

Supplementary Materials for  
**Building water resilience in the face of cascading wildfire risks**

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**The PDF file includes:**

Tables S1 and S2  
Legend for data S1  
References

**Other Supplementary Material for this manuscript includes the following:**

Data S1

**Table S1.**

Wildfires represented in three or more peer-reviewed publications reviewed for this publication. Reference numbers refer to the reference numbers in the body of the main publication.

<b>Wildfire</b>	<b>Fire Year</b>	<b>Location</b>	<b>Occurrences in Literature</b>	<b>References</b>
Old Fire	2003	California, USA	10	(16, 45, 63, 102–108)
Station Fire	2009	California, USA	9	(16, 73, 105, 108–113)
Fourmile Canyon Fire	2010	California, USA	8	(31, 33, 114–119)
Lost Creek Fire	2003	Alberta, Canada	6	(27, 48, 35, 120–122)
Cerro Grande Fire	2002	New Mexico, USA	6	(123–128)
Hayman Fire	2002	Colorado	6	(37, 39, 80, 129–131)
Santiago Fire	2007	California, USA	5	(16, 105, 106, 108, 111)
Rim Fire	2013	California, USA	5	(66, 88, 132–134)
Jesusita Fire	2009	California, USA	4	(105, 106, 108, 109)
Day Fire	2006	California, USA	4	(16, 86, 105, 135)
Missionary Ridge Fire	2002	Colorado, USA	4	(63, 107, 129, 136)
Camp Fire	2018	California, USA	4	(11, 20, 93, 137)
Coal Seam Fire	2002	Colorado, USA	3	(63, 107, 129)
Grand Prix Fire	2003	California, USA	3	(63, 105, 107)
Topanga Fire	2005	California, USA	3	(86, 105, 135)
High Park Fire	2012	Colorado, USA	3	(36, 92, 138)
Tubbs Fire	2017	California, USA	3	(11, 20, 108)
Thomas Fire	2017/18	California, USA	3	(108, 139, 12)

**Table S2.**

Summary of prior reviews of wildfire impacts to water quality, water quantity, or built water infrastructure. Reference numbers refer to the reference in the body of the main publication.

References	Category(s)	Topics Reviewed
(140)	Water Quality	Physical (hydrologic characteristics, suspended sediment, water temperature), chemical (nitrogen, phosphorous, calcium and potassium, conductivity, pH, alkalinity/dissolved inorganic carbon, organic carbon, dissolved oxygen, disinfection byproduct formation potential, metals, polycyclic aromatic hydrocarbons), and biological (macroinvertebrates, fish, algae) responses after wildfire
(141)	Water Quality	Water temperature and light environment, dissolved organic carbon, nutrients, ions and pH, primary productivity, secondary productivity, mercury bioaccumulation
(30)	Water Quality	Metal mobilization, ash composition
(142)	Water Quality	Aquatic ecosystems
(15)	Water Quality	Suspended sediment, ash, nitrogen, phosphorous, trace elements, chloride, sulfate, sodium, organic carbon, cyanide, polycyclic aromatic hydrocarbons, polychlorinated dibenzo-q-dioxins, and polychlorinated biphenyls
(143)	Water Quality	Benthic macroinvertebrate response
(144)	Water Quantity	Hydrologic recovery, metrics and definition
(145)	Water Quality; Water Quantity	Aquatic ecosystem response, debris flow and morphological processes, erosion and sediment transport, runoff and flow regime, water quality
(146)	Water Quality; Water Quantity	Flooding and streamflow, sediment hazards and water contamination, ecologic response, social and human interactions
(65)	Water Quality; Water Quantity	Precipitation, infiltration, runoff, soil and sediment erosion and transport

**Data S1. (separate file)**

Full list of articles reviewed for this publication and the major category of wildfire impact to water systems described in the article.

## REFERENCES AND NOTES

1. P. E. Dennison, S. C. Brewer, J. D. Arnold, M. A. Moritz, Large wildfire trends in the western United States, 1984–2011. *Geophys. Res. Lett.* **41**, 2928–2933 (2014).
2. Z. Liu, M. C. Wimberly, A. Lamsal, T. L. Sohl, T. J. Hawbaker, Climate change and wildfire risk in an expanding wildland-urban interface: A case study from the Colorado front range corridor. *Landsc. Ecol.* **30**, 1943–1957 (2015).
3. J. T. Abatzoglou, A. P. Williams, Impact of anthropogenic climate change on wildfire across western US forests. *Proc. Natl. Acad. Sci. U.S.A.* **113**, 11770–11775 (2016).
4. V. C. Radeloff, D. P. Helmers, H. A. Kramer, M. H. Mockrin, P. M. Alexandre, A. Bar-Massada, V. Butsic, T. J. Hawbaker, S. Martinuzzi, A. D. Syphard, S. I. Stewart, Rapid growth of the US wildland-urban interface raises wildfire risk. *PNAS* **115**, 3314–3319 (2018).
5. C. S. Stevens-Rumann, K. B. Kemp, P. E. Higuera, B. J. Harvey, M. T. Rother, D. C. Donato, P. Morgan, T. T. Veblen, Evidence for declining forest resilience to wildfires under climate change. *Ecol. Lett.* **21**, 243–252 (2018).
6. M. Goss, D. L. Swain, J. T. Abatzoglou, A. Sarhadi, C. A. Kolden, A. P. Williams, N. S. Diffenbaugh, Climate change is increasing the likelihood of extreme autumn wildfire conditions across California. *Environ. Res. Lett.* **15**, 094016 (2020).
7. N. Liu, G. R. Dobbs, P. V. Caldwell, C. F. Miniati, G. Sun, K. Duan, S. A. C. Nelson, P. V. Bolstad, C. P. Carlson, Inter-basin transfers extend the benefits of water from forests to population centers across the conterminous U.S. *Water Resour. Res.* **58**, e2021WR031537 (2022).
8. N. Liu, P. V. Caldwell, G. R. Dobbs, C. F. Miniati, P. V. Bolstad, S. A. C. Nelson, G. Sun, Forested lands dominate drinking water supply in the conterminous United States. *Environ. Res. Lett.* **16**, 084008 (2021).

9. E. Weidner, A. Todd, “From the forest to the faucet drinking water and forests in the US” (USDA Forest Service, 2011).
10. A. E. East, J. B. Logan, P. Dartnell, O. Lieber-Kotz, D. B. Cavagnaro, S. W. McCoy, D. N. Lindsay, Watershed sediment yield following the 2018 Carr Fire, Whiskeytown National Recreation Area, northern California. *Earth Sp. Sci.* **8**, 10.1029/2021EA001828 (2021).
11. C. R. Proctor, J. Lee, D. Yu, A. D. Shah, A. J. Whelton, Wildfire caused widespread drinking water distribution network contamination. *AWWA Water Sci.* **2**, e1183 (2020).
12. R. L. Kelly, X. Bian, S. J. Feakins, K. L. Fornace, T. Gunderson, N. J. Hawco, H. Liang, J. Niggemann, S. E. Paulson, P. Pinedo-Gonzalez, A. J. West, S. Yang, S. G. John, Delivery of metals and dissolved black carbon to the Southern California coastal ocean via aerosols and floodwaters following the 2017 Thomas fire. *J. Geophys. Res. Biogeo.* **126**, e2020JG006117 (2021).
13. D. G. Neary, K. C. Ryan, L. F. DeBano, “Wildland fire in ecosystems: Effects of fire on soils and water” (Gen. Tech. Rep. RMRS-GRT-42-vol.4, USDA Forest Service, 2005).
14. F. Scordo, S. Chandra, E. Suenaga, S. J. Kelson, J. Culpepper, L. Scaff, F. Tromboni, T. J. Caldwell, C. Seitz, J. E. Fiorenza, C. E. Williamson, S. Sadro, K. C. Rose, S. R. Poulson, Smoke from regional wildfires alters lake ecology. *Sci. Rep.* **11**, 10922 (2021).
15. H. G. Smith, G. J. Sheridan, P. N. J. Lane, P. Nyman, S. Haydon, Wildfire effects on water quality in forest catchments: A review with implications for water supply. *J. Hydrol.* **396**, 170–192 (2011).
16. E. D. Stein, J. S. Brown, T. S. Hogue, M. P. Burke, A. Kinoshita, Stormwater contaminant loading following southern California wildfires. *Environ. Toxicol. Chem.* **31**, 2625–2638 (2012).
17. K. Blount, C. J. Ruybal, K. J. Franz, T. S. Hogue, Increased water yield and altered water partitioning follow wildfire in a forested catchment in the western United States. *Ecohydrology.* **13**, e2170 (2020).

18. H. A. Moreno, J. J. Gourley, T. G. Pham, D. M. Spade, Utility of satellite-derived burn severity to study short- and long-term effects of wildfire on streamflow at the basin scale. *J. Hydrol.* **580**, 124244 (2020).
19. M. L. Wine, D. Cadol, Hydrologic effects of large southwestern USA wildfires significantly increase regional water supply: Fact or fiction? *Environ. Res. Lett.* **11**, 085006 (2016).
20. S. S. Schulze, E. C. Fischer, Prediction of water distribution system contamination based on wildfire burn severity in wildland urban interface communities. *ACS ES&T Water.* **1**, 291–299 (2021).
21. S. Reardon, “‘Burn Scars’ of Wildfires threaten drinking water in California and the West,” *Los Angeles Times*, 27 September 2021; <https://www.latimes.com/environment/story/2021-09-27/burn-scars-of-wildfires-threaten-drinking-water-across-much-of-the-west>.
22. L. Madeira, T. Gartner, Forest resilience bond sparks innovative collaborations between water utilities and wide-ranging stakeholders. *J. Am. Water Works Assoc.* **110**, 42–49 (2018).
23. C. H. Sham, M. E. Tuccillo, J. Rooke, “Effects of wildfire on drinking water utilities and best practices for wildfire risk reduction and mitigation” (EPA Web Report #4482, Water Research Foundation, 2013).
24. S. Ozment, T. Gartner, H. Huber-Stearns, K. DiFrancesco, N. Lichten, S. Tognetti, “Protecting drinking water at the source” (World Resources Institute, 2016); [www.wri.org/publication/protecting-drinking-water-source](http://www.wri.org/publication/protecting-drinking-water-source).
25. E. Margolis, M. Savage, L. A. W. Plan, D. Lyons, S. Fe, W. Division, O. Plan, E. Everett, “Santa Fe municipal watershed plan, 2010–2029” (2013); [https://santafenm.gov/document\\_center/document/780](https://santafenm.gov/document_center/document/780).
26. The Nature Conservancy, “Rio Grande water fund comprehensive plan for wildfire and water source protection, 1–44” (2014); [https://riograndewaterfund.org/wp-content/uploads/2017/01/rgwf\\_compplan.pdf](https://riograndewaterfund.org/wp-content/uploads/2017/01/rgwf_compplan.pdf)).

27. M. B. Emelko, U. Silins, K. D. Bladon, M. Stone, Implications of land disturbance on drinking water treatability in a changing climate: Demonstrating the need for “source water supply and protection” strategies. *Water Res.* **45**, 461–472 (2011).
28. S. M. Stein, M. A. Carr, S. J. Comas, S. I. Stewart, H. Cleveland, L. Bramwell, V. C. Radeloff, “Wildfire, wildlands, and people: Understanding and preparing for wildfire in the wildland-urban interface” (Gen. Tech. Rep. RMRS-GTR-299, USDA Forest Service, 2013).
29. N. I. F. Center, “Fire information statistics” (National Interagency Fire Center, 2023); [www.nifc.gov/fire-information/statistics](http://www.nifc.gov/fire-information/statistics).
30. J. Abraham, K. Dowling, S. Florentine, Risk of post-fire metal mobilization into surface water resources: A review. *Sci. Total Environ.* **599-600**, 1740–1755 (2017).
31. S. F. Murphy, J. H. Writer, R. B. McCleskey, D. A. Martin, The role of precipitation type, intensity, and spatial distribution in source water quality after wildfire. *Environ. Res. Lett.* **10**, 084007 (2015).
32. A. J. Rust, T. S. Hogue, S. Saxe, J. McCray, Post-fire water-quality response in the western United States. *Int. J. Wildl. Fire.* **27**, 203–216 (2018).
33. J. H. Writer, S. F. Murphy, “Wildfire effects on source-water quality-lessons from Fourmile Canyon Fire, Colorado, and implications for drinking-water treatment study rationale and approach” (Fact Sheet 2012-3095, USGS, 2012).
34. A. Tecele, D. Neary, Water quality impacts of forest fires. *J. Pollut. Eff. Control.* **3**, 140 (2015).
35. K. D. Bladon, U. Silins, M. J. Wagner, M. Stone, M. B. Emelko, C. A. Mendoza, K. J. Devito, S. Boon, Wildfire impacts on nitrogen concentration and production from headwater streams in Southern Alberta’s rocky mountains. *Can. J. For. Res.* **38**, 2359–2371 (2008).
36. S. L. Rathburn, S. M. Shahverdian, S. E. Ryan, Post-disturbance sediment recovery: Implications for watershed resilience. *Geomorphology* **305**, 61–75 (2018).



37. A. T. Chow, K.-P. Tsai, T. S. Fegel, D. N. Pierson, C. C. Rhoades, Lasting effects of wildfire on disinfection by-product formation in forest catchments. *J. Environ. Qual.* **48**, 1826–1834 (2019).
38. M. Yu, T. F. A. Bishop, F. F. Van Ogtrop, Assessment of the decadal impact of wildfire on water quality in forested catchments. *Water*. **11**, 533 (2019).
39. C. C. Rhoades, A. T. Chow, T. P. Covino, T. S. Fegel, D. N. Pierson, A. E. Rhea, The legacy of a severe wildfire on stream nitrogen and carbon in headwater catchments. *Ecosystems* **22**, 643–657 (2019).
40. J. L. Florsheim, A. Chin, A. M. Kinoshita, S. Nourbakhshbeidokhti, Effect of storms during drought on post-wildfire recovery of channel sediment dynamics and habitat in the Southern California Chaparral, USA. *Earth Surf. Process. Landforms*. **42**, 1482–1492 (2017).
41. A. K. Hohner, K. Cawley, J. Oropeza, R. S. Summers, F. L. Rosario-Ortiz, Drinking water treatment response following a Colorado wildfire. *Water Res.* **105**, 187–198 (2016).
42. F. Z. Maina, E. R. Siirila-Woodburn, Watersheds dynamics following wildfires: Nonlinear feedbacks and implications on hydrologic responses. *Hydrol. Process.* **34**, 33–50 (2020).
43. P. K. Poon, A. M. Kinoshita, Spatial and temporal evapotranspiration trends after wildfire in semi-arid landscapes. *J. Hydrol.* **559**, 71–83 (2018).
44. R. R. Bart, A regional estimate of postfire streamflow change in California. *Water Resour. Res.* **52**, 1465–1478 (2016).
45. A. M. Kinoshita, T. S. Hogue, Increased dry season water yield in burned watersheds in Southern California. *Environ. Res. Lett.* **10**, 14003 (2015).
46. N. Ohana-Levi, A. Givati, T. Paz-Kagan, A. Karnieli, Forest composition effect on wildfire pattern and run-off regime in a Mediterranean watershed. *Ecohydrology* **11**, e1936 (2018).

47. M. L. Wine, D. Cadol, O. Makhnin, In ecoregions across western USA streamflow increases during post-wildfire recovery. *Environ. Res. Lett.* **13**, 14010 (2017).
48. K. Burles, S. Boon, Snowmelt energy balance in a burned forest plot, Crowsnest Pass, Alberta, Canada. *Hydrol. Process.* **25**, 3012–3029 (2011).
49. K. E. Gleason, A. W. Nolin, T. R. Roth, Charred forests increase snowmelt: Effects of burned woody debris and incoming solar radiation on snow ablation. *Geophys. Res. Lett.* **40**, 4654–4661 (2013).
50. P. D. Micheletty, A. M. Kinoshita, T. S. Hogue, Application of MODIS snow cover products: Wildfire impacts on snow and melt in the Sierra Nevada. *Hydrol. Earth Syst. Sci.* **18**, 4601–4615 (2014).
51. J. D. Maxwell, A. Call, S. B. St. Wildfire and topography impacts on snow accumulation and retention in montane forests. *For. Ecol. Manage.* **432**, 256–263 (2019).
52. T. M. Uecker, S. D. Kaspari, K. N. Musselman, S. M. Skiles, The post-wildfire impact of burn severity and age on black carbon snow deposition and implications for snow water resources, cascade range, Washington. *J. Hydrometeorol.* **21**, 1777–1792 (2020).
53. S. Saxe, T. S. Hogue, L. Hay, Characterization and evaluation of controls on post-fire streamflow response across western US watersheds. *Hydrol. Earth Syst. Sci.* **22**, 1221–1237 (2018).
54. A. J. Whelton, C. Seidel, B. P. Wham, E. C. Fischer, K. Isaacson, C. Jankowski, N. MacArthur, E. McKenna, C. Ley, The Marshall fire: Scientific and policy needs for water system disaster response. *AWWA Water Sci.* **5**, e1318 (2023).
55. G. M. Solomon, S. Hurley, C. Carpenter, T. M. Young, P. English, P. Reynolds, Fire and water: Assessing drinking water contamination after a major wildfire. *ACS ES&T Water.* **1**, 1878–1886 (2021).

56. J. A. Moody, D. a. Martin, Wildfire impacts on reservoir sedimentation in the western United States, in *The Ninth International Symposium on River Sedimentation, 1095–1102* (Tsinghua University Press, 2004), pp. 1095–1102.
57. P. Nyman, P. Yeates, C. Langhans, P. Noske, S. Haydon, G. Sheridan, “Probability and consequence of post-fire contamination events in a water supply catchment” (Australian Institute for Disaster Resilience, 2019);  
[www.bnhcrc.com.au/sites/default/files/managed/downloads/peter\\_nyman.pdf](http://www.bnhcrc.com.au/sites/default/files/managed/downloads/peter_nyman.pdf).
58. C. H. S. Williams, U. Silins, S. A. Spencer, M. J. Wagner, M. Stone, M. B. Emelko, C. H. S. Williams, U. Silins, S. A. Spencer, M. J. Wagner, M. Stone, M. B. Emelko, Net precipitation in burned and unburned subalpine forest stands after wildfire in the northern Rocky Mountains. *Int. J. Wildl. Fire* **28**, 750–760 (2019).
59. A. E. Scholl, A. H. Taylor, Fire regimes, forest change, and self-organization in an old-growth mixed-conifer forest, Yosemite National Park, USA. *Ecol. Appl.* **20**, 362–380 (2010).
60. B. M. Collins, R. G. Everett, S. L. Stephens, Impacts of fire exclusion and recent managed fire on forest structure in old growth Sierra Nevada mixed-conifer forests. *Ecosphere* **2**, art51 (2011).
61. S. A. Parks, C. Miller, M. A. Parisien, L. M. Holsinger, S. Z. Dobrowski, J. Abatzoglou, Wildland fire deficit and surplus in the western United States, 1984-2012. *Ecosphere* **6**, 1–13 (2015).
62. H. Mccann, V. Butsic, J. Battles, R. Cisneros, Y. Jin, S. Kocher, M. D. Potts, S. Stephens, C. Herbert, S. Smith, “The benefits of headwater forest management” (Public Policy Institute of California, 2020); [www.ppic.org/wp-content/uploads/the-benefits-of-headwater-forest-management-april-2020.pdf](http://www.ppic.org/wp-content/uploads/the-benefits-of-headwater-forest-management-april-2020.pdf).
63. S. H. Cannon, J. E. Gartner, R. C. Wilson, J. C. Bowers, J. L. Laber, Storm rainfall conditions for floods and debris flows from recently burned areas in Southwestern Colorado and Southern California. *Geomorphology* **96**, 250–269 (2008).

64. D. W. Hallema, G. Sun, P. V. Caldwell, F. Robinne, K. D. Bladon, S. P. Norman, Y. Liu, E. C. Cohen, S. G. McNulty, “Wildland fire impacts on water yield across the contiguous United States” (Gen. Tech. Rep. SRS-238, USDA Forest Service, 2019); [www.fs.usda.gov/research/treesearch/58095](http://www.fs.usda.gov/research/treesearch/58095).
65. J. A. Moody, R. A. Shakesby, P. R. Robichaud, S. H. Cannon, D. A. Martin, Current research issues related to post-wildfire runoff and erosion processes. *Earth Sci. Rev.* **122**, 10–37 (2013).
66. R. B. Abney, T. J. Kuhn, A. Chow, W. Hockaday, M. L. Fogel, A. A. Berhe, Pyrogenic carbon erosion after the Rim Fire, Yosemite National Park: The role of burn severity and slope. *J. Geophys. Res. Biogeo.* **124**, 432–449 (2019).
67. F. K. Rengers, L. A. McGuire, N. S. Oakley, J. W. Kean, D. M. Staley, H. Tang, Landslides after wildfire: Initiation, magnitude, and mobility. *Landslides* **17**, 2631–2641 (2020).
68. G. G. Ice, D. G. Neary, P. W. Adams, Effects of wildfire on soils and watershed processes. *J. For.* **102**, 16–20 (2004).
69. Q. Ma, R. C. Bales, J. Rungee, M. H. Conklin, B. M. Collins, M. L. Goulden, Wildfire controls on evapotranspiration in California’s Sierra Nevada. *J. Hydrol.* **590**, 125364 (2020).
70. D. W. Hallema, G. Sun, P. V. Caldwell, S. P. Norman, E. C. Cohen, Y. Liu, K. D. Bladon, S. G. McNulty, Burned forests impact water supplies. *Nat. Commun.* **9**, 1–8 (2018).
71. D. W. Hallema, G. Sun, K. D. Bladon, S. P. Norman, P. V. Caldwell, Y. Liu, S. G. McNulty, Regional patterns of postwildfire streamflow response in the Western United States: The importance of scale-specific connectivity. *Hydrol. Process.* **31**, 2582–2598 (2017).
72. P. Nyman, H. G. Smith, C. B. Sherwin, C. Langhans, P. N. J. Lane, G. J. Sheridan, Predicting sediment delivery from debris flows after wildfire. *Geomorphology* **250**, 173–186 (2015).

73. F. K. Rengers, L. A. McGuire, J. W. Kean, D. M. Staley, A. M. Youberg, Progress in simplifying hydrologic model parameterization for broad applications to post-wildfire flooding and debris-flow hazards. *Earth Surf. Process. Landforms* **44**, 3078–3092 (2019).
74. C. A. Emmerton, C. A. Cooke, S. Hustins, U. Silins, M. B. Emelko, T. Lewis, M. K. Kruk, N. Taube, D. Zhu, B. Jackson, M. Stone, J. G. Kerr, J. F. Orwin, Severe Western Canadian wildfire affects water quality even at large basin scales. *Water Res.* **183**, 116071 (2020).
75. D. Touma, S. Stevenson, D. L. Swain, D. Singh, D. A. Kalashnikov, X. Huang, Climate change increases risk of extreme rainfall following wildfire in the Western United States. *Sci. Adv.* **8**, eabm0320 (2022).
76. J. B. Sankey, J. Kreitler, T. J. Hawbaker, J. L. McVay, M. E. Miller, E. R. Mueller, N. M. Vaillant, S. E. Lowe, T. T. Sankey, Climate, wildfire, and erosion ensemble foretells more sediment in western USA watersheds. *Geophys. Res. Lett.* **44**, 8884–8892 (2017).
77. D. M. Theobald, W. H. Romme, Expansion of the US wildland-urban interface. *Landsc. Urban Plan.* **83**, 340–354 (2007).
78. H. A. Kramer, M. H. Mockrin, P. M. Alexandre, V. C. Radeloff, High wildfire damage in interface communities in California. *Int. J. Wildl. Fire* **28**, 641 (2019).
79. A. A. Ager, P. Palaiologou, C. R. Evers, M. A. Day, C. Ringo, K. Short, Wildfire exposure to the wildland urban interface in the western US. *Appl. Geogr.* **111**, 102059 (2019).
80. D. N. Pierson, P. R. Robichaud, C. C. Rhoades, R. E. Brown, Soil carbon and nitrogen eroded after severe wildfire and erosion mitigation treatments. *Int. J. Wildl. Fire* **28**, 814 (2019).
81. D. A. Zema, Postfire management impacts on soil hydrology. *Curr. Opin. Environ. Sci. Heal.* **21**, 100252 (2021).

82. J. B. Abrams, M. Knapp, T. B. Paveglio, A. Ellison, C. Moseley, M. Nielsen-Pincus, M. S. Carroll, Re-envisioning community-wildfire relations in the U.S. West as adaptive governance. *Ecol. Soc.* **20**, (2015).
83. R. K. Miller, K. J. Mach, R. K. Miller, K. J. Mach, Roles and experiences of non-governmental organisations in wildfire response and recovery. *Int. J. Wildl. Fire.* **31**, 46–55 (2022).
84. R. K. Miller, C. B. Field, K. J. Mach, Barriers and enablers for prescribed burns for wildfire management in California. *Nat. Sustain.* **3**, 101–109 (2020).
85. M. R. Auer, Considering equity in wildfire protection. *Sustain. Sci.* **16**, 2163–2169 (2021).
86. M. P. Burke, T. S. Hogue, M. Ferreira, C. B. Mendez, B. Navarro, S. Lopez, J. A. Jay, The effect of wildfire on soil mercury concentrations in Southern California watersheds. *Water Air Soil Pollut.* **212**, 369–385 (2010).
87. H. Uzun, R. A. Dahlgren, C. Olivares, C. U. Erdem, T. Karanfil, A. T. Chow, Two years of post-wildfire impacts on dissolved organic matter, nitrogen, and precursors of disinfection by-products in California stream waters. *Water Res.* **181**, 115891 (2020).
88. J.-J. Wang, R. A. Dahlgren, M. S. Erşan, T. Karanfil, A. T. Chow, Wildfire altering terrestrial precursors of disinfection byproducts in forest detritus. *Environ. Sci. Technol.* **49**, 5921–5929 (2015).
89. F. N. Robinne, K. D. Bladon, U. Silins, M. B. Emelko, M. D. Flannigan, M. A. Parisien, X. Wang, S. W. Kienzle, D. P. Dupont, A regional-scale index for assessing the exposure of drinking-water sources to wildfires. *Forests* **10**, 384 (2019).
90. B. M. Gannon, Y. Wei, M. P. Thompson, J. H. Scott, K. C. Short, System analysis of wildfire-water supply risk in Colorado, USA with Monte Carlo wildfire and rainfall simulation. *Risk Anal.* **42**, 406–424 (2022).

91. A. Bento-Gonçalves, A. Vieira, Wildfires in the wildland-urban interface: Key concepts and evaluation methodologies. *Sci. Total Environ.* **707**, 135592 (2020).
92. K. Blount, A. Kroepsch, Improving the resilience of water resources after wildfire through collaborative watershed management: A case study from Colorado. *Case Stud. Environ.* **3**, 1–11 (2019).
93. T. O. Odimayomi, C. R. Proctor, Q. E. Wang, A. Sabbaghi, K. S. Peterson, D. J. Yu, J. Lee, A. D. Shah, C. J. Ley, Y. Noh, C. D. Smith, J. P. Webster, K. Milinkevich, M. W. Lodewyk, J. A. Jenks, J. F. Smith, A. J. Whelton, Water safety attitudes, risk perception, experiences, and education for households impacted by the 2018 Camp Fire, California. *Nat. Hazards.* **108**, 947–975 (2021).
94. J. Abelson, E. Bishop, D. Bruno, G. Bundesen, D. Constable, D. Cordell, A. Garcia, J. Gee, C. Harris, J. Hart, L. Johnson, K. Kasberg, M. Maurino, D. Mcpherson, M. Mouawad, T. Paul, G. Persad, A. Renteria, I. Ridderbusch, G. Sencan, M. Sparks-Kranz, S. Sugar, A. Zimmer, “Fire and water: An emerging nexus in California” (2019); [https://www.watereducation.org/sites/main/files/file-attachments/water\\_leaders\\_final\\_report.pdf?1575675022](https://www.watereducation.org/sites/main/files/file-attachments/water_leaders_final_report.pdf?1575675022).
95. A. Canning, G. Ryan, “Bushfire management: National good practice operational guidelines for the Australian water industry” (Water Services Association of Australia, 2020).
96. T. B. Paveglio, C. Moseley, M. S. Carroll, D. R. Williams, E. J. Davis, A. P. Fischer, Categorizing the social context of the wildland urban interface: Adaptive capacity for wildfire and community “archetypes”. *For. Sci.* **61**, 298–310 (2015).
97. B. M. Gannon, Y. Wei, L. H. MacDonald, S. K. Kampf, K. W. Jones, J. B. Cannon, B. H. Wolk, A. S. Cheng, R. N. Addington, M. P. Thompson, B. M. Gannon, Y. Wei, L. H. MacDonald, S. K. Kampf, K. W. Jones, J. B. Cannon, B. H. Wolk, A. S. Cheng, R. N. Addington, M. P. Thompson, Prioritising fuels reduction for water supply protection. *Int. J. Wildl. Fire.* **28**, 785–803 (2019).

98. B. M. Gannon, Y. Wei, M. P. Thompson, Mitigating source water risks with improved wildfire containment. *Fire* **3**, 45 (2020).
99. D. W. Hallema, F. N. Robinne, K. D. Bladon, Reframing the challenge of global wildfire threats to water supplies. *Earth's Futur.* **6**, 772–776 (2018).
100. G. Boisramé, S. Thompson, S. Stephens, Hydrologic responses to restored wildfire regimes revealed by soil moisture-vegetation relationships. *Adv. Water Resour.* **112**, 124–146 (2018).
101. L. A. L. Hill, R. Blyth, E. M. Krieger, A. Smith, A. McPhail, S. B. C. Shonkoff, “The public health dimensions of California wildfire and wildfire prevention, mitigation and suppression” (Physicians, Scientists, and Engineers for Healthy Energy, 2020).
102. K. Cydzik, T. S. Hogue, Modeling postfire response and recovery using the hydrologic engineering center hydrologic modeling system (HEC-HMS). *JAWRA J. Am. Water Resour. Assoc.* **45**, 702–714 (2009).
103. H. Y. Jung, T. S. Hogue, L. K. Rademacher, T. Meixner, Impact of wildfire on source water contributions in Devil Creek, CA: Evidence from end-member mixing analysis. *Hydrol. Process.* **23**, 183–200 (2009).
104. A. M. Kinoshita, T. S. Hogue, Spatial and temporal controls on post-fire hydrologic recovery in Southern California watersheds. *Catena* **87**, 240–252 (2011).
105. D. M. Staley, J. A. Negri, J. W. Kean, J. L. Laber, A. C. Tillery, A. M. Youberg, Prediction of spatially explicit rainfall intensity–duration thresholds for post-fire debris-flow generation in the western United States. *Geomorphology* **278**, 149–162 (2017).
106. L. E. Flint, E. C. Underwood, A. L. Flint, A. D. Hollander, Characterizing the influence of fire on hydrology in Southern California. *Nat. Areas J.* **39**, 108–121 (2019).
107. P. M. Santi, B. Macaulay, Water and sediment supply requirements for post-wildfire debris flows in the Western United States. *Environ. Eng. Geosci.* **27**, 73–85 (2021).



108. B. A. Wilder, J. T. Lancaster, P. H. Cafferata, D. B. R. Coe, B. J. Swanson, D. N. Lindsay, W. R. Short, A. M. Kinoshita, An analytical solution for rapidly predicting post-fire peak streamflow for small watersheds in southern California. *Hydrol. Process.* **35**, e13976 (2021).
109. J. W. Kean, D. M. Staley, S. H. Cannon, In situ measurements of post-fire debris flows in southern California: Comparisons of the timing and magnitude of 24 debris-flow events with rainfall and soil moisture conditions. *Case Rep. Med.* **116**, 4019 (2011).
110. M. P. Burke, T. S. Hogue, A. M. Kinoshita, J. Barco, C. Wessel, E. D. Stein, Pre- and post-fire pollutant loads in an urban fringe watershed in Southern California. *Environ. Monit. Assess.* **185**, 10131–10145 (2013).
111. D. M. Staley, J. W. Kean, S. H. Cannon, K. M. Schmidt, J. L. Laber, Objective definition of rainfall intensity-duration thresholds for the initiation of post-fire debris flows in southern California. *Landslides* **10**, 547–562 (2013).
112. C. A. Burton, T. M. Hoefen, G. S. Plumlee, K. L. Baumberger, A. R. Backlin, E. Gallegos, R. N. Fisher, Trace elements in stormflow, ash, and burned soil following the 2009 station fire in Southern California. *PLOS ONE* **11**, e0153372 (2016).
113. F. K. Rengers, L. A. McGuire, J. W. Kean, D. M. Staley, D. E. J. Hobbey, Model simulations of flood and debris flow timing in steep catchments after wildfire. *Water Resour. Res.* **52**, 6041–6061 (2016).
114. B. A. Ebel, E. S. Hinckley, D. A. Martin, Soil-water dynamics and unsaturated storage during snowmelt following wildfire. *Hydrol. Earth Syst. Sci.* **16**, 1401–1417 (2012).
115. B. A. Ebel, J. A. Moody, D. A. Martin, Hydrologic conditions controlling runoff generation immediately after wildfire. *Water Resour. Res.* **48**, 3529 (2012).
116. S. F. Murphy, R. Blaine McCleskey, J. H. Writer, Effects of flow regime on stream turbidity and suspended solids after wildfire, Colorado front range. *IAHS-AISH Publ.* **354**, 11–14 (2012).

117. B. A. Ebel, Simulated unsaturated flow processes after wildfire and interactions with slope aspect. *Water Resour. Res.* **49**, 8090–8107 (2013).
118. S. F. Murphy, R. B. McCleskey, D. A. Martin, J. A. M. Holloway, J. H. Writer, Wildfire-driven changes in hydrology mobilize arsenic and metals from legacy mine waste. *Sci. Total Environ.* **743**, 140635 (2020).
119. S. F. Murphy, R. B. McCleskey, D. A. Martin, J. H. Writer, B. A. Ebel, Fire, flood, and drought: Extreme climate events alter flow paths and stream chemistry. *J. Geophys. Res. Biogeo.* **123**, 2513–2526 (2018).
120. U. Silins, K. D. Bladon, E. N. Kelly, E. Esch, J. R. Spence, M. Stone, M. B. Emelko, S. Boon, M. J. Wagner, C. H. S. Williams, I. Tichkowsky, Five-year legacy of wildfire and salvage logging impacts on nutrient runoff and aquatic plant, invertebrate, and fish productivity. *Ecohydrology* **7**, 1508–1523 (2014).
121. M. B. Emelko, M. Stone, U. Silins, D. Allin, A. L. Collins, C. H. S. Williams, A. M. Martens, K. D. Bladon, Sediment-phosphorus dynamics can shift aquatic ecology and cause downstream legacy effects after wildfire in large river systems. *Glob. Chang. Biol.* **22**, 1168–1184 (2016).
122. A. M. Martens, U. Silins, H. C. Proctor, C. H. S. Williams, M. J. Wagner, M. B. Emelko, M. Stone, Long-term impact of severe wildfire and post-wildfire salvage logging on macroinvertebrate assemblage structure in Alberta’s Rocky Mountains. *Int. J. Wildl. Fire* **28**, 738–749 (2019).
123. S. H. Cannon, E. R. Bigio, E. Mine, A process for fire-related debris flow initiation, Cerro Grande Fire, New Mexico. *Hydrol. Process.* **15**, 3011–3023 (2001).
124. J. A. Moody, D. A. Martin, Initial hydrologic and geomorphic response following a wildfire in the Colorado front range. *Earth Surf. Process. Landforms.* **26**, 1049–1070 (2001).
125. T. A. Earles, K. R. Wright, T. E. Langan, Urban drainage system impacts from the Cerro Grande Wildfire. *Glob. Solut. Urban Drain.* (2004).

126. D. V. Malmon, S. L. Reneau, D. Katzman, A. Lavine, J. Lyman, Suspended sediment transport in an ephemeral stream following wildfire. *Case Rep. Med.* **112**, 2006 (2007).
127. S. L. Reneau, D. Katzman, G. A. Kuyumjian, A. Lavine, D. V. Malmon, Sediment delivery after a wildfire. *Geology* **35**, 151–154 (2007).
128. J. A. Moody, D. A. Martin, S. L. Haire, D. A. Kinner, Linking runoff response to burn severity after a wildfire. *Hydrol. Process.* **22**, 2063–2074 (2008).
129. M. R. Stevens, C. R. Bossong, M. G. Rupert, A. J. Ranalli, E. W. Cassidy, A. D. Druliner, “Post-wildfire hydrologic hazards in the Wildland Urban Interface of Colorado and the Western United States” (Fact Sheet 2007-3036, USGS, 2008).
130. C. C. Rhoades, D. Entwistle, D. Butler, The influence of wildfire extent and severity on streamwater chemistry, sediment and temperature following the Hayman Fire, Colorado A. *International.* **20**, 430–442 (2011).
131. P. R. Robichaud, S. A. Lewis, J. W. Wagenbrenner, R. E. Brown, F. B. Pierson, Quantifying long-term post-fire sediment delivery and erosion mitigation effectiveness. *Earth Surf. Process. Landforms.* **45**, 771–782 (2020).
132. K. P. Tsai, H. Uzun, H. Chen, T. Karanfil, A. T. Chow, Control wildfire-induced *Microcystis aeruginosa* blooms by copper sulfate: Trade-offs between reducing algal organic matter and promoting disinfection byproduct formation. *Water Res.* **158**, 227–236 (2019).
133. S. A. Wright, M. D. Marineau, Turbidity current observations in a large reservoir following a major wildfire. *J. Hydraul. Eng.* **145**, 06019011 (2019).
134. H. Chen, H. Uzun, A. T. Chow, T. Karanfil, Low water treatability efficiency of wildfire-induced dissolved organic matter and disinfection by-product precursors. *Water Res.* **184**, 116111 (2020).
135. M. P. Burke, “Investigation of coupled hydrologic and geochemical impacts of wildfire on Southern California Watersheds,” thesis, University of California, Los Angeles, CA (2012).

136. V. G. deWolfe, P. M. Santi, J. Ey, J. E. Gartner, Effective mitigation of debris flows at Lemon Dam, La Plata County, Colorado. *Geomorphology* **96**, 366–377 (2008).
137. K. P. Isaacson, C. R. Proctor, Q. Erica Wang, E. Y. Edwards, Yoorae Noh, A. D. Shah, A. J. Whelton, Drinking water contamination from the thermal degradation of plastics: Implications for wildfire and structure fire response. *Environ. Sci. Water Res. Technol.* **7**, 274–284 (2021).
138. J. H. Writer, A. Hohner, J. Oropeza, A. Schmidt, K. M. Cawley, F. L. Rosario-Ortiz, Water treatment implications after the High Park Wildfire, Colorado. *J. Am. Water Works Assoc.* **106**, E189–E199 (2014).
139. B. A. Ebel, J. A. Moody, Parameter estimation for multiple post-wildfire hydrologic models. *Hydrol. Process.* **34**, 4049–4066 (2020).
140. M. J. Paul, S. D. LeDuc, M. G. Lassiter, L. C. Moorhead, P. D. Noyes, S. G. Leibowitz, Wildfire induces changes in receiving waters: A review with considerations for water quality management. *Water Resour. Res.* **58**, 1–28 (2022).
141. I. M. McCullough, K. S. Cheruvellil, J. F. Lapierre, N. R. Lottig, M. A. Moritz, J. Stachelek, P. A. Soranno, Do lakes feel the burn? Ecological consequences of increasing exposure of lakes to fire in the continental United States. *Glob. Chang. Biol.* **25**, 2841–2854 (2019).
142. R. J. Bixby, S. D. Cooper, R. E. Gresswell, L. E. Brown, C. N. Dahm, K. A. Dwire, Fire effects on aquatic ecosystems: An assessment of the current state of the science. *Freshw. Sci.* **34**, 1340–1350 (2015).
143. G. W. Minshall, Responses of stream benthic macroinvertebrates to fire. *For. Ecol. Manage.* **178**, 155–161 (2003).
144. J. W. Wagenbrenner, B. A. Ebel, K. D. Bladon, A. M. Kinoshita, Post-wildfire hydrologic recovery in Mediterranean climates: A systematic review and case study to identify current knowledge and opportunities. *J. Hydrol.* **602**, 126772 (2021).

145. F. N. Robinne, D. W. Hallema, K. D. Bladon, J. M. Buttle, Wildfire impacts on hydrologic ecosystem services in North American high-latitude forests: A scoping review. *J. Hydrol.* **581**, 124360 (2020).
146. A. M. Kinoshita, A. Chin, G. L. Simon, C. Briles, T. S. Hogue, A. P. O’Dowd, A. K. Gerlak, A. U. Albornoz, Wildfire, water, and society: Toward integrative research in the “Anthropocene”. *Anthropocene* **16**, 16–27 (2016).