the restoration of wetlands, protection of water quality in the Delta, and flows for fish and other related environmental uses

1995 **Bay Delta WQCP:** Plan required CVP and SWP flow objectives for salinity conditions in the Delta and other actions to support fish and wildlife habitat.

2001 **D-1641:** Decision requiring water quality standards for the protection of municipal, industrial, agricultural, and environmental purposes

Trinity ROD: Decision including actions to restore and maintain the anadromous fishery resources of the Trinity River

2006 **SJRRP:** Restoration program including flows and restoration requirements on the San Joaquin River from Friant Dam to the confluence of the Merced River

2008 **FWS BO:** Opinion including requirements on CVP and SWP operations to protect Delta smelt

2009 **NMFS BO:** Opinion including requirements on CVP and SWP operations to protect salmon

An analysis was conducted to demonstrate how regulatory changes have affected the water supply reliability of contract supplies of the CVP and SWP. This analysis simulated the operation of the SWP/CVP system with the same hydrology, facilities, and demands, but under three different regulatory conditions, as shown in Figures 10 and 11: D-1485, D-1641, and the 2008 and 2009 Biological Opinions (BiOps) for Delta smelt and salmon. This analysis is provided as context for GSAs and others to understand how SWP and CVP reliability has changed through time in association with changing regulations. For illustrative purposes, analytical results for SWP and CVP deliveries are provided in the next section.

Example Analysis of the Effect of Past and Current Regulations on SWP and CVP Deliveries

SWP deliveries are reported for contract water supplies (Table A amounts) to its long-term water contractors (Table A contractors) located south of the Delta and shown in Figure 10. Within the SWP, most Table A contractors receive the same allocation each year, and there are no differences in allocation of water between agricultural and municipal and industrial (M&I) contractors. CVP deliveries are reported for agricultural and M&I water service contractors (excluding the Eastside and Friant diversions) and shown in Figure 11.

Figures 10 and 11 illustrate how annual SWP and CVP deliveries were affected by changes in regulatory conditions. Annual deliveries for a single wet year, a period of six wet years, an average across all years (82 years), a single dry year, and a six-year drought are presented in figures 10 and 11. The single years illustrated represent the most extreme single wet (1983) and single dry (1977) years in the period of analysis (1922–2003).

Figure 10. Annual SWP Table A Deliveries

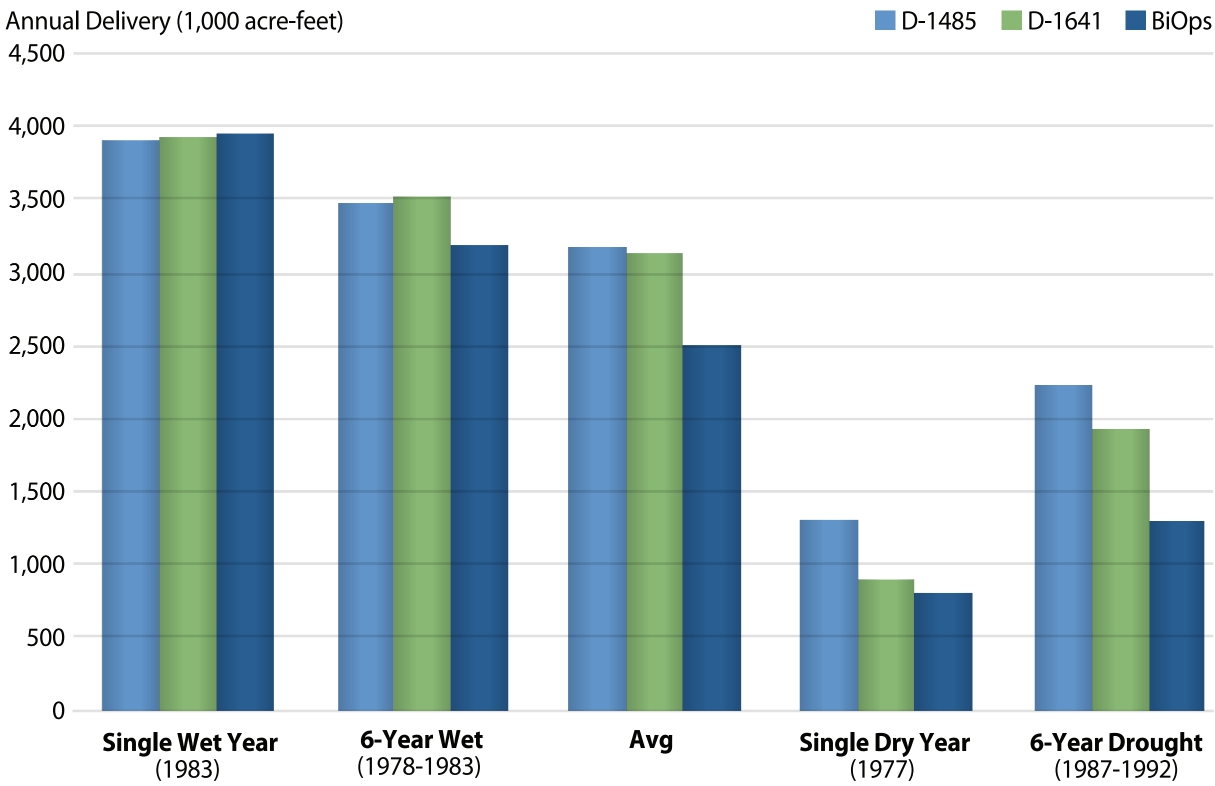
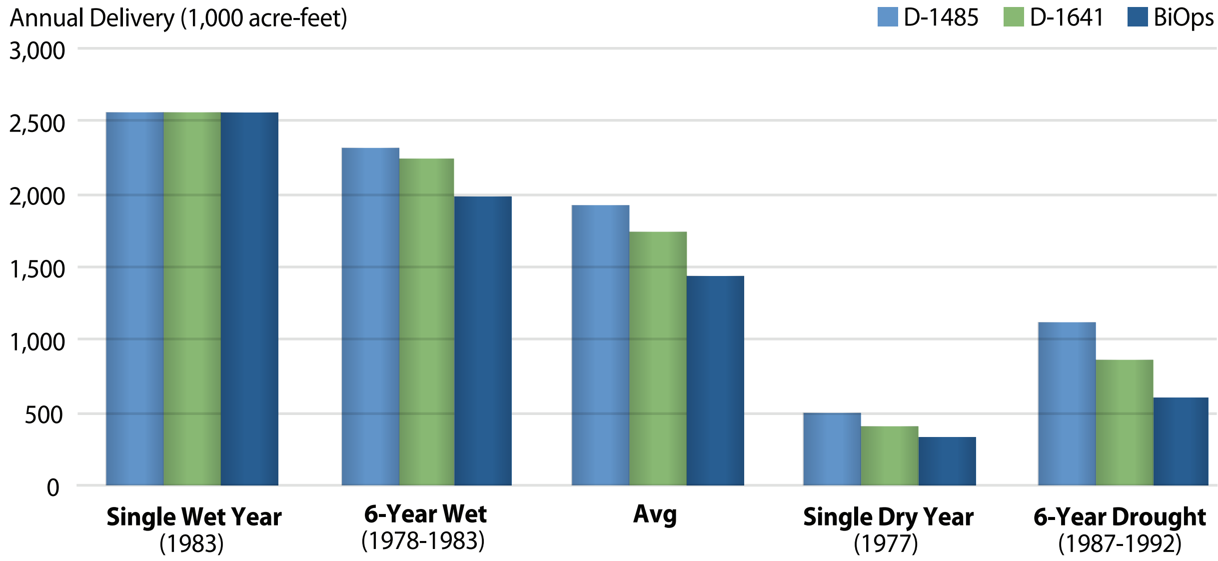


Figure 11. Annual CVP Water Service Contract Deliveries



The results presented in Figure 11 show similar annual deliveries for CVP between the D-1485 and D-1641 simulations, and reductions in annual deliveries in most years and periods under the Biological Opinions (BiOps) simulation. But changing from D-1641 to the BiOps regulatory condition shows a more dramatic regulatory effect. Results indicate that average annual SWP Table A deliveries under the Biological Opinions regulatory condition are over 600,000 acre-feet less than under D-1641 conditions; average CVP deliveries are similarly reduced by almost 500,000 acre-feet. More detail for figures 10 and 11 is provided in Appendix B.

Future Uncertainty of SWP and CVP Reliability and Availability

California is close to making several important water resources investment decisions significantly related to the performance of the CVP and SWP. For example, California EcoRestore proposes to make major capital investments in the long-term health of the Delta ecosystem, including the development of more than 30,000 acres of habitat restoration. California WaterFix proposes new Delta conveyance investments to protect water supplies and fish. Also, as part of Proposition 1 (2014), California voters approved investment in water quality, water supply, and infrastructure improvement, including ecosystem benefits for the Bay-Delta and associated watersheds. The California Water Commission has established the Water Storage Investment Program to identify and fund storage projects that would maximize return on public investment. Many of these studies and others (e.g., the Bay-Delta Water Quality Control Plan) have considered a new regulatory future that would affect the reliability of the SWP and CVP. In addition, WaterFix conveyance studies and CALFED surface storage investigations have proposed new infrastructure to improve the state's water system, specifically the SWP and CVP. These proposed projects may, under certain conditions, improve the reliability of the CVP and SWP. Improved reliability may result in water available for replenishment in areas of the state that receive increased water supplies.

For the following discussion, average South of Delta (SOD) exports and SWP and CVP reliability are used interchangeably. The current average reliability of combined (SWP and CVP) SOD exports is about 4.94 million acre feet (maf), as shown in Table 7. The average future reliability associated with combined SOD exports, with climate change, is about 4.63 maf (about a 6 percent reduction), indicating that the reliability of the projects are expected to be diminished solely by climate change, assuming no other system changes.

Table 7. Baseline Operations and Combined SWP and CVP Delta Exports

Scenario Description	Operations	Climate	Reliability, Combined Delta Exports (maf)
Current Conditions	Existing Infrastructure Current Regulatory	Historical Hydrology	4.94
Future Without Action	Existing Infrastructure Current Regulatory	Climate-changed hydrology and Sea Level Rise	4.63

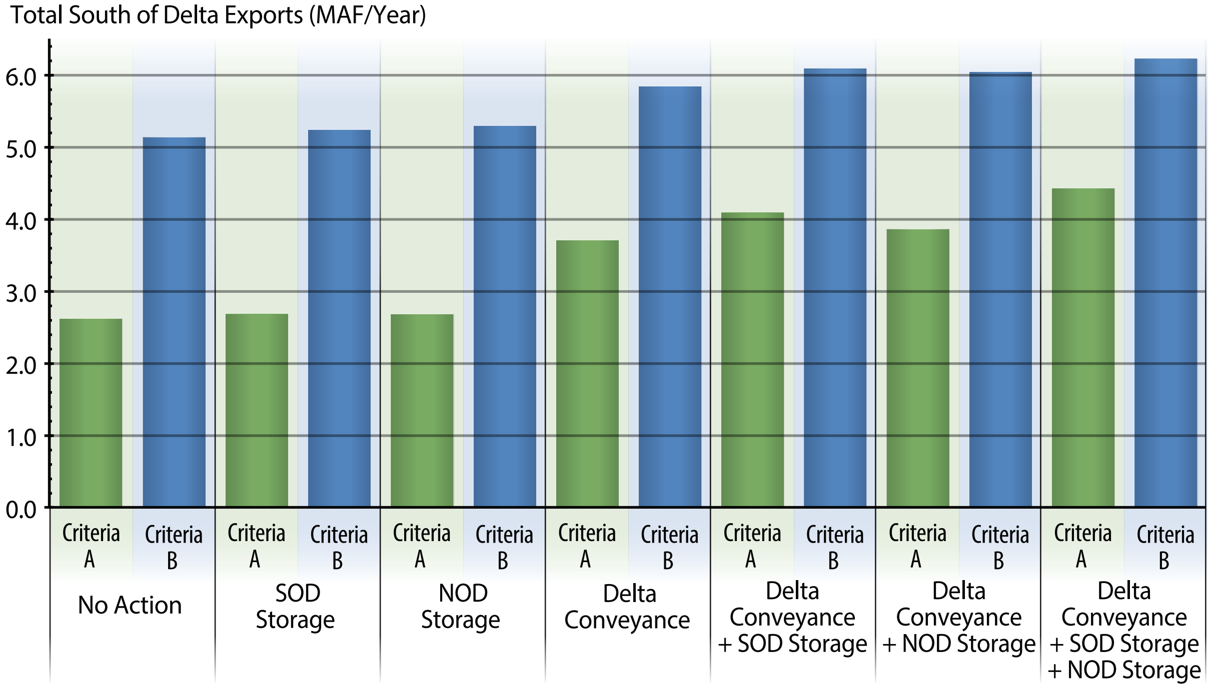
Note: maf = million acre feet.

In addition, various statewide projects might have water available that could be used for replenishment by GSAs in certain locations. Meanwhile, many of these proposed statewide projects are currently developing more refined analyses of project performance than are reflected in the preliminary results shown in Figure 12.

Figure 12 shows the combined South of Delta exports under various future conditions, including two Delta water management regulation criteria (A and B), as well as the possible effects from various potential statewide projects. Criteria A and B are most easily understood by comparing their assumptions with our existing assumptions, which reflect current regulations, including the Biological Opinions and D-1641. Criteria A (see Boundary 2, Final Environmental Impact Report/Environmental Impact Statement for the Bay Delta Conservation Plan/California WaterFix, Appendix 5E, pages 5E-2 ff., DWR and Reclamation, December 2016) includes D-1641, the BiOps (does not include San Joaquin River inflow to export ratio actions), increased Delta outflow (in all months), additional Old and Middle river requirements, and additional closure of the Head of Old River Barrier/Gate. Criteria B (see Boundary 1, same citation as above) includes D-1641 and the BiOps, but does not include the Fall X2 and the San Joaquin River inflow to export ratio actions. These analyses also include the effects of climate change and so can be compared against the Future Without Action scenario's reliability of 4.63 maf.

Changes in future reliability are depicted in the various bar values of Figure 12, and are either associated with changes in Delta water management regulations or proposed statewide projects, or both. No Action — Criteria A assumes the existing infrastructure and a more restrictive Delta regulatory future, resulting in average reliability of 2.61 maf (about a 44 percent reduction) for the combined SOD exports, indicated by the first green bar. No Action — Criteria B assumes the existing infrastructure and a less restrictive Delta regulatory future, resulting in average reliability of 5.13 maf (about a 11 percent increase) for the combined SOD exports, indicated by the first blue bar.

Figure 12. Average Annual South of Delta Exports Under Alternative Regulatory and Management Scenarios



The remaining green and blue bars show the combined South of Delta exports, again assuming Criteria A or B, with various new statewide infrastructure projects, including SOD storage, North Of Delta (NOD) storage, Delta Conveyance, Delta Conveyance and SOD storage, Delta Conveyance and NOD storage, and Delta Conveyance with both NOD and SOD storage. With Criteria A, combined exports range from 2.61 to 4.41 maf (a 44-percent to 5-percent reduction, respectively, when compared to the Future Without Action scenario). With project investments in all new infrastructure options considered, plus Criteria A, exports and reliability are still less than the Future Without Action scenario. With Criteria B, exports range from 5.13 to 6.28 maf (an 11-percent to 36-percent increase, respectively, when compared with the Future Without Action scenario). With project investments in all new infrastructure options considered, plus Criteria B, exports and reliability are increased in all possible infrastructure scenarios, including No Action — Criteria B.

The range of uncertainty in the results presented in Figure 12 shows how environmental requirements and new project capacity (i.e., diversion capacity and storage) influence the water reliability and associated availability to SOD SWP and CVP contractors. This uncertainty is especially important for affected GSAs to understand when developing and planning water portfolio options and groundwater replenishment. Consistent with previously stated assumptions in this report, improvements in reliability of the CVP and SWP may be considered as water available for replenishment, depending on how water managers use the new water.

As noted previously, many statewide projects are being evaluated by project-specific analysis. For project-specific results and statuses, please examine the more refined and detailed project information from the various websites shown in Text Box 7.

Text Box 7. Websites for Statewide Projects

- http://www.water.ca.gov/storage/index.cfm
- http://www.usbr.gov/mp/slwri/
- https://www.usbr.gov/mp/nodos/index.html
- https://www.sitesproject.org/
- https://www.californiawaterfix.com/
- https://www.usbr.gov/mp/vaqueros/index.html
- http://www.ccwater.com/706/los-vaqueros-studies.com/
- http://www.usbr.gov/mp/sccao/storage/

Guidance for GSAs

DWR has developed guidance for GSAs to use in their water available for replenishment planning processes. The guidance to assess and plan water available projects or management actions from each water available method can be found in Appendix C. These water available methods include:

- Surface water, including stormwater
- Recycled water
- Desalination
- Water transfers
- Water conservation

The guidance dedicated to the *for replenishment* methods can be found in Appendix D. The *for replenishment* methods are separated into two categories.

- Active recharge, which includes injection wells or spreading
- In-lieu recharge, which has an indirect recharge effect

The guidance for each method is presented in three sections. First, the method is defined. Then, information specific to the planning and implementation of the method is described. These descriptions will provide an overview of the planning considerations and references that a GSA may need to think about, or should refer to, when developing projects or management actions. Finally, descriptions of successful projects or management actions that, together, have developed water available for replenishment are provided.

While this report focuses on major method categories, DWR also notes specific management actions listed in *California Water Plan Update 2013* that could supplement the surface water method, such as precipitation enhancement; watershed management (including meadow restoration); and other innovative actions. With these types of enhancements, *water available* may be increased.

Findings, This Report, and Methodology

The following lists contain findings, an overview of using this report for GSAs and the State, and a summary of the methodology.

Overview of Findings

- DWR estimates that in total, 1.5 million acre-feet (MAF) of water is available statewide for replenishment of groundwater basins. The estimate is broken down by hydrologic region and the water available for replenishment varies greatly from region to region.

- Getting groundwater basins into a sustainable regime of pumping and recharge will take time and continued commitment on the part of water managers and basin stakeholders. Regions that have for years pumped more groundwater than is replenished — in some cases to the point of causing subsidence, sea water intrusion, or other undesirable effects — must either find other sources of supply or manage with less.

- Effective investments will be required in many locations to produce enough water to meet replenishment needs. Local jurisdictions must take an all-of-the-above approach and develop a diverse water portfolio of conservation, recycling, desalination, additional storage and conveyance, stormwater capture, and transfers. A single method or project will not secure future regional water supply or quality.

- The WAFR estimates in this report indicate a potential range of opportunities, investments, and innovations that may provide a foundation or starting point for local planning. As local planning progresses, analyses will become location- and project-specific, and more comprehensive as entities refine their water available analysis, as required for water right applications, permits, and changes to an existing right. The state and GSAs will need to balance the needs of water users consistent with state law and the need for replenishing groundwater basins.

- Achieving reliability and sustainability requires local, state, and federal agencies to work toward identifying and facilitating appropriate investments in ecosystem restoration, storage, and conveyance, as described in the California Water Action Plan.

Using this Report

- In addition to a "best estimate," this report provides a broader range of WAFR estimates. DWR acknowledges that the water associated with the WAFR estimates shown in this report may be developed for other uses, rather than being dedicated to replenishment, depending on the priorities and needs of water managers and users.

- GSAs should use the information provided in this report and the guidance included in Appendices C and D for direction in developing their description and analysis of the surface water supply used, or available for use, for active groundwater recharge or in-lieu use, as required by California Water Code Section 10727.2 (d)(5).

- WAFR estimates presented in this report can be used to support planning decisions by GSAs, as they consider potential improvements to their water portfolio and water sustainability within their management areas. The estimates indicate that some surface water may be available for replenishment in each of the state's hydrologic regions and many of the planning areas, especially during relatively high-flow events.

- SGMA and GSP regulations specify the requirements of a GSP. The WAFR report does not impose new requirements, but is intended to provide technical assistance for GSAs and/or interested parties to aid in the achievement of sustainable groundwater management. While this report describes methods a GSA may use to identify water available for replenishment, following these methods or any additional guidance in this report does not guarantee approval of the resulting GSP by the Department.

Methodology

- The WAFR estimates were developed by determining outflow using streamflow data and an integrated water resources planning tool that combines information related to precipitation, runoff, water supplies (groundwater and surface water), and water use. A conceptual project that would divert and convey the water was then applied to the outflow estimate. The conceptual project included a project capacity and an instream flow requirement that determined the amount of outflow that could be developed and made available for groundwater replenishment. Therefore, the 1.5 MAF of water DWR estimates is available for replenishment requires new projects to divert and convey the water.

- To underscore the uncertainty associated with the WAFR estimates in this report, DWR is showing a range of values, including a "Best," a "Sensitivity Range," as well as "Maximum" and "No Project" estimates that illustrate the uncertainty and sensitivity associated with conceptual project assumptions for project capacity and instream flow requirement.

- The methodology used in this report may not fully capture competing needs associated with instream flows to support habitat, species (including endangered or threatened species), water quality, and recreation.

- The analytical approach used for this report will not satisfy the State Water Resources Control Board (SWRCB) requirements of a water availability analysis for a water right application, permit, or changes to an existing right. Additional study and data refinement would likely be necessary for such a determination; this information should be developed for specific proposed projects. More detailed analysis at a local level will need to be conducted by the GSAs as part of their GSPs.

- These estimates of water available for replenishment need to be refined by DWR to provide ongoing support and technical assistance to GSAs, and to assist in the review of the WAFR analysis included in GSPs.

State of California
Edmund G. Brown Jr., Governor

California Natural Resources Agency
John Laird, Secretary for Natural Resources

Department of Water Resources
Karla A. Nemeth, Director