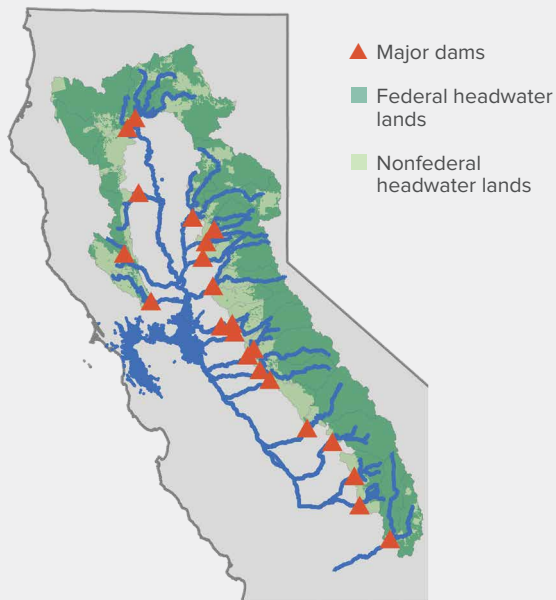


## California needs to manage its main water source more effectively

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.

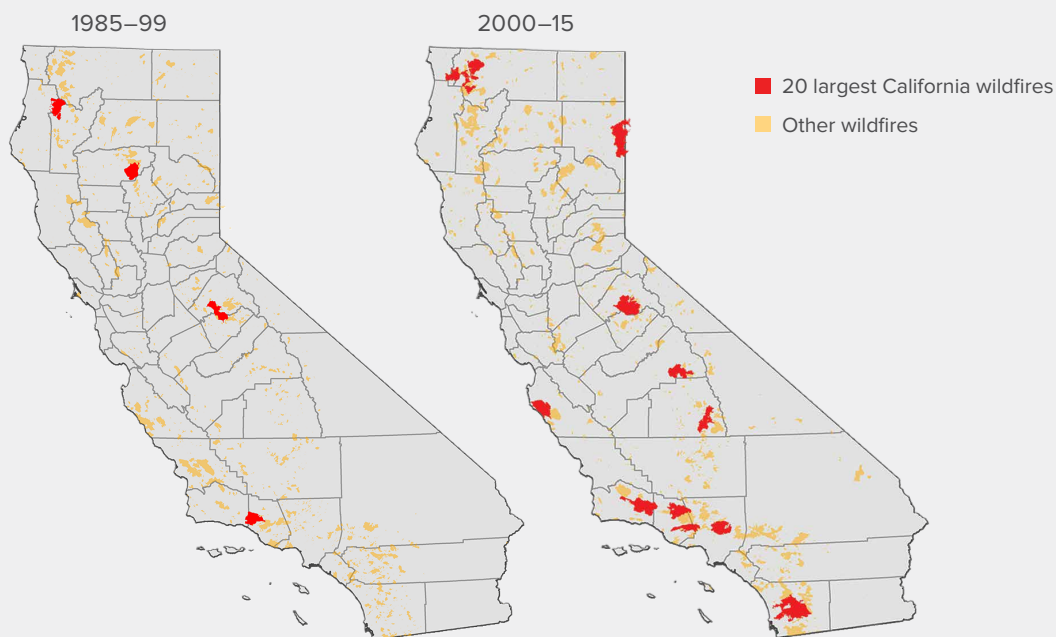
- Homes and suburbs are expanding into areas with high fire risk.

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.

## CONTACT A PPIC EXPERT

Jeffrey Mount  
mount@ppic.org

Ellen Hanak  
hanak@ppic.org

## CONTACT THE RESEARCH NETWORK

Van Butsic, vanbutsic@berkeley.edu  
Ted Grantham, tgrantham@berkeley.edu  
Yufang Jin, yujin@ucdavis.edu  
Scott Stephens, sstephens@berkeley.edu  
Joshua Viers, jviers@ucmerced.edu

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Public Policy Institute of California  
500 Washington Street, Suite 600  
San Francisco, CA 94111  
T 415.291.4400 F 415.291.4401  
**PPIC.ORG/WATER**

PPIC Sacramento Center  
Senator Office Building  
1121 L Street, Suite 801  
Sacramento, CA 95814  
T 916.440.1120 F 916.440.1121



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