FACT SHEET

Fire and Water in the Western United States

How Worsening Wildfires Threaten Water Resources in the West

HIGHLIGHTS

Escalating wildfires across the western United States threaten water resources for millions of people. By altering how precipitation and water move through ecosystems, wildfires can increase the risk of erosion and landslides and disrupt water quality and availability. Climate change is expected to further worsen wildfires, but local, state, and federal actions can help protect against the threats these fires pose to water resources. Reductions in heat-trapping emissions, active forest management, and investments in climate-resilient water infrastructure would limit the risks wildfires pose to the region's already limited water resources.

In recent years, severe wildfires, drought, and postfire flooding and landslides have exposed the vulnerabilities of communities, ecosystems, water resources, and economies in the western United States to worsening climate extremes. Across the West, wildfire season is longer than it has been historically, and wildfires have grown in both size and severity over the last half-century—trends expected to worsen with continued warming from human-caused climate change.

Wildfires threaten lives, reduce air quality, and release large quantities of heat-trapping gases by burning soil, trees, and other vegetation. Because burning alters ecosystems, soils, and human infrastructure, wildfires pose profound risks to the quality and availability of water in the western United States. Scientific evidence shows that fires can increase the load of sediments and toxins in rivers and streams, heighten the risk of dangerous mudslides and debris flows, and lead to the contamination of drinking water.

Although water is a limited and vulnerable resource in the West, many of the potential impacts of wildfire on water resources go underappreciated and unnoticed by regional policymakers. However, scientific research and experience-based knowledge from wildfire-prone regions around the world have shown that local, state, and federal policies can help to minimize the impacts of wildfires on our vital water resources.

Andrew Selsky/AP Photo

A volunteer unloads drinking water for wildfire evacuees in Oregon in 2020. Wildfires not only pose immediate disruptions to water access, but also can affect water quality and quantity for years or even decades after a fire has been extinguished.

Union of Concerned Scientists

History of Western Wildfires

Climate change, together with the displacement of Indigenous peoples and the resulting changes in land use and the handling of fire, has led to an increase in the frequency and severity of wildfires across the western United States (Prichard et al. 2021; Westerling 2016; Westerling et al. 2006). Historically, many of the region's landscapes burned regularly at low severity by fires set intentionally by Indigenous people or ignited by lightning. However, more than a century of intentional fire suppression in forests and surrounding ecosystems has led to a buildup of vegetation that normally would have burned in those low-severity, regularly occurring fires (Hessburg et al. 2019). At the same time, unfettered human development has expanded beyond traditionally inhabited areas and into wildfire-prone areas. This expansion is driving up the number of wildfires sparked by human activity as well as the potential for people to be affected by those wildfires.

Hotter, drier conditions fueled by climate change are further heightening the incidence and intensity of wildfires. Earlier spring thaws (Westerling 2016), record-breaking heat waves, and human-influenced "megadroughts" (Williams et al. 2020) all prime the West for wildfire. In addition, shifts in seasonal weather patterns (Goss et al. 2020; Swain 2021) and an increase in vapor pressure deficit, which is a measure of the atmosphere's ability to draw moisture from plants and soils (Williams et al. 2019), have increased the likelihood of tinderbox forest conditions and prolonged wildfire seasons (Abatzoglou and Williams 2016). These recent trends have helped to enable very large fires, such as Northern California's August Complex Fire, which in 2020 burned more than 1 million acres (Zhuang et al. 2021).

Wildfires and Watersheds

Wildfires visibly harm our air quality, infrastructure, and landscapes, but they also harm our water resources in ways that are less visible. Our water resources can be organized into streams, watersheds, and river basins. Multiple streams form a watershed, and multiple watersheds form a river basin. Large river basins, such as that of the Colorado River, can drain water from nearly 250,000 square miles—an area greater than Arizona and New Mexico combined—and supply drinking water for millions of people. Smaller watersheds, such as the Pueblo San Diego watershed in California, drain fewer than 100 square miles. Within watershed areas, water is stored in surface systems such as rivers and streams, below ground in groundwater aquifers, or on the landscape in soils and trees (McDonnell et al. 2018). These different stores of water are interconnected, but water enters and exits each through different processes. As a result, wildfires affect each part of the water system differently.

Watersheds contain a range of ecosystems, which include organisms that provide critical services for maintaining safe and clean drinking water. Trees and other plants stabilize soil through their root systems and regulate the amount of water and nutrients available in the broader ecosystem through their own water use. Soils act as filtration systems by absorbing precipitation and removing potential pollutants. In streams, insects, small animals, and microorganisms, such as bacteria and fungi, break down organic material and dissolved compounds, further eliminating substances that contaminate drinking water. Wildfires disrupt these processes and, as a result, threaten water availability and quality—sometimes for a period of years or even decades after a fire has been extinguished (Niemeyer, Bladon, and Woodsmith 2020; Rhoades et al. 2019; Robinne et al. 2021).

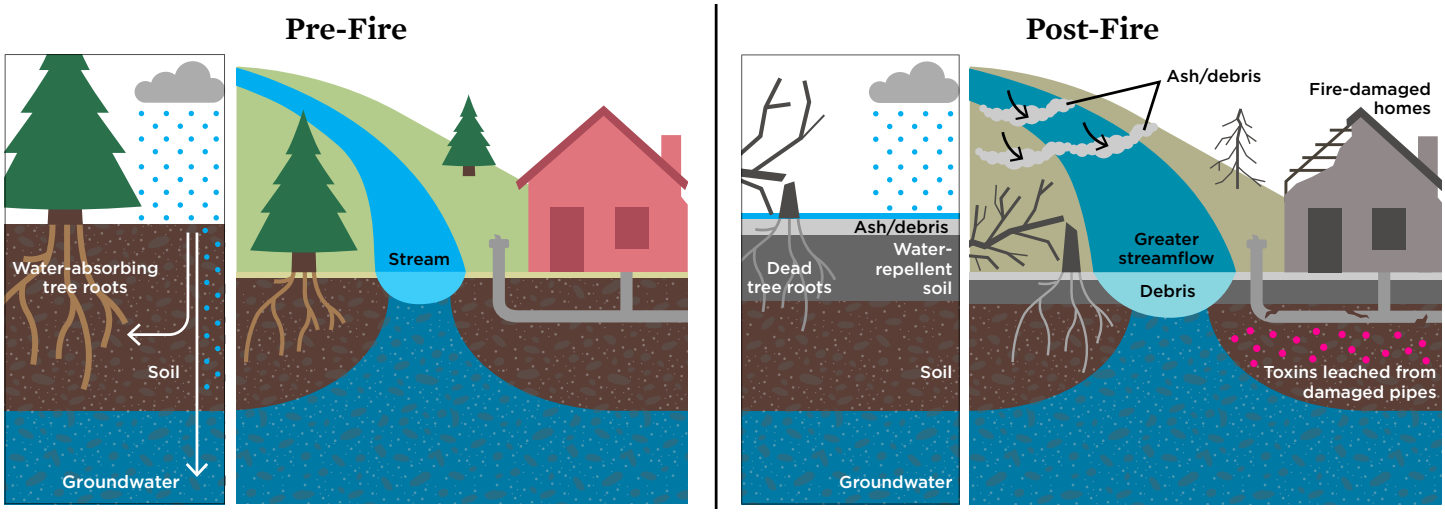
Wildfires and Water Quantity

A fire that burns a watershed can kill the vegetation and alter the soil within that watershed. With high-severity wildfires, more than 90 percent of the vegetation in the affected region can be killed. The roots of these plants no longer stabilize the soil nor do they take up water (Figure 1). Therefore, more water can leave the forested areas and flow into nearby rivers and streams, increasing streamflow (Bart 2016; Hallema et al. 2018; Sankey et al. 2017; Williams et al. 2022). In severely burned ecosystems that experience heavy rainfall, these processes increase the risk of flooding, landslides, and debris flows, in which mud, vegetation, and boulders are carried downstream by water and gravity (Rengers et al. 2020). Such cascading disasters impede community recovery due to the destruction of homes and infrastructure and the loss of roads—or access to them—as occurred in California in 2018, when Montecito experienced fatal mudflows during the rainy season following the Thomas Fire of late 2017 (Figure 2, p. 4; Oakley et al. 2018). Similarly, mudslides closed Interstate 70 in 2021 in areas burned during Colorado's Grizzly Fire in 2020.

The regrowth of plants after a fire can temper this excess streamflow and reduce the risk of subsequent disasters, but regrowth can be jeopardized by runoff and erosion after severe wildfires, enabling species shifts or the establishment of a new and different ecosystem altogether (Coop et al. 2020). Further, climate change is expected to alter rainfall patterns in the West. More frequent extreme rain events, precipitation falling more as rain than snow, and large swings from very wet to very dry years are expected to heighten these fire-induced effects on water supply (Persad et al. 2020).

The consequences of wildfires on water supply are most pronounced in the immediate vicinity of a fire; however, changes attributed to wildfires have been observed up to 100 miles from a burn (Reale et al. 2015). The magnitude of these effects is strongly influenced by the size and severity of a wildfire, with

FIGURE 1. Wildfires Affect Water Quality and Availability



By changing soil properties, killing vegetation, and damaging roots, wildfires can enhance erosion; increase the transport of soil, sediment, debris, and other material into waterways; damage water distribution systems; and reduce water quality.

the greatest damage occurring in large, severely burned areas. Regional precipitation patterns and trends, vegetation types, and other factors also determine postfire streamflow patterns (Hallema et al. 2018).

Wildfires can change conditions belowground as well by altering the amount of water in groundwater reservoirs, such as aquifers. Wildfires have been linked to net increases in groundwater levels; the increased flow of water into streams after a wildfire can serve to recharge—or replenish—groundwater (Bart and Tague 2017). However, wildfires also can reduce groundwater levels for up to two years by lessening the ability of soil to absorb the amount of water that would normally percolate into the groundwater (Johnk and Mays 2021). Challenges with data availability and consistency, though, have led to far fewer studies on how wildfires impact groundwater as compared to surface water. This lack of research highlights the need for future work on the relationship between groundwater and wildfire.

Roughly 60 percent of California's water supply comes from surface water sources such as rivers and lakes, while 40 percent comes from groundwater (Ortiz-Partida et al. 2020). The importance of groundwater, however, is increasing as climate change causes snowpack to dwindle and precipitation patterns to shift. Because of drought and the rising demand for water, groundwater reservoirs are increasingly overdrawn (Bart and Tague 2017). Humans are removing more water from aquifers than is being replenished by the natural seepage of rain and snow. As a result, wildfire effects on groundwater supply could have far-reaching consequences for the roughly 85 percent of Californians who rely partly or wholly on groundwater for their drinking water (Chappelle, Hanak, and Harter 2017) as well as for the state's groundwater-dependent agricultural industry.

Wildfires and Water Quality

During high-severity wildfires, high temperatures change the soil structure and chemistry in ways that make the soil more water repellant. The soil is less able to absorb precipitation, and water more easily flows over the soil surface, taking soil particles, sediment, and nutrients such as nitrogen and phosphorus with it (Figure 1; Ebel, Moody, and Martin 2012). In freshwater systems, large quantities of these same nutrients sometimes cause algal blooms that generate additional toxins that sicken people and aquatic animals if not removed during water treatment (Bladon et al. 2014).

While it is clear that wildfires regularly impact water quality, the consequences of a given fire vary depending on factors such as the type and condition of the affected ecosystem, historical frequency and severity of fires in the region, subsequent rainfall intensity, postfire landscape treatment, and local capacity to treat contaminated water or obtain water from alternative sources (Santos et al. 2019; Tran, Baribeau, and Sullivan 2021).

As people continue to move into and build communities in forested areas, the burning of cars, homes, and other infrastructure during wildfires releases toxic compounds that can contaminate water supplies (Abraham, Dowling, and Florentine 2017). Across the United States, public drinking water systems downstream of large wildfires have experienced high concentrations

FIGURE 2. Recent California Wildfires and Their Impacts on Water Resources

Camp Fire
Human infrastructure damage

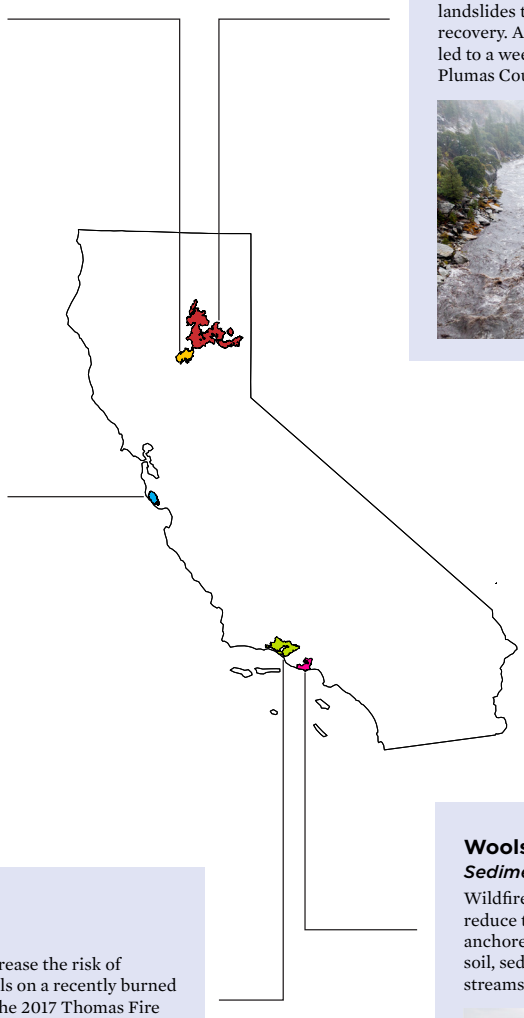
The 2018 Camp Fire burned pipes and other human infrastructure, releasing harmful chemicals and causing widespread contamination of drinking water. Two years after the fire, poor water quality remained a barrier to local recovery.

Dixie Fire
Landslides

Wildfires followed by heavy rains can lead to landslides that, in turn, threaten community recovery. A landslide after the 2021 Dixie Fire led to a weeks-long closure of Highway 70 in Plumas County.

CZU Lightning Complex Fire
Water contamination

The burning of both natural and human-built infrastructure in the 2020 CZU Lightning Complex Fire contaminated waterways and public water sources in the San Lorenzo Valley Water District with cancer-causing chemicals, including benzene.



Thomas Fire
Mudflows

Severe wildfires can increase the risk of mudslides when rain falls on a recently burned area. Heavy rains after the 2017 Thomas Fire caused mudslides that killed 23 people and destroyed 130 homes in Montecito.

Woolsey Fire
Sediment transport

Wildfires like the 2018 Woolsey Fire can reduce the stabilizing effects of plant roots anchored in soils, leading to additional ash, soil, sediment, and other debris washing into streams and lowering water quality.

Recent California fires have affected water resources in several ways, from enabling catastrophic mudflows to contaminating water delivery systems. How severely a wildfire affects water resources depends on many factors, including rainfall patterns and the type and condition of the ecosystems affected by the fire. Similar impacts have been observed in other western US states, as well as in countries around the world.

PHOTOS: NOAH BERGER/AP PHOTO (DIXIE FIRE); REED SAXON/AP PHOTO (WOOLSEY FIRE); LOS ANGELES FIRE DEPARTMENT/CREATIVE COMMONS (FLICKR) (THOMAS FIRE); JAMES FURTADO/SAN LORENZO VALLEY WATER DISTRICT (CZU LIGHTNING FIRE); CALIFORNIA NATIONAL GUARD (CAMP FIRE).

of compounds such as nitrates and arsenic, which, in some cases, have risen above levels considered safe by the Safe Drinking Water Act (Pennino et al. 2021). Many of the compounds found in wildfire-affected water are carcinogens. Being exposed to or ingesting these compounds can be harmful to human health, with groups vulnerable to poor health outcomes, such as infants and people with preexisting health conditions, being particularly at risk (Hohner et al. 2019).

Water pipes destroyed by wildfire can also serve as a source of contamination of the water supply. These pipes are typically not constructed to withstand high temperatures, which can lead to widespread damage and water contamination during and after a wildfire. For example, the 2018 Camp Fire that destroyed Paradise, California, decimated the town's water infrastructure and rendered the local water distribution network contaminated for many months after the fire occurred (Proctor et al. 2020).

Wildfires, Water, and Communities

Access to clean drinking water is a human right, and communities struggle without potable water. While in-home treatment methods—such as filtering water or purchasing bottled water—provide temporary fixes when people cannot access clean drinking water, these measures are available only to those with the resources and income required to acquire water at a substantially greater cost (Ortiz-Partida et al. 2020). Interim water tanks can provide mobile, potable water to impacted communities but also are not long-term, sustainable solutions. Tribal and agricultural communities may be particularly affected by water shortages, which may lead to job losses. Also, low-quality water may impact the taste, growth, and yield of crops (Ortiz-Partida et al. 2020).

For communities dependent on or downstream of burned areas, wildfires can cause particularly serious water quality and availability issues. While water treatment facilities offer an opportunity to remove contaminants and sediments, persistently poor water quality can make water treatment plants less effective over time and come at a substantial cost to local utilities and communities (White et al. 2006). For instance, following a large wildfire in 2003, the city of Denver, Colorado, spent $27 million to rehabilitate their water infrastructure, from ecosystem restoration to sediment removal.

Interconnected Solutions

Across the western United States, wildfires threaten access to unpolluted water resources for millions of people. Reducing that threat will require both limiting future climate change through the decrease of heat-trapping emissions and equipping local and state systems with the means to help maintain safe and adequate water supplies even in the face of worsening wildfires.

Human-caused climate change has been linked to a near doubling of the area burned by US wildfires between 1984 and 2015 (Abatzoglou and Williams 2016), with projections indicating that the observed increase in large fires will continue without a rapid reduction in heat-trapping emissions (Juang et al. 2022). Still, research shows that ample opportunities exist for policymakers at the local, state, and federal levels to prevent catastrophic climate change by drastically reducing emissions and that such emissions reductions would limit how much worse wildfires become in the future (Brey et al. 2021; Gao et al. 2021; IPCC 2022).

Along with cutting emissions, adaptation measures are critical for lessening the severity of wildfires. Interventions that reduce wildfire severity and the likelihood of crown fire—fires burning into forest canopies—protect water supplies. Treatments that reduce excess fuel loads in forests, such as vegetation removal (thinning) and intentional, controlled burning, can restore forest conditions that support the positive benefits of wildfire without impacting water quality or availability (Stephens et al. 2021).

Prescribed fires do not cause the same negative effects on water resources as wildfires, and low-severity prescribed burns limit soil heating and thus reduce the probability of creating soils that repel water and lead to cascades of erosion, runoff, and debris flows (Bladon et al. 2014). Intentional fires also kill far fewer trees, and their roots continue to stabilize soil and absorb water (Klimas et al. 2020). Similarly, the reintroduction or expansion of cultural burns by Indigenous communities can produce ecological benefits (Boisramé et al. 2019; Long, Lake, and Goode 2021). Data from tree rings show that forested lands in New Mexico did not experience widespread fire prior to the late 1500s, when colonizers displaced the Indigenous communities that had inhabited the land for centuries (Palmer 2021). Researchers attribute this finding to the practices of clearing land areas around villages and collecting wood for use as fuel, which served to stop naturally burning fires in their tracks. In California, Indigenous people regularly and intentionally burned their lands and did so during the times of year when fire was less likely to spread uncontrollably (Cowan 2020). While these treatments represent promising opportunities to reduce the impact of wildfire on water quality, they also require consistent, regular reburning or retreatment to maintain their benefits (Prichard et al. 2021).

Some measures to manage the risk of wildfire on water are taken after a fire occurs. Treating landscapes can help to control both water quality and availability. For instance, salvage logging, or timber removal, and replanting can reduce erosion and decrease runoff, but these treatments must be applied in an ecologically appropriate way (Niemeyer, Bladon, and Woodsmith 2020; James and Krumland 2018). Some watersheds are particularly vulnerable given the forest type, forest management history, and

population size supported by their water resources, so proactively identifying and prioritizing treatment in these areas is critical.

Human infrastructure is also a part of the solution. For example, aboveground power lines are a known ignition source. Burying these lines, while very costly, reduces the risk of ignition, as long as the measure is taken as part of a holistic approach that also addresses underlying forest conditions, climate change, and overall grid resilience. Similarly, proactive adaptation within water supply systems helps communities prepare for and minimize the risk of wildfire-related disruptions. Water treatment plants can source drinking water from multiple sources, invest in dynamic treatment capabilities, provide postfire erosion control, and install sediment barriers to impede the transport of sediment loads further downstream (Nunes et al. 2018). In addition, municipal water plants can be made more climate proof by scaling up sediment removal capacity in at-risk areas, as was done in Australia following severe wildfires in 2003 (White et al. 2006).

Policies that support these necessary treatments, interventions, and adaptation measures are imperative. The recent federal infrastructure bill provided more than $31 million to enhance forest and watershed resilience, including funding to facilitate the expansion of traditional burning. Local and state governments can create robust systems to monitor water conditions, communicate with affected individuals about how to best protect their communities and families, and subsidize at-home water testing capacity and high-quality filtration systems (Tran, Baribeau, and Sullivan 2021). Communities can retrofit old homes and mandate the installation of heat-resistant pipes in new construction. Such measures can limit the potential for contamination of water delivery infrastructure and consumption of unsafe water in areas with high wildfire risk (Pennino et al. 2021; Proctor et al. 2020).

By diversifying water sources, prioritizing forest management both before and after fires, and investing in flexible treatment capacity and water-quality monitoring, municipalities can strengthen the resilience of their water infrastructure. We must make these changes in the western United States to prepare our water systems for a changing climate and its projected impacts, particularly in California, Colorado, Oregon, and Washington, where wildfires in recent years have underscored the vulnerability of our forests and water supplies. If we do not limit human-caused climate change and adapt to escalating wildfire incidence and severity, water supplies across the West will continue to be at increasing risk into the future.

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