Water Available for Replenishment

Appendix A: Water Available for Replenishment Information and Estimates

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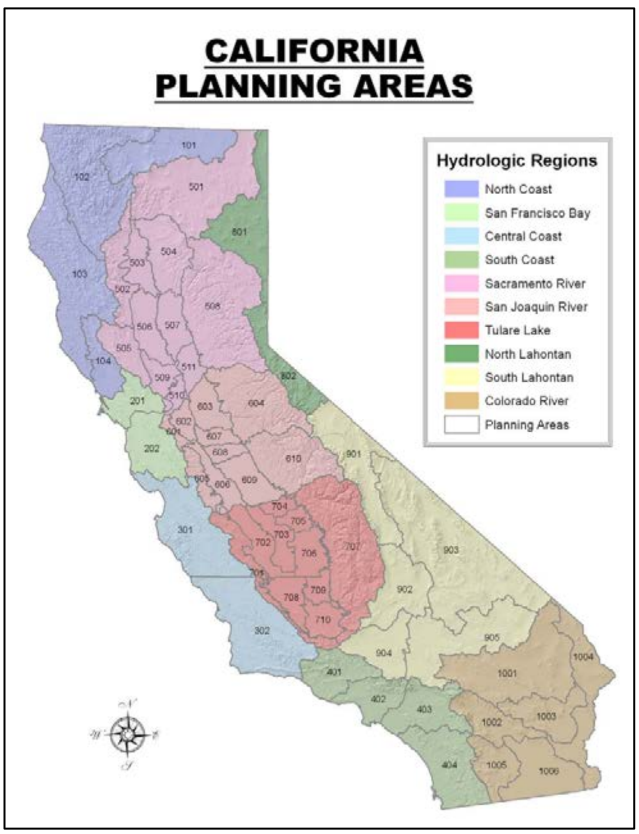
Table of Contents

Introduction

SGMA directed the 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)). The Water Available for Replenishment (WAFR) report provides DWR's estimates of WAFR in the state, based on available information. Groundwater Sustainability Agencies (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 in this appendix. These estimates are provided to indicate the scale of planned water development by urban retailers for each region during this decade.

As part of development of the WAFR Report, a series of technical analyses were conducted to provide DWR's estimates of water available for replenishment in the state, based on available information. An important step in conducting these analyses was to establish existing information and tools. For the purposes of this report, *information* refers to information obtained from existing studies and/or reports, whereas *estimates* refer to the analysis done under this report. WAFR information and estimates, and potential water development by other methods is provided by Hydrologic Region. In addition, WAFR information and estimates are also provided for the State's 56 Planning Areas. California Hydrologic Regions and Planning Areas, as defined by the California Water Plan, are shown in Figure A-I1.

Figure A-I1. California Hydrologic Regions and Planning Areas



Water Available for Replenishment Information and Estimates

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 will not meet requirements of a Water Availability Analysis (WAA), as required 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 Groundwater Sustainability Plans (GSPs).

The organization of this appendix is as follows:

- Introduction section provides background information and discusses limitations of the analysis.
- WAFR Information and Estimates section describes the WAFR information and estimates methodology.
- Potential Water Development by Other Methods section describes the methodology used for estimates of potential water development by other methods (recycled water, desalination and water conservation).
- The remaining sections describe the WAFR information and the estimates and potential water development by other methods by Hydrologic Region (North Coast, San Francisco, Central Coast, South Coast, Sacramento River, San Joaquin River, Tulare Lake, North Lahontan, South Lahontan and Colorado River).

WAFR Information and Estimates

WAFR information and estimates are provided at both the Hydrologic Region and the Planning Area. The data source for the information and the methodology for the estimates are provided in the following sections.

Surface Water and Groundwater Information

Surface Water and groundwater information for the hydrologic region includes regional imports, regional exports, groundwater pumping, natural recharge, and applied recharge. Surface Water information for the planning area includes regional imports and regional exports. Regional imports and regional exports were retrieved from the CalSim II model developed under the State Water Project Delivery Capability Report (DCR) 2015, the California Water Plan Update 2013, DWR Bulletin 132, and other federal, State, or local data. Groundwater pumping and applied and artificial recharge was retrieved from the California Water Plan Update 2013 Water Balances (average of 1998-2010). Natural recharge (average of 1981–2010) was retrieved from the 2017 U.S. Geological Survey (USGS) Basin Characterization Model (BCM) (United States Geological Survey, California Basin Characterization Model 2017). Please note that the groundwater information comes from various sources, does not satisfy a groundwater budget, and is presented for comparison of groundwater information with 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 appendix summarizes the 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.

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 A-SW1). For these reasons, the tools were combined to capture the advantages of each.

Table A-SW1. 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. $$WAFR\ Fraction = \frac{Diversion\ from\ Conceptual\ Project}{Gage\ Data\ Outflow}$$

2. $$WAFR\ Estimate = WAFR\ Fraction \times WEAP\ Outflow$$

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[1] method. 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. The instream flow requirement approach is shown in Figure A-SW1.

3. The conceptual project diversion was determined based on a new conceptual project capacity and the above instream flow requirement (see Figure A-SW2). 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).

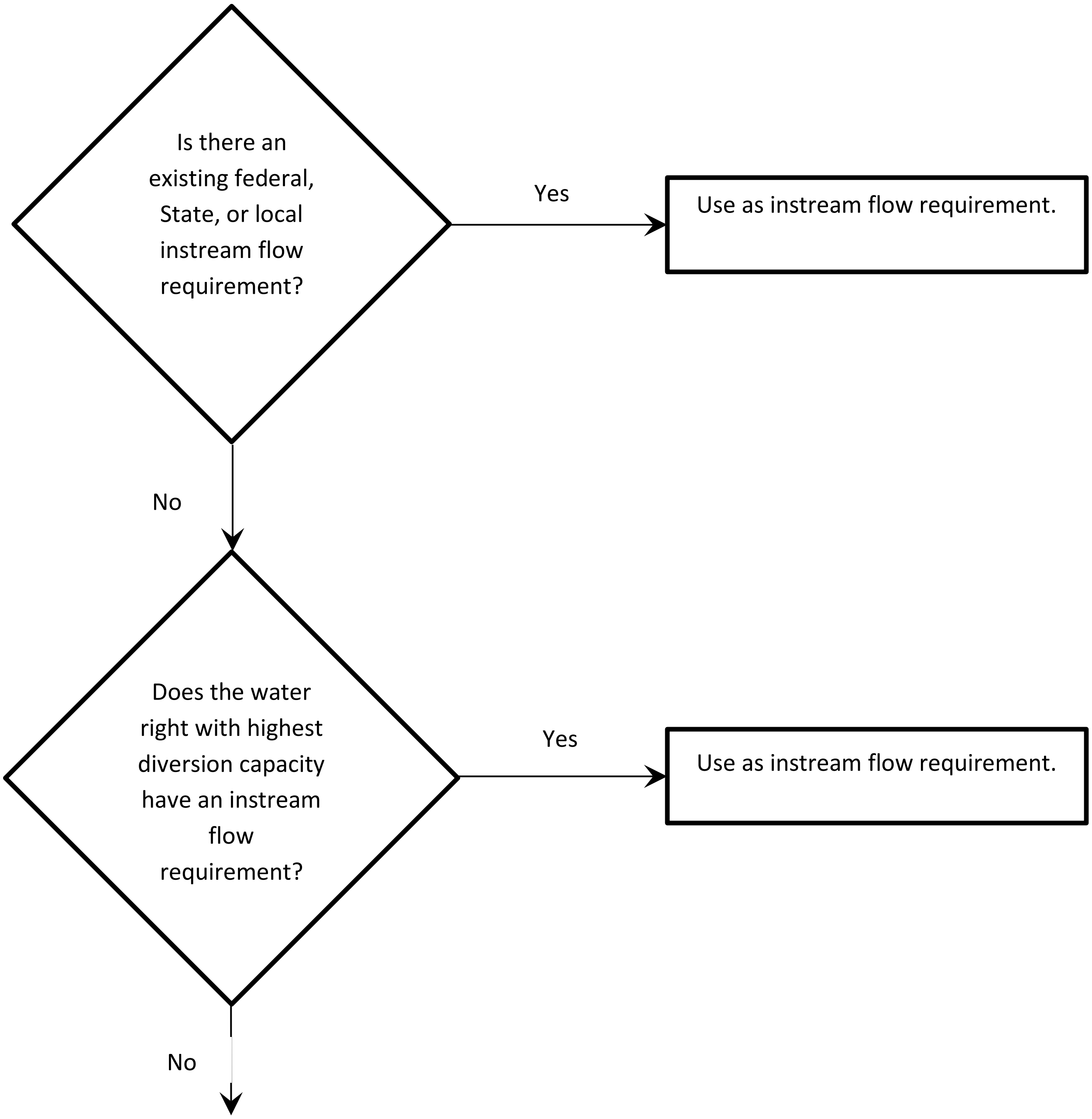
4. WAFR fractions were calculated for each of the streams/rivers.

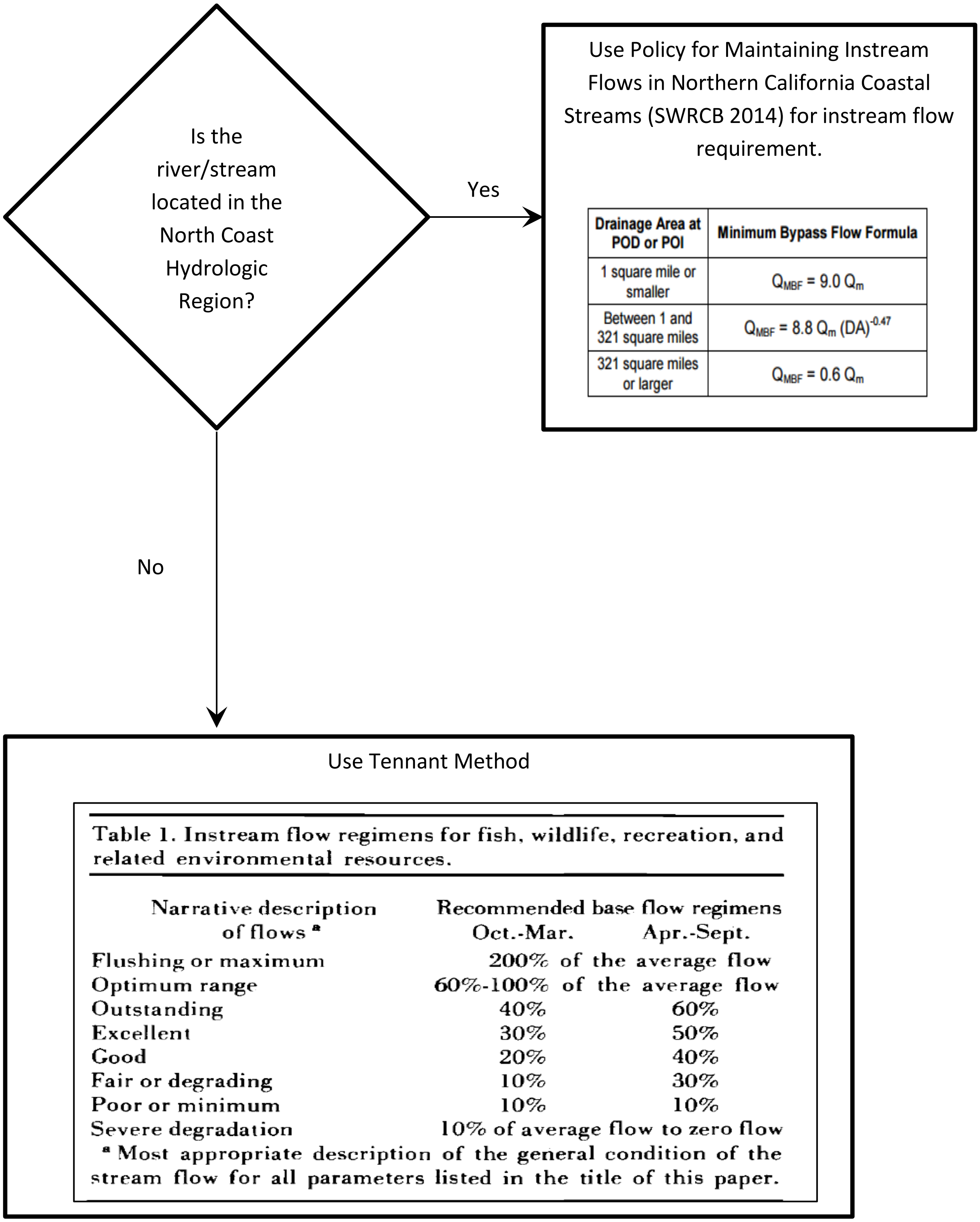
5. The WAFR fractions for all of the gaged streams/rivers were aggregated by hydrologic region. The aggregation process for multiple streams is described below.

Figure A-SW2 and Table A-SW1 show an example application of WAFR fraction development for a two streams, using the Best Estimate Conceptual Project assumptions to determine the conceptual project diversion.

[1] Tennant, D.L. 1975. Instream Flow Regimens for Fish, Wildlife, Recreation and Related Environmental Resources. U.S. Fish and Wildlife Service, Federal Building, Billings, MT. 30 Pages

Figure A-SW1. Instream Flow Requirement Approach





Drainage Area at POD or POI	Minimum Bypass Flow Formula
1 square mile or smaller	$Q_{MBF} = 9.0\ Q_m$
Between 1 and 321 square miles	$Q_{MBF} = 8.8\ Q_m\ (DA)^{-0.47}$
321 square miles or larger	$Q_{MBF} = 0.6\ Q_m$

Table 1. Instream flow regimens for fish, wildlife, recreation, and related environmental resources.

Narrative description of flows [a]	Recommended base flow regimens Oct.-Mar.	Apr.-Sept.
Flushing or maximum	200% of the average flow	
Optimum range	60%-100% of the average flow	
Outstanding	40%	60%
Excellent	30%	50%
Good	20%	40%
Fair or degrading	10%	30%
Poor or minimum	10%	10%
Severe degradation	10% of average flow to zero flow	

[a] Most appropriate description of the general condition of the stream flow for all parameters listed in the title of this paper.

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.

Figure A-SW2. Best Estimate Conceptual Project Application of Water Available for Replenishment for Multiple Streams

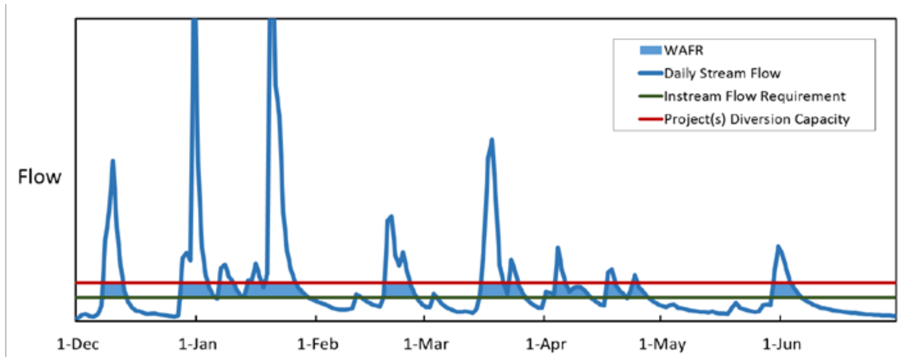


Table A-SW1. Best Estimate Conceptual Project Application of Water Available for Replenishment for Multiple Streams

River /Stream	Current Project Capacity		
	Average Annual Outflow (TAF)	Conceptual Project Diversion (TAF)	WAFR Fraction
Stream 1	400	10	2.5%
Stream 2	230	8	3.6%
Total	**630**	**18**	**2.9%**

The WAFR fraction was aggregated by hydrologic region to have a better representation of the characteristic associated with the general diversions and instream flow requirement happening in the region. Table A-SW1 shows the method using two streams (Stream 1 and 2). Stream 1 has a WAFR fraction of 2.5 percent while Stream 2 has a WAFR fraction of 3.6 percent. For the example streams, using the Best Estimate Conceptual Project, the aggregated gage data outflow is 630 taf, the conceptual project diversion is 18 taf, and the WAFR fraction is 2.9 percent.

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 are described below and shown in Table A-SW2, and contain a range of diversion capacity and instream flow requirement.

The sensitivity range estimates columns 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 A-SW3, A-SW4, and A-SW5 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.

Table A-SW2. Array of Estimates and Conceptual Project Characteristics

Estimate Name	**Conceptual Project Diversion Capacity**	**Conceptual Project Instream Flow Requirement**
Best Estimate	Largest existing project diversion capacity	Existing instream flow requirement
Lower Sensitivity Range Estimate	One half the largest existing project diversion capacity	Two times existing instream flow requirement
Upper Sensitivity Range Estimate	Two times the largest existing project diversion capacity	Existing instream flow requirement
Maximum Estimate	Unlimited capacity	Existing instream flow requirement
No Project Estimate	No Project	No Project

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 A-SW3. Lower Sensitivity Range Estimate (left) Upper Sensitivity Range Estimate (right) Conceptual Projects, with WAFR for Multiple Streams

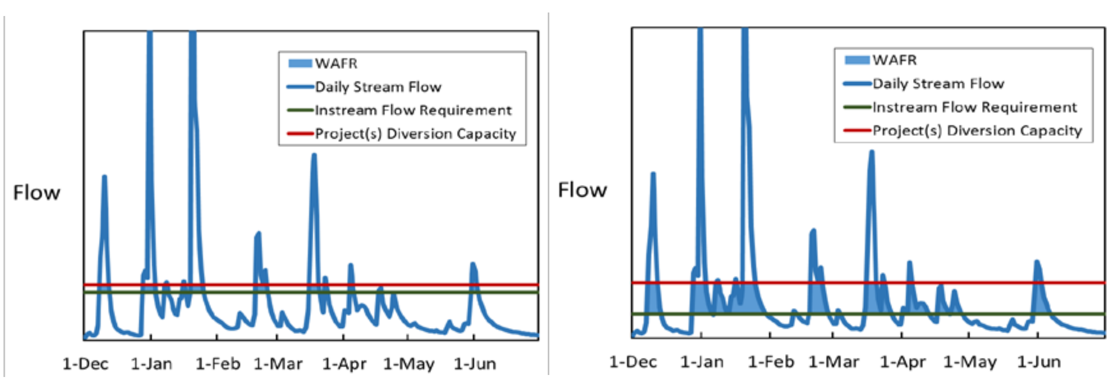


Table A-SW3. Lower and Upper Sensitivity Range Estimate Conceptual Projects for Multiple Streams

River/Stream	Lower Sensitivity Range Estimate. Conceptual Project			Upper Sensitivity Range Estimate. Conceptual Project		
	Average Annual Outflow (TAF)	WAFR (TAF)	WAFR Fraction	Average Annual Outflow (TAF)	WAFR (TAF)	WAFR Fraction
Stream 1	400	5	1.2%	400	18	4.4%
Stream 2	230	3	1.3%	230	12	5.1%
Total	**630**	**8**	**1.2%**	**630**	**29**	**4.6%**

Figure A-SW4. Maximum Project Estimate of water available for replenishment

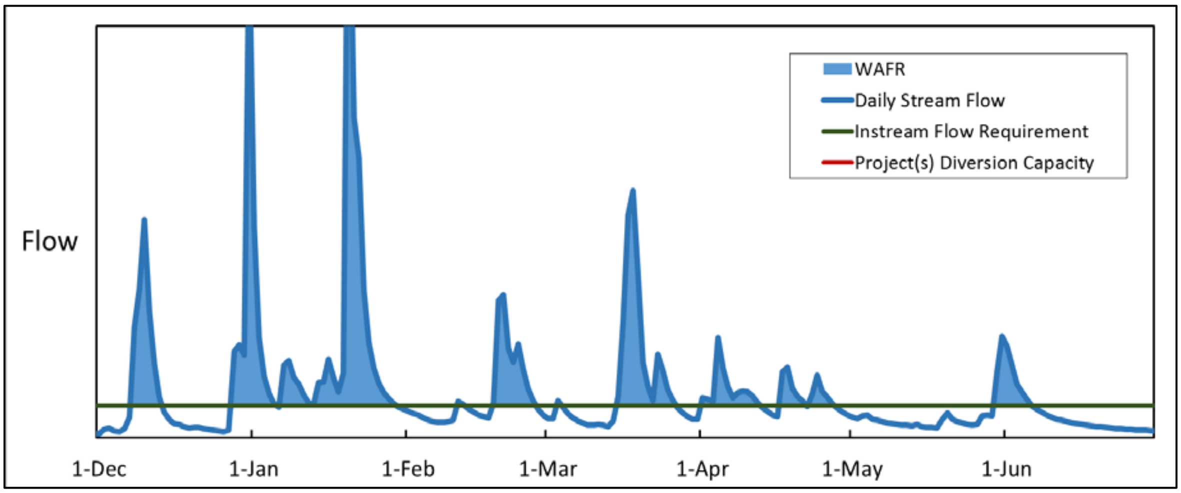


Table A-SW4. Example of Water Available for Replenishment Concept for No Project and Maximum Project and multiple streams

River/Stream	No Project Estimate			Maximum Project Estimate		
	Average Annual Outflow (TAF)	WAFR (TAF)	WAFR Fraction	Average Annual Outflow (TAF)	WAFR (TAF)	WAFR Fraction
Stream 1	400	0	0.0%	400	292	73.0%
Stream 2	230	0	0.0%	230	189	82.5%
Total	**630**	**0**	**0.0%**	**630**	**482**	**76.4%**

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 within the hydrologic region. Table 5 shows the array of WAFR estimates for the example stream, using the water available for replenishment fractions from tables A-SW1, A-SW3, and A-SW4 above.

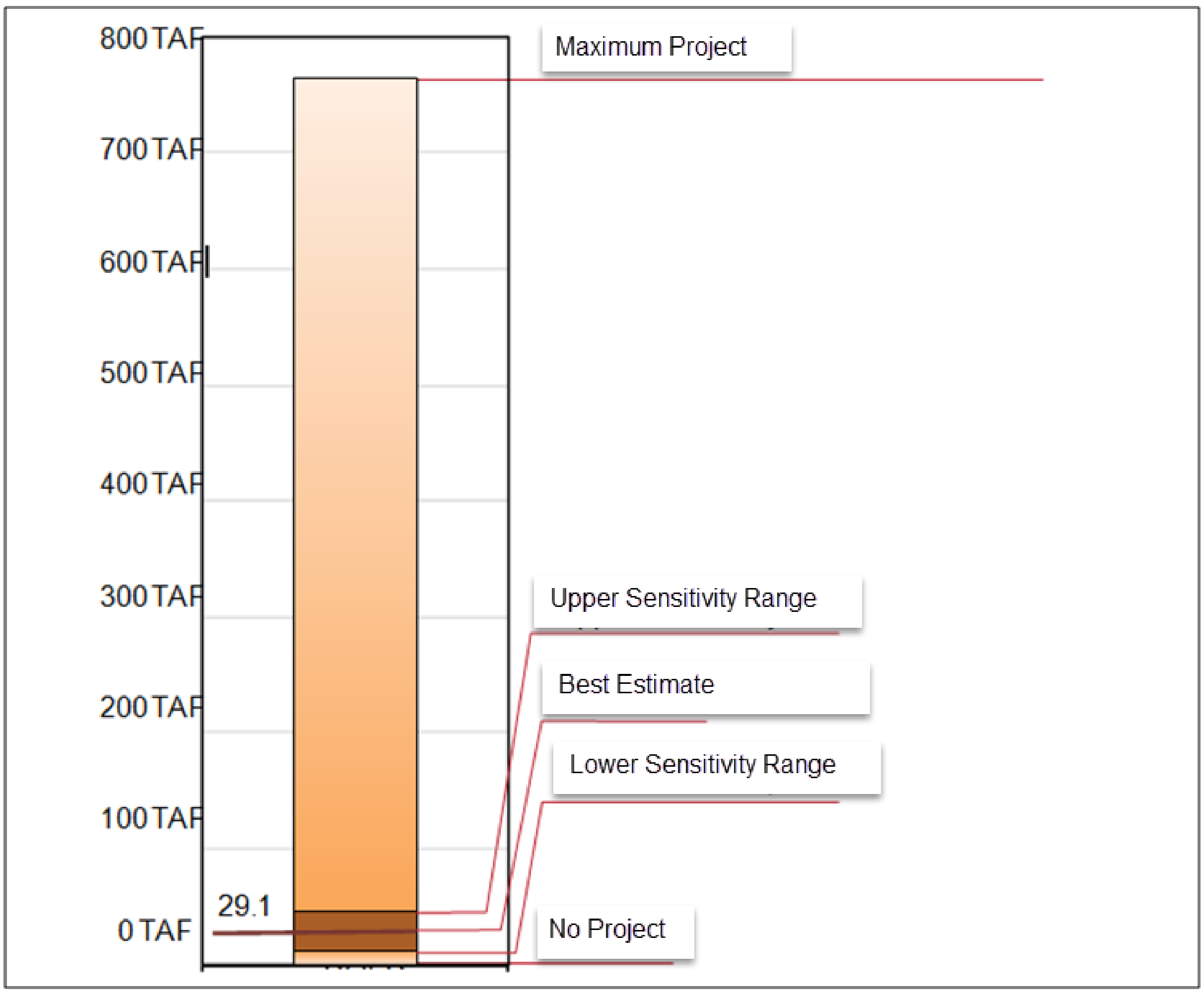
Table A-SW5. Final WAFR estimates Example

WEAP Outflow (taf)	No Project Estimate (taf, WAFR Fraction 0.0%)	Lower Sensitivity Range Estimate (taf, WAFR Fraction 1.2%)	Best Estimate (taf, WAFR Fraction 2.9%)	Upper Sensitivity Range Estimate (taf, WAFR Fraction 4.6%)	Maximum Project Estimate (taf, WAFR Fraction 76.4%)
1,000	0	12	29	46	764

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

Figure A-SW5 presents the “Best Estimate,” the “Sensitivity Range,” as well as the “Maximum Project” and “No Project” WAFR estimates for the example described above.

Figure A-SW5. Schematic example of water available for replenishment array of estimates



This array of estimates is made for each Hydrologic Region of the State and each Planning Area.

Gage Data Method

The Gage Data Method uses daily USGS gage flow data for major rivers and streams within each hydrologic region. For each river and stream, the outflow was assumed to be the most downstream gage in the watershed. Flow at the most downstream gage is assumed to represent the outflow of the stream/river (accounting for upstream diversions and demands).

WEAP Model

The Water Evaluation and Planning (WEAP) system is a comprehensive, fully integrated river basin analysis tool. It is a simulation model that includes a robust and flexible representation of water demands from different sectors, and the ability to program operating rules for infrastructure elements such as reservoirs, canals, and hydropower projects (Yates et al. 2005a, 2005b; Purkey and Huber-Lee 2006; Purkey et al. 2007; Yates et al. 2008; and Yates et al. 2009). Additionally, it has watershed rainfall-runoff modeling capabilities that allow all portions of the water infrastructure and demand to be dynamically nested within the underlying hydrological processes. This integration of watershed hydrology with a water systems planning model makes WEAP suited to study the potential effects of climate change and other uncertainties internal to watersheds. WEAP also provides a comprehensive, flexible, and user-friendly framework for planning analysis.

Overview

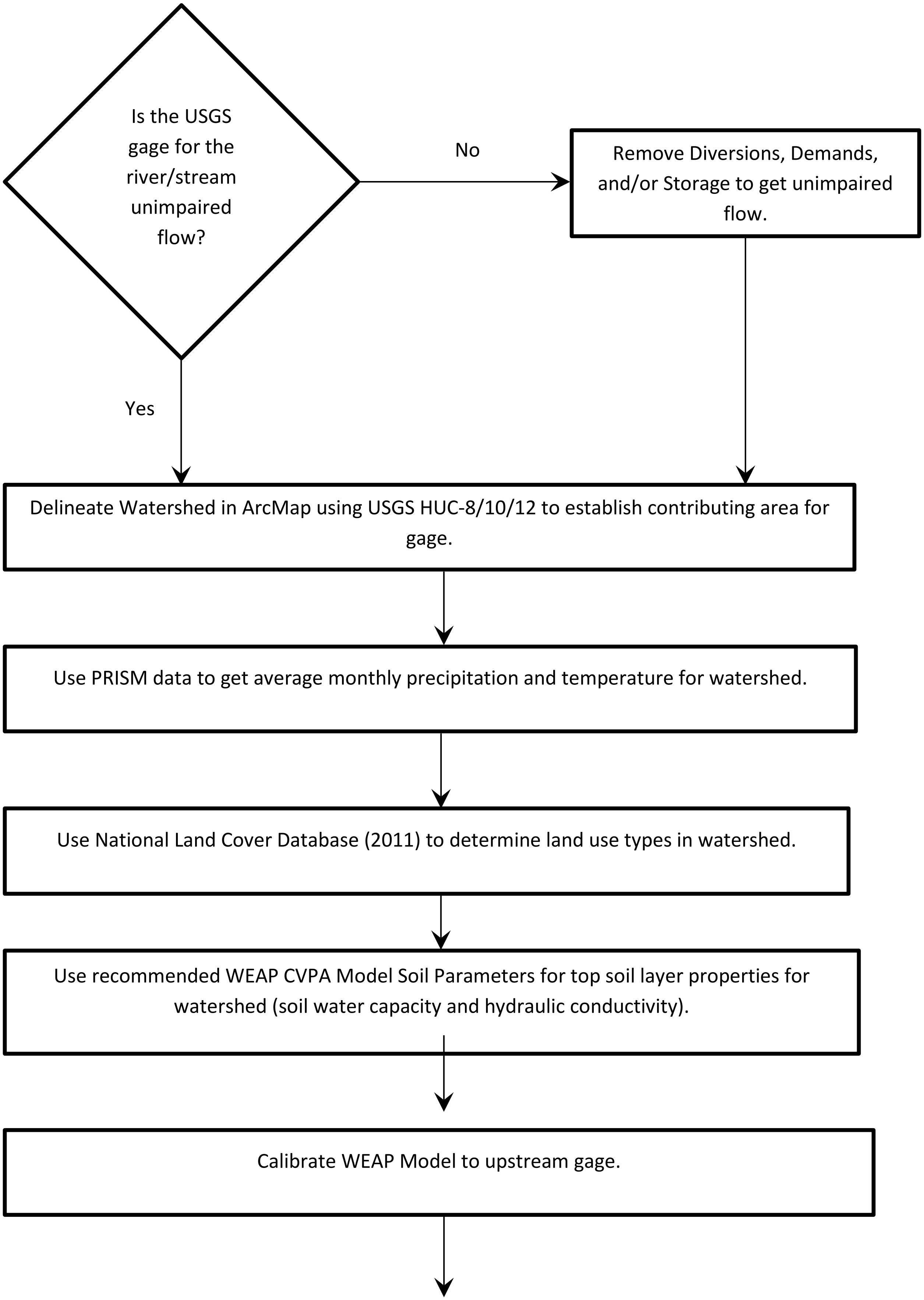
For the Sacramento River, San Joaquin River and Tulare Lake hydrologic regions, the Central Valley Planning Area (CVPA) WEAP Model, developed under the California Water Plan, was used. For the remaining hydrologic regions (North Coast, San Francisco, Central Coast, South Coast, North Lahontan, South Lahontan, and Colorado River), the Statewide Hydrologic Region Model (Statewide HR Model), developed under the California Water Plan, was used as the starting point for this analysis. The Statewide HR models were refined to the Planning Areas using the procedures shown in Figure A-SW6.

Figure A-SW6. WEAP Modeling Procedures

Draw WEAP Schematic and Enter Data

- Rivers/Streams (w/ gage data)
- Reservoirs
- Catchments
- Diversions
- Gage data

Water Available for Replenishment Information and Estimates



Apply the properties of the calibrated watershed(s) to adjacent and downstream watersheds which are similar; average properties of multiple calibrated watersheds can be applied.

↓

Repeat steps above for remaining rivers/streams in Planning Area.

↓

Subtract demands (per Planning Area).

↓

Determine outflow (at Planning Area).

WEAP model functionality and a more detailed description of the steps in the WEAP Modeling Procedures are described in the following sections.

WEAP Water Allocation

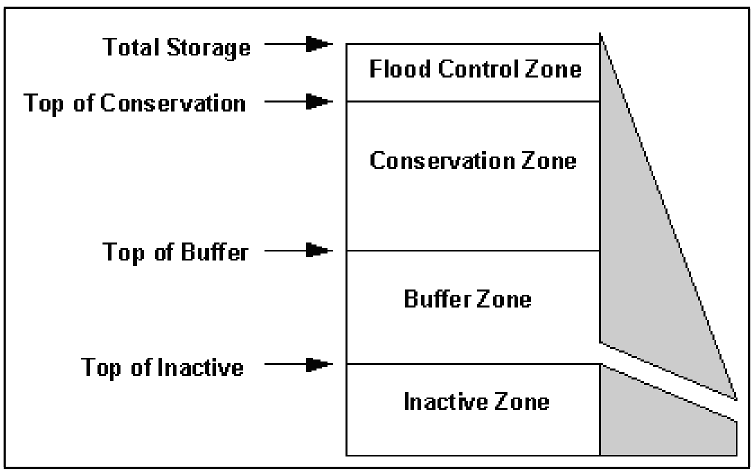
WEAP allocates water based on two user-defined priorities: (1) Demand Priority and (2) Supply Preference. A demand priority is attached to a demand site, catchment, reservoir, or flow requirement, and is ranked from 1 to 99, with 1 being the highest priority and 99 the lowest. Demand sites can share the same priority, which is useful in representing a system of water rights, where water rights are defined by their water usage and/or seniority. In cases of water shortage, higher priority users are satisfied as fully as possible before lower priority users are considered. If priorities are the same, when there is a water shortage, the demand will be equally shared as a percentage of their demands.

When demand sites or catchments are connected to more than one supply source, the order of withdrawal is determined by supply preferences. Similar to demand priorities, supply preferences are ranked between 1 and 99, with lower numbers indicating preferred water sources. The assignment of these preferences usually reflects economic, environmental, historical, legal, and/or political realities. Multiple water sources may be available when a preferred water source is insufficient to satisfy all of an area's water demands. WEAP treats additional sources as supplemental supplies and will draw from these sources only after it encounters a capacity constraint (expressed as either a maximum flow volume or a maximum percent of demand) associated with a preferred water source.

WEAP's allocation routine uses demand priorities and supply preferences to balance water supplies and demands on a monthly time step. To do this, WEAP must assess the available water supplies each time step. While total supplies may be sufficient to meet all of the demands within the system, it is often the case that operational considerations prevent the release of water to do so. These operations are usually intended to preserve water in times of shortage so that long-term delivery reliability is maximized for the highest priority water users (often indoor urban demands). WEAP can represent this controlled release of stored water using its built-in reservoir routines.

WEAP uses generic reservoir objects, which divide storage into four zones, or pools, as illustrated in Figure A-SW7. These include, from top to bottom, the flood-control zone, conservation zone, buffer zone, and inactive zone. The conservation and buffer zones pooled together constitute a reservoir's active storage. WEAP always evacuates the flood-control zone, so that the volume of water in a reservoir cannot exceed the top of the conservation pool. The size of each of these pools can change throughout the year according to regulatory guidelines, such as flood control rule curves.

Figure A-SW7. WEAP Reservoir Zones



WEAP allows reservoirs to freely release water from the conservation pool to fully meet withdrawal and other downstream requirements. Once the reservoir storage level drops into the buffer pool, the release is restricted according to the buffer coefficient, to conserve the reservoir's dwindling supplies. The buffer coefficient is the fraction of the water in the buffer zone available each month for release. Thus, a coefficient close to 1.0 will cause demands to be met more fully, while rapidly emptying the buffer zone. A coefficient close to zero will leave demands unmet, while preserving the storage in the buffer zone. Water in the inactive pool is not available for allocation, although under extreme conditions evaporation may draw the reservoir below the top of the inactive pool.

WEAP Hydrology

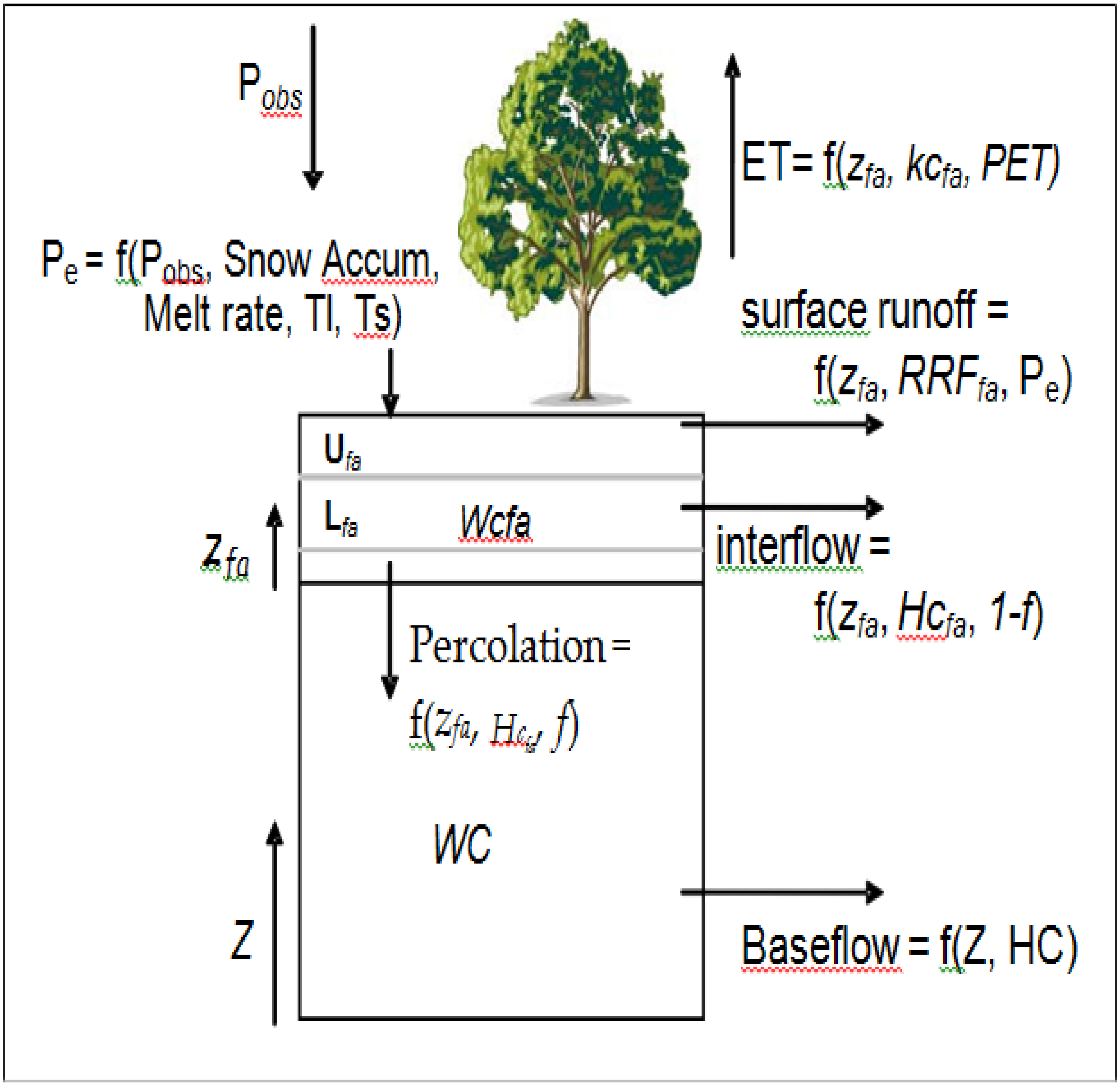
The hydrology module in WEAP is spatially continuous, with a study area configured as a contiguous set of catchments that cover the entire extent of the represented river basin. This continuous representation of the river basin is overlaid with a water management network topology of rivers, canals, reservoirs, demand centers, aquifers, and other features (Yates et al. 2005a and 2005b). Each catchment is fractionally subdivided into a unique set of independent land-use or land-cover classes that lack detail regarding their exact location within the catchment, but which sum to 100 percent of the catchment's area. A unique climate data set of precipitation, temperature, relative humidity, and wind speed is uniformly prescribed across each catchment.

A one-dimensional, quasi-physical water balance model depicts the hydrologic response of each fractional area within a catchment and partitions water into surface runoff, infiltration, evapotranspiration (ET), and interflow, percolation, and baseflow components. Values from each fractional area (fa) within the catchment are then summed to represent the lumped hydrologic response for all land cover classes, with surface runoff, interflow, and baseflow being linked to a river element; deep percolation being linked to a groundwater element where prescribed; and ET being lost from the system.

The hydrologic response of each catchment is depicted by a "two-bucket" water balance model as shown in Figure A-SW8. The model tracks soil water storage, in the upper bucket, z_{fa}, and in the lower bucket, Z. Effective precipitation, P_e, and applied water, AW, are partitioned into evapotranspiration (ET), surface runoff/return flow, interflow, percolation and baseflow.

Effective precipitation is the combination of direct precipitation (P_{obs}) and snowmelt (which is controlled by the temperatures at which snow freezes, T_s, and melts, T_l). Soil water storage in the shallow soil profile (or upper bucket) is tracked within each fractional area, fa, and is influenced by the following parameters: a plant/crop coefficient (kc_{fa}); a conceptual runoff resistance factor (RRF_{fa}); water holding capacity (WC_{fa}); hydraulic conductivity (HC_{fa}); upper and lower soil water irrigation thresholds (Ufa and L_{fa}); and a partitioning fraction, f, which determines whether water moves horizontally or vertically. Percolation from each of these fractional areas contributes to soil water storage (Z) in the deep soil zone (or lower bucket) and is influenced by the following parameters: water holding capacity (WC_{fa}), hydraulic conductivity (HC_{fa}), and the partitioning fraction, f.

Figure A-SW8. Two-Bucket WEAP Hydrology Model



WEAP Water Allocation and Hydrology describe the basic functions of the WEAP model. The following sections describe the data used and how the Statewide HR Model was refined to the Planning Area.

Model Data

The following model data was used in the WEAP model:

- Monthly Precipitation and Temperature Data from the PRISM Climate Group Dataset.
- Relative Humidity and Wind Speed from the Maurer's Dataset, consistent with the CA Water Plan.
- National Land Cover Database (2011) to define the land use types.
- United States Geological Services (USGS) Gage Data.
- Existing Reservoirs.

The NLCD land use types were re-classified to correspond with the CVPA WEAP Model as shown in Table A-SW6.

Table A-SW6. Reclassified NLCD Land Use Types to CVPA WEAP Model Land Use Types

NLCD Land Use Type		CV PA WEAP Model Land Use Types	Description
Developed			
21	**Developed, Open Space**	**Developed Open Space**	Areas with a mixture of some constructed materials, but mostly vegetation in the form of lawn grasses. Impervious surfaces account for less than 20% of total cover. These areas most commonly include large-lot single-family housing units, parks, golf courses, and vegetation planted in developed settings for recreation, erosion control, or aesthetic purposes.
22	**Developed, Low Intensity**	**Urban Low Intensity**	Area with a mixture of constructed materials and vegetation. Impervious surfaces account for 20% to 49% percent of total cover. These areas most commonly include single-family housing units.
23	**Developed, Medium Intensity**	**Urban Medium Intensity**	Areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 50% to 79% of the total cover. These areas most commonly include single-family housing units.
24	**Developed High Intensity**	**Urban High Intensity**	Highly developed areas where people reside or work in high numbers. Examples include apartment complexes, row houses and commercial/industrial. Impervious surfaces account for 80% to 100% of the total cover.
Barren			
31	**Barren Land (Rock/Sand/Clay)**	**Barren**	Area of bedrock, desert pavement, scarps, talus, slides, volcanic material, glacial debris, sand dunes, strip mines, gravel pits and other accumulations of earthen material. Generally, vegetation accounts for less than 15% of total cover.

Forest			
41	**Deciduous Forest**	**Forested**	Areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. More than 75% of the tree species shed foliage simultaneously in response to seasonal change.
42	**Evergreen Forest**	**Forested**	Areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. More than 75% of the tree species maintain their leaves all year. Canopy is never without green foliage.
43	**Mixed Forest**	**Forested**	Areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. Neither deciduous nor evergreen species are greater than 75% of total tree cover.
Shrubland			
51	**Dwarf Scrub**	**Non Forested**	Alaska only areas dominated by shrubs less than 20 centimeters tall with shrub canopy typically greater than 20% of total vegetation. This type is often co-associated with grasses, sedges, herbs, and non-vascular vegetation.
52	**Shrub/Scrub**	**Non Forested**	Areas dominated by shrubs; less than 5 meters tall with shrub canopy typically greater than 20% of total vegetation. This class includes true shrubs, young trees in an early successional stage, or trees stunted from environmental conditions.
Herbaceous			
71	**Grassland/Herbaceous**	**Non Forested**	Areas dominated by gramanoid or herbaceous vegetation, generally greater than 80% of total vegetation. These areas are not subject to intensive management such as tilling, but can be utilized for grazing.

72	**Sedge/Herbaceous**	**Non Forested**	Alaska only areas dominated by sedges and forbs, generally greater than 80% of total vegetation. This type can occur with significant other grasses or other grass like plants, and includes sedge tundra, and sedge tussock tundra.
73	**Lichens**	**Non Forested**	Alaska only areas dominated by fruticose or foliose lichens generally greater than 80% of total vegetation.
74	**Moss**	**Non Forested**	Alaska only areas dominated by mosses, generally greater than 80% of total vegetation.
Planted/Cultivated			
81	**Pasture/Hay**	**Agricultural Land**	Areas of grasses, legumes, or grass-legume mixtures planted for livestock grazing or the production of seed or hay crops, typically on a perennial cycle. Pasture/hay vegetation accounts for greater than 20% of total vegetation.
82	**Cultivated Crops**	**Agricultural Land**	Areas used for the production of annual crops, such as corn, soybeans, vegetables, tobacco, and cotton, and also perennial woody crops such as orchards and vineyards. Crop vegetation accounts for greater than 20% of total vegetation. This class also includes all land being actively tilled.
Wetlands			
90	**Woody Wetlands**	**Non Forested**	Area where forest or shrubland vegetation accounts for greater than 20% of vegetative cover and the soil or substrate is periodically saturated with or covered with water.
95	**Emergent Herbaceous Wetlands**	**Non Forested**	Areas where perennial herbaceous vegetation accounts for greater than 80% of vegetative cover and the soil or substrate is periodically saturated with or covered with water.

Streams/Rivers and Delineation of Watershed

Streams/rivers were represented in the WEAP model using a River node. Watersheds were represented in the WEAP model using a Catchment node. Watersheds were delineated to represent the runoff into the stream. For delineation of watersheds, the USGS Hydrologic Unit (HUC) 8, 10, and 12 were used, herein referred to as USGS HUC. Watersheds were strategically delineated to represent how water flows in the region. Reservoirs were considered when delineating watersheds. When determining reservoir inflow, it was ensured that only the contributing area to the reservoir was included when delineating the watershed. Watershed delineation was separated into two distinct watersheds: (1) calibrated watersheds and (2) adjacent and downstream watersheds.

For calibrated watersheds, the USGS HUC was used in conjunction with the PRISM data to calculate the average monthly precipitation, monthly temperature, and land use type. In cases where the USGS HUC area was larger than the contributing gage area, the contributing watershed gage area was used; it was assumed that the USGS contributing watershed gage area is proportionally represented by the same land use types as the USGS HUC. Once the watershed was calibrated with observed streamflow, the properties of the calibrated USGS gage area were applied to adjacent and downstream watersheds.

For adjacent and downstream watersheds, the USGS HUC was also used. Multiple USGS HUC watersheds were combined using engineering judgment, and WEAP catchment parameters were identified using similar watershed properties as the upstream or adjacent calibrated watersheds. The combined USGS HUC was used to get the average precipitation, temperature and NLCD land use types, similar to the methodology that was used for the calibrated watersheds. The area for two land use types, Developed, Open Space and Cultivated Crops, were excluded from adjacent and downstream watersheds because demands associated with these land use types were included in the Urban Outdoor Demand and Agricultural Demand, respectively. Both these demands will be discussed in greater detail in the following sections.

Reservoir Representation

Existing reservoirs were included in the WEAP models. Reservoir characteristics were based off available information from federal, State, or local data.

Imports

Various Hydrologic Regions receive water from other regions. Imports for the SWP and CVP were determined from the CalSim II model from the State Water Project Delivery Capability Report 2015 for the years 1967–2003. DWR Bulletin 132 Historical SWP deliveries were used for the years 2003–2012. The California Water Plan Update 2013 Water Balances were used to determine what portion of the total water contractor deliveries go to each Planning Area. Other federal, State, or local data was used to determine other imports (i.e., Colorado River).

Demands

Three demands were considered in the WEAP model: (1) Urban Indoor, (2) Urban Outdoor and (3) Agricultural. These demands are described in greater detail in the following sections.

Urban Demand
Urban Indoor and Outdoor Demand is represented in the same manner as the Statewide HR model.

Urban Indoor Demand
The Urban Indoor Demand was divided into the following categories:

- Single-family (SF) households.
- Multifamily (MF) households.
- Commercial employees.
- Industrial employees.

The annual activity level and annual water Use Rate is fixed and based on the Year 2010 for each Planning Area. It was assumed that 25% of all Urban Indoor demand is consumed and 75% is returned back to the system as return flow.

Urban Outdoor Demand
Urban Outdoor demand is estimated using the WEAP hydrology module, and is a function of irrigated landscape area (assumed to be turf), water-use rate factors, parameters defining soil and landscape characteristics, and climate. DWR estimated the irrigated landscape area independently for four urban land use classes: (1) SF households, (2) MF households, (3) commercial, and (4) large landscape. The area for each land use class is based on the Year 2001 and defined for each Planning Area.

Agricultural Demand
Agricultural Demand is also represented in the same manner as the Statewide HR model. Irrigated agricultural demand is estimated using the WEAP hydrology module and is a function of the irrigated area of 20 different crop types, parameters defining soil and land cover characteristics. The 20 crop types are shown in Table A-SW7. The area for each crop type is based on the Year 2010 for each PA.

Table A-SW7. Crop Types

No.	Crop Category
1	Grain
2	Rice
3	Cotton
4	Sugar Beet
5	Corn
6	Dry Bean
7	Safflower
8	Other Field
9	Alfalfa
10	Pasture
11	Processed Tomato
12	Fresh Tomato
13	Cucurbits
14	Onion and Garlic
15	Potato
16	Other Truck
17	Almond and Pistachio
18	Other Deciduous
19	Sub-Tropical
20	Vine

Connecting Supplies and Demands

The demands (Urban Indoor, Urban Outdoor and Ag) are connected at the most downstream location of the stream. The demand with the highest priority (closer to 1) will be met first. The supply with the highest preference (closer to 1) will be used first to meet the demand. The demand priorities and supply preferences are shown in Table A-SW8 and Table A-SW9, respectively.

Table A-SW8. WEAP Demand Priorities

Demand	Priority
Urban Indoor	1
Urban Outdoor	2
Agricultural	2

Table A-SW9. WEAP Supply Preferences

Water Source	Preference
SWP/CVP Imports	1
River/Stream Runoff	2

Return flow from the Urban Indoor Demand and runoff from the Urban Outdoor and Agricultural Demand is equally proportioned to the streams within the Planning Area. Further refinement is needed to better quantify how much each stream contributes to meeting the Planning Area demands.

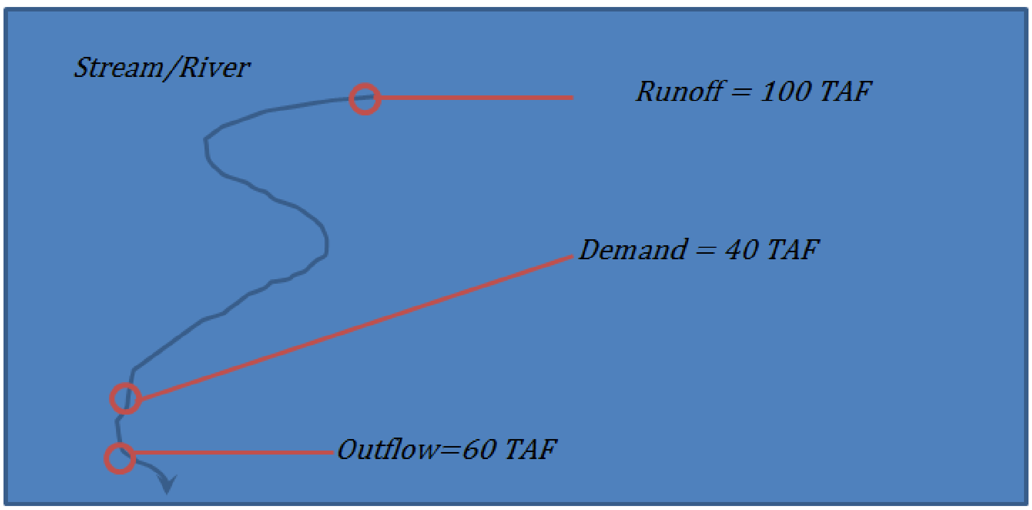
Computation Time and Time Step

The WEAP Model and its inputs were run on a monthly time step from 1967–2012.

WEAP Outflow

Outflow from the WEAP model is determined by summing up the remaining water for each stream after the demands have been removed. In the simplest form (assuming no reservoirs, imports, etc.), the outflow is determined as shown in Figure A-SW9.

Figure A-SW9. WEAP Outflow Concept



Calibration

The calibration process includes setting soil parameters for defined catchments so that WEAP can accurately simulate rainfall-runoff using input climate data. Calibration was done at the most upstream gage on the stream to ensure that the flow was mostly unimpaired (no effect of reservoir, diversion, etc.). If the most upstream gage was immediately downstream of a reservoir, the inflow into the reservoir was calculated by using the following formula: Inflow = Change in Storage + Outflow.

It was important to spatially represent each Planning Area with calibrated watersheds to ensure calibrated watersheds were within close proximity of adjacent and downstream watersheds because similar watershed properties were used for adjacent and downstream watersheds.

Calibration Procedures

The following steps were used to calibrate the simulated streamflow to the observed streamflow at the most upstream gage:

1. Retrieve monthly streamflow at upstream gage location from USGS/CDEC
2. Determine total contributing watershed area to gage per USGS
3. Determine land use types in contributing watershed area per NLCD
4. Use Central Valley Planning Area WEAP Model as starting point for soil parameters for each land use type. Values are shown in Table A-SW11.

Figure A-SW11. Central Valley PA Model Land Cover Classifications and Final Parameters

	Soil Water Capacity (inches)	Hydraulic Conductivity (inches/month)	Runoff Resistance Factor	Irrigated
Urban				
Low-Intensity	4	8	1.0	No
Medium-Intensity	4	8	1.0	No
High-Intensity	4	8	1.0	No
Commercial Landscape	14	6	5.0	Yes
Residential Landscape	14	6	5.0	Yes
Natural Vegetation				
Forested	28	6	4.0 to 7.0	No
Non-Forested	18	8	5.0	No
Barren	10	10	3.5	No
Agriculture				
Pasture	20	5	6.0	Yes
Cultivated	26	8	4.0	Yes

5. Modify soil parameters within reasonable range to match simulated streamflow to observed streamflow and ensure Nash Sutcliffe Coefficient of Efficiency (NSE) is 0.6 or above and Percent Bias (PBIAs) is within -15 to 15 percent. NSE is commonly used in hydrologic modeling to evaluate how well modeled stream flow matches observed. The NSE indicates how well a plot of observed versus simulated data fits to a 1:1 line. NSE ranges from -∞ to 1.0. If NSE=1, there is a perfect match between the observed and modeled, if NSE=0, the modeled is only as good as the observed mean of the data, and NSE <0 indicates the model performs worse than the mean. Generally in hydrologic modeling, NSE > 0.6 is desired, while NSE > 0.8 is good. PBIAS as a measure of the model's ability to match the total volume of flow or the cumulative flow volume error relative to observed volume, usually referred to as water balance error (%WBL) in hydrologic modeling literature. In general, lower values of PBIAS indicate better model performance.

Potential Water Development by Other Methods (recycled water, desalination and water conservation)

Potential water development by other methods (recycle, desalination, and water conservation) is provided at the Hydrologic Region. The data source for the information and the methodology for the estimates are provided in the following sections.

Urban Water Portfolio Actions

GSAs can and should consider water available from other methods such as recycle, desalination, and water conservation when developing WAFR. Estimates of potential water development by other methods are presented in this section and are called urban water portfolio actions estimates. The estimates are based from the California Water Plan Update 2013 (Update 2013), Urban Water Management Plan 2010 (UWMP 2010) and 2015 (UWMP 2015) and other mandates from the State. These estimates are provided to indicate the scale of planned water development by urban retailers for each region during this decade.

Water Conservation

Three sources of data were used to estimate potential water development from water conservation:

1. California Water Plan Update 2013
2. Urban Water Management Plan 2010
3. Urban Water Management Plan 2015 (Accessed: Dec. 12th, 2016)

The urban water management plans (UWMPs) are prepared by California's urban water suppliers to support their long-term resource planning, and ensure adequate water supplies are available to meet existing and future water demands.

Every urban water supplier that either provides over 3,000 acre-feet of water annually, or serves more than 3,000 urban connections is required to assess the reliability of its water sources over a 20-year planning horizon, and report its progress on 20% reduction in per-capita urban water consumption by the year 2020, as required in the Water Conservation Bill of 2009 SBX7-7.

The water conservation estimates were calculated by taking the difference of the 2020 targeted water usage and the 2010 usage reported in the UWMPs.

The 2010 water conservation quantity for each hydrologic region were calculated by using the 2010 population from the CWP 2013 and the water use in gallons per capita per day (GPCD) from the UWMP 2010. The results are calculated in annual million acre-feet (maf) and are presented in Table A-OM1.

Table A-OM1. 2010 CWP Population and Water Usage

Hydrologic Region	2010 Population (CWP 2013)	2010 Water Usage (GPCD) (UWMP 2010)	2010 Water Usage (maf*)
North Coast	671,344	149	0.11
San Francisco Bay	6,345,194	154	1.09
Central Coast	1,528,708	145	0.25
South Coast	19,579,208	187	4.10
Sacramento River	2,983,156	272	0.91
San Joaquin River	2,104,206	236	0.56
Tulare Lake	2,267,335	283	0.72
North Lahontan	96,910	265	0.03
South Lahontan	930,786	256	0.27
Colorado River	747,109	399	0.33

*maf = million acre-feet

The 2020 targeted water conservation quantity for each hydrologic regions were calculated by using the 2020 current trend population from CWP 2013 and 2020 confirmed target of water use in GPCD from the UWMP 2015 (retrieved: Dec 12th, 2016, and still being updated) were used to estimate the water conservation by hydrologic regions by 2020. The results were calculated in maf and are presented in Table A-OM2.

Table A-OM2. 2010 CWP Population and Water Usage and 2020 Water Usage

Hydrologic Region	2010 Population (CWP 2013)	2010 Water Usage (GPCD) (UWMP 2015, results retrieved on Dec 12th, 2016 and still updated)	2020 Annual Water Usage (maf*)
North Coast	671,344	134	0.11
San Francisco Bay	6,345,194	143	1.08
Central Coast	1,528,708	133	0.24
South Coast	19,579,208	163	3.86
Sacramento River	2,983,156	210	0.78
San Joaquin River	2,104,206	166	0.45
Tulare Lake	2,267,335	221	0.67
North Lahontan	96,910	236	0.03
South Lahontan	930,786	204	0.25
Colorado River	747,109	323	0.34

*maf-million acre-feet

The difference between the 2010 and 2020 annual water usage provides the potential water conservation development estimates and can be found on Table A-OM3.

Table A-OM3. 2010 and 2020 Annual Water Usages and Estimates of Water Conservation

Hydrologic Region	2010 Annual Water Usage (maf*)	2020 Annual Water Usage (maf*)	Estimates of Water Conservation Increase from 2010 to 2020 (maf*)
North Coast	0.11	0.10	0.01
San Francisco Bay	1.09	1.07	0.02
Central Coast	0.25	0.24	0.01
South Coast	4.10	3.86	0.24
Sacramento River	0.91	0.78	0.13
San Joaquin River	0.56	0.45	0.11
Tulare Lake	0.72	0.67	0.05
North Lahontan	0.03	0.03	0.00
South Lahontan	0.27	0.26	0.01
Colorado River	0.33	0.33	0.00
Total	**8.37**	**7.79**	**0.58**

*maf = million acre-feet

Recycled Water

Two sources of data were used to estimate potential water development from recycled water:

1. 2009 Municipal Wastewater Recycling Survey Results. Reported to State Water Board on November 1, 2011.
2. Urban Water Management Plan 2010 reported in the Water Plan Update 2013.

The 2009 Municipal Wastewater Recycling Survey Results were collected by the SWRCB during the period of January, 2009, to December 31, 2009. This statewide survey was assumed to be very similar to the 2010 level of recycle for the determination of the estimates.

From the survey, the SWRCB established a mandate to increase the use of recycled water in California by 200 thousand acre-feet (taf) by 2020 and by an additional 300 taf by 2030. The 200 taf of increase in recycled water by 2020 was distributed by hydrologic region using the 2009 municipal wastewater recycling results and DWR's goal for 2020 as reported in the California Water Plan 2013. Table A-OM4 presents this information and distribution of the statewide 200 TAF.

Table A-OM4. Summary of Recycled Water

Hydrologic Region	2009 Municipal Wastewater Recycling Survey Results (taf*)	2020 DWR Target (taf*)	Distribution of the SWRCB 2020 Statewide mandate to Hydrologic Regions (taf*)	Estimates of Recycled Water Increase from 2010 to 2020 (taf*)
North Coast	25.8	36.0	32.1	6.3
San Francisco Bay	48.4	86.0	71.5	23.1
Central Coast	23.5	30.0	27.5	4.0
South Coast	353.9	519.0	455.5	101.6
Sacramento River	12.4	40.0	29.4	17.0
San Joaquin River	29.3	70.0	54.3	25.0
Tulare Lake	130.2	149.0	141.8	11.6
North Lahontan	4.9	6.0	5.6	0.7
South Lahontan	26.5	35.0	31.7	5.2
Colorado River	14.1	23.0	19.6	5.5
Total	**669.0**	**994.0**	**869.0**	**200.0**

*taf = thousand acre-feet

Desalination

One source of data was used to estimate potential water development from desalination:

1. California Water Plan Update 2013

The CWP Update 2013 provides a table which summarizes desalination projects in three categories: "In operation," "in design and construction," and "proposed."

Figure A-OM1. CWP Update 2013 Summary of California Desalting

Table 10-6 Summary of California Desalting, 2013

General Source Water Designation	In Operation			In Design and Construction		Proposed	
	NO. OF PLANTS	2010 PRODUCTION	ANNUAL CAPACITY	NO. OF PLANTS	ANNUAL CAPACITY	NO. OF PLANTS	ANNUAL CAPACITY
Brackish groundwater	23	79,812	139,627	3	9,050	17	74,629
Brackish surface water	0	0	0	0	0	1	22,403
Ocean water	3	130	562	1	56,007	15	381,791
Total	**26**	**79,942**	**140,189**	**4**	**65,057**	**33**	**478,823**
Cumulative	**--**	**--**	**--**	**30**	**205,246**	**63**	**684,069**

Note: Production and capacity are in acre-feet per year.

The desalination estimates for this report are calculated by examining the desalination projects put in operations between 2010 and 2020. The table above from the CA Water Plan was inspected specifically under the “in design and construction” and “proposed” categories.

Table A-OM5 shows the estimates of desalination increase from 2010 to 2020 in TAF by hydrologic region.

Table A-OM5. 2010 to 2020 Estimates of Desalination Increase by Hydrologic Region

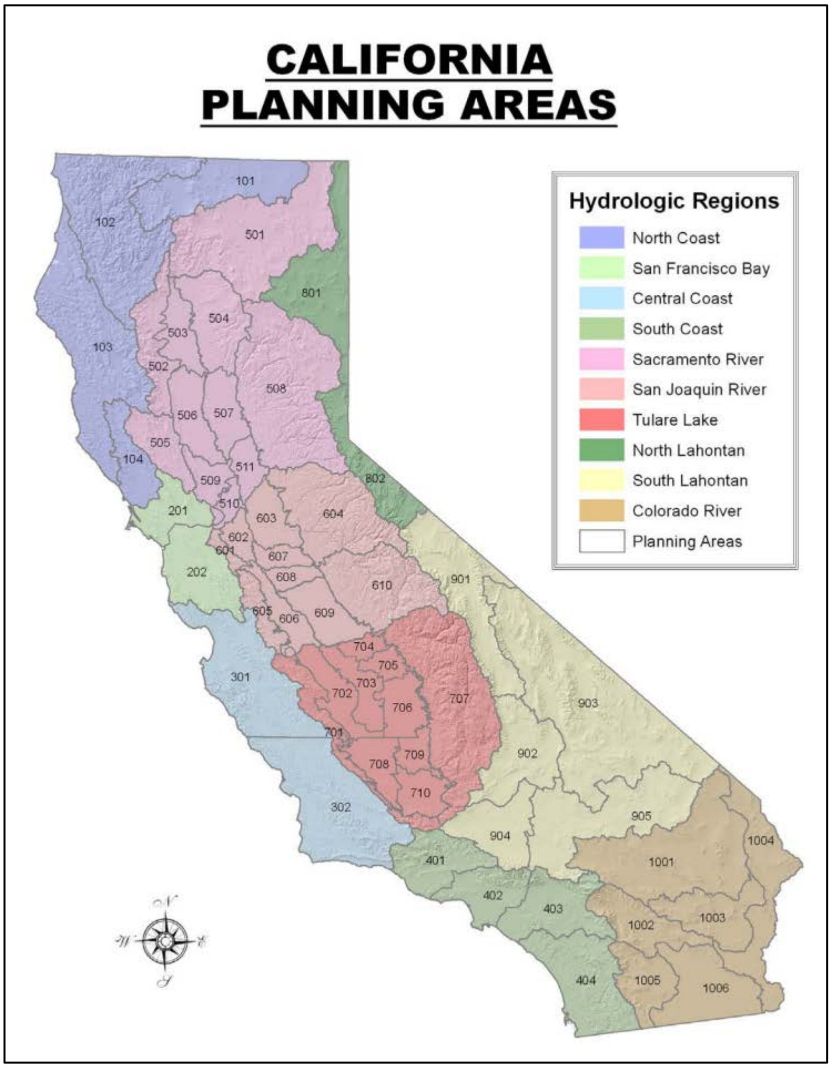
Hydrologic Region	Estimates of Desalination Water Increase from 2010 to 2020 (TAF)
Central Coast	24.2
South Coast	313.7
Total	**337.8**

North Coast Hydrologic Region

The North Coast Hydrologic Region (HR) covers a total of 19,390 square miles, spanning from the Oregon border in the north and to the northern end of Marin County in the south. This is the wettest HR in the state with an average precipitation of 50 inches, primarily falling as rain, with snow in the high Klamath Mountains and Cascades. The bulk of water leaving the HR goes to the ocean, with some water exported into the Sacramento River HR by way of the Clear Creek Tunnel out of Lewiston Reservoir, and some exported to the San Francisco HR by the Petaluma Aqueduct. The region is sparsely populated; major population centers include Eureka, Santa Rosa, and Ukiah. The North Coast HR has the largest environmental flow requirements of any hydrologic region, with the three largest rivers being designated Wild and Scenic for most of their length (California Water Plan 2013).

The North Coast is divided into four Planning Areas: Planning Area 101 (PA 101) Planning Area 102 (PA 102), Planning Area 103 (PA 103), and Planning Area 104 (PA 104) which are shown in Figure A-NC1.

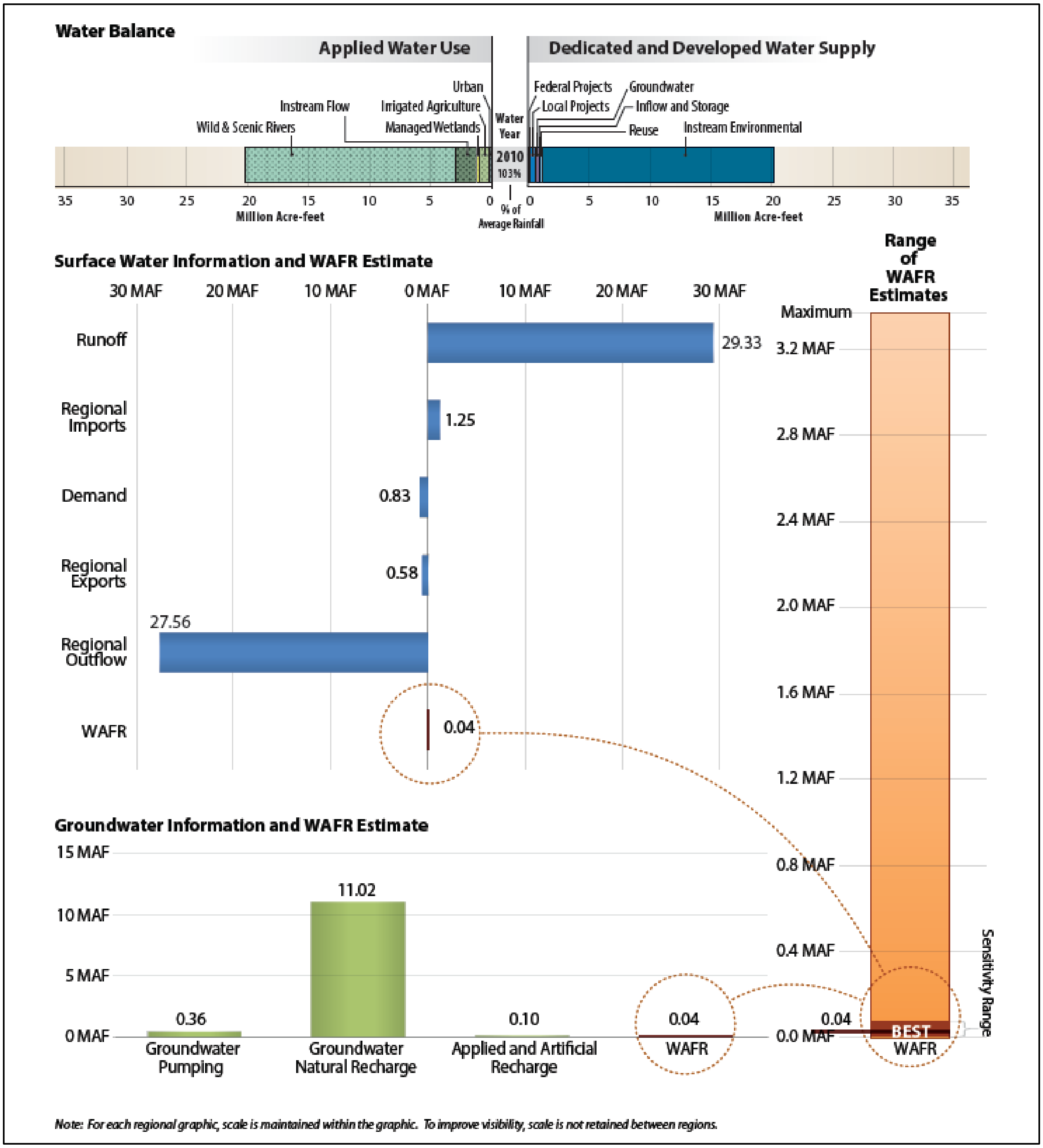
Figure A-NC1. North Coast HR- PA 101, PA 102, PA 103, and PA 104



Summary of WAFR Information and Estimates

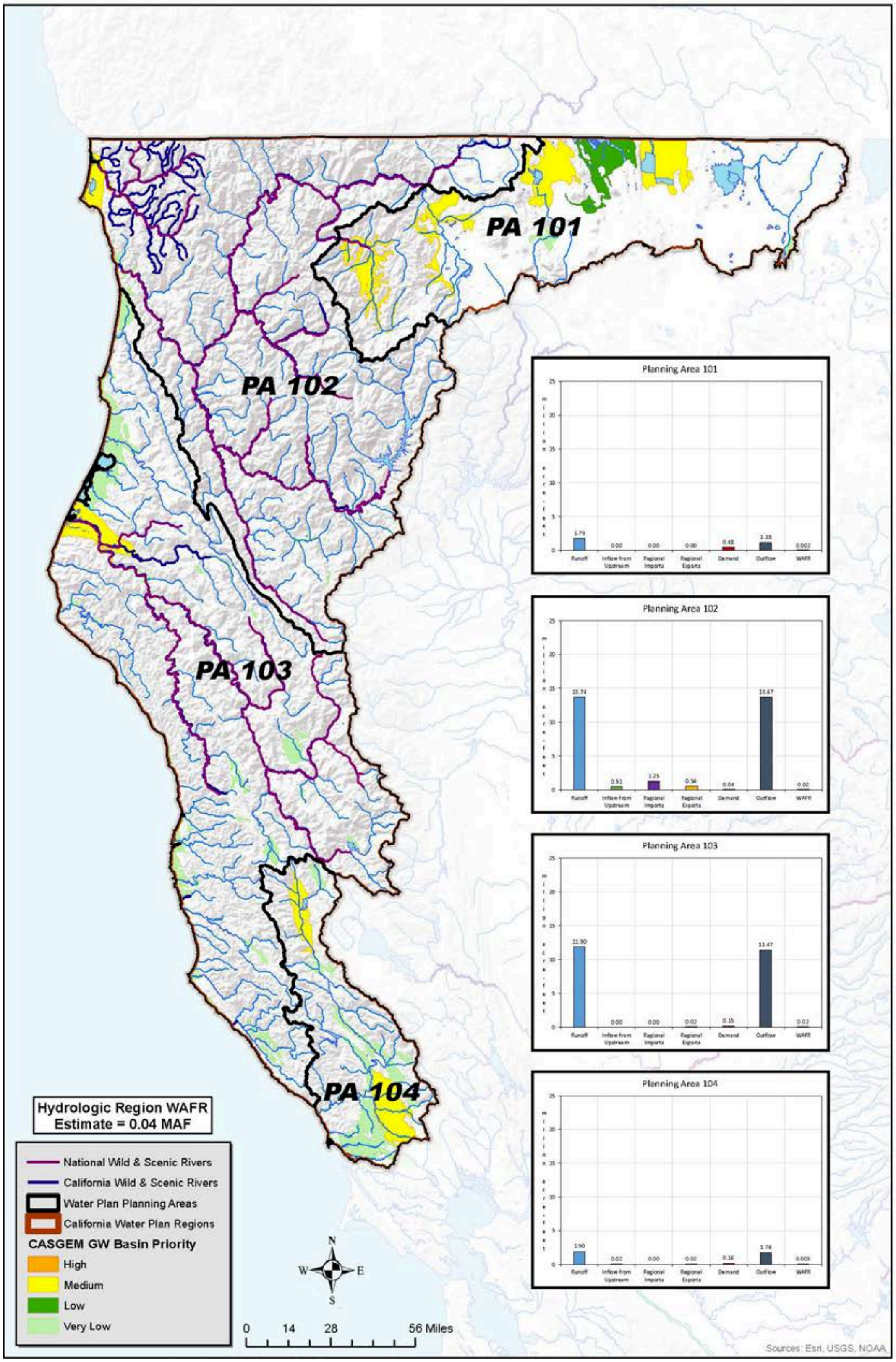
WAFR information and estimates for North Coast Hydrologic Region, Planning Area 101, Planning Area 102, Planning Area 103, and Planning Area 104 are shown in Figures A-NC2 and A-NC3.

Figure A-NC2. North Coast Hydrologic Region WAFR Information and Estimates



*Regional imports are flows from contributing watersheds in Oregon which flow into California.

Figure A-NC3. North Coast PA 101, 102, 103, and 104
WAFR Information and Estimates



WAFR Information and Estimates

The major rivers and streams in the North Coast are the Big River, Eel River, Gualala River, Klamath River, Little River, Lost River, Mad River, Mattole River, Navarro River, Noyo River, Russian River, Shasta River, Smith River, Ten Mile River, and Trinity River. North Coast exports water to both the Central Valley Project (CVP) and San Francisco Hydrologic Region. Actual volume of water delivered varies annually (California Water Plan Update 2013).

The WAFR information and estimates are provided in the following sections.

Surface Water and Groundwater Information

North Coast, PA 101, PA 102, PA 103, and PA 104 surface water and groundwater information is (as defined in the Surface Water and Groundwater Information section) provided in Table A-NC1.

Table A-NC1. North Coast, PA 101, PA 102, PA 103, and PA 104 Surface Water and Groundwater Information

Geographical Region	Regional Imports (maf)	Regional Exports (maf)	Groundwater Pumping (maf)	Groundwater Natural Recharge (maf)	Applied and Artificial Recharge (maf)
North Coast HR	1.25*	0.58	0.36	11.02	0.10
PA 101			-	-	-
PA 102	1.25*	0.54			
PA 103		0.02			
PA 104		0.02	-	-	-

maf – million acre-feet

*Regional imports are flows from contributing watersheds in Oregon which flow into California.

WAFR Estimates

The following sections describe how the WAFR estimates were determined.

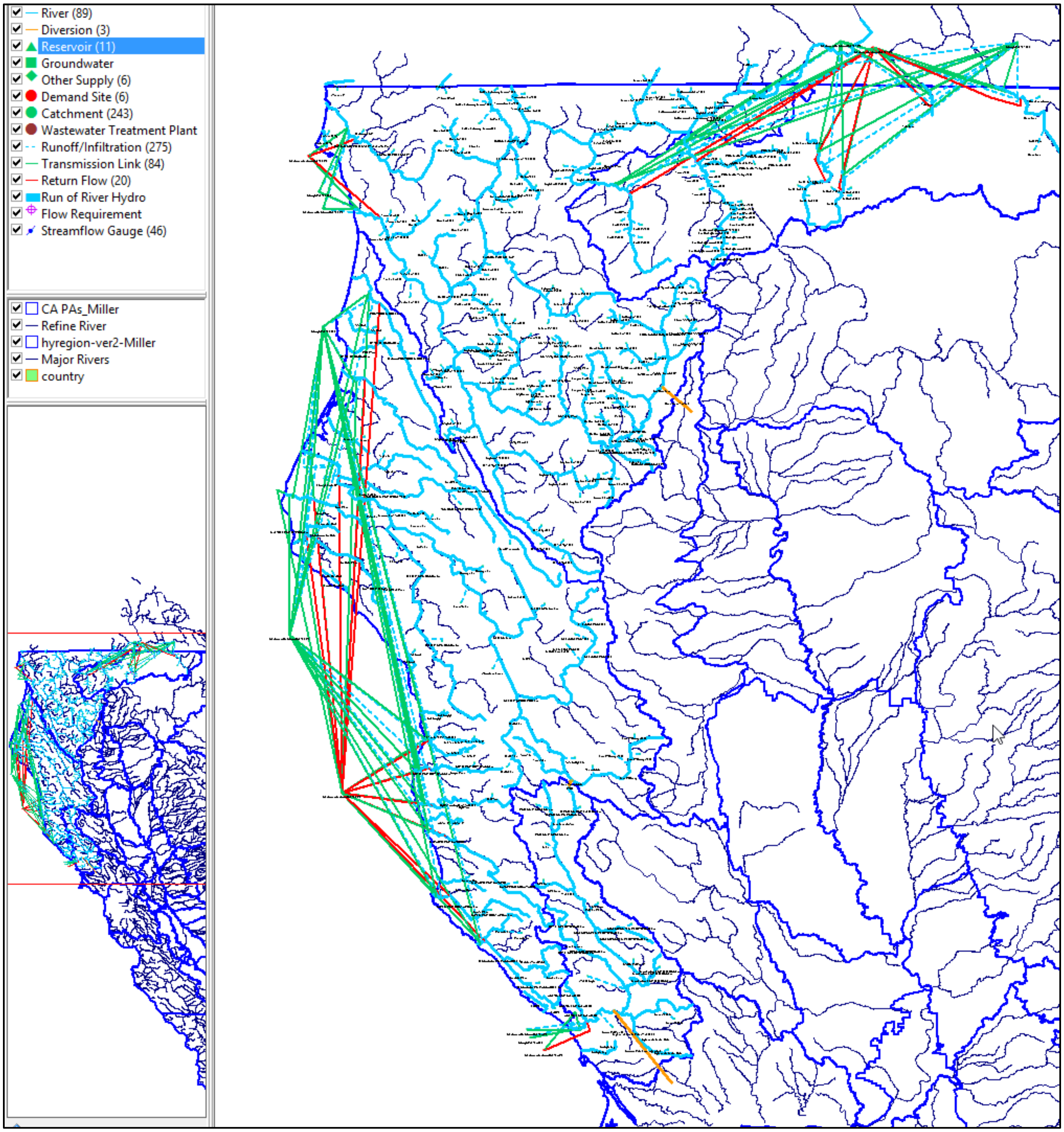
WEAP Model

The North Coast WEAP Model was developed using the procedures described in the WEAP Model Methodology section and described in more detail in the following sections.

Model Domain

The North Coast WEAP Model domain is shown in Figure A-NC4.

Figure A-NC4. North Coast WEAP Model



Streams/Rivers and Delineation of Watershed

The North Coast WEAP Model streams/rivers with corresponding Planning Area are shown in Table A-NC2.

Table A-NC2. North Coast Streams/Rivers

River/Stream (PA 101)	River/Stream (PA 102)	
Butte Creek	Beaver Creek	Mingo Creek
Butte Creek_2	Big French Creek	New River
Little Shasta River	Blue Creek	N.F. Trinity River
Lost River	Bluff Creek	Palmer Creek
Scott River	Browns Creek	Red Cap Creek
Shasta River	Canyon Creek	Rock Creek
	Clear Creek	Rush Creek
	Coffee Creek	Salmon River
	Cottonwood Creek	Scott River
	Crescent City*	Smith River
	Dutton Creek	Stuart Fork
	E.F. Trinity River	Swift Creek
	Elk Creek	Thompson Creek
	Fall Creek	Trinity River
	Grass Valley Creek	S.F. Trinity River
	Hayfork Creek	Ukonom Creek
	Horse Linto Creek	Willow Creek
	Indian Creek	Winchuk River
	Indian Creek @ Douglas City	Clear Creek Tunnel**
	Klamath River	
River/Stream (PA 103)		**River/Stream (PA 104)**
Albion River	Middle Fork Eel River	Austin Creek
Bear River	North Fork Eel River	Big Sulphur Creek
Big River	Navarro River	Bodega Bay*
Coastal Mattole*	Noyo River	Dry Creek
Dobbyn Creek	Outlet Creek	East Fork Russian River
Eel River	South Fork Eel River	Laguna de Santa Rosa
Eureka*	Redwood Creek	Feliz Creek
Fort Bragg*	Rockpile Creek	Maacama Creek
Garcia River	Salt Point*	Mark West Creek
Gualala Wheatfield*	Ten Mile River	Russian River
House Creek	Tomki Creek	PVID Tunnel**
Larabee Creek	Trinidad	Sonoma-Petaluma Aqueduct**
Little River	Lower Mattole River*	
Gualala River	Van Duzen River	
Mad River	Westport*	
Manchester*	Yager Creek	
Mattole River	PVID Tunnel**	
M.F. Ten Mile River		

* - Representation of smaller streams/creeks within nearby area

** - Diversion Tunnels

Watersheds in North Coast were delineated to determine the runoff from each stream using the procedures described in the WEAP Model section.

Reservoir

Reservoirs included in the North Coast HR WEAP model with the corresponding Planning Areas are:

- Clear Lake (Lost River , PA 101)
- Lake Shastina (Shasta River, PA 101).
- Copco Lake (Klamath River, PA 102)
- Iron Gate Reservoir (Klamath River, PA102)
- Lewiston Lake (Trinity River, PA 102).
- Trinity Lake (Trinity River, PA 102).
- Lake Pillsbury (Eel River, PA 103).
- Lake Van Arsdale (Eel River, PA 103).
- Ruth Reservoir (Mad River, PA 103).
- Lake Mendocino (East Fork Russian River, PA 104).
- Lake Sonoma (Dry Creek, PA 104).

Demands

The North Coast demands were determined using the procedures described in the WEAP Model Methodology section and described in the following sections.

Urban Indoor Demand

The Urban Indoor Annual Activity Level and Annual Water Use Rate for each Planning Area are shown in Table A-NC3.

Table A-NC3. Annual Activity Level and Annual Water Use Rate by Category

Category	Annual Activity Level (person/household)	Annual Water Use Rate (taf per person/household)	Annual Activity Level (person/household)	Annual Water Use Rate (taf per person/household)
	PA 101		**PA 102**	
Commercial	23,088	0.000033	42,623	0.000033
Industrial	906	0.000886	1,309	0.000886
Multi-Family	4,400	0.000168	6,519	0.000168
Single-Family	12,229	0.000201	18,118	0.000201
	PA 103		**PA 104**	
Commercial	88,799	0.000033	165,166	0.000033
Industrial	22,158	0.000886	604	0.000886
Multi-Family	24,446	0.000168	34,550	0.000168
Single-Family	67,941	0.000201	96,024	0.000201

taf= thousand acre-feet

Urban Outdoor Demand

The acres for each land use class by Planning Area are shown in Table A-NC4.

Table A-NC4. Urban Outdoor Land Use Class Acres

Land Use Class	PA 101 (thousand Acres)	PA 102 (thousand Acres)	PA103 (thousand Acres)	PA104 (thousand Acres)
Commercial	0.0684	0.1579	0.2398	0.5233
Multi-Family	0.0861	0.079	0.2301	0.6007
Public	0.1504	0.0909	0.2	0.5752
Single-Family	0.0861	0.079	0.2301	0.6007
Total	**0.4594**	**0.5647**	**1.1398**	**2.8232**

Agricultural Demand

The acres for each crop type by Planning Area are shown in Table A-NC5.

Table A-NC5. Crop acres by Crop Type

Crop	PA 101 (thousand Acres)	PA 102 (thousand Acres)	PA 103 (thousand Acres)	PA 104 (thousand Acres)
Grain	58.293	1.534	1.437	0.548
Pasture	78.48	11.26	43.592	8.671
Processed Tomato	0	0	0	0
Fresh Tomato	0	0	0	0
Cucurbits	0.003	0	0.032	0.015
Onion and Garlic	2.262	0	0	0
Potato	6.94	0	0.164	0
Other Truck	6.607	0.725	0.615	0.873
Almond and Pistachio	0	0	0.013	0
Other Deciduous	0.058	0.13	0.406	5.024
Sub-Tropical	0	0	0.023	0.456
Rice	0.028	0	0	0
Vine	0.002	0.171	3.622	58.507
Cotton	0	0	0	0
Sugar Beet	0	0	0	0
Corn	0	0	0.136	0.136
Dry Bean	0	0	0.004	0
Safflower	0	0	0	0
Other Field	0.568	0.063	0.386	1.98
Alfalfa	62.997	0.327	0.2	0
Total	**216.238**	**14.21**	**50.63**	**76.21**

Calibration

The North Coast WEAP Model was calibrated using the procedures described in the WEAP Model Methodology section.

Calibration Data Collection

Calibrated Watersheds with corresponding gage information are shown in Table A-NC6.

Table A-NC6. Calibrated Gage Locations

Gage Name	Site Number	Drainage Area (Square Miles)	Gage Flow Starting Date	Gage Flow Ending Date
AUSTIN C NR CAZADERO CA	11467200	62.8	2/8/1960	2/8/2014
BEAVER C NR KLAMATH R CA	11517800	106	3/9/1954	12/22/1964
BIG R BLW TWO LOG CR NR COMPTCHE CA	11468092	88.7	12/6/2001	12/27/2006
BIG SULPHUR C NR CLOVERDALE CA	11463200	85.5	12/22/1955	1/23/1972
BLUE C NR KLAMATH CA	11530300	120	12/22/1964	12/14/1977
BLUFF C NR WEITCHPEC CA	11523050	74.6	12/22/1955	12/22/1964
BROWNS C NR DOUGLAS CITY CA	11525900	72.7	2/24/1957	12/4/1966
BUTTE C NR MACDOEL CA	11490500	178	6/7/1952	5/14/1960
COFFEE C NR TRINITY CENTER CA	11523700	107	1955-12	5/4/1966
COTTONWOOD C A HORNBROOK CA	11516600	89.8	12/22/1964	1/16/1971
DRY C NR CLOVERDALE CA	11464500	87.8	1937-12	2/17/1980
ELK C NR HAPPY CAMP CA	11522200	90.4	12/21/1955	1/20/1964
FELIZ C NR HOPLAND CA	11462700	31.3	2/16/1959	1/4/1966
GARCIA R NR POINT ARENA CA	11467600	98.5	12/26/1951	1/26/1983
GRASS VALLEY C NR LEWISTON CA	11525630	36.2	12/27/2004	12/11/2014
HAYFORK C NR HYAMPOM CA	11528500	378	1/17/1954	1/16/1974
INDIAN C NR DOUGLAS CITY CA	11525670	33.5	12/27/2004	12/11/2014
INDIAN C NR HAPPY CAMP CA	11521500	120	2/17/1912	2/14/2014
LAGUNA DE SANTA ROSA C NR SEBASTOPOL CA	11465750	79.6	2/13/2000	2/10/2014
LARABEE C NR HOLMES CA	11476700	84.1	2/8/1960	12/22/1964
LITTLE R NR TRINIDAD CA	11481200	40.5	1/17/1953	3/10/2014
MAACAMA C NR KELLOGG CA	11463900	43.7	1/31/1961	12/3/1980
MAD R NR ARCATA CA	11481000	485	1/19/1911	3/10/2014
MATTOLE R NR PETROLIA CA	11469000	245	1/25/1912	3/29/2014
MF EEL R NR DOS RIOS CA	11473900	745	1/4/1966	3/29/2014
MF TEN MILE R NR FORT BRAGG CA	11468600	32.9	12/21/1964	1/16/1974
NAVARRO R NR NAVARRO CA	11468000	303	1937-12	3/29/2014

Gage Name	Site Number	Drainage Area (Square Miles)	Gage Flow Starting Date	Gage Flow Ending Date
NEW R A DENNY CA	11527400	173	3/26/1928	1/21/1969
NF EEL R NR MINA CA	11474500	248	1/17/1954	12/8/2004
NF TRINITY R A HELENA CA	11526500	151	1/25/1912	1/14/1980
NOYO R NR FORT BRAGG CA	11468500	106	12/27/1951	3/29/2014
OUTLET C NR LONGVALE CA	11472200	161	2/24/1957	1/1/1997
RED CAP C NR ORLEANS CA	11523030	56.1	1/12/1959	12/22/1964
REDWOOD C A ORICK CA	11482500	277	2/17/1912	3/10/2014
RUSH C NR LEWISTON CA	11525530	22.3	2/17/2004	3/9/2014
RUSSIAN R NR UKIAH CA	11461000	100	3/15/1912	3/29/2014
SALMON R A SOMES BAR CA	11522500	751	2/17/1912	3/10/2014
SF EEL R NR MIRANDA CA	11476500	537	1/25/1941	3/29/2014
SF GUALALA R NR THE SEA RANCH CA	11467510	161	1/4/2008	2/8/2014
SF TRINITY R BL HYAMPOM CA	11528700	764	12/22/1964	3/29/2014
SHASTA R NR YREKA CA	11517500	793	1/3/1934	2/7/2015
SMITH R NR CRESCENT CITY CA	11532500	614	4/10/1905	2/14/2014
TRINITY R AB COFFEE C NR TRINITY CENTER CA	11523200	149	12/22/1955	3/5/2014
VAN DUZEN R NR BRIDGEVILLE CA	11478500	222	2/28/1940	3/29/2014
WILLOW C NR WILLOW C CA	11529800	40.9	2/9/1960	4/1/1974

Calibration Results

Calibrated Watersheds with corresponding NSE and PBIAS are shown in Table A-NC7.

Table A-NC7. Calibrated Watersheds with corresponding NSE and PBIAS

Stream Gage Name and River Name	Nash Sutcliffe Coefficient of Efficiency (NSE)	Percent Bias (PBIAS)
Austin C @ Austin Creek	0.84	-7.37
Big Sulphur C @ Big Sulphur Cr	0.93	-10.37
Beaver Cr @ nr Klamath	0.64	2.09
Big R @ Two Log Cr	0.76	-11.00
Blue Cr @ Blue Cr	0.84	7.68
Bluff Cr @ Bluff Cr	0.82	-9.18
Browns Cr @ Browns Cr	0.84	-1.67
Coffee Cr @ 11523700	0.65	-11.35
Cottonwood Cr @ Hornbrook_11516600	0.88	-6.67
Dry C @ Cloverdale	0.96	-0.24
Feliz Creek @ Nr Hopland	0.88	-5.88
Garcia R @ Garcia R nr Pt Arena	0.84	-6.70
Grass Valley @ GV Cr_Lewiston	0.76	-2.16
Gualala River @ SF Gualala R	0.92	-5.77
Hayfork Cr @ Hayfork_11528500	0.80	1.84
Indian C @ Happy Camp	0.78	0.07
Laguna de SR @ Laguna de Santa Rosa	0.87	14.01
Larabee Cr @ Larabee Cr_1147670	0.80	-7.09
Little R @ Trinidad CA	0.91	-5.28
Maacama C @ nr Kellog	0.97	-2.91
MF Ten Mile R @ MF Ten Mile R	0.96	0.84
Mad River @ Arcata	0.94	-2.39
Mattole R @ nr Petrolia	0.86	-2.59
Middle Fork Eeel @ MF EEL NR DO	0.88	-8.38
N Fork Eeel @ Mina	0.89	-11.13
NF Trinity @ NF Trinity	0.76	-3.80

Navarro R @ Navarro R	0.95	2.24
New River @ New R_11527400	0.62	9.06
Noyo R @ nr Fort Bragg	0.91	-11.83
Outlet Cr @ Outlet Cr	0.95	0.80
Red Cap Cr @ 1152303	0.83	8.64
Redwood Cr @ Orick	0.91	-0.33
Rush Cr @ Lewiston	-0.99	-100
Russian River @ nr Ukiah	0.96	-4.15
S Fork Eel River @ SF EEL R NR	0.95	-2.99
Salmon R @ Somes Bar	0.73	-9.26
Smith R @ nr_Crescent City	0.92	-11.19
Trinity @ Trinity	0.63	-7.71
Trinity River SF @ SF Trinity	0.87	8.71
Van Duzen R @ Van Duzen R Bridge	0.93	-10.91
Willow Cr @ Willow Cr_11529800	0.67	8.43

WEAP Outflow

The WEAP outflow for North Coast HR, PA 101, PA 102, PA 103, and PA 104 is shown in Table A-NC8.

Table A-NC8. North Coast, PA 101, PA 102, PA 103, and PA 104 WEAP Outflow

Geographical Region	Outflow (maf)
North Coast HR	27.56*
PA 101	1.18
PA 102	13.67
PA 103	11.47
PA 104	1.76

maf = million acre-feet

*Please note the sum of the Planning Area outflow does not equal the hydrologic region outflow; since major rivers flow through multiple Planning Areas, the outflow from an upstream Planning Area may be double counted in the outflow for a downstream Planning Area.

WAFR Fraction

The following sections describe how the WAFR Fraction was determined for North Coast, PA 101, PA 102, PA 103, and PA 104.

Gage Data

Gage data for 17 major rivers and streams in the North Coast HR was compiled. In each river or stream, the most downstream gage was selected to account for water demands within the watershed and to develop a WAFR fraction that is applicable to regional outflow.

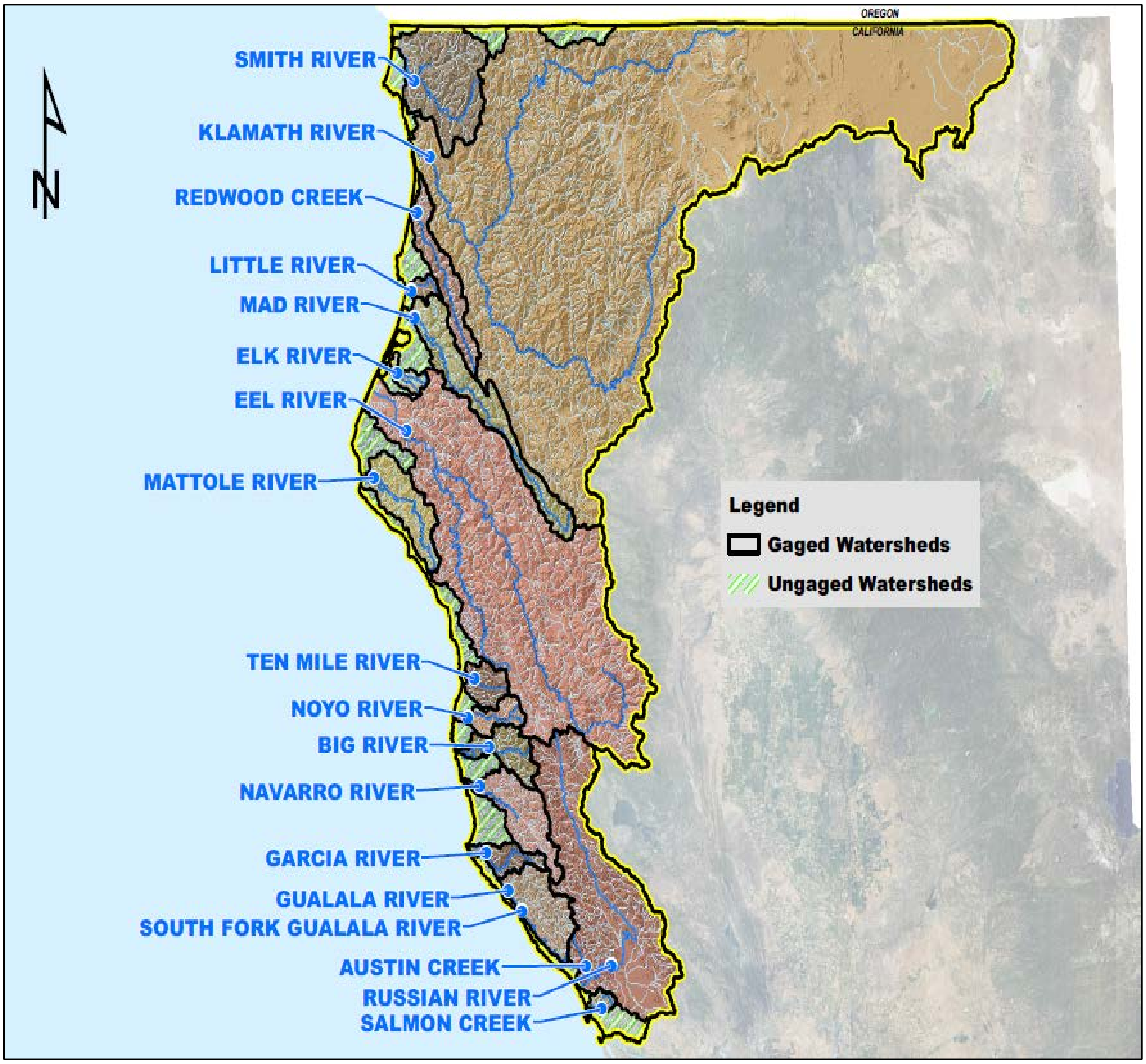
The total area of the gaged watersheds is 19,131 square miles of the 19,390 square mile region, or approximately 98.7 percent of the hydrologic region. A summary of the stream gages used in this analysis is presented in Table A-NC9. A map showing the locations of the gages used, and their respective watersheds are shown as Figure A-NC5.

River/Stream	Location	USGS Gage Number	Area (square miles)
Big Sur	Big Sur	11143000	47
Carmel	Carmel	11143250	247
Pajaro	Watsonville	11159500	1,272
Salinas	Spreckels	11152500	4,156
San Antonio	Casmalia	11136100	135
San Jose	Goleta	11120500	6
San Lorenzo	Santa Cruz	11161000	115
Santa Maria	Guadalupe	11141000	1,741
Santa Ynez	Lompoc	11133000	789

Table A-NC9. Major Rivers and Gages in North Coast HR Analysis

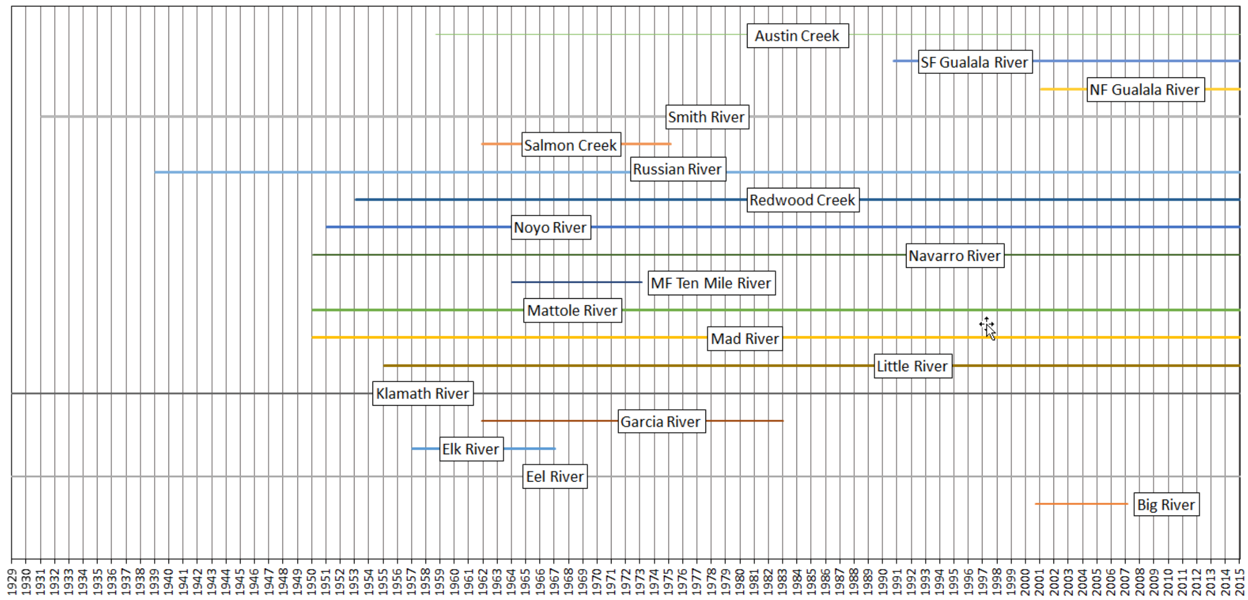
River/Stream	Location	USGS Gage Number	Area (square miles)
Smith River	Crescent City	11532500	614
Klamath River	Klamath	11530500	12,100
Redwood Creek	Orick	11482500	277
Little River	Trinidad	11481200	41
Mad River	Arcata	11481000	485
Elk River	Falk	11479700	44
Eel River	Scotia	11477000	3,113
Mattole River	Petrolia	11469000	245
MF Ten Mile River	Fort Bragg	11468600	54
Noyo River	Fort Bragg	11468500	106
Big River	Comptche	11468092	89
Navarro River	Navarro	11468000	303
Garcia River	Point Arena	11467600	99
NF Gualala River	Gualala	11467553	47
SF Gualala River	The Sea Ranch	11467510	161
Russian River	Guerneville	11467000	1,338
Salmon Creek	Bodega	11460920	16
Austin Creek	Cazadero	11467200	63

Figure A-NC5. Watersheds for Major Gaged Streams in North Coast



Once the available gage data was compiled, the periods of available data for the 17 gages were compared. Data availability by year is presented in Figure A-NC6.

Figure A-NC6. Period of Available Gage Data



The Wild and Scenic Rivers Act (Public Law 90-542) prohibits any new diversion from a river or stream designated as Wild, Scenic, or Recreational. Therefore, to develop a WAFR fraction for North Coast Rivers, any river holding one of these designations was removed from the analysis.

The California State Water Resources Control Board (SWRCB) also keeps an inventory of Fully Appropriated Streams (Board Order 98-08). The SWRCB has determined that the amount of water in a Fully Appropriated Stream is able to meet only the requirements of existing water right holders, and new water right permits are unlikely. Unlike Wild and Scenic Rivers, a stream can be designated Fully Appropriated for only a portion of the year; therefore, rivers and streams that are designated Fully Appropriated for only a portion of the year were included in this analysis.

A table of Fully Appropriated Streams and Wild and Scenic Rivers on the North Coast is shown in Table A-NC10.

Table A-NC10. Designation of Rivers/Streams in North Coast HR

River	Designation	Time Period	Considered in Analysis?
Smith River	Wild and Scenic	Year Round	No
Klamath River	Wild and Scenic	Year Round	No
Mad River	Fully Appropriated	Jun-Oct	Yes
Eel River	Wild and Scenic	Year Round	No

Water Available for Replenishment Information and Estimates

The gage data outflow, diverted water using a Conceptual Project (WAFR), and WAFR Fraction (diverted water using Conceptual Project (WAFR)/Gage Data Outflow) for each stream and the North Coast Hydrologic Region is shown in Table A-NC11.

Table A-NC11. WAFR Fraction

River/ Stream	Gage Data Outflow (taf)*	Lower Sensitivity Range Estimate		Best Estimate		Upper Sensitivity Range Estimate		Maximum Project Estimate	
		WAFR (taf)	WAFR Fraction (%)	WAFR (taf)	WAFR Fraction (%)	WAFR (taf)	WAFR Fraction (%)	WAFR (taf)	WAFR Fraction (%)
Smith River	2,674	-	0%	-	0%	-	0%	-	0%
Klamath River	12,241	-	0%	-	0%	-	0%	-	0%
Redwood Creek	696	0.02	0%	0.06	0.01%	0.12	0.02%	458.45	65.89%
Little River	96	-	0%	-	0%	-	0%	-	0%
Mad River	953	-	0%	-	0%	-	0%	-	0%
Elk River	68	0.01	0.01%	0.04	0.05%	0.07	0.11%	40.89	60.47%
Eel River	5,536	-	0%	-	0%	-	0%	-	0%
Mattole River	886	0.06	0.01%	0.19	0.02%	0.38	0.04%	601.46	67.90%
Mf Ten Mile River	62	-	0%	-	0%	-	0%	-	0%
Noyo River	144	0.62	0.43%	1.50	1.04%	2.89	2.01%	137.50	95.58%
Big River	166	-	0%	-	0%	-	0%	101.53	61.06%
Navarro River	352	0.97	0.28%	2.36	0.67%	4.62	1.31%	335.50	95.27%
Garcia River	253	0.06	0.03%	0.22	0.09%	0.43	0.17%	168.54	66.60%
Nf Gualala River	81	0.03	0.04%	0.10	0.12%	0.19	0.24%	11.92	14.72%
Sf Gualala River	75	0.08	0.11%	0.22	0.30%	0.45	0.60%	63.48	84.70%
Russian River	1,591	10.39	0.65%	30.85	1.94%	59.76	3.76%	1144.32	71.91%
Salmon Creek	19	0.07	0.38%	0.15	0.77%	0.28	1.44%	19.19	99.79%
Austin Creek	111	0.01	0.01%	0.01	0.01%	0.01	0.01%	100.81	90.51%
HR Total	26,005	12	0.05%	36	0.14%	69	0.27%	3,184	12.24%

taf = thousand acre-feet

* Please note that the outflow is based on gaged streams only. The final WAFR estimates include outflow from the WEAP model for both gaged and ungaged watersheds.

Final WAFR Estimates

The outflow estimate simulated using the WEAP model was then multiplied by the range of water available for replenishment fractions determined by the historical gage data to determine the estimated range of WAFR estimates within the hydrologic region. The array of estimates for the North Coast HR, PA 101, PA 102, PA 103, and PA 104 are shown in Table A-NC11 using the WEAP outflow from Table A-NC8 and water available for replenishment fractions from Table A-NC11 above.

Table A-NC12. Final WAFR estimates

Geographical Region	WEAP Outflow (maf)	No Project Estimate (maf)	Lower Sensitivity Range Estimate (maf, WAFR Fraction 0.05%)	Best Estimate (maf, WAFR Fraction 0.14%)	Upper Sensitivity Range Estimate (maf, WAFR Fraction 0.27%)	Maximum Project Estimate (maf, WAFR Fraction 12.24%)
North Coast HR	27.56	0	0.0138	0.0386	0.0744	3.3740
PA 101	1.18	0	0.0006	0.0017	0.0032	0.1447
PA 102	13.67	0	0.0068	0.0191	0.0369	1.6734
PA 103	11.47	0	0.0057	0.0161	0.0310	1.4043
PA 104	1.76	0	0.0009	0.0025	0.0048	0.2158

maf = million acre-feet

WAFR = Water Available for Replenishment

Potential Water Development by Other Methods (recycled water, desalination and water conservation)

Estimates of potential water development by other methods (recycled water, desalination and water conservation) are also shown for North Coast hydrologic region in Table A-NC13. Note that these estimates were not specifically made for use for groundwater replenishment and will need to be considered by GSAs more thoroughly for such purpose.

Table A-NC13. North Coast Urban Water Portfolio Actions

Method	Volume of Water Increase from 2010 to 2020
Recycle	0.01 taf
Desalination	0 taf
Conservation	0.01 taf

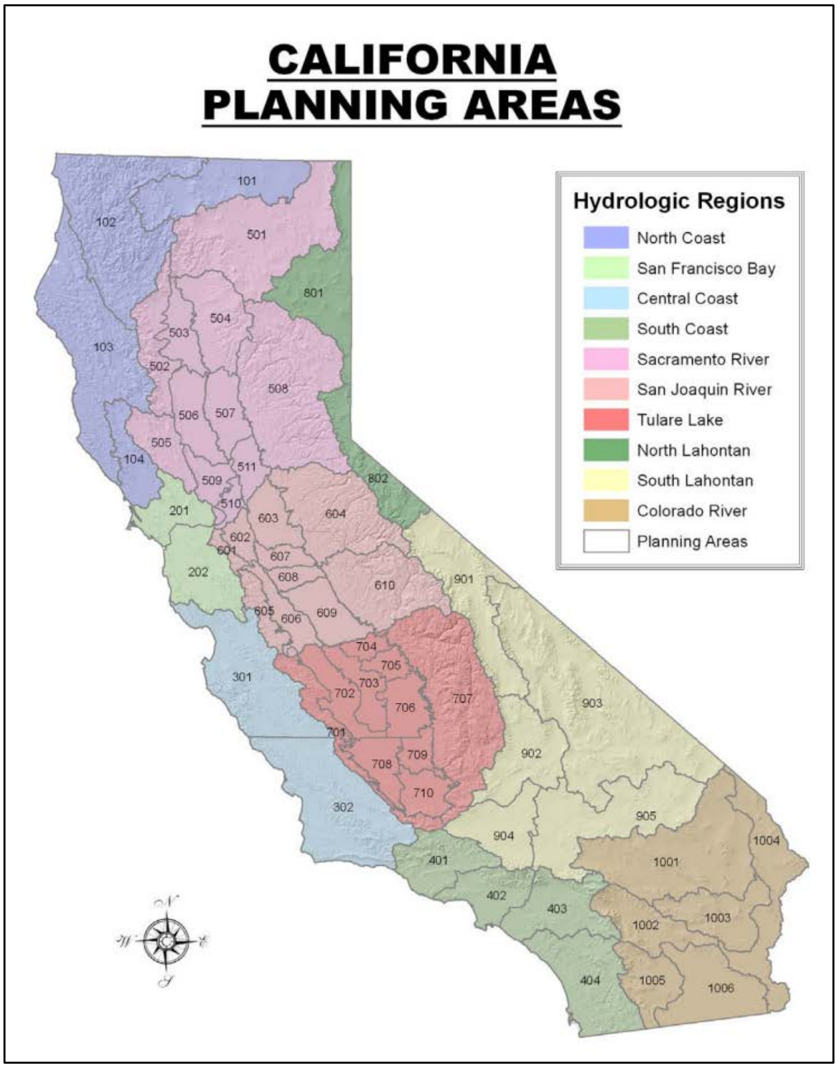
taf-Thousand Acre-feet

San Francisco Hydrologic Region

The San Francisco Bay Hydrologic Region includes all of San Francisco County and portions of Marin, Sonoma, Napa, Solano, San Mateo, Santa Clara, Contra Costa, and Alameda counties. It occupies approximately 4,500 square miles; from southern Santa Clara County to Tomales Bay in Marin County; and inland to near the confluence of the Sacramento and San Joaquin rivers at the eastern end of Suisun Bay. The eastern boundary follows the crest of the Coast Ranges, where the highest peaks are more than 4,000 feet above mean sea level (California Water Plan Update 2013).

The San Francisco Bay region is divided into two Planning Areas: Northern Planning Area, PA 201, and Southern Planning Area, PA 202. San Francisco Bay, PA 201 and PA 202 are shown in Figure A-SF1.

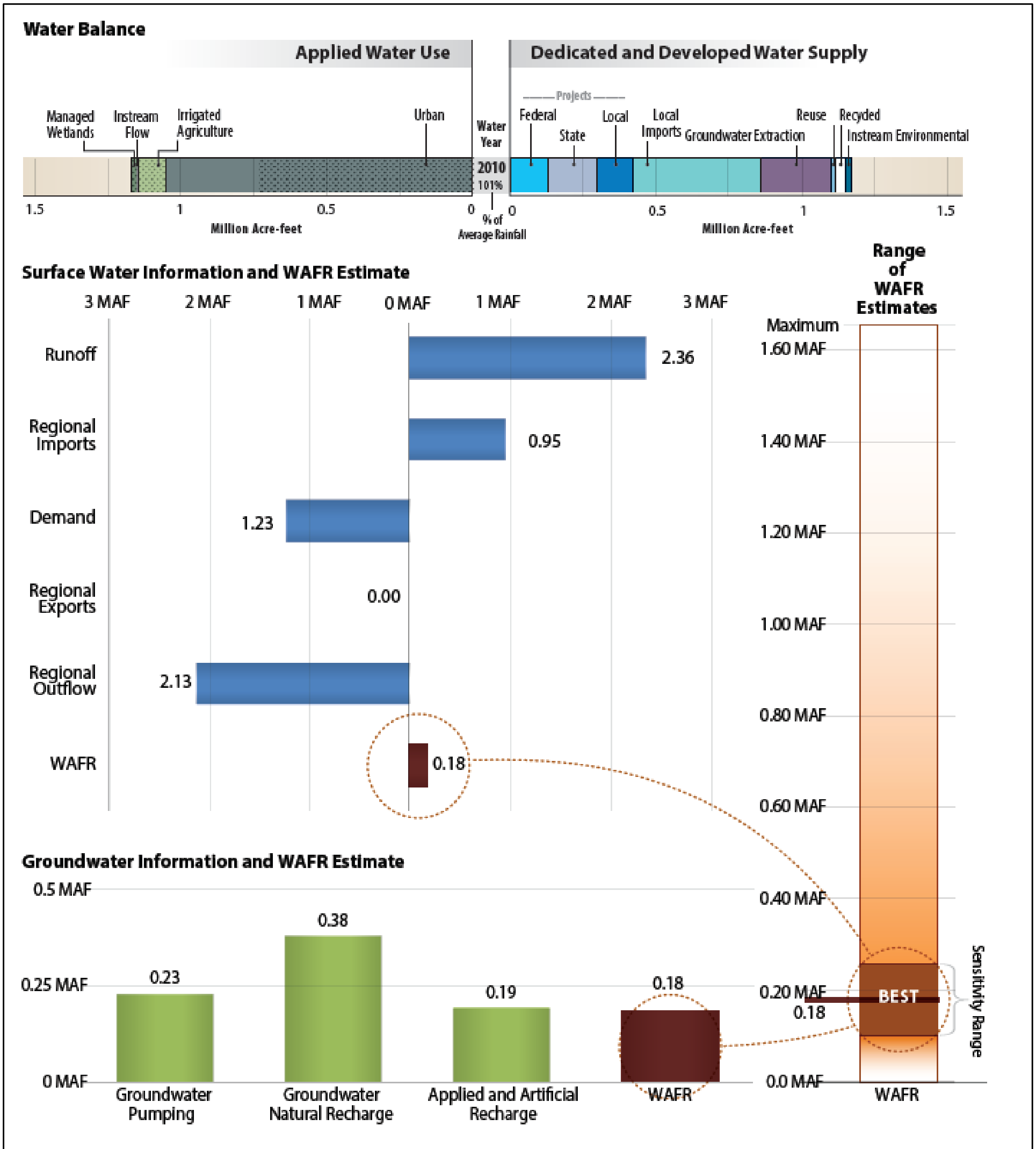
Figure A-SF1. San Francisco Bay, PA 201 and PA 202



Summary of WAFR Information and Estimates

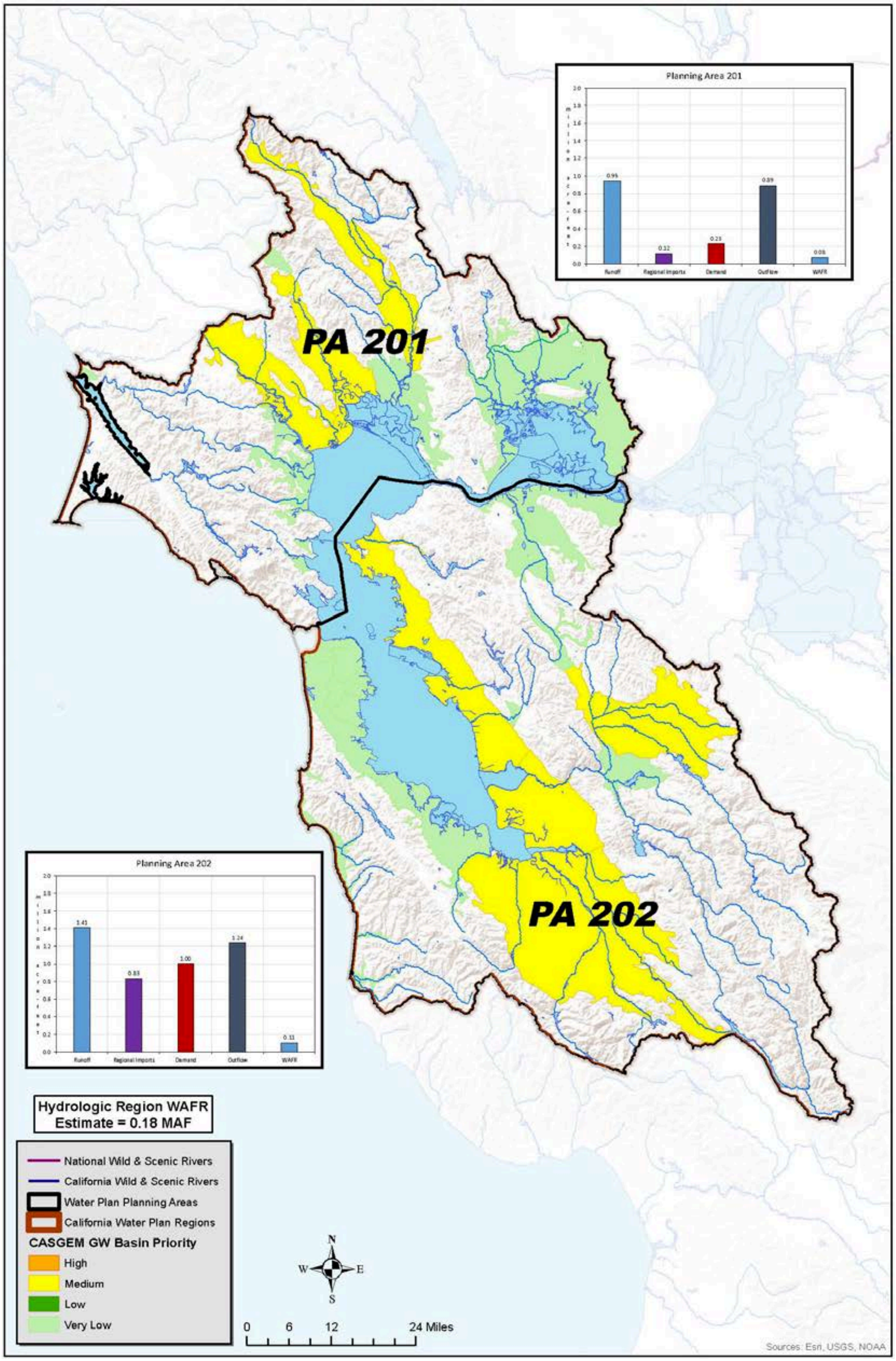
WAFR information and estimates for San Francisco Bay Hydrologic Region, Planning Area 201, and Planning Area 202 are shown in Figures A-SF2 and A-SF3.

Figure A-SF2. San Francisco Bay Hydrologic Region WAFR Information and Estimates



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

Figure A-SF3. San Francisco Bay Hydrologic Region PA 201 and 202 WAFR Information and Estimates



WAFR Information and Estimates

Covering a total of 4,560 square miles, the San Francisco Bay Hydrologic Region (HR) spans from Marin County in the north to the northern end of Santa Cruz County in the south. The region is heavily populated, and includes San Francisco and numerous other surrounding cities. The San Francisco Bay Hydrologic Region is the discharge point for a significant portion of California's runoff. The entire Bay-Delta watershed discharges into the region through the Sacramento River and the water eventually leaves the region through the Golden Gate.

Some water agencies in the region have imported water from the Sierra Nevada for nearly a century to supply their customers. Water from the Mokelumne and Tuolumne rivers accounts for about 38 percent of the region's average annual water supply. Water from the Sacramento-San Joaquin Delta (Delta), via the federal Central Valley Project (CVP) and the State Water Project (SWP), accounts for another 28 percent. Approximately 31 percent of the average annual water supply is from local groundwater and surface water; and 3 percent is from miscellaneous sources such as harvested rainwater, recycled water, and transferred water. Population growth and diminishing water supply and water quality have led to the development of local surface water supplies, recharge of groundwater basins, and incorporation of conservation guidelines to sustain water supply and water quality for future generations (California Water Plan Update 2013).

The Sacramento and San Joaquin rivers flow into the Delta and into San Francisco Bay. The Delta is the largest estuary on the West Coast, receiving nearly 40 percent of the state's surface water from the Sierra Nevada and the Central Valley. The interaction between Delta outflow and Pacific Ocean tides determines how far salt water intrudes into the Delta. The resulting salinity distribution influences the distribution of many estuarine fish and invertebrates, as well as the distribution of plants, birds, and animals in wetlands areas. Delta outflow varies with precipitation, reservoir releases, and upstream diversions (California Water Plan Update 2013).

The average precipitation for the region is 27.6 inches, primarily falling as rain. The following sections provide the WAFR information and estimates and describe how it was determined for each Planning Area within the San Francisco Bay Hydrologic Region.

Surface Water and Groundwater Information

San Francisco Bay, PA 201, and PA 202 surface water and groundwater information (as defined in the Surface Water and Groundwater Information section) is provided in Table A-SF1.

Table A-SF1. San Francisco Bay, PA 201, and PA 202 Surface Water and Groundwater Information

Geographical Region	Regional Imports (MAF)	Regional Exports (MAF)	Groundwater Pumping (MAF)	Groundwater Natural Recharge (MAF)	Applied and Artificial Recharge (MAF)
San Francisco Bay HR	0.95	0.00	0.23	0.38	0.19
PA 201	0.12	0	-	-	-
PA 202	0.83	0	-	-	-

WAFR Estimates

The following sections describe how the WAFR estimates were determined.

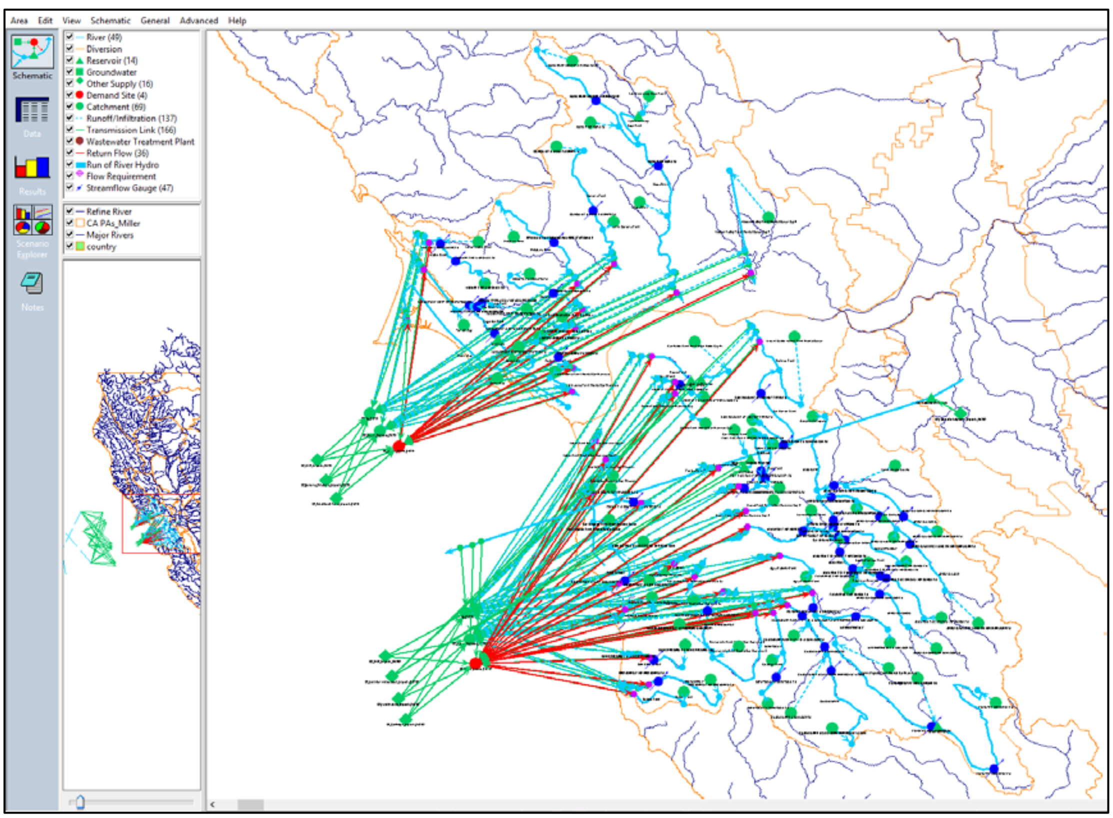
WEAP Model

The San Francisco Bay WEAP Model was developed using the procedures described in the [WEAP Model Methodology section] and described in more detail in the following sections.

Model Domain

The San Francisco Bay WEAP Model domain is shown in Figure A-SF4.

Figure A-SF4. San Francisco Bay WEAP Model



Streams/Rivers and Delineation of Watershed

The San Francisco Bay WEAP Model streams/rivers with corresponding Planning Area are shown in Table A-SF2.

Table A-SF2. San Francisco Bay Streams/Rivers

River/Stream (PA 201)	River/Stream (PA 202)	
Corte Madera Creek	Agua Caliente	Permanente Creek
Drakes Bay	Alameda Creek	Pescadero Creek
Lagunitas Creek	Alamo Creek	Pilarcitos Creek
Miller Creek	Arroyo Hondo	Pruisima Creek
Napa River	Arroyo Mocho	Rodeo Creek
Nicasio Creek	Arroyo Valle	San Antonio Creek
Novato Creek	Butano Creek	San Francisquito Creek
Petaluma River	Cerrito Creek	San Gregorio Creek
Sage Creek	Colma Creek	San Leandro Creek
Sonoma Creek	Coyote Creek	San Lorenzo Creek
Walker Creek	Crow Creek	San Mateo Creek
Wooden Valley Creek	Cull Creek	San Ramon Creek
	Frontal San Francisco Bay	Saratoga Creek
	Guadalupe River	Sausal Creek
	Lobos Creek	Up Penitencia Creek
	Los Gatos Creek	Wildcat Creek
	Pacheco Creek	

Watersheds in San Francisco Bay region were delineated to determine the runoff from each stream using the procedures described in the WEAP Model Methodology section.

Reservoir

Reservoirs included in the San Francisco Bay WEAP model with the corresponding Planning Areas are:

- Alpine Lake (Lagunitas Creek, PA 201).
- Anderson Lake (Coyote Creek, PA 202).
- Briones Reservoir (Rodeo Creek, PA 202).
- Calaveras Reservoir (Arroyo Hondo, PA 202).
- Crystal Springs Reservoir (San Mateo Creek, PA 202).
- Kent Lake (Lagunitas Creek, PA 201).
- Lake Chabot (San Leandro Creek, PA 202).
- Lake Del Valle (Arroyo Valle, PA 202).
- Lake Hennessey (Sage Creek, PA 201).

- Los Vaqueros Reservoir (Contra Costa Canal System, PA 202).
- Nicasio Reservoir (Nicasio Creek, PA 201).
- San Andreas Lake (San Mateo Creek, PA 202).
- San Antonio Reservoir (San Antonio Creek, PA 202).
- San Pablo Reservoir (Rodeo Creek, PA 202).
- Upper San Leandro Reservoir (San Leandro Creek, PA 202).

Demands

The San Francisco Bay region demands were determined using the procedures described in WEAP Model Methodology section and described in the following sections.

Urban Indoor Demand

The Urban Indoor Annual Activity Level and Annual Water Use Rate for each Planning Area are shown in Table A-SF3.

Table A-SF3. Annual Activity Level and Annual Water Use Rate by Category

	PA 201		PA 202	
Category	**Annual Activity Level (person/household)**	**Annual Water Use Rate (TAF per person/household)**	**Annual Activity Level (person/household)**	**Annual Water Use Rate (TAF per person/household)**
Commercial	393,640	0.000033	3,203,111	0.000033
Industrial	49,532	0.000277	256,184	0.000277
Multi-Family	113,363	0.000154	761,730	0.000154
Single-Family	186,139	0.000217	1,250,735	0.000217

Urban Outdoor Demand

The acres for each land use class by Planning Area are shown in Table A-SF4.

Table A-SF4. Urban Outdoor Land Use Class Acres

Land Use Class	PA 201 Acres	PA 202 Acres
Commercial	2,511.74	22,357.01
Multi-Family	1,986.32	10,987.68
Public	4,863.41	19,924.59
Single-Family	12,702.75	70,267.50
Total	**22,064.22**	**123,536.78**

Agricultural Demand

The acres for each crop type by Planning Area are shown in Table A-SF5.

Table A-SF5. Crop acres by Crop Type

Crop	PA 201 Acres (thousand)	PA 202 Acres (thousand)
Grain	1.331	0.096
Pasture	4.61	1.97
Processed Tomato	0.014	0.004
Fresh Tomato	0	0.003
Cucurbits	0.186	0.491
Onion and Garlic	0.013	0.107
Potato	0	0
Other Truck	1.183	5.24
Almond and Pistachio	0.008	0.132
Other Deciduous	1.26	0.588
Sub-Tropical	0.658	0.1
Rice	0	0
Vine	57.574	3.301
Cotton	0	0
Sugar Beet	0	0
Corn	0.199	0.23
Dry Bean	0.146	0.053
Safflower	0.706	0
Other Field	0.077	0
Alfalfa	0	0.068
Total	**67.965**	**12.383**

Calibration

The San Francisco Bay WEAP Model was calibrated using the procedures described in the WEAP Model Methodology section.

Calibration Data Collection

Calibrated Watersheds with corresponding gage information are shown in Table A-SF6.

Table A-SF6. Calibrated Gage Locations

Gage Name	Site Number	Drainage Area (Square Miles)	Gage Flow Starting Date	Gage Flow Ending Date
ALAMEDA C AB DIV DAM NR SUNOL CA	11172945	33.3	10/1/1994	5/31/2016
ARROYO HONDO NR SAN JOSE CA	11173200	77.1	10/1/1968	5/31/2016
ARROYO MOCHO NR LIVERMORE CA	11176000	38.2	4/1/1912	1/31/2002
ARROYO VALLE BL LANG CN NR LIVERMORE CA	11176400	130	10/1/1963	4/30/2016
COLMA C A SOUTH SAN FRANCISCO CA	11162720	10.8	10/1/1963	11/30/1996
COYOTE C NR GILROY CA	11169800	109	10/1/1960	10/31/2016
CORTE MADERA C A ROSS CA	11460000	18.1	2/1/1951	5/31/2016
CROW C NR HAYWARD CA	11180900	10.5	10/1/1997	5/31/2016
CULL C AB CULL C RES NR CASTRO VALLEY CA	11180960	5.79	10/1/1978	7/31/2016
GUADALUPE R AB ALMADEN EXPRESSWAY A SAN JOSE CA	11167800	61.8	10/1/2003	10/31/2011
NAPA RIVER NEAR ST. HELENA CALIF	11456000	78.8	10/1/1929	3/31/2016
NOVATO C A NOVATO CA	11459500	17.6	10/1/1946	3/31/2016
PESCADERO C NR PESCADERO CA	11162500	45.9	4/1/1951	10/31/2016
PILARCITOS C A HALF MOON BAY CA	11162630	27.1	7/1/1966	10/31/2016
SAN FRANCISQUITO C A STANFORD UNIVERSITY CA	11164500	37.4	10/1/1930	6/30/2016
SAN GREGORIO C A SAN GREGORIO CA	11162570	50.9	10/1/1969	6/30/2016
SARATOGA C A SARATOGA CA	11169500	9.22	10/1/1933	2/28/2016
SAN LORENZO C A SAN LORENZO CA	11181040	44.6	10/1/1967	6/30/2016
SAN RAMON C AT WALNUT CREEK CA	11183000	50.8	10/1/1952	9/30/1973

SONOMA C A AGUA CALIENTE CA	11458500	58.4	2/1/1955	6/30/2016
UP PENITENCIA C A SAN JOSE CA	11172100	21.5	10/1/1961	9/30/1987
WALKER C NR MARSHALL CA	11460750	31.1	10/1/1983	5/31/2016
WILDCAT C A VALE RD AT RICHMOND CA	11181390	7.79	10/1/1975	6/30/1996

Calibration Results

Calibrated Watersheds with corresponding NSE and PBIAS are shown in Table A-SF7.

Table A-SF7. Calibrated Watersheds with corresponding NSE and PBIAS

Location	Nash Sutcliffe Coefficient of Efficiency (NSE)	Percent Bias (PBIAS)
ALAMEDA CREEK	0.88	-2.94
ARROYO HONDO	0.89	6.75
ARROYO MOCHO	0.76	-7.40
COLMA CREEK	0.76	3.73
ARROYO VALLE	0.81	0.90
COYOTE CREEK	0.83	-9.59
CORTE MADERA	0.92	-6.11
CROW CREEK	0.91	-0.11
CULL CREEK	0.83	6.92
GUADALUPE RIVER	0.64	7.99
NAPA RIVER	0.96	0.21
NOVATO CREEK	0.91	7.76
PESCADERO CREEK	0.91	-2.27
PILARCITOS CREEK	0.88	-3.23
SAN FRANCISQUITO CREEK	0.88	5.57
SAN GREGORIO CREEK	0.87	-5.67
SARATOGA CREEK	0.87	-6.11
SAN LORENZO CREEK	0.88	10.38
SAN RAMON CREEK	0.79	-4.57
SONOMA CREEK	0.93	-3.80
UP PENITENCIA CREEK	0.84	-4.61
WALKER CREEK	0.92	8.00
WILDCAT CREEK	0.90	1.66

WEAP Outflow

The WEAP outflow for San Francisco Bay, PA 201, and PA 202 is shown in Table A-SF8.

Table A-SF8. San Francisco Bay, PA 201, and PA 202 WEAP Outflow

Geographical Region	Outflow (MAF)
San Francisco Bay	2.13
PA 201	0.89
PA 202	1.24

WAFR Fraction

The following sections describe how the WAFR Fraction was determined for San Francisco Bay, PA 201, and PA 202.

Gage Data

To begin this analysis, gage data for the major rivers in the San Francisco Bay region was compiled. In each river or stream, the most downstream gage was selected to account for water demands within the watershed and to develop a WAFR fraction that is applicable to regional outflow.

The San Francisco Bay region has many gages, yet finding gaged streams with relatively complete records was challenging. A total of 23 gages were used, representing runoff from approximately 44 percent of the region. A summary of the stream gages used in this analysis is presented in Table A-SF9. A map showing the locations of the gages used, and their respective watersheds, is shown as Figure A-SF5.

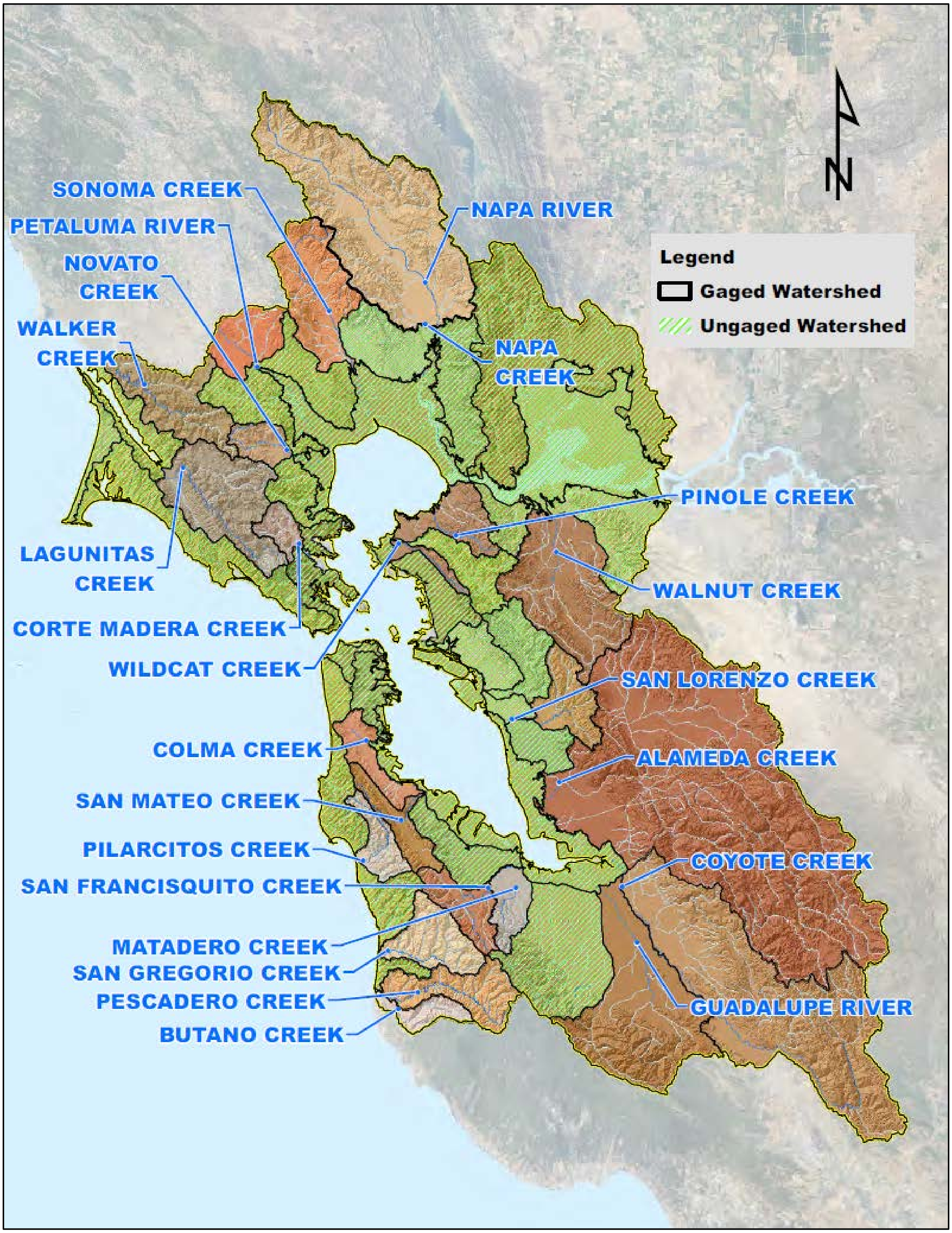
Table A-SF9. Major Rivers and Gages in San Francisco Bay Hydrologic Region Analysis

River/Stream	Location	USGS Gage Number	Area (square miles)
Alameda Creek	Union City	11180700	639
Coyote Creek	San Jose	11172175	319
Guadalupe River	San Jose	11169000	146
Napa River	Napa	11458000	218
Pescadero Creek	Pescadero	11162500	46
Petaluma River	Petaluma	11459150	45
San Lorenzo Creek	San Lorenzo	11181040	45
Sonoma Creek	Agualiente	11458500	58
Walnut Creek	Concord	11183600	85
Butano Creek	Pescadero	11162540	18
Colma Creek	S San Franciso	11162720	11
Corte Madera Creek	Ross	11460000	18

Water Available for Replenishment Information and Estimates

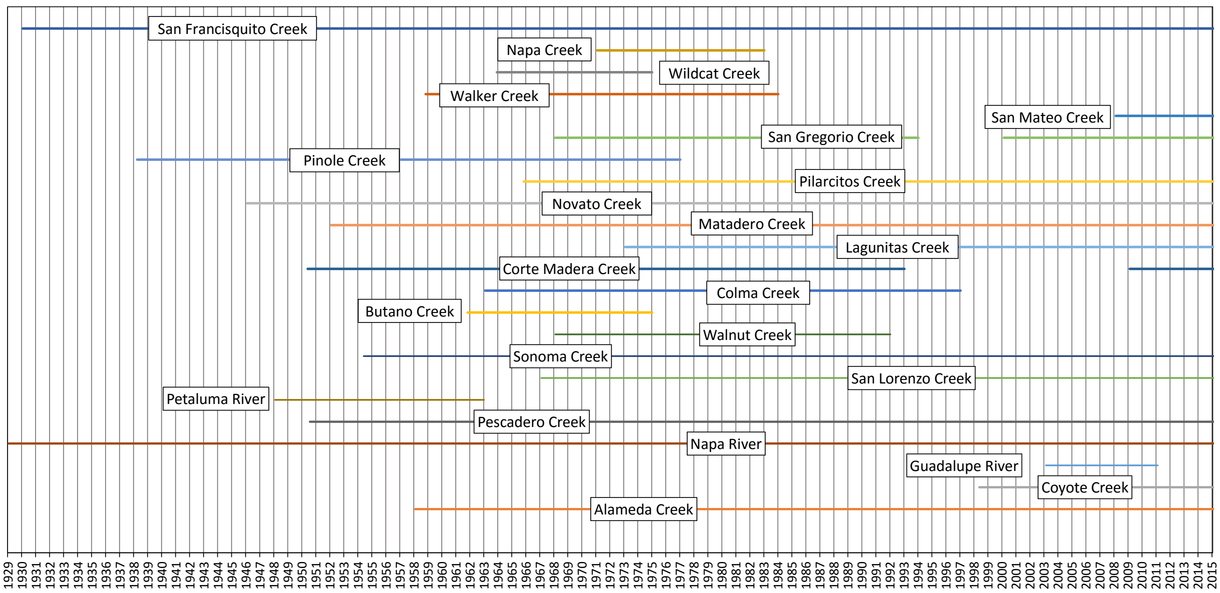
River/Stream	Location	USGS Gage	Area
Lagunitas Creek	Pt Reyes Station	11460600	82
Matadero Canal	Palo Alto	11166000	7
Novato Creek	Novato	11459500	18
Pilarcitos Creek	Half Moon Bay	11162630	27
Pinole Creek	Pinole	11182100	10
San Gregorio Creek	San Gregorio	11162570	51
San Mateo Creek	San Mateo	11162753	30
Walker Creek	Tomales	11460800	40
Wildcat Creek	Richmond	11181400	9
Napa Creek	Napa	11458300	15
San Francisquito Creek	Stanford University	11164500	37

Figure A-SF5. Watersheds for Major Gaged Streams in San Francisco Bay Hydrologic Region Analysis



Once the available gage data was compiled, the periods of available data for the twenty tree gages were compared to determine a period of analysis. Data availability, by year, is presented in Figure A-SF6.

Figure A-SF6. Period of Available Gage Data in San Francisco Bay Hydrologic Region Analysis



In the San Francisco Bay Hydrologic Region, several streams are listed as Fully Appropriated, but no stream is designated Fully Appropriated year-round.

The gage data outflow, diverted water using Conceptual Project (WAFR), and WAFR Fraction (diverted water using Conceptual Project (WAFR)/Gage Data Outflow) for each stream and the San Francisco Bay Hydrologic Region is shown in Table A-SF10.

Table A-SF10. WAFR Fraction

River/Stream	Gage Data Outflow (TAF) *	Lower Sensitivity Range Estimate		Best Estimate		Upper Sensitivity Range Estimate		Maximum Project Estimate	
		WAFR (TAF)	WAFR Fraction (%)	WAFR (TAF)	WAFR Fraction (%)	WAFR (TAF)	WAFR Fraction (%)	WAFR (TAF)	WAFR Fraction (%)
Alameda Creek	77.2	24.62	31.88%	40.18	52.04%	52.31	67.75%	67.24	87.09%
Butano Creek	18	0.16	0.90%	0.42	2.31%	0.79	4.38%	16.22	90.38%
Colma Creek	6.2	0	0.00%	0	0.00%	0	0.00%	4.47	72.40%
Corte Madera Creek	20.1	0.02	0.12%	0.07	0.34%	0.14	0.68%	16.76	83.34%
Coyote Creek	29.4	6.72	22.91%	12.52	42.66%	15.77	53.72%	17.63	60.07%
Guadalupe River	44.4	0.04	0.08%	0.1	0.23%	0.2	0.45%	35.4	79.72%
Lagunitas Creek	65.3	2.73	4.18%	6.95	10.63%	11.79	18.05%	50.15	76.79%
Matadero Canal	2.3	0	0.00%	0	0.00%	0	0.00%	1.85	81.00%
Napa Creek	14.8	0	0.02%	0.01	0.07%	0.02	0.13%	12.39	83.95%
Napa River	151.2	4.58	3.03%	9.86	6.52%	17.33	11.46%	144.5	95.59%
Novato Creek	9.6	0.14	1.46%	0.38	3.96%	0.7	7.32%	8.06	83.75%
Pescadero Creek	29.5	0.01	0.05%	0.04	0.15%	0.09	0.29%	22.48	76.21%
Petaluma River	200.4	0.25	0.13%	0.93	0.46%	1.84	0.92%	118.37	59.06%
Pilarcitos Creek	11.2	0.1	0.87%	0.29	2.60%	0.56	4.95%	8.57	76.36%
Pinole Creek	3.1	0	0.00%	0	0.00%	0	0.00%	2.51	82.15%
San Francisquito Creek	16.4	0.21	1.29%	0.59	3.57%	1.09	6.63%	13.7	83.60%
San Gregorio Creek	23.3	0.05	0.20%	0.15	0.63%	0.29	1.24%	18.1	77.74%
San Lorenzo Creek	15.6	0.02	0.11%	0.05	0.33%	0.1	0.64%	11.87	76.10%
San Mateo Creek	2.5	1.44	56.76%	1.7	67.02%	1.7	67.02%	1.7	67.02%
Sonoma Creek	49.1	0.03	0.06%	0.09	0.18%	0.18	0.37%	40.28	81.99%
Walker Creek	43.7	0	0.00%	0	0.00%	0	0.00%	36.74	84.17%
Walnut Creek	33.6	0.02	0.05%	0.06	0.18%	0.12	0.36%	23.77	70.80%
Wildcat Creek	4.4	0.04	0.88%	0.11	2.50%	0.21	4.78%	3.55	80.98%
HR Total	871.10	41.18	4.73%	74.48	8.55%	105.21	12.08%	676.32	77.64%

* Please note that the outflow is based on gaged streams only. The final WAFR estimates include outflow from the WEAP model for both gaged and ungaged watersheds.

Final WAFR Estimates

The outflow from the Gage Data was then multiplied by the range of water available for replenishment fractions determined by the historical gage data to determine the estimated range of WAFR estimates within the hydrologic region. The array of estimates for San Francisco Bay, PA 201 and PA 202 are shown in Table A-SF11 using the WEAP outflow from Table A-SF8 and water available for replenishment fractions from Table A-SF10 above.

Table A-SF11. Final WAFR Estimates

Geographical Region	WEAP Outflow (MAF)	No Project Estimate (MAF)	Lower Sensitivity Range Estimate (MAF, WAFR Fraction 4.73%)	Best Estimate (MAF, WAFR Fraction 8.55%)	Upper Sensitivity Range Estimate (MAF, WAFR Fraction 12.08%)	Maximum Project Estimate (MAF, WAFR Fraction 77.64%)
San Francisco Bay Hydrologic Region	**2.13**	**0**	**0.101**	**0.182**	**0.257**	**1.655**
PA 201	**0.89**	**0**	**0.042**	**0.076**	**0.108**	**0.694**
PA 202	**1.24**	**0**	**0.059**	**0.106**	**0.149**	**0.961**

Potential Water Development by Other Methods (recycled water, desalination and water conservation)

Estimates of potential water development by other methods (recycled water, desalination and water conservation) are also shown for San Francisco Bay region in Table A-SF12. Note that these estimates were not specifically made for use for groundwater replenishment and will need to be considered by GSAs more thoroughly for such purpose.

Table A-SF12. San Francisco Bay Urban Water Portfolio Actions

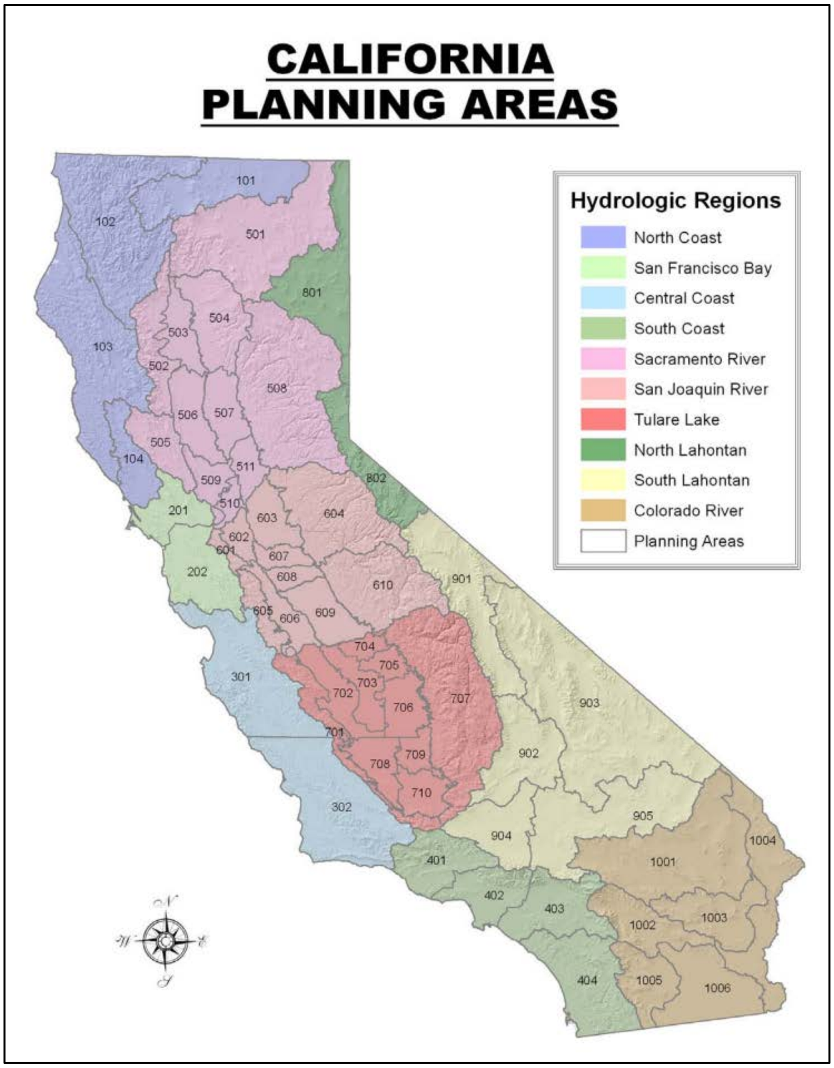
Method	Volume of Water Increase from 2010 to 2020
Recycle	0.02 MAF
Desalination	-
Conservation	0.02 MAF

Central Coast Hydrologic Region

The Central Coast HR covers a total of 11,326 square miles, and spans from southern San Mateo County in the North to the southern end of Santa Barbra County in the South. The region has several major population centers, including Santa Cruz, San Luis Obispo, Santa Maria, and Santa Barbara. The region includes highly variable vegetation and topography. Central Coast economy relies heavily on agriculture and viticulture and includes the Salinas Valley, a major agricultural hub. On an average annual basis, 23.5 inches of precipitation fall upon the region, with the vast majority falling as rain and very little falling as snow. The region receives some State Water Project (SWP) water from the Coastal Branch of the California Aqueduct. The region is the most groundwater-dependent HR in California. 80 percent of the agricultural, municipal, and domestic water demands are met by extraction of groundwater (California Water Plan Update 2013).

The Central Coast is divided into two Planning Areas: Northern Planning Area, PA 301, and Southern Planning Area, PA 302. Central Coast HR, PA 301 and PA 302 are shown in Figure A-CC1.

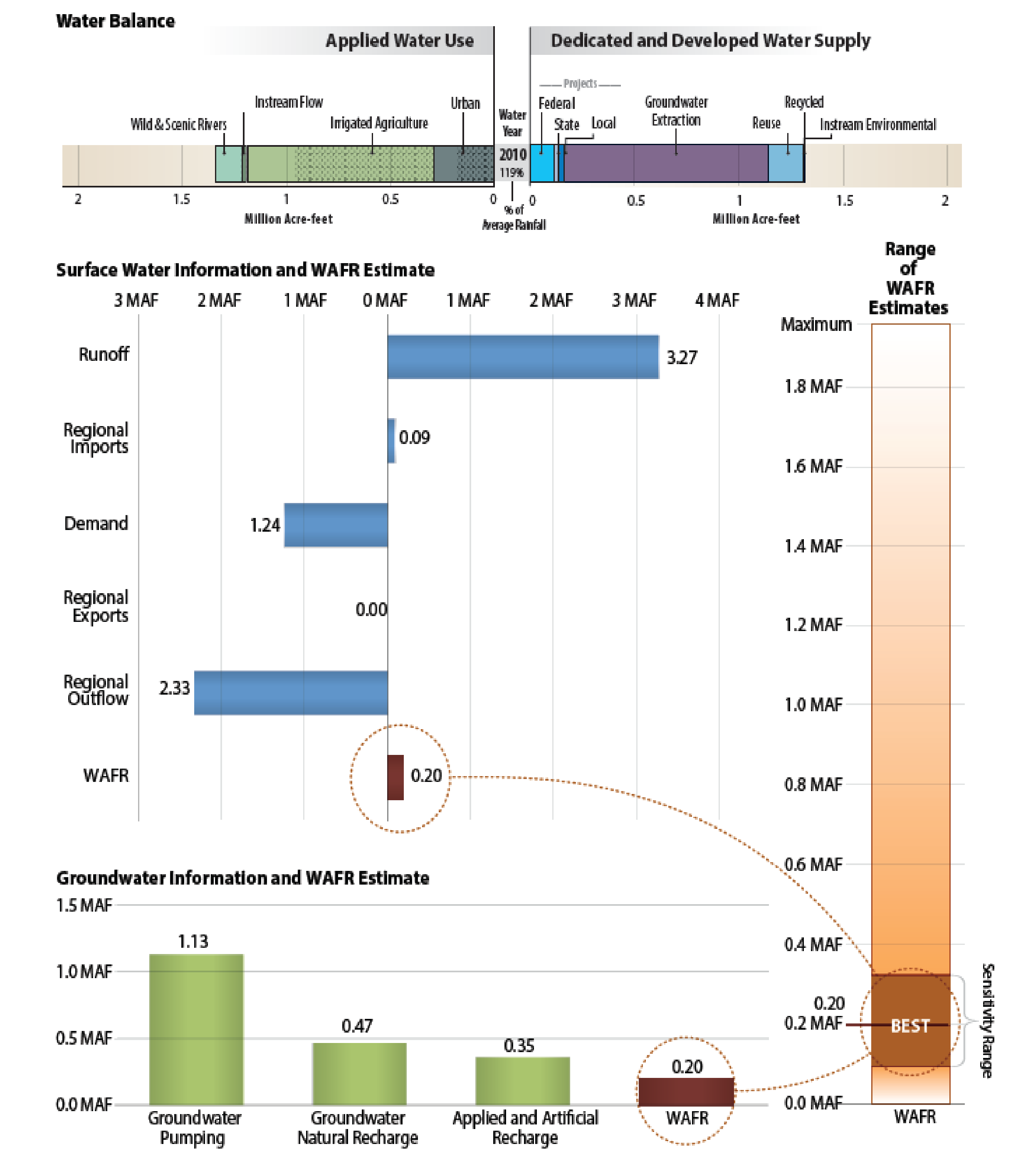
Figure A-CC1. Central Coast HR, PA 301 and PA 302



Summary of WAFR Information and Estimates

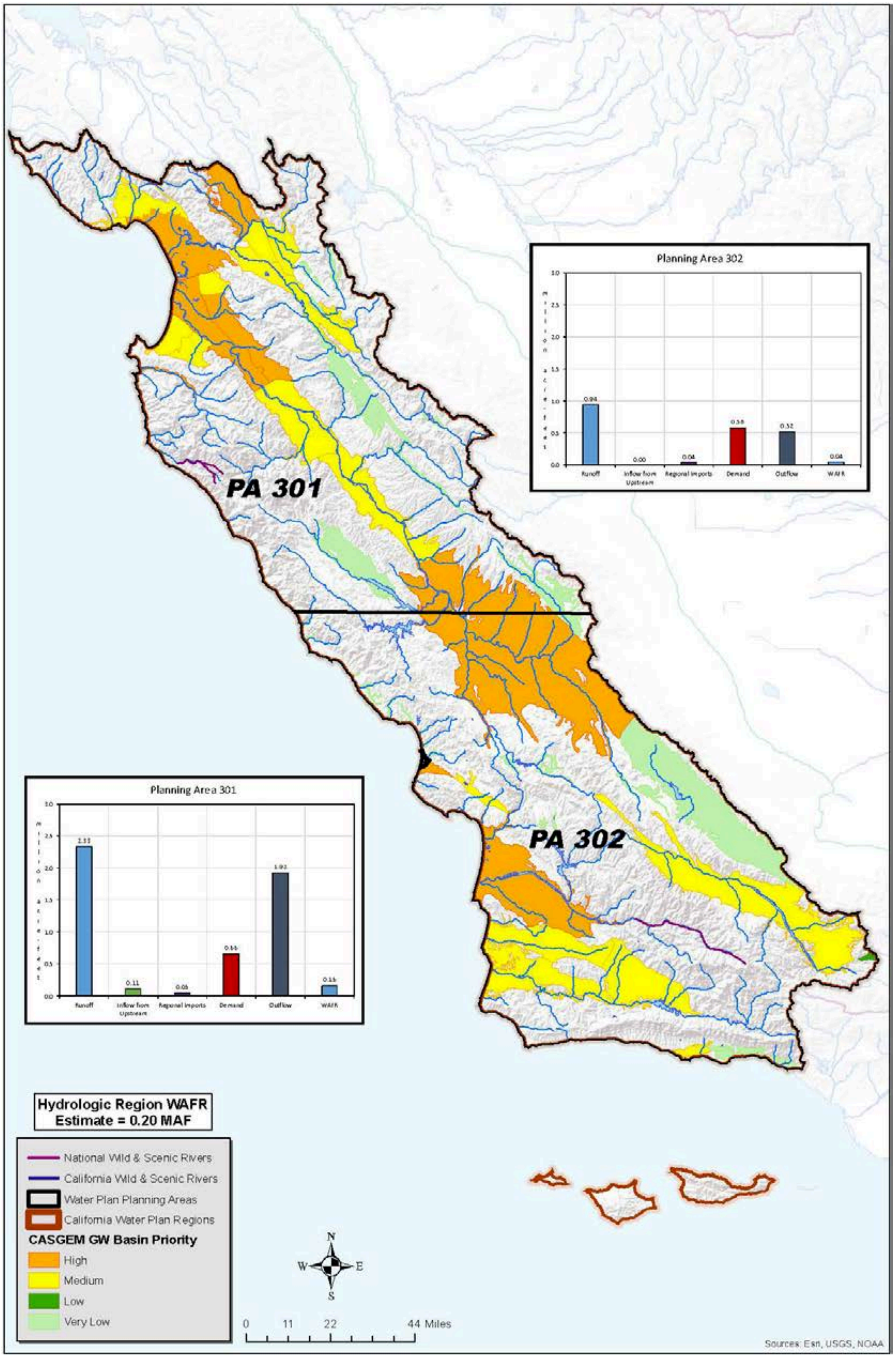
WAFR information and estimates for Central Coast Hydrologic Region, Planning Area 301, and Planning Area 302 are shown in Figures A-CC2 and A-CC3.

Figure A-CC2. Central Coast Hydrologic Region WAFR Information and Estimates



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

Figure A-CC3. Central Coast PA 301 and 302 WAFR Information and Estimates



WAFR Information and Estimates

The major tributaries in the Central Coast are the Santa Ynez River, Santa Maria River, Nacimiento River, San Antonio River, Salinas River, San Benito River and Pajaro River.

Central Coast also receives imports from both the State Water Project (SWP) and Central Valley Water Project (CVP). Actual volume of water delivered varies annually (California Water Plan Update 2013).

The WAFR information and estimates is provided in the following sections.

Surface Water and Groundwater Information

Central Coast, PA 301, and PA 302 surface water and groundwater information (as defined in the Surface Water and Groundwater Information section) is provided in Table A-CC1.

Table A-CC1. Central Coast, PA301, and PA 302 Surface Water and Groundwater Information

Geographical Region	Regional Imports (MAF)	Regional Exports (MAF)	Groundwater Pumping (MAF)	Groundwater Natural Recharge (MAF)	Applied and Artificial Recharge (MAF)
Central Coast HR	0.09	0.00	1.13	0.47	0.35
PA 301	0.05	0	-	-	-
PA 302	0.04	0	-	-	-

WAFR estimates

The following sections describe how the WAFR estimates were determined.

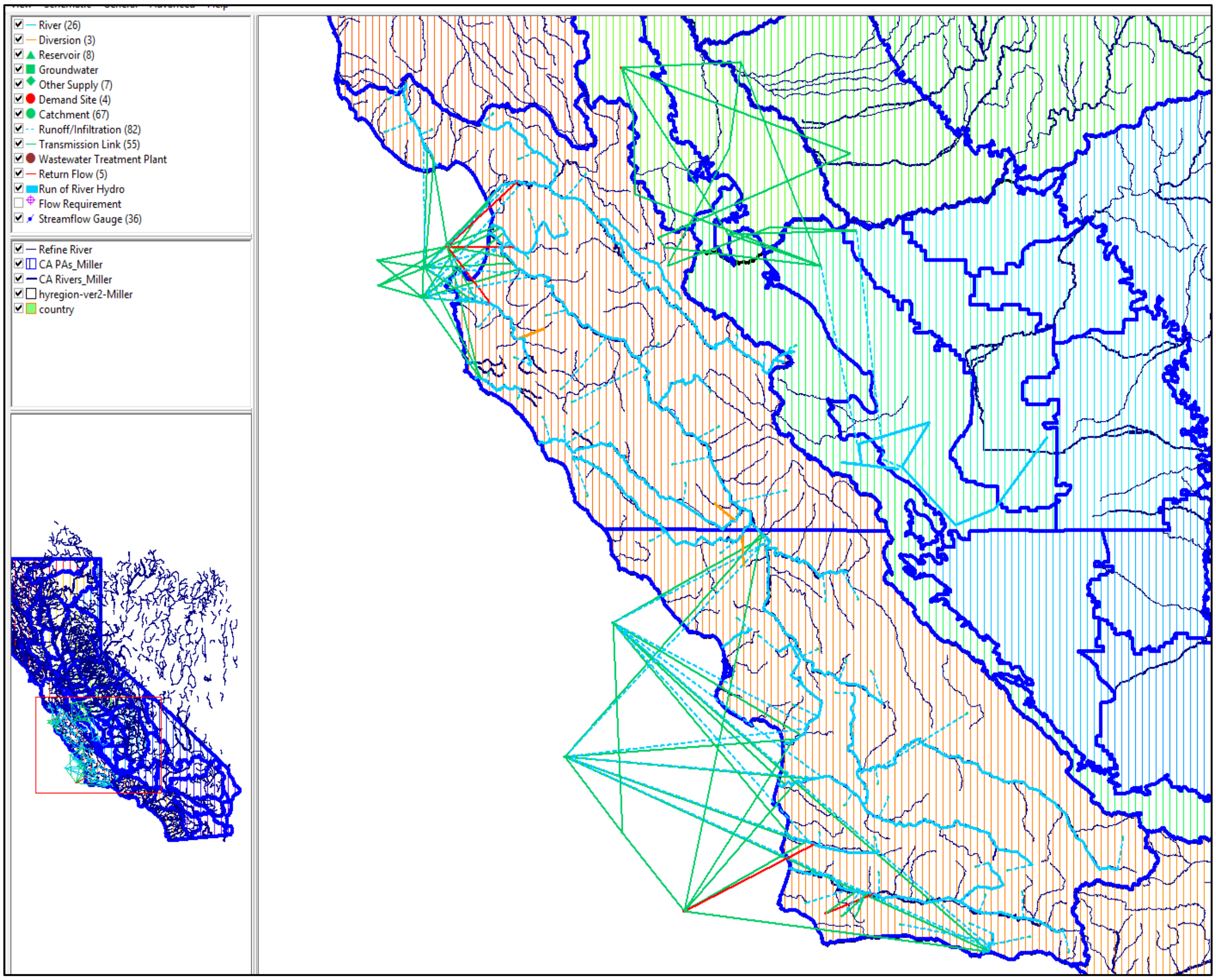
WEAP Model

The Central Coast WEAP Model was developed using the procedures described in the WEAP Model Methodology section and described in more detail in the following sections.

Model Domain

The Central Coast WEAP Model domain is shown in Figure A-CC4.

Figure A-CC4. Central Coast WEAP Model



Streams/Rivers and Delineation of Watershed

The Central Coast WEAP Model streams/rivers with corresponding Planning Area are shown in Table A-CC2.

Table A-CC2. Central Coast Streams/Rivers

River/Stream (PA 301)	River/Stream (PA 302)
Big Sur River	Cuyama River
Tres Pinos Creek	Estrella River
Uvas Creek	Huasna River
Carmel River	Lopez Creek
Clear Creek	San Antonio Creek
Gabilan Creek	San Jose Creek
Nacimiento River	Santa Cruz Creek
San Antonio River	Santa Maria River
San Benito River	Santa Ynez River
San Lorenzo River	Sisquoc River
Pajaro River	Salinas River
Salinas River	
San Lorenzo Creek	

Watersheds in Central Coast were delineated to determine the runoff from each stream using the procedures described in the [WEAP Model Methodology section](#).

Reservoir

Reservoirs included in the Central Coast HR WEAP model with the corresponding Planning Areas are:

- Gibraltar Reservoir (Santa Ynez River, PA 302).
- Jameson Reservoir (Santa Ynez River, PA 302).
- Lake Cachuma (Santa Ynez River, PA 302).
- Twitch Reservoir (Cuyama River, PA 302).
- Salinas Reservoir (Salinas River, PA 302).
- Nacimiento Reservoir (Nacimiento River, PA 301).
- San Antonio Reservoir (San Antonio River, PA 301).

Demands

The Central Coast demands were determined using the procedures described in WEAP Model Methodology section and described in the following sections.

Urban Indoor Demand

The Urban Indoor Annual Activity Level and Annual Water Use Rate for each Planning Area are shown in Table A-CC3.

Table A-CC3. Annual Activity Level and Annual Water Use Rate by Category

Category	PA 301		PA 302	
	Annual Activity Level (person/household)	Annual Water Use Rate (TAF per person/household)	Annual Activity Level (person/household)	Annual Water Use Rate (TAF per person/household)
Commercial	536,813.24	0.000032	276,540.16	0.000032
Industrial	30,201.60	0.00035	15,558.40	0.00035
Multi-Family	103,076.82	0.000196	53,100.18	0.000205
Single-Family	242,841.98	0.000221	125,100.42	0.000228

Urban Outdoor Demand

The acres for each land use class by Planning Area are shown in Table A-CC4.

Table A-CC4. Urban Outdoor Land Use Class Acres

Land Use Class	PA 301 Acres	PA 302 Acres
Commercial	2,883.54	1,289.46
Multi-Family	1,380.12	1,874.88
Public	670.49	1,478.51
Single-Family	4,821.73	6,550.27
Total	**9,755.88**	**11,193.12**

Agricultural Demand

The acres for each crop type by Planning Area are shown in Table A-CC5.

Table A-CC5. Crop acres by Crop Type

Crop	PA 301 Acres (thousand)	PA 302 Acres (thousand)
Grain	1.3	4.84
Pasture	7.4	7.57
Processed Tomato	2.9	0
Fresh Tomato	1.3	0.59
Cucurbits	1.8	2.49
Onion and Garlic	4.7	0.24
Potato	0	0.27
Other Truck	344.3	115.56
Almond and Pistachio	0	0.98
Other Deciduous	6.6	4.2
Sub-Tropical	1.5	15.37
Rice	0	0
Vine	45.8	56.48
Cotton	0	0
Sugar Beet	0	0
Corn	0.2	1.02
Dry Bean	0.9	2.47
Safflower	0.6	0.05
Other Field	2.3	0.75
Alfalfa	0.5	4.33
Total	**422.1**	**217.21**

Calibration

The Central Coast WEAP Model was calibrated using the procedures described in the WEAP Model Methodology section.

Calibration Data Collection

Calibrated Watersheds with corresponding gage information are shown in Table A-CC6.

Table A-CC6. Calibrated Gage Locations

Gage Name	Site Number	Drainage Area (Square Miles)	Gage Flow Starting Date	Gage Flow Ending Date
SAN LORENZO R NR BOULDER C CA	11160020	6.17	6/26/1969	12/10/1996
UVAS C AB UVAS RES NR MORGAN HILL CA	11153900	21	2/9/1962	1/4/1982
CLEAR C NR IDRIA CA	11154700	14.5	2/19/1994	12/12/2014
ESTRELLA R NR ESTRELLA CA	11148500	922	2/27/1955	2014
SAN LORENZO C BL BITTERWATER C NR KING CITY CA	11151300	233	2/18/1959	3/1/2014
SAN ANTONIO R NR LOCKWOOD CA	11149900	217	12/31/1965	3/3/2014
NACIMIENTO R BL SAPAQUE C NR BRYSON CA	11148900	162	12/25/1971	2/8/2015
BIG SUR R NR BIG SUR CA	11143000	46.5	3/24/1950	2/8/2015
CUYAMA R BL BUCKHORN CYN NR SANTA MARIA CA	11136800	886	3/12/1904	3/2/2014
HUASNA R NR ARROYO GRANDE CA	11137900	103	2/1/1960	5/1/2014
SISQUOC R NR GAREY	11140000	471	3/5/1941	3/2/2014
SAN ANTONIO C A LOS ALAMOS CA	11135800	34.9	12/21/1970	2014
SANTA CRUZ C NR SANTA YNEZ CA	11124500	74	12/28/1941	3/1/2014
CARMEL R A ROBLES DEL RIO CA	11143200	193	12/23/1955	12/12/2014
SAN JOSE C NR GOLETA CA	11120500	5.51	4/4/1941	3/1/2014
SAN LORENZO C A KING CITY CA	11151500	259	3/8/1943	1/27/1997
GABILAN C NR SALINAS CA	11152600	36.7	12/21/1970	2/28/2014
TRES PINOS C NR TRES PINOS CA	11157500	208	1938-02	2015

Calibration Results

Calibrated Watersheds with corresponding NSE and PBIAS are shown in Table A-CC7.

Table A-CC7. Calibrated Watersheds with corresponding NSE and PBIAS

Stream Gage Name and River Name	Nash Sutcliffe Coefficient of Efficiency (NSE)	Percent Bias (PBIAS)
NR Santa Maria @ Cuyama River	0.60	14.53
NR Garey @ Sisquoc River	0.55	-3.61
NR Arroyo Grande CA @ Huasna River	0.77	3.80
NR Estrella CA @ Estrella River	0.65	3.70
Nacimiento Full Natural Flow @ Nacimietno River	0.83	0.96
NR Big Sur CA @ Big Sur River	0.69	4.95
A Robles Del Rio @ Carmel River	0.67	-0.89
Arroyo Grande CA @ Lopez Creek	0.66	0.76
Los Alamos CA @ San Antonio Creek	0.64	16.35
NR King City CA @ San Lorenzo Creek	0.41	-5.96
NR Idria CA @ Clear Creek	0.69	-8.33
NR Boulder @ San Lorenzo R	0.84	12.68
NR Santa Ynez @ Santa Cruz Creek	0.20	-0.09
NR POZO CA @ Salinas River	0.77	3.66
NR Goleta CA @ San Jose Creek	0.66	12.76
NR Lockwood CA @ San Antonio River	0.77	6.13
NR Salinas @ Gabilan Creek	0.81	-0.83
NR Morgan Hill @ Uvas Creek	0.82	-0.47
NR Tres Pinos @ Tres Pinos Creek	0.77	1.19

WEAP Outflow

The WEAP outflow for Central Coast HR, PA 301, and PA 302 is shown in Table A-CC8.

Table A-CC8. Central Coast, PA 301, and PA 302 WEAP Outflow

Geographical Region	Outflow (MAF)
Central Coast HR	2.33*
PA 301	1.92
PA 302	0.52

*Please note the sum of the Planning Area outflow does not equal the hydrologic region. The Salinas River runs from PA 302 to PA 301. The outflow at the boundary of PA 302 (0.14 MAF) is double counted therefore adding the outflow from PA 302 and PA 301 yields 2.44 MAF (0.14 greater than the Central Coast HR).

WAFR Fraction

The following sections describe how the WAFR Fraction was determined for Central Coast, PA 301, and PA 302.

Gage Data

The total area of the gaged watersheds in Central Coast HR is 8,507 square miles of the 11,326 square mile region or approximately 75 percent of the hydrologic region. Gage data for the major rivers in the Central Coast HR was compiled. In each river or stream, the most downstream gage was chosen. Gage data for a total of nine major rivers and streams was compiled. A summary of the stream gages used in this analysis is presented in Table A-CC9. A map showing the locations of the gages used, and their respective watersheds are shown in Figure A-CC5.

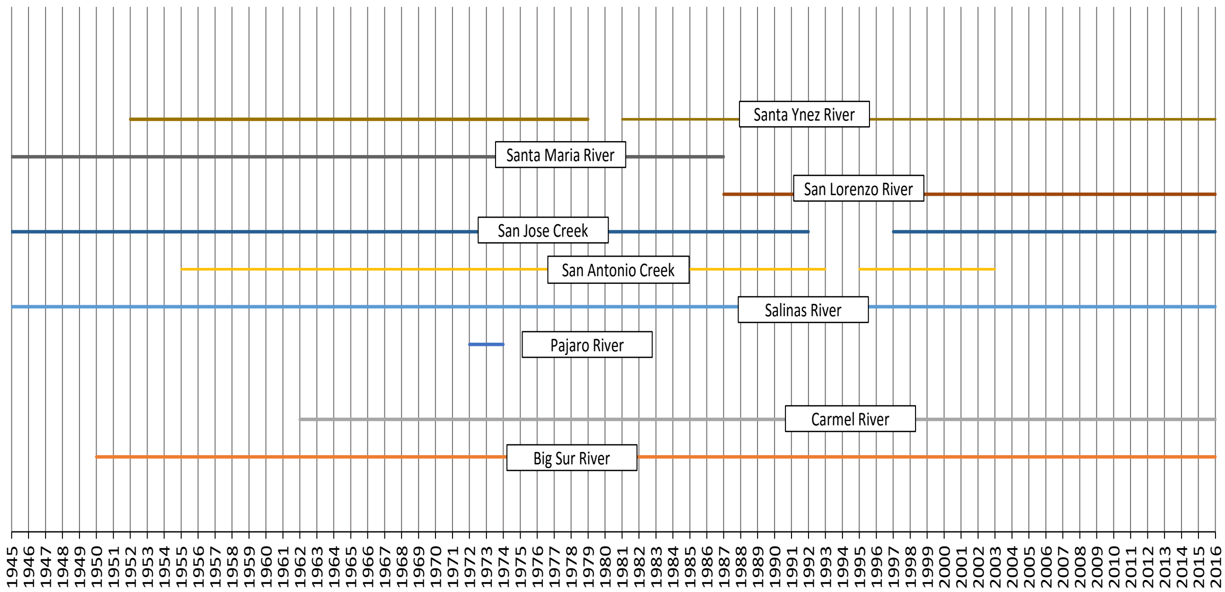
Table A-CC9. Major Rivers and Gages Used in Central Coast

River/Stream	Location	USGS Gage Number	Area (square miles)
Big Sur	Big Sur	11143000	47
Carmel	Carmel	11143250	247
Pajaro	Watsonville	11159500	1,272
Salinas	Spreckels	11152500	4,156
San Antonio	Casmalia	11136100	135
San Jose	Goleta	11120500	6
San Lorenzo	Santa Cruz	11161000	115
Santa Maria	Guadalupe	11141000	1,741
Santa Ynez	Lompoc	11133000	789

Figure A-CC5. Watersheds for Major Gaged Streams in Central Coast

For each gage, data availability by year is presented in Figure A-CC6.

Figure A-CC6. Period of Available Gage Data



Two rivers in the Central Coast HR have been designated Wild & Scenic or Fully Appropriated. The Big Sur River is designated Wild and Scenic for most of its length, although a short stretch near the ocean is not designated as such; therefore water is available. The Carmel River is fully appropriated from May to December and is also considered in this analysis.

The gage data outflow, diverted water using conceptual project (WAFR), and WAFR Fraction (diverted water using conceptual project (WAFR)/Gage Data Outflow) for each stream and the Central Coast Hydrologic Region is shown in Table A-CC10. The Central Coast HR WAFR fraction is also used for Central Coast PA 301 and PA 302.

Table A-CC10. WAFR Fraction

River/Stream	Gage Data Outflow (TAF)*	Lower Sensitivity Range Estimate		Best Estimate		Upper Sensitivity Range Estimate		Maximum Project Estimate	
		WAFR (TAF)	WAFR Fraction (%)	WAFR (TAF)	WAFR Fraction (%)	WAFR (TAF)	WAFR Fraction (%)	WAFR (TAF)	WAFR Fraction (%)
Big Sur River	72.5	0.0	0.00%	0.0	0.00%	0.0	0.00%	44.6	61.49%
Carmel River	72.2	2.8	3.91%	7.2	10.03%	12.8	17.76%	59.2	81.93%
San Lorenzo River	33.6	0.9	2.77%	2.7	8.04%	4.5	13.26%	29.2	86.91%
Pajaro River	135.7	0.0	0.01%	0.1	0.04%	0.1	0.08%	117.5	86.61%
Salinas River	268.6	14.1	5.23%	34.0	12.64%	57.5	21.39%	227.1	84.54%
Santa Ynez River	93.06	9.48	10.18%	14.29	15.36%	20.84	22.40%	92.55	99.45%
Santa Maria River	16.35	0.08	0.46%	0.22	1.37%	0.45	2.73%	12.73	77.82%
San Antonio Creek	4.71	0.01	0.12%	0.02	0.35%	0.03	0.69%	2.82	59.92%
Central Coast HR Total	**696.75**	**27.39**	**3.93%**	**58.49**	**8.39%**	**96.17**	**13.80%**	**585.65**	**84.06%**

* Please note that the outflow is based on gaged streams only. The final WAFR estimates include outflow from the WEAP model for both gaged and ungaged watersheds.

Final WAFR Estimates

The outflow estimate simulated using the WEAP model was then multiplied by the range of water available for replenishment fractions determined by the historical gage data to determine the estimated range of WAFR estimates within the hydrologic region. The array of estimates for the Central Coast HR, PA 301 and PA 302 are shown in Table A-CC11 using the WEAP outflow from Table A-CC8 and water available for replenishment fractions from Table A-CC10 above.

Table A-CC11. Final WAFR Estimates

Geographical Region	WEAP Outflow (MAF)	No Project Estimate (MAF)	Lower Sensitivity Range Estimate (MAF, WAFR Fraction 3.93%)	Best Estimate (MAF, WAFR Fraction 8.39%)	Upper Sensitivity Range Estimate (MAF, WAFR Fraction 13.80%)	Maximum Project Estimate (MAF, WAFR Fraction 84.06%)
Central Coast HR*	**2.33**	**0**	**0.10**	**0.20**	**0.32**	**1.96**
PA 301	**1.92**	**0**	**0.08**	**0.16**	**0.27**	**1.62**
PA 302	**0.52**	**0**	**0.02**	**0.04**	**0.07**	**0.44**

*Please note the sum of the Planning Area outflow does not equal the hydrologic region. The Salinas River runs from PA 302 to PA 301. The outflow at the boundary of PA 302 (0.14 MAF) is double counted therefore adding the outflow from PA 302 and PA 301 yields 2.54 MAF (0.14 greater than the Central Coast HR). For the same reason, the sum of the PA WAFR does not equal the Central Coast HR WAFR.

Potential Water Development by Other Methods (recycled water, desalination and water conservation)

Estimates of potential water development by other methods (recycled water, desalination and water conservation) are also shown for Central Coast hydrologic region in Table A-CC12. Note that these estimates were not specifically made for use for groundwater replenishment and will need to be considered by GSAs more thoroughly for such purpose.

Table A-CC12. Central Coast Urban Water Portfolio Actions

Method	Volume of Water Increase from 2010 to 2020
Recycle	0 MAF
Desalination	0.024 MAF
Conservation	0.01 MAF

South Coast Hydrologic Region

Covering a total of 10,925 square miles, the South Coast Hydrologic Region spans from Ventura County in the north to the Mexican border in the south. This is the most populated HR in California, with a population of over 19 million – slightly less than half of the state's population. On an average annual basis, 17.6 inches of precipitation falls upon the region, with the majority falling as rain and very little falling as snow, making this one of the driest hydrologic regions in the state. The region receives a significant portion of water from non-local sources, with the State Water Project (SWP) importing water from the Delta through the California Aqueduct, Los Angeles importing water from the eastern Sierra through the LA Aqueduct, in addition to water being imported from Colorado River through the Colorado Aqueduct (California Water Plan 2013).

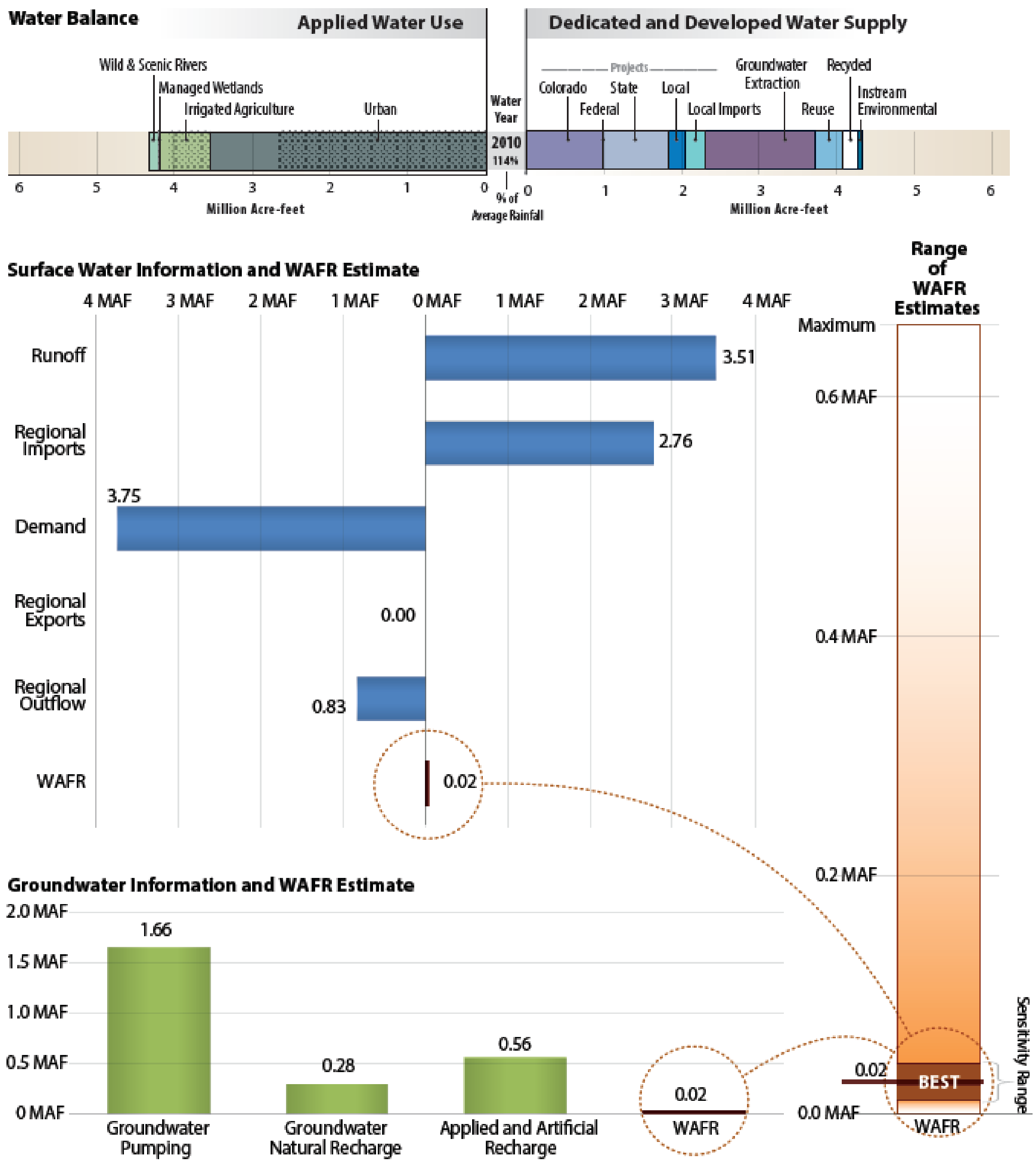
The South Coast is divided into four Planning Areas. Santa Clara (PA 401), Metro Los Angeles (PA402), Santa Ana (PA403), and San Diego (PA404).

Figure A-SC1. South Coast HR, PA 401, PA 402, PA 403, and PA 404

Summary of WAFR Information and Estimates

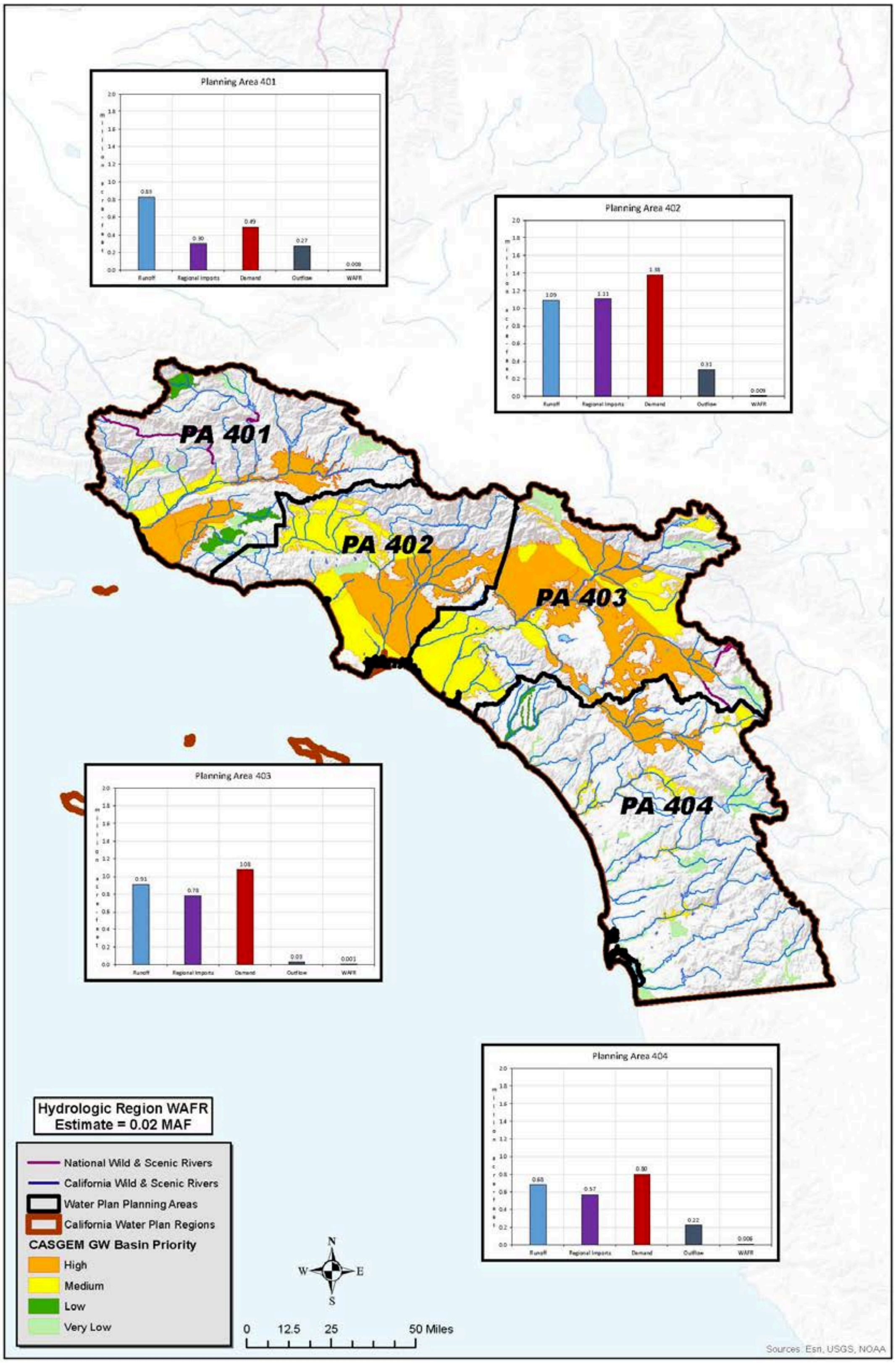
WAFR information and estimates for South Coast Hydrologic Region, Planning Area 401, Planning Area 402, Planning Area 403, and Planning Area 404 are shown in Figures A-SC2 and A-SC3.

Figure A-SC2. South Coast Hydrologic Region WAFR Information and Estimates



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

Figure A-SC3. South Coast Planning Area WAFR Information and Estimates



WAFR Information and Estimates

The major tributaries in the South Coast are the Ventura River, Santa Clara River, Los Angeles River, San Gabriel River, Santa Ana River, Santa Margarita River, San Luis Rey River, San Dieguito River, San Diego River, and Sweetwater River.

South Coast also receives imports from the State Water Project (SWP), The Colorado River Aqueduct, and The Los Angeles Aqueduct. Actual volume of water delivered varies annually (California Water Plan Update 2013).

The WAFR information and estimates is provided in the following sections.

Surface Water and Groundwater Information

South Coast, PA 401, PA 402, PA 403, and PA 404 surface water and groundwater information (as defined in the Surface Water and Groundwater Information section) is provided in Table A-SC1.

Table A-SC1. South Coast, PA 401, PA 402, PA 403, and PA 404 Surface Water and Groundwater Information

Geographical Region	Regional Imports (MAF)*	Regional Exports (MAF)	Groundwater Pumping (MAF)	Groundwater Natural Recharge (MAF)	Applied and Artificial Recharge (MAF)
South Coast HR	2.76	0.0	1.66	0.28	0.56
PA 401	0.3	0.0	-	-	-
PA 402	1.11	0.0	-	-	-
PA 403	0.78	0.0	-	-	-
PA 404	0.57	0.0	-	-	-

*Regional imports for the South Coast HR account for Colorado River, Los Angeles Aqueduct, and SWP imports.

WAFR Estimates

The following sections describe how the WAFR estimates were determined.

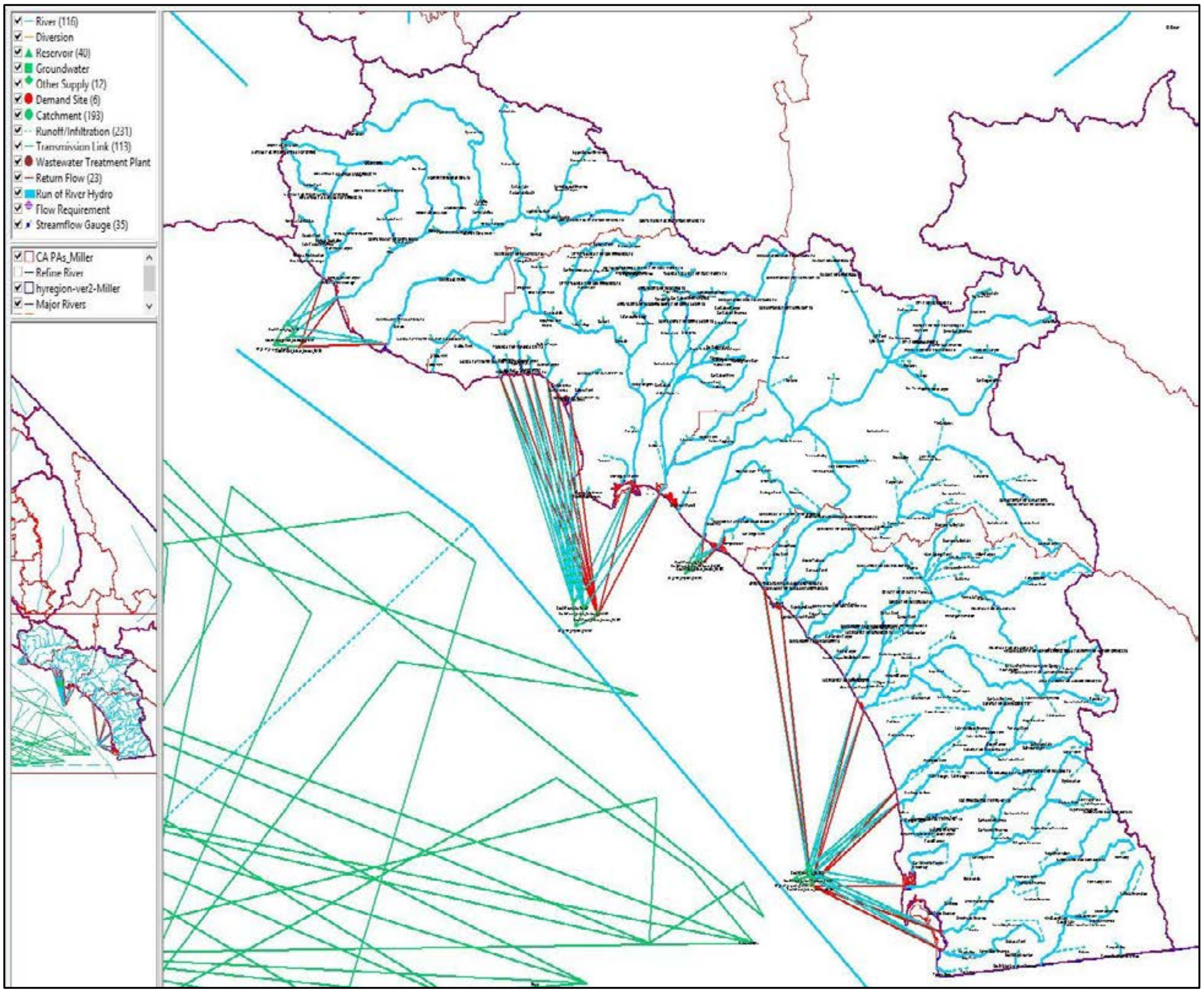
WEAP Model

The South Coast WEAP Model was developed using the procedures described in the WEAP Model Methodology section and described in more detail in the following sections.

Model Domain

The South Coast WEAP Model domain is shown in Figure A-SC4.

Figure A-SC4. South Coast WEAP Model



Streams/Rivers and Delineation of Watershed

The South Coast WEAP Model streams/rivers with corresponding Planning Area are shown in Table A-SC2.

Table A-SC2. South Coast Streams/Rivers

PA401 Rivers/Streams	PA402 River/Stream	PA403 River/Stream	PA404 River/Stream	
Santa Clara River	Malibu East	Carbon Creek	Temecula Creek	Wilson Creek
Bouquet Canyon	Quarry Canyon	Santa Ana River	Tucalotta Creek	Warm Springs Creek
Castaic Creek	Santa Monica	Plunge Creek	Murieta Creek	Santa Margarita River
Piru Creek	Rancho Palos Verdes	San Bernardino	Sandia Creek	De Luz Creek
Hopper Creek	Los Angeles River	Lytle Creek	Aliso Canyon Runoff	Las Pulgas Canyon
Sespe Creek	Aliso Canyon Wash	Chino Creek	Horno Canyon Runoff	San Onofre Canyon
Santa Paula Creek	Little Tujunga Creek	Lake Mathews	San Mateo Creek	Capistrano Beach Runoff
Red Mountain Drainage	Arroyo Seco	San Diego Creek	San Juan Creek	Arroyo Trabuco
Sexton Canyon Drainage	Santa Anita Creek	Bautista Creek	Aliso Creek	San Luis Rey River
Calleguas Creek	San Gabriel River	Bernasconi Pass	Caliente Creek	Buena Vista Creek
North Fork Matilija Creek	Walnut Creek	Coyote Creek	San Luis Rey River/Warner Springs	Keys Creek
Matilija Creek	Malibu West	Bear Creek	Moses Canyon	Pilgrim Creek
Ventura River	Malibu Creek	Mill Creek	Carlsbad Drainage	Santa Ysabel Creek
Coyote Creek	Topanga Creek	City Creek	Temascal Creek	Guejito Creek
Hammond Canyon	Sullivan Canyon	Cajon Creek	Santa Maria Creek	San Diegito River
	Ballona Creek	San Timoteo Canyon	Escondido Creek	San Diego River
	Dominguez Channel	Temescal Wash	Boulder Creek	San Vicente Creek
	Canoga Park	Santiago Creek	Los Penasquitos Creek	Unnamed Stream NR Carroll Canyon
	Pacoima Creek	Seal Beach Runoff	San Clemente Canyon	San Diego Drainage
	Big Tujunga Canyon	San Jacinto River	Sweetwater River	Dulzurra Creek
	Eaton Wash	Unnamed Stream	Otay River	Tijuana River
	San Gabriel River West Fork		South Otay Mountain Drainage	Pine Valley Creek
	Big Dalton Wash		Cottonwood Creek (to Mexico)	
	San Jose Creek		Campo Drainage (to Mexico)	

Watersheds in South Coast were delineated to determine the runoff from each stream using the procedures described in the WEAP Model Methodology section.

Reservoirs

Reservoirs included in the South Coast HR WEAP model with the corresponding Planning Areas are:

- Barrett Lake (Cottonwood Creek, PA404).
- Big Bear lake (Bear Creek, PA403).
- Big Tujunga Reservoir (Big Tujunga Canyon, PA402).
- Bouquet Reservoir (Bouquet Canyon, PA401).
- Canyon Lake (San Jacinto River, PA403).
- Castaic Lake (Castaic Creek, PA401).
- Cogswell Reservoir (San Gabriel River West Fork, PA402).
- Diamond Valley Lake (Warm Springs Creek, PA404).
- El Capitan Reservoir (San Diego River, PA404).
- Hansen Lake (Big Tujunga Canyon, PA402).
- Irvine Lake (Santiago Creek, PA403).
- Lake Casitas Reservoir (Coyote Creek, PA401).
- Lake Cuyamaca (Boulder Creek, PA404).
- Lake Elsinore (San Jacinto River, PA403).
- Lake Henshaw Reservoir (San Luis Rey River, PA404).
- Lake Hodges (Santa Ysabel Creek, PA404).
- Lake Mathews (near Temescal Wash, PA403).
- Lake Perris (Bernasconi Pass, PA403).
- Lake Piru (Piru Creek, PA401).
- Lake Skinner Reservoir (Tucalotta Creek, PA404).
- Lake Wohlford Reservoir (Escondido Creek, PA404).
- Loveland Reservoir (Sweetwater River, PA404).
- Lower Otay Reservoir (Dulzurra Creek, PA404).
- Miramar Reservoir (Near Carroll Canyon, PA404).
- Morena Reservoir (Cottonwood Creek, PA404).
- Morris Reservoir (San Gabriel River, PA402).
- Pacoima Reservoir (Pacoima Creek, PA402).
- Prado Reservoir (Santa Ana River, PA403).
- Puddingstone Dam (Walnut Creek, PA402).
- Pyramid Lake (Piru Creek, PA 401).

- San Gabriel Reservoir (San Gabriel River, PA402).
- San Vicente Reservoir (San Vicente Creek, PA404).
- Santa Fe Dam (San Gabriel River, PA402).
- Sepulveda Dam (Los Angeles River, PA402).
- Seven Oaks Reservoir (Santa Ana River, PA403).
- Sutherland Lake (Santa Ysabel Creek, PA404).
- Sweetwater Reservoir (Sweetwater River, PA404).
- Vail Lake (Temecula Creek, PA404).
- Villa Park Dam (Santiago Creek, PA403).
- Whittier Narrows (Santa Anita Creek, PA402).

Demands

The South Coast demands were determined using the procedures described in the WEAP Model Methodology section and described in the following sections.

Urban Indoor Demand

The Urban Indoor Annual Activity Level and Annual Water Use Rate for each Planning Area are shown in Table A-SC3.

Table A-SC3. Annual Activity Level and Annual Water Use Rate by Category

	PA 401		PA 402	
Category	**Annual Activity Level (person/household)**	**Annual Water Use Rate (TAF per person/household)**	**Annual Activity Level (person/household)**	**Annual Water Use Rate (TAF per person/household)**
Commercial	688874.37	.000036	4396940.00	.000036
Industrial	64984.70	.000138	369506.053	.000138
Multi-Family	150363.95	.000181	1134974.99	.000181
Single-Family	250135.72	.000231	1888070.78	.000231
	PA 403		**PA 404**	
Category	**Annual Activity Level (person/household)**	**Annual Water Use Rate (TAF per person/household)**	**Annual Activity Level (person/household)**	**Annual Water Use Rate (TAF per person/household)**
Commercial	2980352.63	.000036	1678236.98	.000036
Industrial	241047.91	.000138	107300.32	.000138
Multi-Family	611241.71	.000181	522792.32	.000181
Single-Family	1016822.07	.000231	869683.41	.000231

Urban Outdoor Demand

The acres for each land use class by Planning Area are shown in Table A-SC4.

Table A-SC4. Urban Outdoor Land Use Class Acres

Land Use Class	PA 401 Acres	PA 402 Acres
Commercial	9,408	76,769
Multi-Family	4,969	32,526
Public	9,444	16,083
Single-Family	23,002	150,558
Total	**46,823**	**275,936**
Land Use Class	**PA 403 Acres**	**PA 404 Acres**
Commercial	40,179	29,379
Multi-Family	27,384	10,238
Public	58,346	32,154
Single-Family	126,758	47,391
Total	**252,667**	**119,162**

Agricultural Demand

The acres for each crop type by Planning Area are shown in Table A-SC5.

Table A-SC5. Crop acres by Crop Type

Crop	PA 401 Acres (thousand)	PA 402 Acres (thousand)	PA 403 Acres (thousand)	PA 404 Acres (thousand)
Grain	0.42	0	4.66	1.2
Rice	0	0	0	0
Cotton	0	0	0	0
Sugar Beet	0	0	0	0
Corn	0.83	0.02	0.83	0.25
Dry Bean	0.45	0	0.68	0.18
Safflower	0	0	0	0
Other Field	0.22	0	1.14	0.06
Alfalfa	0.27	0	5.33	0.26
Pasture	2.47	0.11	6.09	2.86
Processed Tomato	0.12	0	0	0.12
Fresh Tomato	1.64	0	0.15	2.28
Cucurbits	0.4	0	0.67	1.07
Onion and Garlic	0.22	0	0.09	0.08
Potato	0	0	1.28	0.39
Other Truck	46.04	3.51	8.64	11.6
Almond and Pistachio	0	0	0.01	0

Other Deciduous	0.32	0	0.47	1.5
Sub-Tropical	58.09	0.25	13.13	48.52
Vine	0.04	0	0.77	2.49
Total	**111.53**	**3.89**	**43.94**	**72.86**

Calibration

The South Coast WEAP Model was calibrated using the procedures described in the WEAP Model Methodology section.

Calibration Data Collection

Calibrated Watersheds with corresponding gage information are shown in Table A-SC6.

Table A-SC6. Calibrated Gage Locations

Gage Name	Site Number	Drainage Area (Square Miles)	Gage Flow Starting Date	Gage Flow Ending Date
NF MATILIJA C A MATILIJA HOT SPRINGS CA	11116000	15.6	12/31/1933	3/1/1983
MATILIJA C AB RES NR MATILIJA HOT SPRINGS CA	11114500	50.7	3/11/1949	1/25/1969
SANTA PAULA C NR SANTA PAULA	11113500	38.4	1/19/1933	3/1/2014
SESPE C NR FILLMORE	11113000	252	1/19/1933	3/1/2014
HOPPER CREEK NEAR PIRU CA	11110500	23.6	12/31/1933	3/1/1983
SANTA CLARA R AB RR STATION NR LANG CA	11107745	157	2/6/1950	1/9/2005
CALLEGUAS C NR CAMARILLO CA	11106550	248	2/25/1969	2/28/2014
BALLONA C NR CULVER CITY CA	11103500	89.5	5/8/1928	2/10/1978
TOPANGA C NR TOPANGA BCH CA	11104000	18	3/15/1930	3/27/1979
MALIBU C AT CRATER CAMP NR CALABASAS CA	11105500	105	2/4/1931	3/27/1979

ARROYO SECO NR PASADENA CA	11098000	16	2/20/1914	2/28/2014
SANTA ANITA C NR SIERRA MADRE CA	11100000	9.71	12/24/1916	2/28/1970
LITTLE TUJUNGA C NR SAN FERNANDO CA	11096500	21.1	1914-01	2/11/1973
BIG TUJUNGA C BL MILL C NR COLBY RANCH CA	11094000	64.9	4/29/1948	11/29/1970
EF SAN GABRIEL R NR CAMP BONITA CA	11080500	84.6	1/19/1933	3/27/1979
SAN JACINTO R NR SAN JACINTO	11069500	142	3/13/1921	9/7/2014
PLUNGE C NR EAST HIGHLANDS CA	11055500	16.9	3/15/1919	2/28/2014
CITY C NR HIGHLAND CA	11055800	19.6	3/22/1920	2/28/2014
CAJON C NR KEENBROOK CA	11063000	40.6	3/22/1920	3/1/1983
SAN ANTONIO C NR CLAREMONT CA	11073000	17.1	3/7/1918	12/24/1971
SAN DIEGO C AT CULVER DRIVE NR IRVINE CA	11048500	41.8	2/6/1950	11/24/1984
LAS FLORES C NR OCEANSIDE CA	11046100	26.6	1/16/1952	3/1/2014
SAN ONOFRE C A SAN ONOFRE CA	11046250	42.2	1947	1/21/2010
SAN MATEO C NR SAN CLEMENTE CA	11046300	80.8	1/7/1953	3/1/2014
SAN JUAN C NR SAN JUAN CAPISTRANO CA	11046500	106	3/10/1929	2/25/1969
ARROYO TRABUCO NR SAN JUAN CAPISTRANO CA	11047000	35.7	2/8/1932	1/29/1981

TEMECULA C NR AGUANGA CA	11042400	131	4/3/1958	3/1/2014
SANDIA C NR FALLBROOK CA	11044350	21.1	2/17/1990	5/14/2015
DE LUZ C NR DE LUZ CA	11044800	33	1/16/1993	12/4/2014
AGUA CALIENTE C NR WARNER SPRINGS CA	11031500	19	1961	3/7/1987
WF SAN LUIS REY R NR WARNER SPRINGS CA	11033000	25.5	2/19/1914	2/15/1986
SWEETWATER R NR DESCANSO CA	11015000	45.4	3/24/1906	3/1/2014
LOS PENASQUITOS C NR POWAY CA	11023340	42.1	4/8/1965	3/1/2014
GUEJITO C NR SAN PASQUAL CA	11027000	22.5	12/28/1946	2/28/2014
SANTA MARIA C NR RAMONA CA	11028500	57.6	2/21/1914	2/28/2014

Calibration Results

Calibrated Watersheds with corresponding NSE and PBIAS are shown in Table A-SC7.

Table A-SC7. Calibrated Watersheds with corresponding NSE and PBIAS

Stream Gage Name and River Name	Nash Sutcliffe Coefficient of Efficiency (NSE)	Percent Bias (PBIAS)
NF Matilija Creek @ Matilija	0.87	2.84
Matilija @ Matilija Hot Springs	0.78	1.9
Santa Paula Creek @ Santa Paula	0.84	3.59
Sespe Creek @ Fillmore	0.89	1.28
Hopper Creek @ Piru	0.81	10.71
Stanta Clara River @ Lang	0.63	5.34
Calleguas Creek @ Camarillo	0.88	0.34
Ballona Creek @ Culver City	0.94	1.05
Topanga Creek @ Topanga Beach	0.85	12.79
Malibu Creek @ Crater Camp	0.69	13
Arroyo Seco @ Pasadena	0.88	2.12
Santa Anita Ck @ Sierra Madre	0.85	6.16
Little Tujunga @ San Fernando	0.68	3.91
San Gabriel River @ Camp Bonita	0.9	1.23
Big Tujunga Canyon @ Colby Ranc	0.6	-4.37
San Jacinto River @ San Jacinto	0.67	6.95
Plunge Creek @ East Highlands	0.79	2.36
City Creek @ Highland	0.78	7.12
Cajon Creek @ Keenbrook	0.71	3.25
San Antonio Creek @ Claremont	0.78	13.52
San Diego Creek @ Culver Drive	0.78	6.67
Las Flores Creek @ Oceanside	0.66	101.18
San Onofre Canyon @ San Onofre	0.66	38.41
San Mateo Creek @ San Clemente	0.79	8.42
San Juan Ck @ San Juan Capistra	0.68	10.21
Arroyo Trabuco @ San Juan Capis	0.65	4.18
Temecula Creek @ Aguanga	0.71	11.21
Sandia Creek @ Fallbrook	0.87	-12.22
De Luz Creek @ De Luz	0.86	24.37
Agua Caliente @ Warner Springs	0.85	12.1
San Luis Rey River @ Warner Spr	0.83	-1.45
Sweetwater River @ Descanso	0.81	7.82
Los Penasquitos @ Poway	0.83	4.13
Guejito Creek @ San Pasqual	0.68	13.86
Santa Maria Creek @ Ramona	0.7	5.35

WEAP Outflow

The WEAP outflow for South Coast HR, PA 401, PA 402, PA 403, and PA 404 is shown in Table A-SC8.

Table A-SC8. South Coast HR, PA 401, PA 402, PA 403, and PA 404 WEAP Outflow

Geographical Region	Outflow (MAF)
South Coast HR	0.83*
PA 401	0.274*
PA 402	0.308*
PA 403	0.032*
PA 404	0.22*

*The outflow simulated using the South Coast WEAP Model was considered outside a reasonable range as compared to the gage data therefore the outflow from the gage data was used.

WAFR Fraction

The following sections describe how the WAFR Fraction was determined for each Planning Area within the South Coast HR.

Gage Data

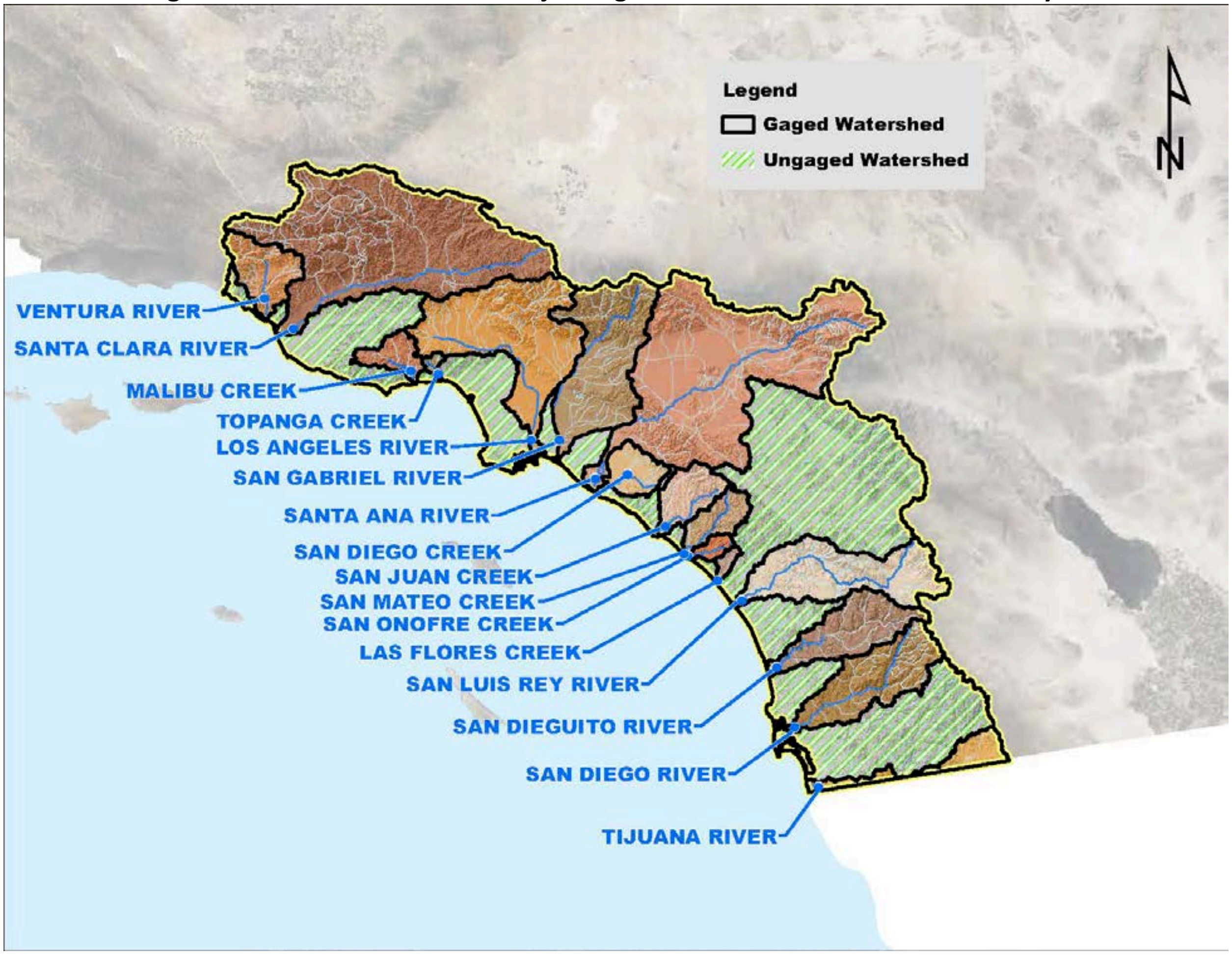
Gage data for the 13 major rivers and streams in the South Coast HR was compiled. In each river or stream, the most downstream gage was selected to account for water demands within the watershed and to develop a WAFR fraction that is applicable to regional outflow.

The total area of the gaged watersheds is 8,197 square miles of the 10,925 square mile region, approximately 75 percent of the HR. A summary of the stream gages used in this analysis is presented in Table A-SC9. A map showing the locations of the gages used, and their respective watersheds is shown in Figure A-SC5.

Table A-SC9. Major Rivers and Gages Used in South Coast HR Analysis

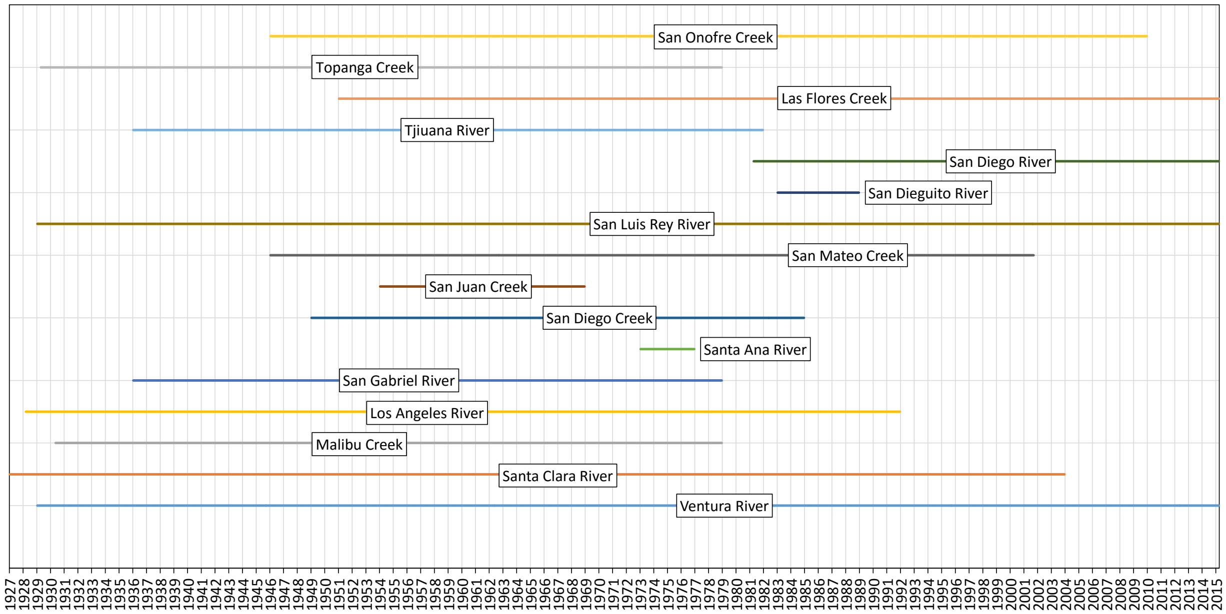
River/Stream	Location	USGS Gage Number	Area (square miles)
Ventura River	Ventura	11118500	188
Santa Clara River	Montalvo	11114000	1,594
Malibu Creek	Crater	11105500	105
Los Angeles River	Long Beach	11103000	827
San Gabriel River	Los Alamitos	11088000	472
Santa Ana River	Costa Mesa	11078100	1,701
San Diego Creek	Irvine	11048500	42
San Juan Creek	San Juan Capistrano	11046501	117
San Mateo Creek	San Onofre	11046370	132
San Luis Rey River	Oceanside	11042000	557
San Dieguito River	Del Mar	11030500	338
San Diego River	San Diego	11023000	429
Tijuana River	Nestor	11013500	1,695

Figure A-SC5. Watersheds for Major Gaged Streams in South Coast HR Analysis



Once the available gage data was compiled, the period of available data for the 13 gages were compared. Data availability, by year, is presented in Figure A-SC6.

Figure A-SC6. Period of Available Gage Data in South Coast HR Analysis



The Santa Ana River and San Gabriel River are both designated as Fully Appropriated year-round and are excluded from the WAFR fraction calculations.

The gage data outflow, diverted water using Conceptual Project (WAFR), and WAFR Fraction (diverted water using Conceptual Project (WAFR)/Gage Data Outflow) for each stream and the South Coast Hydrologic Region is shown in Table A-SC10.

Table A-SC10. WAFR Fraction

River/ Stream	Gage Data Outflow (TAF)*	Lower Sensitivity Range Estimate		Best Estimate		Upper Sensitivity Range Estimate		Maximum Project Estimate	
		WAFR (TAF)	WAFR Fraction (%)	WAFR (TAF)	WAFR Fraction (%)	WAFR (TAF)	WAFR Fraction (%)	WAFR (TAF)	WAFR Fraction (%)
Ventura River	44.97	0.71	1.57%	1.99	4.43%	3.48	7.74%	36.96	82.19%
Santa Clara River	139.11	5.35	3.85%	9.92	7.13%	16.94	12.18%	138.20	99.35%
Malibu Creek	18.24	0.01	0.04%	0.02	0.13%	0.05	0.26%	14.96	81.98%
Los Angeles River	200.56	0.07	0.03%	0.30	0.15%	0.59	0.29%	164.76	82.15%
San Gabriel	33.61	0.00	0	0.00	0	0.00	0	0.00	0.00%
Santa Ana	4.94	0.00	0	0.00	0	0.00	0	0.00	0.00%
San Diego Creek	5.12	0.03	0.66%	0.09	1.76%	0.17	3.42%	3.16	61.75%
San Juan Creek	11.11	0.34	3.02%	0.84	7.59%	1.40	12.56%	8.82	79.39%
San Mateo Creek	4.09	0.00	0.00%	0.00	0.00%	0.00	0.00%	0.00	0.00%
San Luis Rey River	27.51	0.71	2.60%	2.04	7.42%	3.53	12.84%	22.35	81.24%
San Dieguito River	2.69	0.48	17.94%	0.91	33.92%	1.36	50.46%	2.39	88.75%
San Diego River	26.28	0.01	0.03%	0.02	0.09%	0.05	0.19%	20.20	76.86%
Tjiuana River	24.78	0.00	0.00%	0.00	0.01%	0.01	0.02%	23.47	94.71%
Las Flores Creek	1.20	0.00	0.00%	0.00	0.00%	0.00	0.00%	0.00	0.00%
Topanga Creek	4.35	0.00	0.00%	0.00	0.00%	0.00	0.00%	0.00	0.00%
San Onofre Creek	1.38	0.00	0.00%	0.00	0.00%	0.00	0.00%	0.00	0.00%
HR Total	**549.93**	**7.71**	**1.42%**	**16.15**	**2.97%**	**27.57**	**5.08%**	**435.26**	**80.16%**

* Please note that the outflow is based on gaged streams only. The final WAFR estimates include outflow from both gaged and ungaged watersheds.

Final WAFR Estimates

The outflow estimate simulated using the WEAP model was then multiplied by the range of water available for replenishment fractions determined by the historical gage data to determine the estimated range of WAFR estimates within the hydrologic region. The array of estimates for the South Coast HR, PA 401 PA 402, PA 403, and PA 404 are shown in Table A-SC11 using the WEAP outflow from Table A-SC8 and water available for replenishment fractions from Table A-SC10 above.

Table A-SC11. Final WAFR Estimates

Geographical Region	Gage Data Outflow (MAF)	No Project Estimate (TAF)	Lower Sensitivity Range Estimate (MAF, WAFR Fraction 1.40%)	Best Estimate (MAF, WAFR Fraction 2.94%)	Upper Sensitivity Range Estimate (MAF, WAFR Fraction 5.01%)	Maximum Project Estimate (MAF, WAFR Fraction 79.15%)
HR	0.83	0	0.012	0.024	0.042	0.660
PA 401	0.274	0	0.004	0.008	0.014	0.217
PA 402	0.308	0	0.004	0.009	0.015	0.244
PA 403	0.032	0	0.000	0.001	0.002	0.025
PA 404	0.22	0	0.003	0.006	0.011	0.174

Potential Water Development by Other Methods (recycled water, desalination and water conservation)

Estimates of potential water development by other methods (recycled water, desalination and water conservation) are also shown for South Coast Hydrologic Region in Table A-SC12. Note that these estimates were not specifically made for use for groundwater replenishment and will need to be considered by GSAs more thoroughly for such purpose.

Table A-SC12. South Coast Urban Water Portfolio Actions

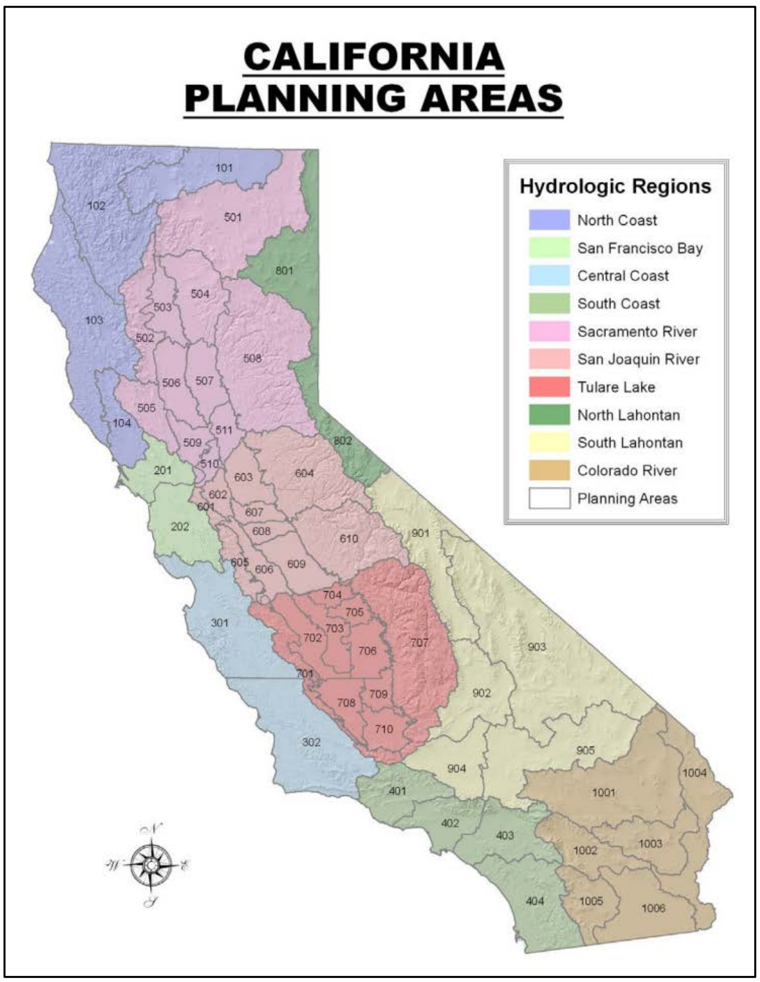
Method	Volume of Water Increase from 2010 to 2020
Recycle	0.10 MAF
Desalination	0.31 MAF
Conservation	0.24 MAF

Sacramento River Hydrologic Region

The Sacramento River Hydrologic Region includes the entire California drainage area of the Sacramento River (the state's largest river) and its tributaries. The region extends from Chipps Island in Solano County north to Goose Lake in Modoc County. It is bounded by the Sierra Nevada on the east, the Coast Ranges on the west, the Cascade and Trinity mountains on the north, and the Sacramento-San Joaquin Delta (Delta) on the south. The northernmost area, mainly high desert plateau, is characterized by cold, snowy winters with only moderate rainfall, and hot, dry summers. The mountainous parts in the north and east typically have cold, wet winters with large amounts of snow providing runoff for summer water supplies. The Sacramento Valley floor has mild winters with less precipitation and hot, dry summers. Overall annual precipitation in the region generally increases from south to north and west to east. The snow and rain that fall in this region contribute to the overall water supply for the entire state (California Water Plan Update 2013).

The Sacramento River HR is divided into 11 Planning Areas: PA 501, PA 502, PA 503, PA 504, PA 505, PA 506, PA 507, PA 508, PA 509, PA 510, and PA 511. The Sacramento River HR and its PA's are shown in Figure A-SR1.

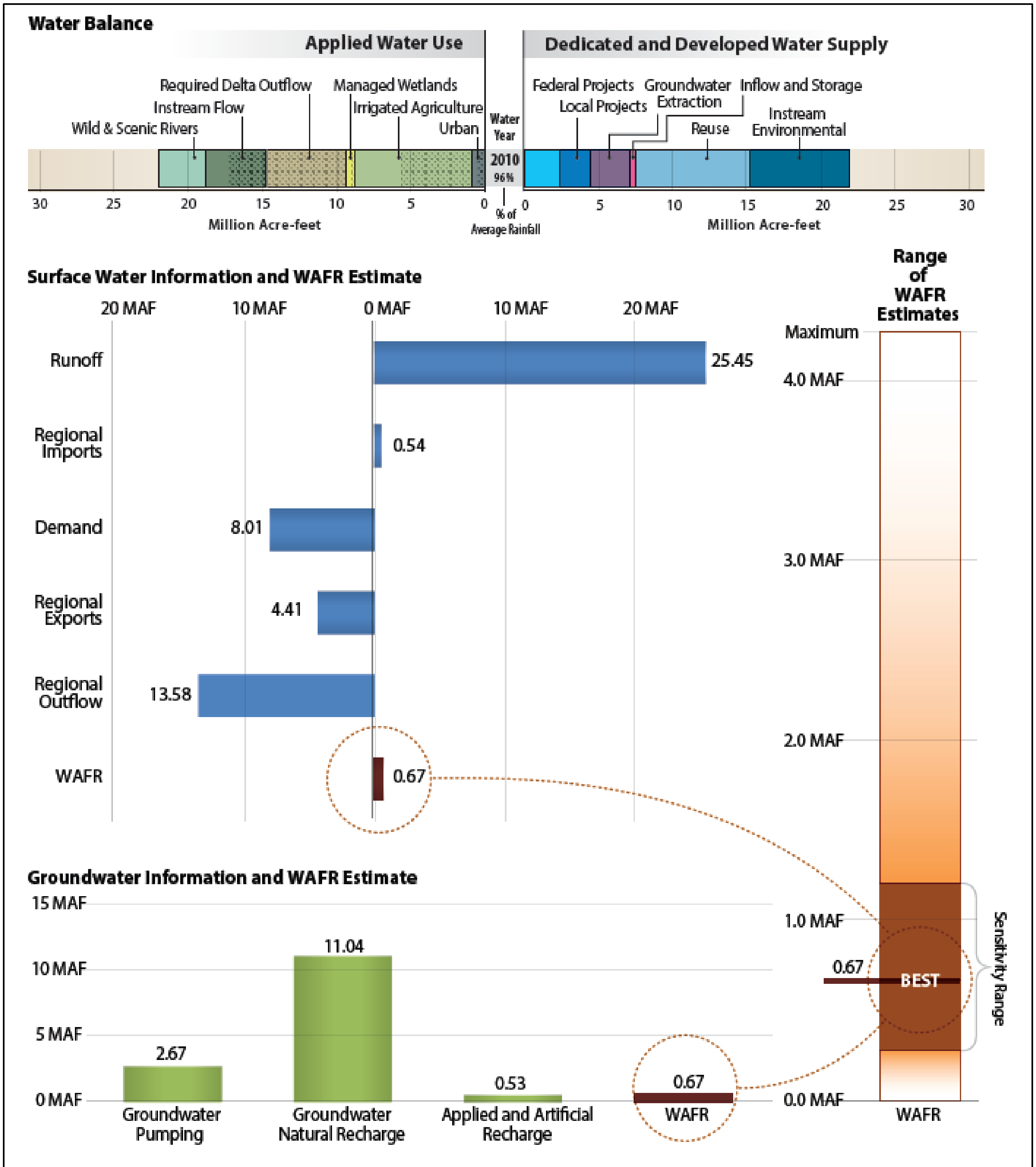
Figure A-SR1. Sacramento River HR and Sacramento Planning Areas



Summary of WAFR Information and Estimates

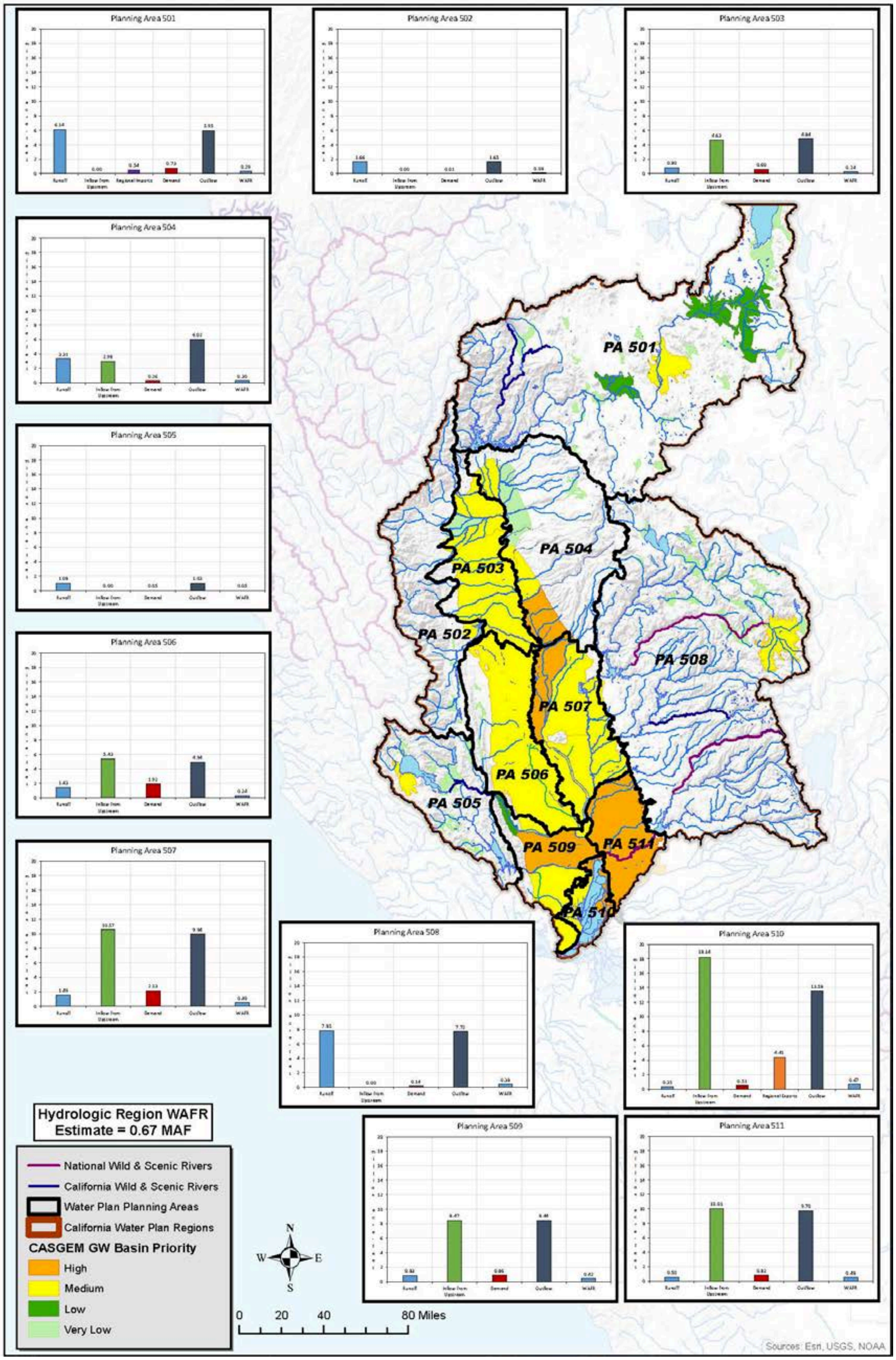
WAFR information and estimates for Sacramento River Hydrologic Region and its Planning Areas are shown in Figures A-SR2 and A-SR3.

Figure A-SR2. Sacramento River Hydrologic Region WAFR Information and Estimates



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

Figure A-SR3. Sacramento River HR Planning Area WAFR Information and Estimates



WAFR Information and Estimates

The major tributaries in the Sacramento River HR are the Sacramento River, Stoney Creek, Feather River, Yuba River, Bear River and American River.

Water is imported into the Sacramento River HR from the Trinity River through the Central Valley Project's Clear Creek Tunnel.

The WAFR information and estimates is provided in the following sections.

Surface Water and Groundwater Information

Sacramento River HR and its Planning Areas surface water and groundwater information (as defined in the Surface Water and Groundwater Information section) is shown in Table A-SR1.

Estimates of regional imports and exports are based on CalSim II modeling performed for the 2015 SWP Delivery Capability Report (DCR) for the existing conditions with historical hydrology.

Table A-SR1. Sacramento River HR and Sacramento Planning Area Surface Water and Groundwater Information

Geographical Region	Regional Imports (MAF)	Regional Exports (MAF)	Groundwater Pumping (MAF)	Groundwater Natural Recharge (MAF)	Applied and Artificial Recharge (MAF)
Sacramento River HR	0.54	4.41	2.67	11.04	0.53
PA 501	0.54	0.00	-	-	-
PA 502	0.00	0.00	-	-	-
PA 503	0.00	0.00	-	-	-
PA 504	0.00	0.00	-	-	-
PA 505	0.00	0.00	-	-	-
PA 506	0.00	0.00	-	-	-
PA 507	0.00	0.00	-	-	-
PA 508	0.00	0.00	-	-	-
PA 509	0.00	0.00	-	-	-
PA 510	0.00	4.41	-	-	-
PA 511	0.00	0.00	-	-	-

WAFR Estimates

The following sections describe how the WAFR estimates were determined.

WEAP Model

The Central Valley Planning Area (CVPA) WEAP model, developed under the CA Water Plan, was used to determine the runoff, demand and outflow for the Sacramento River HR and its Planning Areas. The CVPA WEAP model does not calculate outflow by Planning Area so a mass balance/flow routing approach was developed to estimate the outflow from each Planning Area. An approximate mass balance was developed for each Planning Area that compared available surface water supplies (runoff, inflow from upstream PAs, and regional imports) with demands and regional exports. Remaining supply after subtracting demands and exports was assumed to be outflow from the PA. Outflow from each PA was routed through the HR, starting from the upstream PAs and moving downstream, to calculate inflow from upstream PAs available in downstream PAs. Outflow from several PAs flows into or is available to multiple downstream PAs. Outflow from mountain PAs such as PA 508 was apportioned to downstream PAs 507 and 511 based on watershed area that drains to each downstream PA. Outflow from several PAs (see 503 and 504) flows into the Sacramento River and is available to downstream PAs on both sides of the river (see 506 and 507). In this case, it was assumed that each downstream PA had an equal share of outflow from the upstream PAs.

WEAP Outflow

The WEAP outflow for Sacramento River HR and its Planning Areas is shown in Table A-SR2.

Table A-SR2. Sacramento River HR and Sacramento Planning Area WEAP Outflow

Geographical Region	Outflow (MAF)
Sacramento River HR	13.58*
PA 501	5.95
PA 502	1.65
PA 503	4.84
PA 504	6.02
PA 505	1.03
PA 506	4.94
PA 507	9.94
PA 508	7.72
PA 509	8.44
PA 510	13.58
PA 511	9.70

*Please note the sum of the Planning Area outflow does not equal the hydrologic region outflow; since the Sacramento River flows through multiple Planning Areas, the outflow from an upstream Planning Area may be double counted in the outflow for a downstream Planning Area. For this reason, adding the outflow from all the Planning Areas will not equal the Sacramento River HR outflow.

WAFR Fraction

The following section describes how the WAFR fraction was determined for the Sacramento River HR. The approach for the Sacramento River and San Joaquin River HRs was similar to the gage data analysis applied to HRs outside of the Sacramento-San Joaquin Delta (Delta) watershed, but was modified to address the unique situation of the Delta. While Delta outflow is not gaged, an estimate of the daily average Delta outflow is available for an adequate period of record for analysis.

Estimated WAFR Fraction

DWR calculates and publishes the daily average Delta outflow as generated by Dayflow. Dayflow is a computer program designed to estimate daily average Delta outflow. The program uses daily river inflows, water exports, rainfall, and estimates of Delta agricultural depletions to estimate the “net” flow at the confluence of the Sacramento and San Joaquin rivers, nominally at Chipps Island. The Dayflow estimate of Delta outflow is referred to as the “net Delta outflow index”.

Daily average Delta outflow is available for an 86-year period, from water year 1930 through 2015. The entire period was used in the analysis, and a sensitivity analysis was also performed for a more recent period after the construction of the CVP and SWP (WY 1975 through 2015). Delta outflow is the outflow from two hydrologic regions; the Sacramento River and San Joaquin River. Dayflow includes separate estimates of Delta inflow from each HR, and these estimates of Delta inflow were used to determine the approximate outflow from each HR.

Daily average Delta outflow from the Sacramento River HR was evaluated against a range of Conceptual Projects that varied in capacity and instream flow requirements. Analysis in the Delta also considered whether the Delta was likely to be in either a balanced or excess condition. Balanced conditions exist when it is agreed by the State Water Project (SWP) and the Central Valley Project (CVP) that releases from upstream reservoirs plus unregulated flow approximately equal the water supply needed to meet Sacramento Valley inbasin uses, plus exports. Excess conditions exist when upstream reservoir releases plus unregulated natural flow exceed Sacramento Valley inbasin uses, plus exports (SWRCB Water Right Decision 1641). An approximation of Delta conditions was developed through analysis of CalSim II model results from the 2015 SWP Delivery Capability Report for the existing conditions with historical hydrology and review of historical CVP records. CalSim II results were used to estimate periods when the Delta was likely to be in either balanced or excess conditions and these conditions were applied to the daily average Delta outflow.

Outflow from all Planning Areas in the Sacramento HR flows into the Delta; therefore, the WAFR fraction for each Planning Area must consider Delta conditions. WAFR fractions for all Planning Areas in the Sacramento River HR are the same and are based on the analysis performed at the Delta.

Table A-SR3. WAFR Fraction

River/Stream	Gage Data Outflow (MAF)	Lower Sensitivity Range Estimate		Best Estimate		Upper Sensitivity Range Estimate		Maximum Project Estimate	
		WAFR (MAF)	WAFR Fraction (%)	WAFR (MAF)	WAFR Fraction (%)	WAFR (MAF)	WAFR Fraction (%)	WAFR (MAF)	WAFR Fraction (%)
Sacramento River HR	15.94	0.32	2.01%	0.79	4.93%	1.42	8.88%	5.02	31.46%

Final WAFR Estimates

The outflow estimate simulated using the WEAP model was then multiplied by the range of water available for replenishment fractions determined by the Dayflow data to determine the estimated range of WAFR estimates within the hydrologic region. The array of estimates for the Sacramento River HR and its Planning Areas are shown in Table A-SR4 using the WEAP outflow from Table A-SR2 and water available for replenishment fractions from Table A-SR3 above.

Table A-SR4. Final WAFR Estimates

Geographical Region	WEAP Outflow (MAF)	No Project Estimate (MAF)	Lower Sensitivity Range Estimate (MAF, WAFR Fraction 2.01%)	Best Estimate (MAF, WAFR Fraction 4.93%)	Upper Sensitivity Range Estimate (MAF, WAFR Fraction 8.88%)	Maximum Project Estimate (MAF, WAFR Fraction 31.46%)
Sacramento River HR*	13.58	0	0.27	0.67	1.21	4.27
PA 501	5.95	0	0.12	0.29	0.53	1.87
PA 502	1.65	0	0.03	0.08	0.15	0.52
PA 503	4.84	0	0.10	0.24	0.43	1.52
PA 504	6.02	0	0.12	0.30	0.53	1.89
PA 505	1.03	0	0.02	0.05	0.09	0.32
PA 506	4.94	0	0.10	0.24	0.44	1.56
PA 507	9.94	0	0.20	0.49	0.88	3.13
PA 508	7.72	0	0.16	0.38	0.69	2.43
PA 509	8.44	0	0.17	0.42	0.75	2.66
PA 510	13.58	0	0.27	0.67	1.21	4.27
PA 511	9.70	0	0.20	0.48	0.86	3.05

*Please note the sum of the Planning Area outflow does not equal the hydrologic region outflow; since the Sacramento River flows through multiple Planning Areas, the outflow from an upstream Planning Area may be double counted in the outflow for a downstream Planning Area. For this reason, adding the outflow from all the Planning Areas will not equal the Sacramento River HR outflow. Also, for this same reason, adding the WAFR from all the Planning Areas will not equal the Sacramento River HR WAFR.

Potential Water Development by Other Methods (recycled water, desalination and water conservation)

Estimates of potential water development by other methods (recycled water, desalination and water conservation) are also shown for the Sacramento River HR in Table A-SR5. Note that these estimates were not specifically made for use as groundwater replenishment and will need to be considered by GSAs more thoroughly for such purpose.

Table A-SR5. Sacramento River HR Urban Water Portfolio Actions

Method	Volume of Water Increase from 2010 to 2020
Recycle	0.02 maf*
Desalination	0 maf*
Conservation	0.13 maf*

*maf - million acre-feet

Example: Sacramento Valley Sensitivity 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.

Figure A-SR4 shows the double mass plot relationship of the Sacramento River and watershed from 1950 to 2015. The bottom "x-axis" represents the cumulative annual North Sierra precipitation from DWR's 8 station index. The "y-axis" represents the cumulative annual flow accretion during the months of April to September. River accretion is the volume of water gained in-between two specific locations in a river reach[2]. And the top "x-axis" shows a rough estimation of the water year.

The theory of the double-mass plot is that a graph of the cumulative of one variable (in this case, annual accretion during the months April to September) against the cumulative of another variable (in this case, annual precipitation) during the same period will plot as a straight line so long as the data are proportional; the slope of the line will represent the constant of proportionality between the variables. A break in the slope of the double-mass plot indicates that a change in the constant of proportionality (ratio) between the two variables has occurred or perhaps that the proportionality is not a constant at all rates of accumulation. If the proportionality constant does not vary, then a break in the slope

[2] The Sacramento River accretion was calculated by taking the difference of the Sacramento River flows leaving the Sacramento Basin (flows at Freeport, Fremont Weir, and Sacramento Weir) and entering the Sacramento Valley (Keswick Dam, Feather River below Oroville Dam and Thermalito Afterbay, and Nimbus Dam).

indicates the time at which a change occurs in the ratio. The difference in the slope of the lines on either side of the break in the slope indicates the degree of change in the ratio, i.e., proportionality constant[3].

In Figure A-SR4, several observations can be made:

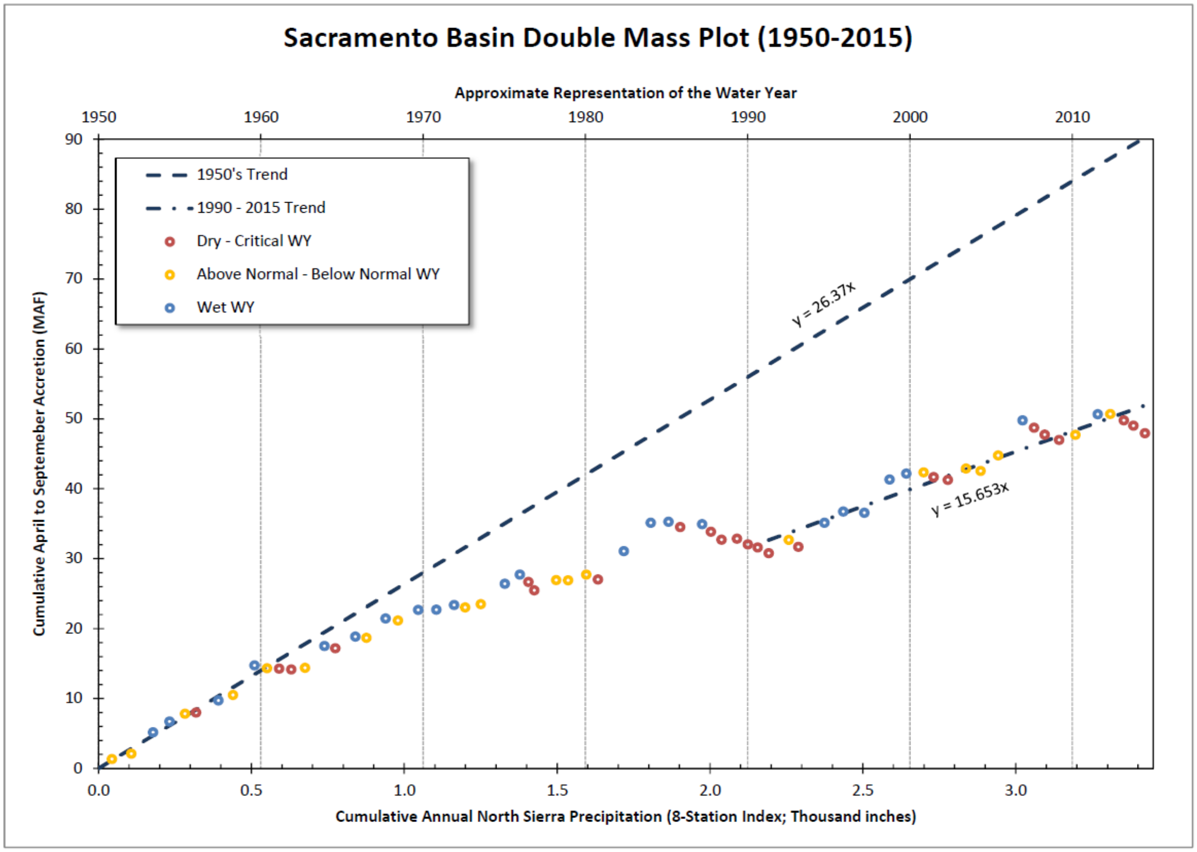
- The ratio between the two variables decreased when comparing the 1950's trend (1950-1960) and the 1990-2015 trend.
- The multi-year drought water years, 1976-1977, 1987-1992, 2007-2009, and 2012-2015 had negative ratios, which depleted the river flows. For example, water years from 1987 to 1992 significantly depleted the river flow and the depletion effect is easily observed.

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.

[3] Searcy, T. K.; Hardison, C.H. 1960: Double-mass Curves. U.S. Geological Survey Water-Supply Paper 1541-B. USGS, Washington. 66 p. http://pubs.usgs.gov/wsp/1541b/report.pdf

Figure A-SR4. Sacramento Basin double mass plot between the cumulative annual North Sierra precipitation and cumulative April to September Accretion



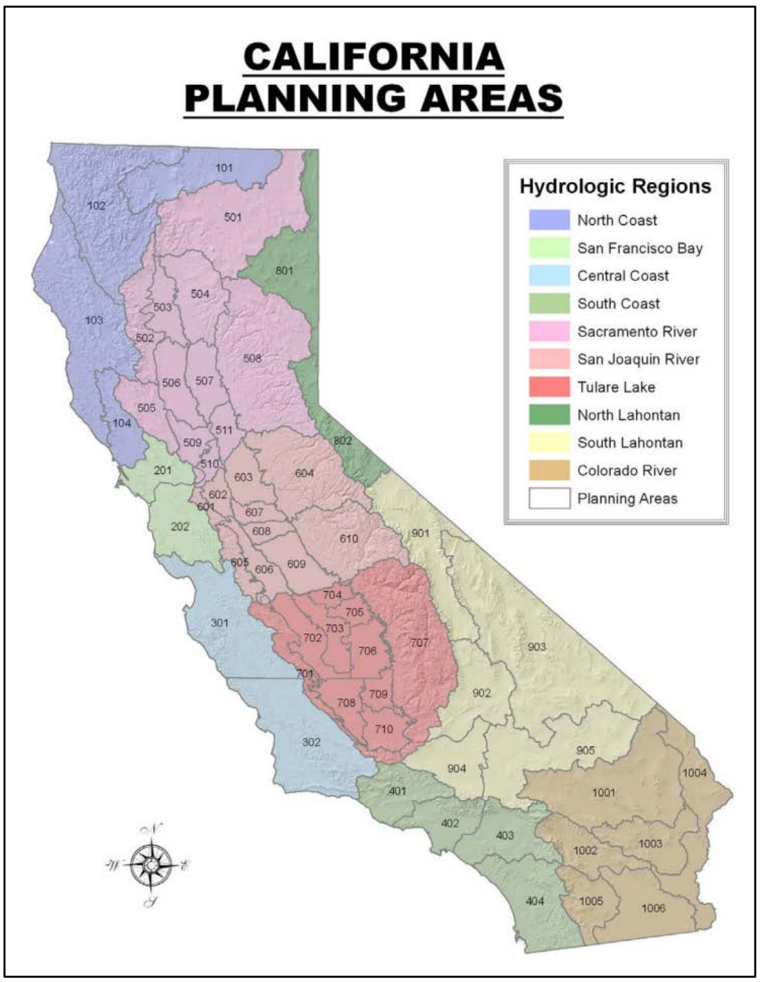
While there is uncertainty regarding the relative importance of these factors associated with the observed changes in the Sacramento River, changes have occurred. A fundamental challenge associated with sustainable groundwater management and water available for replenishment is to better understand how physical or natural changes can influence the hydraulic connection between groundwater and surface water. In particular, understanding the inter-dependent 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.

San Joaquin Hydrologic Region

The San Joaquin River Hydrologic Region is in California's great Central Valley and is generally the northern portion of the San Joaquin Valley. The region is south of the Sacramento River Hydrologic Region and north of the Tulare Lake Hydrologic Region. The region includes approximately half of the Sacramento-San Joaquin Delta (Delta). The San Joaquin HR is bordered on the east by the Sierra Nevada and on the west by the coastal mountains of the Diablo Range. This region experiences a wide range of precipitation that varies from low rainfall amounts on the valley floor to extensive snowfall in the higher elevations of the Sierra Nevada. The snow that remains after winter serves as stored water before it melts in the spring and summer. The average annual precipitation of several Sierra Nevada stations is about 35 inches. Snowmelt from the mountains is a major contributor to local eastern San Joaquin Valley water supplies (California Water Plan Update 2013).

The San Joaquin River HR is divided into 10 Planning Areas: PA 601, PA 602, PA 603, PA 604, PA 605, PA 606, PA 607, PA 608, PA 609, and PA 610. The San Joaquin River HR and its PA's are shown in Figure A-SR1.

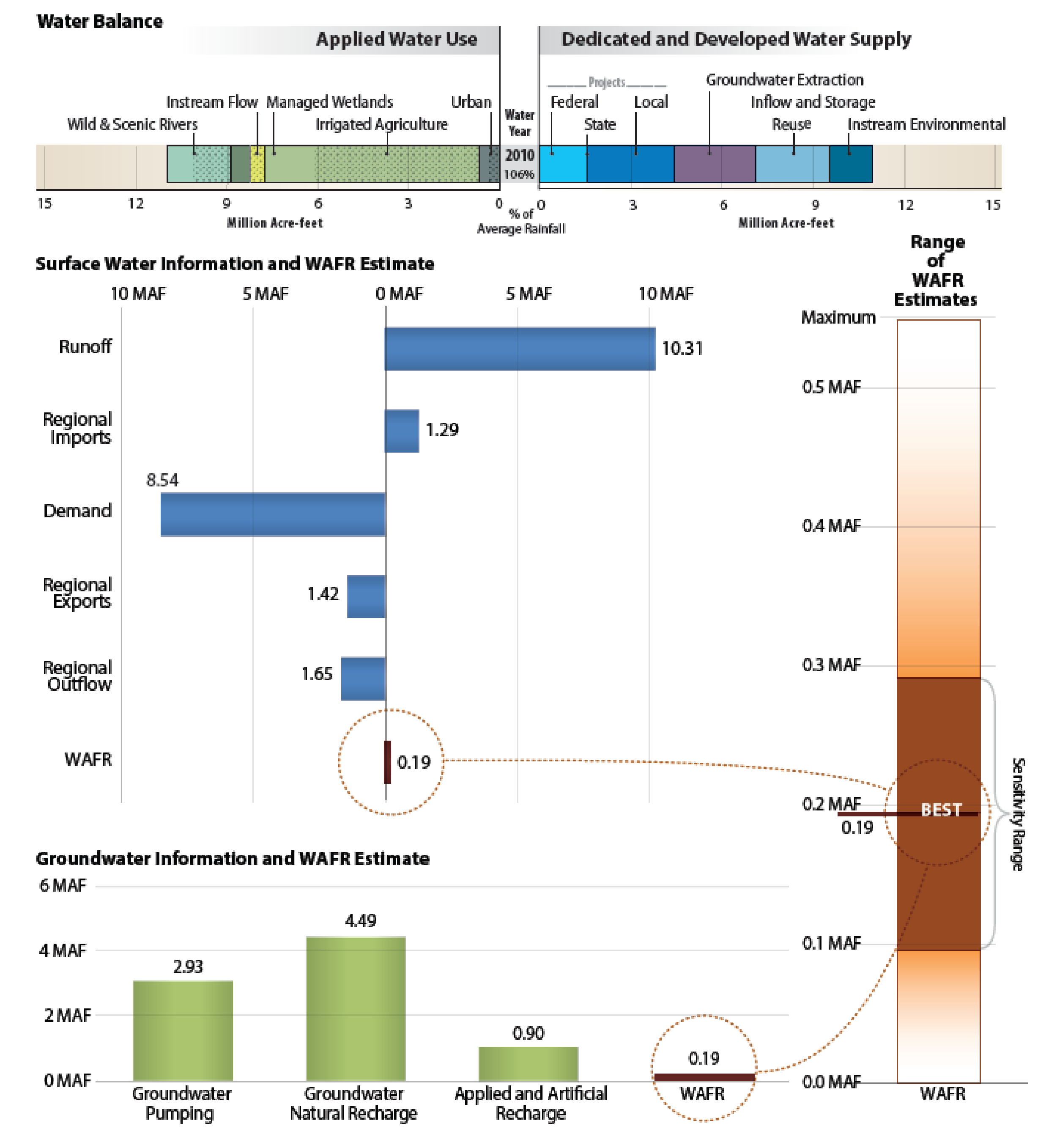
Figure A-SR1. San Joaquin River HR and San Joaquin Planning Areas



Summary of WAFR Information and Estimates

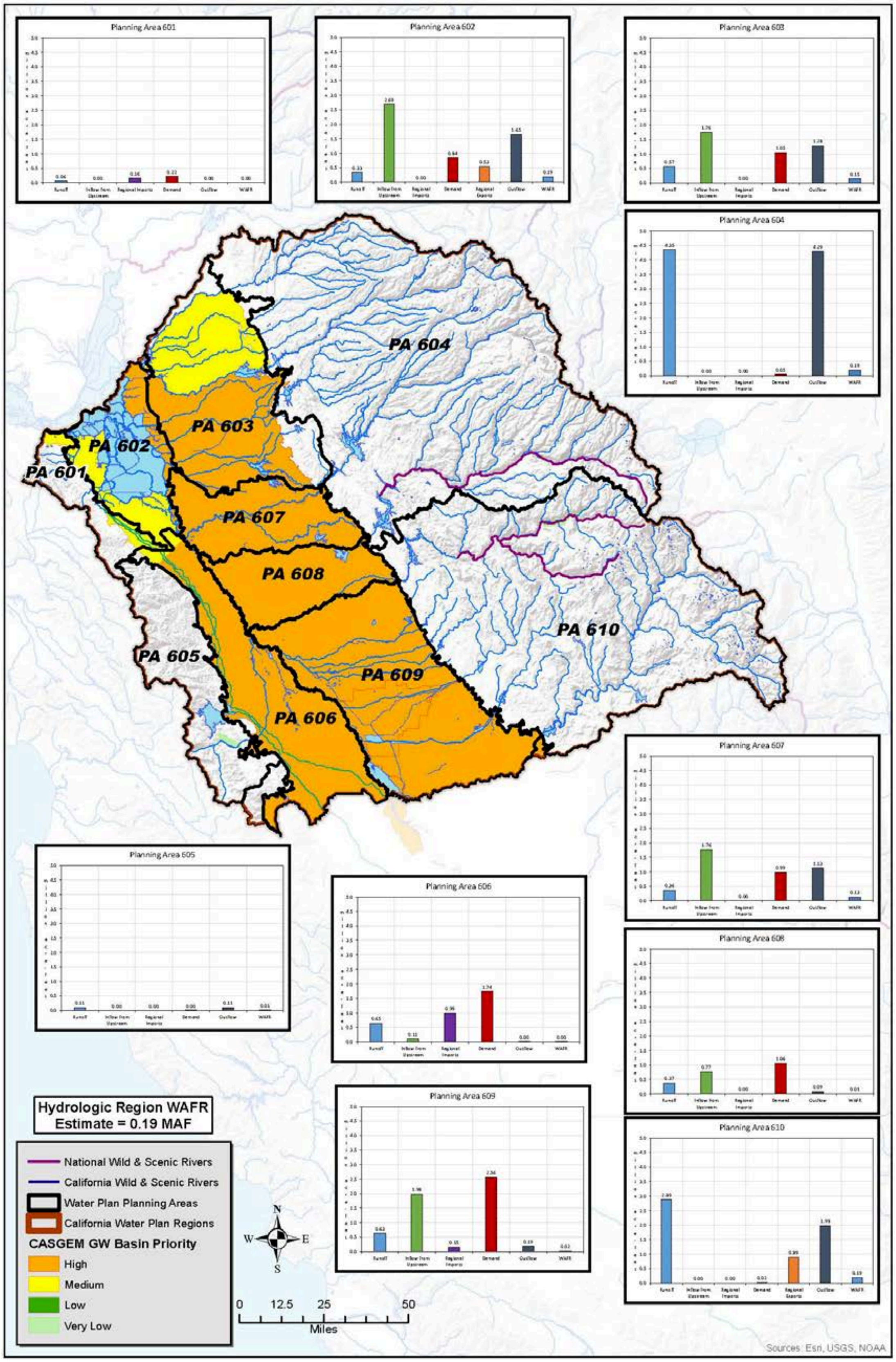
WAFR information and estimates for San Joaquin River Hydrologic Region and its Planning Areas are shown in Figures A-SJ2 and A-SJ3.

Figure A-SJ2. San Joaquin Hydrologic Region WAFR Information and Estimates



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

Figure A-SJ3. San Joaquin Planning Area WAFR Information and Estimates



WAFR Information and Estimates

The major tributaries in the San Joaquin River HR are the San Joaquin River, Mokelumne River, Calaveras River, Consumes River, Stanislaus River, Tuolumne River, Merced River, Chowchilla River and Fresno River.

Water is imported into the San Joaquin River HR from the Sacramento River HR and exported into the Tulare Lake, Central Coast, and South Coast HRs.

The WAFR information and estimates are provided in the following sections.

Surface Water and Groundwater Information

San Joaquin River HR and its Planning Area surface water and groundwater information (as defined in the Surface Water and Groundwater Information section) is shown in Table A-SJ1.

Estimates of regional imports and exports are based on CalSim II modeling performed for the 2015 SWP Delivery Capability Report for the existing conditions with historical hydrology. Exports from the San Joaquin River HR include Friant Kern Canal and the combined CVP and SWP exports from the Delta. Regional imports to individual PAs are based on the types of CVP and SWP contracts and the volume of contract supply held by individual contractors within the PA.

Table A-SJ1. San Joaquin River HR and San Joaquin Planning Area Surface Water and Groundwater Information

Geographical Region	Regional Imports (MAF)	Regional Exports (MAF)	Groundwater Pumping (MAF)	Groundwater Natural Recharge (MAF)	Applied and Artificial Recharge (MAF)
San Joaquin River HR	1.29	1.42	2.93	4.49	0.90
PA 601	0.16	0.00	-	-	-
PA 602	0.00	0.53	-	-	-
PA 603	0.00	0.00	-	-	-
PA 604	0.00	0.00	-	-	-
PA 605	0.00	0.00	-	-	-
PA 606	0.99	0.00	-	-	-
PA 607	0.00	0.00	-	-	-
PA 608	0.00	0.00	-	-	-
PA 609	0.15	0.00	-	-	-
PA 610	0.00	0.89	-	-	-

WAFR Estimates

The following sections describe how the WAFR estimates were determined.

WEAP Model

The Central Valley Planning Area (CVPA) WEAP model, developed under the CA Water Plan, was used to determine the runoff, demand and outflow for the San Joaquin River HR and its Planning Areas. The CVPA WEAP model does not calculate outflow by Planning Area so a mass balance/flow routing approach was developed to estimate the outflow from each Planning Area. An approximate mass balance was developed for each Planning Area that compared available surface water supplies (runoff, inflow from upstream PAs, and regional imports) with demands and regional exports. Remaining supply after subtracting demands and exports was assumed to be outflow from the PA. Outflow from each PA was routed through the HR, starting from the upstream PAs and moving downstream, to calculate inflow from upstream PAs available in downstream PAs. Outflow from several PAs flows into or is available to multiple downstream PAs. Outflow from the mountain PAs such as 604 and 610 was apportioned to downstream PAs 603, 607, 608, and 609 based on watershed area that drains to each downstream PA.

WEAP Outflow

The WEAP outflow for San Joaquin River HR and its Planning Areas is shown in Table A-SR2.

Table A-SJ2. San Joaquin River HR and San Joaquin Planning Area WEAP Outflow

Geographical Region	Outflow (MAF)
San Joaquin River HR*	1.65*
PA 601	0.00
PA 602	1.65
PA 603	1.28
PA 604	4.29
PA 605	0.11
PA 606	0.00
PA 607	1.13
PA 608	0.09
PA 609	0.19
PA 610	1.98

*Please note the sum of the Planning Area outflow does not equal the hydrologic region outflow; since the San Joaquin River flows through multiple Planning Areas, the outflow from an upstream Planning Area may be double counted in the outflow for a downstream Planning Area. For this reason, adding the outflow from all the Planning Areas will not equal the San Joaquin River HR outflow.

WAFR Fraction

The following section describes how the WAFR Fraction was determined for the San Joaquin River HR. The approach for the Sacramento River and San Joaquin River hydraulic regions was similar to the gage data analysis applied to HRs outside of the Delta watershed, but was modified to address the unique situation of the Delta. While Delta outflow is not gaged, an estimate of the daily average Delta outflow is available for an adequate period of record for analysis.

Estimated WAFR Fraction

The Department calculates and publishes the daily average Delta outflow as generated by Dayflow. Dayflow is a computer program designed to estimate daily average Delta outflow. The program uses daily river inflows, water exports, rainfall, and estimates of Delta agricultural depletions to estimate the "net" flow at the confluence of the Sacramento and San Joaquin rivers, nominally at Chipps Island. The Dayflow estimate of Delta outflow is referred to as the "net Delta outflow index."

Daily average Delta outflow is available for an 86-year period, from water year 1930 through 2015. The entire period was used in the analysis, and a sensitivity analysis was also performed for a more recent period after the construction of the CVP and SWP (WY 1975 through 2015). Delta outflow is the outflow from two hydrologic regions, the Sacramento River and San Joaquin River. Dayflow includes separate estimates of Delta inflow from each HR, and these estimates of Delta inflow were used to determine the approximate outflow from each HR.

Daily average Delta outflow from the San Joaquin River HR was evaluated against a range of Conceptual Projects that varied in capacity and instream flow requirements. Analysis in the Delta also considered whether the Delta was likely to be in either a balanced or excess condition. Balanced conditions in the Delta indicate that all Delta inflow and outflow is meeting current demands and there is no WAFR estimates. An approximation of Delta conditions was developed through analysis of CalSim II model results from the 2015 SWP Delivery Capability Report for the existing conditions with historical hydrology and review of historical CVP records. CalSim II results were used to estimate periods when the Delta was likely to be in either balanced or excess conditions and these conditions were applied to the daily average Delta outflow.

Outflow from all Planning Areas in the San Joaquin HR flows into the Delta; therefore, the WAFR fraction for each Planning Area must consider Delta conditions. WAFR fractions for all Planning Areas in the San Joaquin River HR are the same and are based on the analysis performed at the Delta.

Table A-SJ3. WAFR Fraction

River/Stream	Gage Data Outflow (MAF)	Lower Sensitivity Range Estimate		Best Estimate		Upper Sensitivity Range Estimate		Maximum Project Estimate	
		WAFR (MAF)	WAFR Fraction (%)	WAFR (MAF)	WAFR Fraction (%)	WAFR (MAF)	WAFR Fraction (%)	WAFR (MAF)	WAFR Fraction (%)
San Joaquin River HR	3.66	0.21	5.81%	0.43	11.82%	0.65	17.68%	1.22	33.40%

Initial WAFR estimates for mountain Planning Areas 602 and 604 were developed by applying the WAFR fraction. However, for these Planning Areas this resulted in an unrealistically high WAFR considering that much of the outflow goes to meet demand in other Planning Areas under contracts and water rights. In these instances, WAFR was adjusted to not exceed the WAFR from the entire San Joaquin River HR.

Final WAFR Estimates

The outflow estimate simulated using the WEAP model was then multiplied by the range of water available for replenishment fractions determined by the Dayflow data to determine the estimated range of WAFR estimates within the hydrologic region. The array of estimates for the San Joaquin River HR and its Planning Areas are shown in Table A-SJ4 using the WEAP outflow from Table A-SJ2 and water available for replenishment fractions from Table A-SJ3 above.

Table A-SJ4. Final WAFR Estimates

Geographical Region	WEAP Outflow (MAF)	No Project Estimate (MAF)	Lower Sensitivity Range Estimate (MAF, WAFR Fraction 5.81%)	Best Estimate (MAF, WAFR Fraction 11.82%)	Upper Sensitivity Range Estimate (MAF, WAFR Fraction 17.68%)	Maximum Project Estimate (MAF, WAFR Fraction 33.40%)
San Joaquin River HR*	1.65*	0	0.10	0.19	0.29	0.55
PA 601	0.00	0	0.00	0.00	0.00	0.00
PA 602	1.65	0	0.10	0.19	0.29	0.55
PA 603	1.28	0	0.07	0.15	0.23	0.43
PA 604	4.29	0	0.10	0.19	0.29	0.55
PA 605	0.11	0	0.01	0.01	0.02	0.04
PA 606	0.00	0	0.00	0.00	0.00	0.00
PA 607	1.13	0	0.07	0.13	0.20	0.38
PA 608	0.09	0	0.00	0.01	0.02	0.03
PA 609	0.19	0	0.01	0.02	0.03	0.06
PA 610	1.98	0	0.10	0.19	0.2	0.55

*Please note the sum of the Planning Area outflow does not equal the hydrologic region outflow; since the San Joaquin River flows through multiple Planning Areas, the outflow from an upstream Planning Area may be double counted in the outflow for a downstream Planning Area. For this reason, adding the outflow from all the Planning Areas will not equal the San Joaquin River HR outflow. Also, for this same reason, adding the WAFR from all the Planning Areas will not equal the San Joaquin River HR WAFR.

Potential Water Development by Other Methods (recycled water, desalination and water conservation)

Estimates of potential water development by other methods (recycled water, desalination, and water conservation) are also shown for San Joaquin River HR in Table A-SJ5. Note that these estimates were not specifically made for use as groundwater replenishment and will need to be considered by GSAs more thoroughly for such purpose.

Table A-SJ5. San Joaquin River HR Urban Water Portfolio Actions

Method	Volume of Water Increase from 2010 to 2020
Recycle	0.03 maf*
Desalination	0 maf*
Conservation	0.11 maf*

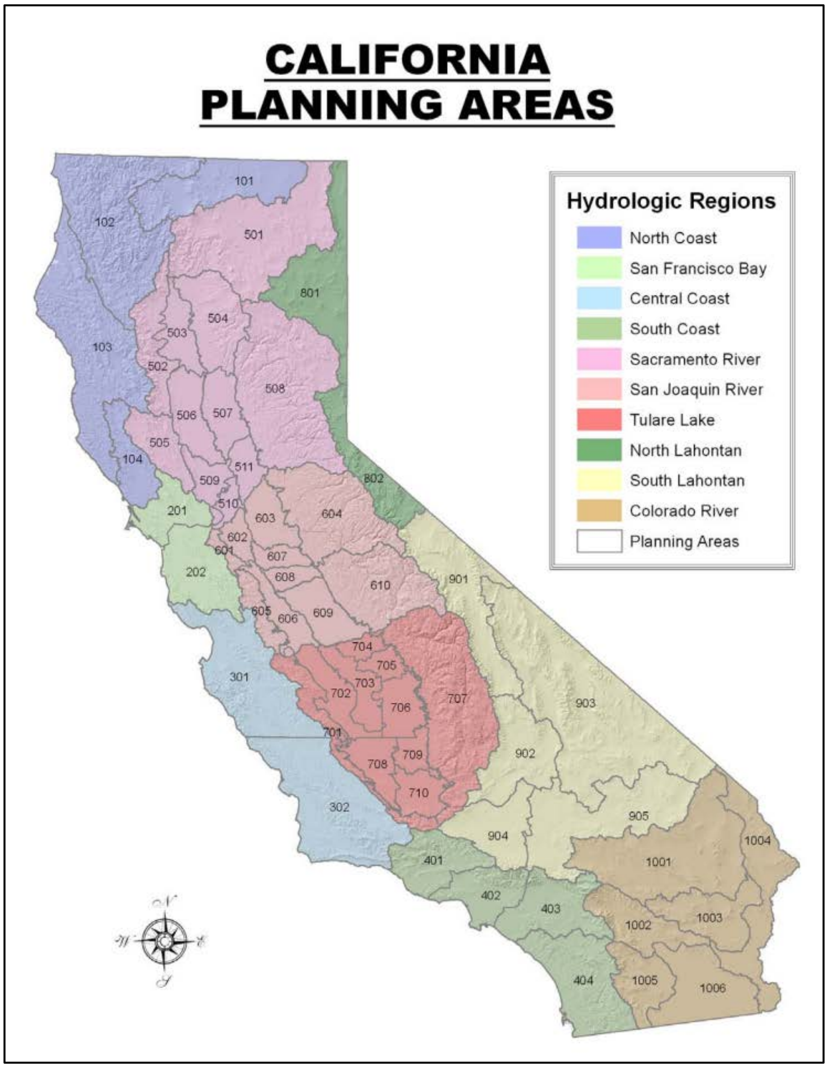
*maf - million acre-feet

Tulare Lake Hydrologic Region

The Tulare Lake Hydrologic Region covers approximately 10.9 million acres (17,050 square miles) and includes all of Kings and Tulare counties and most of Fresno and Kern counties. The San Joaquin Valley is divided into the San Joaquin River and the Tulare Lake regions by the San Joaquin River with the Tulare Lake region in the southern portion. Historically, the valley floor in this region had been a complex series of interconnecting natural sloughs, canals, and marshes. The Tulare Lake region is one of the nation's leading agricultural production areas, growing a wide variety of crops on about 3 million irrigated acres. The Sierra Nevada receives most of the precipitation in the Tulare Lake region in the form of rain and snow. The Sierra Nevada is the principal source of water for the foothills and the valley floor (California Water Plan Update 2013).

The Tulare Lake HR is divided into 10 Planning Areas: PA 701, PA 702, PA 703, PA 704, PA 705, PA 706, PA 707, PA 708, PA 709, and PA 710. The Tulare Lake HR and its PA's are shown in Figure A-TL1.

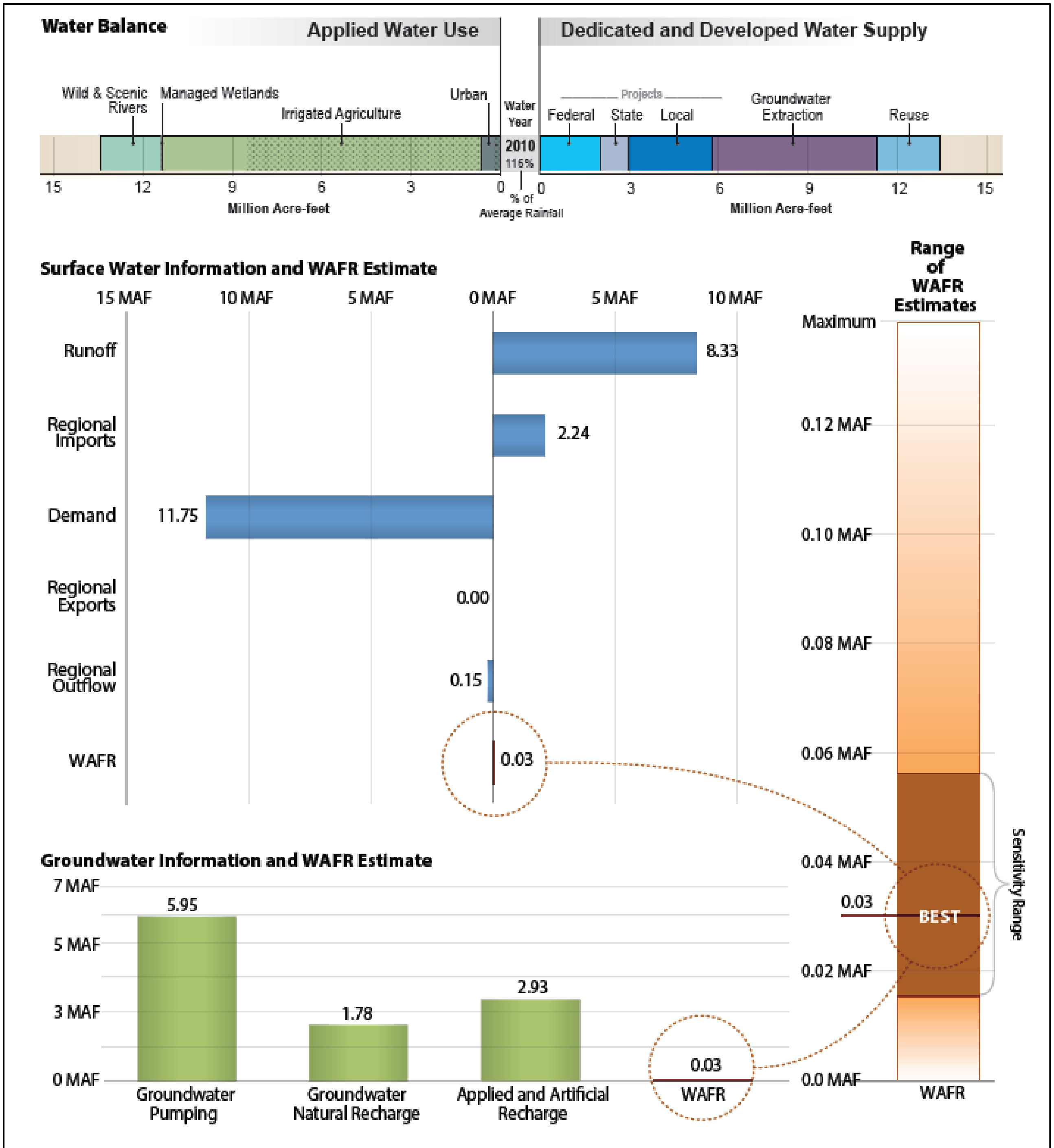
Figure A-TL1. Tulare Lake HR and Tulare Planning Areas



Summary of WAFR Information and Estimates

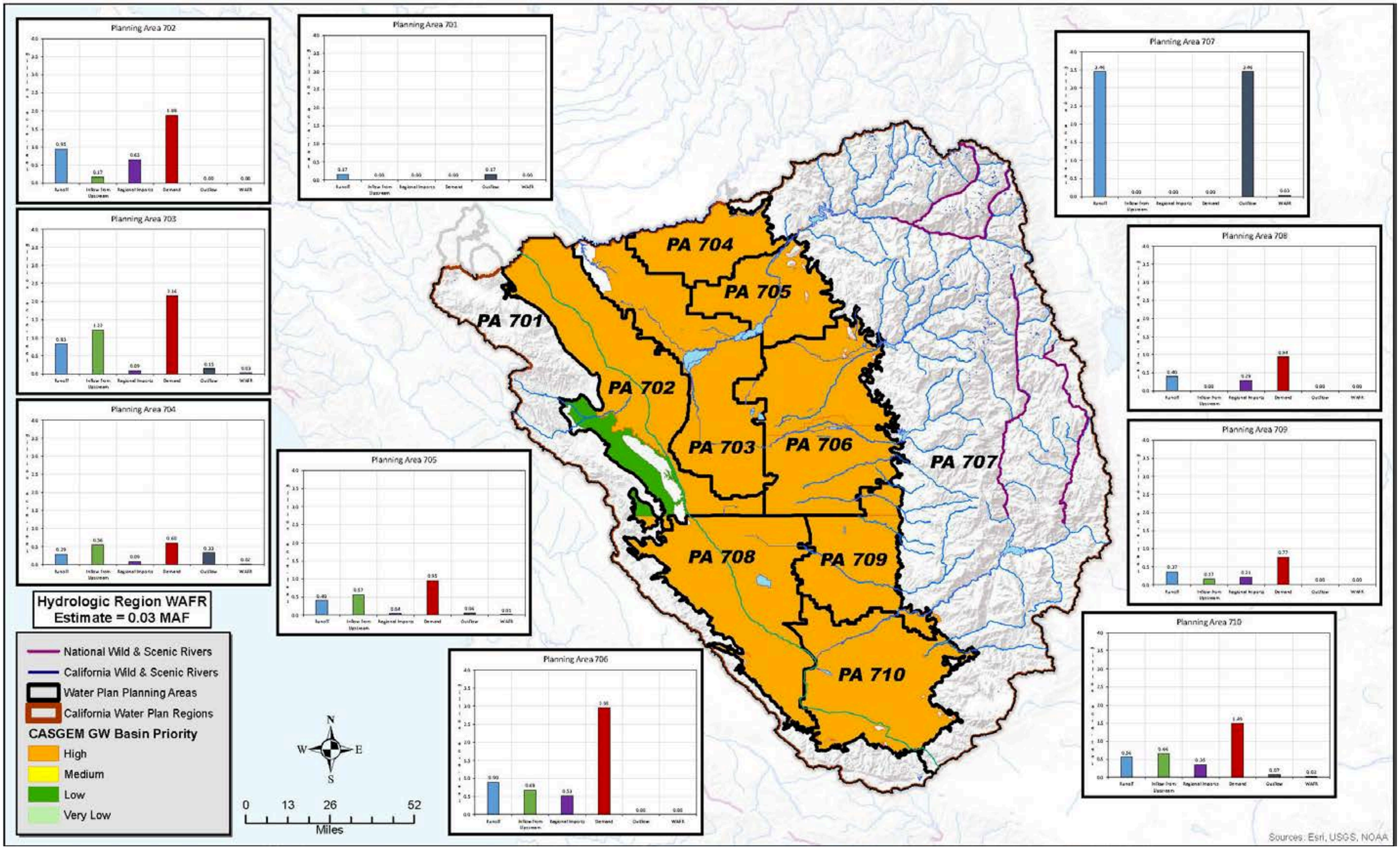
WAFR information and estimates for the Tulare Lake Hydrologic Region and its Planning Areas are shown in Figures A-TL2 and A-TL3.

Figure A-TL2. Tulare Lake Hydrologic Region WAFR Information and Estimates



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

Figure A-TL3. Tulare Lake Planning Areas WAFR Information and Estimates



WAFR Information and Estimates

The major tributaries in the Tulare Lake HR are the Kings River, Kaweah River, Tule River and Kern River.

Water is imported into the Tulare Lake HR from the Sacramento and San Joaquin hydrologic regions.

The WAFR information and estimates are provided in the following sections.

Surface Water and Groundwater Information

Tulare Lake HR and its Planning Areas surface water and groundwater information (as defined in the Surface Water and Groundwater Information section) is shown in Table A-TL1.

Estimates of regional imports and exports are based on CalSim II modeling performed for the 2015 SWP Delivery Capability Report for the existing conditions with historical hydrology. Imports to the Tulare Lake HR include the Friant Kern Canal and CVP and SWP exports from the Delta. Regional imports to individual PAs are based on the types of CVP and SWP contracts and the volume of contract supply held by individual contractors within the PA.

Table A-TL1. Tulare Lake HR and Tulare Area Surface Water and Groundwater Information

Geographical Region	Regional Imports (MAF)	Regional Exports (MAF)	Groundwater Pumping (MAF)	Groundwater Natural Recharge (MAF)	Applied and Artificial Recharge (MAF)
Tulare Lake HR	2.24	0.00	5.95	1.78	2.93
PA 701	0.00	0.00	-	-	-
PA 702	0.65	0.00	-	-	-
PA 703	0.09	0.00	-	-	-
PA 704	0.09	0.00	-	-	-
PA 705	0.04	0.00	-	-	-
PA 706	0.53	0.00	-	-	-
PA 707	0.00	0.00	-	-	-
PA 708	0.29	0.00	-	-	-
PA 709	0.21	0.00	-	-	-
PA 710	0.35	0.00	-	-	-

WAFR Estimates

The following sections describe how the WAFR estimates were determined.

WEAP Model

The Central Valley Planning Area (CVPA) WEAP model, developed under the CA Water Plan, was used to determine the runoff, demand and outflow for the Tulare Lake HR and its Planning Areas. The CVPA

WEAP model does not calculate outflow by Planning Area so a mass balance/flow routing approach was developed to estimate the outflow from each Planning Area. An approximate mass balance was developed for each Planning Area that compared available surface water supplies (runoff, inflow from upstream PAs, and regional imports) with demands and regional exports. Remaining water supply after subtracting demands and exports was assumed to be outflow from the PA. Outflow from each PA was routed through the HR, starting from the upstream PAs and moving downstream, to calculate inflow from upstream PAs available in downstream PAs. Outflow from several PAs flows into or is available to multiple downstream PAs. Outflow from PA 707 was apportioned to downstream PAs based on watershed area and within the Kings River area by the supply available to Kings River Water Association member agencies.

WEAP Outflow

The WEAP outflow for Tulare Lake HR and its Planning Areas is shown in Table A-TL2.

Table A-TL2. Tulare Lake HR and Tulare Planning Area WEAP Outflow

Geographical Region	Outflow (MAF)
Tulare Lake HR*	0.15*
PA 701	0.17
PA 702	0.00
PA 703	0.15
PA 704	0.33
PA 705	0.06
PA 706	0.00
PA 707	3.46
PA 708	0.00
PA 709	0.00
PA 710	0.07

*Please note the sum of the Planning Area outflow does not equal the hydrologic region outflow; since major rivers flow through multiple Planning Areas, the outflow from an upstream Planning Area may be double counted in the outflow for a downstream Planning Area. For this reason, adding the outflow from all the Planning Areas will not equal the Tulare Lake HR outflow.

WAFR Fraction

The Tulare Lake HR is nearly a closed basin with the majority of the Tulare Lake HR draining to the historic Tulare Lake bed. The single outflow location is the James Bypass that connects the North Fork of the Kings River with the Mendota Pool on the San Joaquin River. Water typically only leaves the Tulare Lake HR through the James Bypass when flood control releases from Pine Flat Dam exceed demands, or when there are high, unregulated natural discharges from Mill and Hughes creeks. In very rare circumstances, surplus Kern River flow can be diverted into the California Aqueduct, but due to the rare occurrence it is not considered within this report.

Gage Data

An analysis of USGS gage records for the James Bypass (11253500) was performed to estimate the fraction of WAFR estimates. USGS gage records are available for a period of 62 years, from water year 1948 through 2009. Daily gage records were analyzed with a range of Conceptual Project capacities and instream flow requirements.

Table A-TL3. WAFR Fraction

River/Stream	Gage Data Outflow (TAF)	Lower Sensitivity Range Estimate		Best Estimate		Upper Sensitivity Range Estimate		Maximum Project Estimate	
		WAFR (TAF)	WAFR Fraction (%)	WAFR (TAF)	WAFR Fraction (%)	WAFR (TAF)	WAFR Fraction (%)	WAFR (MAF)	WAFR Fraction (%)
Tulare Lake HR	222	25	10.68%	47	21.1%	86	38.81%	213	95.73%

Initial WAFR estimates for individual Planning Areas within the Tulare Lake HR were developed by applying the WAFR fraction. However, for some Planning Areas this resulted in an unrealistically high WAFR considering that much of the outflow from some Planning Areas meets demand in other Planning Areas under contracts and water rights. In these instances, WAFR from some Planning Areas was adjusted to not exceed the WAFR from the entire HR.

Final WAFR Estimates

The outflow estimate simulated using the WEAP model was then multiplied by the range of water available for replenishment fractions using the James Bypass gage data to determine the estimated range of WAFR estimates within the hydrologic region. The array of estimates for the Tulare Lake HR and its Planning Areas are shown in Table A-TL4 using the WEAP outflow from Table A-TL2 and water available for replenishment fractions from Table A-TL3 above.

Table A-TL4. Final WAFR Estimates

Geographical Region	WEAP Outflow (MAF)	No Project Estimate (MAF)	Lower Sensitivity Range Estimate (MAF, WAFR Fraction 10.68%)	Best Estimate (MAF, WAFR Fraction 21.10%)	Upper Sensitivity Range Estimate (MAF, WAFR Fraction 38.81%)	Maximum Project Estimate (MAF, WAFR Fraction 95.73%)
Tulare Lake HR*	0.15	0	0.02	0.03	0.06	0.14
PA 701	0.17	0	0.00	0.00	0.00	0.00
PA 702	0.00	0	0.00	0.00	0.00	0.00
PA 703	0.15	0	0.02	0.03	0.06	0.14
PA 704	0.33	0	0.01	0.02	0.03	0.08
PA 705	0.06	0	0.01	0.01	0.02	0.06
PA 706	0.00	0	0.00	0.00	0.00	0.00
PA 707	3.46	0	0.02	0.03	0.06	0.14
PA 708	0.00	0	0.00	0.00	0.00	0.00
PA 709	0.00	0	0.00	0.00	0.00	0.00
PA 710	0.07	0	0.01	0.02	0.03	0.07

*Please note the sum of the Planning Area outflow does not equal the hydrologic region outflow; since major rivers flow through multiple Planning Areas, the outflow from an upstream Planning Area may be double counted in the outflow for a downstream Planning Area. For this reason, adding the outflow from all the Planning Areas will not equal the Tulare lake HR outflow. Also, for this same reason, adding the WAFR from all the Planning Areas will not equal the Tulare Lake HR WAFR.

Potential Water Development by Other Methods (recycled water, desalination and water conservation)

Estimates of potential water development by other methods (recycled water, desalination and water conservation) are also shown for Tulare Lake hydrologic region in Table A-TL5. Note that these estimates were not specifically made for use for groundwater replenishment and will need to be considered by GSAs more thoroughly for such purpose.

Table A-TL5. Tulare Lake HR Urban Water Portfolio Actions

Method	Volume of Water Increase from 2010 to 2020
Recycle	0.01 maf*
Desalination	0 maf*
Conservation	0.05 maf*

*maf - million acre-feet

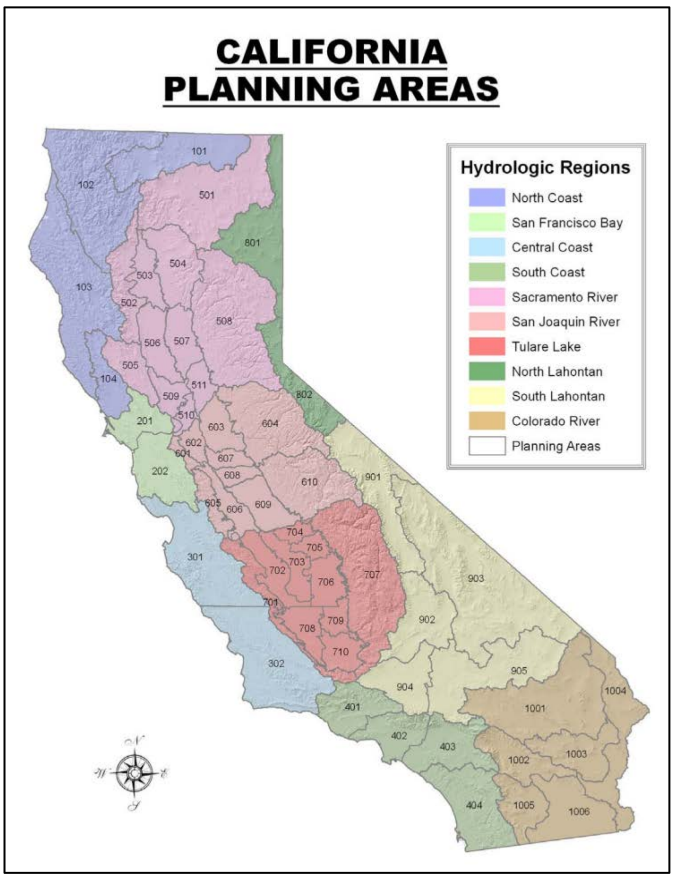
North Lahontan Hydrologic Region

The North Lahontan Hydrologic Region (North Lahontan region) includes part of the western edge of the Great Basin, a large landlocked area that covers most of Nevada and northern Utah. The eastern drainages of the Cascade Range and the eastern Sierra Nevada, north of the Mono Lake drainage, make up the region. All surface water drains eastward toward Nevada. This hydrologic region extends about 270 miles from the Oregon border to the southern boundary of the Walker River drainage in Mono County. The region covers 6,122 square miles, about 4 percent of California's total area, but is inhabited by only about 0.3 percent of the state's population. The region includes portions of Modoc, Lassen, Sierra, Nevada, Placer, El Dorado, Alpine, and Mono counties (California Water Plan Update 2013).

The region abounds with large, natural landscapes. The northern part is primarily arid high desert with relatively flat valleys at elevations of 4,000 to 5,000 feet. The eastern slopes of the Sierra Nevada comprise the central and southern portions of this region, which includes the California portion of the Lake Tahoe Basin and the western Great Basin. The major rivers of the region — Truckee, Carson, and Walker — carry the mountain snowmelt through California into Nevada. Mountain peaks up to 12,279 feet from the western boundary of the region (California Water Plan Update 2013).

The North Lahontan region is divided into two Planning Areas: Northern Planning Area, PA 801, and Southern Planning Area, PA 802. North Lahontan, PA 801 and PA 802 are shown in Figure A-NL1.

Figure A-NL1. North Lahontan, PA 801 and PA 802



Summary of WAFR Information and Estimates

WAFR information and estimates for North Lahontan Hydrologic Region, Planning Area 801, and Planning Area 802 are shown in Figures A-NL2 and A-NL3.

Figure A-NL2. North Lahontan Hydrologic Region WAFR Information and Estimates

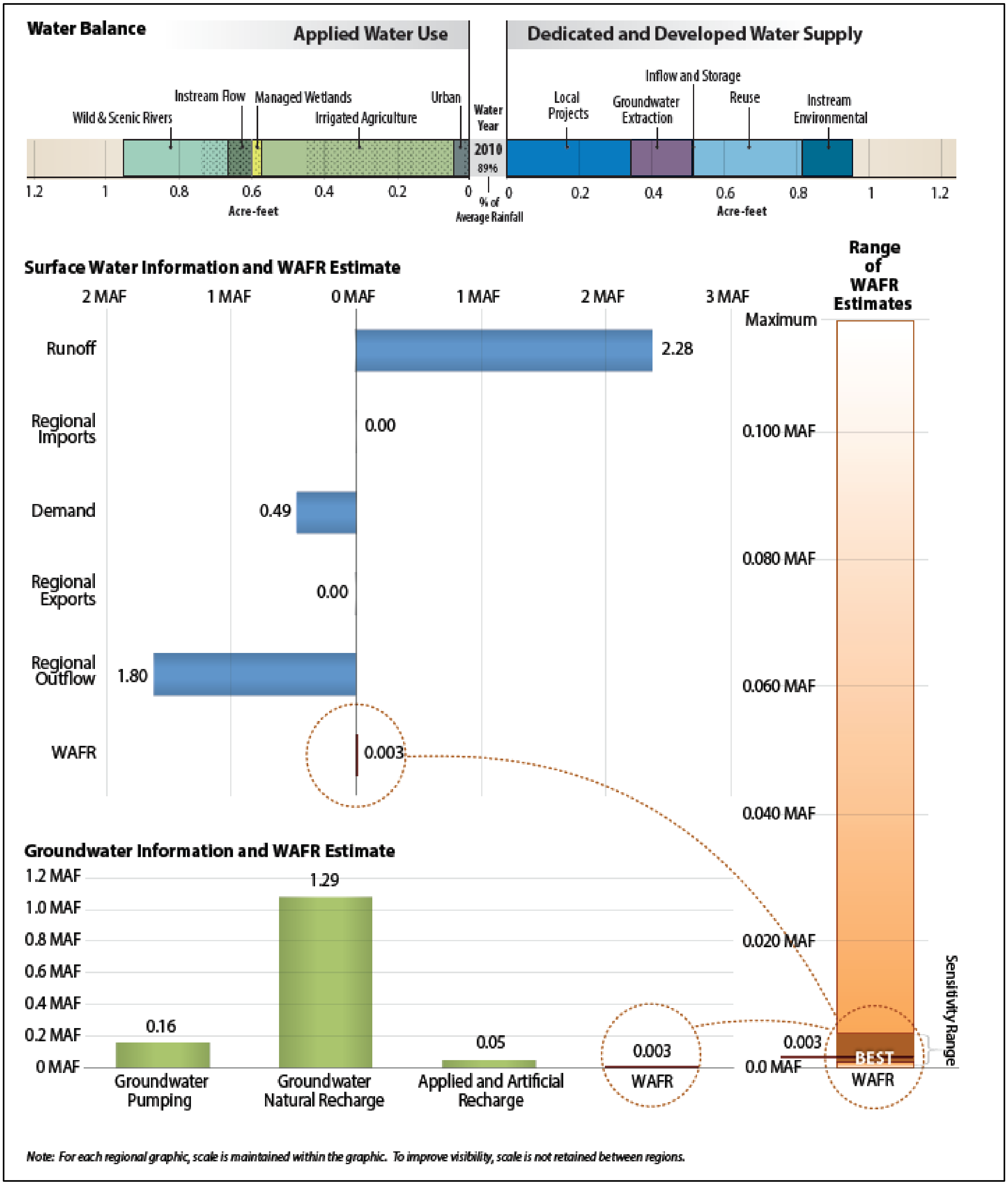
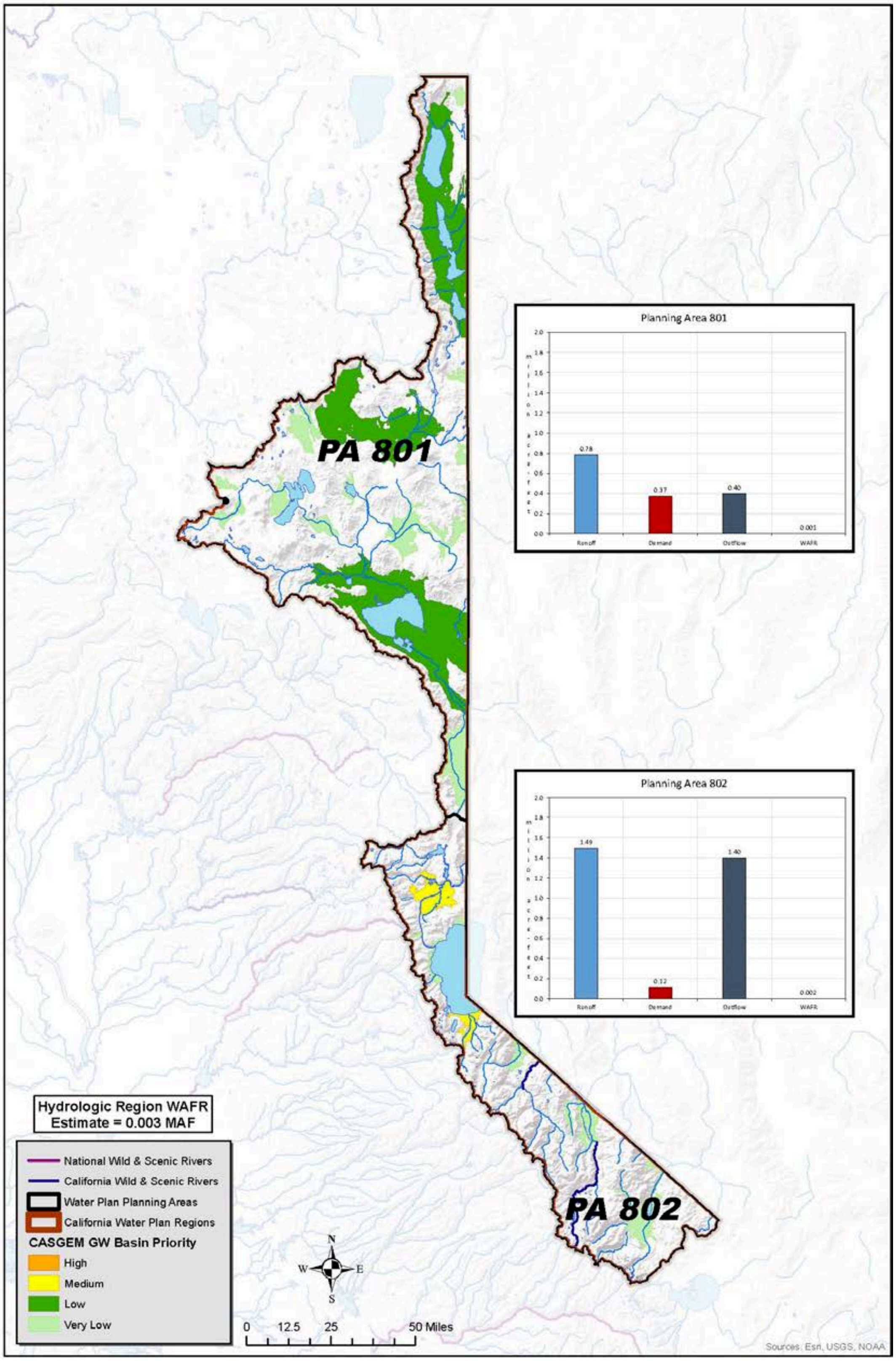


Figure A-NL3. North Lahontan Hydrologic Region PA 801 and 802 WAFR Information and Estimates



WAFR Information and Estimates

The North Lahontan region contains all of the Susan River; the upper parts of the Truckee, Carson, and Walker River basins; and the Surprise Valley watersheds. These streams have no outlets to the sea and terminate in lakes or playas. Most rivers have elevated baseflows due to snowmelt from the Sierra Nevada and Cascade mountains, and from reservoir releases that maintain instream flows (California Water Plan Update 2013).

In the north, the Susan River flows southeasterly and empties into Honey Lake. Other minor streams in the north begin in the Warner Mountains and drain into Lower, Middle, or Upper Alkali lakes in Surprise Valley. The major portion of the Truckee River system originates in California and flows into Lake Tahoe and out toward Reno, Nevada, and then into Pyramid Lake. Trout Creek and the Upper Truckee River flow from the western slopes of the Carson Range and the eastern slopes of the Sierra into Lake Tahoe at the city of South Lake Tahoe. The Little Truckee River conflates with the Truckee River near the head of Truckee Canyon just west of the river's exit into Nevada. The east and west forks of the Carson River are separate in California. These watersheds drain Alpine County and flow into Nevada. The two forks of the Carson River meet near Minden, Nevada, and terminate near Fallon, Nevada, in either Carson Lake and Pasture or the Carson Sink. The East and West Walker rivers, entirely separate in California, originate in Mono County, flow into Nevada, join near Yerington, and then flow to Walker Lake (California Water Plan Update 2013).

On an average annual basis, 23.1 inches of precipitation falls upon the region, with most precipitation falling as snow along the crest of the Sierra Nevada Mountains and Warner Mountains (California Water Plan Update 2013). The following sections provide the WAFR information and estimates and describe how it was determined for each Planning Area within the North Lahontan Hydrologic Region.

Surface Water and Groundwater Information

North Lahontan, PA 801, and PA 802 surface water and groundwater information (as defined in the Surface Water and Groundwater Information section) is provided in Table A-NL1.

Table A-NL1. North Lahontan, PA 801, and PA 802 Surface Water and Groundwater Information

Geographical Region	Regional Imports (maf)	Regional Exports (maf)	Groundwater Pumping (maf)	Groundwater Natural Recharge (maf)	Applied and Artificial Recharge (maf)
North Lahontan HR	0.00	0.00	0.16	1.29	0.05
PA 801	0	0	-	-	-
PA 802	0	0	-	-	-

WAFR Estimates

The following sections describe how the WAFR estimates were determined.

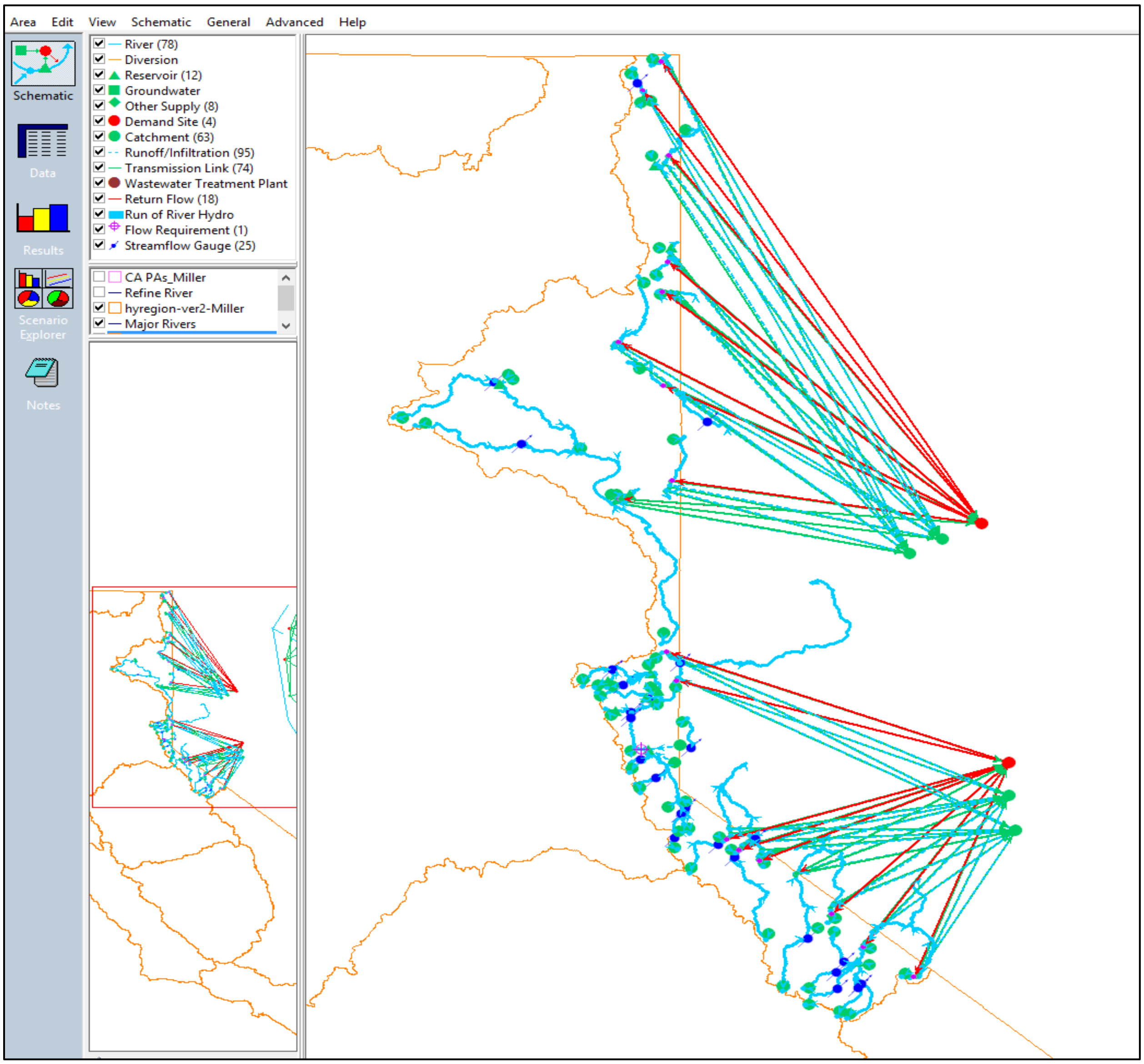
WEAP Model

The North Lahontan WEAP Model was developed using the procedures described in the WEAP Model Methodology section and described in more detail in the following sections.

Model Domain

The North Lahontan WEAP Model domain is shown in Figure A-NL4.

Figure A-NL4. North Lahontan WEAP Model



Streams/Rivers and Delineation of Watershed

The North Lahontan WEAP Model streams/rivers with corresponding Planning Area are shown in Table A-NL2.

Table A-NL2. North Lahontan Streams/Rivers

River/Stream (PA 801)	River/Stream (PA 802)	
Bare Creek	Blackwood Creek	Prosser Creek
Bidwell Creek	Bodie Creek	Robinson Creek
Cold Springs Creek	Bryant Creek	Rough Creek
Long Valley Creek	Buckeye Creek	Sagenen Creek
Pine Creek	Desert Creek	Saxon Creek
Red Rock Creek	Dog Creek	Swauger Creek
Sand Creek	Donner Creek	Truckee Marsh
Skedaddle	East Fork Carson River	Truckee River
Smoke Creek	East Walker River	Upper Truckee River
Susan River	General Creek	Virginia Creek
Tenmile Creek	Green Creek	West Fork Carson River
Tudedad Canyon Wash	Independence Creek	West Walker River
Willow Creek	Little Truckee River	

Watersheds in North Lahontan region were delineated to determine the runoff from each stream using the procedures described in the WEAP Model Methodology section.

Reservoir

Reservoirs included in the North Lahontan WEAP model with the corresponding Planning Areas are:

- Boca Reservoir (Little Truckee River, PA 802).
- Bridgeport Reservoir (East Walker River, PA 802).
- Donner Lake (Donner Creek, PA 802).
- Eagle Lake (PA 801).
- Honey Lake (PA 801).
- Independence Lake (Independence Creek, PA 802).
- Lake Tahoe (PA 802).
- Lower Lake (PA 801).
- Middle Alkali Lake (PA 801).
- Prosser Creek Reservoir (Prosser Creek, PA 802).
- Stampede Reservoir (Little Truckee River, PA 802).
- Upper Lake (PA 801).

Demands

The North Lahontan region demands were determined using the procedures described in the WEAP Model Methodology section and described in the following sections.

Urban Indoor Demand

The Urban Indoor Annual Activity Level and Annual Water Use Rate for each Planning Area are shown in Table A-NL3.

Table A-NL3. Annual Activity Level and Annual Water Use Rate by Category

Category	PA 801		PA 802	
	Annual Activity Level (person/household)	Annual Water Use Rate (TAF per person/household)	Annual Activity Level (person/household)	Annual Water Use Rate (TAF per person/household)
Commercial	15,927	0.000047	29,729	0.000047
Industrial	1,223	0.006694	11	0.006694
Multi-Family	1,836	0.000160	5,466	0.000160
Single-Family	6,967	0.000182	20,743	0.000182

Urban Outdoor Demand

The acres for each land use class by Planning Area are shown in Table A-NL4.

Table A-NL4. Urban Outdoor Land Use Class Acres

Land Use Class	PA 801 Acres	PA 802 Acres
Commercial	196.15	482.10
Multi-Family	97.14	107.36
Public	187.20	332.80
Single-Family	649.56	717.94
Total	**1,130.05**	**1,640.20**

Agricultural Demand

The acres for each crop type by Planning Area are shown in Table A-NL5.

Table A-NL5. Crop acres by Crop Type

Crop	PA 801 Acres (thousand)	PA 802 Acres (thousand)
Grain	5.293	0
Pasture	52.58	33.71
Processed Tomato	0	0
Fresh Tomato	0	0
Cucurbits	0	0
Onion and Garlic	0.311	0
Potato	0	0
Other Truck	0.473	0
Almond and Pistachio	0	0
Other Deciduous	0.005	0
Sub-Tropical	0	0
Rice	10.208	0
Vine	0	0
Cotton	0	0
Sugar Beet	0	0
Corn	0	0
Dry Bean	0.154	0
Safflower	0.42	0
Other Field	0	0
Alfalfa	31.665	3.028
Total	**101.109**	**36.738**

Calibration

The North Lahontan WEAP Model was calibrated using the procedures described in the WEAP Model Methodology section.

Calibration Data Collection

Calibrated Watersheds with corresponding gage information are shown in Table A-NL6.

Table A-NL6. Calibrated Gage Locations

Gage Name	Site Number	Drainage Area (Square Miles)	GageGage Flow Starting Date	Gage Flow Ending Date
BIDWELL C BL MILL C NR FORT BIDWELL CA	10360900	25.6	10/1/1960	9/30/1982
SMOKE CK BLW RESERVOIR NR SMOKE CK NV	10353800	50.1	12/15/1988	7/18/2011
PINE C NR SUSANVILLE CA	10359300	226	10/1/1960	9/30/1982
SUSAN R A SUSANVILLE CA	10356500	184	6/1/1900	10/12/1994
DOG CK AT VERDI NV	10347310	24.2	11/5/1992	8/8/2016
LITTLE TRUCKEE R NR HOBART MILLS CA	10342000	36.5	1/1/1947	10/10/1972
SAGEHEN C NR TRUCKEE CA	10343500	10.5	10/1/1953	8/8/2016
Third Ck nr Crystal Bay NV	10336698	6.05	10/1/1969	8/8/2016
BLACKWOOD C NR TAHOE CITY CA	10336660	11.2	10/1/1960	8/8/2016
GENERAL C NR MEEKS BAY CA	10336645	7.44	7/7/1980	8/8/2016
UPPER TRUCKEE RV AT S UPPER TRUCKEE RD NR MEYERS	10336580	14.09	5/12/1990	9/30/2011
UP TRUCKEE R A SOUTH LAKE TAHOE CA	10336610	54.9	10/1/1971	8/8/2016
TROUT C NR TAHOE VALLEY CA	10336780	36.7	10/1/1960	8/8/2016
WEST FORK CARSON RIVER AT WOODFORDS CA	10310000	65.4	10/1/1900	8/8/2016
BRYANT C NR GARDNERVILLE NV	10308800	31.5	6/1/1961	8/8/2016
E F CARSON R BL MARKLEEVILLE C NR MARKLEEVILLECA	10308200	276	9/1/1960	8/8/2016
W WALKER R BLW L WALKER R NR COLEVILLE CA	10296000	181	4/1/1938	8/8/2016
Green Creek near Bridgeport CA	10289500	19.5	10/1/1953	10/13/2015
Virginia C nr Bridgeport CA	10289000	63.6	10/1/1953	9/30/2009
Robinson C at Twin Lks Outlet nr Bridgeport CA	10290500	39.1	10/1/1953	3/10/2016
Buckeye C nr Bridgeport CA	10291500	44.1	4/1/1911	3/3/2016
Swauger C nr Bridgeport CA	10292000	52.8	10/1/1953	9/30/2006

Calibration Results

Calibrated Watersheds with corresponding NSE and PBIAS are shown in Table A-NL7.

Table A-NL7. Calibrated Watersheds with corresponding NSE and PBIAS

Location	Nash Sutcliffe Coefficient of Efficiency (NSE)	Percent Bias (PBIAS)
BIDWELL C BL MILL C	0.80	-13.98
Buckeye C nr Bridgeport CA	0.91	-5.92
BLACKWOOD C NR TAHOE CITY CA	0.72	-14.89
BRYANT C NR GARDNERVILLE NV	0.65	-8.97
E F CARSON R BL MARKLEEVILLE C	0.85	-7.52
W F CARSON R AT WOODFORDS CA	0.75	-8.69
DOG CK AT VERDI NV	0.66	-5.49
Green Creek near Bridgeport CA	0.85	-14.22
GENERAL C NR MEEKS BAY CA	0.74	-12.53
LITTLE TRUCKEE R	0.76	-11.51
PINE C NR SUSANVILLE CA	0.30	2.02
Robinson C at Twin Lks	0.90	2.46
SAGEHEN C NR TRUCKEE CA	0.80	-7.89
TROUT C NR TAHOE VALLEY CA	0.86	-10.49
SMOKE CK BLW RESERVOIR	0.61	1.65
SUSAN R A SUSANVILLE CA	0.67	13.65
Swauger C nr Bridgeport CA	0.76	7.54
Third Ck nr Crystal Bay NV	0.83	-5.25
UPPER TRUCKEE RV NR MEYERS	0.80	-13.07
UP TRUCKEE R A S LAKE TAHOE	0.68	-5.61
Virginia C nr Bridgeport CA	0.68	-11.64
W WALKER R NR COLEVILLE CA	0.87	-6.76

WEAP Outflow

The WEAP outflow for North Lahontan, PA 801, and PA 802 is shown in Table A-NL8.

Table A-NL8. North Lahontan, PA 801, and PA 802 WEAP Outflow

Geographical Region	Outflow (MAF)
North Lahontan	1.80
PA 801	0.40
PA 802	1.40

WAFR Fraction

The following sections describe how the WAFR Fraction was determined for North Lahontan, PA 801, and PA 802.

Gage Data

Gage data for seven major rivers in the North Lahontan region was compiled. In each river or stream, the most downstream gage was selected to account for water demands within the watershed and to develop a WAFR fraction that is applicable to regional outflow.

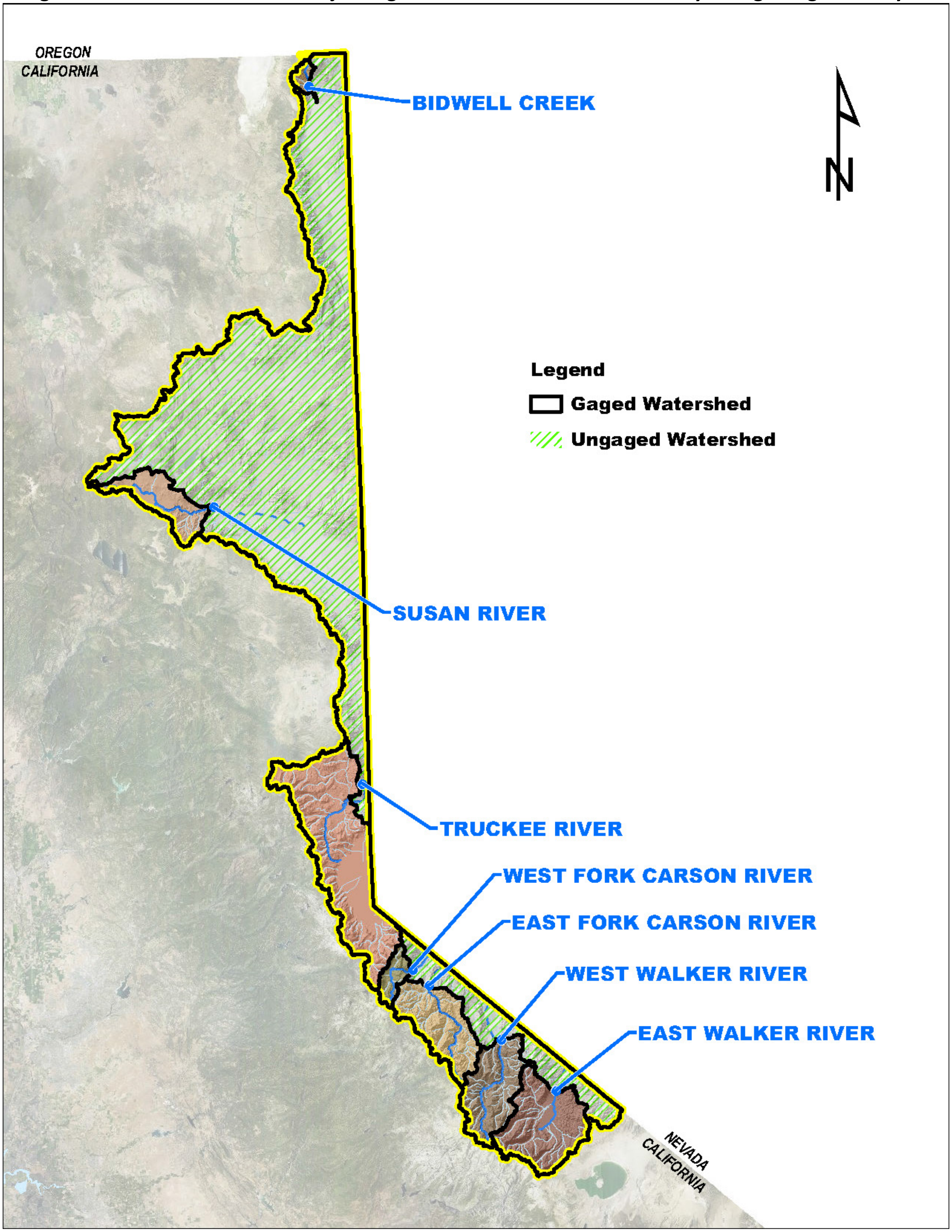
From the Truckee River watershed south, gage records are very complete, with the Truckee, Carson, and Walker rivers covering most of the region's southern half. The northern half of the region has very limited gage data. Data for the Susan River was compiled, as it is the largest river in this area. Bidwell Creek, on the eastern slope of the Warner Mountains, was chosen as a representative stream for the rest of the region.

A summary of the stream gage used in this analysis is presented in Table A-NL9. A map showing the locations of the gages used, and their respective watersheds is shown in Figure A-NL5.

Table A-NL9. Major Rivers and Gages in North Lahontan Hydrologic Region Analysis

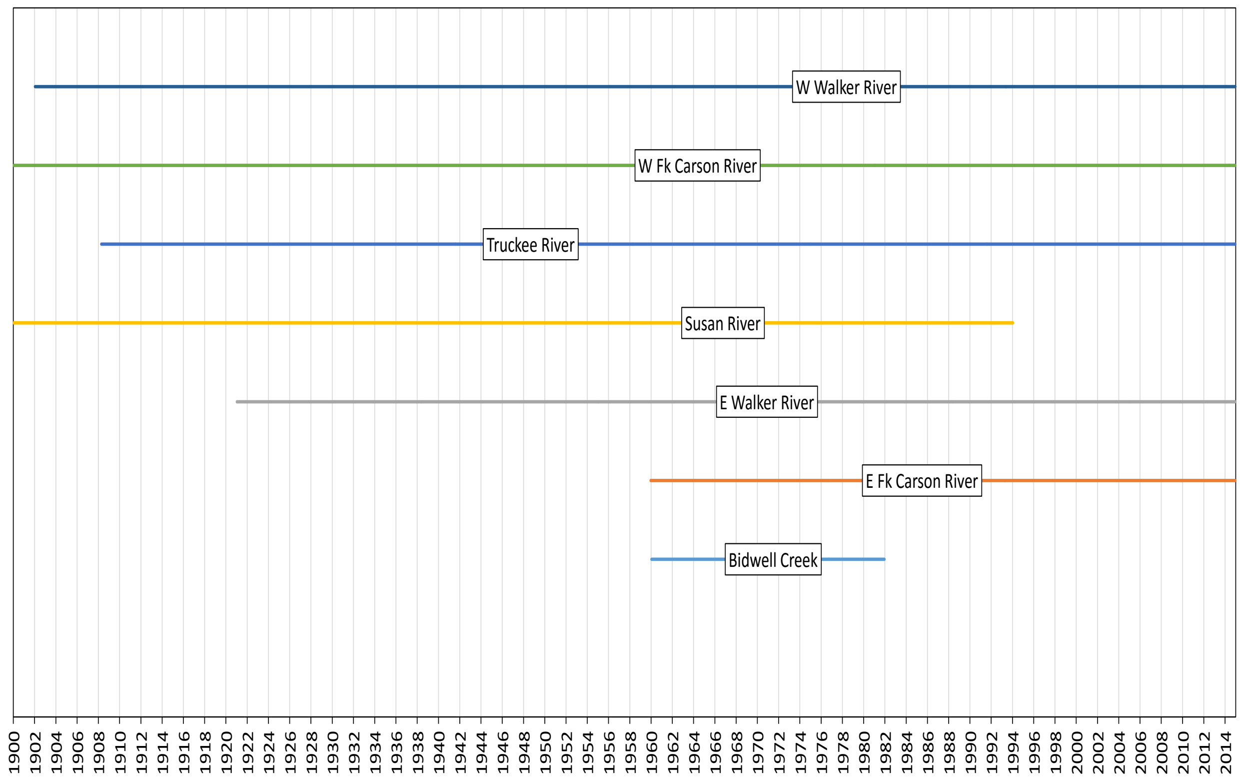
River/Stream	Location	USGS Gage Number	Area (square miles)
Bidwell Creek	Fort Bidwell	10360900	26
Susan River	Susanville	10356500	184
Truckee River	Farad	10346000	932
W Fk Carson River	Woodfords	10310000	65
E Fk Carson River	Markleeville	10308200	276
W Walker River	Coleville	10296500	250
E Walker River	Bridgeport	10293000	359

Figure A-NL5. Watersheds for Major Gaged Streams in North Lahontan Hydrologic Region Analysis



Once the available gage data was compiled, the periods of available data for the seven gages were compared. Data availability, by year, is presented in Figure A-NL6.

Figure A-NL6. Period of Available Gage Data in North Lahontan Hydrologic Region Analysis



In addition to streams declared Fully Appropriated, the State Water Resources Control Board maintains a list of adjudicated rivers and streams. Adjudicated streams are excluded from this analysis because an adjudication is typically preceded by water rights litigation and is an indication that only limited volumes of water may be infrequently available for new purposes. Additionally, the two major rivers of the region, the Truckee and Walker, both flow into Nevada and hence into desert terminal lakes (Pyramid Lake and Walker Lake, respectively). In both instances, there has been significant litigation and effort spent to maintain or even increase the volume of flow into both lakes. Therefore, the ability to develop a project to make water available for replenishment from these rivers is limited.

Of the gage data compiled, the only streams not Fully Appropriated year-round or adjudicated are the East Fork of the Carson River and Bidwell Creek. These streams were used in determining WAFR fractions.

The gage data outflow, diverted water using Conceptual Project (WAFR), and WAFR Fraction (diverted water using Conceptual Project (WAFR)/Gage Data Outflow) for each stream and the North Lahontan Hydrologic Region is shown in Table A-NL10.

Table A-NL10. WAFR Fraction

River/Stream	Gage Data Outflow (TAF)*	Lower Sensitivity Range Estimate		Best Estimate		Upper Sensitivity Range Estimate		Maximum Project Estimate	
		WAFR (TAF)	WAFR Fraction (%)	WAFR (TAF)	WAFR Fraction (%)	WAFR (TAF)	WAFR Fraction (%)	WAFR (TAF)	WAFR Fraction (%)
Bidwell Creek	15.8	0.28	1.74%	0.85	5.25%	1.58	9.73%	9.98	63.15%
Susan River	61.5	0.01	0.00%	0.00	0.00%	0.00	0.00%	0.00	0.00%
Truckee River	576.5	0.00	0.00%	0.00	0.00%	0.00	0.00%	0.00	0.00%
W Fk Carson River	73.7	0.00	0.00%	0.00	0.00%	0.00	0.00%	0.00	0.00%
E Fk Carson River	249.6	0.00	0.00%	0.00	0.00%	0.00	0.00%	0.00	0.00%
W Walker River	193.6	0.00	0.00%	0.00	0.00%	0.00	0.00%	0.00	0.00%
E Walker River	111.7	0.42	0.37%	1.14	1.02%	2.26	0.71%	73.54	65.86%
HR Total	**1,282.41**	**0.70**	**0.05%**	**2.00**	**0.16%**	**3.84**	**0.30%**	**83.52**	**6.51%**

* Please note that the outflow is based on gaged streams only. The final WAFR estimates include outflow from the WEAP model for both gaged and ungaged watersheds.

Final WAFR Estimates

The outflow estimate simulated using the WEAP model was then multiplied by the range of water available for replenishment fractions determined by the historical gage data to determine the estimated range of WAFR estimates within the hydrologic region. The array of estimates for North Lahontan, PA 801 and PA 802 are shown in Table A-NL11 using the WEAP outflow from Table A-NL8 and water available for replenishment fractions from Table A-NL10 above.

Table A-NL11. Final WAFR Estimates

Geographical Region	WEAP Outflow (maf)	No Project Estimate (maf)	Lower Sensitivity Range Estimate (maf, WAFR Fraction 0.05%)	Best Estimate (maf, WAFR Fraction 0.16%)	Upper Sensitivity Range Estimate (maf, WAFR Fraction 0.30%)	Maximum Project Estimate (maf, WAFR Fraction 6.51%)
North Lahontan Hydrologic Region	**1.80**	**0**	**0.001**	**0.003**	**0.005**	**0.177**
PA 801	**0.40**	**0**	**0.000**	**0.001**	**0.001**	**0.026**
PA 802	**1.40**	**0**	**0.001**	**0.002**	**0.004**	**0.091**

Potential Water Development by Other Methods (recycled water, desalination and water conservation)

Estimates of potential water development by other methods (recycled water, desalination and water conservation) are also shown for North Lahontan region in Table A-NL12. Note that these estimates were not specifically made for use for groundwater replenishment and will need to be considered by GSAs more thoroughly for such purpose.

Table A-NL12. North Lahontan Urban Water Portfolio Actions

Method	Volume of Water Increase from 2010 to 2020
Recycle	0 maf
Desalination	-
Conservation	0 maf

South Lahontan Hydrologic Region

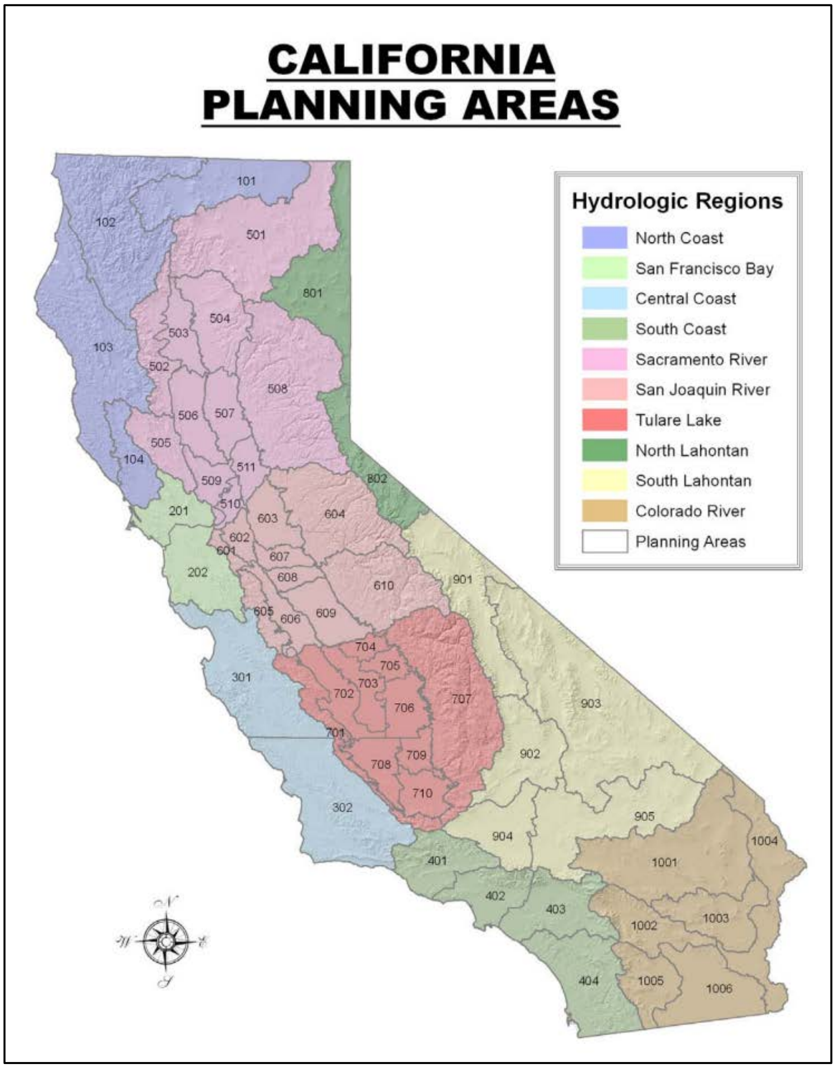
The South Lahontan Hydrologic Region represents about 17 percent of the land area in California: more than 17 million acres of land. The region includes Inyo County and portions of Mono, San Bernardino, Kern, and Los Angeles counties. It is bounded to the north by the drainage divide between Mono Lake and East Walker River; to the west and south by the Sierra Nevada, San Gabriel, San Bernardino, and Tehachapi mountains; to the southeast by the New York Mountains and to the east by the state of Nevada (California Water Plan Update 2013).

The topography of the South Lahontan region is characterized by fault-bounded mountain blocks separated by basins filled principally with alluvial and lake sediments and lesser volcanic material. The region is part of the basin and range province, which spans Nevada, western Utah, southern Idaho, southern Oregon, southeastern California, and southwestern Arizona. The highest and lowest points in the conterminous United States are in the central part of the region: Mt. Whitney with an elevation of 14,495 feet above sea level and Badwater in Death Valley at 282 feet below sea level. The most prominent mountain ranges are the Sierra Nevada, the White-Inyo Mountains, the Panamint Range, the Amargosa Range, the Tehachapi Mountains, the San Gabriel Mountains, and the San Bernardino Mountains (California Water Plan Update 2013).

On an average annual basis, 7.8 inches of precipitation falls upon the region, with the vast majority falling as snow along the crest of the high southern Sierra Nevada. The region is primarily desert, and includes Death Valley National Park, the region that receives the least rainfall in the country. The majority of the runoff in the region is originates from the eastern slopes of the Sierra Nevada Mountains and forms the Owens River Watershed, which is notable as the source of water for the Los Angeles Aqueduct (California Water Plan Update 2013).

The South Lahontan region is divided into five Planning Areas: PA 901, PA 902, PA 903, PA 904, and PA 905. South Lahontan, PA 901, PA 902, PA 903, PA 904, and PA 905 are shown in Figure A-SL1.

Figure A-SL1. South Lahontan, PA 901, PA 902, PA 903, PA 904 and PA 905



Summary of WAFR Information and Estimates

WAFR information and estimates for South Lahontan Hydrologic Region, PA 901, PA 902, PA 903, PA 904, and PA 905 are shown in Figures A-SL2 and A-SL3.

Figure A-SL2. South Lahontan Hydrologic Region WAFR Information and Estimates

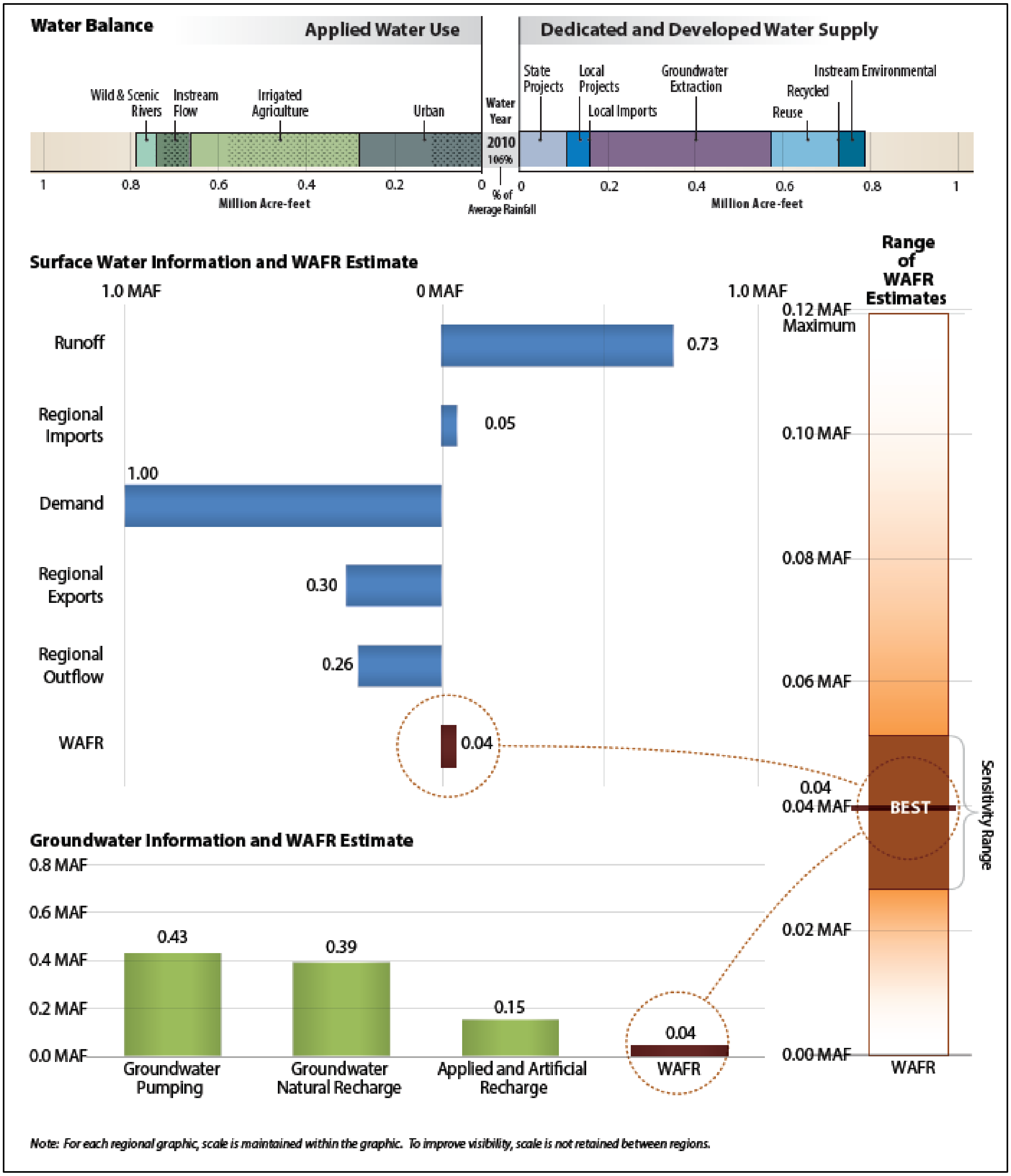
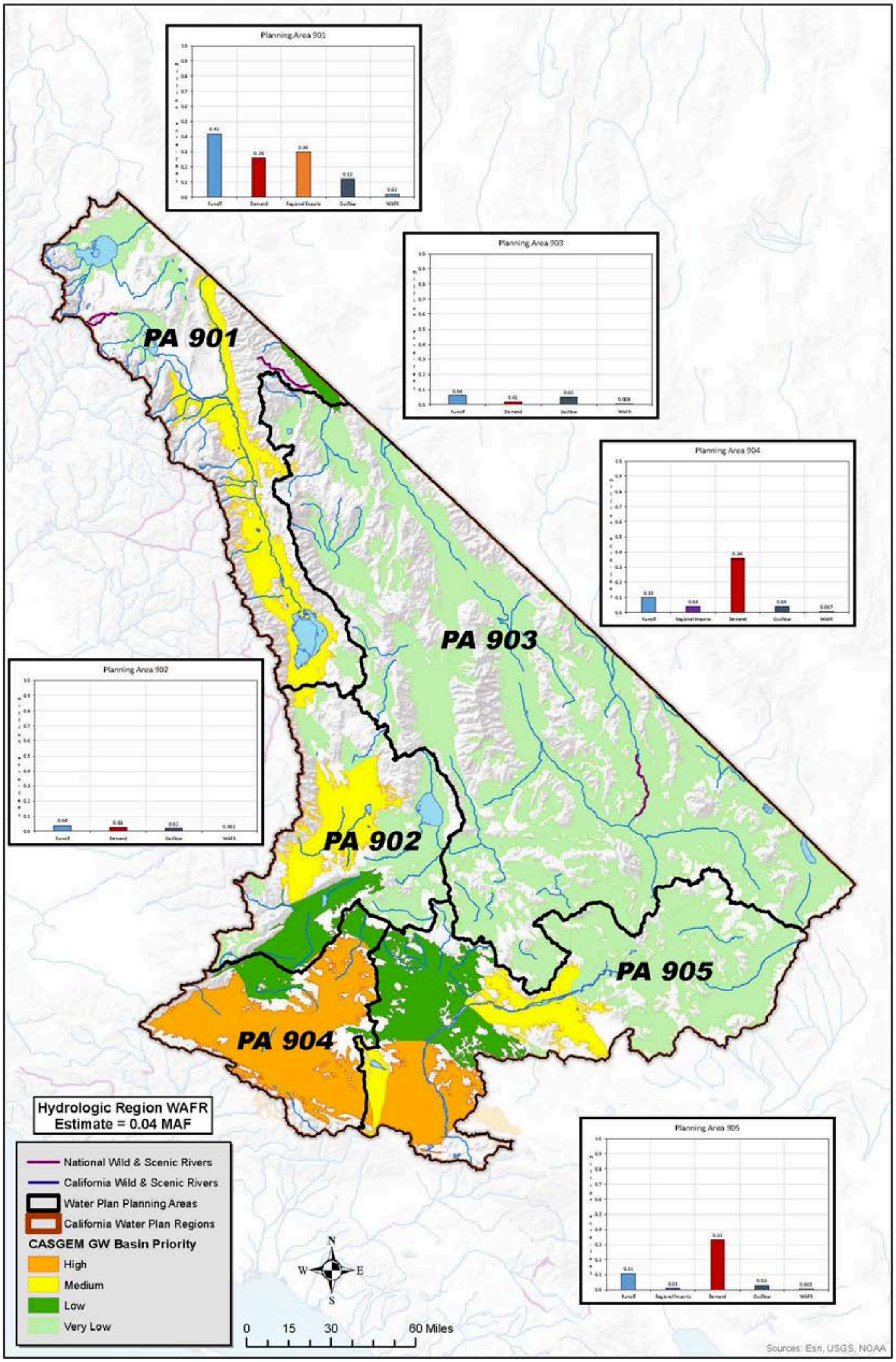


Figure A-SL3. South Lahontan Hydrologic Region PA 901, PA 902, PA 903, PA 904, and PA 905 WAFR Information and Estimates



WAFR Information and Estimates

The region's past tectonic activities and current climate are responsible for the region's present day hydrologic and drainage characteristics. The bordering mountain ranges have left the region without an outlet to the Pacific Ocean. As a result, all rivers and streams drain to internal basins. For most of the year, flows in these waterways are, at best, ephemeral and intermittent — a condition that reflects the region's present day arid conditions. Surface runoff can result from summer thunderstorms and occasionally winter storms (California Water Plan Update 2013).

Major tributaries in South Lahontan HR are Owens River, Rush Creek, Lee Vining Creek, and Mill Creek.

The WAFR information and estimates are provided in the following sections.

Surface Water and Groundwater Information

South Lahontan, PA 901, PA 902, PA 903, PA 904, and PA 905 surface water and groundwater information (as defined in the Surface Water and Groundwater Information section) is provided in Table A-SL1.

Table A-SL1. South Lahontan, PA 901, PA 902, PA 903, PA 904, and PA 905 Surface Water and Groundwater Information

Geographical Region	Regional Imports (maf)	Regional Exports (maf)	Groundwater Pumping (maf)	Groundwater Natural Recharge (maf)	Applied and Artificial Recharge (maf)
South Lahontan HR	0.05	0.30	0.43	0.39	0.15
PA 901	0.0	0.30	-	-	-
PA 902	0.0	0.0	-	-	-
PA 903	0.0	0.0	-	-	-
PA 904	0.04	0.0	-	-	-
PA 905	0.01	0.0	-	-	-

WAFR Estimates

The following sections describe how the WAFR estimates were determined.

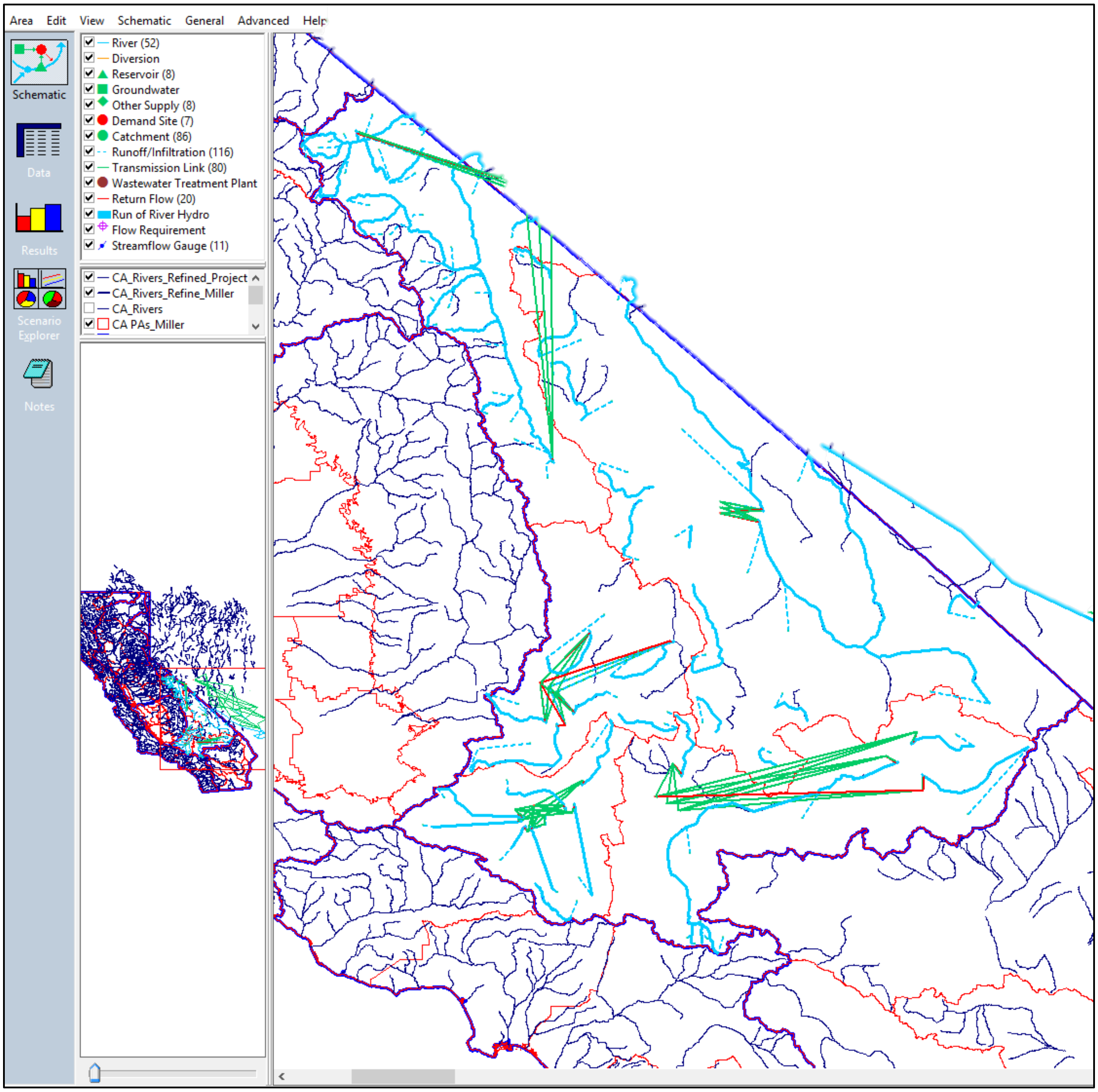
WEAP Model

The South Lahontan WEAP Model was developed using the procedures described in the WEAP Model Methodology section and described in more detail in the following sections.

Model Domain

The South Lahontan WEAP Model domain is shown in Figure A-SL4.

Figure A-SL4. South Lahontan WEAP Model



Streams/Rivers and Delineation of Watershed

The South Lahontan WEAP Model streams/rivers with corresponding Planning Areas are shown in Table A-SL2.

Table A-SL2. South Lahontan Streams/Rivers

River/Stream (PA 901)	River/Stream (PA 902)	River/Stream (PA 903)	River/Stream (PA 904)	River/Stream (PA 905)
AdobeValley	Cache Creek	Alkali Flat Drainage	Little Rock Creek	Black Canyon
Big Pine Creek	Cottonwood Creek	Amargosa River	Cottonwood Creek	Kelso Wash
Bishop Creek	CuddlebackLake	Crooked Creek	Fremont Valley Drainage	Mojave River
Dry Creek	Little Dixie Wash	Darwin Wash	Kern Drainage	West Fork Mojave River
East Mono Lake Drainage	Teagle Wash	Death Valley Wash	Pearblossom Runoff	Willow Creek
Huntoon Creek	Unnamed Stream 8945	Kingston Wash	Rogers Dry Lake Drainage	Willow Wash
Independence Creek		Marble Canyon	Unnamed Stream 8940	
Lee Vining Creek		Potosi Wash	Unnamed Stream 8946	
Mammoth Creek		Salt Creek		
Mill Creek		Unnamed Stream 8931		
Owens River		Unnamed Stream 8934		
Rush Creek		Unnamed Stream 8947		
Unnamed Stream 7800		Unnamed Stream 8948		
Unnamed Stream 8887		Unnamed Stream 8952		
West Mono Lake Drainage		Waucoba Wash		

Watersheds in South Lahontan region were delineated to determine the runoff from each stream using the procedures described in the WEAP Model Methodology section.

Reservoir

Reservoirs included in the South Lahontan WEAP model with the corresponding Planning Areas are:

- Grant Lake (Rush Creek, PA 901).
- Lake Arrowhead (Willow Creek, PA 905).
- Lake Crowley (Owens River, PA 901).
- Lake Sabrina (Bishop Creek, PA 901).
- Mono Lake (PA 901).
- Saddlebag Lake (Lee Vining Creek, PA 901).
- Silverwood Lake (West Fork Mojave River, PA 905).
- Tinemaha Reservoir (Owens River, PA 901).

Demands

The South Lahontan region demands were determined using the procedures described in the WEAP Model Methodology section and described in the following sections.

Urban Indoor Demand

The Urban Indoor Annual Activity Level and Annual Water Use Rate for each Planning Area are shown in Table A-SL3.

Table A-SL3. Annual Activity Level and Annual Water Use Rate by Category

	Annual Activity Level (person/household)	Annual Water Use Rate (TAF per person/household)	Annual Activity Level (person/household)	Annual Water Use Rate (TAF per person/household)
	PA 901		**PA 902**	
Commercial	26,765	0.000032	22,647	0.000032
Industrial	0	0.000105	692	0.000105
Multi-Family	5,722	0.000190	9,537	0.000190
Single-Family	11,494	0.000236	19,156	0.000236
	PA 903		**PA 904**	
Commercial	61,766	0.000032	123,531	0.000032
Industrial	0	0.000105	16,613	0.000105
Multi-Family	2,861	0.000190	30,835	0.000190
Single-Family	5,747	0.000236	61,939	0.000236
	PA 905			
Commercial	170,885	0.000032		
Industrial	13,152	0.000105		
Multi-Family	48,955	0.000190		
Single-Family	98,337	0.000236		

Urban Outdoor Demand

The acres for each land use class by Planning Area are shown in Table A-SL4.

Table A-SL4. Urban Outdoor Land Use Class Acres

Land Use Class	PA 901 Acres	PA 902 Acres	PA 903 Acres	PA 904 Acres	PA 905 Acres
Commercial	103.25	74.64	194.65	405.27	506.26
Multi-Family	64.20	89.70	0	803.99	598.02
Public	143.26	136.09	0	753.81	244.93
Single-Family	594.64	830.77	0	7,446.65	5,538.91
Total	**905.35**	**1,131.20**	**194.65**	**9,409.72**	**6,888.12**

Agricultural Demand

The acres for each crop type by Planning Area are shown in Table A-SL5.

Table A-SL5. Crop acres by Crop Type

Crop	PA 901 Acres (thousand)	PA 902 Acres (thousand)	PA 903 Acres (thousand)	PA 904 Acres (thousand)	PA 905 Acres (thousand)
Grain	0.1	0	0	4.16	0.78
Rice	0	0	0	0	0
Cotton	0	0	0	0	0
Sugar Beet	0	0	0	0	0
Corn	0	0	0	0.04	0.08
Dry Bean	0	0	0	0	0
Safflower	0	0	0	0	0
Other Field	0.5	0.04	0	0.7	0.42
Alfalfa	12.36	0.66	0.64	7.18	10.36
Pasture	16.5	0.09	0.41	0.28	1.0
Processed Tomato	0	0	0	0	0
Fresh Tomato	0	0	0	0	0
Cucurbits	0	0	0	0.1	0
Onion and Garlic	0.06	0.2	0	1.63	0
Potato	0	0.24	0	0.56	0
Other Truck	0	0.62	0	2.2	0.06
Almond and Pistachio	0	0.06	0.06	0.08	0.33
Other Deciduous	0.01	0.18	0	1.33	0.22
Sub-Tropical	0	0	0.02	0	0
Vine	0	0	0	0.33	0
Total	**29.53**	**2.09**	**1.13**	**18.59**	**13.25**

Calibration

The South Lahontan WEAP Model was calibrated using the procedures described in the WEAP Model Methodology section.

Calibration Data Collection

Calibrated Watersheds with corresponding gage information are shown in Table A-SL6.

Table A-SL6. Calibrated Gage Locations

Gage Name	Site Number	Drainage Area (Square Miles)	Gage Flow Starting Date	Gage Flow Ending Date
MILL C BL LUNDY LK NR LEE VINING CA	10287069	17.1	7/19/1991	7/17/2014
RUSH C AT FLUME BL AGNEW LAKE NR JUNE LAKE CA	10287289	23.3	10/31/1990	6/4/2014
HOT C A FLUME NR MAMMOTH LAKES CA	10265150	68.3	6/11/1990	10/17/2013
MF BISHOP C BL LK SABRINA NR BISHOP CA	10270872	16.7	7/15/1991	5/23/2014
BIG PINE C NR BIG PINE CA	10276000	32.6	7/15/1908	9/5/1978
INDEPENDENCE C BL PINYON C NR INDEPENDENCE CA	10281800	18.1	7/3/1923	7/27/1978
AMARGOSA RV AT TECOPA, CA	10251300	3090	9/26/1962	11/22/2013
LITTLE ROCK C AB LITTLE ROCK RES NR LITTLEROCK CA	10264000	49	4/26/1931	1/9/2005

Calibration Results

Calibrated Watersheds with corresponding NSE and PBIAS are shown in Table A-SL7.

Table A-SL7. Calibrated Watersheds with corresponding NSE and PBIAS

Location	Nash Sutcliffe Coefficient of Efficiency (NSE)	Percent Bias (PBIAS)
Amargosa Creek @ Tecopa	0.66	3.02
Big Pine Creek WS	0.70	2.25
Upper Bishop Creek WS	0.47	-25.0
Independence Creek WS	0.71	-9.98
Lower Little Rock C WS	0.62	-6.5
Hot Creek WS	0.76	-13.33
Mill Creek WS	0.72	3.24
Grant Lake Rush Creek WS	0.70	13.52

WEAP Outflow

The WEAP outflow for South Lahontan, PA 901, PA 902, PA 903, PA 904, and PA 905 is shown in Table A-SL8.

Table A-SL8. South Lahontan, PA 901, PA 902, PA 903, PA 904, and PA 905 WEAP Outflow

Geographical Region	Outflow (maf)
South Lahontan	0.26
PA 901	0.12
PA 902	0.02
PA 903	0.05
PA 904	0.04
PA 905	0.03

WAFR Fraction

The following sections describe how the WAFR Fraction was determined for South Lahontan, PA 901, PA 902, PA 903, PA 904, and PA 905.

Gage Data

Gage data for five major rivers in the South Lahontan Hydrologic Region was compiled. In each river or stream, the most downstream gage was selected to account for water demands within the watershed and to develop a WAFR fraction that is applicable to regional outflow.

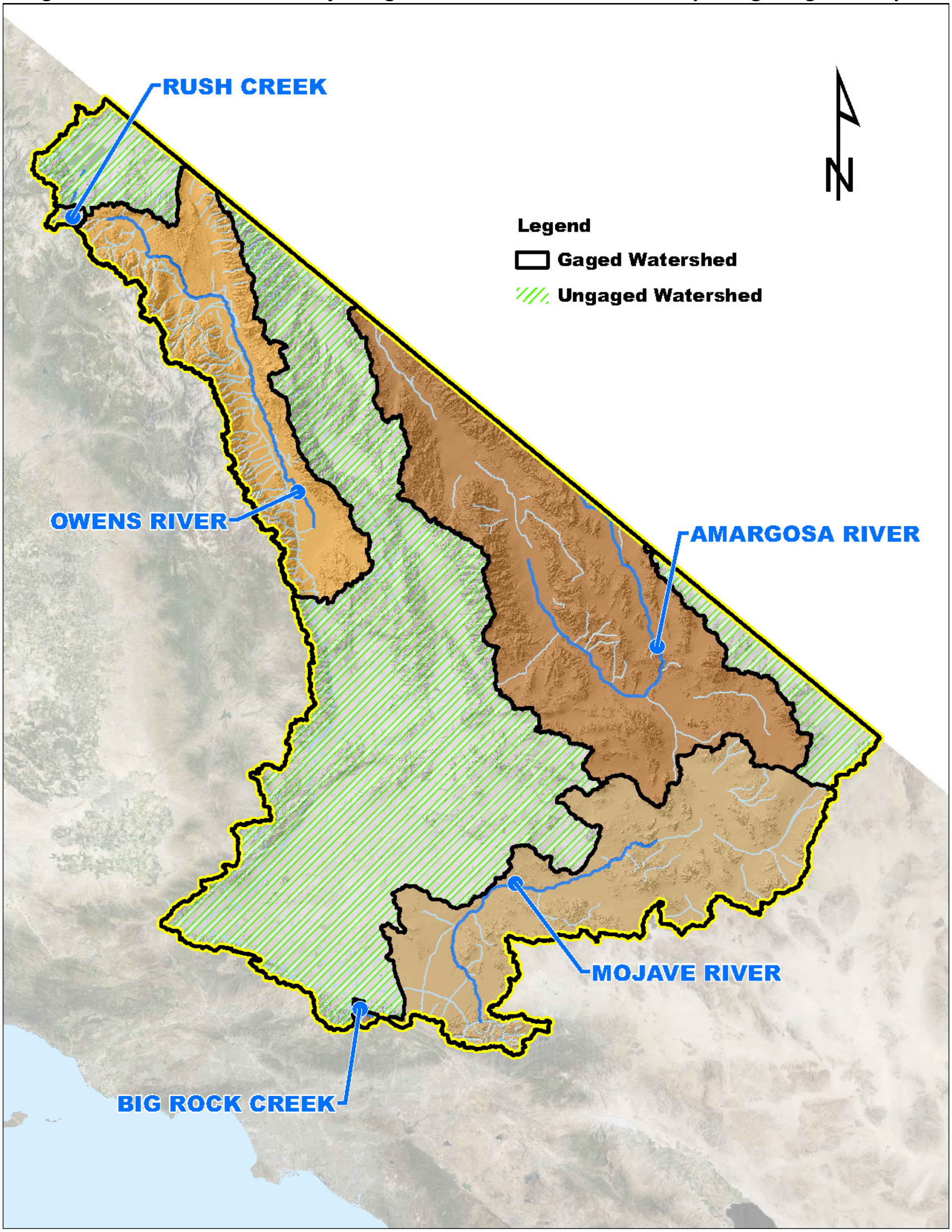
The total area of the gaged watersheds is 7,030 square miles of the 26,732 square mile region, or approximately 26 percent of the total hydrologic region. A summary of the stream gages used in this analysis is presented in Table A-SL9. A map showing the locations of the gages used, and their respective watersheds is shown as Figure A-SL5.

Table A-SL9. Major Rivers and Gages in South Lahontan Hydrologic Region Analysis

River/Stream	Location	USGS Gage Number	Area (square miles)
Amargosa River	Tecopa	10251300	3,090
Big Rock Creek	Valyermo	10263500	23
Mojave River	Barstow	10262500	1,290
Owens River	Lone Pine	10285700	2,604
Rush Creek	June Lake	10287300	23

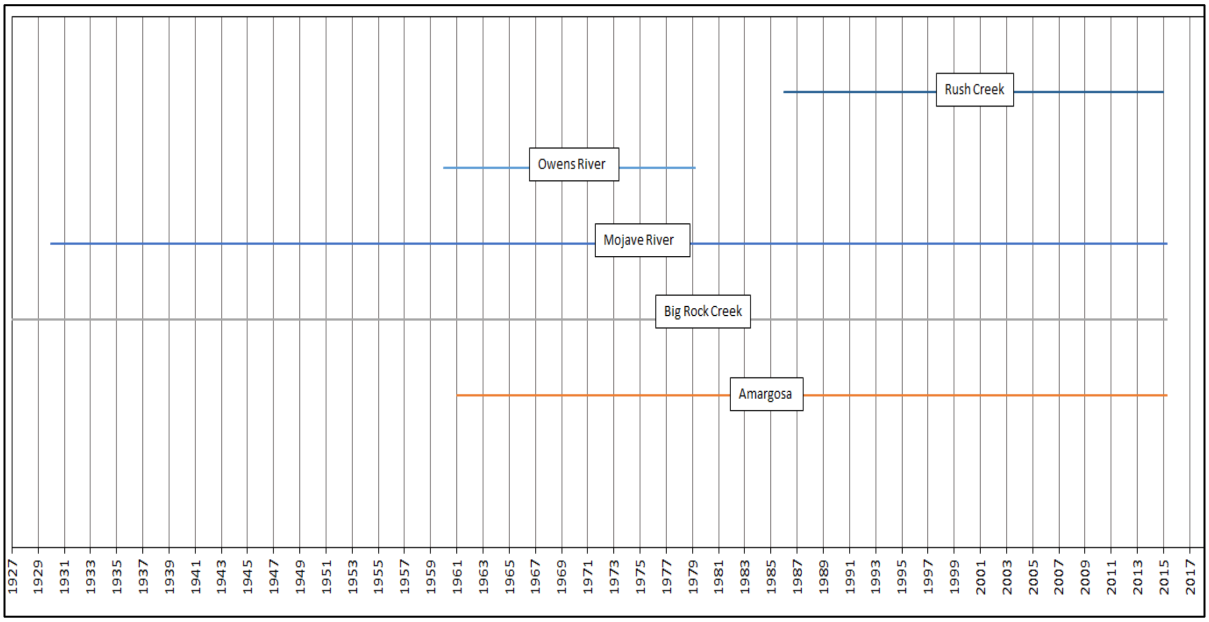
The bulk of the runoff in the South Lahontan Hydrologic Region drains the eastern slope of the Sierra Nevada Mountains along the Owens River and Rush Creek. Complete gage records are available for these major streams. In the southern portion of the region, the Mojave River and the Amagosa River drain a large portion of the desert floor. Gage data is also available for these rivers.

Figure A-SL5. Watersheds for Major Gaged Streams in South Lahontan Hydrologic Region Analysis



Once the available gage data was compiled, the period of available data for the five gages were compared. Data availability by year is presented in Figure A-SL6.

Figure A-SL6. Period of Available Gage Data in South Lahontan Hydrologic Region Analysis



Most rivers and streams in the South Lahontan Hydrologic Region are either designated as Wild and Scenic, Fully Appropriated year-round, or the subject of significant litigation. Therefore, WAFR fractions for the Planning Areas in this region are small.

The gage data outflow, diverted water using Conceptual Project (WAFR), and WAFR Fraction (diverted water using Conceptual Project (WAFR)/Gage Data Outflow) for each stream and the South Lahontan Hydrologic Region is shown in Table A-SL10.

Table A-SL10. WAFR Fraction

River/Stream	Gage Data Outflow (TAF)*	Lower Sensitivity Range Estimate		Best Estimate		Upper Sensitivity Range Estimate		Maximum Project Estimate	
		WAFR (TAF)	WAFR Fraction (%)	WAFR (TAF)	WAFR Fraction (%)	WAFR (TAF)	WAFR Fraction (%)	WAFR (TAF)	WAFR Fraction (%)
Amargosa	2.4	0.00	0.00%	0.00	0.00%	0.00	0.00%	0.00	0.00%
Big Rock	13.3	0.34	2.57%	1.15	8.62%	1.94	14.57%	8.92	66.99%
Mojave	13.6	0.13	0.93%	0.25	1.85%	0.47	3.43%	13.54	99.50%
Owens	17.3	7.42	43.01%	11.18	64.82%	12.88	74.63%	12.95	75.08%
Rush	30.6	0.00	0.00%	0.00	0.00%	0.00	0.00%	0.00	0.00%
HR Total	**77.2**	**7.9**	**10.219 %**	**12.6**	**16.30%**	**15.3**	**19.80%**	**35.4**	**45.88%**

* Please note that the outflow is based on gaged streams only. The final WAFR estimates include outflow from the WEAP model for both gaged and ungaged watersheds.

Final WAFR Estimates

The outflow estimate simulated using the WEAP model was then multiplied by the range of water available for replenishment fractions determined by the historical gage data to determine the estimated range of WAFR estimates within the hydrologic region. The array of estimates for South Lahontan, PA 901, PA 902, PA 903, PA 904, and PA 905 are shown in Table A-SL11 using the WEAP outflow from Table A-SL8 and water available for replenishment fractions from Table A-SL10 above.

Table A-SL11. Final WAFR Estimates

Geographical Region	WEAP Outflow (MAF)	No Project Estimate (MAF)	Lower Sensitivity Range Estimate (MAF, WAFR Fraction 10.22%)	Best Estimate (MAF, WAFR Fraction 16.3%)	Upper Sensitivity Range Estimate (MAF, WAFR Fraction 19.8%)	Maximum Project Estimate (MAF, WAFR Fraction 45.88%)
South Lahontan Hydrologic Region	0.26	0.0	0.027	0.042	0.051	0.119
PA 901	0.12	0.0	0.012	0.020	0.024	0.055
PA 902	0.02	0.0	0.002	0.003	0.004	0.009
PA 903	0.05	0.0	0.005	0.008	0.010	0.023
PA 904	0.04	0.0	0.004	0.007	0.008	0.018
PA 905	0.03	0.0	0.003	0.005	0.006	0.014

Potential Water Development by Other Methods (recycled water, desalination and water conservation)

Estimates of potential water development by other methods (recycled water, desalination and water conservation) are also shown for South Lahontan region in Table A-SL12. Note that these estimates were not specifically made for use for groundwater replenishment and will need to be considered by GSAs more thoroughly for such purpose.

Table A-SL12. South Lahontan Urban Water Portfolio Actions

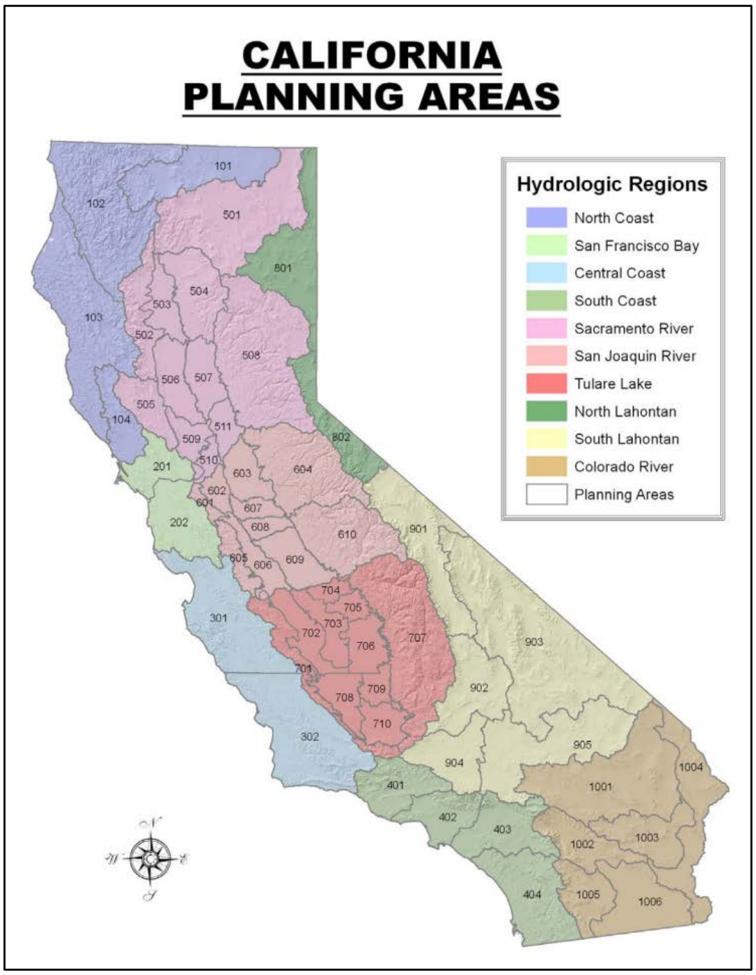
Method	Volume of Water Increase from 2010 to 2020
Recycle	0.01 MAF
Desalination	-
Conservation	0.01 MAF

Colorado River Hydrologic Region

The Colorado River Hydrologic Region is located in southeastern California and contains 12 percent of the state's land area. The Colorado River provides most of the eastern boundary, and the border with Mexico forms the southern boundary. The region includes Imperial County and portions of Riverside, San Bernardino, and San Diego counties. Many of the prominent watersheds in the Colorado River Hydrologic Region offer combinations of native vegetation and human-made environmental, urban, and agricultural land and water uses. Most of the Colorado River region has a subtropical desert climate with hot summers and short, mild winters. Annual average rainfall amounts range from a little over 6 inches to less than 3 inches. Most of the precipitation for the region occurs in the winter and spring. However, monsoonal thunderstorms, spawned by the movement of subtropical air from the south, do occur in the summer and can generate significant rainfall in some years. The region receives some water from State Water Project and the Colorado River (California Water Plan Update 2013).

The Colorado River HR is divided into six Planning Areas: PA 1001, PA 1002, PA 1003, PA 1004, PA 1005, and PA 1006. Colorado River HR, PA 1001, PA 1002, PA 1003, PA 1004, PA 1005, and PA 1006 are shown in Figure A-CR1.

Figure A-CR1. Colorado River HR, PA 1001, PA 1002, PA 1003, PA 1004, PA 1005, and PA 1006



Summary of WAFR Information and Estimates

WAFR information and estimates for Colorado River HR, PA 1001, PA 1002, PA 1003, PA 1004, PA 1005, and PA 1006 are shown in Figures A-CC2 and A-CC3.

Figure A-CR2. Colorado River Hydrologic Region WAFR Information and Estimates

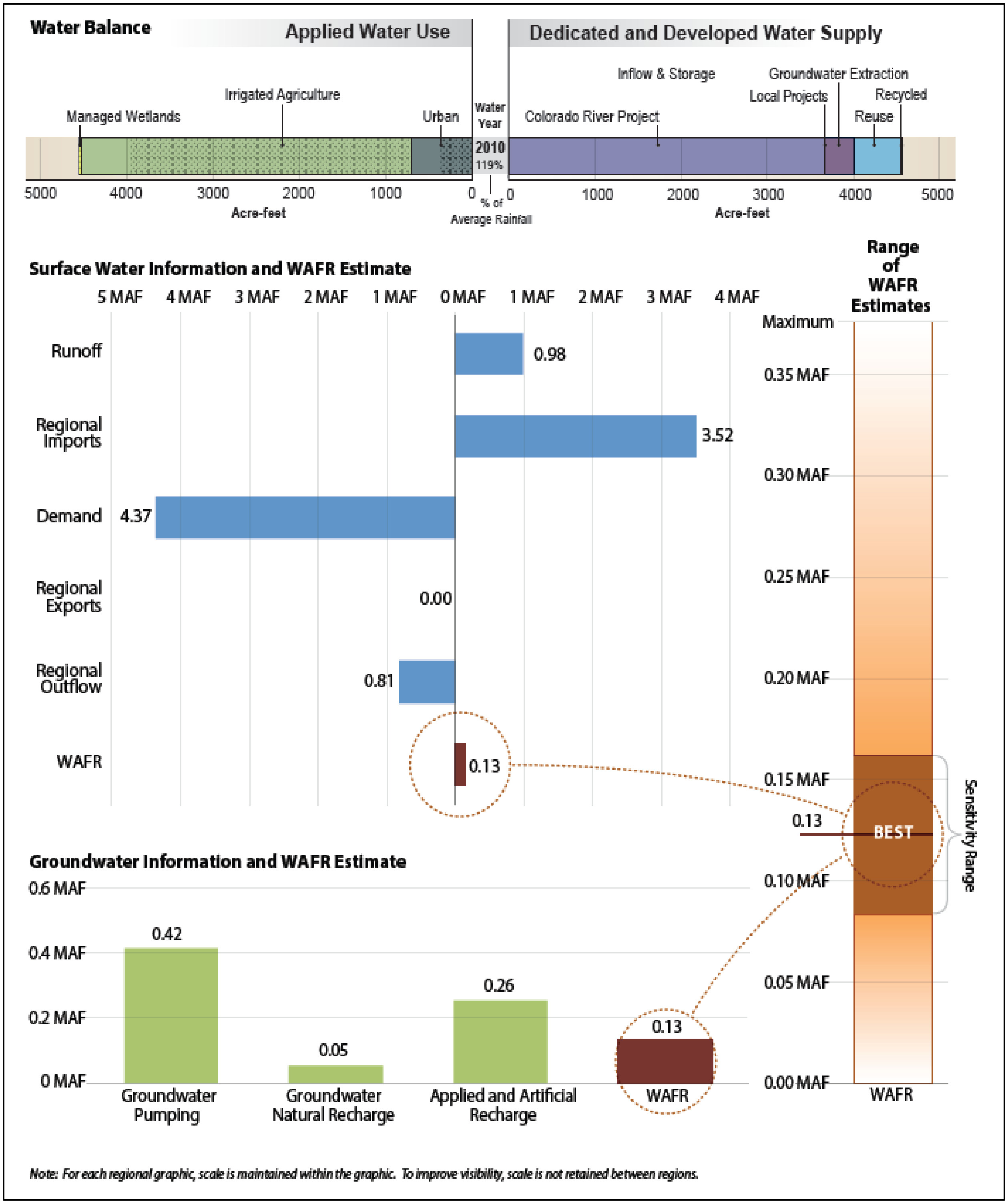
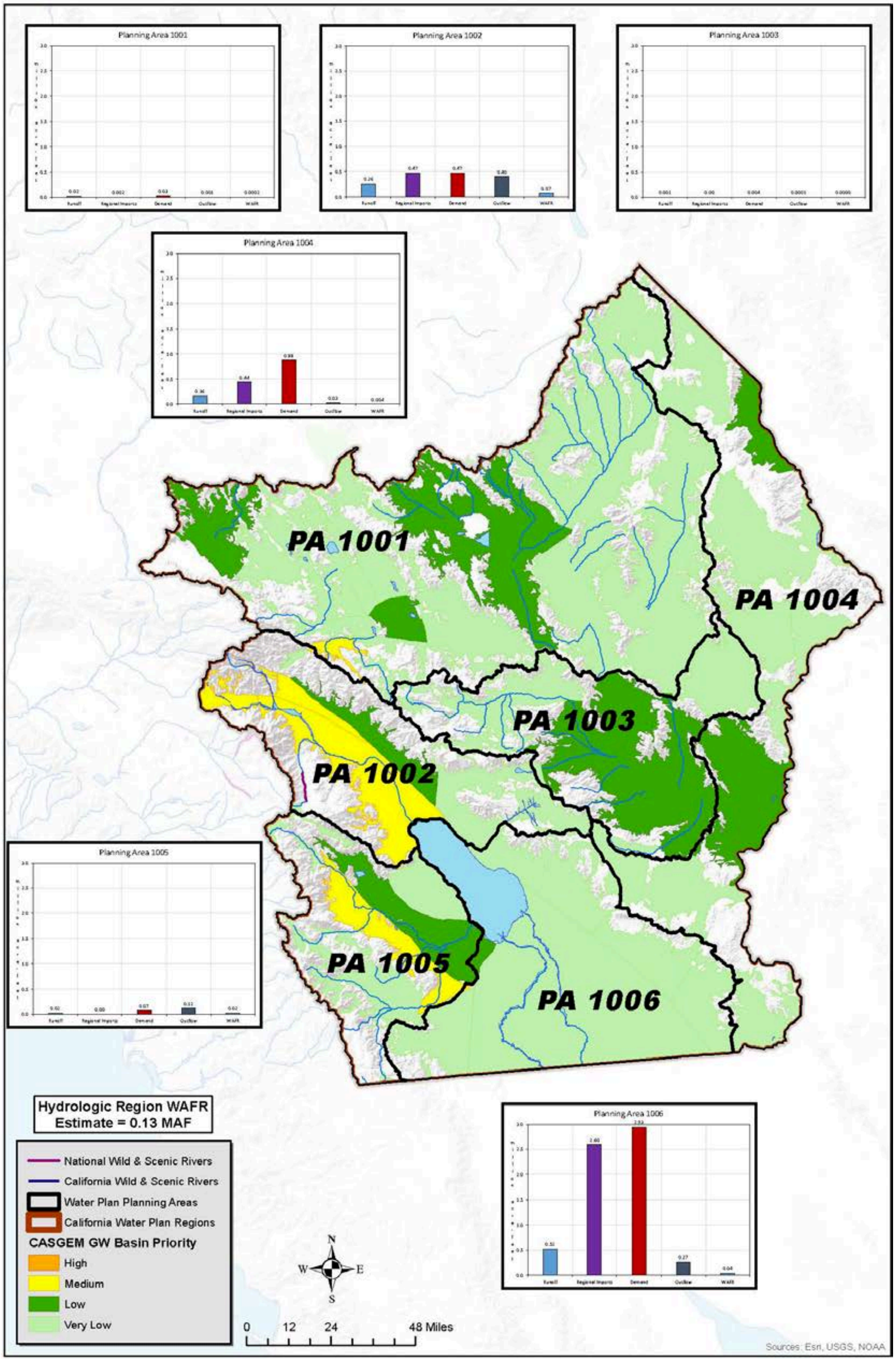


Figure A-CR3. Colorado River PA 1001, PA 1002, PA 1003, PA 1004, PA 1005, and PA 1006 WAFR Information and Estimates



WAFR Information and Estimates

The major tributaries in the Colorado River HR are the Watson Wash, Pipes Creek, White Water River, San Filipe, New River, Alamo River, Pinto Wash, and Arroyo Seco Milpitas Wash. Very little gage data exists for the Colorado River HR.

The Colorado River HR also receives imports from both the State Water Project (SWP) and Colorado River.

The WAFR information and estimates is provided in the following sections.

Surface Water and Groundwater Information

Colorado River HR, PA 1001, PA 1002, PA 1003, PA 1004, PA 1005, and PA 1006 surface water and groundwater information (as defined in Surface Water and Groundwater section) is provided in Table A-CR1.

Table A-CR1. Colorado River HR, PA 1001, PA 1002, PA 1003, PA 1004, PA 1005, and PA 1006 Surface Water and Groundwater Information

Geographical Region	Regional Imports (maf)*	Regional Exports (maf)	Groundwater Pumping (maf)	Groundwater Natural Recharge (maf)	Applied Recharge (maf)
Colorado River HR	3.52	0.0	0.42	0.05	0.26
PA 1001	0.002	0.0	-	-	-
PA 1002	0.47	0.0	-	-	-
PA 1003	0	0.0	-	-	-
PA 1004	0.44	0.0	-	-	-
PA 1005	0	0.0	-	-	-
PA 1006	2.60	0.0	-	-	-

* Regional imports for the Colorado HR account for Colorado River imports and SWP imports.

WAFR Estimates

The following sections describe how the WAFR estimates were determined.

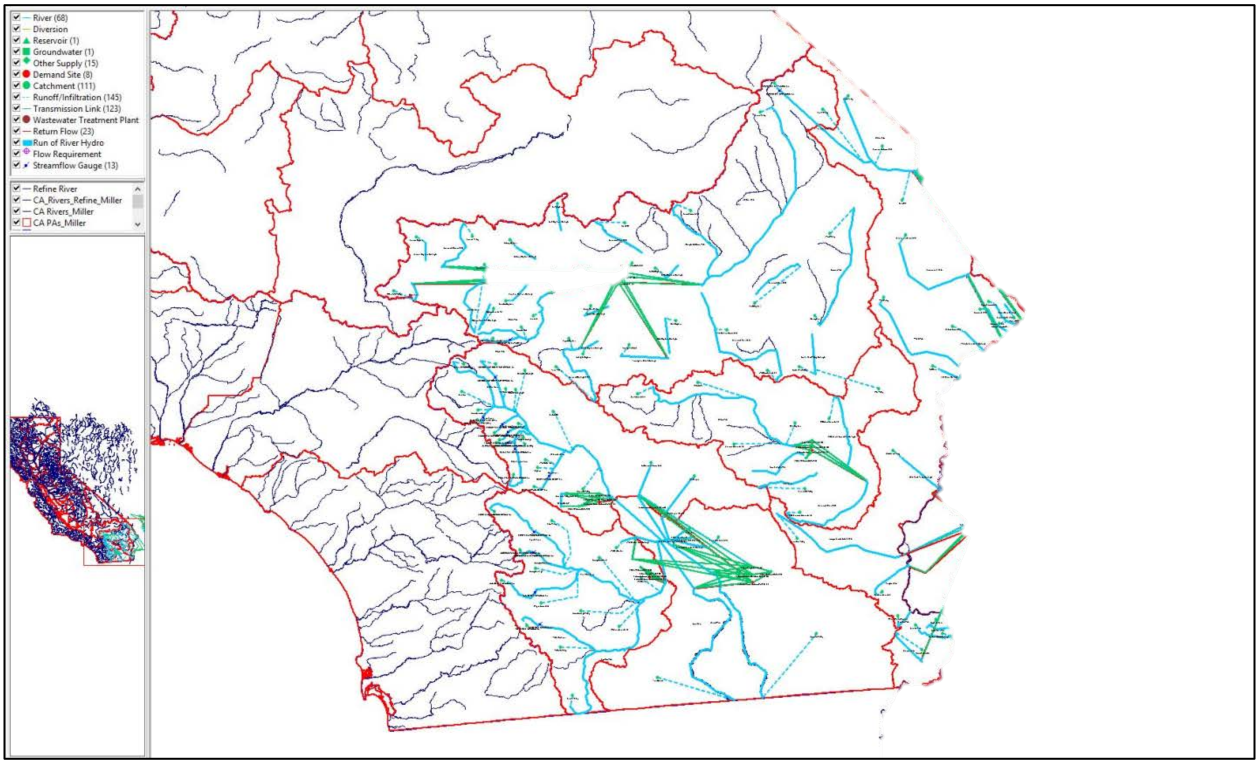
WEAP Model

The Colorado River WEAP Model was developed using the procedures described in the WEAP Model Methodology section and described in more detail in the following sections.

Model Domain

The Colorado River WEAP Model domain is shown in Figure A-CR4.

Figure A-CR4. Colorado River WEAP Model



Streams/Rivers and Delineation of Watershed

The Colorado River WEAP Model streams/rivers with corresponding Planning Area are shown in Table A-CR2.

Table A-CR2. Colorado River Streams/Rivers

PA1001 Streams	PA1002 Streams	PA1003 Streams	PA1004 Streams	PA1005 Streams	PA1006 Streams
Watson Wash	Whitewater River	Unnamed River 9023	Caruthers Creek	Coyote Creek	Salton Sea
Homer Wash	Snow Creek	Corn Springs Wash	Chemehuevi Wash	San Filipe Creek	Alamo River
South Ward Valley Drainage	Tahquitz Creek	Little Maria Mountains Drainage	Copper Basin Wash	Carrizo Wash	Chocolate Mountains Drainage
Bristol Dry Lake Drainage	Deep Creek	Ship Creek	Whipple Mountains Drainage	Borrego Palm Creek	New River
Dale Dry Lake Drainage	Red Canyon Drainage	Pinto Wash	Lost Lake Drainage	Vallecito Creek	
Unnamed Drainage 9003	Mission Creek		Arroyo Seco Milpitas Wash	West Salton Sea Drainage	
Homestead Drainage	Chino Canyon Creek		Carrizo Wash		
Lavic Dry Lake Drainage	Palm Canyon Creek		Senator Wash		
Emerson Dry Lake Drainage	Cottonwood Mountains Drainage		Piute Wash		
Pipes Creek			Parker Dam Drainage		
Arrastre Creek			Bowmans Wash		
Lucerne Dry Lake Drainage			Vidal Wash		
Orange Blossom Wash			Palo Verde Valley Drainage		
Unnamed River 8972			Vinagre Wash		
Unnamed River 9004			Ferguson Wash		
Unnamed River 8995			Picacho Wash		
Twentynine Palms Drainage					
Mesquite Dry Lake Drainage					
Deadman Dry Lake Drainage					
Galway Dry Lake Drainage					
Pipes Wash					
Bighorn Mountains Drainage					
Unnamed Stream 8997					
Silver Creek					

Watersheds in Colorado River were delineated to determine the runoff from each stream using the procedures described in the WEAP Model Methodology section.

Reservoir

The Salton Sea was modeled as a reservoir in the Colorado River HR WEAP model. No other reservoirs were modeled.

Demands

The Colorado River demands were determined using the procedures described in the WEAP Model Methodology section and described in the following sections.

Urban Indoor Demand

The Urban Indoor Annual Activity Level and Annual Water Use Rate for each Planning Area are shown in Table A-CR3.

Table A-CR3. Annual Activity Level and Annual Water Use Rate by Category

	PA 1001		PA 1002	
Category	**Annual Activity Level (person/household)**	**Annual Water Use Rate (TAF per person/household)**	**Annual Activity Level (person/household)**	**Annual Water Use Rate (TAF per person/household)**
Commercial	12008	0.000084	193323	0.000084
Industrial	0	0.000097	13704	0.000097
Multi-Family	3631	0.000217	36645	0.000217
Single-Family	10288	0.000226	103815	0.000226
	PA 1003		**PA 1004**	
Category	**Annual Activity Level (person/household)**	**Annual Water Use Rate (TAF per person/household)**	**Annual Activity Level (person/household)**	**Annual Water Use Rate (TAF per person/household)**
Commercial	2402	0.000084	25816	0.000084
Industrial	0	0.000097	0	0.000097
Multi-Family	330	0.000217	2311	0.000217
Single-Family	935	0.000226	6547	0.000226
	PA 1005		**PA 1006**	
Category	**Annual Activity Level (person/household)**	**Annual Water Use Rate (TAF per person/household)**	**Annual Activity Level (person/household)**	**Annual Water Use Rate (TAF per person/household)**
Commercial	1801	0.000084	27618	0.000084
Industrial	0	0.000097	979	0.000097
Multi-Family	1321	0.000217	15186	0.000217
Single-Family	3741	0.000226	43022	0.000226

Urban Outdoor Demand

The acres for each land use class by Planning Area are shown in Table A-CR4.

Table A-CR4. Urban Outdoor Land Use Class Acres

Land Use Class	PA 1001 Acres	PA 1002 Acres
Commercial	248	4,375
Multi-Family	91	920
Public	102	24,160
Single-Family	818	8,271
Total	**1,259**	**37,726**
Land Use Class	**PA 1003 Acres**	**PA 1004 Acres**
Commercial	97	682
Multi-Family	1	52
Public	122	109
Single-Family	8	468
Total	**228**	**1,311**
Land Use Class	**PA 1005 Acres**	**PA 1006 Acres**
Commercial	56	669
Multi-Family	16	214
Public	401	540
Single-Family	148	1,926
Total	**621**	**3,349**

Agricultural Demand

The acres for each crop type by Planning Area are shown in Table A-CR5. Agricultural demands generated using these acreage values produced about half of the demand found in the California Water Plan. Agricultural demands were artificially increased to match the water plan.

Table A-CR5. Crop acres by Crop Type

Crop	PA 1001 Acres (thousand)	PA 1002 Acres (thousand)	PA 1003 Acres (thousand)	PA 1004 Acres (thousand)	PA 1005 Acres (thousand)	PA 1006 Acres (thousand)
Grain	0.08	-	-	5.76	0.66	55.62
Rice	-	-	-	-	-	-
Cotton	-	-	-	10.18	-	3.2
Sugar Beet	-	-	-	-	-	26.1
Corn	-	2.9	-	2.5	0.34	8.46
Dry Bean	-	-	-	0.08	-	0.14
Safflower	-	-	-	-	-	0.4
Other Field	0.1	0.6	-	8.73	0.8	58.44
Alfalfa	0.78	0.5	-	52.55	1.5	138.1
Pasture	0.02	2.78	-	6.72	-	71.3
Processed Tomato	-	-	-	-	-	-
Fresh Tomato	-	0.14	-	-	-	0.14
Cucurbits	0.02	1.1	-	4.57	0.8	9.23
Onion and Garlic	-	0.2	-	0.4	0.74	8.17
Potato	-	0.65	-	-	0.2	1.2
Other Truck	0.01	24.4	-	13.48	2.1	72.92
Almond and Pistachio	0.04	-	-	-	-	-
Other Deciduous	0.06	0.23	-	0.02	-	0.06
Sub-Tropical	0.41	18.5	0.44	4.94	2.95	5.76
Vine	0.78	11.96	-	-	-	-
Total	**2.3**	**63.96**	**0.44**	**109.93**	**10.09**	**459.24**

Calibration

The Colorado River WEAP Model was calibrated using the procedures described in the WEAP Model Methodology section.

Calibration Data Collection

Calibrated Watersheds with corresponding gage information are shown in Table A-CR6.

Table A-CR6. Calibrated Gage Locations

Gage Name	Site Number	Drainage Area (Square Miles)	Gage Flow Starting Date	Gage Flow Ending Date
PIPES C NR YUCCA VALLEY CA	10260200	15.1	1958	1971
CARUTHERS C NR IVANPAH CA	9423350	0.84	1963	2016
SNOW C NR WHITE WATER CA	10256500	10.9	1921	2016
MISSION C NR DESERT HOT SPRINGS CA	10257600	35.6	1967	2016
CHINO CYN C NR PALM SPRINGS CA	10257710	3.84	1974	1985
ANDREAS C NR PALM SPRINGS CA	10259000	8.65	1948	2016
PALM CYN C NR PALM SPRINGS CA	10258500	93.1	1930	2016
DEEP C NR PALM DESERT CA	10259200	30.6	1962	2016

TAHQUITZ C NR PALM SPRINGS CA	10258000	16.9	1947	2016
COYOTE C NR BORREGO SPRINGS CA	10255800	144	1950	1983
BORREGO PALM C NR BORREGO SPRINGS CA	10255810	21.8	1950	2016
SAN FELIPE C NR JULIAN CA	10255700	89.2	1958	1983
VALLECITO C NR JULIAN CA	10255850	39.7	1963	1983

Calibration Results

Calibrated Watersheds with corresponding NSE and PBIAS are shown in Table A-CR7.

Table A-CR7. Calibrated Watersheds with corresponding NSE and PBIAS

Stream Gage Name and River Name	Nash Sutcliffe Coefficient of Efficiency (NSE)	Percent Bias (PBIAS)
Pipes Creek @ Yucca Valley	0.14	15.97
Caruther C @ Ivanpah	0.28	7.95
Snow C @ White Water	0.66	-2.81
Mission C @ Desert Hot Springs	0.32	5.01
Chino Canyon C @ Palm Springs	0.61	4.99
Andreas C @ Palm Springs	0.71	-1.32
Palm Canyon C @ Palm Springs	0.61	-2.76
Deep C @ Palm Desert	0.65	-8.88
Tahquitz @ Palm Springs	0.44	7.54
Coyote C @ Borrego Springs	0.46	-0.64
Borrego Palm @ Borrego Springs	0.63	-7.05
San Filipe C @ Julian	0.35	21.63
Vallecito C @ Julian	-0.11	-3.96

WEAP Outflow

The WEAP outflow for Colorado River HR, PA 1001, PA 1002, PA 1003, PA 1004, PA 1005, and PA 1006 is shown in Table A-CR8.

Table A-CR8. Colorado River, PA 1001, PA 1002, PA 1003, PA 1004, PA 1005, and PA 1006 WEAP Outflow

Geographical Region	Outflow (MAF)
Colorado River HR*	0.81
PA 1001	0.001
PA 1002	0.40
PA 1003	0.0001
PA 1004	0.03
PA 1005	0.12
PA 1006	0.27

*Please note the sum of the Planning Area outflow does not equal the hydrologic region outflow; since the multiple rivers/streams flow through multiple Planning Areas, the outflow from an upstream Planning Area may be double counted in the outflow for a downstream Planning Area. For this reason, adding the outflow from all the Planning Areas will not equal the Colorado River HR outflow.

WAFR Fraction

The following sections describe how the WAFR Fraction was determined for Colorado River, PA 1001, PA 1002, PA 1003, PA 1004, PA 1005, and PA 1006.

Gage Data

Limited gage data existed for Colorado River HR therefore the South Lahontan HR WAFR Fraction was used. The same WAFR Fraction is also used for PA 1001, PA 1002, PA 1003, PA 1004, PA 1005, and PA 1006.

Table A-CR9. WAFR Fraction

Hydrologic Region	Lower Sensitivity Range Estimate	Best Estimate	Upper Sensitivity Range Estimate	Maximum Project Estimate
	WAFR Fraction (%)	WAFR Fraction (%)	WAFR Fraction (%)	WAFR Fraction (%)
Colorado River*	**10.22%**	**16.3%**	**19.8%**	**45.88%**

*Colorado River HR uses the same WAFR Fraction as South Lahontan HR due to limited gage data in Colorado River HR.

Final WAFR Estimates

The outflow estimate simulated using the WEAP model was then multiplied by the range of water available for replenishment fractions determined by the historical gage data to determine the estimated range of WAFR estimates within the hydrologic region. The array of estimates for the Colorado River HR, PA 1001, PA 1002, PA 1003, PA 1004, PA 1005, and PA 1006 are shown in Table A-CR10 using the WEAP outflow from Table A-CR8 and water available for replenishment fractions from Table A-CR9 above.

Table A-CR10. Final WAFR Estimates

Geographical Region	WEAP Outflow (maf)	No Project Estimate (taf)	Lower Sensitivity Range Estimate (maf, WAFR Fraction 10.22%)	Best Estimate (maf, WAFR Fraction 16.3%)	Upper Sensitivity Range Estimate (maf, WAFR Fraction 19.8%)	Maximum Project Estimate (maf, WAFR Fraction 45.88%)
Colorado River HR*	0.81	0	0.083	0.13	0.161	0.372
PA 1001	0.001	0	0.0	0.0002	0.0	0.0
PA 1002	0.4	0	0.041	0.07	0.079	0.183
PA 1003	0.0001	0	0.0	0.0	0.0	0.0
PA 1004	0.03	0	0.003	0.004	0.005	0.012
PA 1005	0.12	0	0.012	0.02	0.024	0.055
PA 1006	0.27	0	0.027	0.04	0.053	0.122

*Please note the sum of the Planning Area outflow does not equal the hydrologic region outflow; since multiple rivers/streams flow through multiple Planning Areas, the outflow from an upstream Planning Area may be double counted in the outflow for a downstream Planning Area. For this reason, adding the outflow from all the Planning Areas will not equal the Colorado River HR outflow. Also, for this same reason, adding the WAFR from all the Planning Areas will not equal the Colorado River HR WAFR.

Potential Water Development by Other Methods (recycled water, desalination and water conservation)

Estimates of potential water development by other methods (recycled water, desalination and water conservation) are also shown for Colorado River hydrologic region in Table A-CR11. Note that these estimates were not specifically made for use for groundwater replenishment and will need to be considered by GSAs more thoroughly for such purpose.

Table A-CR11. Colorado River Urban Water Portfolio Actions

Method	Volume of Water Increase from 2010 to 2020
Recycle	0.01 maf
Desalination	0 maf
Conservation	0 maf

References

1. User Guide. Water Evaluation and Planning System (WEAP). SEI. 2015.
2. Technical Memorandum: Integrated Scenario Analysis for the 2009 California Water Plan Update. DWR. February 2010.
3. Central Coast. Volume 2. California Water Plan Update 2013. DWR. 2013.
4. PRISM. http://www.prism.oregonstate.edu/. PRISM Climate Group.
5. National Land Cover Database. https://www.mrlc.gov/nlcd2011.php. 2011.
6. Hydrologic Unit Maps. http://water.usgs.gov/GIS/huc.html. USGS.
7. Fully Appropriated Streams. State Water Resources Control Board. http://www.waterboards.ca.gov/waterrights/water_issues/programs/fully_appropriated_streams/
8. Instream Flow Regimens for Fish, Wildlife, Recreation and Related Environmental Resources. Donald Leroy Tennant. January 2011.
9. Policy for Maintaining Instream Flows in Northern California Coastal Streams. Division of Water Rights. State Water Resources Control Board. February 2014.