Chapter 4
Water Resources Management in California

Samuel Sandoval-Solis

Abstract California has an intense history of water management and resources manipulation. The main drivers for some of the largest water management infrastructure projects are (1) a spatial mismatch between where most of the precipitation falls on the state and where most of the water is needed and (2) a temporal mismatch of precipitation during winter months and the agriculture season on summer. This chapter describes the legal framework and water allocation systems to manage surface water, groundwater, and environmental water that are guiding California toward adopting an integrated water resources management framework.

Keywords Groundwater management · Water rights · Water allocation · SGMA

4.1 Background

Depending on the economic cycles, California fluctuates between the 5th to 7th largest economies in the world (Corcoran 2018; Forbes 2017). Furthermore, there is no other state in the United States (USA) wherein the economic development has been linked so tight to the water resources development, for instance, in 1849 during the gold rush when miners used high-pressure jets of water to wash entire hillsides (a procedure called hydraulic mining) to excavate sediments and separate the gold at industrial proportions. Nowadays, water still supports the economic development of the state such as providing clean pure water from Hetch Hetchy aqueduct to produce computer processors in Silicon Valley, all the way to collecting and transporting rainfall and snowfall originated in the Northern California, Wyoming, Colorado, and Utah into Southern California to support the entertainment and movie industry.

S. Sandoval-Solis (✉)
Department of Land, Air and Water Resources, University of California, Davis, Davis, CA, USA
e-mail: samsandoval@ucdavis.edu

E. O. Vieira et al. (eds.), *Integrated Water Resource Management*,
https://doi.org/10.1007/978-3-030-16565-9_4

Because water is not equitably distributed in time and place, in the right quantity with the adequate quality, a discipline called water resources planning and management (WRPM) is used to redistribute the resource in a way that satisfies the needs of water users, including the environment, today and in the future (Loucks et al. 2005). In California, WRPM has been widely used because there is a mismatch between the hydrologic cycle and when and where water is needed. First, the Mediterranean climate brings precipitation (rainfall and snowfall) during winter and snowmelt during spring. However, water is needed year-round for cities and the environment, during summer for agriculture and during certain hours of the day in summer to supply electric energy at peak hours (Hanak et al. 2011). To close this temporal gap, an important amount of natural water storage (such as aquifers) are managed, and man-made reservoirs (such as dams) were built throughout the state (USBR 2018). The main purpose of a reservoir is to store water during seasons of water abundance to release it later when water is needed. Some reservoirs have such a large storage capacity that can store water between years.

Similarly, WRPM is widely used in the state of California because there is a spatial mismatch between where precipitation occurs and where water is needed (Fig. 4.1). Generally, precipitation occurs in the northern part of the state and along the Sierra Nevada. In contrast, water is needed everywhere in the state, but mostly (a) along the coast, i.e., the San Francisco Bay Area; (b) in the center of the state, i.e., the entire Central Valley (Sacramento, San Joaquin, and Tulare basins) for agriculture production; and (c) in in the south, in Southern California to provide water to three quarters of the population of the state and the Imperial Valley. To close this spatial gap, an important amount of man-made conveyance infrastructures (e.g., canals, aqueducts, tunnels, and pipes) were built throughout the state (DWR 2018). The main purpose of this infrastructure is to transport water where it is needed; the California Aqueduct and the Delta-Mendota Canal move water from the north to the south of the state; the Hetch Hetchy and Mokelumne aqueducts transport water from the Sierra Nevada to the San Francisco Bay Area; Los Angeles and Colorado aqueducts move water to Southern California to supply urban and agriculture water needs.

Integrated water resources management (IWRM) is a process which promotes the coordinated development and management of water, land, and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems (GWP 2000). Unfortunately, in California, IWRM has not been applied until the last decade. During the nineteenth and twentieth century, water supplies, infrastructure, and economic and land resources were planned and managed independently, without much of coordination. Many of the water projects were designed and built independently, or in a piecemeal fashion as one piece of a bigger system, or they were developed and built (or not build) opportunistically when there was enough political willingness and resources. For instance, there is no single water code that explains the rules of how water is used throughout the state. In lieu, there is a body of legal cases and legislation that have been passed throughout the years describing the procedures,

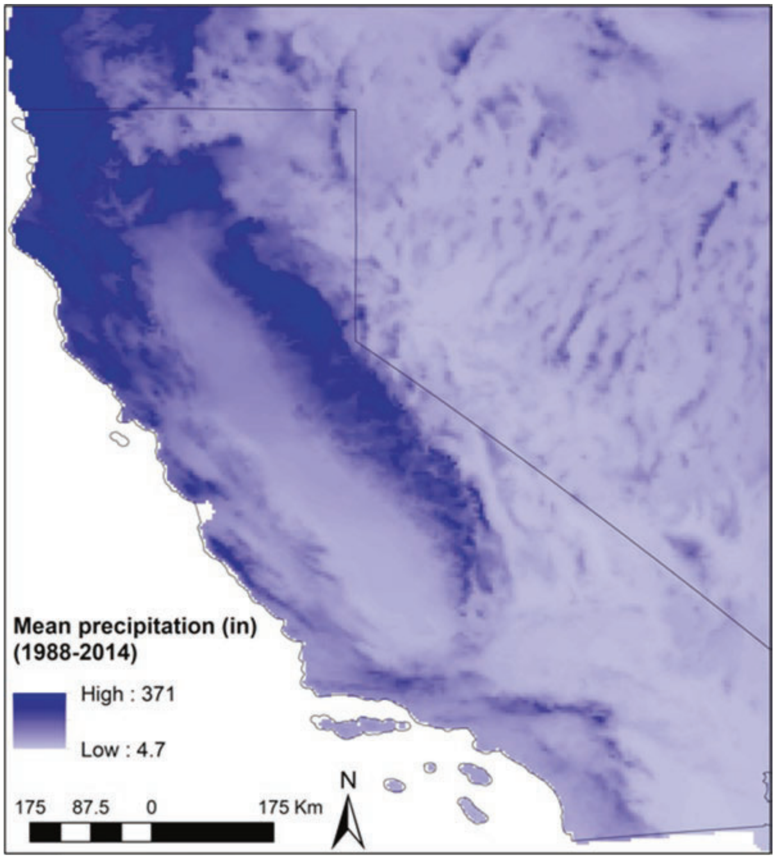

Fig. 4.1 Mean precipitation in the state of California

priorities, and allocation policies to distribute water in the state. In addition, there was no protection to the environment until the California Environmental Quality Act (CEQA) (Olshansky 1996), the Clean Water Act (2008), the Endangered Species Act (Congress 1973), the designation of wild and scenic rivers (Tarlock and Tippy 1969), and recently all the lawsuits to supply environmental flows to the mainstem of the most important river in the state. The only common rule is that water in the state of California must be used reasonably and for a well-defined beneficial use (Trelease 1957).

Depending on the *water source*, there are different *legal frameworks*, *decision-making processes*, and *water allocation systems*. Unfortunately, this means that water resources management in California is a fragmented system (opposite to integrated) that depends on the specific context. The following section describes these processes.

4.2 Water Resources Management in California

4.2.1 Surface Water Management

Legal framework There are two main surface water rights in the state of California: riparian and appropriative. A landowner with a property adjacent to a watercourse has a *riparian water right*. Riparian water rights are correlative, meaning that the owners share the water in case of shortage. Riparian water right holders have equal rights among themselves; the water right must be used in the watershed where the land property is located; there is no seasonal storage allowed. The water availability is estimated or measured based on natural conditions; there is no permit required from the State Water Resources Control Board (SWRCB). In general, riparian water rights have higher priority over appropriative rights (but not always); priority vis-à-vis appropriators depends on date of patent (the parcel deed from US Government), not date of first use. Riparian rights are not lost by nonuse but can be given lower priority than presently exercised rights when the SWRCB determines all the rights to a stream (statutory adjudication).

In terms of appropriative water rights, there are two main subcategories: Pre-1914 and Post-1914. For *Pre-1914 appropriative water rights* (Pre-1914), there is no permit required, and the right of use was acquired by diverting and applying water to beneficial use prior to December 19, 1914. For *Post-1914 appropriative water rights* (Post-1914), the water right holder requires a permit (or license) from the SWRCB; the permit is granted only if water is available for appropriation and if proposed use is in the public interest. The amount of diversion, timing, and use of water is subject to terms and conditions specified by SWRCB. There are common characteristics between Pre-1914 and Post-1914 water rights. Their order of water allocation, commonly known as priority, is based on time of use (for Pre-1914) or date of application (for Post-1914); this prioritization is usually referred as first in time, first in right. In times of scarcity, later (junior) appropriators are cut off before earlier (senior) appropriators. That is, early priority rights must be satisfied before later rights receive any water. The water right has a defined amount of water, which is the maximum amount of water that can be diverted under that right. However, this amount is not necessarily available in every year, and it can be cut back during drought periods. The water right title specifies the type and place of use and point and period of diversion. Furthermore, a water right may be lost through 5 or more years of nonuse (this action is commonly referred as use it or lose it) (Littleworth and Garner 2007).

Water allocation system Typically, riparian water rights are assigned first than appropriative water rights, this is because riparian water rights withdraw water during the wet season (winter and spring, when water is naturally available) and the amount of water withdrawn compared with the appropriative water rights is smaller. First, the natural flow is estimated for every basin and at different point of interest, called control points. Control points are usually located at streamflow gauges.

Second, the water available for every control point is estimated by subtracting the environmental flow requirements (see Environmental Flows section) to the natural flow. Third, the available water is compared with the riparian water right volume associated at a specific control point. Finally, the SWRCB decides if there is enough water available to supply the entire volume of water compromised in the water right permits or a portion of the total volume in which case the shortages are distributed equally by calculating the share among all riparian water users. In practice, the SWRCB monitors the water diversions and compliance of environmental flows by monitoring control point located at streamflow gauges. At the end of the water year, September 30, every water right holder submits a report to the SWRCB notifying the amount of water diverted, so the authority has an estimate of the water diverted.

As mentioned before, because of the Mediterranean climate of California, riparian water right holder mostly withdraws water during winter and spring. One of the main technical problems associated with riparian water rights is the estimation of the natural flows. In control points located at the headwaters with no major infrastructure upstream (such as weirs, dams, canals, tunnel intakes, major land use change, etc.), the natural flow is considered the streamflow at a determined gauge station. Downstream of major infrastructure, the natural flow is determined by using a mass balance method to calculate the naturalized streamflow (Wurbs 2006) or water resources modeling to determine the unimpaired flows (Kadir and Huang 2015).

Appropriative water rights have a different allocation system. Appropriative water rights have usually the following two characteristics: (1) water for appropriative water rights are usually stored in surface water reservoirs and transported through natural (mainstem of the river) and man-made infrastructure (canals and pipes), and (2) water can be stored and released at the discretion of the water right holder, meaning the period of use can be all year around (municipal users) or during specific portion of the years (e.g., the growing season for agriculture users). First, every April 1, the available water for appropriative water rights from every reservoir is estimated by subtracting the environmental flow requirements, conveyance, and evaporation losses to the reservoir storage on that date. Second, the water available for every reservoir is allocated in an orderly manner based on the priority (seniority) of the appropriative water rights (first in time, first in right). Third, in case of drought, junior water right holders can be notified that they can withdraw only a portion of their water right or no water at all. This procedure is performed by the institution or agency that owns and operates a determined reservoir (e.g., the US Bureau of Reclamation for the Central Valley Project or the California Department of Water Resources for the State Water Project, Sonoma Water for Coyote Valley Dam, etc.), and the allocation plan is submitted to the SWRCB for approval. In case of basins with no reservoirs, water right holders only can withdraw water after the flow at determined control points (usually streamflow gauges) are equal or above certain flow threshold. These thresholds have been previously calculated by the SWRCB to guarantee that environmental flows and senior water right holders will be able to withdraw water before junior water right holders.

4.2.2 Environmental Water Management

Legal framework There are three legal frameworks under which environmental flows, water to support the aquatic and riparian ecosystems, are determined and implemented in the state of California: (1) the Endangered Species Act (ESA) (Congress 1973), (2) Section 5937 of Fish and Game Code (Bork et al. 2011), (3) the Federal Energy Regulation Commission (FERC) relicensing process for hydropower dams, and (4) public trust doctrine (Sax 1970).

The ESA has been used historically as a mechanism to sue the owners and operators of water resources infrastructure to modify their operations, so they are not detrimental of endangered species. Usually, a nongovernmental organization (NGO) or an environmental agency within the government (e.g., US Fish and Game) is the institution suing the infrastructure-operational agency to modify their operations, mostly releases from reservoir. During the legal process, the court request biological opinions (BOs) to determine what are the impacts of the current reservoir operation as well as potential alternative strategies to support endangered species. The BOs are used as the basis and guidelines to modify reservoir operations. This strategy has been used in the mainstem of the most important rivers in California, because reservoirs were built in these places.

Section 5937 of Fish and Game Code states that “the owner of any dam shall allow sufficient water at all times to pass over, around or through the dam, to keep in good condition any fish that may be planted or exist below the dam” (Bork et al. 2011). Thus Section 5937 enforces the longitudinal connectivity of rivers by allowing fish to migrate upstream and downstream. Similar to ESA, there should be an institution (usually the California Department of Fish and Wildlife) that request infrastructure-operational agency to modify their infrastructure for allowing the passage of fish up and down the reservoir.

The FERC relicensing process for hydropower dam forces the hydropower owners and operators (HP-operator) to renew their dam operation license every determined number of years (usually between 20 and 30 years). When the HP-operator is renewing their license, FERC request that the proposed future operations are protective of any endangered species and in general of the environment. Thus, HP-operators are forced to design dam operations that meet state regulation (Section 5937) and that are protective of the environment and economically feasible to continue producing electricity. This procedure occurs mostly in relatively small dams built in the headwaters of different rivers.

The public trust doctrine is a state power that allows an institution (the SWRCB) to protect natural resources, including water, for the common benefit of the public above any individual benefit. The public trust doctrine allows the state of California to preserve and conserve rivers for the benefit of the public above any individual benefit. This policy is commonly used to protect or restore natural resources along the riparian corridor, including rivers, estuaries, and other water bodies for the entertainment of the public today and in the future. The SWRCB use this doctrine in degraded watershed where overuse of water has led to ecosystem degradation. The public thrust doctrine was applied in different legal cases; it is most frequently used to protect or restore tributaries of main rivers when the aquatic and riparian ecosystems living on the tributaries have been degraded. In addition to the previous legal mechanisms, in 1972 the state of California enacted the Wild and Scenic Rivers Act that protects many rivers throughout the state, including the Eel and Klamath rivers.

Water allocation system Typically, environmental flows have the highest priority, and water is allocated first to this water use because (a) environmental flows were determined out of a federal regulation (ESA or FERC relicensing) or (b) it is a state of California mandate to implement a regulation (Section 5937) or to protect natural resources (public trust doctrine) for the benefit of the public. Environmental flows, however, have been mostly misunderstood. While about 50% of the total water on the state is considered to be allocated to the environment, the percentage of allocation is not evenly distributed across the state. Most of the environmental water is allocated in the North Coast rivers where there is little competition with other users (PPIC 2016).

4.2.3 Groundwater Management

Legal framework Before 2014, there was groundwater management in the state of California; however, (a) it was localized in certain basins, mostly in Southern California through groundwater basin adjudications, a legal, contentious, and costly procedure to allocate the water of an aquifer; or (b) it was voluntary; local water agencies developed and implemented groundwater plans as a requirement to pursue economic incentives from the state of California in the form of bonds. These actions were not statewide; thus, benefits were only local. For instance, in certain basins of the state of California, there are still long-lasting problems of groundwater overdraft, land subsidence, and seawater intrusion (Zektser et al. 2005).

The most recent 5-year drought (2011–2016) changed the previous legal framework; the Sustainable Groundwater Management Act (SGMA), passed in September 2014, is the first legislation in the state of California to manage groundwater resources. SGMA does not provide a definition for sustainability; however, it does describe a list of undesirable results that must be avoided to achieve sustainable groundwater management. Each groundwater basin should be managed to avoid any of the following undesirable results: (1) chronic lowering down of groundwater table, (2) groundwater overdraft, (3) land subsidence product of groundwater overdraft, (4) seawater intrusion, (5) recharge of degraded water into the aquifers, and (6) adverse impacts on beneficial uses of surface water due to groundwater operations. SGMA considers three main steps for its implementation to make sure that none of these undesirable results occur in any groundwater basin. First, groundwater sustainable agencies (GSAs) were created for implementing SGMA. The legislation incentivizes that GSAs are formed by members of local organizations that are already managing water (such as irrigation districts) or land (county government, cities) on the overlaying area of the groundwater basin. Members from other groups of interest (e.g., tribes, agriculture, and environment) can be included in the GSA organization, if the members first listed agree to include them as member of the GSA. Conversely, if the local institutions do not agree to form a GSA, then the SWRCB will step in and implement SGMA. GSAs are allowed to keep records of wells, install water meters for monitoring water use, and impose fees for groundwater extraction and if necessary a moratorium on groundwater extraction if undesirable conditions persist. At this moment, more than 100 water agencies have been formed throughout the state of California. Second, water budgets (WB) for every water source will be estimated to provide a current diagnostic of each groundwater basin. A mass balance for every water source available in basin (surface water, groundwater, recycled water, desalinated water) will be estimated to determine the water supply, water use, and change of storage. This diagnostic will help to identify if the basin is currently experiencing any of the undesirable results. Third, groundwater sustainable plans (GSPs) will be developed to identify strategies that will impede or prevent any of the undesirable effects for happening by 2040.

Water allocation system For the adjudicated basins, the adjudication verdict prescribes the amount of water that each water user can extract from the ground, in which order and when. For the groundwater basins managed through SGMA, the groundwater allocation system will be defined for each groundwater basin by the respective GSP. Each GSP will manage groundwater basins by dividing it into subregions. Within each subregion, the overall groundwater recharge and extractions will be determined. Every groundwater user will have a maximum quota for groundwater extraction determined on the subregion's water balance. GSAs will monitor each groundwater user by installing water meters on wells. Also, GSAs will collect fees to manage and monitor each groundwater basin. Groundwater recharge and extractions will be monitored and managed to avoid any of the six undesirable results. Each GSP will include a suit of strategies to manage: (a) water demands that rely on groundwater resources, such as water conservation strategies for cities to reduce water use, incentives for changing agricultural production to less water-intensive crops, deficit irrigation techniques, and land use fallowing, just to mention a few strategies, and (b) water sources to increase aquifer recharge through active or passive managed aquifer recharge (MAR). Active MAR includes the construction and operation of recharge basins that divert excess surface water during the rainy season to infiltration ponds where water infiltrates into the aquifer. Passive MAR strategies include in lieu groundwater banking where groundwater users temporally use surface water during years where there is an excess of surface water reservoirs letting the aquifer rest and actively use groundwater when surface water resources are scarce.

4.3 Looking into the Future

SGMA is highly influencing water resources management in the state of California. For the first time in the history of water resources management in the state, there is a legal clause in a regulation that explicitly protects the interaction of surface water and groundwater. This will have an important impact for protecting baseflows during the dry season that are significantly beneficial for aquatic and riparian ecosystems. Furthermore, this clause will prevent the disconnection of surface water and groundwater resources due to groundwater overdraft. Scientifically, SGMA is a very complex scientific and methodological challenge that demands adequate climate, water, economic, and operational data of water resources systems, as well as the integration of models. Surface water and groundwater models are coupled with operations, plant physiology, and economic models to estimate the impacts of different strategies in groundwater basins. Economically, SGMA is incentivizing creative thinking to address any undesirable results that can or are already occurring. In some places this legislation will limit the groundwater extraction and, thus, the economic development of certain activities. Other economic activities are likely to emerge as a substitution of agriculture, such as solar energy harvesting.

Scientist, engineers, authorities, water users, and practitioners are thinking out of the box to avoid or mitigate any undesirable result. SGMA is making us think system-wise for basin water management considering hydrologic, social, economic, and environmental aspects of the basin. For a long time, we have thought about operating these aspects together but never with the detail and integration that we are doing it now. For instance, intentional groundwater recharge through agricultural land referred as agricultural groundwater banking (Ag-GB) is a strategy where water released from a reservoir for flood control purposes are diverted into canals and spread out into agricultural fields that have the adequate type soil and crop for short periods of time to intentionally recharge water into the underlying aquifer. Ag-GB is linking agricultural practices, landscape and soil characteristics, plant physiology for water tolerance, and flood management for improving system's storage for future water supply. Recent studies suggest that there is sufficient unmanaged water available to mitigate groundwater overdraft impact in places where groundwater overdraft is happening (Kocis and Dahlke 2017). Furthermore, borrowing a concept from the energy sector, net water metering has been implemented in some basins, giving farmers economic credits of the water recharged in their property from Ag-GB toward their overall groundwater extraction bill from wells. Moreover, in some places of California, Ag-GB and net metering are implemented in conjunction with the use of recycled water for agricultural water supply, deficit irrigation for certain crops, and land fallowing to reduce the overall water demand in groundwater basin. In other regions of the state, reservoirs are operated considering short-term weather forecast (FIRO – Forecast Informed Reservoir Operations), so surface water storage can be maximized to meet human and environmental water needs and decrease the pressure on groundwater resources. Newly formed GSAs are reaching their constituents to get ideas and support implementation of some of these strategies. As you can see, this is the next level of integrated water resources management where every water sources is accounted and managed conjunctively; where water supply, demand, and storage policies are intertwined with economic incentives and regulations; where the community is working side by side with the newly formed regulatory agencies to get the most out of the water scarce resources; and where economic incentives and out of the box strategies are proposed, tested, and implemented.

References

Bork KS, Krovoza JF, Katz JV, Moyle PB (2011) The rebirth of California fish & game code section 5937: water for fish. UCDL Rev 45:809

Clean Water Act (2008) Clean Water Act. EPA's Office

Congress US (1973) Endangered Species Act. US Code 16:1534–1544

Corcoran K (2018) California's economy is now the 5th-biggest in the world, and has overtaken the United Kingdom. https://www.businessinsider.com/california-economy-ranks-5th-in-the-world-beating-the-uk-2018-5. Accessed Sept 2018

DWR (2018) State water project. Department of Water Resources. https://water.ca.gov/Programs/State-Water-Project. 2018

Forbes (2017) California gross state product. https://www.forbes.com/places/ca/. Accessed Sept 2018

GWP (2000) Integrated water resources management, vol 4. Global Water Partnership

Hanak E et al (2011) Managing California's water: from conflict to reconciliation. Public Policy Institute of California, San Francisco

Kadir T, Huang G (2015) Unimpaired flows vs. natural flows to the Sacramento–San Joaquin Delta: what's the difference? In: California water and environmental modeling forum, Folsom, California. Retrieved from http://www.cwemf.org/AMPresentations/2015/Kadir_NaturalFlow.pdf

Kocis TN, Dahlke HE (2017) Availability of high-magnitude streamflow for groundwater banking in the Central Valley, California. Environ Res Lett 12:084009

Littleworth AL, Garner EL (2007) Chapter 3: Surface water rights. In: California water II. Solano Press, Point Arena, pp 37–67

Loucks DP, Van Beek E, Stedinger JR, Dijkman JPM, Villars MT (2005) Water resources systems planning and management; an introduction to methods, models and applications. United Nations Educational, Scientific and Cultural Organization, Delft

Olshansky RB (1996) The California Environmental Quality Act and local planning. J Am Plan Assoc 62:313–330

PPIC (2016) Water for the environment. Public Policy Institute of California, Water Policy Center

Sax JL (1970) The public trust doctrine in natural resource law: effective judicial intervention. Mich Law Rev 68:471–566

Tarlock AD, Tippy R (1969) Wild and Scenic Rivers Act of 1968. Cornell L Rev 55:707

Trelease FJ (1957) The concept of reasonable beneficial use in the law of surface streams. Wyo LJ 12:1

USBR (2018) Central valley project. US. Bureau of Reclamation

Wurbs RA (2006) Methods for developing naturalized monthly flows at gaged and ungaged sites. J Hydrol Eng 11:55–64

Zektser S, Loáiciga HA, Wolf JT (2005) Environmental impacts of groundwater overdraft: selected case studies in the southwestern United States. Environ Geol 47:396–404. https://doi.org/10.1007/s00254-004-1164-3