https://doi.org/10.5194/egusphere-2025-6193
Preprint. Discussion started: 13 January 2026

Title: Wildfire-induced disruptions to evapotranspiration, runoff, and water-balance closure across California's water supply watersheds

Authors:

Ziying Han[1], Han Guo[12]*, Michael L. Goulden[3], Roger C. Bales[12]

Affiliations:

[1] Department of Civil and Environmental Engineering, University of California, Berkeley, CA, USA

[2] Sierra Nevada Research Institute, University of California, Merced, CA, USA

[3] Department of Earth System Science, University of California, Irvine, Irvine, CA, USA

**Correspondence*: Han Guo (hguo7@berkeley.edu)

https://doi.org/10.5194/egusphere-2025-6193
Preprint. Discussion started: 13 January 2026

Abstract

Wildfire activity has intensified across forested mountain watersheds globally, yet the basin-scale hydrologic consequences of large, high-severity fires remain poorly quantified. Here we integrate four decades of satellite-derived evapotranspiration (ET), precipitation (P), full natural flow (FNF) records, and spatially explicit fire-perimeter data to evaluate how wildfire alters ET, basin outflow, and water-balance closure across major water-supply basins in California. High-severity fires consistently suppressed ET by 100–250 mm in the first postfire year, with recovery strongly modulated by vegetation traits, moisture availability, and disturbance recurrence. Structurally diverse and moisture-rich basins recovered 75% of prefire ET within 4–5 years, whereas drier, conifer-dominated systems required up to a decade. Although interannual P remained the dominant control on basin outflow, reduced ET partially offset drought-year declines in FNF within heavily burned sub-basins, indicating a localized compensatory effect. Water-balance analysis revealed systematic negative residuals (P − ET − FNF) during years with substantial fire disturbance, demonstrating measurable departures from steady-state closure. Basin-specific diagnostics showed that these deviations arise from both disturbance-driven hydrologic shifts and observational uncertainties, including precipitation underestimation and stream-gauge bias. Proportional and two-parameter adjustments improved closure across most basins, underscoring the need for disturbance-aware calibration in regional water-balance assessments. Collectively, our findings reveal that wildfires act as short-term hydrologic shocks that suppress ET, alter basin outflow patterns, and distort modeled water budgets across fire-prone headwater systems. Incorporating fire history, disturbance intensity, and ET-recovery patterns into hydrologic models and reservoir operations will be essential for improving postfire flow prediction and sustaining long-term water-supply reliability in an increasingly disturbance-affected climate.

Keywords: wildfire, evapotranspiration, runoff, forest disturbance, water balance.

https://doi.org/10.5194/egusphere-2025-6193
Preprint. Discussion started: 13 January 2026

1. Introduction

Wildfire activity across the western United States has intensified dramatically over recent decades, driven by rising temperatures, prolonged droughts, and shifts in vegetation composition associated with climate change and historical land-use practices (Abatzoglou & Williams 2016; Williams et al. 2019; Westerling 2016). In California, this trend is especially pronounced: fire seasons have lengthened, large high-severity events have become more frequent, and cumulative burned area has expanded across montane-forest ecosystems historically shaped by infrequent, low-intensity fires (Keeley & Syphard 2016; Miller & Safford 2012; Westerling et al. 2006). These compound disturbances not only restructure forest composition but also exert cascading effects on watershed hydrology, with implications for water-supply reliability, flood control, and downstream ecosystem services (Paul et al., 2022, Robinne et al., 2021).

The hydrologic consequences of wildfire are mediated by changes in vegetation cover, soil properties, and energy exchange. Canopy loss reduces interception and transpiration, while soil combustion and hydrophobicity may alter infiltration and subsurface flow pathways (Hallema et al., 2017). These changes affect evapotranspiration (ET), a dominant component of the terrestrial water budget, and modify the partitioning of precipitation (P) into basin outflow, recharge, and storage. In the short term, postfire ET typically declines due to vegetation mortality surplus, potentially enhancing surface and shallow-subsurface runoff. Over time, as vegetation recovers, ET may gradually return toward prefire levels. However, the rate and completeness of recovery depend on fire severity, postfire climate, and landscape context (Boisramé et al. 2017; Roche et al. 2020).

These shifts in hydrologic partitioning have significant implications for water supply in California, a state where water availability and demand are geographically misaligned. The majority of P falls in the northern mountains, while water use in the southern and central regions exceeds supply. To bridge this divide, California has constructed extensive redistribution infrastructure, including the Central Valley Project and the State Water Project (California Department of Water Resources, 2023). These systems rely heavily on consistent basin outflow from snow-fed mountain basins, many of which are now increasingly affected by high-severity wildfire. As fire disturbs vegetation cover, soil structure, and water fluxes in these source watersheds, the reliability of downstream supply may be undermined. Ensuring long-term water security in California will therefore depend not only on engineered conveyance systems but also on active management and protection of upstream hydrologic sources, particularly in fire-prone landscapes (Wayburn 2019).

ET is not only a dominant flux in the water balance but also a diagnostic indicator of ecosystem disturbance and recovery. It reflects both biological attributes (e.g., leaf area, rooting depth) and physical drivers (e.g., temperature, radiation), and responds dynamically to shifts in land cover

https://doi.org/10.5194/egusphere-2025-6193
Preprint. Discussion started: 13 January 2026

and climate (Roche et al. 2020). In managed mountain watersheds that support regional water supply, fluctuations in ET can serve as a sensitive indicator of ecosystem disturbance and hydrologic change, particularly following wildfire (Chung et al., 2024). Because ET integrates vegetation structure, physiological activity, and energy availability, fire-induced shifts in canopy cover or soil properties may propagate through the broader water cycle. Deviations between expected (P–ET) and basin outflow (FNF) therefore provide a window into how wildfire modifies vegetation water use, soil-water interactions, and basin-scale routing, highlighting the need to understand these processes to assess postfire hydrologic behavior (Guzmán-Rojo et al., 2024).

While many studies have explored fire–hydrology interactions using paired catchments, empirical regressions, or process-based models (Atwood et al., 2023, Bart & Tague, 2017, Bart, 2016), there remains a critical gap in basin-to-regional scale analyses that directly integrate disturbance history, satellite-derived ET, and observed basin outflow across water-supplying watersheds. The absence of such data-integrated assessments limits our ability to empirically trace how wildfire-driven vegetation loss and regrowth translate into hydrologic consequences, resulting in insufficient guidance for water managers to anticipate postfire changes in water availability and diagnose hydrologic anomalies in heavily disturbed source watersheds.

In this study, we address these knowledge gaps by analyzing wildfires, evapotranspiration, and observed basin outflow patterns over the last four decades across five major northern California watersheds that serve as critical water sources for the state. We combine fire-perimeter data from the California Fire and Resource Assessment Program (FRAP), gridded hydrologic data from the Center for Ecosystem Climate Solutions (CECS), and long-term FNF records from the California Data Exchange Center (CDEC). This integrated dataset enables us to evaluate: (1) how ET responds to and recovers from wildfires across watersheds with varying climate and terrain; (2) in what ways wildfires influence annual basin outflow in major water-supply basins; and (3) how wildfires and other factors contribute to water-balance-closure errors across basins, and how these imbalances can be diagnosed.

2. Methods

To assess how wildfires reshape ET, runoff, and basin-scale water balance across California's critical water-supply watersheds, we conducted an integrated fire–hydrology analysis that links disturbance history, remote-sensing-derived ET, and observed full natural flow (FNF) through annual mass-balance relationships. This approach directly operationalizes the three research questions outlined above by tracing postfire ET changes, evaluating wildfire influences on basin outflow (FNF), and examining the stability of the water-balance relation (P − ET versus FNF) under varying disturbance conditions.

2.1 Study areas

https://doi.org/10.5194/egusphere-2025-6193
Preprint. Discussion started: 13 January 2026

The Trinity, Upper Sacramento, McCloud, Pit, and Feather watersheds (Table 1, Figure 1) span the Cascade Range and the northern Sierra Nevada, with elevations from 200 meters to over 4300 meters (Mount Shasta). These watersheds drain into both Shasta Lake and Oroville Reservoir, and to the Sacramento River, and exhibit diverse topographic and climatic characteristics.

The Trinity, McCloud, and Upper Sacramento River watersheds lie in Northern California's Klamath-Cascade region and share steep mountainous terrain, deep incised canyons, and pronounced elevation gradients that support dense mixed-conifer forests, primarily composed of Douglas-fir, ponderosa pine, white fir, and sugar pine. These areas receive substantial winter precipitation, with high-elevation snow accumulation driving spring runoff. Mount Shasta strongly influences the McCloud and Upper Sacramento, contributing snowmelt and volcanic springs to cold, perennial flows. The Pit watershed features volcanic soils and groundwater-fed baseflow, but receives less precipitation overall and has a drier climate as it descends into lower agricultural valleys. In contrast, the Feather watershed in the Sierra Nevada covers forested western ridges and drier eastern slopes that occupy the Sierra Nevada rain shadow. Its hydrology is regulated by both volcanic terrain and infrastructure such as Oroville Dam, which manages downstream water deliveries and flood control.

These watersheds experience a Mediterranean climate, characterized by wet, cold winters and long, dry summers. Precipitation occurs primarily between November and March, with significant snowfall at higher elevations. Annual precipitation varies from around 400 mm in the lower elevations of the Pit watershed to over 3000 mm at higher elevations in the Upper Sacramento watershed. Winter temperatures range from -5°C to 9°C, while summer temperatures range from 10°C to 25°C, depending on elevation (PRISM Climate Group).

2.2 Data

To analyze fire impacts, we used the historical fire-perimeter dataset from the Fire and Resource Assessment Program (FRAP) (https://www.fire.ca.gov/what-we-do/fire-resource-assessment-program), focusing on 37 fires exceeding 10,000 acres between 1985 and 2020 (Table 2). Given the overlapping fire boundaries and shared ecological characteristics, we combined the Trinity, Upper Sacramento, and McCloud watersheds into a unified area (MTUS) to analyze fire impacts at a broader scale while maintaining hydrologic relevance. The Center for Ecosystem Climate Solutions (CECS) (https://california-ecosystem-climate.solutions) provides annual evapotranspiration (ET) and precipitation (P) raster products from 1985 to 2024 at 30-m resolution, derived from its internal water-balance calculations. These datasets have been widely used in previous studies (Guo et al., 2023; Chung et al., 2024).

Additionally, we obtained monthly full natural flow (FNF) data from the California Data Exchange Center (CDEC) (https://cdec.water.ca.gov/index.html). This dataset includes nine

https://doi.org/10.5194/egusphere-2025-6193
Preprint. Discussion started: 13 January 2026

continuously monitored sites within key water-supply watersheds, spanning from 1985 to the 2023 water year (Table 3). Using California's digital elevation model (DEM) and the Watershed tool in ArcGIS Pro, we delineated the contributing area for each FNF site to ensure consistent spatial matching among P, ET, and FNF.

2.3 Analysis

Quantifying ET reduction and recovery. We assessed the net ET response to wildfire by comparing burned and unburned areas before and after each fire. Areas within each watershed that have never experienced fire and that fall within a 500-m buffer surrounding each fire perimeter were defined as unburned areas. The net ET reduction in burned area was calculated as follows (Roche et al., 2020):

$$\Delta ET = \left(ET_{burned,\ postfire} - ET_{unburned,\ postfire}\right) - \left(ET_{burned,\ prefire} - ET_{unburned,\ prefire}\right) \quad (1)$$

where $ET_{burned,\ prefire}$ and $ET_{unburned,\ prefire}$ represent the mean ET in the five years preceding a fire, and $ET_{burned,\ postfire}$, $ET_{unburned,\ postfire}$ denote ET after the fire. When fewer than five pre-fire years were available, ET was averaged from 1985 until the year of the fire. This paired approach isolates the net disturbance signal by removing background climatic variability. For each watershed, we calculated the cumulative burned area and averaged ΔET over burned pixels to derive both per-area reduction (mm) and total volumetric change (km^3). ET recovery was tracked annually following each fire, and the time required for ET to reach 75% of the five-year pre-fire mean was used as the recovery benchmark.

Assessing wildfire impacts on runoff response. To evaluate how wildfires influence runoff generation in key water-supply watersheds, we examined the relationships among P, ET, and observed basin outflow (FNF) at the sub-basin scale. For each water year from 1985 to 2023, we used FRAP fire-perimeter data to calculate the annual proportion of burned area within each delineated sub-watershed. Corresponding annual P and ET values were obtained from CECS gridded datasets and area-averaged for each sub-watershed. Monthly FNF records from CDEC were aggregated to annual totals and matched to their upstream contributing areas. We then compared interannual variation in P, ET, and FNF for each sub-basin, focusing on whether reductions in ET, particularly in fire years, were associated with observable changes in FNF. We also evaluated potential lagged effects of wildfire by examining FNF anomalies one to three years after major fire events.

Diagnosing wildfire-induced disruption to basin-scale water balance. To evaluate whether wildfire influences water-balance closure, we compared annual residuals (P − ET − FNF) between high-fire years and non-fire years. High-fire years were defined as those in which more than 3% of the watershed area burned, a threshold chosen to identify years with substantial disturbance; all remaining years were classified as non-fire years. A Welch's two-sample t-test

https://doi.org/10.5194/egusphere-2025-6193
Preprint. Discussion started: 13 January 2026

was used to assess whether this difference reflects a systematic effect of wildfire on hydrologic closure.

To further assess basin-scale water balance, we compared annual P − ET with observed FNF for each sub-watershed. Under steady-state conditions ($\Delta S \approx 0$), P − ET should closely match FNF. Deviations from the 1:1 relationship were therefore used to identify potential imbalance and diagnose hydrologic processes such as enhanced deep infiltration, preferential subsurface routing, or unaccounted surface flows. For each site, we examined linear relationships among FNF, P, and P − ET. Where persistent discrepancies existed, we applied proportional adjustments to either P or FNF, depending on which correction produced improved alignment, to interpret which component contributed most to the imbalance. Watersheds were grouped into categories such as: basins exhibiting minimal imbalance; basins requiring scaling of P or FNF; and basins requiring both scaling and an intercept correction. These adjustments were used solely as diagnostic tools rather than for calibration or data fitting.

3. Results

3.1 **Quantifying ET reduction and recovery**

Wildfires caused substantial reductions in ET across burned areas, ranging from 40 to 440 mm yr^{-1} depending on fire severity and vegetation conditions, with the strongest suppression occurring in the first postfire year (Table 2; Figures 2). ET gradually increased in subsequent years as vegetation recovered.

Following the 1987 Lost Fire in the Pit basin, ET in the 92 km^2 burned area declined by 177 mm in the first postfire year (16 million m^3) and accumulated to 83 million m^3 over the eight years required for ET to return to 75% of its prefire mean. The 1992 Fountain Fire, also in the Pit and characterized by high severity and a large burned extent (244 km^2), produced a first-year ET reduction of 439 mm (107 million m^3) and a cumulative reduction of 960 million m^3 before reaching the 75% recovery threshold in year 12. In 1993, the combined effects of multiple fires resulted in a net ET reduction of 347 mm across burned areas in the Pit basin (Figure S1). In the Feather basin, the 2007 Moonlight Fire burned 263 km^2 and generated a first-year ET reduction of 325 mm (85 million m^3). ET recovered to 75% of its prefire value by year 8, yielding a cumulative loss of 452 million m^3 (Figure S2). The 2008 Motion Fire in MTUS caused a first-year reduction of 292 mm across 115 km^2, corresponding to 33 million m^3, and a cumulative impact of 79 million m^3 over the three-year recovery period (Figure S3). These examples show that both burn severity and burned area govern the magnitude and duration of ET reductions. Cumulative losses ranged from tens to hundreds of millions of cubic meters before partial recovery was achieved.

https://doi.org/10.5194/egusphere-2025-6193
Preprint. Discussion started: 13 January 2026

Net ET reductions at the watershed scale were derived using area-weighted averages across all fires within each basin. In the Pit basin, repeated fires between 1993 and 2011 produced substantial interannual variability in net ET reduction, yet total reductions remained relatively stable until 2005, declining steadily thereafter (Figure 2c). The 2012 fires burned 617 km², producing a larger total ET reduction (147 million m³) despite a modest per-area reduction (75 mm, Figure 2a-b). In the Feather basin, fluctuations in net ET reduction reflected both fire severity and the re-burning of previously affected areas. From 1988 to 2017, reductions ranged between 75 and 163 mm yr^{-1}, generally lower than in the Pit (Figure 2b). However, successive large fires between 2018 and 2020 sharply increased both burned area and basin-wide ET reduction. Although MTUS experienced fewer fires overall, its events were relatively severe. Three overlapping fires in 2018 burned 421 km² and led to a per-area ET reduction of 143 mm, equivalent to 420 million m³ of total reduction. Among the three basins, the Feather experienced the largest individual fires (Table 2), whereas the Pit experienced the slowest rate of ET recovery.

Across the 37 fires examined, post-fire ET recovery occurred steadily with time, but repeated fires often prevented full return to prefire conditions. Because ET reductions were concentrated in the first postfire year, due to the use of annual ET, the second postfire year was considered the first year of recovery. On average, ET recovered 18% in this first recovery year, with some fires (e.g., Loyalton) reaching 67%. Most fires (31 of 37) reached 75% recovery within an average of 3.9 years (range: 1–12 years). Fires that had not reached 75% recovery by 2023 were excluded from this calculation.

At the watershed scale (Figure 3), the Pit basin showed the slowest recovery, requiring an average of 10 years to reach 75% of prefire ET, followed by MTUS (5 years) and Feather (4 years). Five years after a fire, ET had recovered to 69% of prefire levels in the Pit, 75% in MTUS, and 78% in the Feather (Table 2). In the Feather basin, recovery was interrupted by large fires occurring in years 9 and 21, lowering ET sharply (by ~100 mm), but subsequent recovery rates were faster than after the initial fire. Similar patterns of partial recovery followed by renewed suppression were observed in MTUS, where secondary fires occurred 11 years after initial burning.

3.2 Assessing wildfire impacts on basin outflow

At the sub-basin scale, evapotranspiration is influenced by both wildfire and dry years, while annual basin outflow, represented by observed full natural flow, is primarily driven by precipitation and shows a small but detectable response to changes in ET (Figure 4). For example, although no fires occurred in the DAV region between 1985 and 2020, ET still exhibited fluctuations, indicating that regional climate variability played a substantial role (Figure 4a). Between 1985 and 2023, two major declines in ET occurred in DAV. The first

https://doi.org/10.5194/egusphere-2025-6193
Preprint. Discussion started: 13 January 2026

decline, from 1987 to 1992, involved a 17% reduction in ET and coincided with sharp ET decreases in other basins, driven by low precipitation and corresponding reductions in basin outflow. The second notable decline occurred in 2022, when ET decreased by 20% relative to the preceding five-year average during another dry year.

This 2022 decline was synchronized across nearly all sub-watersheds in the Feather basin, particularly in areas overlapping with the 2020 North Complex and 2021 Dixie fires, where ET dropped sharply, by 58% and 54%, respectively, following extensive high-severity canopy loss (Figure S4). The strong spatial coherence likely reflects the combined impacts of drought and the two large fires, which together produced a broad, contiguous burn footprint and reduced vegetation water use across the region. However, the modest increase in P in 2022 introduces uncertainty in interpreting the observed increase in basin outflow. The FTO station, which represents basin-wide outflow for the Feather, captured these variations (Figure 4b). Although the Feather experienced frequent fires, the limited proportion of burned area prior to 2021 constrained fire impacts on whole-basin ET. The rapid ET declines observed in 2021 and 2022 were therefore likely dominated by the 2021 fire.

Across all basins, interannual P variation was strongly correlated with annual FNF, indicating that precipitation remains the dominant control on basin outflow. Because most fires affected only small fractions of sub-basin areas, ET reductions were generally insufficient to produce measurable changes in FNF at gauging stations. A notable exception occurred in the ANT basin in 2007, where a fire burned 47% of the basin area and reduced ET by 31% (Figure 4c). In the same year, P declined by 26%, yet FNF decreased by only 10%, suggesting that reduced ET partially offset the precipitation deficit. However, quantifying this compensatory effect requires information on subsurface storage changes, which were not available.

3.3 Diagnosing wildfire-induced disruption and water-balance closure across basins

To assess whether wildfire contributes to basin-scale water-balance discrepancies, we compared annual residuals of $P - ET$ and full natural flow ($P - ET - FNF$) between high-fire years and non-fire years across all basins from 1985 to 2023. High-fire years were defined as years in which more than 3% of the watershed area burned ($n = 13$), while all remaining years were classified as non-fire years ($n = 54$). High-fire years consistently exhibited more negative residuals, indicating that observed FNF exceeded expected $P - ET$ to a greater degree during periods of extensive fire activity (Figure S5). A Welch's two-sample t-test confirmed that the difference was statistically significant ($t = -2.76$, $p = 0.017$), demonstrating that years with extensive fire activity systematically depart from hydrologic closure relative to non-fire years.

To further evaluate the nature of these discrepancies, we analyzed the relationships between FNF, P, and $P - ET$ using annual data from nine study watersheds. Under ideal conditions, modeled P and ET should closely reproduce observed runoff, resulting in well-aligned $P - ET$ and FNF

https://doi.org/10.5194/egusphere-2025-6193
Preprint. Discussion started: 13 January 2026

curves. In basins where ET remains stable and unaffected by disturbance, a near-linear relationship between P and FNF is expected, with data points clustering along the 1:1 line (reflecting annual storage change) and a slope approaching unity. However, substantial deviations from this ideal behavior were observed, reflecting combined influences of data uncertainties, basin heterogeneity, and disturbance legacies (Roche et al., 2022).

To diagnose the sources of imbalance, we applied basin-specific adjustments to P or FNF. Watersheds were grouped into three categories based on closure behavior. First, for well-balanced basins with good alignment between P-ET and FNF, such as those in the upper Feather watershed (Figure 5a,b), FNF vs. P and P − ET vs. P exhibited consistent relationships, and only minor proportional adjustment (e.g., 1.01 scaling of FNF in FRD) was needed for $P - ET - FNF \approx 0$. Second, in basins where $FNF > P - ET$ (e.g., DAV), the imbalance likely arose from underestimated precipitation. Multiplying P by 1.03 reduced residuals to near zero, aligning with previous evidence of precipitation underestimation in mountainous terrain. Third, in other basins, $P - ET > FNF$, suggesting incomplete runoff measurement. Applying a proportional scaling to FNF reduced these discrepancies; for example, in FTO, a small adjustment achieved a post-correction residual of 132 mm (Figure 5c).

For several basins (e.g., PSH, MSS, SIS), large residuals persisted even after proportional adjustment. The intersection of regression lines indicated structural bias rather than simple scaling errors. Introducing a second parameter (intercept) to adjust FNF produced near-perfect alignment between P − ET and FNF, reducing residuals to within 50 mm and confirming that multi-parameter corrections better captured hydrologic consistency (Figure 5d,e; Figure S6).

Overall, this basin-level diagnosis demonstrates that deviations from closure stem from a combination of disturbance-induced hydrologic shifts, input-data biases, and structural measurement errors. Identifying and classifying these imbalances enables clearer interpretation of hydrologic responses to wildfire and improves the reliability of regional water-balance assessments.

4. Discussion

Understanding how wildfires alter ET, basin outflow (FNF), and overall water balance is essential for diagnosing watershed resilience and supporting adaptive water-resource management in fire-prone landscapes. This study contributes new insights into (1) the magnitude and variability of ET reduction and recovery following wildfire of different extent and severity, (2) the extent to which fire-induced ET suppression influences observed outflow, and (3) the spatial heterogeneity and diagnostic interpretation of water-balance closure across multiple watersheds. Our multi-basin, post-fire hydrologic assessment highlights the need to reconcile spatial patterns, disturbance history, and observational uncertainty to better characterize watershed-scale impacts.

https://doi.org/10.5194/egusphere-2025-6193
Preprint. Discussion started: 13 January 2026

4.1 Determinants of postfire ET suppression and recovery patterns

Postfire reductions in ET were largely controlled by burn severity and burned area, producing first-year unit-area losses of 100 to 250 mm per year, consistent with canopy combustion, loss of transpiring leaf area, and reductions in soil water retention (Mappin et al. 2003; Clemente et al. 2005; Nolan et al. 2014; Roche et al. 2018; Baur et al. 2024). High-severity events such as the 1992 fires in the Pit watershed (242 mm ET loss over 244 km²) and the 2018 fires in the MTUS (143 mm over 421 km²) illustrate this strong suppression, and align with previous findings that high-severity burns in the Sierra Nevada produce early ET losses around 265 mm, with moderate-severity burns reducing ET by 150 to 200 mm over multiple years and requiring more than 15 years for full recovery in severely affected areas (Roche et al. 2020; Ma et al. 2020).

Recovery trajectories varied across basins and reflected vegetation structure, climatic water availability, and disturbance history. Feather and MTUS showed faster recovery, returning to 75 percent of prefire ET within four to five years, supported by favorable moisture conditions and rapid regrowth of fire-adapted shrubs. Pit, with a drier climate and repeated high-severity fires, recovered more slowly, reaching only 69 percent of prefire ET by year five and requiring approximately ten years to meet the 75 percent threshold. These patterns are consistent with hydrologic stress associated with drought and persistent soil-moisture deficits (Silveiro et al. 2024). Across the 37 fires, 31 reached 75 percent recovery within an average of 3.9 years, although several remained below this threshold by 2023, underscoring the importance of species traits. Shrub communities frequently resprouted quickly, but long-term ET recovery depended on tree canopy regeneration, and surviving conifers may experience long-term physiological impairment that limits transpiration (Niccoli et al. 2023).

Vegetation composition patterns derived from CECS datasets further highlight the central role of postfire structural change in governing ET recovery (Figures S1–S3). In high-severity burns such as the 2007 Bucks fire (Figure S3c), ET declined sharply and remained suppressed as shrubs and herbaceous cover increased relative to trees. A similar trajectory occurred in the Scotch fire footprint (Figure S3j), where the 2008 burn was followed by reburning during the 2020–2021 North Complex event, illustrating how repeated disturbance can constrain canopy re-establishment and prolong low-ET states. Even modest increases in low-stature vegetation combined with delayed tree regrowth contributed to sustained watershed-scale ET suppression extending more than a decade in some areas.

Climatic and ecological heterogeneity across basins further shaped cumulative responses. MTUS, despite having the smallest burned area, experienced the highest total ET loss during the 2018 fire (420 million m³), while Feather, which accumulated the largest burned area from 1985 to 2022, exhibited pronounced increases in total ET loss after successive fires between 2018 and 2022. These patterns emphasize that repeated disturbance is a major constraint on hydrologic

https://doi.org/10.5194/egusphere-2025-6193
Preprint. Discussion started: 13 January 2026

recovery and that forests with complex canopy structure, functional diversity, and high ecological elasticity tend to recover more rapidly. In contrast, it has been suggested that ecosystems such as the Russian River watershed showed limited ET response, likely due to deep soils, Mediterranean climate, and buffering from subsurface storage and fire-adapted vegetation (Newcomer et al. 2023). Postfire soil hydrophobicity may also suppress ET by reducing infiltration and enhancing overland flow, a mechanism more relevant in coarse-textured or shallow volcanic soils such as in the Pit basin (Huffman et al. 2001; Boisramé et al. 2019).

Taken together, our results show that the magnitude of initial ET loss is controlled by burn severity and burned area, the pace of recovery is governed by vegetation regrowth pathways and moisture availability, and long-term suppression arises from disturbance recurrence. These factors jointly explain the heterogeneous ET responses observed across California's water-supply basins and provide the ecological basis for interpreting subsequent impacts on basin outflow and water-balance closure.

4.2 **Drivers of postfire runoff response**

Although interannual precipitation variability remains the dominant driver of runoff patterns across most basins, our results suggest that postfire reductions in ET may partially offset precipitation declines, particularly in high-severity burn areas. In most cases, runoff closely tracked precipitation trends, while ET fluctuated more moderately. However, the ANT basin illustrates a potential compensatory mechanism. After a 2007 fire reduced ET by 31%, reduction in ET, runoff declined by only 10% despite 26% lower annual precipitation. This divergence suggests that suppressed ET may enhance water availability for basin outflow (FNF) under certain conditions. Mechanistically, fire-induced canopy loss and root mortality reduce transpiration and interception (Ice et al. 2004; Ma et al. 2020), while soil water repellency can inhibit infiltration and promote surface runoff (Shakesby & Doerr 2006; Pradhan & Floyd 2021). Together, these processes shift hydrologic partitioning toward runoff, particularly in water-limited systems where vegetation loss is extensive (Boisramé et al. 2019; Bart et al. 2021; Guzmán-Rojo et al. 2024).

However, such effects were not consistently detectable across all basins due to scale and context. Most fires affected limited portions of each watershed, limiting their measurable hydrologic impact at larger scale. Consistent with other studies, significant runoff responses typically emerge only when ≥20–30% of a watershed is burned (Wine & Cadol 2016; Newcomer et al. 2023). Additionally, topographic complexity, vegetation recovery rates, and subsurface storage can modulate responses, making it difficult to isolate ET impacts (Kinoshita & Hogue 2011; Wilder & Kinoshita 2022). For example, in the Feather basin, postfire ET dropped sharply in 2022, but concurrent increases in precipitation obscured runoff attribution. Limited spatial coverage of stream gauges and ET monitoring further hampers inference, especially at sub-basin

https://doi.org/10.5194/egusphere-2025-6193
Preprint. Discussion started: 13 January 2026

scales. While remote sensing has improved ET estimation (Poon & Kinoshita 2018; Lahmers et al. 2025), establishing causal links between ET reduction and runoff response remains difficult without high-resolution hydrometeorological networks. These challenges underscore the importance of spatial scale, burn extent, and observational capacity in understanding postfire hydrologic responses.

4.3 Diagnosing and correcting postfire water-balance closure errors

Wildfire disturbance emerged as an important driver of deviations from expected water-balance closure across California's major watersheds. As shown in our analysis, fire years consistently exhibited more negative residuals (P − ET − FNF), indicating that observed basin outflow (FNF) systematically exceeded modeled P − ET during and immediately after disturbance. This divergence demonstrates that wildfires can create short-term hydrologic imbalances, enhancing basin outflow or subsurface losses beyond what steady-state P–ET frameworks predict. Likely mechanisms include reduced canopy interception, increased overland and subsurface flow, accelerated snowmelt, and postfire changes in infiltration capacity. These findings are consistent with earlier plot- and catchment-scale observations showing that fire simplifies canopy structure and redistributes water fluxes, often producing a transient "hydrologic release" followed by delayed recovery (Kinoshita & Hogue, 2015, Williams et al., 2022).

However, disturbance alone cannot explain the full range of discrepancies among basins. Even under non-disturbed conditions, achieving water-balance closure across California's heterogeneous landscapes requires careful interpretation and basin-specific adjustment strategies. Climatic gradients, lithologic differences, and variable human regulation contribute to strong spatial heterogeneity in the relationship between simulated (P − ET) and observed (FNF) fluxes. Our diagnostic framework categorized nine sub-basins into three closure types, each reflecting distinct physical and measurement characteristics.

In contrast, the DAV watershed exhibited FNF consistently exceeding P–ET, which is unlikely due to enhanced runoff generation given consistent ET simulation methods across basins. Instead, this discrepancy likely reflects precipitation underestimation. A modest 3% increase in the gridded precipitation substantially reduced residuals, aligning with prior findings that sparse station density and complex terrain in California's mountains often lead to interpolation errors (Avanzi et al. 2020; Safeeq et al. 2021, Roche et al. 2022). Orographic and localized rainfall patterns, common in such regions, may further exacerbate this issue (Avanzi et al. 2020). The DAV case underscores that seemingly excessive FNF may reflect incomplete precipitation inputs, emphasizing the need for finer-resolution meteorological data and improved validation.

In other basins (e.g., FTO, ANT, TNL, SDT), P–ET exceeded FNF, suggesting that FNF observations may underestimate actual water yield. This systematic underestimation likely results from subsurface bypass flow, vertical seepage, or unmeasured groundwater discharge

https://doi.org/10.5194/egusphere-2025-6193
Preprint. Discussion started: 13 January 2026

(Avanzi et al. 2020; Roche et al. 2022). Permeable lithology, faulting, and reservoir operations further obscure true basin outflow (Safeeq et al. 2021; Roche et al. 2022). Applying proportional corrections reduced residuals to within 100–150 mm, indicating that flow underestimation was the dominant error in these cases.

However, in PSH, MSS, and SIS, large residuals persisted even after proportional adjustment, and regression lines exhibited crossing patterns, signaling structural bias beyond simple scaling errors. Potential causes include gauge misalignment, cross-sectional changes, or sensor drift (Safeeq et al. 2021; Roche et al. 2022). Here, we applied a dual-parameter correction (scaling + intercept), which improved alignment and reduced residuals to within 50 mm. This suggests that in basins with mixed error sources, flexible calibration models that reflect physical measurement processes are necessary for reliable water balance closure.

Achieving water-balance closure across heterogeneous basins requires context-specific correction strategies, as no single method universally resolves discrepancies. Proportional adjustments are suitable for diagnosing fluxes where systematic underestimation dominates and temporal patterns are coherent, while dual-parameter approaches are more appropriate in basins with structural biases or complex error signatures. Critically, identifying the underlying sources of imbalance, rather than enforcing statistical fit, enhances the physical credibility of hydrologic assessments under multi-source uncertainty. Nonetheless, even error-informed corrections face practical limitations. P and ET inputs often rely on spatial interpolation or remotely sensed products, which may fail to capture localized variability in regions with complex terrain or sparse monitoring infrastructure. Similarly, full natural flow (FNF) estimates can be compromised by stream-gauge placement and design, particularly when gauges do not align with actual contributing areas, resulting in long-term structural bias. In addition, many watersheds may be affected by data gaps or inaccurately reported upstream diversions, reservoir operations, and inter-basin transfers, complicating attribution of observed runoff deficits. These constraints reduce the generalizability of empirical corrections and highlight the need for next-generation hydrologic models that couple high-resolution observations, detailed management records, and process-based representations of watershed behavior.

4.4 Implications for hydrologic modeling and water resource management

Wildfires disrupt the balance among precipitation, ET, and basin outflow in ways that conventional hydrologic models do not fully capture. The systematic deviations between modeled (P–ET) and observed basin outflow (FNF) during fire years show that disturbance fundamentally alters basin water budgets. Postfire ET suppression, delayed vegetation recovery, and shifts in infiltration or snowmelt processes create hydrologic conditions that steady-state models cannot represent. These findings highlight the need for disturbance-sensitive model

https://doi.org/10.5194/egusphere-2025-6193
Preprint. Discussion started: 13 January 2026

components, including flexible ET recovery functions, representations of vegetation structural change, and nonlinear thresholds linking burn extent to runoff response.

At the basin-integration scale, wildfire effects interact with substantial observational uncertainties. Persistent negative P–ET–FNF residuals reflect not only process-level shifts but also precipitation underestimation, gauge bias, and heterogeneous subsurface pathways. No single correction approach ensures water-balance closure across diverse terrain; instead, models should pair physically based process representations with diagnostic calibration schemes that explicitly account for disturbance and measurement uncertainty. Such strategies will reduce misinterpretation of postfire hydrologic anomalies and improve runoff estimation in complex landscapes.

From a management perspective, incorporating fire history, burn severity, and ET recovery patterns into reservoir operations and water-allocation planning is essential for avoiding overestimation of water availability or underestimation of infrastructure vulnerability. Ultimately, reliable water-balance assessments in fire-prone regions will require integrating high-resolution disturbance mapping, continuous ET and precipitation monitoring, and process-based ecohydrologic modeling to anticipate watershed responses to wildfire, drought, and climate variability and support resilient water-resource governance.

5. Conclusions

Large wildfires impose short-term but measurable disruptions to evapotranspiration, basin outflow, and water-balance closure in California's major water-supply watersheds. High-severity burns suppressed ET by 100–250 mm in the first year, with recovery rates governed by vegetation traits, moisture availability, and disturbance recurrence. Although precipitation remained the primary control on basin outflow, ET losses occasionally moderated drought-year flow declines in heavily burned basins, indicating a limited compensatory effect. Fire years also produced systematically negative P–ET–FNF residuals, revealing that wildfire amplifies existing closure errors from precipitation underestimation and stream-gauge bias. Together, these results show that wildfire acts as a hydrologic shock that alters water partitioning and exposes structural uncertainties in observational datasets. Incorporating disturbance history, ET-recovery patterns, and closure diagnostics will improve postfire flow prediction and strengthen water-resource planning under rising fire activity.

https://doi.org/10.5194/egusphere-2025-6193
Preprint. Discussion started: 13 January 2026

499 **Table 1. Information for California key water supply watersheds**

Watershed	Area, km²	Elevation range, m	Topography	Hydrologic influence	Precipitation range/mean, mm
Trinity	1861	573 - 2751	Mountainous terrain	Snowmelt and precipitation contribute to river systems	756 - 2626 / 1399
Upper Sacramento	1551	178 - 4069	Mountainous terrain	Snowmelt and volcanic springs from Mount Shasta contribute to cold, clear rivers	810 - 3003 /1572
McCloud	1773	306 - 4306	Mountainous terrain	Snowmelt and volcanic springs contribute to river systems	772 - 2526 / 1413
Pit	14,753	301 - 3161	Gradual terrain at lower elevations with alluvial valleys; volcanic soils	Groundwater from volcanic aquifers and snowmelt influence river flows	432 - 1081 / 665
Feather	9335	221 - 2773	Diverse terrain: high altitude in west and center, decreasing south and north	Influenced by volcanic activity and regulated by Oroville Dam, impacting water distribution and flood control	547 - 1982 / 1085

500
501

https://doi.org/10.5194/egusphere-2025-6193
Preprint. Discussion started: 13 January 2026

Table 2. Information for 37 large fires in key water supply watersheds

Fire Name	Year	Area burned, km^2	5-year pre-fire ET average, mm	ET change[1]		Years to recovery[3]	Map ID
				First-year post-fire, mm^2	Cumulative ET reduction over recovery period, million m^3		
Pit							
Lost	1987	92	370	-178	83	8	29
Fountain	1992	244	701	-439	960	12	18
Damon/Long	1996	95	239	-84	8	1	28
Jones	2000	106	682	-256	27	1	19
Blue	2001	139	381	-157	81	5	17
Bear	2004	42	626	-330	31	3	30
Corral Fire	2008	50	336	-136	38	7	31
Bagley	2012	186	880	-279	80	3	20
Barry Point	2012	376	379	-224	210	3	21
Reading	2012	114	480	-239	259*	/	24
Bald	2014	161	334	-139	37	2	22
Eiler	2014	130	497	-322	254*	/	23
Day	2014	53	470	-298	116*	/	32
Cove	2017	125	359	-163	68	5	25
Stone	2018	160	306	-95	26	2	26
W-5 Cold Springs	2020	344	191	-39	5	2	16
Gold	2020	92	319	-132	30*	/	27
Feather							
Clark (Plumas #531)	1987	162	687	-141	124	8	5
Cottonwood	1994	195	296	-233	138	4	4
Bucks	1999	139	644	-196	47	2	6
Storrie	2000	227	750	-224	205	5	7
Wheeler	2007	90	656	-229	58	4	12
Moonlight	2007	263	352	-325	452	8	3
South-Frey	2008	50	818	-169	8	1	14
Scotch	2008	53	785	-173	9	1	15
Cub	2008	60	833	-98	38	6	13
Btu Lightning Complex	2008	217	597	-290	209	4	8
Chips	2012	309	653	-239	330	4	9
Camp	2019	621	472	-297	532	4	10
Walker	2020	221	461	-232	140	4	11
Loyalton	2020	189	240	-82	17	2	1
Sheep	2020	120	496	-251	68*	/	2
MTUS							
Sheep #1	1999	50	774	-209	19	2	37
Motion	2008	115	717	-292	79	3	33
Carr	2018	930	715	-277	917*	/	34
Delta	2018	257	752	-393	398*	/	35
Hirz	2018	164	815	-240	71	2	36

https://doi.org/10.5194/egusphere-2025-6193
Preprint. Discussion started: 13 January 2026

503 **Table 2. Information for 37 large fires in key water supply watersheds (Cont.)**

504 [1] ET data is based on net ET reduction.

505 [2]Minus indicates a reduction relative to the previous year

506 [3]Years to recovery was defined as the number of years after the fire until the mean annual ET equaled or exceeded 75% of the
507 pre-fire 5-year mean. /: ET recovery did not reach 75% in the available years of data.

508 *The mean annual ET did not reach 75% of the pre-fire 5-year mean in the available years of data.

509

510

https://doi.org/10.5194/egusphere-2025-6193
Preprint. Discussion started: 13 January 2026

Table 3. Information for CDEC FNF stations in key water supply watersheds

Station Name	Station ID	Area, km²	Average annual value, mm				WBal[1]
			P	ET	FNF	P-ET	
Lake Davis (DWR)	DAV	115	707	410	322	296	1.03P
Frenchman Dam	FRD	214	478	350	131	128	1.01FNF
Antelope Lake	ANT	184	634	443	207	191	1.05FNF
Feather River at Oroville	FTO	9482	1084	522	538	562	1.08FNF
Sacramento R at Delta	SDT	1102	1525	644	895	881	1.01FNF
McCloud R abv L Shasta	MSS	1569	1391	630	871	760	1.74FNF-0.75
Trinity R at Lewiston	TNL	1863	1399	575	820	824	1.03FNF
Pit River at Shasta Lake	PSH	16176	613	347	209	265	2.44FNF-0.25
Sacto Inflow-Shasta	SIS	19995	787	408	329	379	1.67FNF-0.17

[1]Water-balance components were adjusted, with the number preceding 'P' or 'FNF' indicating the multiplier applied to the data.

https://doi.org/10.5194/egusphere-2025-6193
Preprint. Discussion started: 13 January 2026

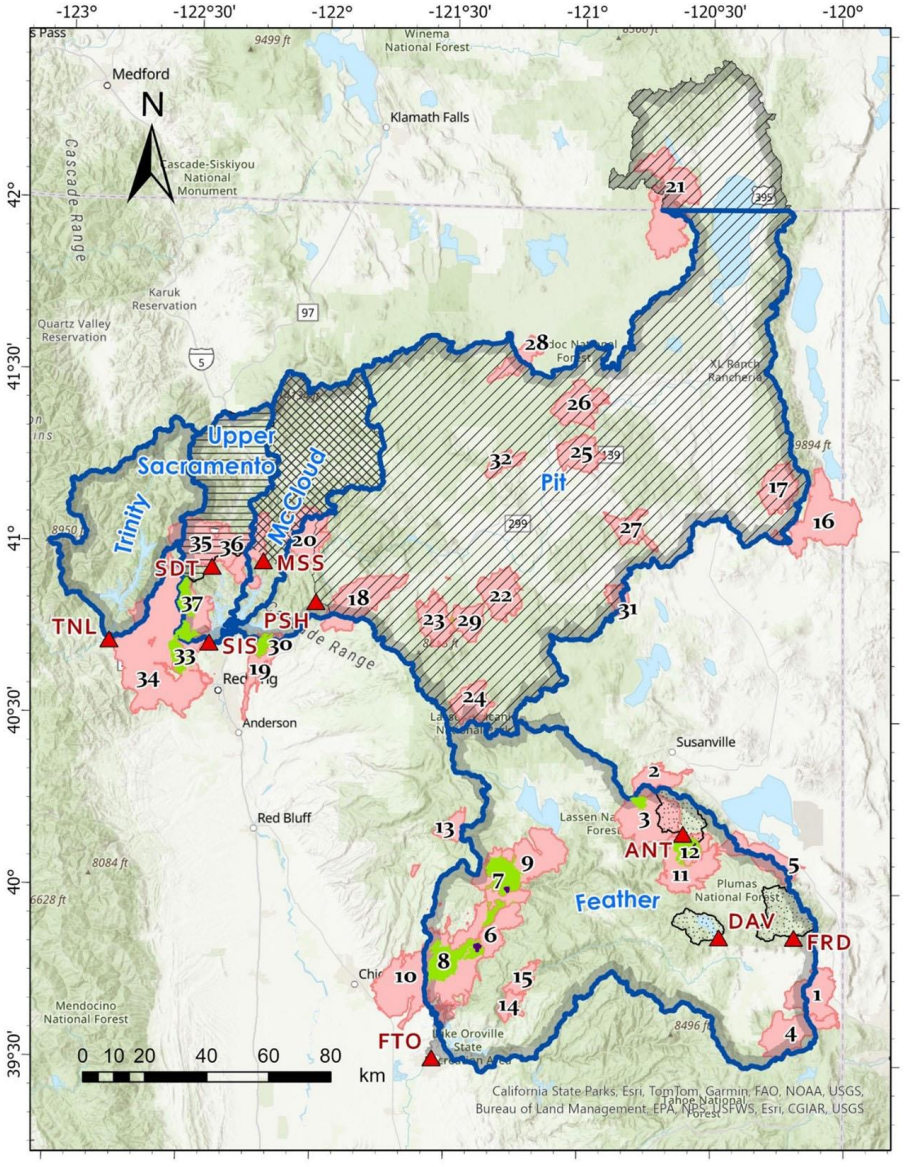

Figure 1.
Study area. The blue outlined watersheds are the five key water supply watersheds. Red triangles are sites with full natural flow (FNF) data, and shaded areas are the corresponding watersheds. The pink parts are areas showing the 37 large fires analyzed. The green and dark purple parts respectively indicate areas that burned twice and three times. Table 1 and Table 2 list the information on FNF sites and large fires.

https://doi.org/10.5194/egusphere-2025-6193
Preprint. Discussion started: 13 January 2026

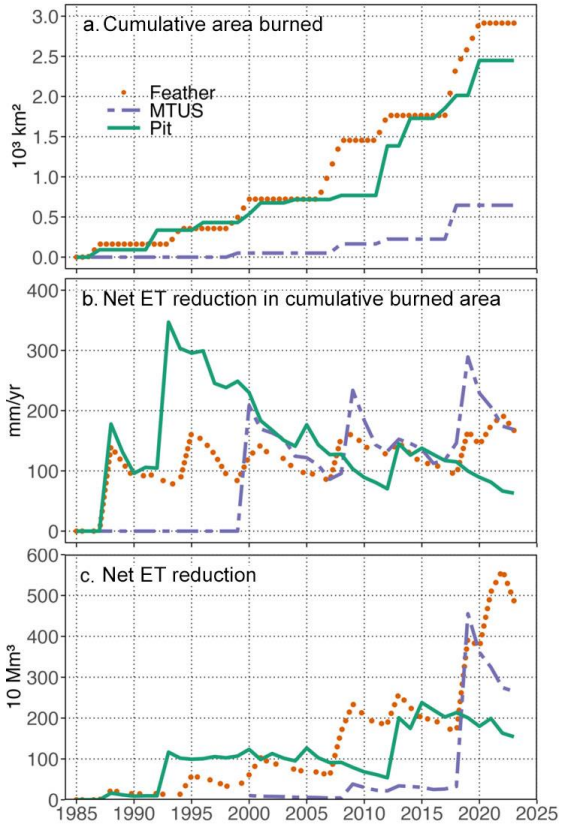

Figure 2.

Net evapotranspiration (ET) reductions and cumulative area burned in the three study areas. (a) cumulative area burned (Table 2), (b) Net annual ET reduction depth per unit area burned (See Figure S 1 to 3 for ET declines due to individual fire and increases with regrowth), and (c) net annual ET reduction volume resulting from fires in the three watersheds 1985–2023 (product of data on panels a and b).

https://doi.org/10.5194/egusphere-2025-6193
Preprint. Discussion started: 13 January 2026

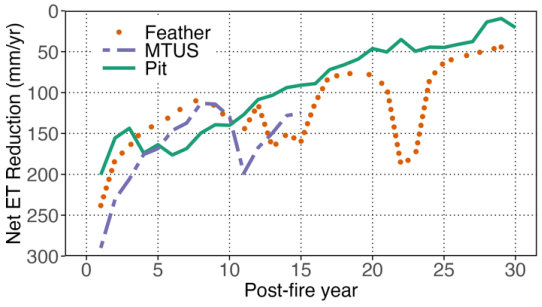

Figure 3.

Post-fire ET recovery. Post-fire evapotranspiration (ET) recovery trajectories were tracked over 30 years across three watersheds: Feather (orange dots), MTUS (purple dashed line), and Pit (green solid line). The y-axis shows net ET reduction (mm/year) relative to pre-fire conditions. Data reflect averaged changes across burned areas, with at least three fire events. While all three watersheds exhibit gradual ET recovery, the rate and magnitude vary, and Feather displays notable variability in later post-fire years.

https://doi.org/10.5194/egusphere-2025-6193
Preprint. Discussion started: 13 January 2026

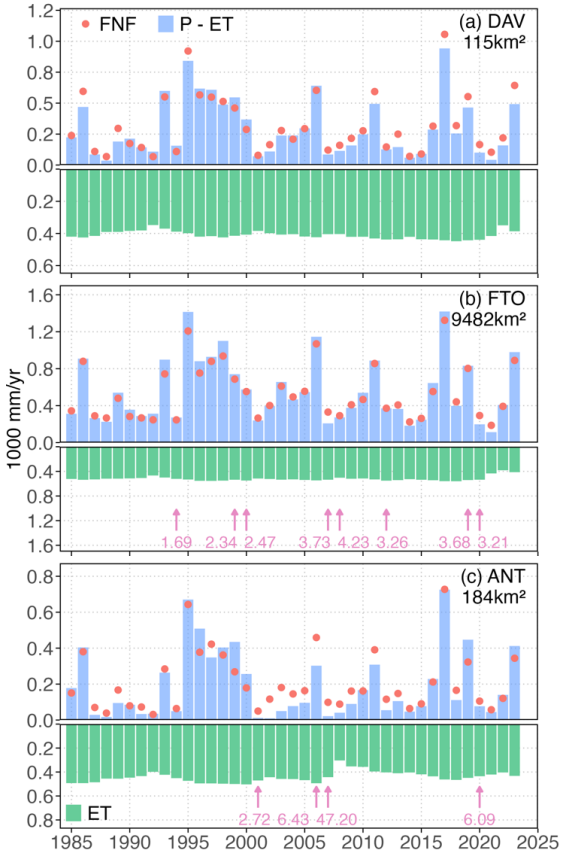

Figure 4.

Changes in precipitation, evapotranspiration, full natural flow, and burned area from 1985 to 2023 in the Feather basin. The changes in ET, P, P-ET and FNF over time for the sub-watersheds are located. The pink arrows and labels indicate the year of fire and the percentage of burned area. The figures only show years where the area burned was greater than 1% of the area of the watershed. Data for additional sites are in Supplementary Figure S6.

https://doi.org/10.5194/egusphere-2025-6193
Preprint. Discussion started: 13 January 2026

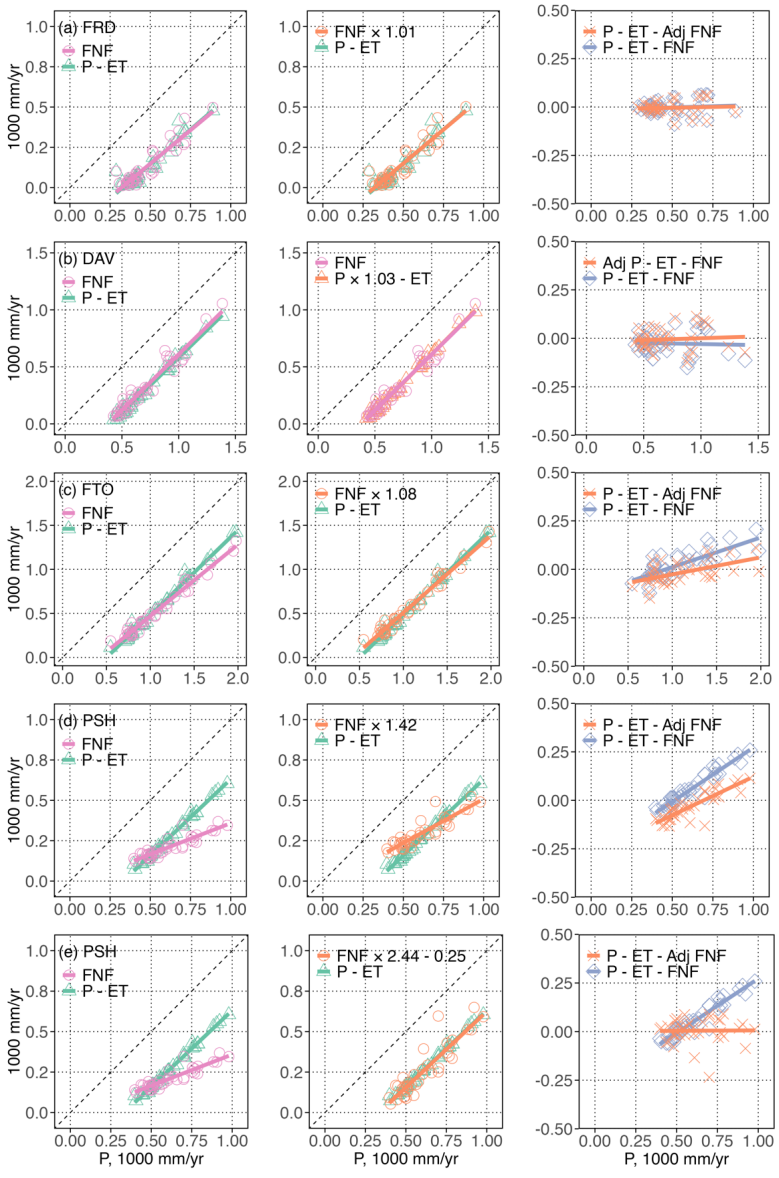

Figure 5.

Water balance analysis of representative watersheds. Show unadjusted annual water balance constituent discharge (FNF) and precipitation minus evapotranspiration (P-ET) versus annual precipitation (P). Also, adjust the FNF or P values (with one or two parameters) to improve the agreement between P-ET and FNF. The dashed diagonal line is a 1:1 line. Water balance residuals (P-ET-FNF) using unadjusted and adjusted components. Data for additional sites is in Supplementary Figure S7 ans S8.

https://doi.org/10.5194/egusphere-2025-6193
Preprint. Discussion started: 13 January 2026

Data availability

The wildfire perimeter dataset is publicly available through the California Fire and Resource Assessment Program (FRAP). Full natural flow (FNF) records are publicly available from the California Data Exchange Center (CDEC). The evapotranspiration and precipitation datasets generated by the Center for Ecosystem Climate Solutions (CECS) were previously publicly accessible; access is currently provided upon request from CECS.
Derived watershed-scale metrics and analysis scripts are available from the corresponding author upon reasonable request.

Author contributions

Conceptualization: ZH, RB. Data curation: ZH, MG, HG. Formal analysis: ZH, HG. Methodology: ZH, HG, RB. Project administration: RB. Resources: RB, MG. Software: ZH, HG. Supervision: RB. Validation: ZH. Visualization: ZH. Writing – original draft: ZH. Writing – review and editing: all authors.

Competing interests

The authors declare that they have no conflict of interest.

Acknowledgements

We thank the Center for Ecosystem Climate Solutions (CECS) for providing the datasets used in this study, which was supported by the California Climate Investments program through the Strategic Growth Council (grant no. CCR20021).

https://doi.org/10.5194/egusphere-2025-6193
Preprint. Discussion started: 13 January 2026

References:

Abatzoglou, J. T., & Williams, A. P. (2016). Impact of anthropogenic climate change on wildfire across western US forests. *Proceedings of the National Academy of Sciences of the United States of America*, *113*(42), 11770–11775. https://doi.org/10.1073/pnas.1607171113

Atwood, A., Hille, M., Clark, M. K., Rengers, F., Ntarlagiannis, D., Townsend, K., & West, A. J. (2023). Importance of subsurface water for hydrological response during storms in a post-wildfire bedrock landscape. *Nature Communications*, *14*(1). https://doi.org/10.1038/s41467-023-39095-z

Avanzi, F., Rungee, J., Maurer, T., Bales, R., Ma, Q., Glaser, S., & Conklin, M. (2020). Climate elasticity of evapotranspiration shifts the water balance of Mediterranean climates during multi-year droughts. *Hydrology and Earth System Sciences*. https://doi.org/10.5194/hess-24-4317-2020

Bart, R. R. (2016). A regional estimate of postfire streamflow change in California. *Water Resources Research*, *52*(2), 1465–1478. https://doi.org/10.1002/2014WR016553

Bart, R. R., Ray, R. L., Conklin, M. H., Safeeq, M., Saksa, P. C., Tague, C. L., & Bales, R. C. (2021). Assessing the effects of forest biomass reductions on forest health and streamflow. *Hydrological Processes*, *February*, 1–17. https://doi.org/10.1002/hyp.14114

Bart, R. R., & Tague, C. L. (2017). The impact of wildfire on baseflow recession rates in California. *Hydrological Processes*, *31*(8), 1662–1673. https://doi.org/10.1002/hyp.11141

Baur, M. J., Friend, A. D., & Pellegrini, A. F. A. (2024). Widespread and systematic effects of fire on plant–soil water relations. *Nature Geoscience*, *17*(11), 1115–1120. https://doi.org/10.1038/s41561-024-01563-6

Boisramé, G. F. S., Thompson, S. E., Tague, C. (Naomi), & Stephens, S. L. (2019). Restoring a Natural Fire Regime Alters the Water Balance of a Sierra Nevada Catchment. *Water Resources Research*, *55*(7), 5751–5769. https://doi.org/10.1029/2018WR024098

Boisramé, G., Thompson, S., Collins, B., & Stephens, S. (2017). Managed Wildfire Effects on Forest Resilience and Water in the Sierra Nevada. *Ecosystems*, *20*(4), 717–732. https://doi.org/10.1007/s10021-016-0048-1

California Department of Water Resources. (2023). *California Water Plan Update 2023*. https://water.ca.gov/Programs/California-Water-Plan/Update-2023.

Chung, M. G., Guo, H., Nyelele, C., Egoh, B. N., Goulden, M. L., Keske, C. M., & Bales, R. C. (2024). Valuation of forest-management and wildfire disturbance on water and carbon fluxes in mountain headwaters. Ecohydrology, February. https://doi.org/10.1002/eco.2642

Clemente, A. S., Rego, F. C., & Correia, O. A. (2005). Growth, water relations and photosynthesis of seedlings and resprouts after fire. *Acta Oecologica*, *27*(3), 233–243. https://doi.org/10.1016/j.actao.2005.01.005

Guo, H., Goulden, M., Chung, M. G., Nyelele, C., Egoh, B., Keske, C., Conklin, M., & Bales, R. (2023). Valuing the benefits of forest restoration on enhancing hydropower and water supply in California's Sierra Nevada. Science of The Total Environment, 876, 162836. https://doi.org/10.1016/j.scitotenv.2023.162836

Guzmán-Rojo, M., Fernandez, J., D'Abzac, P., & Huysmans, M. (2024). Impacts of Wildfires on Groundwater Recharge: A Comprehensive Analysis of Processes, Methodological Challenges, and Research Opportunities. In *Water (Switzerland)* (Vol. 16, Issue 18). https://doi.org/10.3390/w16182562

Hallema, D. W., Sun, G., Bladon, K. D., Norman, S. P., Caldwell, P. V., Liu, Y., & McNulty, S. G. (2017). Regional patterns of postwildfire streamflow response in the Western United States: The importance of scale-specific connectivity. *Hydrological Processes*, *31*(14), 2582–2598. https://doi.org/10.1002/hyp.11208

Huffman, E. L., MacDonald, L. H., & Stednick, J. D. (2001). Strength and persistence of fire-induced soil

https://doi.org/10.5194/egusphere-2025-6193
Preprint. Discussion started: 13 January 2026

hydrophobicity under ponderosa and lodgepole pine, Colorado Front Range. *Hydrological Processes*, *15*(15), 2877–2892. https://doi.org/10.1002/hyp.379

Ice, G. G., Neary, D. G., & Adams, P. W. (2004). Effects of Wildfire on Processes. *Journal of Forestry*, *102*(September), 16–20.

Keeley, J. E., & Syphard, A. D. (2016). Climate change and future fire regimes: Examples from California. *Geosciences (Switzerland)*, *6*(3), 1–14. https://doi.org/10.3390/geosciences6030037

Kinoshita, A. M., & Hogue, T. S. (2011). Spatial and temporal controls on post-fire hydrologic recovery in Southern California watersheds. *Catena*, *87*(2), 240–252. https://doi.org/10.1016/j.catena.2011.06.005

Kinoshita, A. M., & Hogue, T. S. (2015). Increased dry season water yield in burned watersheds in Southern California. *Environmental Research Letters*, *10*(1). https://doi.org/10.1088/1748-9326/10/1/014003

Lahmers, T. M., Kumar, S. V., Ahmad, S. K., Holmes, T., Getirana, A., Orland, E., Locke, K., Biswas, N. K., Nie, W., Pflug, J., Whitney, K., Anderson, M., & Yang, Y. (2025). An Observation-Driven Framework for Modeling Post-Fire Hydrologic Response: Evaluation for Two Central California Case Studies. *Water Resources Research*, *61*(2). https://doi.org/10.1029/2023WR036582

Ma, Q., Bales, R. C., Rungee, J., Conklin, M. H., Collins, B. M., & Goulden, M. L. (2020). Wildfire controls on evapotranspiration in California's Sierra Nevada. *Journal of Hydrology*, *590*. https://doi.org/10.1016/j.jhydrol.2020.125364

Mappin, K. A., Pate, J. S., & Bell, T. L. (2003). Productivity and water relations of burnt and long-unburnt semi-arid shrubland in Western Australia. *Plant and Soil*, *257*(2), 321–340. https://doi.org/10.1023/A:1027349501441

Miller, J. D., & Safford, H. (2012). Trends in wildfire severity: 1984 to 2010 in the Sierra Nevada, Modoc Plateau, and southern Cascades, California, USA. *Fire Ecology*, *8*(3), 41–57. https://doi.org/10.4996/fireecology.0803041

Newcomer, M. E., Underwood, J., Murphy, S. F., Ulrich, C., Schram, T., Maples, S. R., Peña, J., Siirila-Woodburn, E. R., Trotta, M., Jasperse, J., Seymour, D., & Hubbard, S. S. (2023). Prolonged Drought in a Northern California Coastal Region Suppresses Wildfire Impacts on Hydrology. *Water Resources Research*, *59*(8). https://doi.org/10.1029/2022WR034206

Niccoli, F., Pacheco-Solana, A., Delzon, S., Kabala, J. P., Asgharinia, S., Castaldi, S., Valentini, R., & Battipaglia, G. (2023). Effects of wildfire on growth, transpiration and hydraulic properties of Pinus pinaster Aiton forest. *Dendrochronologia*, *79*(January), 126086. https://doi.org/10.1016/j.dendro.2023.126086

Nolan, R. H., Lane, P. N. J., Benyon, R. G., Bradstock, R. A., & Mitchell, P. J. (2014). Changes in evapotranspiration following wildfire in resprouting eucalypt forests. *Ecohydrology*, *7*(5), 1363–1377. https://doi.org/10.1002/eco.1463

Paul, M. J., LeDuc, S. D., Lassiter, M. G., Moorhead, L. C., Noyes, P. D., & Leibowitz, S. G. (2022). Wildfire Induces Changes in Receiving Waters: A Review With Considerations for Water Quality Management. *Water Resources Research*, *58*(9). https://doi.org/10.1029/2021WR030699

Poon, P. K., & Kinoshita, A. M. (2018). Estimating evapotranspiration in a post-fire environment using remote sensing and machine learning. *Remote Sensing*, *10*(11). https://doi.org/10.3390/rs10111728

Pradhan, N. R., & Floyd, I. (2021). Event based post-fire hydrological modeling of the upper Arroyo Seco watershed in southern California. *Water (Switzerland)*, *13*(16). https://doi.org/10.3390/w13162303

PRISM Climate Group, Oregon State University, https://prism.oregonstate.edu.

https://doi.org/10.5194/egusphere-2025-6193
Preprint. Discussion started: 13 January 2026

Robinne, F. N., Hallema, D. W., Bladon, K. D., Flannigan, M. D., Boisramé, G., Bréthaut, C. M., Doerr, S. H., Di Baldassarre, G., Gallagher, L. A., Hohner, A. K., Khan, S. J., Kinoshita, A. M., Mordecai, R., Nunes, J. P., Nyman, P., Santín, C., Sheridan, G., Stoof, C. R., Thompson, M. P., … Wei, Y. (2021). Scientists' warning on extreme wildfire risks to water supply. *Hydrological Processes*, *35*(5), 1–11. https://doi.org/10.1002/hyp.14086

Roche, J. W., Goulden, M. L., & Bales, R. C. (2018). Estimating evapotranspiration change due to forest treatment and fire at the basin scale in the Sierra Nevada, California. *Ecohydrology*, *11*(7), 1–10. https://doi.org/10.1002/eco.1978

Roche, J. W., Ma, Q., Rungee, J., & Bales, R. C. (2020). Evapotranspiration Mapping for Forest Management in California's Sierra Nevada. *Frontiers in Forests and Global Change*. https://doi.org/10.3389/ffgc.2020.00069

Roche, J. W., Wilson, K. N., Ma, Q., & Bales, R. C. (2022). Water balance for gaged watersheds in the Central Sierra Nevada, California and Nevada, United States. *Frontiers in Forests and Global Change*, *5*(July), 1–16. https://doi.org/10.3389/ffgc.2022.861711

Safeeq, M., Bart, R. R., Pelak, N. F., Singh, C. K., Dralle, D. N., Hartsough, P., & Wagenbrenner, J. W. (2021). How realistic are water-balance closure assumptions? A demonstration from the southern sierra critical zone observatory and kings river experimental watersheds. *Hydrological Processes*, *35*(5), 1–16. https://doi.org/10.1002/hyp.14199

Shakesby, R. A., & Doerr, S. H. (2006). Wildfire as a hydrological and geomorphological agent. *Earth-Science Reviews*, *74*(3–4), 269–307. https://doi.org/10.1016/j.earscirev.2005.10.006

Silveiro, A. C., Silvério, D. V., Macedo, M. N., Coe, M. T., Maracahipes, L., Uribe, M., Maracahipes-Santos, L., Oliveira, P. T. S., Rattis, L., & Brando, P. M. (2024). Droughts Amplify Soil Moisture Losses in Burned Forests of Southeastern Amazonia. *Journal of Geophysical Research: Biogeosciences*, *129*(10), 1–15. https://doi.org/10.1029/2024JG008011

Westerling, A. L., Hidalgo, H. G., Cayan, D. R., & Swetnam, T. W. (2006). Warming and earlier spring increase Western U.S. forest wildfire activity. *Science*, *313*(5789), 940–943. https://doi.org/10.1126/science.1128834

Westerling, A. L. R. (2016). Increasing western US forest wildfire activity: Sensitivity to changes in the timing of spring. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *371*(1696). https://doi.org/10.1098/rstb.2015.0178

Wilder, B. A., & Kinoshita, A. M. (2022). Incorporating ECOSTRESS evapotranspiration in a paired catchment water balance analysis after the 2018 Holy Fire in California. *Catena*, *215*(March), 106300. https://doi.org/10.1016/j.catena.2022.106300

Williams, A. P., Abatzoglou, J. T., Gershunov, A., Guzman-Morales, J., Bishop, D. A., Balch, J. K., & Lettenmaier, D. P. (2019). Observed Impacts of Anthropogenic Climate Change on Wildfire in California. *Earth's Future*, *7*(8), 892–910. https://doi.org/10.1029/2019EF001210

Williams, A. P., Livneh, B., McKinnon, K. A., Hansen, W. D., Mankin, J. S., Cook, B. I., Smerdon, J. E., Varuolo-Clarke, A. M., Bjarke, N. R., Juang, C. S., & Lettenmaier, D. P. (2022). Growing impact of wildfire on western US water supply. *Proceedings of the National Academy of Sciences of the United States of America*, *119*(10), 1–8. https://doi.org/10.1073/pnas.2114069119

Wine, M. L., & Cadol, D. (2016). Hydrologic effects of large southwestern USA wildfires significantly increase regional water supply: Fact or fiction? *Environmental Research Letters*, *11*(8). https://doi.org/10.1088/1748-9326/11/8/085006