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# CALIFORNIA'S WATER

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# Climate Change and Water

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OCTOBER 2016

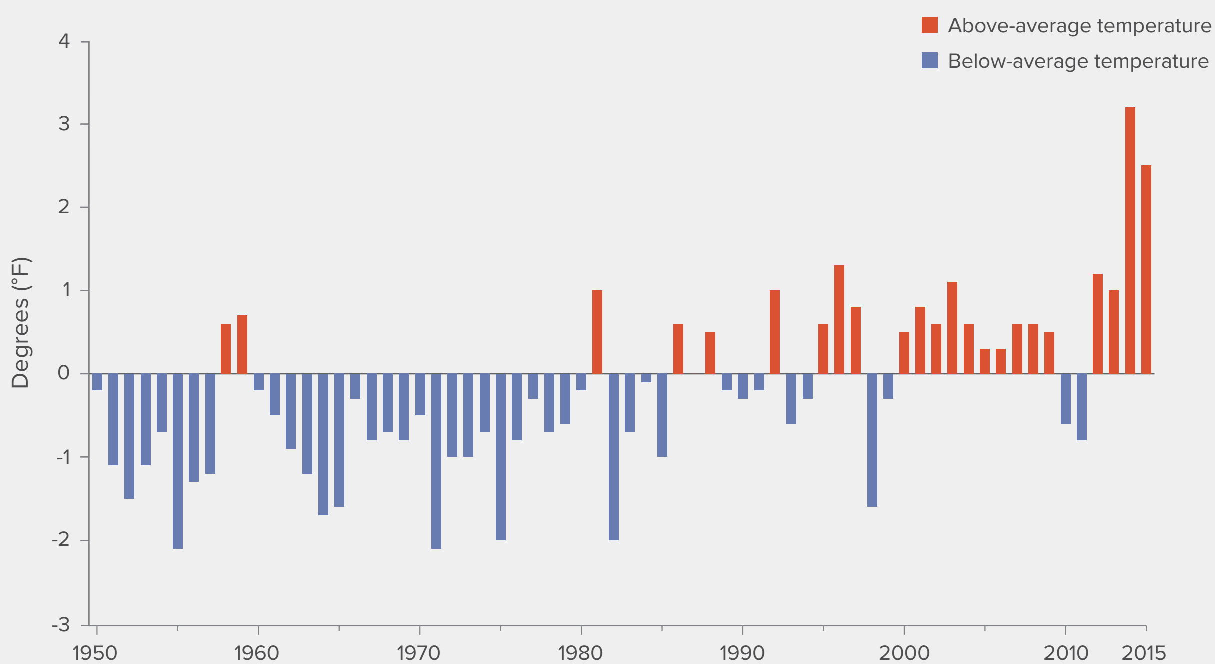
## Climate change will affect California water management in many ways

California's climate is highly variable, with frequent droughts and floods. Climate models predict significant changes: warmer temperatures and more variable precipitation, with short, concentrated wet periods and more frequent and intense droughts.

Warming is already a reality for California. Since the early 1980s, average temperatures have been significantly higher than they were during the previous 50 years. The year 2014 was the warmest on record, and 2015 was the second warmest. Warming has complex and interrelated effects: it reduces the share of precipitation that falls as snow, causes earlier snowpack melting with higher winter runoff and winter floods, raises water temperatures, and amplifies the severity of droughts. Meanwhile, the sea level has been rising, which increases pressure on coastal flood defenses. Sea level rise and larger freshwater floods threaten fragile levees in the Sacramento–San Joaquin Delta, an important hub of the state's water supply.

California has been a national leader in addressing greenhouse gas emissions that contribute to climate change. However, the state is only in the early stages of developing water policies that help it adapt to a changing climate in areas such as supply, flooding, and ecosystem management. California's water management systems were designed for the conditions of the past century. Reconfiguring them to respond to climate change—against the background of growing population and rising demand for healthy ecosystems—is a major challenge. Meeting this challenge will require a concerted public- and private-sector effort that involves all levels of government.

### CALIFORNIA IS GETTING WARMER




SOURCE: National Oceanic and Atmospheric Administration.

NOTE: The figure reports degrees above or below the average statewide temperature for 1981–2000 (58.3° F).

## Water supply management must adapt to a warmer, more variable climate

California's mountain snowpack has historically provided critical seasonal storage for meeting summer irrigation needs. A smaller spring snowpack—along with possible increases in California's already high climate variability—will stress supply. Meanwhile, rising temperatures are likely to raise demand for irrigation water and to increase the volume of water natural landscapes use.

- **There are no easy substitutes for lost snowpack.**
  New surface storage can increase flexibility, but it is costly and unlikely to provide abundant new supplies. Given its high costs, seawater desalinization is also unlikely to yield large new supplies, though it could be a useful part of some urban water portfolios.
- **Adaptation will require changes in storage management.**
  To address snowpack loss and high climate variability, managers will need to improve coordination of water storage in surface reservoirs and groundwater basins. "Conjunctive use"—the movement of some water from reservoirs into groundwater basins for use during dry periods—will be especially valuable. Making conveyance across the Delta more reliable will allow more storage for drought in the southern half of the state.
- **Urban water managers can adapt in many ways.**
  Options include expanding connections between urban systems with different supply sources, trading water with other cities and farmers, and using more treated wastewater and captured stormwater. Urban areas can also reduce water demand through pricing and other incentives, such as rebates for adopting water-saving technology or replacing lawns with less-thirsty landscaping.
- **California's agricultural sector can also adapt …**
  Farmers will continue shifting to higher revenue crops and will rely increasingly on water markets to meet irrigation demands. Some land will probably have to come out of production—particularly if average precipitation falls. Even with these changes, farm revenues can continue to rise.
- **… but adaptation will be more difficult without better groundwater management.**
  Farms—particularly in the Central Valley—will become increasingly reliant on groundwater to manage droughts. Excessive groundwater pumping today will make it harder to manage aquifers in the future. Rapid implementation of the 2014 Sustainable Groundwater Management Act (SGMA), the first statewide effort to manage groundwater, can reduce the impacts of climate change on farms.

## Managing water to preserve ecosystems will become more difficult

Rising temperatures and changing runoff patterns are likely to stress many native riverine and wetland species whose populations are already depleted by habitat loss, water operations, and other factors.

- **Approaches based on entire ecosystems will be needed.**
  Past approaches to managing environmental water have focused on improving habitats for one species at a time, typically once a species gets listed under state or federal endangered species acts. These efforts will need to give way to more flexible approaches that focus on ecosystem health.
- **Competition for water will probably increase.**
  Difficult trade-offs are likely, for instance, when keeping cold water in reservoirs to protect downstream salmon habitat means less water for farms and cities. Reusing treated wastewater—a growing strategy for stretching supplies—can have the unintended consequence of reducing water available to the environment.
- **State and federal policies will need to address trade-offs.**
  State policy—along with federal and state environmental laws—may need to be modified to manage difficult trade-offs both *between* human and environmental water uses and *among* environmental uses. For example, in warm, dry years there are trade-offs between maintaining cold water in reservoirs for salmon late in summer and increasing outflows earlier in the year for native fish in the Delta.

## SEA LEVEL RISE THREATENS BAY AREA COMMUNITIES


SOURCES: Map from San Francisco Bay Conservation and Development Commission; inundation data from N. Knowles, "Potential Inundation Due to Rising Sea Levels in the San Francisco Bay Region" (California Climate Change Center, 2009).

NOTE: The map illustrates potential inundation with 16 inches and 55 inches of sea level rise, toward the upper end of the range expected by 2050 and 2100, respectively.

## Flood planning must anticipate population growth and changing hydrology

Rising sea level, bigger and more frequent floods, growing population, and more building in vulnerable areas will increase the economic and social risks of flooding.

- **Major new investments will be needed.**
To manage future urban and coastal flooding, state and local agencies will need to invest a minimum of $34 billion to improve dams, levees, coastal defenses, and urban stormwater systems. These infrastructure investments should be part of an integrated approach that also improves water supply and ecosystem health.

- **Regional flood management tools must be updated.**
Regional flood management will require coordinated, forecast-based reservoir operations. These can be carried out as part of conjunctive use strategies that make more room for floods in reservoirs by moving water into groundwater storage. Modest investments to improve forecasting—and better use of existing forecasting tools—will significantly cut the costs of managing supply and responding to floods.

- **Nonstructural approaches will become more valuable.**
California must do more than improve its flood protection infrastructure. To reduce risk, managers should also emphasize land use planning, flood insurance, flood-proofing of buildings, and emergency preparation. The state should require local hazard mitigation plans to include these nonstructural approaches and to anticipate future conditions.

## Climate change will affect the water-energy relationship

In-state hydropower is a clean energy source that provides 15 percent of California's electricity on average. Snowpack changes will reduce the output of some hydropower reservoirs. Warming will also boost energy demand.

- **The effects of warming on energy production will vary.**
The state's large, multipurpose reservoirs have enough storage in most years to adapt to changes in the timing of snowmelt runoff. The outlook is different for California's high-altitude hydropower reservoirs, which are among the most important sources of peaking power during hot summers. As temperatures rise, power availability from these reservoirs will shift to late winter and spring. If the climate becomes drier, total hydropower production will fall. In 2014 and 2015—critically dry years—production fell by half, requiring a significant increase in the use of fossil fuels to make up the difference.

- **Some water management changes could increase energy demand.**
Climate change is likely to make surface water scarcer, particularly in agricultural areas. Farmers may respond by using more groundwater and switching to more efficient, pressurized irrigation systems. Both of these responses will increase farm energy use. Meanwhile, in urban areas, increasing temperatures will likely boost demand for cooling. Increased efficiency in urban water use and development of local sources can potentially offset these trends, reducing overall energy demand while helping communities adapt.

## Looking ahead

California needs to adopt water supply, flood control, and ecosystem management strategies that will prepare the state for a changing climate and rising sea level.

**Integrate climate change into water supply management.** Strategies should increase flexibility by promoting conjunctive use; more flexible, forecast-based reservoir operations; water trading; and improved conveyance. Conveyance investments are most critical to maintain water supplies now drawn through the Delta, which could be disrupted by sea level rise, seasonal flooding, and earthquakes. Conservation will continue to be important, especially in urban areas.

**Upgrade information systems.** Federal, state, and local agencies should upgrade information technology for water and ecosystem management. One priority is enhancing decision makers' ability to use existing information, such as weather forecasts. In addition, strategic investments are needed in modeling of weather and water supply and demand.

**Incorporate climate projections in flood planning.** To reduce flooding's economic and social risks, state and local agencies need to incorporate climate change projections into land use planning decisions, flood insurance programs, and the design and construction of new flood infrastructure. Legislation may be required to encourage adoption of important risk reduction strategies such as insurance.

**Adopt a riverine and wetland biodiversity strategy.** Such a strategy is needed to manage aquatic and wetland biodiversity changes as the climate warms and becomes more variable. This strategy should inform water supply and flood management decisions.

**Consider energy implications.** Given the links between water and energy use, it is important to consider how California's water strategies affect energy demand, costs, and greenhouse gas emissions.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# The Colorado River

PPIC WATER POLICY CENTER

OCTOBER 2016

## The Colorado River is a major source of water for California

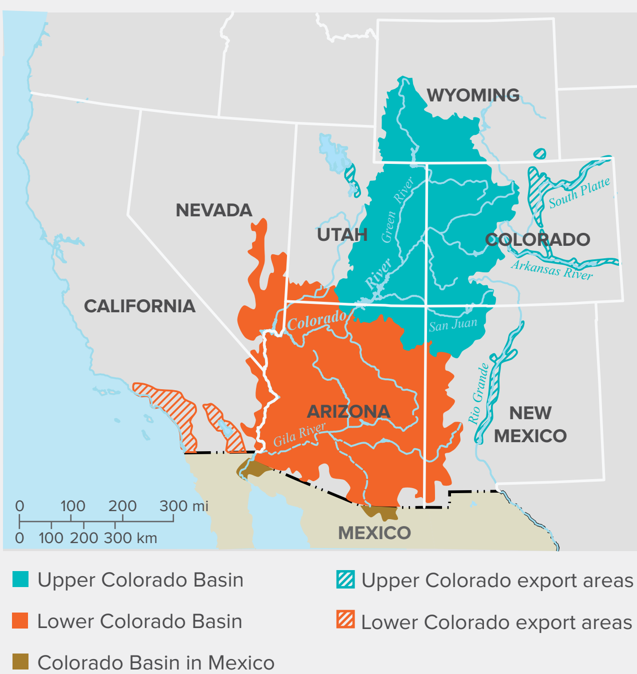
The Colorado River provides roughly a third of all supplies for Southern California cities and suburbs. It also supports a large farming industry in Imperial and Riverside Counties.

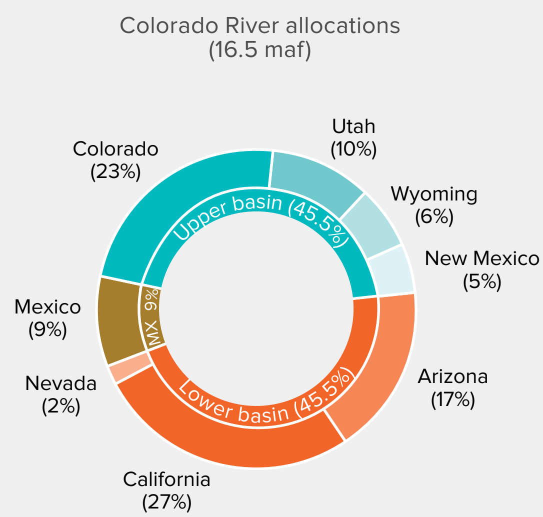
California shares this resource with six other states and Mexico, and water allocation is governed by an interstate compact and an international treaty. The US share of the river is divided among four upper basin states (Wyoming, Colorado, Utah, and New Mexico) and three lower basin states (Arizona, Nevada, and California). The federal government has key roles in managing infrastructure and supplies. Under current agreements, 15 million acre-feet (maf) of water per year is allocated to the United States, and 1.5 maf to Mexico. This exceeds average annual supplies, and long-term drought has sharply reduced storage in the major reservoirs. Climate change studies project an overall decline in water in the river, exacerbating the imbalance of supply and demand.

As other states began to use their full allocations in the early 2000s, California was required to reduce its use of the river. Cooperation between urban and agricultural agencies has made this possible. Quantitative Settlement Agreement (QSA) programs save water by lining earthen canals and improving irrigation efficiency, along with some land fallowing. This makes more water available, but some of these programs reduce inflows to the Salton Sea—a vast saline sea in Southern California whose main water source is irrigation runoff from Imperial Valley farms.

Under the QSA, in 2018 the state of California becomes responsible for mitigating the ecological and public health impacts of a shrinking Salton Sea. California also needs to stay engaged in regional efforts to bring the Colorado River Basin into balance.

### CALIFORNIA IS A MAJOR USER OF COLORADO RIVER WATER



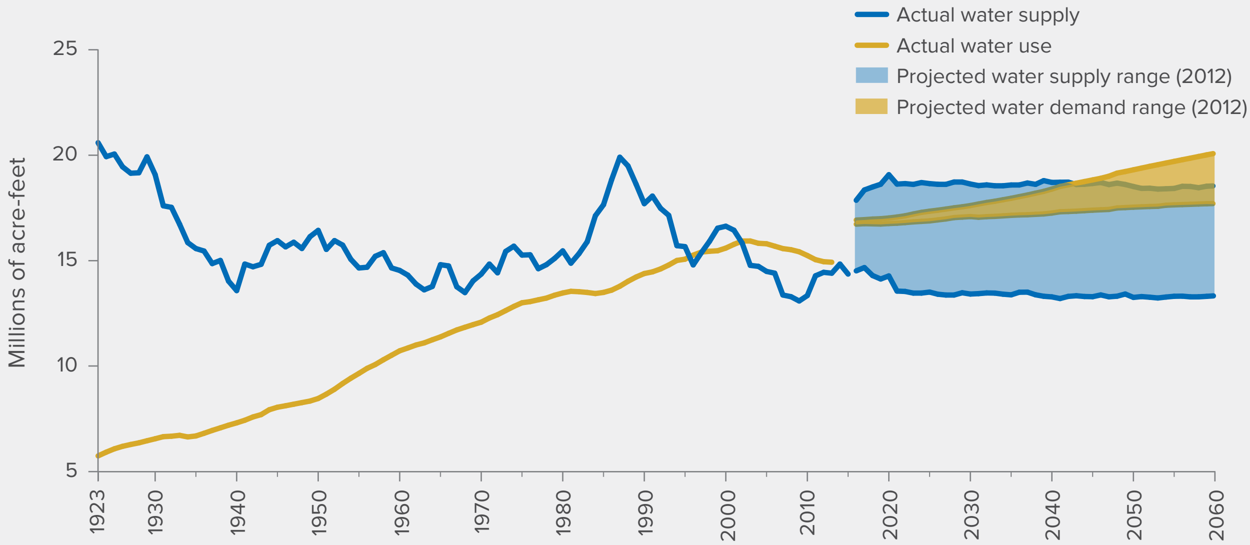

SOURCE: Author illustrations using maps from the US Bureau of Reclamation.

NOTES: The circle graph shows how the 16.5 million acre-feet (maf) are apportioned among the seven basin states and Mexico. Totals do not sum to 100 percent because of rounding. Most of California's allocation is delivered by canals and aqueducts to agricultural and urban export areas outside the river basin. Other export areas in the upper basin include the Denver metropolitan area, Albuquerque, and Salt Lake City. Arizona receives 2.80 maf as a lower basin state and 0.05 maf as an upper basin state.

## The Colorado River Basin has a water budget deficit

A prolonged drought that began in 1999 prompted the seven US states to adopt interim guidelines in 2007 to manage supplies and allow more flexible water management to avoid shortages. A 2012 agreement—known as Minute 319—included similar provisions for Mexico. But a 2012 basin study estimated a persistent deficit of about 1.2 maf per year, due to excess use by the lower basin states. It projected that demand could significantly outstrip supply in the coming decades.

### WATER USE HAS BEEN OUTSTRIPPING SUPPLY IN THE BASIN




SOURCE: Adapted from US Bureau of Reclamation (USBR), *Colorado River Basin Water Supply and Demand Study* (2012), with updated historical supply and use data from USBR.

NOTES: The 2012 basin study provided actual water use data through 2007 and supply through 2011, and presented long-term supply and demand projections identified through scenario development. This figure updates actual water use through 2013 and supply through 2015, and shows that water use has continued to decline in recent years. Historical water use and supply are shown as 10-year running averages.

- **Shortages would affect parties differently.**
  The laws that govern water allocation require the upper basin states to allow an average of 7.5 maf to reach the lower basin each year. Within the next few years, storage at Lake Mead—which serves the three lower basin states and Mexico—is expected to fall below the level that triggers usage cuts. Arizona, Nevada, and Mexico would lose supplies first. Although California has senior and relatively secure rights, Californians will benefit from solutions that reduce the costs of shortages for all parties. Arizona, Nevada, and California are negotiating a voluntary agreement to reduce use to slow the decline of Lake Mead and avoid mandatory cuts.

- **Adapting to scarcity requires overcoming inflexible laws governing the river.**
  Trading water and "carrying over" supplies for use in later years can reduce the costs of shortages. The laws that govern the river restrict these practices, but parties have begun to find work-arounds. For example, California and Nevada have stored water in Arizona groundwater basins, and some carryover storage is now allowed in Lake Mead. Cities in the upper and lower basins generally have junior rights, which are more likely to be reduced during shortages. They have been funding conservation programs, primarily for upper basin irrigators, to help maintain water levels in Lakes Powell and Mead. Recent declines in overall water use suggest these kinds of innovations are beginning to reduce the imbalance of supply and demand.

## California has been adapting to reduced availability of Colorado River supplies

Within California, irrigators have first rights to 3.85 maf of the total 4.4 maf annual allocation. In the early 2000s, when California had to end a decades-long practice of using more than its share, cities would have borne the brunt of those reductions. The QSA was negotiated then and has helped the state adapt, but not without difficulties.

- **The QSA encouraged regional collaboration and more flexible management.**
State funding helped line canals, which reduced seepage and increased usable supplies. Urban agencies now also have several major long-term trades with irrigators for more than 500,000 acre-feet annually. The Metropolitan Water District of Southern California is acquiring water from the Palo Verde Irrigation District, the Imperial Irrigation District (IID), and the Bard Water District. The San Diego County Water Authority has a large purchase agreement with IID. These deals make water available from land fallowing and investments in more efficient irrigation techniques.

- **Some QSA actions have involved trade-offs.**
Lining the All-American Canal—a critical conduit along the Mexican border—saved water for California but reduced groundwater supplies for Mexican farmers. The water trades that involve land fallowing can reduce jobs and tax revenues in farming communities. To address this, urban agencies have established funds to mitigate negative impacts. Irrigation efficiency improvements at IID reduce runoff of excess irrigation water into the Salton Sea, accelerating environmental problems there.

- **Salinity is also a concern for California cities using Colorado River water.**
By the time the Colorado River water reaches California, it has a higher salt content than most local supplies. During droughts, when other sources are reduced, this raises water treatment costs for urban agencies.

## Water use in the Colorado River Basin poses environmental challenges

The overallocation of supplies to farms and cities has harmed native species along the river. It has also dried up the Colorado River Delta where it enters the Gulf of California, destroying riparian habitat that once served as an important part of the Pacific Flyway. Conditions in and around the Salton Sea pose major ecological and public health challenges. Some of these issues are easier to address than others.

- **A multispecies conservation plan is in place on the lower Colorado River.**
The first of its kind, this aquatic ecosystem plan was adopted in 2005 and aims to restore habitat and recover species between Lake Mead and the Mexican border.

- **Recent efforts to rewater the Colorado River Delta show promise.**
In 2014, short "pulses" of water were sent down the dry riverbed in Mexico, briefly reconnecting the river to the ocean. This pilot project—established under the Minute 319 agreement—shows promise for recovering riparian habitat with modest amounts of water.

- **The Salton Sea poses difficult challenges …**
In the 19th century the Salton Sea was known as the Salton Sink—a vast salt pan in the Colorado Desert. Levee failures in 1905 caused massive flooding, creating the modern Salton Sea. Since then, the sea has been sustained by irrigation runoff from Imperial Valley farms. A key stopover on the Pacific Flyway and once-popular recreation area, the sea is shrinking and becoming hypersaline. This is destroying bird habitat and worsening air pollution from increased dust along exposed shorelines. By reducing irrigation runoff, the QSA transfers will exacerbate this problem.

- **… and solutions have remained elusive.**
As part of the QSA, California agreed to mitigate the effects of shrinking the Salton Sea. There have been many engineering proposals to reduce dust pollution and maintain bird habitat. But so far the high price of the solutions ($9 billion or more)—and the costly alternative of reallocating large volumes of water to the sea from existing uses—have limited actions.

## Looking ahead

California and its partners in the Colorado River Basin must continue to adapt so that the river can continue to provide essential economic, social, and environmental benefits to the region.

**Build on recent efforts to manage demand.** There are no significant opportunities to expand supplies in the Colorado River Basin, and available runoff appears to be in decline. Additional efforts to reduce water use will be needed to achieve balance.

**Foster flexible solutions to stretch scarce supplies.** To reduce the economic costs of scarcity, parties will need to increase water trading and carryover storage. This is especially important for urban supply reliability throughout the basin, since cities generally have lower priority rights to river water.

**Protect local economies.** The large share of water use in relatively low-revenue farming (80–90% of the total within the seven states) creates opportunities for trading, but such deals need to protect local economies. Rotational fallowing—where farmers take turns fallowing some land rather than permanently retiring it—is a promising option, already being used in the Palo Verde Irrigation District. So is seasonal fallowing—where farmers cut back on farming lower revenue crops in the hot summer months—now being piloted in Bard. Mitigation funds for fallowing, like those being offered in the Palo Verde and Imperial Irrigation Districts, are another option worth expanding.

**Improve ecological conditions in the basin.** Solutions should be explored to extend the promising experiment of rewatering the Colorado River Delta. Temporary and longer-term water purchases for the environment can be used for this purpose.

**Address public health and environmental problems at the Salton Sea.** California must take the lead in addressing air and water quality impacts of a shrinking Salton Sea. This includes deciding on a course of action and securing reliable funding to implement it.

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# Energy and Water

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OCTOBER 2016

## Energy and water use in California are interconnected

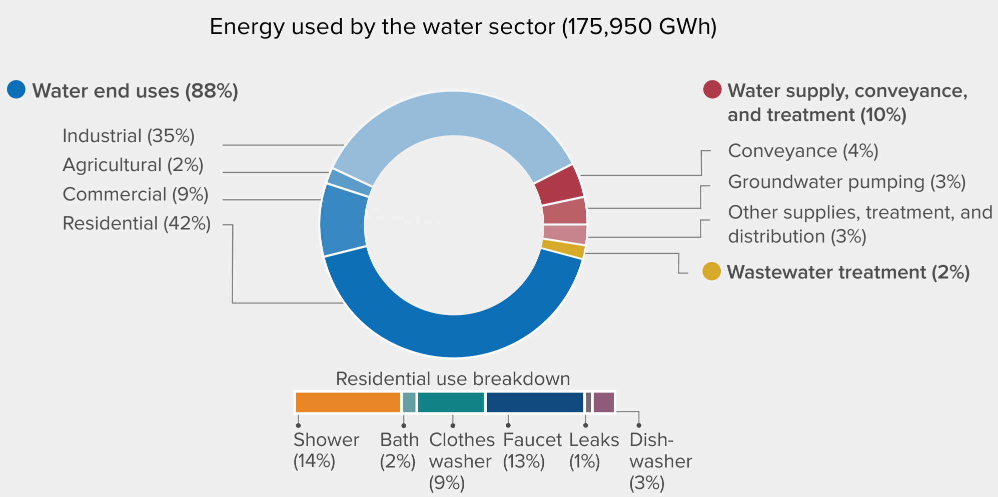
California's water system is energy intensive, accounting for nearly 10 percent of the state's greenhouse gas (GHG) emissions. According to the most recent estimates, approximately 20 percent of statewide electricity use—and 30 percent of business and home use of natural gas—goes to pumping, treating, and heating water. Water is also required for the production of energy. Hydropower generation, thermoelectric power plants, and oil and gas extraction all use water.

Actions that improve water-use efficiency can reduce energy use. Actions that improve energy efficiency can, in turn, reduce energy sector impacts on water supply and quality. In contrast, some actions to boost the water sector's resilience to droughts can increase energy use. And measures to reduce the energy sector's water use can make energy production more costly.

State policies—including efforts to reduce GHG emissions—have begun to promote managing water and energy in tandem. Some state programs provide grants for water and energy efficiency programs, and the California Public Utilities Commission (CPUC) is working with utilities to quantify energy savings from water conservation. During the latest drought, the California Energy Commission (CEC) also launched an effort to reduce the energy sector's vulnerability to water shortages.

Continued population growth and a changing climate will place increasing pressure on water and energy supplies. To meet this challenge, California will need to continue adopting policies and technologies that improve water and energy management, while being attentive to potential trade-offs.

### MOST ENERGY CONSUMED BY CALIFORNIA'S WATER SECTOR GOES TO RESIDENTIAL USE




SOURCE: California Public Utilities Commission, *Embedded Energy in Water Studies. Study 1: Statewide and Regional Water-Energy Relationship* (prepared by GEI Consultants/Navigant Consulting, Inc., 2010).

NOTES: The figure shows total energy use by California's water sector—175,950 gigawatts per hour (GWh). The figure includes water-related electricity (29% of the total) and natural gas (71%), converted to equivalent measures, for 2001—the last year for which end-use estimates are available. Conveyance includes the energy used in the California State Water Project, the Central Valley Project, the Colorado River Aqueduct, and several regional water systems. Groundwater pumping is for urban and farm uses. Irrigation system management, such as pressurization, is an agricultural water end use. Residential end uses include energy used in heating water and running appliances, but not the embedded energy for supplying or treating water.

## California's water sector is a large energy user

Although California's agriculture uses roughly four times more water than cities, cities use most water-related energy. End uses of water—especially for water heating—make up almost 90 percent of the total. Pumping, conveying, and treating water and wastewater make up the remainder. Opportunities for reducing energy use often depend on local conditions.

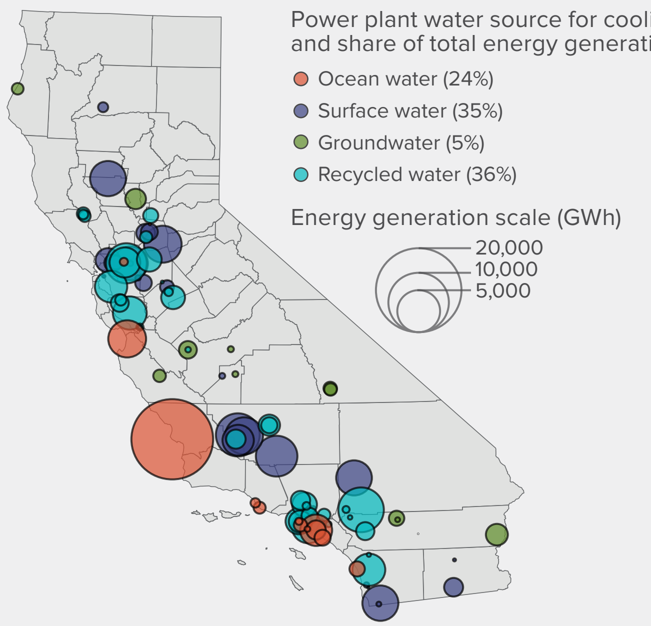
- **Water heating is a major energy user statewide …**
  Heating water uses a quarter of total energy in homes, so reducing hot water use and improving the efficiency of water heating methods can significantly decrease energy consumption. Understanding behavioral factors that affect water use and employing data from smart metering technologies can improve conservation efforts.
- **… but energy needs for conveyance vary by region.**
  Delivering water relies on gravity in some regions; in others it must be pumped to its destination. Southern California water imported from the northern part of the state is especially energy intensive, because it must be pumped through the Sacramento–San Joaquin Delta and over the Tehachapi Mountains.
- **Groundwater pumping also requires energy.**
  Energy is used to pump water from wells to supply both farms and cities. During the latest drought, farmers significantly increased groundwater use to make up for surface water shortages. This roughly doubled their energy consumption compared to pre-drought conditions. Long-term groundwater depletion—especially in the San Joaquin Valley—has increased farm energy use because water has to be pumped from greater depths.
- **Some new water sources are energy intensive.**
  To increase the reliability of water supplies, many urban agencies are investing in local sources, including recycled wastewater and desalination of brackish groundwater and seawater. These sources generally use more energy than traditional surface and groundwater supplies. But they can reduce water's total energy footprint if they displace more energy-intensive imported water—a possibility in Southern California.
- **Water-efficient irrigation technologies can also increase energy use.**
  Improving irrigation system efficiency decreases the amount of water applied to fields. These upgrades can reduce energy used to pump groundwater or to import water from other regions. But these technologies are often pressurized, requiring additional energy. And they enable expansion of acreage farmed, increasing both water and energy use.

## Energy production requires reliable water supplies

California's in-state electricity portfolio includes thermoelectric power (roughly 70%), hydropower (7% to 22% depending on precipitation), and a growing share of other renewable sources, particularly solar and wind power (up from 3% in 2010 to 14% in 2015). Thermoelectric power and hydropower are highly dependent on water. Extracting oil and gas also raises issues of water supply and quality.

- **Coastal power plants are changing water use to lessen environmental impacts.**
  These coastal plants historically used "once-through cooling" systems, which take water from the ocean, circulate it through the plant's pipes to absorb heat, and discharge it back into the sea. In 2010, the State Water Board announced that this practice must be discontinued to reduce its harmful effects on aquatic life. The "closed-cycle wet cooling" and "dry cooling" power systems being introduced use less water and recycle it multiple times. While these changes help to preserve the ocean environment, upgrading the plants is expensive.
- **Inland thermoelectric plants are vulnerable to drought.**
  Most inland plants already use closed-cycle wet cooling systems. During the latest drought, some Central Valley plants that rely on surface water were at risk of shortages. The CEC is encouraging the industry to develop drought contingency plans and to switch to more reliable recycled water supplies, already the cooling source for 36 percent of power production.
- **Hydropower generation is also vulnerable to drought and a warming climate.**
  Hydropower production relies on water in rivers and reservoirs. Between 2000 and 2015, in-state hydropower supplied an average of 15 percent of all electricity used, but this share was halved during the latest drought. As the climate warms, loss of snowpack and increased winter runoff will diminish high-elevation hydropower generation in summer months when demand is highest.
- **Growth of renewables will decrease the electricity sector's reliance on water.**
  Senate Bill 350, enacted in 2015, requires that half of the state's electricity come from renewable resources by 2030—up from a 33 percent target for 2020. Although some renewables also need water—especially geothermal and concentrated solar power plants—this shift will decrease the energy sector's overall water dependence.

MOST THERMOELECTRIC GENERATION IN CALIFORNIA RELIES ON RECYCLED WATER OR SEAWATER




SOURCE: Authors' calculations using data from the California Energy Commission.

NOTES: The map presents the thermoelectric power plants—including nuclear, natural gas, geothermal, and biomass—with installed capacity over 75 megawatts per hour. The size of the bubbles represents the actual energy generated in 2015, and the color represents the primary source of water used for cooling. The largest coastal plant, the Diablo Canyon nuclear power plant, generated 9.5 percent of all in-state electricity in 2015. It is slated to close by 2025.

- **Oil and gas production can impact water quality and local supplies.**
  California is the nation's third largest oil-producing state, with 6 percent of US production in 2015. It also produces some natural gas (0.7% of US output). As part of the extraction process, water is injected into wells—more than 55,000 around the state. During the extraction, many wells also produce water that is mixed with oil and drilling fluids. This water must be disposed of or treated. A 2014 law requires well owners to report water volumes used and produced. In 2015 they reported using 5,600 acre-feet (af) of surface water and groundwater (less than 0.2% of all freshwater used by the urban and farm sectors). The production process yielded more than 80,000 af of water, roughly 13,000 of which met standards for domestic or irrigation use.

## Looking ahead

California has been a pioneer in recognizing the nexus between water and energy. But it is still in the early stages of understanding synergies and trade-offs in managing the two sectors to benefit the economy and environment and meet climate policy goals.

**Update estimates of the energy in water end uses.** Much has changed in California's water sector since 2001, when the most recent estimates of energy in water end uses were made. Even before the latest drought, per capita urban water use had fallen considerably, and at least some of the more recent water savings are likely to persist. Updating the profile of water-related energy can help target effective actions.

**Evaluate the benefits of water conservation and more energy-efficient water systems.** To guide water and energy planning, the state should assess the costs and benefits of various options from both water and energy perspectives. As an example, reducing the energy used in heating water may be an inexpensive way to reduce GHG emissions.

**Recognize trade-offs of new water and energy technologies.** To avoid unintended consequences, policymakers and managers need to anticipate such trade-offs. For instance, some new water sources can improve water supply reliability but increase energy loads, and water-saving energy technologies like closed-cycle cooling can benefit aquatic habitat but increase costs.

**Explore synergies in water operations and power grid management.** As California increases the use of renewable energy, it will need to accommodate more variable supplies within its power grid. Shifting the timing of some water supply and treatment operations to periods when renewable sources provide higher shares of energy supply may help in this process.

**Manage the quality and supply of water used in oil and gas extraction.** The new reporting requirements on water use and production by oil and gas wells are an important first step in understanding the water impacts of this sector. Better understanding of water quality issues—including opportunities for safe disposal and safe reuse in other activities—is the next priority.

**Reduce the energy system's vulnerability to drought and a changing climate.** The latest drought's combination of record warm temperatures, low snowpack, and reduced rainfall has provided a window into the future. State and energy industry officials should continue efforts to understand and reduce the power grid's vulnerability to future droughts and a warming climate.

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# Managing Droughts



OCTOBER 2016

## California must keep improving its ability to weather droughts

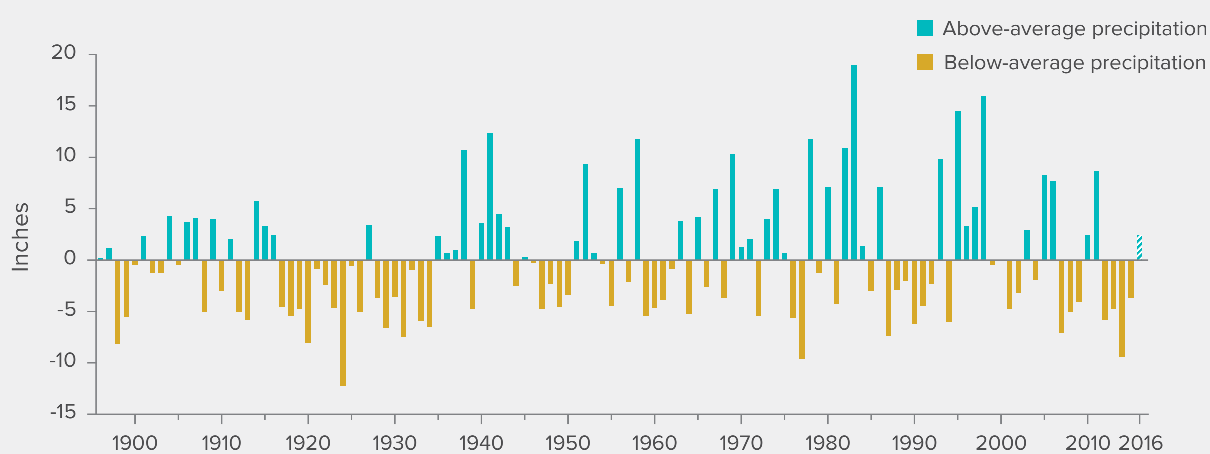
Droughts are a regular feature of California's variable, semiarid climate. The laws that govern the allocation and use of water—as well as the operation of reservoirs, groundwater basins, canals, and aqueducts—were created in part to manage water scarcity during dry periods.

California has weathered many droughts, including four in the past four decades. These ranged from a short, severe drought from 1976 to 1977 to a prolonged six-year drought from 1987 to 1992. The latest drought began in 2012, and it includes the driest four-year stretch in 120 years of record keeping. This drought has been more widespread than most, covering the entire state. The years 2014 and 2015 were also the two hottest on record, which made conditions even drier. Rains in Northern California in early 2016 provided some relief, but this drought is not over. It is not unusual for one or two wetter years to fall within a series of dry years.

It is difficult to specifically link the latest dry period—or any individual weather event—to climate change caused by human activity. Nonetheless, climate change models suggest that the current drought may be a "dry run" for a drier and warmer future. This poses major challenges for managing water to support a growing population and economy, while also sustaining a healthy environment.

Droughts test California's water management systems and expose their weaknesses. They also provide opportunities to improve the state's ability to weather future droughts. California needs to learn from the latest drought and begin preparing for the next one.

### DROUGHTS ARE A RECURRING FEATURE OF CALIFORNIA'S CLIMATE




SOURCE: Western Regional Climate Center.

NOTES: Bars show the number of inches above and below the long-term California statewide average precipitation level of 21.45 inches, based on water years (October–September) since 1896. The dashed 2016 bar is based on data through June and author estimates for the remaining three months based on 2015 values.

## Urban and rural areas have fared differently in the latest drought

California's diverse sectors and regions have experienced this drought in different ways.

- **Large urban areas have fared reasonably well.**
  Most large metropolitan utilities were better prepared to handle this drought than past ones, despite population increases. Those that have performed well—mainly in Southern California and the San Francisco Bay Area—invested extensively to diversify their water supply portfolios following the 1987–92 drought. Utilities built interconnections with neighboring systems that drew on different supply sources, reduced per capita water use,

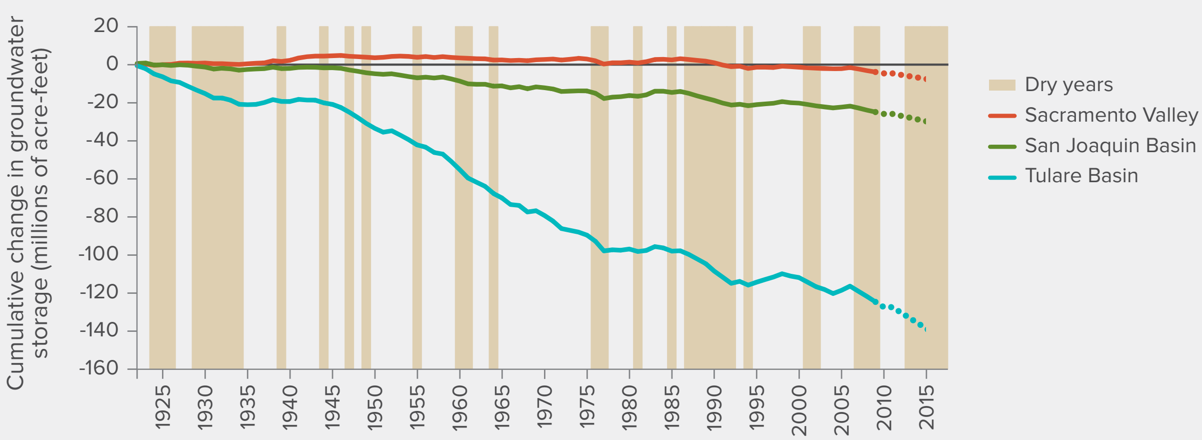
stored conserved water in new reservoirs and groundwater storage facilities, and purchased water from farmers. From 2013 to 2015, urban residents further reduced water use by nearly 25 percent in response to voluntary local programs and a statewide conservation mandate. On the downside, this rapid decline in water sales caused financial problems for some utilities.

- **Some communities were vulnerable.**
  Some communities faced extreme shortages, reflecting their high dependence on a single source and their lack of connections with other water utilities. By late 2015, more than 100 small water systems faced shortages and more than 2,000 domestic wells went dry in some small, poor, rural communities—particularly in the Central Valley and the Sierra Nevada foothills. The state provided emergency aid for replacement water.

- **Agriculture faced major problems.**
  In 2014, deliveries of surface water to Central Valley farms were just 63 percent of average; in 2015 they dropped to 52 percent. Farmers with the oldest and highest-priority water rights were better served, but many received little or nothing. Farmers offset most of the missing surface water by pumping additional groundwater. Some purchased water from other farmers to keep tree crops alive. But they also had to fallow some land—more than 500,000 acres, or 6 percent of irrigated acreage in 2015. Increased groundwater pumping and land fallowing led to increased costs and lost revenues and jobs. Strong commodity prices partially offset production losses. The state provided financial and food assistance to hard-hit farmworker communities.

- **The drought exposed weaknesses in groundwater management.**
  Although farmers in most areas were able to pump more groundwater, decades of unsustainable pumping have made this resource more costly and less reliable. High pumping volumes—both before and during the drought—have lowered groundwater tables. This has boosted pumping costs, degraded water quality, and caused land to sink, damaging aqueducts and other infrastructure. Legislation enacted in 2014 requires local agencies with the most stressed basins to adopt sustainable groundwater management plans by 2020. These plans can improve drought resilience over the long term, but their implementation may limit farm water supplies.

**UNSUSTAINABLE GROUNDWATER PUMPING IS DEPLETING RESERVES IN THE CENTRAL VALLEY**




SOURCE: Ellen Hanak et al., *What If California's Drought Continues?* (PPIC, 2015), Figure 3, using data through 2009 from the California Department of Water Resources and author estimates thereafter.

NOTES: Lines show cumulative change in groundwater storage based on water years (October–September). Projections since 2009 may underestimate depletions since the onset of the latest drought in 2012. Dry years are those classified as critical or dry in the Sacramento Valley based on the California Cooperative Snow Survey.

## The latest drought has hit ecosystems hard

Water and habitat management during droughts can have lasting impacts on migratory birds, fish, and other species.

- **Wetland and river ecosystems have suffered.**
  Rivers throughout California have experienced record-low flows and poor water quality. Many coastal and mountain streams have dried up, harming salmon, steelhead, and other native fishes. Conditions have further deteriorated

for fish in rivers below Central Valley dams, and some hatcheries have lacked adequate cold water. Water supplies also fell dramatically in wildlife refuges in the Central Valley and Klamath Basin—key habitats for migratory birds and other species. This forced birds to gather in smaller areas, increasing their vulnerability to disease outbreaks and predation.

- **Regulators have been forced to make trade-offs on the fly.**
  With little advance planning for managing fish and wildlife during severe droughts, regulators had to make difficult decisions in 2014 and 2015 based on limited knowledge and almost no scientific or public review. Environmental flow protections in Central Valley rivers were reduced to send water to cities and farms. Most eggs of endangered winter-run Chinook salmon died because of poor management of cold water releases from Shasta Reservoir. Fish and wildlife agencies carried out many fish rescue efforts. In some cases, they had to make difficult choices between competing environmental needs—such as water for salmon versus smelt, or for fish versus waterbirds.

- **Species declines usually increase future costs.**
  As many as 18 native fish species—including most salmon runs—are at near-term risk of extinction with continued drought. The failure to protect native biodiversity during drought can have long-term consequences. These can include greater risk of extinction for some species, as well as increased future regulatory costs and water supply reductions for cities and farms if actions taken during drought cause some species to move into threatened or endangered status.

## The latest drought has tested state water allocation policies

Water is a scarce resource in California even in normal years. The state government oversees water rights and must be prepared to manage cutbacks during droughts to balance competing needs fairly. In 2014 and 2015, California's interagency drought task force managed many aspects of the emergency in an effective and coordinated manner. But the drought also exposed weaknesses in the water allocation system.

- **California's fragmented water rights system creates unnecessary problems.**
  The State Water Board's efforts to allocate scarce water supplies were made more difficult by an archaic water rights system. Some senior water-right holders successfully challenged the board's authority to curtail their water use.

- **The state lacks a comprehensive policy on water allocation priorities.**
  In addition to overseeing urban and agricultural users' water rights, the state must consider the water needed to protect public health and aquatic ecosystems. It did not have clear and comprehensive policies on how to prioritize these vital interests.

- **Drought water allocations have not fully followed two important legal doctrines.**
  The state constitutional "reasonable use" requirement mandates that all water uses must be reasonable under current hydrologic conditions. The "public trust" doctrine requires the state to consider the effects of its water allocation decisions on aquatic ecosystems, water quality, and fisheries, and to protect such uses to the extent feasible under the circumstances. The state has not followed these doctrines sufficiently when allocating water, instead relying principally on the priority of water rights.

- **The state's information systems are inadequate.**
  Water use reporting has advanced in recent years. Still, state agencies lack sufficient information on water rights, surface water flows, and water use to manage droughts more effectively. As a result, recent curtailment decisions have been based on rough estimates and may unfairly harm some water users and the environment.

## Looking ahead

Now is the time to plan for the next drought, while experience gained in this latest drought is still fresh. Better preparation will also help California adapt to a warming climate and an increasingly variable hydrology.

**Build on progress in urban drought management.** Some cities still need to diversify water supply sources and reach sharing agreements with neighboring communities. Many utilities must improve their drought pricing policies to give customers incentives to conserve, while generating adequate revenue to remain financially healthy when water sales decline. The state needs to refine its conservation policy to encourage continued local investments in drought resilience.

**Build resilience for disadvantaged rural communities.** Proposition 1—a water bond approved by voters in November 2014—provides funds to improve drinking water systems in communities now at risk. Where feasible, these communities should be connected to larger water systems. Legislation passed in 2015 will make this easier.

**Implement sustainable groundwater management.** The new groundwater legislation should be implemented rapidly to improve agriculture's drought resilience. Proposition 1 provides $100 million to support local planning efforts in this area, and legislation passed in 2015 makes it easier for groundwater users to clarify pumping rights.

**Modernize management of cutbacks.** The sources and uses of water should be tracked better, the State Water Board's direct regulatory authority should be extended to all surface water rights, the reasonable use and public trust doctrines should be applied in allocation decisions, and priorities for protecting environmental flows and public health should be explicitly defined and comprehensively implemented.

**Develop an environmental stewardship strategy.** State leaders should commission an aquatic biodiversity task force to develop recommendations for action—and related funding—for managing riverine and wetland areas during droughts and prioritizing conservation actions. Some ecosystem-oriented funds from Proposition 1 could be directed toward restoring aquatic habitats to improve their drought resilience.

**Conduct periodic dry runs for drought emergencies.** California regularly assesses preparedness for floods, wildfires, earthquakes, and other emergencies. The state should also carry out simulations to test agency performance and evaluate impacts to water users and the environment during drought emergencies.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# Paying for Water

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OCTOBER 2016

## Successful water management requires adequate, reliable funding

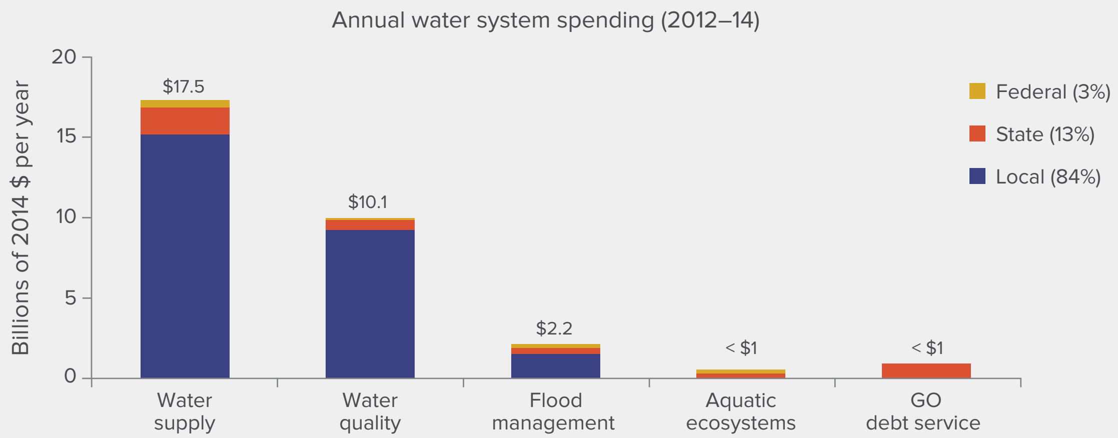
California's water system supplies water to cities and farms; prevents pollution of lakes, rivers, and coastlines; protects people and businesses from floods; and supports freshwater ecosystems. Numerous local, state, and federal agencies oversee this system and raise revenues from a variety of sources. Identifying funding gaps—and finding the best ways to fill them—are perennial concerns.

Most public attention has focused on state general obligation bonds—voter-approved debt reimbursed with General Fund taxes. Six such bonds were approved between 2000 and 2006, providing roughly $15 billion for water projects. In November 2014, voters approved Proposition 1—a $7.5 billion bond that extends this support.

State bonds are important, but they actually play a minor role in funding California's water. Bonds provide at most $1 billion of the more than $30 billion in annual water-related spending. Local revenue—from water and sewer bills to taxes—provides the lion's share, 84 percent. The state contributes 13 percent and the federal government 3 percent.

California's urban water and wastewater agencies face challenges, including how to balance their checkbooks during droughts when they collect less revenue. But overall they are in reasonably good fiscal health. Other areas face critical gaps totaling $2–3 billion annually—a result of legal constraints on local funding, a shrinking federal contribution, and unreliable state support. In California's $2.5 trillion economy, this problem is manageable. But dealing with it requires a focused effort. Looking beyond bonds to fill funding gaps should be a top priority.

### LOCAL UTILITIES RAISE MOST OF THE MONEY SPENT ON WATER IN CALIFORNIA




SOURCE: Updated from Ellen Hanak et al., *Paying for Water in California* (PPIC 2014).

NOTES: The figure reports average spending for 2012–14. Local expenditures exclude grants from higher levels of government. The water quality category includes management of wastewater and approximately $500 million for polluted stormwater and other runoff. GO debt service is repayment of state general obligation bonds.

## Constitutional changes have harmed local water finance

Local finance is the lifeblood of California's water system. But a series of constitutional amendments approved by voters—Propositions 13 (1978), 218 (1996), and 26 (2010)—have made raising funds for local water services more difficult than ever.

- **The changes have increased accountability, but with unintended consequences.**
  Proposition 218's rate-setting reforms have improved transparency and public accountability. But they have also imposed overly simplistic cost recovery requirements that inhibit local agencies from investing in new supplies—including recycled water and conservation—and in pollution controls, such as stormwater capture and treatment.

- **Stricter voter requirements impede delivery of some essential water services.**
  For flood and stormwater management, a majority of landowners or a two-thirds majority of all local voters must now approve new fees and assessments. Before Proposition 218, these could be approved by elected governing boards. In addition, new local taxes for water programs must now get two-thirds voter approval—a much higher hurdle than the simple majority required for local general taxes or state ballot measures. Proposition 1—enacted in November 2014 by what was widely considered to be a landslide with a 67.1 percent approval vote—would barely have squeaked by under the rules governing local tax measures.

## Urban water and sewer systems are performing reasonably well

Unlike flood and stormwater agencies, water supply and sewer service are exempt from Proposition 218's two-thirds voter approval requirement. These utilities have generally been able to get the funds needed to replace aging infrastructure and to comply with new treatment requirements. Investments since the 1990s in conservation, water reuse, and local conveyance and storage have been invaluable in preparing cities for the latest drought.

- **Utilities face looming legal uncertainties.**
  Proposition 218's cost-recovery requirement specifies that rates cannot exceed the cost of providing a service. Some courts have interpreted this requirement narrowly, jeopardizing the implementation of important programs such as conservation-oriented water rates. During the latest drought this was an issue, as utilities struggled to adjust their rates to promote conservation. Recent decisions have ruled that utilities may charge for the costs of groundwater management, recycled wastewater, and other nontraditional supplies, regardless of whether each customer actually receives water from these sources. But Proposition 218's constraints on water rates remain highly uncertain.
- **Keeping water affordable for low-income households will be a challenge.**
  Water and sewer bills have been rising to keep pace with investment needs. For most Californians, these charges are a small share of income. For low-income households, however, affordability is a growing concern. Proposition 218 restricts the ability of water utilities to provide them with "lifeline" discounts. Such discounts have helped make energy and telephone billing systems more equitable.

## California's water system has multiple fiscal orphans

California is failing to adequately fund five services that protect public health and safety and the environment: safe drinking water in small, disadvantaged communities; flood protection; control of stormwater and other polluted runoff; management of aquatic ecosystems; and integrated water management.

- **Safe water is unaffordable in some rural communities.**
  Providing safe and reliable drinking water is a special challenge in small, disadvantaged rural communities, where costs per household are high and local funding resources are scant. The drought highlighted this challenge, with shortages in more than 100 small water systems and more than 2,000 dry domestic wells.
- **Federal funding for flood projects has been inadequate.**
  Federal policy authorizes matching grants of up to 65 percent of project costs for flood protection. But this authorization is mostly unfunded, leading to a large investment backlog. And federal contributions are shrinking because of budgetary restrictions. Voters in some communities have approved modest local cost shares, but it will be much more difficult to pass the larger charges needed to fill the gap.
- **Stormwater agencies have been hit hardest by constitutional changes.**
  Stormwater management once focused solely on draining streets after storms. Over the past two decades, mandates have expanded to prevent pollution of rivers, lakes, and beaches by limiting discharges and cleaning runoff before it enters waterways. It is especially difficult to persuade local voters to approve funds for cleanup that mainly benefits downstream communities.
- **Most ecosystem management programs lack a reliable funding base.**
  Funding is usually straightforward for ecosystem investments that are a mandatory part of new projects. But most environmental problems result from past water- and land-use practices, and financial responsibility for fixing them

is frequently disputed. Some communities have approved taxes to support their watersheds. However, this approach is limited by the requirement to have special taxes approved by two-thirds of the voters.

- **Integrated water management is hard to fund locally, despite its benefits.**
  Integrated water management involves collaboration among agencies with different responsibilities to improve overall system performance. Proposition 218's cost-recovery requirements make it hard for water and wastewater agencies to share the costs of activities that extend beyond their mandates, and financially weaker partners overseeing flood, stormwater, and ecosystem programs have trouble coming up with their share.

- **State bonds have helped fill gaps, but they also have drawbacks.**
  Since 2000, state bonds have helped fund all five gap areas, and Proposition 1 extends some of that support. But bonds are not a reliable long-term funding source, and they generally don't cover operating costs. In addition, bonds are repaid from the state General Fund. During economic downturns, bond repayment can take funds from other important budget areas such as higher education and health and human services.

- **Other funding sources are needed to pay for fiscal orphans.**
  To close funding gaps, California needs a broader, more reliable mix of state and local funding sources, including new fees and taxes. Some examples are parcel taxes, small surcharges on water and chemical use, and small increments to the sales tax. Such measures are already used in some California communities and in other states.

### CALIFORNIA NEEDS TO GO BEYOND BONDS TO CLOSE FUNDING GAPS

| Gap area | Annual gap ($ millions) | Onetime infusion from Prop 1 ($ millions) | Other long-term funding options |
|---|---|---|---|
| Safe drinking water in small rural systems | $30–160 | $260* | ▪ Statewide surcharges on water, chemical use |
| Flood protection | $800–1,000 | $395 | ▪ Developer fees<br>▪ Property assessments<br>▪ Special state, local taxes |
| Stormwater management | $500–800 | $200 | ▪ Developer fees<br>▪ Property assessments<br>▪ Special state, local taxes<br>▪ Surcharges on water, chemical, or road use |
| Aquatic ecosystem management | $400–700 | $2,845** | ▪ Special state, local taxes<br>▪ Surcharges on water use, hydropower production |
| Integrated management | $200–300 | $510 | ▪ Special state, local taxes<br>▪ Surcharges on water use |

SOURCES: Ellen Hanak et al., *Paying for Water in California* (PPIC 2014), and bill text for AB 1471, the Water Quality, Supply, and Infrastructure Improvement Act of 2014, approved by the voters as Proposition 1.

* These funds are available for communities of all sizes. Another $260 million is available for small community wastewater systems.

** This includes the $1.495 billion earmarked for ecosystem investments and $1.35 billion from water storage project matching funds set aside for ecosystem benefits.

## Looking ahead

California must fill a critical $2–3 billion annual funding gap across a number of essential functions: ensuring clean drinking water for all residents; protecting residents from flooding; keeping beaches, rivers, and lakes safe for recreation; safeguarding threatened aquatic ecosystems; and fostering integrated water management. Action is also needed to avoid funding problems for urban water and wastewater systems, given the uncertain legal status of financing these services.

**Use new bond funds to fill real gaps.** Proposition 1 will inject $7.5 billion into the water system. The legislature and state agencies should make sure these state funds are not simply substituting for local funds.

**Look beyond bonds.** One legislative priority should be to help local agencies raise needed funds. For example, the legislature could expand local funding authority and provide guidance to the courts on how their interpretations of Proposition 218 may affect water program financing. Another priority is to enact new state fees and taxes to boost funding for fiscal orphans.

**Adjust local water rates to cope with drought.** New strategies—including rate structure adjustments and drought surcharges—are needed to reduce the fiscal effects of conservation and encourage continued urban investment in drought resilience. During droughts, customers are often unprepared for the rate increases needed to offset revenue losses from water use restrictions. Utilities must effectively communicate the reasons for rate changes. They must also build strong administrative records of ratemaking decisions to meet potential Proposition 218 court challenges.

**Clarify constitutional requirements.** To solidify local funding bases for water services, voters may need to approve several constitutional changes that address the unintended consequences of previous amendments—while retaining transparency and accountability requirements. These might include clarifying Proposition 218's cost-recovery requirements (to allow for conservation and lifeline rates) and stipulating that flood and stormwater programs should be treated like water and wastewater programs. There has been a growing awareness of the need to address these aspects of Proposition 218, but the process is still under way.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# Preparing for Floods

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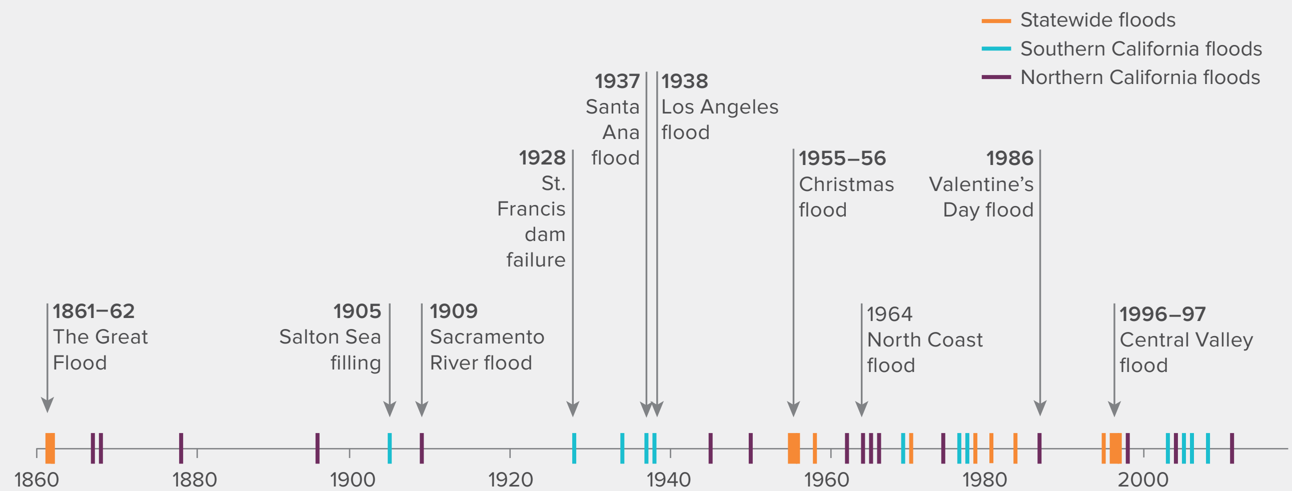
OCTOBER 2016

## California is flood prone

Damaging floods are common throughout California. Over the past 60 years, every county has been declared a state or federal flood disaster area multiple times. And since the early 1980s, Central Valley levees have failed on more than 70 occasions, including more than 40 times in the Sacramento–San Joaquin Delta. More than 7 million residents and hundreds of billions of dollars in assets are vulnerable.

California flood management faces significant challenges. There is a large and growing gap between flood infrastructure needs and rates of investment. Population growth and new development are increasing the threats to public safety and the economic risk from flooding. The *Paterno v. State of California* court decision in 2003 held the state liable for damages caused by failure of a locally maintained levee, exposing taxpayers to billions of dollars in potential costs. The changing climate is likely to bring larger and more frequent floods, increasing pressure on flood management systems that were designed for conditions in the early 20th century. Finally, a rising sea level and extreme high tides are increasing flood risk in communities bordering the ocean, the San Francisco Bay, and the Delta.

### DAMAGING FLOODS ARE COMMON IN CALIFORNIA




SOURCE: Developed by the authors using California Department of Water Resources and US Army Corps of Engineers, *California's Flood Future: Recommendations for Managing the State's Flood Risk* (2013).

NOTES: The figure depicts floods that caused significant property damage and/or loss of life. Floods named above are the largest and most damaging. Thicker lines indicate floods that crossed over two calendar years.

## Vulnerability to floods is high and rising

Most of California's annual precipitation occurs during a few intense storms. One type of storm, called an atmospheric river, is California's version of a hurricane, with extreme rainfall, high winds, and coastal storm surges. When these storms occur, runoff flows rapidly into valleys and coastal areas, potentially creating widespread, damaging floods. Exposure to both large and smaller floods is already high and on the rise.

- **One in five residents lives in a flood-prone area.**
  Four percent of all Californians live in areas that flood frequently. Another 17 percent are protected by levees and other infrastructure against a "100-year" flood—a flood with a 1 percent chance of occurring in any year. But these

people remain vulnerable to larger, less frequent floods that often cause levee failures. The 100-year flood standard is generally considered insufficient for urban areas, where damages from larger floods would be quite high. In the San Francisco Bay Area and South Coast, coastal flooding is a concern from extreme tides, waves, and storm surges. Inadequate drainage systems also make many cities vulnerable to localized flooding from storm runoff. The replacement value of buildings vulnerable to floods exceeds $575 billion. Roads, airports, and other public infrastructure are also exposed.

- **Major losses would occur from a disaster like the Great Flood of 1861–62.**
  The US Geological Survey recently assessed the probable effects of a series of intense atmospheric rivers—similar to those in late 1861 and early 1862. One in five California homes would be damaged or destroyed, and loss of life would be extensive. More than 1.5 million people would require evacuation, and economic losses would approach $725 billion. Such losses far exceed those from large earthquakes, which occur with similar frequency—on average, once every few centuries. It is not economically feasible to protect California against all losses. Still, it is essential that the state prepare for these rare events, developing evacuation and recovery plans and reducing impacts where possible.

- **The likelihood of large and small floods is growing.**
  Recent climate change simulations for California suggest that conditions that cause flooding, including atmospheric rivers and extreme high tides, may increase in intensity and frequency. This would mean more large, dangerous floods and more "nuisance" floods—which are smaller but more frequent, and can be very disruptive for communities. These changes, coupled with a growing population, will require significant investments in flood protection infrastructure and innovative approaches to reducing risk.

## Effective risk management requires a comprehensive tool kit

People living in flood-prone areas—particularly those behind levees—will always face some risk. Reducing the frequency and consequences of flooding will require a combination of approaches. California needs to make infrastructure investments to strengthen flood protection and to take nonstructural measures, such as better land use planning and stronger building codes, to keep people and buildings out of harm's way. The state must also invest in communicating flood risk to improve local decision making.

- **California's flood infrastructure is underfunded.**
  A recent state study put the cost of upgrading levees and other defenses at more than $34 billion. PPIC found an annual funding gap of $800 million to $1 billion for making these investments within a 25-year time frame. Because federal and state funds are limited, the funding burden will increasingly fall on local communities. Local taxes and fees currently fund most maintenance but pay for less than half of infrastructure investments. On average, filling the gap would require roughly doubling local spending. In the flood-prone Sacramento and San Joaquin River regions, the increases would need to be much larger.

- **Better land-use planning can reduce risk …**
  Land-use planning is widely seen as the most cost-effective and sustainable way to reduce economic and social risks from floods. This approach keeps new high-value development away from vulnerable areas. Relocating vulnerable buildings and roads may be desirable in some low-density areas—and may even be necessary as the climate changes—though it is often politically unpopular and can be costly.

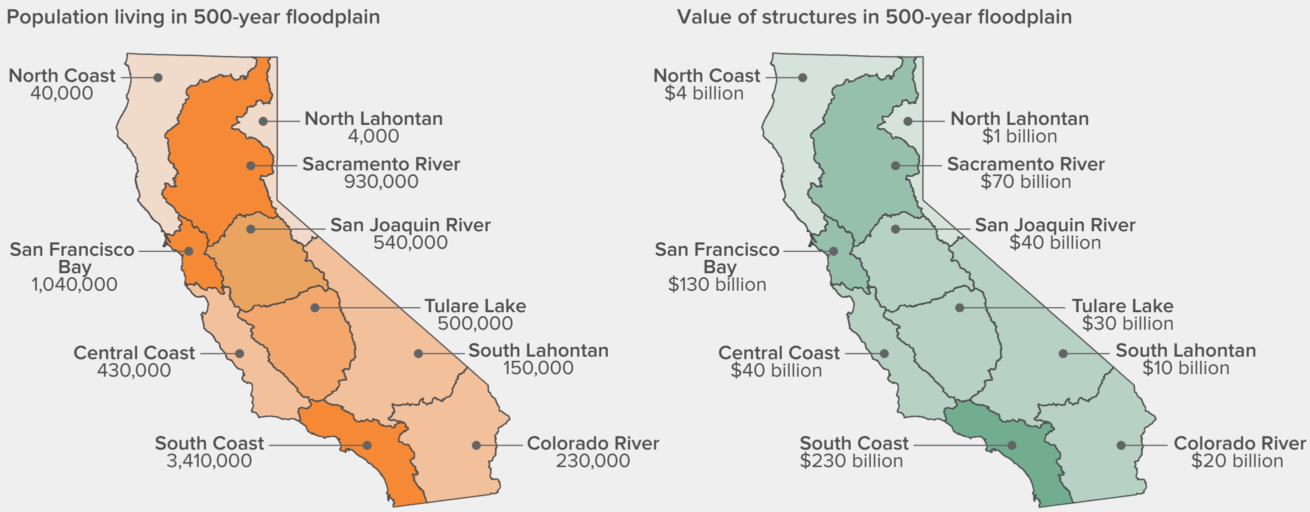
- **… but policies do not adequately discourage floodplain development.**
  To participate in the National Flood Insurance Program and to be eligible for federal disaster relief, communities must require protection for new buildings that would be inundated by a 100-year flood. Many California communities have constructed levees and other flood infrastructure that protect entire neighborhoods to this minimum federal standard. Concentrated development within these minimally protected areas increases the economic risk from inevitable flooding. The state recently doubled the protection standard for urban areas in the Central Valley. The cost of meeting this standard will probably discourage some development.

- **Federal flood insurance is undersubscribed in California, but the recent El Niño caused an uptick …**
  Federal flood insurance reduces flooding's economic costs by helping homeowners, businesses, and communities recover more quickly. Purchases of flood insurance vary with the perception of risk. In 1998—the year following widespread flooding in the Central Valley—flood insurance policies hit a historic high of more than half a million.

A decade later, the number of policies had fallen by half. However, late 2015 saw a sharp increase in anticipation of potential El Niño flooding.

- **.... yet costs can be high for low- and middle-income homeowners.**
  Congress recently required the phaseout of some insurance discounts for older properties. Along with new mandated fees, this may significantly increase premiums for many homeowners and create disincentives for buying insurance.

**MILLIONS OF RESIDENTS AND MANY BILLIONS OF DOLLARS IN PROPERTY ARE VULNERABLE TO FLOODS**




SOURCE: Adapted from California Department of Water Resources and US Army Corps of Engineers, *California's Flood Future: Recommendations for Managing the State's Flood Risk* (2013).

NOTES: The figure shows population and structures in the 500-year floodplain—the area susceptible to floods so large that they have just a 0.2 percent chance of occurring in a given year. Levees protect much of this area from a 100-year flood, which has a 1 percent chance of occurring in a given year. Population is adjusted to 2010 levels. Value of structures is based on the depreciated replacement value of structures and their contents in 2010 dollars.

- **Flood infrastructure can provide environmental and water supply benefits.**
  Flood protection can be improved by setting levees back from rivers and allowing waters to spread out on undeveloped floodplains. Such an approach also boosts habitat, as the Yolo Bypass near Sacramento shows. Better fire management in upstream forests can diminish peak flood flows and mudslides. Low-impact development—such as permeable pavement and rain gardens that capture urban stormwater so that it soaks into the ground—can reduce nuisance flooding, improve surface water quality, and recharge groundwater basins.

- **Adapting to a rising sea level will require balancing goals.**
  Traditional infrastructure for protecting coastal communities—such as seawalls and levees—is costly, restricts public coastal access, and harms the environment. To balance flood protection with other coastal management goals, California should consider where to protect existing development by building new infrastructure and where to retain or restore more natural coastline features such as beaches and marshes.

- **Protecting farming in floodplains may require special policies.**
  Viable farms on floodplains reduce pressure to develop these lands. That helps to avoid the high economic, social, and environmental costs of large flood protection infrastructure. But federal rules on new construction can make it very expensive to maintain farms in the Central Valley's deep floodplains.

## Looking ahead

It is hard to draw attention to flood management during a drought, although heightened awareness of the recent El Niño helped. Nevertheless, this is precisely the time to act to reduce future flood risk.

**Expand local funding tools.** Since 1996, constitutional restrictions have made it difficult to fund needed investments. The funding gap could be reduced by treating flood agencies like water and sewer utilities—requiring transparent accounting but allowing elected governing boards to raise fees.

**Improve flood risk information and communication.** To promote flood resilience, communities need to better understand flood risk. This includes utilizing modern technology to identify vulnerable areas, and using new tools for communicating risk and the potential array of responses.

**Increase incentives to carry flood insurance.** To help manage risk, California should expand flood insurance purchases. One novel approach would authorize local flood management agencies to buy insurance for all properties within a community. This could increase coverage and cut costs. The legislature could encourage it by creating mechanisms to recover costs through assessments or fees and by subsidizing costs for low-income homeowners.

**Build on Central Valley reforms.** The 2007 package of reforms for this region included higher protection standards, greater risk-reduction responsibility for communities, new planning tools, and incorporation of ecosystem objectives and the risks from climate change. Many of these reforms should be adopted in other flood-prone regions of the state.

**Prioritize state funding.** Since 2006, the state has used bonds to finance flood projects. Proposition 1, approved in November 2014, earmarks an additional $595 million for flood and stormwater management. State funding is especially useful for projects that take integrated approaches to water management—benefiting water supply, water quality, ecosystems, and open space—in addition to flood protection.

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# Protecting Headwaters

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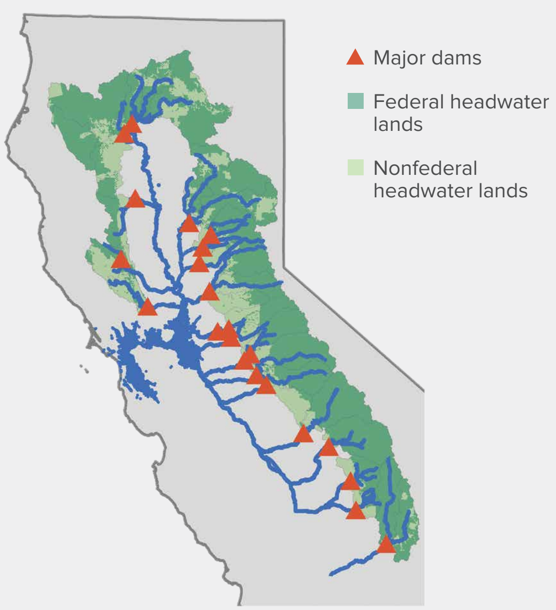
OCTOBER 2016

## California needs to manage its main water source more effectively

The headwaters—or upper watersheds—of the Sierra Nevada and Cascade regions supply most of the water used by California's farms, cities, and aquatic ecosystems. These heavily forested, mountainous areas are part of the state's natural water infrastructure—and essential for a sustainable future.

The health of California's headwaters is at risk. Historic forest and fire management practices have made forests overly dense and prone to extreme—and costly—wildfires. Historic grazing practices have damaged mountain meadows and grasslands, degrading habitat for many native species and reducing water supplies and quality. And the expansion of rural communities into wildland areas complicates efforts to manage fire risk.

THE FEDERAL GOVERNMENT OWNS MOST OF THE LAND ABOVE THE STATE'S MAJOR RESERVOIRS




SOURCE: Compiled by the authors using data from the California Department of Water Resources and the US Geological Survey.

NOTE: The figure depicts ownership of lands that drain into the major water supply reservoirs of the Central Valley. The federal government owns more than 70 percent of these lands and more than half of all forestland in California.

Headwaters are also under stress from a changing climate. The hot, dry conditions of the latest drought led to record tree mortality and wildfires—a glimpse of what the future might hold. Large fires raise numerous challenges for water management—they can reduce water quality and reservoir storage capacity, while increasing risks of flooding and landslides. Recent planning efforts have underscored the importance of large-scale programs to restore forest health, but there are numerous institutional and funding barriers. The state needs to partner with local agencies, stakeholder groups, and the federal government—the largest landowner by far—to develop a new approach to managing its headwaters.

## Upper watersheds are California's natural infrastructure

Most of California's biodiversity is found in the mix of federal and privately held forests, grasslands, meadows, and alpine areas that make up the upper watersheds. These areas are also critical for the state's water and energy supplies and for local economies.

- **Upper watersheds provide most of the runoff …**
  Mountainous headwaters occupy roughly one third of the state but provide two-thirds of its surface water. The most important watersheds are on the western slope of the Sierra Nevada and in the southern Cascade Range. These are the main sources of water for the Central Valley and Bay Area, and they contribute 30 percent of the water used by Southern California cities.

- **… and they store water.**
  Roughly a third of the state's annual supply is stored as snowpack that melts during the spring and early summer when water demands are high. Water is also stored in the ground and released through springs. More than 40 percent of the inflow to Shasta Reservoir—the state's largest—comes from springs in the northern Sierra Nevada and Cascade Range.

- **Headwaters also supply high-quality water …**
  The quality of the water that comes from the state's mountainous headwaters is exceptionally high. Much of the Bay Area, for example, can avoid the costs of filtration because of water sourced directly from the Sierra Nevada.

- **… and help reduce greenhouse gas emissions.**
  On average, 15 percent of the state's electricity comes from hydropower produced in the upper watersheds—a clean source of energy that generates no carbon dioxide, the most common greenhouse gas associated with burning fossil fuels. (The hydropower share declines during droughts.) The forests and grasslands of these watersheds also sequester carbon by storing it in plants and soil.

- **Rural economies depend upon this natural infrastructure.**
  Although not a large part of the state economy, upper watersheds are job generators in local towns. This includes timber harvesting, grazing, and recreation.

## Headwater forests face extreme wildfire risk

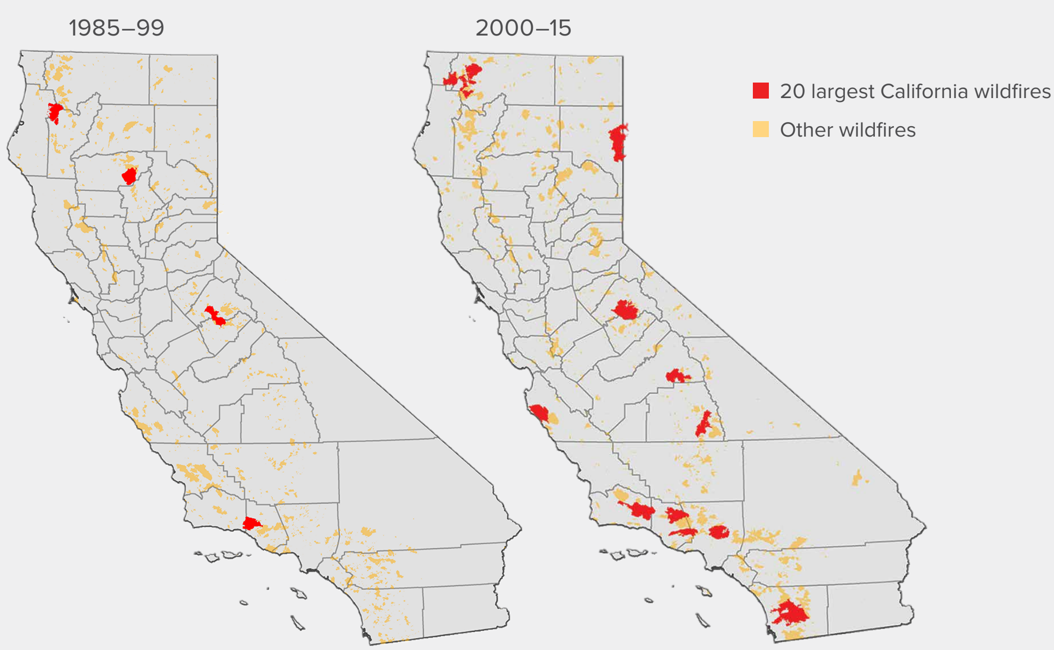
Over the past century, California's forested upper watersheds have become dense and unhealthy. Today, the economic, social, and environmental costs of extreme wildfire pose the greatest management challenge in these areas.

- **Fire is a natural feature of the state's forested watersheds.**
  Since the early 20th century, fire suppression policies have sought to extinguish fires as quickly as possible. Along with reduced timber harvesting, this has led to exceptionally dense vegetation in many California forests. There are now fewer large trees and many more small trees. These denser forests may be reducing water supplies available to downstream users. Rising temperatures and extended drought have further stressed these dense forests, leading to unprecedented tree mortality and accumulation of fuels.

- **Homes and suburbs are expanding into areas with high fire risk.**
  This poses a threat to public safety and raises the potential economic losses from wildfire. It also creates more pressure to suppress smaller fires quickly, limiting the benefits of using fire to keep forests healthy.

- **Extreme wildfires are becoming larger and more frequent.**
  Fires are becoming increasingly costly to manage, now accounting for more than half of the budget of the US Forest Service and its state equivalent, the California Department of Forestry and Fire Protection (CAL FIRE). This is a vicious cycle, because it shifts resources away from programs to reduce fire risk and restore forests.

**MOST OF CALIFORNIA'S LARGEST WILDFIRES HAVE OCCURRED SINCE 2000**




SOURCE: CAL FIRE Fire and Resource Assessment Program fire perimeter database, adapted by the authors.

NOTES: CAL FIRE's fire perimeter data set is a complete record of acreage burned by wildfires from 1985 to 2014. The 20 largest wildfires are measured in terms of acres burned. The figure includes one top-20 fire from 2015 (the Rough Fire) and excludes three top-20 fires that burned before 1985. The four top-20 fires from 1985 to 1999 burned 531,000 acres, and the 13 top-20 fires from 2000 to 2015 burned 2,463,000 acres.

- **Extreme fires have many negative impacts.**
  Air quality problems are often severe across wide areas during and immediately following extreme fires. Afterward, erosion of ash and exposed soils can reduce water quality and reservoir storage capacity. Risks of flooding, landslides, and debris flows also increase.

## The natural infrastructure of upper watersheds needs repair

Beyond a growing wildfire risk, the upper watersheds have also been changing in other ways as a result of land use practices and warming temperatures. The scale of these changes—occurring over a vast area—makes them difficult and costly to address.

- **Historic land uses have degraded the natural infrastructure.**
  In some places, mining has affected water quality, particularly with acid mine drainage and mercury. Intensive logging has impaired streams and wetlands across the state. And overgrazing has damaged many meadows and their streams, degrading habitat and the ability of meadows to store groundwater and slow down floods.
- **Dams have altered rivers and streams.**
  Hydropower and water supply dams block fish and amphibian migration and change the timing, magnitude, and temperature of flows. Large dams along the edge of the Central Valley block access to more than 70 percent of historic spawning and rearing habitat for salmon and steelhead, contributing to the decline of these species.
- **Dense forests may be reducing runoff and snowpack.**
  Small-scale experiments and modeling studies have shown that dense forests intercept and evaporate more precipitation than less dense forests. Dense forests also tend to warm up faster in late winter and spring, reducing the water storage in the snowpack. These studies suggest that better forest management could increase runoff by as much as 10 percent.
- **A changing climate is compounding these problems.**
  The climate in the upper watersheds is expected to become warmer and more variable. As seen in the latest drought, these conditions are likely to have far-reaching impacts, ranging from more frequent and intense fire to changes in the amount and quality of runoff to changes in biodiversity.

## Looking ahead

To sustain its natural infrastructure, California needs to tackle upper watershed problems along a variety of fronts.

**Reintroduce fire and forest thinning as management tools.** More frequent use of prescribed and managed wildfires is needed to reduce the accumulation of fuel and reduce the risks of wildfire to public safety and water supplies. Mechanical thinning, or removal of trees, will also be necessary in some areas. This will often require easier federal and state permitting, as well as better community acceptance of managed burns.

**Fund and implement existing forest plans.** The US Forest Service has developed plans with state and local partners to improve California's forest health while reducing fire risk. But the program lacks sufficient funding. Shifting costs of fighting the largest fires to the Federal Emergency Management Agency can free up Forest Service funds for this purpose.

**Identify other funds for forest management.** A particularly promising source is payments for sequestering carbon. Revenues from California's cap-and-trade program can be used for this purpose, but current program rules are too restrictive. They do not authorize using funds for forest thinning and restoration—even though this is critical to reducing extreme wildfire risks and the associated emission of carbon into the atmosphere.

**Develop pilot programs to assess water supply and quality benefits.** Funding from water agencies is another potential source, but California needs better field-level information on the water supply and quality benefits of fuel reduction and forest restoration. Large-scale experimental programs are needed to measure these benefits.

**Consider investments in forest product infrastructure.** The decline in the state's logging industry has reduced infrastructure needed to support forest harvesting. Support for lumber mills and biofuel-generation plants in proximity to forests may be warranted.

**Reduce urban encroachment on wildland areas.** California needs to discourage development in wildland areas at risk of extreme fires. Options include strengthening requirements for local hazard-mitigation plans and reforming the State Responsibility Area Fire Prevention Fee to recover costs of both fire prevention and fire suppression.

**Develop integrated watershed plans.** Beyond current efforts, broader multiparty plans are also needed for managing federal and private headwater lands. Objectives should include reducing wildfire risk, conserving native biodiversity, protecting water supplies, reducing urban encroachment on wildland areas, and sustaining local economies.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# The Sacramento–San Joaquin Delta

PPIC WATER POLICY CENTER

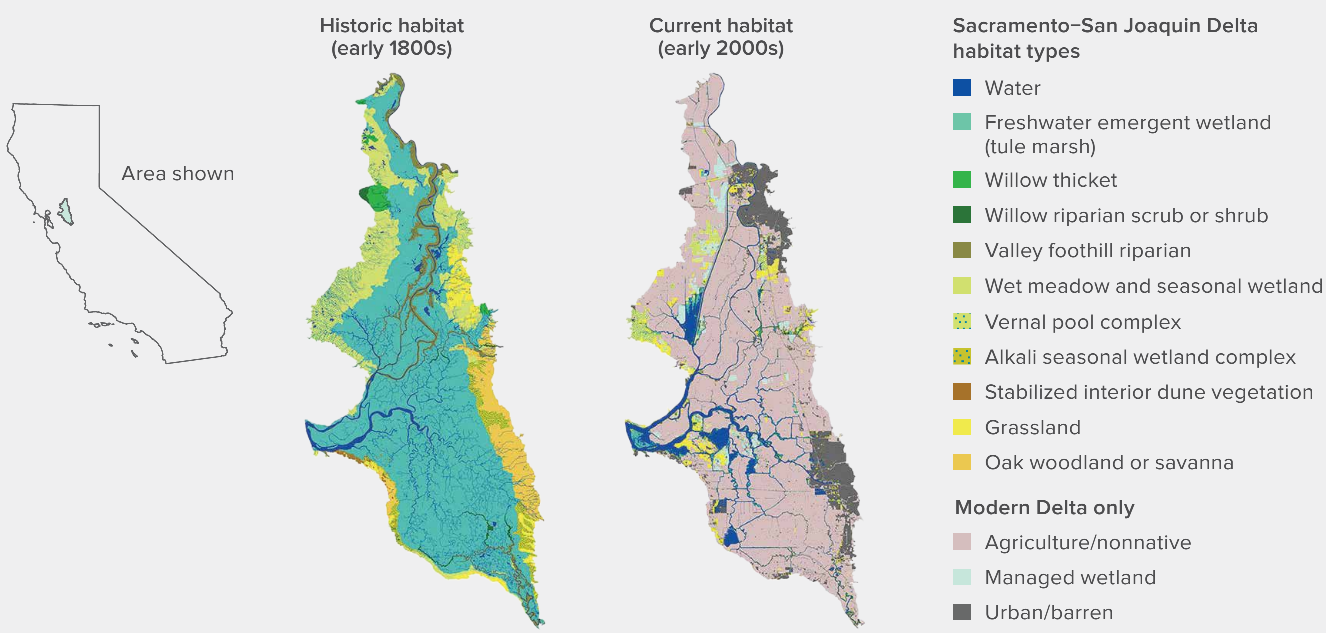
OCTOBER 2016

## The Delta is California's greatest water management challenge

The Sacramento–San Joaquin Delta is a network of engineered channels and agricultural lowlands at the confluence of the Sacramento and San Joaquin Rivers. Together with the San Francisco Bay, the Delta forms the largest estuary on the Pacific Coast of the United States. It is the terminus of California's largest watershed and a major hub for the state's water supply. The California State Water Project and the federal Central Valley Project export water from the southern Delta to more than 25 million people and 3 million acres of irrigated farmland in the Bay Area, the San Joaquin Valley, and Southern California. The reliability of this supply is declining. Levees needed to protect Delta farmland and keep salt water at bay are at risk from rising sea levels, winter floods, sinking farmland, and earthquakes. Changes in the ecosystem are harming native species, including salmon and smelt, which are now threatened with extinction. Efforts to protect these species are putting pressure on water supplies. The local Delta economy is also vulnerable to levee failure and declining water quality.

The Delta Reform Act of 2009 requires the state to manage the Delta for the "coequal goals" of providing a more reliable water supply for California and improving the health of the Delta ecosystem, while also protecting it as a unique and evolving cultural, recreational, natural, and agricultural place. Implementing this law has been controversial, but the economic, social, and environmental costs of failure would be high.

### FARMING HAS RADICALLY CHANGED DELTA HABITAT




SOURCE: A. Whipple et al., *Sacramento–San Joaquin Delta Historical Ecology Investigation: Exploring Pattern and Process* (San Francisco Estuary Institute & The Aquatic Science Center, 2012).

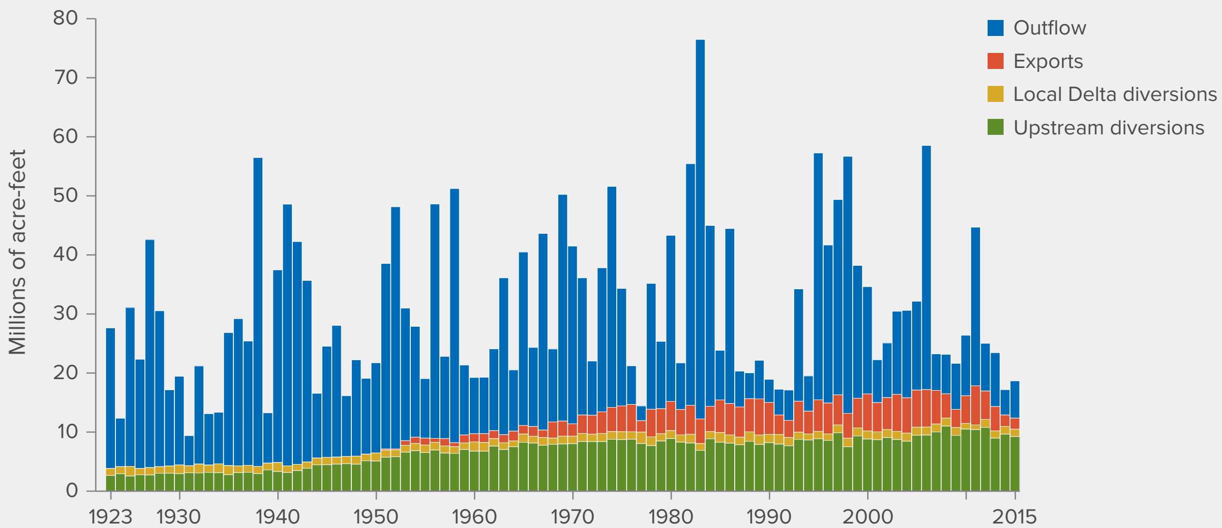
## The Delta is changing

Today's Delta is dramatically different from the Delta that existed before its lands, waterways, and upstream watersheds were developed. This distinctive landscape and ecosystem are still changing in ways that make achieving the Delta Reform Act's goals difficult.

- **Land reclamation for farming transformed the Delta landscape.**
  In the late 19th and early 20th centuries, some 1,100 miles of levees were built to convert 700,000 acres of tidal marsh into farms. "Islands" of farmland were created by surrounding marshlands with levees. Farming caused peat-rich soils to oxidize and land to sink. Today, many islands are 10 to 25 feet below sea level. Sinking land causes drainage problems and increases pressure on levees—making flooding more likely.

- **Water supply for farms and cities has reduced Delta outflows.**
  The Sacramento–San Joaquin River watershed is California's largest source of water for farms and urban areas. From 2000 to 2015, on average 33 percent of the water that would otherwise have flowed through the Delta was consumed upstream, 17 percent was exported, and 5 percent was used by farmers in the Delta. The water that remains flows into San Francisco Bay where it supports aquatic species and repels seawater so that water in the Delta remains fresh enough for farming and urban uses. Water management alters seasonal flow patterns, affecting aquatic habitat throughout the Delta.

### DELTA OUTFLOWS HAVE DECLINED AS FARMS AND CITIES HAVE INCREASED THEIR WATER USE




SOURCE: Updated from Delta Vision Blue Ribbon Task Force, *Our Vision for the California Delta*, Figure 7b (2007). For the period 2010–15, upstream diversions (green) are estimated based on water-year type and historical upstream uses.

- **Ecosystem changes have harmed native species.**
  More than 35 native plants and animals that live in or pass through the Delta are now listed under state or federal endangered species acts. Many factors account for the decline of native fishes such as delta smelt, longfin smelt, Chinook salmon, and green sturgeon: loss of habitat, changes in the volume and timing of flows, changes in water quality, and unfavorable hatchery and fishing practices. In addition, many alien species have invaded the estuary, often altering the environment and competing with or preying on native species.

- **Water exports and the Delta economy are also threatened.**
  The reliability of water exports is falling as the risk of levee failure increases and conflicts intensify over flows required to protect endangered species. Levee instability also threatens Delta farming and infrastructure. Invasive aquatic plants such as water hyacinth clog water intakes and interfere with boating—a key part of the Delta's recreation economy.

- **The changing climate will make it harder to achieve all management goals.**
  Conflicts between urban and agricultural uses of Delta water and environmental goals are growing. Higher temperatures and increasing climate variability will change the timing and magnitude of flows into the Delta, raising levee failure risks and reducing the reliability of water exports. A rising sea level will put more pressure on levees and require larger outflows to keep Delta waters fresh. Warming, increasing salinity, continued invasions of alien species, and flow changes will compound the threats to native fishes. Meanwhile, population growth will raise the demand for reliable water supplies.

## Balancing water supply and ecosystem goals is a major challenge

California has struggled for decades to find a balance between diverting Delta water for economic purposes and allowing it to flow through the Delta to support the ecosystem. The water quality and endangered species regulations that now govern water exports are controversial. During the latest drought, state regulators relaxed standards to allow increased exports, and proposed federal legislation would go further in this direction. Since 2006, federal, state, and local agencies that use Delta exports have been exploring a longer-term solution involving new water conveyance infrastructure and ecosystem improvements. The latest version of this proposal—put forth in 2015—is called California Water Fix.

- **California Water Fix is ambitious …**
  Most Delta exports are now drawn through the Delta's channels from the Sacramento River to large pumps in the southern Delta. California Water Fix would move water directly from the Sacramento River to the pumps through two tunnels. A complementary effort—California EcoRestore—has a near-term goal of restoring 30,000 acres of tidal marsh and floodplain habitat within and adjacent to the Delta.

- **… and involves many uncertainties.**
  California Water Fix—together with California EcoRestore—is likely to improve water supply reliability. But it is uncertain how future climatic, ecosystem, and regulatory conditions will affect program goals. For example, it is unknown whether the proposed ecosystem improvements will substantially benefit native fish populations. To succeed, both programs will require ongoing flexibility, experimentation, and refinement.

- **Costs are high, with no clear funding for the ecosystem.**
  Tunnel construction costs of approximately $17 billion are to be paid by urban and farm customers who use Delta exports rather than by taxpayers. The first phase of California EcoRestore will cost $300 million—also borne by water users. But there is no clear mechanism for funding longer-term ecosystem improvements and related science and monitoring. Proposition 1—the state bond approved by voters in November 2014—provides less than $140 million for the Delta ecosystem.

## Improving Delta levees is another big challenge

The Delta's 1,100 miles of levees support the local economy and the current system of water exports. High costs to upgrade levees as well as low land values and limited state and federal funding create tough choices on how and where to invest.

- **Economic justification and funds to improve all Delta levees are insufficient.**
  According to recent state estimates, more than $12 billion in flood investments are needed in the five Delta counties. This includes levees in the inner Delta, where few people live, and urban areas such as West Sacramento and Stockton, where large populations are vulnerable. The entire region faces a sizable funding gap. Furthermore, costs of upgrading many of the Delta's agricultural levees exceed the economic value of the land they protect, and only some Delta levees are needed to keep Delta waters fresh.

- **Limited state funds need to be prioritized.**
  State bonds approved in 2006 dedicated nearly $600 million to Delta levees. Proposition 1 earmarks another $295 million. The Delta Stewardship Council is now setting priorities for using these funds.

## Looking ahead

If Californians put off difficult decisions about the Delta, then the Delta's growing population, changing climate, and changing ecosystem will make it even harder to find solutions. Five areas need immediate attention.

**Make a strategic decision on water supplies.** In taking action to ensure future water supplies, the state must decide whether to move forward with California Water Fix; adopt a scaled-back version of the plan with reduced export capacity, costs, and other impacts; or prepare for large permanent reductions in Delta water exports. The last alternative would force cities in the Bay Area and Southern California to turn to more expensive sources of water. In the southern Central Valley, it would reduce farming and make it harder to achieve sustainable groundwater management.

**Ensure robust scientific support.** Scientific and technical support for managing the Delta has been underfunded and poorly organized. To improve decision making and reduce controversy and litigation, the state and federal governments should make substantial, sustained investments in more integrated scientific work, as outlined in the new Delta Science Plan.

**Reverse the decline of native fishes.** California has compelling social and economic reasons to reverse the decline of Delta fish populations, including avoiding regulatory costs. Because the science is uncertain, bold experiments are needed in habitat restoration, flow changes, and management of fisheries and invasive species. Agencies will need to adjust flow management and take other actions as scientific understanding improves. This work requires reliable funding.

**Set priorities for state levee funding.** California needs a transparent and effective plan for investing limited state funds in Delta levees. Priority should go to investments that provide broad social, economic, and environmental benefits for the Delta region. Some funds should be set aside to support economic transitions in places where levees cannot be sustained.

**Incorporate long-term change into all aspects of planning.** The state should consistently take into account the significant effects on the Delta of climate change, rising sea level, shrinking sediment supply, introductions of new species, and other changes over the long term. Adaptation strategies are needed for improving water supply, managing ecosystems and species, and prioritizing levee maintenance.

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# Storing Water

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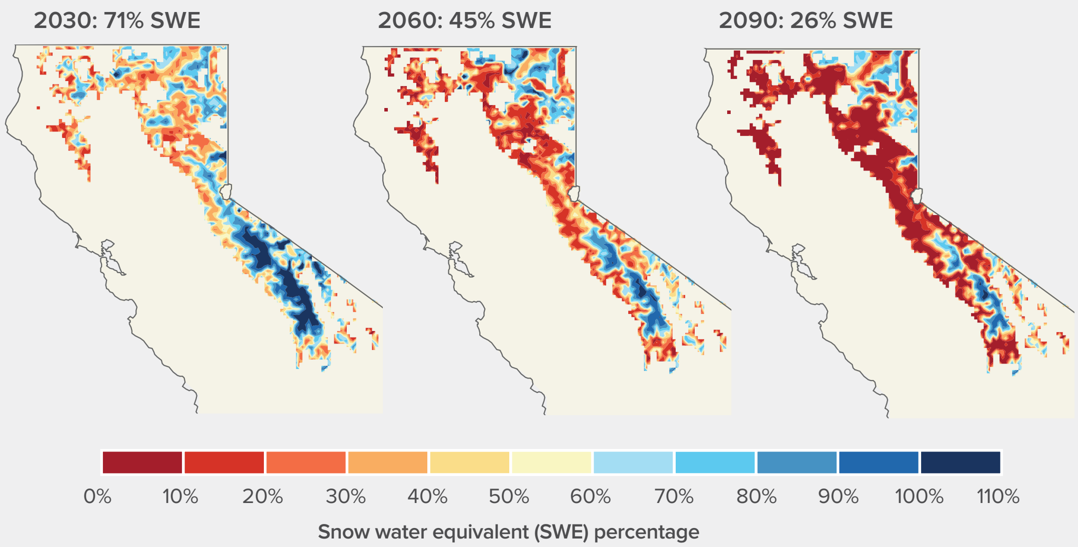
## Storage is essential for managing California's water

Water stored during California's wet winter and spring months provides supplies for its dry summers and frequent droughts. Stored water is also used for recreation, hydropower, and to mitigate harmful effects of dams on river and wetland ecosystems. During large storms, storage reduces peak flood flows and downstream damage.

Water storage in California takes many forms. As much as a third of the state's supply comes from snowpack, which releases water during spring and summer when demand is highest. Water stored in soils supports plant growth and helps regulate storm runoff. Some 1,400 surface reservoirs can store up to 42 million acre-feet—a year's supply for farms and cities. The state's 515 groundwater basins hold at least three times as much usable water as the surface reservoirs, and decades of groundwater depletion have created unused space in many aquifers.

California faces numerous challenges in managing water storage: balancing competing goals, such as flood protection versus water supply; reducing environmental harm from dams; addressing long-term deterioration of groundwater resources from excess pumping and pollution; and adapting to a smaller snowpack as the climate warms. Groundwater users across California have begun implementing the 2014 Sustainable Groundwater Management Act (SGMA), the first statewide effort to manage groundwater. The state has also been preparing to disburse $2.7 billion in bond funds for water storage projects under 2014's Proposition 1.

### RISING TEMPERATURES WILL SHRINK THE SIERRA NEVADA SNOWPACK



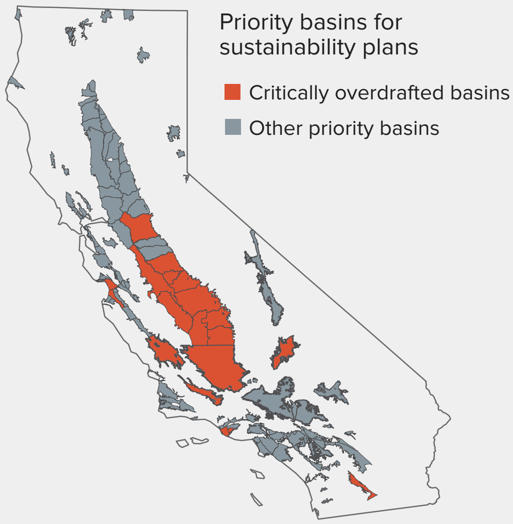

SOURCE: Modeling and mapping by Daniel Cayan, David Pierce, and Laurel DeHaan, Scripps Institution of Oceanography, and Noah Knowles, US Geological Survey (2016), with support from the California Energy Commission, California Department of Water Resources, the US Geological Survey (Southwest Climate Science Center), the National Oceanic and Atmospheric Administration (through the California Nevada Applications Program), and the US Army Corps of Engineers.

NOTES: Snow water equivalent (SWE) measures the amount of water stored in the snowpack. It is expressed as a percentage of estimated recent historical conditions (1965–2005). These scenarios are based on projected temperature increases—1.8˚C (2030), 3.5˚C (2060), and 5.2˚C (2090)—from 10 different climate models, over temperature averages during recent historical conditions (1965–2005). SWE and temperature values for 2030, 2060, and 2090 are averages over 19 years centered on these dates. These projections are based on the Representative Concentration Pathways 8.5 high greenhouse gas emissions scenario, in which emissions continue to rise throughout the 21st century.

## Groundwater is California's most important drought reserve

Groundwater is California's largest source of storage. On average, it supplies about a third of the water cities and farms use annually, and more in some regions. During droughts groundwater can supply more than half of statewide water. Aquifers can be replenished, but they fill more slowly than surface reservoirs.

THE SUSTAINABLE GROUNDWATER MANAGEMENT ACT APPLIES TO BASINS ACROSS CALIFORNIA




SOURCE: California Department of Water Resources, California Statewide Groundwater Elevation Monitoring Program.

NOTES: Under SGMA, groundwater users in critically overdrafted basins must adopt sustainability plans by 2020 and attain sustainable management within 20 years; for other priority basins, plans must be adopted by 2022. In all, 127 basins, accounting for 96 percent of annual groundwater pumping, are considered priority basins that must comply within this time frame. Priority reflects reliance on groundwater; current and projected population and irrigated acreage in the basin; and documented impacts, including overdraft, subsidence, and water quality degradation.

- **Unregulated pumping causes multiple problems.**
Until recently, the state only loosely regulated groundwater use. Many basins have experienced overdraft—excess pumping that causes long-term groundwater declines. Lower groundwater levels increase energy costs of pumping, dry out shallower wells, reduce flows to rivers and wetlands, and cause land to sink—damaging roads and other infrastructure.

- **Many urban areas now have well-developed groundwater programs.**
In the early-to-mid 20th century, many Southern California cities and the San Jose area faced problems from unregulated pumping. They now have tightly managed basins and regulate, meter, and charge for pumping. Local management agencies replenish basins from local rainfall, distant rivers, and, increasingly, recycled wastewater and stormwater. Recharge methods include placing water in ponds and injecting it into wells. To store excess stormwater, some cities are installing permeable pavement and rain gardens.

- **Groundwater oversight in agricultural areas is limited.**
Groundwater overdraft in agricultural regions—mostly in the southern Central Valley and Central Coast—averages about 2 million acre-feet annually. Many farms are shifting to orchards and vineyards, which are costly to fallow and often rely on groundwater to survive droughts. Meanwhile, irrigation is declining as a source of recharge as farmers adopt more efficient technology.

- **Poor groundwater quality is also a problem.**
In Southern California and the Sacramento area, industrial pollutants limit groundwater use for drinking and hinder some basins from being replenished. In farming regions, much of the shallow groundwater contains high nitrate concentrations from fertilizers and manure. This contamination deteriorates drinking water quality. Salt accumulation is a growing problem for farming in the San Joaquin Valley and coastal areas, where overdrafting draws in seawater. Treatment is an option for large urban systems, but it is usually too costly for small communities and farms. Recharging basins with clean water can improve quality.

- **The new groundwater law holds promise.**
SGMA requires water users in the most stressed basins to develop sustainable groundwater management plans by 2020 and reach sustainability by 2040. The law gives local agencies authority to implement these plans, including the ability to measure use and charge fees for pumping and to cover the cost of recharge projects. The State Water Resources Control Board can intervene if it deems local efforts inadequate, or if local authorities request assistance.

## Surface reservoirs provide California's most flexible storage

The state's surface reservoirs—mostly constructed between the 1930s and 1970s—serve many purposes. They are a flexible form of storage that can be filled and emptied quickly to meet water supply and hydropower demand.

- **Surface storage has limited value during long droughts.**
Reservoirs store water for seasonal uses and reserve some water for dry years. During extended droughts, these reserves are depleted. By the fourth year of the latest drought, most large reservoirs were at or near record lows.

- **Flood storage competes with water supply storage.**
Many large, multipurpose reservoirs release water in the fall and winter to free up space for winter flood flows. Under US Army Corps of Engineers rules, this flood reserve cannot be refilled until late winter or spring, when the flood season has passed. If the winter is dry, reservoirs won't fill up. So early releases can reduce water supply for the year ahead.

- **Dams disrupt river ecosystems.**
  Dams limit access to fish spawning habitat and alter the natural patterns of flow, harming native fish, plants, and animals. Reservoir releases can sometimes mitigate these impacts—for example, by releasing cold water for salmon. Some dams are being removed to restore more natural flows and give fish access to better upstream habitats. Plans are under way to remove four aging hydropower dams on the Klamath River—the nation's largest dam removal project.

- **Climate change will complicate reservoir operations.**
  Most climate models predict rising temperatures, increasing climate variability, and more rain than snow. A decrease in snowpack storage and corresponding rise in winter runoff will increase the challenges of managing reservoirs for flood control, water supply, and summer hydropower. Rising temperatures will also make it harder to provide cold water for fish.

- **New surface storage may be costly relative to its water supply benefits.**
  New storage could improve water system flexibility. But the average volume of new water from these facilities is small, and costs are high. Five proposed projects—costing roughly $9 billion—would expand statewide reservoir *capacity* by about 4 million acre-feet but raise annual average *supply* by just 410,000 acre-feet, or 1 percent of annual farm and city use.

## Managing California's storage resources as a system can boost benefits

California has a vast interconnected surface and groundwater storage network, linked to major water demand centers by rivers, canals, and aqueducts. Operating this network as a system can boost usable supplies, improve quality, and help mitigate the impacts of climate change.

- **Groundwater and surface storage work better together.**
  Some storm runoff and water in surface reservoirs can be moved to groundwater basins. Such joint management of groundwater and surface water—known as conjunctive use—can boost resilience to droughts and a warming climate and improve groundwater quality.

- **Conveyance is often a bigger bottleneck than storage capacity.**
  Significantly expanding groundwater storage in the southern half of California—where basins are most depleted—will be hard without investments to improve the reliability of water conveyance across the Sacramento–San Joaquin Delta. Some conjunctive use projects also need local conveyance investments.

- **Institutional bottlenecks are also an issue.**
  More flexibility in reservoir operations would increase the benefits of conjunctive use, but this requires lengthy federal and state agency approvals. Better local aquifer management is also needed. And state law regulating groundwater recharge may be too restrictive.

- **Better flood management can help ...**
  Making more room on floodplains by setting back levees can improve flood protection and create temporary storage for floodwaters. This practice can also recharge local aquifers, improve habitat, and preserve open space for farming and recreation. Spreading excess winter flows on farmland is also promising.

- **... and so can better watershed management.**
  Forest management in upper watersheds can increase available streamflow by as much as 10 percent by reducing losses from plant growth and improving the storage of water in snowpack and soils. However, implementing these changes on millions of mountain acres is a challenge.

## Looking ahead

In 2014, California took important steps to address water storage by enacting landmark groundwater management legislation and approving bond funds for new storage projects. But the hardest work lies ahead.

**Develop groundwater sustainability plans.** Delay will encourage more overdraft and make future choices harder. Proposition 1 provides resources for local planning efforts, and legislation enacted in 2015 makes it easier for agencies to allocate pumping rights. Additional state action may be needed to clarify groundwater recharge and storage rights.

**Protect and restore groundwater quality.** Controlling new sources of pollution and cleaning up contaminated basins can improve groundwater storage. Meanwhile, safe drinking water in rural, groundwater-dependent communities is urgently needed. Bond funds are available for both purposes.

**Promote flexibility and integrate operations.** The state and its federal partners should establish more flexibility in reservoir operation rules to allow more efficient use of storage. Modern forecasting technology and better system coordination can help improve the timing and uses of reservoir releases.

**Prioritize bond investments in storage.** Proposition 1 supports the public benefits of new storage projects—including environmental restoration, flood protection, recreation, and emergency preparedness. When evaluating them, the state should seek maximum flexibility and the highest return on public dollars. This may favor improvements in groundwater storage and conveyance facilities that connect surface and groundwater.

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# Water for Cities

PPIC WATER POLICY CENTER

OCTOBER 2016

## Despite progress, California's cities face water management challenges

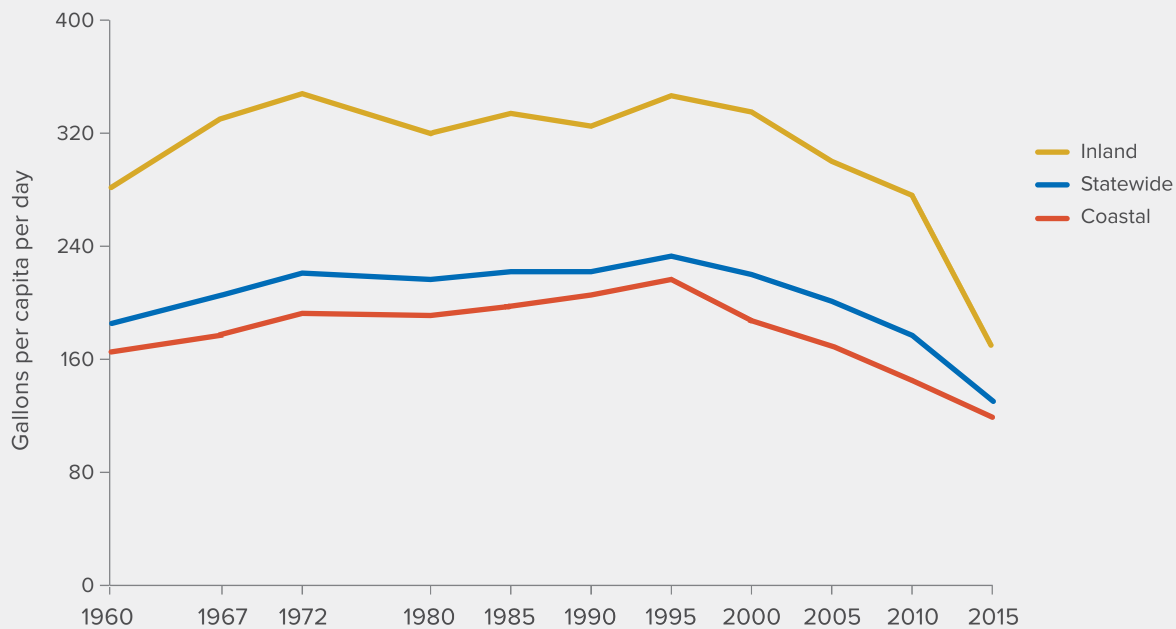
The water systems that supply California's households, businesses, and industries are vast and complex. Nearly 400 large utilities—each serving more than 10,000 people—supply more than 90 percent of the state's residents. Thousands of smaller utilities provide water to rural communities. Most utilities are public agencies with locally elected governing boards. Privately owned utilities serve about 16 percent of Californians.

Large utilities enjoy many advantages. They can spread fixed infrastructure costs over a wide customer base. They often have several water sources and extensive technical expertise. In recent decades, they have expanded connections with neighboring utilities, which allows water sharing during shortages. By contrast, smaller utilities are often geographically isolated and face high costs per customer for new investments. They usually rely on local groundwater and have limited in-house resources.

Despite the addition of 9 million new residents, the state's large urban systems were better prepared for the latest severe drought than for the last one (1987–92). This improvement reflects significant investments in conservation, storage, new supplies, and interconnections. Some small systems have not fared as well.

Large and small utilities face water supply and quality challenges. Many large utilities import water from the Sacramento–San Joaquin Delta and other distant locations. Infrastructure weaknesses and claims on water for the environment are making these sources increasingly vulnerable. Many utilities that rely on groundwater must contend with contamination and protect basin supplies. Utilities also need to prepare for a growing population and the likelihood that climate change will bring more frequent and sustained droughts.

### PER CAPITA URBAN WATER USE HAS FALLEN SHARPLY DURING THE LATEST DROUGHT




SOURCE: Author calculations (for 1960–2010) using data from California Department of Water Resources, *California Water Plan Update* (various years) and urban water conservation reports from the State Water Resources Control Board (2015).

NOTES: The figure shows "applied" water delivered to homes and businesses. "Net" water use—i.e., the volume consumed by people or plants, embodied in manufactured goods, evaporated, or discharged to saline waters—is lower. The totals exclude water used by power plants and groundwater recharge projects and water lost during conveyance. Except for 2015 (a severe drought year), the estimates are for normal or "normalized" rainfall years (i.e., adjusted to levels that would have been used in a year of normal rainfall). Estimates are for water years (October to September), except for 2015, which is for the calendar year. Inland per capita use in 2015 was 168 gallons per capita per day (gpcd) and coastal use was 119 gpcd. Inland areas tend to have higher per capita use because of higher temperatures and larger landscaped areas.

## Water use in cities is changing

Following decades of increases, total urban water use began to flatten in the mid-1990s, reflecting declines in per capita use. Cities now consume about 10 percent of California's available water, farms 40 percent. The remaining half is categorized as environmental, such as flows in wild and scenic rivers along the state's north coast.

- **Per capita water use has been falling since the mid-1990s …**
  In 2010, average urban daily water use was 178 gallons per capita, down from 232 in 1995. The adoption of low-flow plumbing fixtures and appliances has been a major factor. Since the early 1990s, low-flow toilets and shower-heads have been required in new construction and encouraged in older buildings by rebate programs.

- **… and communities have significantly cut use during the latest drought.**

In response to voluntary local programs and a statewide conservation mandate announced in April 2015, urban areas cut water use by nearly 25 percent between 2013 and early 2016, bringing per capita use down to 130 gallons per day. In 2016, urban agencies were given more flexibility, and some have relaxed restrictions in response to local supply conditions. It is too early to know how much of the recent savings will persist.

- **The urban economy has become less dependent on water-intensive activities.**

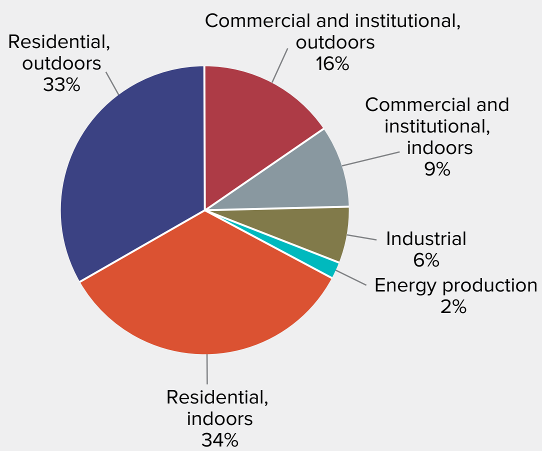
Some activities that require a lot of water, such as computer chip manufacturing, have moved out of state, and manufacturing now uses only 6 percent of urban water, down from 8 percent in 1990. Overall, businesses have been reducing water use while continuing to grow. In 2014, water used by cities generated more than three times the economic value per gallon that it did in 1967, measured by output of goods and services in inflation-adjusted dollars.

- **Landscape irrigation is the largest urban water use.**

Outdoor watering accounts for roughly half of statewide urban use and more in inland areas, where summers are hotter and lots tend to be larger. Savings can come from installing more efficient irrigation systems and replacing thirsty lawns with less thirsty plants. Many conservation efforts during the latest drought focused on reducing landscape watering.

**LANDSCAPING ACCOUNTS FOR ROUGHLY HALF OF TOTAL URBAN WATER USE**

Urban water use, 2006–10
8.5 million acre-feet (maf)




SOURCE: California Department of Water Resources.

NOTES: The figure shows the average "applied" urban water use, as defined in the notes to the preceding figure. "Net" urban water use (also defined above) was lower (5.9 maf). Commercial and institutional outdoor use includes official estimates for "large landscapes" (parks, golf courses, cemeteries, etc.) and a third of the total estimate for commercial and institutional demand, which includes other outdoor water use.

## Cities need to manage for reliability, cost, and financial stability

Utilities are pursuing a range of strategies to manage demand and diversify water sources. These investments are mainly funded by revenues from local water sales.

- **Pricing is important for managing demand …**
  Many utilities use regulations and rebates to encourage conservation. But water prices provide fundamental incentives. Many agencies now use tiered rates, with higher prices per gallon for higher use levels. Such rate structures can be effective. So can providing information on bills about how a household's use compares with similar homes. Bills also need to be simple enough to understand.

- **… and pricing must also keep utilities fiscally strong.**
  To avoid financial problems, rate structures should recover costs when water sales fall or when supply costs increase. This has been a challenge during the latest drought, when sales fell much more rapidly than costs, leaving many utilities in the red.

- **To increase resilience, many utilities are developing local supplies.**
  Some investments can be relatively low cost, such as recharging local groundwater basins with recycled wastewater or stormwater. Others are often more costly, such as building new surface storage facilities or seawater desalination plants. Some local sources require agencies to work together in new ways. For instance, several water utilities may share the cost of new interconnections or a desalination plant. Expanding recycled water use or stormwater capture usually requires water utilities to work with other agencies that have traditionally operated separately.
- **Imported supplies remain critical for many cities.**
  Cities in the San Francisco Bay Area and Southern California get more than half of their water supplies from other regions. Some of this water—notably imports from the Delta—will require major new investments to remain reliable. In developing their water portfolios, cities must weigh the relative cost and reliability of imported versus local supplies, while keeping in mind the value of diversifying water sources.
- **Water trading is a growing supply source.**
  In several regions, cities are reaching long-term agreements to lease water from farmers. More than 10 percent of Southern California urban supplies comes from such trades. Storing water in rural groundwater basins is also on the rise. And leases and exchanges with neighboring cities have proven very valuable during the latest drought.
- **Proposition 218 poses challenges for water management.**
  This constitutional change, adopted by voters in 1996, specifies that certain rates and fees cannot exceed the cost of providing a service. Narrow court interpretations question the feasibility of tiered water rates. Proposition 218 also restricts the use of water rates to fund lifeline programs, which help low-income customers. The proposition also limits the ability of larger communities to share the cost of annexing smaller systems—a promising way to ensure safe drinking water in some rural communities.

## Looking ahead

Although local agencies bear most frontline responsibility for providing safe and reliable water supplies, state action is also important to shape the regulatory environment and provide financial incentives. The following actions address top concerns.

**Establish state drought policies that incentivize local action.** The 2015 conservation mandate proved Californians can reduce water use quickly. But it may also have undermined the ability of local programs to build resilient supplies by requiring some agencies to save much more than local conditions warranted and exposing them to added financial risk. The state needs a predictable policy that incentivizes both conservation and continued local investments in diversified supplies.

**Guide the courts on water management priorities.** Legislation can guide courts in interpreting Proposition 218's cost recovery requirements. The legislature should emphasize the importance of supply diversification and conservation as strategies for responding to growing water scarcity.

**Use new bond funds for cutting-edge actions.** Urban agencies are eligible for more than $2.3 billion in state bond funds for regional water supply and water quality projects under 2014's Proposition 1. The state should ensure these funds go primarily to innovative projects—especially those that require new types of investment and collaboration—rather than simply substituting for money that urban utilities can raise from water bills.

**Consider local solutions within a regional context.** As utilities develop local sources such as recycled water and stormwater capture, they should consider the regional impacts. By reducing discharges, these local projects can reduce streamflows that now provide important environmental benefits or supply water to communities downstream.

**Develop flexible and resilient water pricing.** Utilities need to hone their rate structures to provide incentives for water efficiency while maintaining financial stability. They must anticipate how to remain financially healthy while encouraging conservation—for instance, by charging higher prices per gallon during droughts.

**Encourage more outdoor conservation.** Although indoor water conservation efforts must continue, the greatest potential source for urban water savings is outdoors, particularly with shifts to low-water landscaping. Turf replacement programs set important examples but cost too much for widespread use. A combination of new technologies, economic incentives, and education and consumer awareness campaigns are needed to make significant progress.

**Step up public education.** Public concern about water has been very high during the latest drought, but it will probably wane once the drought abates. Wide-reaching education programs are needed to encourage Californians to use water more sustainably and to explain why higher prices are often needed to maintain resilient local systems. Information on the safety of highly treated recycled water is critical, as are campaigns to encourage less water use in landscapes and gardens.

**Keep an eye on costs.** Utilities must weigh the relative costs and reliability of different supply options. And, when setting prices, they need to consider efficacy, fairness, and affordability for low-income households.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# Water for the Environment

PPIC WATER POLICY CENTER

OCTOBER 2016

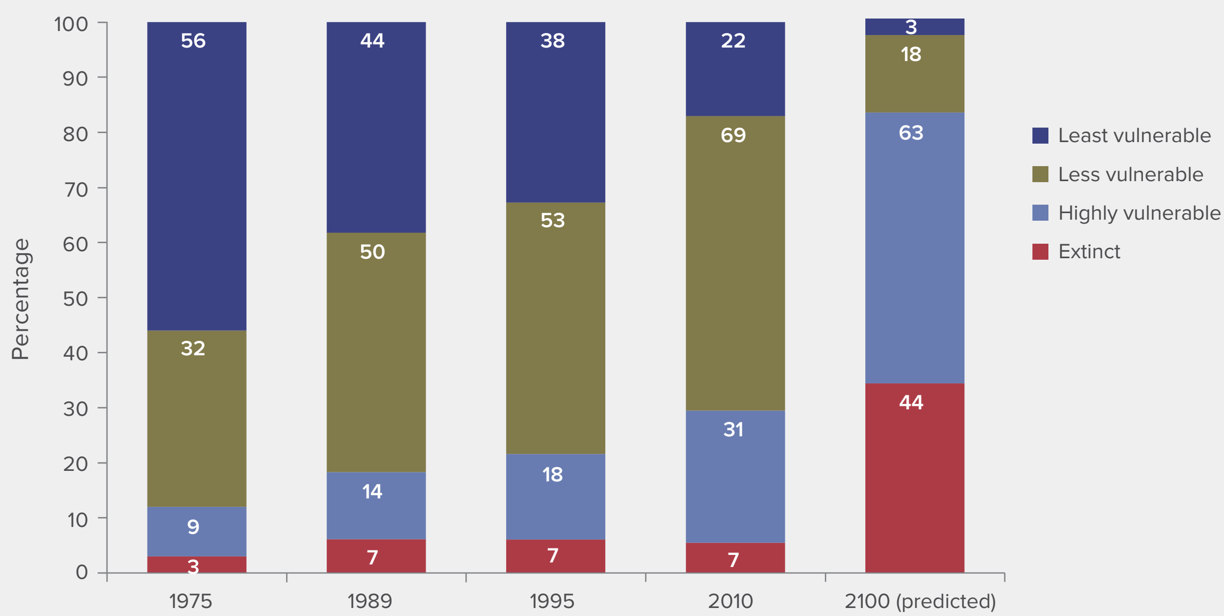
## Water is vital for California's diverse and troubled ecosystems

With its diverse landscape and climate, California is a biodiversity hot spot—home to more endemic plants and animals than any other state. California is also an important stop on the Pacific Flyway, providing habitat for millions of migratory ducks, geese, shorebirds, and songbirds. The state's rivers, lakes, wetlands, and estuaries support this rich biodiversity.

Dramatic changes in water and land use since statehood in 1850 have transformed California's freshwater landscape. Today, more than 1,400 dams cut off most historical salmon and steelhead spawning habitat. Roughly 95 percent of the native vegetation that once lined Central Valley rivers and creeks has been eliminated, along with wetlands that once hosted migratory waterfowl. Farms and cities use about half of the state's available water, while discharging harmful chemicals and other pollutants into waterways.

Four decades after the enactment of major state and federal environmental laws, California's freshwater biodiversity is at risk. Native freshwater fishes—indicators of the health of aquatic ecosystems—have been hit hardest. A quarter of these species are listed as threatened or endangered under state or federal endangered species acts, and many more are headed toward listing. The hot, dry conditions of the latest drought have put 18 fish species at near-term risk of extinction. For both economic and social reasons, California must improve its stewardship of freshwater ecosystems. With a changing climate and a growing population, one of California's great challenges is to strike a balance between improving ecosystem health and providing water supply, flood control, and hydropower.

### CALIFORNIA'S NATIVE FRESHWATER FISHES ARE IN TROUBLE




SOURCES: R. M. Quiñones and P. B. Moyle, "California's Freshwater Fishes: Status and Management," *FiSHMED Fishes in Mediterranean Environments* (2015). P. B. Moyle, J. D. Kiernan, P. K. Crain, and R. M. Quiñones, "Climate Change Vulnerability of Native and Alien Freshwater Fishes of California: A Systematic Assessment Approach," *PLoS One* 8 (5), doi:10.1371/journal.pone.0063883.

NOTES: The figure shows freshwater native fish status based on field surveys. Bars display the number of fish species for which adequate information for evaluation was available in the specified time period. Predicted status in 2100 assumes continuation of current trends, with added stress from climate change. Extinct means no longer found in California; highly vulnerable means highly vulnerable to extinction by 2100; less vulnerable means less vulnerable to extinction than the previous group; least vulnerable means very low vulnerability to extinction.

## Environmental water use is not well understood

Water counted by the state as “environmental” serves a variety of purposes. Although much of this water is not in direct competition with other uses, a growing volume of water is being dedicated to protecting endangered species or water quality. This causes controversy because it can reduce water available for other uses. A better understanding of environmental water use can help inform future decisions about water management.

- **Water that stays in rivers, streams, and wetlands is assigned to the environment.**
  There are four broad types of environmental water: water that flows in rivers protected as “wild and scenic” under federal and state laws, water needed to maintain aquatic habitat within streams, water that supports wetlands for migratory birds, and water needed to maintain water quality. Water categorized as environmental accounts for half of state use; farms (40%) and cities (10%) make up the other half.

- **Most environmental water does not affect other uses.**
  Most environmental water occurs in remote North Coast rivers where there is little competition for use. In the rest of California, where water is shared by all three sectors, environmental water represents 33 percent of all uses (versus 53% for farms and 14% for cities). In these regions, water dedicated to the environment may reduce water available for other uses.

- **Environmental water often achieves multiple benefits.**
  In the Central Valley, most flows in wild and scenic rivers are captured by reservoirs and reused downstream. In many rivers, minimum flow standards that help fish and other species are set to maintain water quality for drinking water and irrigation. For instance, in the Sacramento–San Joaquin Delta, freshwater outflows (viewed by some as water “wasted to the sea”) also protect Delta water quality for farms and cities. In addition, environmental water that goes to wetlands and floodplains recharges groundwater basins.

- **Droughts heighten conflicts over environmental water allocations.**
  Because the environment relies principally on surface water, it experiences larger cutbacks during droughts than farms and cities, which can often pump extra groundwater when rivers are low. In some places, this extra pumping further reduces streamflows and harms fish. Droughts also put pressure on regulators to relax environmental standards in order to boost supplies. In 2014 and 2015, the state approved requests to reduce environmental flows and relax salinity standards in the Delta so that water exports for farms and cities could be increased.

## California needs to make environmental water use more efficient

Although more freshwater flows will likely be required to improve ecosystem conditions in some regions, new approaches to ecosystem management are also needed.

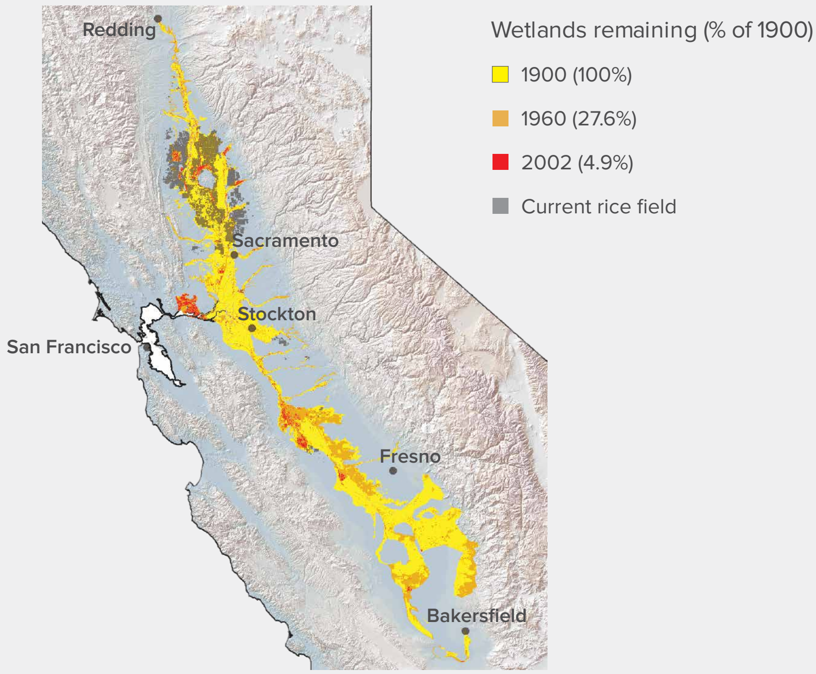
- **Reduced flows are not the only source of ecosystem stress.**
  Habitat loss, water pollution, invasive species, and fishery and wildlife management practices also need to be addressed. It is not possible to undo all the ecological changes that have occurred over decades of human water and land use. Environmental managers and regulators need to find strategies that adapt to changing conditions.

- **Environmental water can get more “pop per drop.”**
  Significant environmental improvements can come from managing water in ways that mimic natural flow variability, even with smaller flow volumes. Also, a drop of water may have very different environmental benefits depending on where it is used. In some places, a little water—applied in the right place at the right time—can go a long way toward protecting species.

- **Restoring habitat requires water *and* land.**
  Riparian zones, floodplains, and wetlands require periodic flooding to provide high-quality habitat. This can be accomplished by changing the timing of releases from reservoirs and removing or setting back levees. Selective removal of dams can also restore fish access to high-quality upstream habitat. Some dams are no longer useful for water supply, flood control, or hydropower purposes because of silt buildup or other factors. To improve habitat, a large dam was just removed on the Carmel River, and four more are planned to come down on the Klamath River.

- **Farming can be wildlife friendly.**
  Sacramento Valley rice farms now provide essential habitat for migratory waterfowl. Corn and alfalfa fields support many other types of birds. The Yolo Bypass offers habitat to birds and juvenile salmon, while supporting rice farms and protecting Sacramento from flooding. Farmers face economic pressure to shift to crops that have low habitat value but earn higher revenues and profits, such as fruits, nuts, and vegetables. They may require financial incentives to keep practicing wildlife-friendly agriculture.
- **Reliable funding for environmental management is a key hurdle.**
  Bond funds, while helpful, are short-lived and project-based. The state needs a new approach to funding public-trust resources (including fish and wildlife), such as a small surcharge on water use.

**CENTRAL VALLEY RICE FIELDS NOW PROVIDE WILDLIFE HABITAT IN PLACE OF NATIVE WETLANDS**




SOURCE: Ellen Hanak et al., *Managing California's Water: From Conflict to Reconciliation* (PPIC, 2011), Figure 1.2.

NOTES: Wetlands in 1900 include yellow, orange, and red areas; the 1960 wetlands include orange and red areas. Sacramento Valley rice fields perform some seasonal wetland functions for migrating birds and terrestrial and riparian species such as the giant garter snake.

## Looking ahead

California has a long-term economic and social interest in supporting native biodiversity in freshwater ecosystems. But new approaches are needed to make environmental water allocations more effective.

**Prepare for droughts and climate change.** California should commission a biodiversity task force to develop a strategy to make species and ecosystems less vulnerable to drought and a changing climate. Promising approaches include identifying and prioritizing environmental strongholds that can support species during droughts and warm periods (such as streams fed by cold water springs) and developing mechanisms to purchase or lease water for environmental uses.

**Prioritize watersheds for conservation management.** The state should also develop a freshwater ecosystem conservation plan that identifies high-priority watersheds for conservation management. A systematic approach—which goes beyond single-species management—would greatly improve the chances of survival for the state's native fishes and other species dependent on fresh water.

**Identify environmental water needs.** For many rivers and wetlands, the state has not identified the quantity, quality, and timing of water required to sustain ecosystem health. Establishing clear environmental water targets is critical for prioritizing conservation actions and providing guidance to agencies responsible for balancing human and ecosystem water needs.

**Acquire water rights for the environment.** To increase management flexibility, the state should purchase existing water rights (or provide incentives for private parties to acquire them) and dedicate those rights to environmental uses. Environmental managers should be authorized to lease these rights to raise funds for other restoration projects. Such practices are working well in Australia, which faces similar water management challenges. Proposition 1, the water bond approved in November 2014, makes available up to $200 million for this purpose. While helpful, the sum is insufficient.

**Reform environmental permitting.** Environmental water is most effective when paired with habitat restoration. However, obtaining permits for restoration is unnecessarily difficult because of multiple, often conflicting, agency reviews. The Habitat Restoration and Enhancement Act of 2014, which reduces permitting hurdles for private land owners seeking to improve habitat, is a model worth expanding.

**Promote projects with multiple benefits.** Water can simultaneously provide benefits to people and nature. For example, wildlife-friendly farming can support ecosystems while maintaining the economic viability of farms. Cooperation on storing and releasing water from reservoirs can benefit fish while meeting downstream users' needs. Investing in healthy watersheds can help protect drinking water supplies and provide recreational opportunities.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# Water for Farms

PPIC WATER POLICY CENTER

OCTOBER 2016

## California's farms face growing water management challenges

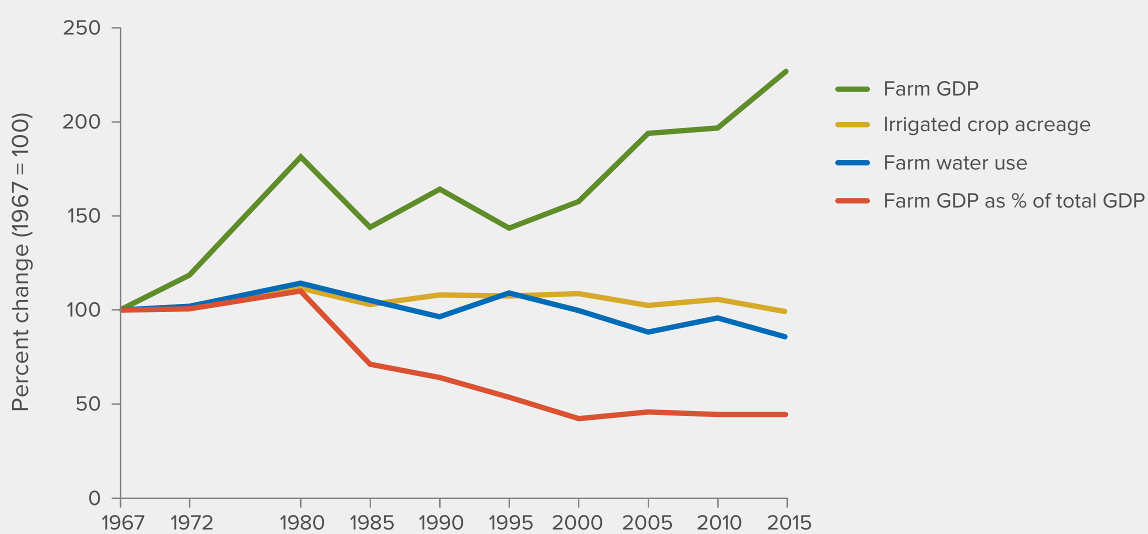
California is an agricultural powerhouse—the nation's largest farm state and a world market leader, with 2015 sales of $47 billion. California's dry summers make irrigation essential. To irrigate some 9 million acres of crops, farmers use about 40 percent of California's available water, compared with 10 percent used in cities. The remaining half is categorized as environmental water.

Farmers have steadily improved productivity and shifted to crops like fruits, nuts, and vegetables that generate more revenue and profit per unit of water, as well as more farm jobs. Adjusted for inflation, the value of farm output and related food processing has more than doubled since the late 1960s despite little change in acreage or irrigation water used. But California's nonfarm sectors have grown faster, and agriculture is now around 2 percent of the state economy.

Water is a perennial concern. Many farmers get surface water from federal, state, and local projects. Many also pump groundwater. In some regions, groundwater reserves have been shrinking for decades. Since the 1980s, environmental regulations have limited—and sometimes cut—the surface water supplies, thereby encouraging more groundwater pumping. Pumping increased dramatically during the latest drought.

The drought has exposed farming's growing vulnerability to water shortages. Climate change is expected to make severe droughts more likely. New groundwater legislation, local efforts, and Proposition 1—the state water bond approved in 2014—provide opportunities to strengthen water management.

### THE VALUE OF FARM WATER IS RISING, BUT FARMING IS DECLINING AS A SHARE OF THE ECONOMY




SOURCE: Author calculations using data from the US Bureau of Economic Analysis (total GDP), the US Department of Agriculture (farm GDP), the California Department of Water Resources (water and land use through 2010), and UC Davis (water and land use data for 2015, as summarized in Table A5 of Ellen Hanak et al., *What If California's Drought Continues?* [PPIC, 2015]).

NOTES: GDP is California's gross domestic product, adjusted for inflation. Farm GDP is for primary crop and animal production and other farm-related income. Irrigated crop acreage includes land used for multiple crops within a year. Farm water use is the amount applied to fields. Net water use—the volume consumed by plants, evaporated, or discharged to saline waters—is lower, but reliable long-term estimates are unavailable. Pre-2000 water use estimates are adjusted to levels that would have been used in a year of normal rainfall. Estimates from 2000 onward are for actual use in years with near normal precipitation, except 2015, a critically dry year. Estimates omit conveyance losses and active groundwater recharge.

## Farm water use is changing

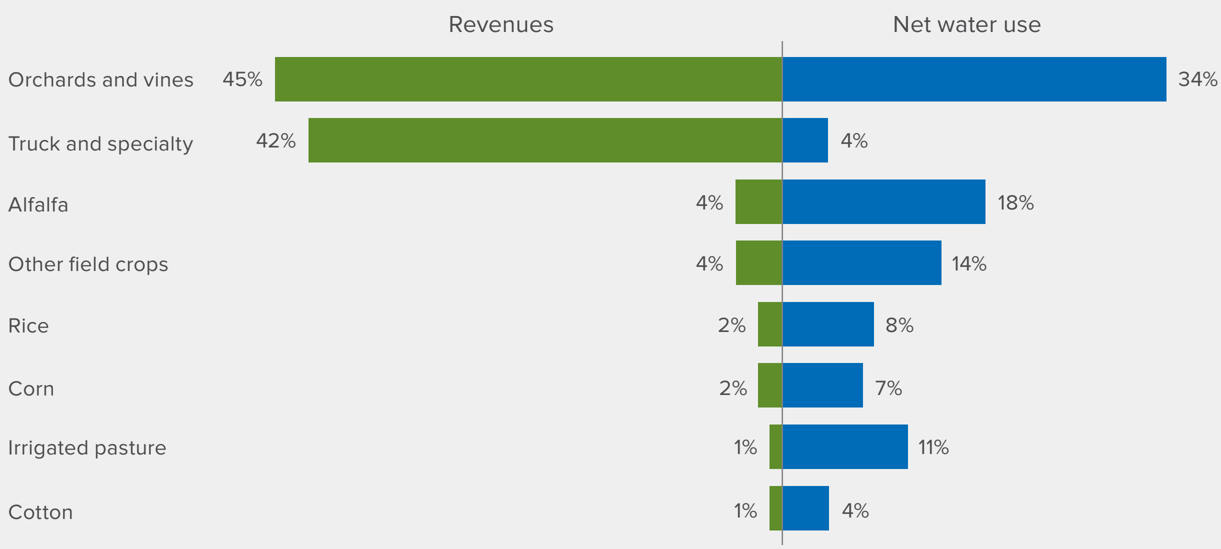
California farmers respond continually to changing market and technological opportunities. These adaptations have boosted earnings and raised the value of scarce farm water supplies. But they have also brought new challenges.

- **Acreage is shifting toward higher revenue—but less flexible—crops.**
  California farmers have shifted markedly to fruits, nuts, vegetables, and nursery crops, which made up roughly 47 percent of irrigated crop acreage, 38 percent of farm water use, and 86 percent of crop revenue in 2012. By comparison, forage crops, such as alfalfa and corn silage—inputs for the important dairy and cattle industries—generate less revenue per unit of water. In the water-limited San Joaquin Valley, orchards grew from 34 percent to 40 percent of irrigated cropland between 2000 and 2010. The rise in fruit and especially nut orchards—which must be watered every year—has reduced farmers' ability to withstand intermittent water shortages. Because silage for dairies is costly to transport, corn is also fairly inflexible in that region, at 12 percent of total acreage.

- **Water delivery and field irrigation efficiencies are rising.**
  Many irrigation districts have been upgrading delivery systems to provide more flexible service and minimize canal spills and seepage. Farmers have been switching from flood irrigation to drip- and micro-irrigation systems, which improve crop yields and quality, reduce the application of water and chemicals, and help prevent chemicals from seeping into aquifers. However, in some regions—especially the San Joaquin Valley—these upgrades have the unintended consequence of lowering groundwater levels. That is because irrigation water not consumed by crops is a major source of groundwater recharge.

- **Groundwater is becoming more important—and more threatened.**
  Even before the latest drought, San Joaquin Valley farmers were pumping more groundwater to replace surface water previously shipped through the Sacramento–San Joaquin Delta or diverted from the San Joaquin River, as both those sources have been decreased to support endangered fish habitats. Groundwater is also being used to establish new orchards in previously unirrigated areas that lack surface water. High returns on orchard crops have made it profitable for farmers to invest in deeper wells, aggravating groundwater depletion. Groundwater quality is also declining in many areas, threatening crop yields and drinking water.

### CALIFORNIA HAS A DIVERSE CROP MIX, WITH WIDE VARIATIONS IN REVENUE AND WATER USE




SOURCE: Author calculations using data from the California Department of Water Resources (2010 water use) and the National Agricultural Statistics Service (2012 crop prices). Revenues are estimated using the Statewide Agricultural Production (SWAP) model.

NOTES: Total 2010 net water use for crops was 20.2 million acre-feet (maf), versus 29 maf applied to fields. Total 2012 crop revenues were $36.4 billion; dairy cattle and milk brought in $6.9 billion and other animal production brought in $2 billion. Alfalfa, corn, and irrigated pasture are key inputs for animal production. Crop revenues do not sum to 100 percent because of rounding. Truck and speciality includes non-tree fruits, vegetables, flowers, and garden plants.

## California needs to manage farm water for the long term

California will continue to be an agricultural leader, but it must keep adapting and focus on sustainably managing both water quantity and quality. To achieve this goal, farmers will likely farm less acreage but more intensively.

- **The latest drought has exposed strengths and vulnerabilities.**
  During 2014, surface water deliveries to Central Valley farmers fell by over a third, and in 2015, by nearly half, with reductions varying hugely depending on location. The drought caused hardship in some farm communities. In each year, about half a million acres were fallowed, costing the farm economy nearly $2 billion, along with as many as 10,000 full- and part-time jobs. But the losses would have been far greater if farmers had been unable to pump much more groundwater than usual or buy water from other farmers. Groundwater pumping replaced roughly 70 percent of the lost surface water.

- **Better groundwater management is a top priority.**
  Groundwater is California agriculture's largest water reserve in dry years. But long-term declines in groundwater levels will limit its availability in many farming areas. The Sustainable Groundwater Management Act of 2014 requires local water users to create basin-level agencies with the ability to monitor, manage, and charge for groundwater pumping and the cost of recharge programs. The state can step in if local water users fail to put in place sustainable management plans. Implementation—which can include increasing recharge and/or reducing pumping—will likely require better measurement of pumping and the allocation of pumping rights to groundwater users. Today, landowners can generally pump without quantity restrictions.

- **Better integration of surface water and groundwater management is key.**
  Many irrigation districts already manage surface and groundwater resources jointly to encourage groundwater basin replenishment in wet years. These local efforts need to increase. For instance, basins can be recharged with recycled wastewater from neighboring urban areas. Pilot programs are also exploring opportunities for spreading winter and spring floodwaters on fields, including those normally watered by drip irrigation. By shifting the timing of reservoir releases, federal, state, and local agencies can increase the availability of surface water for underground storage. Investments in new storage and conveyance can increase system flexibility and boost water supplies.

- **Water markets provide essential flexibility.**
  California farmers have been active participants in the state's water market for more than two decades. This market has supported productive farming areas that lack reliable supplies of their own, and it has helped to keep orchards alive during the latest drought. Markets also make water available for the environment and growing urban areas, while providing revenue to farmers who sell water. Localized trading of groundwater pumping rights within basins can help implement the new groundwater law by allowing farmers who need more water for their orchards to compensate other farmers for reducing use.

- **Agricultural stewardship can do more to support the environment.**
  Further improvements in irrigation practices, and in the management of agricultural chemicals and drainage, will reduce harmful discharges. Beneficial on-farm practices that provide habitat for California's fish and wildlife also merit expansion. Programs may be warranted to compensate farmers for providing habitat services on their lands.

## Looking ahead

Farmers and irrigation districts are the frontline stewards of agriculture's future, but the state and federal governments can provide technical, regulatory, and financial support to help California agriculture adapt to changing conditions.

**Support local groundwater management efforts.** Proposition 1 provides $100 million to help implement the new groundwater law. Legislation enacted in 2015 will make it easier to allocate pumping rights. These rights should be tied to recharge sources. All landowners should share the recharge from natural precipitation, while irrigation districts should retain rights to water they bring into the basin. Local plans will also need to adjust pumping rights when farmers make efficiency upgrades to keep these investments from reducing long-term supplies.

**Improve information flows.** Data on groundwater use, water use by crops, and other key information about agricultural water management are still fragmented—and in some areas rudimentary. California also lags behind some other western states in using advanced technology, such as remote sensing, that can enhance or replace sometimes costly data collection on the ground. Developing good accounts to track rights, pumping, and recharge will be essential for successful groundwater management. Informing growers about efficient management options can also yield dividends.

**Strengthen and streamline water markets.** State and federal agencies have expedited water transfers during the latest drought. However, California would benefit greatly from clarifying the conditions under which water transfers can be carried out without causing harm to the environment or other water users, and from simplifying the approval process.

**Develop funding sources to improve water reliability.** Proposition 1 will provide up to $2.7 billion to fund the public benefits of new surface and groundwater storage, including ecosystem, recreation, and flood protection improvements. Water tunnels beneath the Delta are another key infrastructure project under consideration. Tunnels would be expensive, but the resulting improvements in the reliability and quality of water supplies may make it worth the investment for some farmers and urban residents.

**Support farmworker communities.** Proposition 1 and some federal programs can help fund safe drinking water for rural communities where groundwater is contaminated by nitrate from farming and other contaminants, or where shallow domestic wells have gone dry from falling groundwater levels. Farmworkers are also vulnerable to losing jobs, commuting longer distances, or having their hours reduced when cropland is fallowed due to water scarcity. The state has provided emergency financial and food assistance to farmworker communities during the latest drought. Beyond that, the state should support workforce development programs in farm communities.

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