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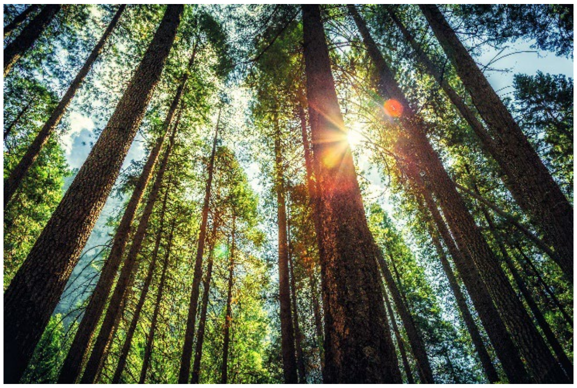
Long-Term Economic Impacts of Large Fires in California from 2018-2021: Losses and Opportunities



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Technical Advisory Committee

This study was overseen by CAL FIRE and the U.S. Forest Service (USFS). CAL FIRE convened a Technical Advisory Committee (TAC) to provide input on the scope to study technical details related to forest management, carbon estimates, fire impacts, and review the drafts of this report.

TAC members were:

Justin Britton, Wood Products & Bioenergy Forester II, CAL FIRE

John McCarthy, Wood Products & Bioenergy Forester III, CAL FIRE

Tim Robards, Climate and Energy Staff Chief (retired), CAL FIRE

Robin Bellows, Forest Health Development Program Manager, CAL FIRE

Nadia Tase, Climate Change and Forest Inventory Specialist, CAL FIRE

Helena Murray, Wood and Biomass Utilization Program Manager, USFS

Larry Swan, Wood & Biomass Utilization Program Leader (retired), USFS

George "YG" Gentry, Senior Vice President, California Forestry Association

Elliot Vander Kolk, Senior Forest and Climate Advisor, Sierra Nevada Conservancy

Martin Twer, Biomass Program Director, Watershed Research and Training Center

Executive Summary

California appears to have entered an era of megafires with more wildfires burning hundreds of thousands of acres, and a few individual fires burning over 1 million acres. Lives have been lost, thousands of homes destroyed, and communities forever changed overnight. This report focuses on impacts of the large fires in 2018 through 2021 on the timber industry sector and characterizes some of the economic impacts caused by these fires. A similar report was completed by Mason, Bruce & Girard (MB&G) for Oregon after a large series of fires that occurred over the 2020 Labor Day Weekend (Rasmussen et al. 2021).

CAL FIRE and USFS engaged MB&G to assess forest sector impacts and carbon emissions from large California fires over 10,000 acres in size from 2018 through 2021. The project focuses on fires within a 40-million-acre area across the North Coast, Cascade Mountains, and Sierra Nevada Mountains (refer to map 1 in Appendix D). MB&G first developed a forest inventory and calculated the area and severity of selected fires, and then developed a forest carbon loss estimate. MB&G then modeled a future management scenario to calculate the potential timber harvest volume lost over the next 50 years, due to fires over 10,000 acres in size from 2018 through 2021. These results are then used to calculate the impact to jobs and economic production in the forest products sector. The future management scenario is informed by a landowner/land manager survey conducted as part of this project. The survey responses from Registered Professional Foresters (RPFs) working with small forestland owners, forest industry staff, and USFS staff provided insight into current forest management, opportunities, challenges, and impacts of the large fires on landowners.

This analysis found that of the 21.7 million acres of forest in the 40-million-acre project area, over 4 million acres, 20% of the forest area, burned from 2018 through 2021. This includes 1,570,000 acres of high severity fire, 37% of the total burned area, where overstory tree mortality typically exceeds 75%. If fires continue to burn at this rate and severity of distribution, all the forested areas in the project area will experience fire over the next 20 years, and high severity fire would impact 36% of the forest area. In addition, the 49 fires in the analysis generated nearly 1,500 high severity patches over 40 acres in size and greater than 100 meters from potential natural seed source where forest regeneration will be delayed. Due to the distance from potential natural seed sources, these patches are at risk of conversion to non-forest vegetation. Thirteen high severity fire patches sprawl over 10,000 acres or more. The amount of carbon volatilized from standing live trees associated with the fires totaled 44 million metric tons, which is equivalent to 160 million metric tons of carbon dioxide (CO_2e) that was previously sequestered by the forest. Actual air pollutant emissions would have been in a variety of forms, including CO_2e, other carbonaceous compounds, and particulate matters.

The large fires in this study will reduce the potential future timber harvest volume by 11,032 million board feet (MMbf) over the next 50 years, after accounting for legal and policy requirements, and differences in management intensity by different landowners. Future harvest volume loss will occur on both public and private lands over the next 50 years, with public losses totaling 8,240 MMbf, private forest industry losses totaling 2,403 MMbf, and private non-industrial losses totaling 389 MMbf. On average, 221 MMbf will be lost per year, equivalent to 14% of the annual harvest across California from 2018 through 2021. The value of the lost 11,032 MMbf is $12.7 billion (2022 dollars) based on the value of primary wood products that could be produced. The lost future timber harvest potential would support an average of 4,800 forestry, logging, and wood products manufacturing jobs in California with a range from 4,300 to 5,900 jobs over the 50-year period, assuming employment per MMbf remains at 2016 levels. Forestry, logging, and wood products manufacturing supported nearly 34,000 jobs in California in 2016.

Interviews with California RPFs who work with small forestland owners (owners of tens to a few thousand acres of forest) and federal land managers pointed to the lack of logging operators and the lack of log market capacity as hindering both pre-fire, proactive management, and post-fire salvage. The RPFs noted the value of grant programs, such as CAL FIRE's California Forest Improvement Program (CFIP), in helping landowners reforest following forest fires. However, the impact of fires and the difficulty of managing lands due to the lack of operators and market capacity has caused some landowners to question whether continuing to own forestland is desirable and if they should sell their lands.

All private forest industry land managers interviewed reported that portions of the lands they manage had burned in large fires. They reported that the initial response to fire damage was to salvage timber that was economically viable to harvest, as well as to repair and upgrade roads. In the long-run, land managers expect to see reduced harvest levels, and possibly a shift from uneven-aged to even-aged management. This is due to the perception that fire risk remains, even in stands that have been thinned. All managers expressed a commitment to continue to manage timber in California, with some managers interested in increasing the area under their management.

Background

California appears to have entered an era of megafires. In recent years, California has experienced fires covering hundreds of thousands of acres to 1 million acres. These fires have resulted in the loss of human life, extensive property damage, and environmental impacts, including habitat loss (Stephens et al. 2016), carbon emissions (Christensen et al. 2021), lower water quality (Oliver et al. 2011), and loss of both commercial-size timber and trees expected to grow into commercial-size timber over the next 50 years.

The loss of live green trees available for harvest could decrease the economic viability of local mills and logging operators. Reduced mill and logging capacity will reduce the ability of landowners and land managers to generate revenue from active forest management, such as commercial timber harvest. Since commercial activities can help pay for activities like thinning to promote health and vigor of remaining trees, and hazardous fuels reduction, the loss of this capacity will reduce the area treated. It would also reduce capacity to maintain road access and assist in preparing areas for prescribed burning. Cumulatively, this will reduce forest restoration efforts, allow more build-up of hazardous fuels, and along with long-term climate change impacts, it will increase the risk of future megafires. Given decreased revenue potential, increased costs of management, and increase in risk of large wildfires, more forestland is likely to be sold and converted to other land uses.

Methods Summary

The following section provides a methods summary for various components of this study. Detailed methods are provided in Appendix A.

Project scope

MB&G, CAL FIRE, and USFS collaborated with a technical advisory committee, including agency staff, non-profit representatives and industry representatives to develop the scope for this analysis. The committee recommended a project area defined by the CAL FIRE CALVEG[1] system, including the Great Basin, North Coast, North Interior, North Sierran, and South Sierran Zones (Figures 1 and 2). These zones include most commercial forest land in California and the areas most affected by large fires. The committee also recommended a focus on fires over 10,000 acres that occurred from 2018 through 2021. Initial analysis by MB&G showed that fires over 10,000 acres accounted for more than 95% of the burned acres in the project area in these years, based on fire perimeter data. While large fires occurred prior to 2018, the 2018 through 2021 period includes some of the most significant large fires in recent years, including the August Complex, Caldor, Camp, and Dixie fires.

Figure 1. CAL FIRE CALVEG zones used to define the project area (USFS 2022).

[1] A classification system for existing vegetation that follow USFS standards and procedures following the National Vegetation Classification Standard. More information available at: https://www.fs.usda.gov/detail/r5/landmanagement/resourcemanagement/?cid=stelprdb5347192

Forest inventory

MB&G estimated the current forest inventory within the project area (Figure 2, Map 1) using a combination of Landscape Ecology, Modeling, Mapping, and Analysis (LEMMA),[2] a forest cover layer developed by American Forests,[3] and the USFS Forest Inventory and Analysis (FIA)[4] data. Both the LEMMA and FIA data reflect 2017 conditions. The American Forests data are based on re-analysis for LEMMA data to include FIA forest type groups, reflecting 2017 conditions. Forest lands in the project area are defined as areas identified as forest in both LEMMA and American Forests data. These data sets follow the FIA definition of forest, which is areas of at least 10% tree cover. Based on the overlap of LEMMA and the American Forests data, this analysis shows 21.7 million acres of forest in the project area. The American Forest layer alone shows 25.1 million acres of forest in the project area, while FIA data from the 2017 AB 1504 carbon inventory show 28.5 million acres of forest in the project area (Table 1, Map 2; Christensen et al. 2019).

Figure 2. Project area.

The inventory developed for this project assigns each LEMMA 30m-by-30m cell to a stratum based on a collection of FIA plots. The LEMMA forest type (FORTYPBA) was used to translate each LEMMA cell to an FIA forest type (FORTYPCD) and assigned quartiles to basal area (BA) and trees per acre. With these stratum assignments linking each LEMMA cell to a set of FIA plots, plot-level yield forecasts of merchandized volume and standing live carbon at the stratum level were calculated. The inventory was validated by comparing the average volume per acre of each of the forest types in the inventory with FIA data (refer to Appendix A for more detail). Looking across the entire project area, the 2017 average volume per acre in the inventory was 18.17 thousand board feet (Mbf) per acre in International ¼" (18.54 Mbf per acre Scribner decimal C short scale)[5], compared to 18.56 Mbf per acre in International ¼" (18.93 Mbf per acre Scribner) in FIA data from counties within the project area, a 2.1% difference.

[2] https://lemma.forestry.oregonstate.edu/

[3] Unpublished. Developed as part of American Forests' ongoing project for CAL FIRE, "Effects of Forest Management and Wood Utilization on Carbon Sequestration and Storage in California".

[4] USFS Inventory and Analysis program maintains field plots in forests nationwide that are remeasured periodically.

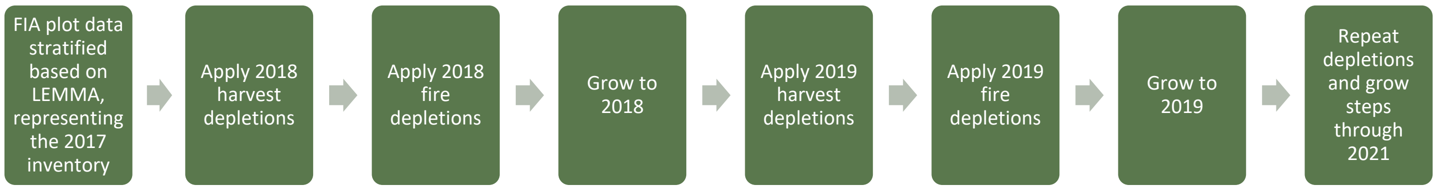
[5] FIA volume reported in International ¼". We converted to Scribner using a conversion factor of 1.02, a factor derived by MB&G in past work with both log scales.

For each year, live tree growth was modeled, and the inventory was depleted for the fires in this analysis and timber harvests.[6] Timber harvest data came from USFS and CAL FIRE Timber Harvest Plan (THP) data to update the inventory to 2021 (Figure 3).[7]

Table 1. Comparison of forest acres by CAL FIRE vegetation zone (Cleland et al. 2007) found in this study and in the 2017 AB 1504 carbon inventory using FIA data from Christensen et al. (2019).

CAL FIRE vegetation zone	2017 AB 1504 carbon inventory (ac)	This study (ac)
Eastside	2,827,000	1,678,000
Klamath/Interior Coast Ranges	7,877,000	6,882,000
North Coast	2,699,000	2,667,000
Sierra/Cascades	15,146,000	10,475,000
Total	28,549,000	21,701,000

Figure 3. Flow chart showing the steps used to create the post-fire inventory for the project area



Included in the inventory raster dataset is information regarding all the reporting levels required by the USFS and CAL FIRE, including:

1. Fire name
2. Fire year (Maps 3-7)
3. County (Map 8)
4. Timber Valuation Areas (Map 9)
5. Ownership group (Map 1)
6. Land allocation (Map 10)
7. CAL FIRE-designated High Hazard Zones (Map 11) [8]
8. USFS Wildfire Crisis Strategy Firesheds (Maps 12-16)
9. Vegetation zone (Map 17)

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[6] We did not deplete the inventory using post-fire salvage data. In burned areas, the live tree inventory is reduced, based on fire severity.

[7] USFS data available at https://data.fs.usda.gov/geodata/edw/edw_resources/fc/S_USA.Activity_TimberHarvest.gdb.zip, https://hub-calfire-forestry.hub.arcgis.com/maps/CALFIRE-Forestry::cal-fire-timber-harvesting-plans-all-ta83/about

[8] High Hazard Zone tiers identify areas where tree mortality has the greatest potential to result in wildfire and/or falling trees and threaten people and property. Tier 1 lands are areas where tree mortality and assets to be protected coincide. Tier 2 lands are watersheds that have significant tree mortality as well as significant community and natural resource assets. Tier 3 lands are areas in both Tiers 1 and 2.

Fire severity

Fire severity was drawn from Monitoring Trends in Burn Severity (MTBS) fire severity data[9] or, if unavailable, Rapid Assessment of Vegetation Condition after Wildfire (RAVG) fire severity data. [10] Both data sets show burn severity for 30m-by-30m cells within a fire perimeter (Figure 4). [11]

Fire severity data was resampled using the Focal Statistics tool in ArcPro by Esri.[12] The resampling process re-coded each raster cell based on the average of the nine surrounding cells. This method was used as it is unlikely that an area identified in a single 30m-by-30m cell of moderate or lower severity fire would significantly change the likelihood of regeneration. By resampling a 3-by-3 group of raster cells, which cover about 1 acre, the impact of a single or a few moderate or lower severity cells is reduced (Figure 5).

Carbon volatilized

Carbon volatilization from standing live trees due to large fires (>10,000 acres) within the project area was estimated based on data from Maestrini et al. (2017). Volatilized carbon represents carbon consumed by fire. It does not include carbon in live vegetation that is killed by fire and transferred to other forest carbon pools, such as woody debris. Maestrini et al. calculated the change in forest carbon stocks in a mixed conifer forest following the 70,000-acre Chips Fire in 2012, located in the Plumas and Lassen National Forests at the border of the southern Cascade and Sierra Nevada mountain ranges. Carbon volatilization by fire severity follows the proportions found by Maestrini et al. for live and dead trees (Table 2). California Air Resources Board staff who have completed detailed modeling of carbon volatilized from California wildfires following the assumptions in USFS First Order Fire Effect Model (FOFEM) reported that live tree volatilization typically ranges between 20% and 30%. These results are similar to Maestrini et al., but based on a different set of assumptions.[13] This analysis does not include estimates for carbon volatilized from down dead wood, litter, and understory vegetation, resulting in an underestimate of the total forest carbon volatilized.

[9] https://www.mtbs.gov/project-overview

[10] https://burnseverity.cr.usgs.gov/products/ravg

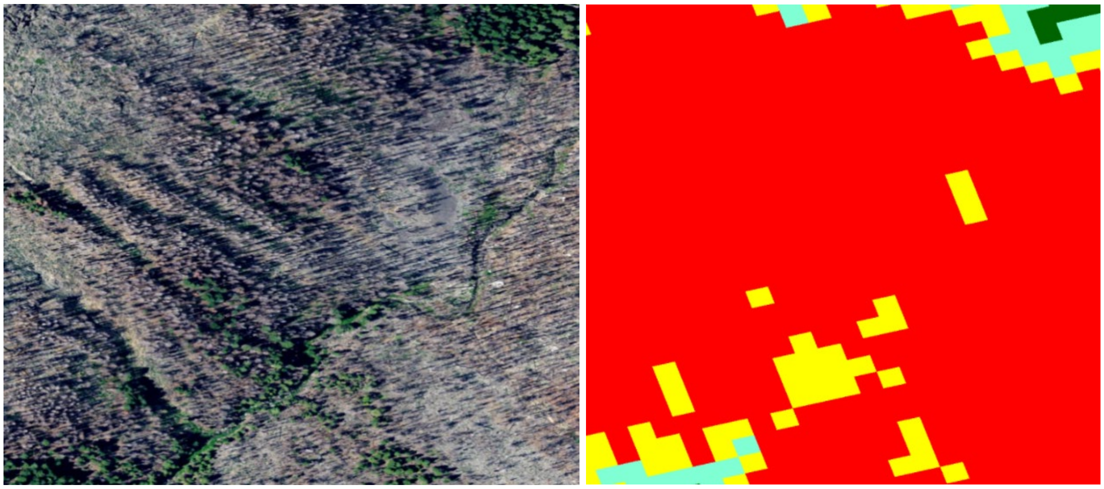
[11] Burn severity classes in these layers are from USFS Burned Area Emergency Response or Monitoring Trends in Burn Severity assessments. Within high burn severity areas, forest floor duff is typically nearly entirely consumed, medium and heavy woody debris are at least partially consumed and at least deeply charred with mostly ash and charcoal remaining, overstory trees typically exhibit greater than 75% mortality, crown char is typically 100% from torching fire, and significant branch loss is present at the highest crown levels. Moderate burn severity includes areas that exhibit conditions that are transitional in magnitude and/or uniformity between characteristics within low and high burn severity classes. Low burn severity typically results in high (up to 100%) consumption of litter, significant scorch, char, or consumption of low (<1 m) vegetation and shrubs and trees to 5 meters. Intermediate and large trees may exhibit up to 25% mortality.

[12] https://pro.arcgis.com/en/pro-app/latest/tool-reference/spatial-analyst/focal-statistics.htm

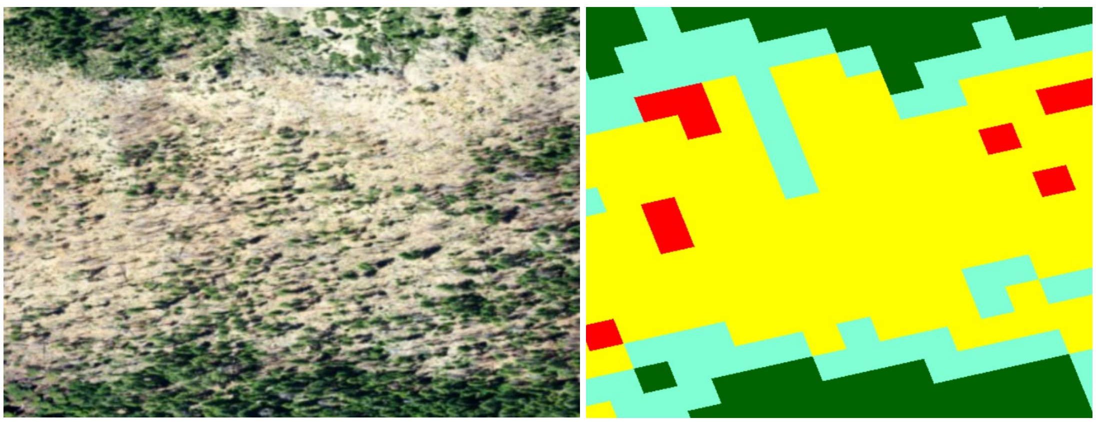
[13] Pers. Comm. Klaus Scott, Staff Air Pollution Specialist, California Air Resources Board, 8/24/2022

Figure 4. Examples of fire severity in aerial images and corresponding fire severity data: A) high fire severity, B) moderate fire severity, C) low fire severity. Red indicates high severity, yellow is moderate, teal is low, and dark green is unburned.

A) High severity



B) Moderate severity



C) Low severity

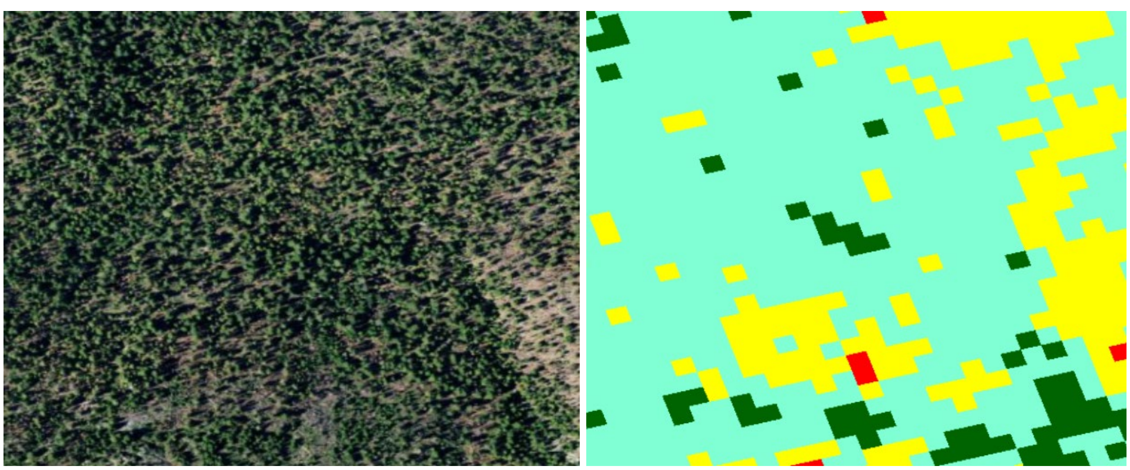


Figure 5. Two examples of the resampling. 1a and b) An area of mainly high severity fire (red) with small areas of lower severity fire (yellow: moderate; teal: low; dark green: unburned). a) is the original MTBS raster, b) is the same area following resampling. 2a and b) An area with a mosaic of high, moderate, and low severity fire.

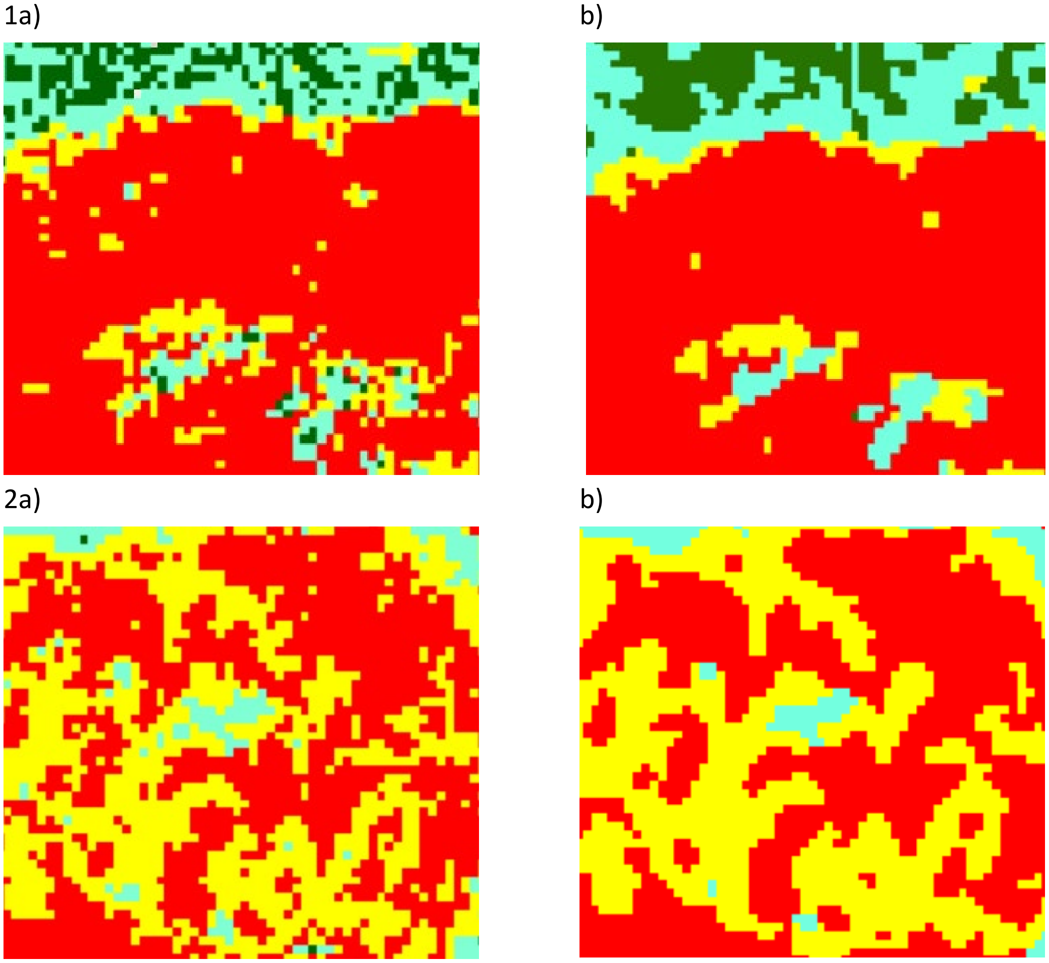


Table 2. Summary of the average post-fire carbon in standing trees from Maestrini et al. (2017).

Fire severity	Post-fire carbon† in standing live and dead trees (kg C/m^2)	Post-fire pyrogenic†† carbon in standing trees (kg C/m^2)	Total post-fire carbon (kg C/m^2)	Percent post-fire carbon remaining compared to unburned forests (rounded)
Unburned	31	0	31	100%
Low-to-Moderate	24	0.015	24.015	77%
High	22	0.051	22.051	71%

†Post-fire carbon is carbon in remaining biomass following a fire. For example, carbon in tree stems and branches present after a fire.

††Pyrogenic carbon is carbon-containing materials produced by the incomplete combustion of organic matter. Biochar is an example of pyrogenic carbon.

High severity fire area

High severity fire patches are defined for this project as areas over 40 acres and greater than 100m from unburned, low or moderate fire severity areas (Figure 6), criteria of which is consistent with other studies (e.g., LTWRP 2019). The 100m distance accounts for seed dispersal. Areas beyond 100m from a viable seed source have a low probability of natural reseeding (Welch et al. 2016). This analysis identifies the extent and number of forest-stand-sized areas that are at risk of poor natural tree regeneration due to their size, fire severity, and proximity to a natural seed source.

Loss of future timber harvest volume

Estimating the future timber harvest volume loss requires two key assumptions about the future: the harvest prescriptions, and the area that would have been harvested except for the large fires.

The prescriptions are based on survey responses from RPFs working with small forest landowners and staff from industrial or large forestland owners, as well as input from CAL FIRE and USFS staff (Table 3). Prescriptions apply to commercial forest types and landowner group. Harvest volume estimates included only volume from commercial species in the analysis of volume from these forest types. For this analysis, the California Forestry Association provided spatial data for lands owned and managed by the forest industry. For high level analyses, results for forest industry lands are reported separately from other private lands. However, to maintain confidentiality, all private lands are grouped for more detailed analyses.

The estimate of the area that could have been harvested takes into account the severity of the fires, management policies, and management practices of each landowner. Areas of high and moderate severity fire are assumed to be unavailable for harvest in the 50-year analysis period. Timber on these lands is assumed to have been consumed by fire or salvaged. Plantations in these areas, if any, are assumed to be unavailable for harvest until after the analysis period. Federal lands unavailable for harvest were removed from the analysis, including wilderness areas and other reserves.

A landscape harvest intensity factor was then applied to each landowner group (Table 4). This factor accounts for the area unavailable for harvest due to regulations, economic limitations, and management practice. This factor was developed by comparing the volume outcome of applying prescriptions to all commercial forest types in the project area with actual harvest volumes from 2014 through 2021 from the California Department of Tax and Fee Administration,[14] and data in Marcille (2019) (Table 5). Decreasing the harvest intensity factor resulted in less harvest. The lowest factors were applied to federal lands, based on harvest data, and non-industrial landowners, based on the RPF interviews indicating low levels of harvest from these lands.

Numerous studies have considered possible impacts of climate change on California's forests (e.g., Lenihan et al. 2003, Lenihan et al. 2008, Battles et al. 2008, Williams et al. 2019). Climate change impacts will depend on location, with some areas increasing in productivity and others decreasing in productivity or transitioning from forest to non-forest vegetation. Climate change may also impact future disturbance rates, though the impacts will depend on the site and the effects of forest health treatment and fuels mitigation activities. However, this report is concerned with the potential lost harvest volume from existing stands affected by large fires. In these stands, a substantial portion of the volume existed prior to the fires. As a result, impacts on the estimated loss of potential harvest volume are not expected to be greatly affected by climate change induced changes to productivity. Harvest volume lost estimates in the early decades of this analysis are more certain than in later decades and will have a greater impact on current planning for investments in harvest infrastructure. However, volume loss in future disturbances is possible. Climate impacts that do occur will have the greatest effect on harvest projections in the latter part of the 50-year analysis period.

In addition to climate change, several other factors that may influence harvest prescription and harvest intensity could not be factored into the model due to the inherent uncertainty associated with such factors. No adjustment in harvest prescription or harvest intensity was applied to future harvests to account for possible changes in technology, regulations, or product demand. Changes in product demand and regulations could result in increased or decreased harvest levels depending on the change. Technology changes would likely increase harvest.

[14] https://www.cdtfa.ca.gov/taxes-and-fees/timber-tax.htm

Figure 6. A high severity burn patch in the 2018 Camp Fire near Concow, CA. Photo: Owen Bettis/Deer Creek Resources.

Table 3. General prescriptions used in this analysis to represent typical forest management in commercial forest types in California by different landowners.

Prescription	Harvest method	Harvest timing	Minimum harvest	Residual
D1	Thin through a diameter range	Harvest when BA exceeds 125 ft^2/ac, > 15 years between entries	4 Mbf/ac	125 ft^2 of BA
D2	Thin through a diameter range	Harvest when BA exceeds 150 ft^2/ac, > 20 years between entries	5 Mbf/ac	150 ft^2 of BA
D3	Thin from below	70% canopy cover	7 Mbf/ac	70% canopy cover
Regeneration	Clearcut	Clear cut at approximately age 80	See Note†	NA
M1	Thin through a diameter range	Harvest when BA exceeds 120 ft^2/ac, > 15 years between entries	4 Mbf/ac	2/3 of initial BA
M2	Thin through a diameter range	Harvest when BA exceeds 150 ft^2/ac, > 20 years between entries	5 Mbf/ac	2/3 of initial BA
M3	Thin from below	Harvest when BA exceeds 120 ft^2/ac, > 15 years between entries	4 Mbf/ac	2/3 of initial BA

† Regeneration harvests are modeled as occurring when stands reach 42 Mbf per acre, or the approximate harvest volume of a moderately productive unthinned stand at age 80 (mean annual increment = 525 bf per acre per year). In practice, many areas under even-aged management have been previously thinned and typical even age-management includes commercial thinning activities. As a result, regeneration harvests rarely produce 42 Mbf per acre. By not including thinning activities as part of the even-age harvest prescription, the certainty of the timing of volume loss due to fires is reduced, but there is little impact on the overall harvest volume.

Table 4. General prescription applied to each landowner and assumed landscape-level harvest intensity.

Landowner	Forest type	Prescriptions applied	Landscape harvest intensity
BLM	All dry types	D3	40%
BLM	All mesic types	M3	20%
Local	All forest types	Assumed no harvest	NA
Other Federal	All forest types	Assumed no harvest	NA

Landowner	Forest type	Prescriptions applied	Landscape harvest intensity
Private – Forest Industry	California mixed conifer	Regeneration	90%
Private – Forest Industry	Other dry types	D1	90%
Private – Forest Industry	Redwood	M1	80%
Private – Forest Industry	Other mesic types	Regeneration	80%
Private – Small Forestland Owners	All dry types	D2	20%
Private – Small Forestland Owners	All mesic types	M2	20%
State	All dry types	D3	70%
State	All mesic types	Assume no harvest	NA
Tribal	All dry types	D1	80%
Tribal	All mesic types	M1	70%
National Forest	All dry types	D2	40%
National Forest	All mesic types	M3	20%

† Dry forest types: California mixed conifer, Jeffrey pine, Ponderosa pine, western white pine

‡ Mesic forest types: Douglas-fir, grand fir, Port Orford cedar, redwood, western hemlock

Table 5. Estimated harvest by landowner type when landscape harvest intensity factors are applied to all commercial forest types in the project area.

Landowner type	Estimated harvest using intensity values in Table 4 (MMbf/yr)	2014-2021 Average (MMbf/yr)	2014-2021 Range (MMbf/yr)
Public	232	179	114-235
Private (all)	1,378	1,360	1,230-1,586
Total	**1,610**	**1,539**	

Wood products value estimate

Marcille et al. (2020, pgs. 18 and 32) reported a total harvest volume in California in 2016 of 1,572 MMbf and a total sales value of California's primary wood products of $1.524 billion. Dividing California's 2016 primary wood products value by the 2016 harvest volume calculates to $969 per Mbf. Adjusting to 2022 dollars, the value is $1,182 per Mbf. Primary wood products include lumber, biofuel, chips, veneer, and other wood products. This value assumes all timber harvested in California was processed in California. The value is a slight underestimate due to export of timber prior to milling. In 2016, about 2% of timber harvested in California was processed in neighboring states, and another 3% was exported internationally. Inflows of timber from neighboring states was equivalent to less than 1% of the harvest in California and did not make up for the volume exported prior to milling.

Employment estimate

Marcille et al. (2020, pg. 53) reported that forestry, primary forest products manufacturing, and logging directly employed 33,951 people in 2016, or about 21.6 people per MMbf harvested. This does not include support services jobs, secondary manufacturing, indirect jobs, or induced jobs.

Land manager survey

The project included a telephone survey of five RPFs in California, seven forestry operations staff from six private industrial forestland owners, and USFS Regional Sale Administrator, to better understand how larger fires have affected management of forestlands in California (refer to Appendix 3 for the survey questions). The RPFs' working areas span most of the project area, including the length of the Sierras, North Interior, and eastern side of the North Coast. Collectively they have worked with hundreds of small forestland owners who each own tens to a few thousand acres within the project area. The forest industry staff manage between 50,000 and 2 million acres of land in the project area, across all CAL FIRE

CALVEG zones, except the Great Basin. Industry lands are managed for long-term revenue generation. Managers noted that to achieve this objective, management for forest resiliency and healthy forest conditions is necessary.

Results and discussion

Burned area

Within the project area, 21.7 million acres are forested, while 18.3 million acres are non-forest (Table 6). Slightly more than a third of the forested acres are privately owned. The remaining roughly two-thirds of the forestlands are public, primarily National Forest System lands. Across these forestlands there are 402 billion board feet (Bbf) of post-fire standing timber volume, with 50% of the volume located on National Forest System lands and 39% on private lands (Table 7).

The large fires (>10,000 acres) that occurred from 2018 through 2021 have resulted in a significant change to California's forestlands. The 21.7 million acres of forestland in the project area included about 70 percent of the forested area in California.[15] Across these forests, nearly 4.8 million acres were within fire perimeters and nearly 4.3 million acres, or 20% of the total forest areas have burned,[16] not including acres that burned repeatedly in separate fires (Tables 8, 9, and 10; refer to Appendix B for results by year). Nearly 1.6 million acres, or 7% of the forest area, experienced nearly complete loss of live tree cover in high severity fire. If fires continue to burn at this rate and severity distribution, all the forest in the project area will experience fire in 20 years, and high severity fire will impact 36% of the forest area.

All landownership groups were affected by fires, but federal lands collectively had the highest proportion of lands burned. In this report, federal lands are spilt across the National Forest System, Bureau of Land Management (BLM), and other federal lands. These federally managed ownership groups had the highest proportions of burned forest at 28%, 15%, and 18%, respectively. Private forest industry lands and tribal lands were at the other end of the range, with only 10% and 8%, respectively burned. In total, National Forest System lands accounted for 73% of the total burned acres in the project area and 74% of the high severity fire. National Forest System reserved lands (e.g., Late Successional Reserves in the Northwest Forest Plan area and congressionally designated Wilderness areas) burned at a similar rate to the National Forest System overall, with 28% of these lands burned. High severity fire was less prevalent on these lands than other National Forest System lands, accounting for 30% of the burned area, compared to 37% of the burned area on National Forest System lands as a whole.

High severity fire accounted for 37% of the burned area across all ownerships (Table 9). High severity fire accounted for more than 30% of the burned acres on federal lands and non-industrial private lands. On private forest industry lands, high severity fire accounted for 41% of the total burned area. High severity fire was less common on state and local lands at 25% of the burned area, and tribal lands at only 16% of the burned area. This analysis did not identify whether differences in area of high severity fire are due to management, environmental differences, or the impacts of fires under 10,000 acres, which are not included in this study.

Within the project area, fires have been particularly common in the northern-most parts of California, as shown by both the acres burned by County (Table 11), and by CAL FIRE vegetation zone (Table 12). Together, Plumas, Trinity, Siskiyou, and Shasta counties accounted for 48% of the forest area burned. Plumas County had the largest area of forest burned with 764,000 acres. Proportionally, Glenn County's forests area was most affected, with 92% of the county burned in a 4-year period, and 31% of the forests burned severely. Likewise, northern California vegetation zones experienced the

[15] Estimates of the total forest area in California vary. Christensen et al. (2019) reports 31.6 million acres of forests. American Forest estimates 29 million acres.

[16] Fire perimeters contain both burned and unburned areas.

highest rates of fire. By percent of forest area, the Klamath/Interior Coast Ranges CAL FIRE Vegetation Zone experienced the most fire, with 28% of the forest in this vegetation zone burned. The total area burned in the Sierra/Cascades was larger, but the overall percent of the forest area was lower at 21%. Thirty-six percent of forests in Timber Valuation Zone[17] (TVA) 4, which includes parts of Glenn, Trinity, Siskiyou, and Shasta counties has burned (Table 13). At least 10% of forests in all TVA burned, except TVA 1, which is on the coast. Finally, fires occurred across all High Hazard Zone tiers, with most fires in Tier 2 lands (Table 14).[18]

Table 6. Forested acres in project area by ownership group.

Ownership category	Forested acres	Non-forest acres	% of forested acres
BLM	886,000	3,422,000	4%
Other Federal	973,000	2,489,000	4%
Private – Forest Industry	4,255,000	234,000	20%
Private – Non-industrial	3,757,000	5,861,000	17%
State and Local	397,000	619,000	2%
Tribal	141,000	43,000	1%
National Forest	11,293,000	5,615,000	52%
All ownerships	**21,701,000**	**18,282,000**	**100%**

Table 7. Standing post-fire volume by ownership group.

Ownership category	Standing volume (Bbf)	% of total live tree volume
BLM	8.5	2%
Other Federal	20	5%
Private (all)	155	39%
State and Local	13	3%
Tribal	3.1	1%
National Forest	202	50%
All ownerships	**402**	**100%**

Table 8. Forested area burned in fires over 10,000 acres from 2018 through 2021, by severity and landowner.

	Severity				
Ownership category	Low (ac)	Moderate (ac)	High (ac)	Total	% of ownership's forest burned
BLM	40,000	52,000	41,000	133,000	15%
Other Federal	64,000	54,000	56,000	175,000	18%
Private – Forest Industry	129,000	118,000	170,000	417,000	10%
Private – Non-industrial	137,000	133,000	131,000	401,000	11%
State and Local	12,000	12,000	8,000	32,000	8%
Tribal	9,400	6,100	2,900	18,000	13%
National Forest	1,046,000	901,000	1,161,000	3,108,000	28%
All ownerships	**1,437,000**	**1,277,000**	**1,570,000**	**4,284,000**	**20%**

[17] A TVA is an area defined by the California Department of Tax and Feed Administration and applicable to the assessment of the timber yield tax. In this report TVAs are used to define a market area.
[18] Tier 2 lands are watersheds that have significant tree mortality as well as significant community and natural resource assets.

Table 9. Percent forested area burned in fires over 10,000 acres from 2018 through 2021, by severity and landowner.

Ownership category	Severity			Total
	Low	Moderate	High	
BLM	30%	39%	31%	100%
Other Federal	37%	31%	32%	100%
Private – Forest Industry	31%	28%	41%	100%
Private – Non-industrial	34%	33%	33%	100%
State and Local	38%	37%	25%	100%
Tribal	51%	33%	16%	100%
National Forest	34%	29%	37%	100%
All ownerships	**34%**	**30%**	**37%**	**100%**

Table 10. Forested acres burned in fires over 10,000 acres from 2018 through 2021, by year.

Ownership category	Year				Total (ac)
	2018 (ac)	2019 (ac)	2020 (ac)	2021 (ac)	
BLM	75,000	1,500	44,000	13,000	133,000
Other Federal	38,000	10	17,000	120,000	175,000
Private (all)	183,000	31,000	353,000	251,000	818,000
State and Local	4,300	500	24,000	3,100	32,000
Tribal	69	27	3,100	15,000	18,000
National Forest	434,000	34,000	1,337,000	1,304,000	3,108,000
All ownerships	**734,000**	**67,000**	**1,779,000**	**1,705,000**	**4,284,000**

Table 11. Forested acres burned in fires over 10,000 acres from 2018 through 2021, by county.

County	Forested acres burned	Total forested acres	% of forested acres in the project area burned by fires >10,000 acres by county
Plumas	764,000	1,245,000	61%
Trinity	582,000	1,640,000	35%
Siskiyou	395,000	2,693,000	15%
Shasta	321,000	1,536,000	21%
Tulare	266,000	859,000	31%
Lake	227,000	375,000	61%
Butte	192,000	347,000	55%
Tehama	190,000	473,000	40%
El Dorado	174,000	649,000	27%
Lassen	170,000	1,055,000	16%
Mendocino	147,000	1,634,000	9%
Madera	140,000	330,000	42%
Fresno	137,000	706,000	19%
Glenn	136,000	148,000	92%
Sonoma	87,000	474,000	18%
Mariposa	70,000	378,000	19%
Napa	67,000	157,000	43%
Alpine	46,000	239,000	19%
Humboldt	39,000	1,803,000	2%
Colusa	29,000	41,000	71%

County	Forested acres burned	Total forested acres	% of forested acres in the project area burned by fires >10,000 acres by county
Modoc	29,000	871,000	3%
Del Norte	27,000	524,000	5%
Kern	17,000	298,000	6%
Tuolumne	16,000	746,000	2%
Mono	8,700	415,000	2%
Sierra	6,100	434,000	1%
Amador	350	131,000	0%
Yolo	17	120	14%
Placer	0	496,000	0%
Nevada	0	376,000	0%
Calaveras	0	239,000	0%
Inyo	0	189,000	0%
Marin	0	101,000	0%
Yuba	0	95,000	0%
Solano	0	6,000	0%
Total	**4,284,000**	**21,701,000**	**20%**

Table 12. Forested acres burned in fires over 10,000 acres from 2018 through 2021, by CAL FIRE vegetation zone.

CAL FIRE Vegetation Zone	Ownership	Forested acres burned	Total forested acres	% forested area in vegetation zone burned, by ownership
Eastside	BLM	12,000	266,000	5%
	Other Federal	10	1,600	1%
	Private (all)	11,000	384,000	3%
	State and Local	1,500	11,000	14%
	Tribal	60	4,900	1%
	National Forest	53,000	1,010,000	5%
	Subtotal	78,000	1,678,000	5%
Klamath/Interior Coast Ranges	BLM	106,000	256,000	41%
	Other Federal	31,000	78,000	40%
	Private (all)	351,000	2,297,000	15%
	State and Local	6,900	42,000	16%
	Tribal	2,800	106,000	3%
	National Forest	1,445,000	4,103,000	35%
	Subtotal	1,943,000	6,882,000	28%
North Coast	BLM	580	103,000	1%
	Other Federal	700	60,000	1%
	Private (all)	74,000	2,224,000	3%

CAL FIRE Vegetation Zone	Ownership	Forested acres burned	Total forested acres	% forested area in vegetation zone burned, by ownership
	State and Local	10,800	258,000	4%
	Tribal	0	4,200	0%
	National Forest	0	19,000	0%
	Subtotal	86,000	2,667,000	3%
Sierra/Cascades	BLM	14,000	261,000	5%
	Other Federal	143,000	834,000	17%
	Private (all)	381,000	3,106,000	12%
	State and Local	13,000	86,000	15%
	Tribal	15,000	25,700	58%
	National Forest	1,610,292	6,162,000	26%
	Subtotal	2,178,000	10,475,000	21%
Total		**4,284,000**	**21,701,000**	**20%**

Table 13. Forested acres burned in fires over 10,000 acres from 2018 through 2021, by timber valuation area.

Timber valuation area	Forested acres burned	Total forested acres	% forested area in each TVA burned
1	66,000	2,327,000	3%
2	302,000	2,371,000	13%
4	1,595,000	4,375,000	36%
5	265,000	2,288,000	12%
6	199,000	1,926,000	10%
7	981,000	3,235,000	30%
8	236,000	2,004,000	12%
9	641,000	3,175,000	20%
All areas	**4,284,000**	**21,701,000**	**20%**

Table 14. Forested acres burned in fires over 10,000 acres from 2018 through 2021, by High Hazard Zone tier (refer to footnote 8).

High Hazard Tier	Landowner	Forested acres burned	Total forested acres	% forested area in each High Hazard Zone tier burned, by ownership
1	BLM	80	1,700	4%
	Other Federal	60	1,200	5%
	Private	3,800	28,000	13%
	State and Local	10	360	3%
	Tribal	2	110	2%
	National Forest	3,400	15,000	22%
	Subtotal	7,300	47,000	16%
2	BLM	103,000	423,000	24%
	Other Federal	154,000	555,000	28%
	Private	528,000	4,113,000	13%
	State and Local	18,000	135,000	13%

High Hazard Tier	Landowner	Forested acres burned	Total forested acres	% forested area in each High Hazard Zone tier burned, by ownership
	Tribal	15,000	71,000	20%
	National Forest	2,251,000	8,071,000	28%
	Subtotal	3,068,000	13,369,000	23%
3	**BLM**	1,800	19,000	10%
	Other Federal	4,500	20,000	23%
	Private	47,000	393,000	12%
	State and Local	1,200	12,000	10%
	Tribal	1,400	2,900	49%
	National Forest	73,000	270,000	27%
	Subtotal	129,000	717,000	18%
Non-HHZ	**BLM**	28,000	442,000	6%
	Other Federal	16,000	397,000	4%
	Private	239,000	3,478,000	7%
	State and Local	13,000	249,000	5%
	Tribal	2,300	67,000	4%
	National Forest	781,000	2,936,000	27%
	Subtotal	1,080,000	7,568,000	14%
Total		**4,286,000**	**4,284,000**	**21,701,000**

High severity patches

Though a certain amount of high severity fire is within the natural variation of historic fire regimes, high severity patches have the potential to cause long-term impacts to timber production as well as environmental services, including natural carbon storage and sequestration capacity, water resources, recreational opportunities, and wildlife habitat. Large patches of high severity fire reduce the likelihood that trees will naturally regenerate following the fire (Welch et al. 2016). Typical seed dispersal distances are under 100 meters for conifer species in California. With a lack of seed source, large high severity patches are at risk of conversion to shrubland or will remain comparatively unvegetated.

Large fires from 2018 through 2021 in the project area created 1,494 high severity patches greater than 40 acres, and greater than 100 meters from intact to moderate severity burn areas. These patches cover 668,000 acres (Table 15; Map 18). These high severity patches account for 43% of the area burned at high severity and 16% of the total area burned. High severity patches account for 17% and 14% of the total fire area on National Forest System and private lands, respectively, and only 2% of the fire area on tribal lands (Table 16).

While patches between 40 and 100 acres are most common, at 47% of all patches, patches between 1,000 and 10,000 acres account for the most area with 245,000 acres, or 37% of the high severity patch area. Eight patches in the largest size class, greater than 10,000 acres, account for 27% of the total area of high severity patches. Two patches are larger than 30,000 acres, with the largest single patch, located in the 2020 Slater fire, spanning 39,000 acres (Table 17). Impacts to environmental services are likely particularly acute in these extremely large individual high severity patches as they can span across multiple watersheds. Just three fires, the August Complex, Claremont, and Dixie fires, account for 54% of the area of the high severity patches (Appendix B, Table B-5). The Dixie fire alone contains 197,000 acres in high severity patches, 29% of the total for all fires.

With 668,000 acres, or 3% of the forested area in the project area, in high severity patches larger than 40 acres, the risk to long-term forest cover loss is substantial. Reforesting this area will require substantial resources. Planting 668,000 acres at 100 to 200 trees per acre[19] (21' to 15' spacing) will require 67 million to 134 million seedlings, well beyond the normal annual requirement of timber managers. In response to lack of seedling production capacity in California and fire damage to its own lands, Sierra Pacific Industries plans to open a large, modern $10 million dollar tree nursery in Gazelle, CA, capable of producing 25 million seedlings per year at full production expected in 2026.[20] This nursery is partially supported by a $3 million grant from CAL FIRE.

Table 15. Acres and number of large high severity patches in fires over 10,000 acres from 2018 through 2021 at risk of vegetation type conversion by patch size class.

	Patch size class (ac)				
	40 – 100 (ac)	100 – 1,000 (ac)	1,000 – 10,000 (ac)	>10,000 (ac)	Total
Acres	44,000	198,000	245,000	182,000	668,000
% of large patches (area)	7%	30%	37%	27%	100%
Number	702	679	105	8	1,494
% of large patches (number)	47%	45%	7%	1%	100%

Table 16. Acres in large high severity patches in fires over 10,000 acres from 2018 through 2021 at risk of vegetation type conversion by patch size class and landowner.

	Patch size class (ac)					
Ownership	40 – 100 (ac)	100 – 1,000 (ac)	1,000 – 10,000 (ac)	>10,000 (ac)	Total	% of total fire area of each landowner in large high severity patches
BLM	1,400	6,600	5,400	190	14,000	10%
Other Federal	1,700	5,500	15,000	3,400	25,000	15%
Private	8,400	37,000	28,000	39,000	113,000	14%
State and Local	460	700	380	110	1,700	5%
Tribal	60	260	1	-	320	2%
National Forest	32,000	147,000	196,000	139,000	514,000	17%
Total	**43,600**	**197,600**	**245,200**	**181,700**	**668,200**	**16%**

Table 17. List of high severity patches over 10,000 acres in fires over 10,000 acres from 2018 through 2021 at risk of vegetation type conversion by fire name. Fire names are repeated if a fire includes multiple patches over 10,000 acres.

Fire	Fire year	High severity patch size (ac)
Slater	2020	39,000
Claremont	2020	30,000
Claremont	2020	26,000
Dixie	2021	23,000
Caldor	2021	23,000
Dixie	2021	15,000
Dixie	2021	14,000
Haypress	2021	11,000

[19] The minimum standard for replanting varies by site class and ranges from 100 to 200 (Title 14 CCR 9
12.7, 932.7, 952.7)
[20] https://www.spi-ind.com/Home/PressRelease?Name=CAL_FIRE_Press_Release_12062022

Carbon volatilized

The fires in this study volatilized into the atmosphere 44 million metric tons (MMt) of carbon. This is equivalent to 11 MMt carbon (C) in annual volatilization. This result is similar to results found by CAL FIRE staff who found carbon volatilized totaling 7.9 MMt per year between 2001 and 2019, based on emissions assumptions in Stinson et al. (2011), which do not account for differences in fire severity.[21]

The remaining forest contains 873 MMt of carbon in the live tree carbon pool. To help contextualize the result of this study, the amount of carbon emitted by the fires is equivalent to 160 MMt of CO_2, which trees had previously sequestered from the atmosphere.[22] However, this does not mean that 160 MMt of CO_2 have been emitted back to the atmosphere, as carbon can be emitted in a variety of forms into the atmosphere, including carbon dioxide, particulate matters, and other carbonaceous compounds. Ultimately, these results are an underestimate of the forest carbon consumed by fire because other pools (e.g., standing dead, down dead wood, litter, understory vegetation) were not included. In addition, these estimates do not account for post-fire decay of vegetation killed in the fires. Future carbon sequestration will not mitigate losses from these fires if forests do not regenerate and are instead replaced by non-forest vegetation with lower carbon storing capability. The risk of this is particularly great on the 668,000 acres in high severity patches.

Consistent with acres burned, three-quarters of the carbon volatilized from fires came from fires on National Forest System lands (Table 18). Fires on private lands accounted for 17% of carbon volatilized. Geographically, the Klamath/Interior Coast Ranges and Sierra/Cascades CAL FIRE vegetation zones contributed 97% of the carbon volatilized from fires (Table 19).

Carbon volatilization from fires in High Hazard Zone tier 2 accounted for 72% of the total carbon volatilized. Lands outside of High Hazard Zones accounted for most of the rest of the carbon volatilized (25%, Table 20).

Five fires, Dixie, August Complex, Claremont, Creek, and Caldor resulted in 54% of the total carbon volatilization from fires over 10,000 acres. The Dixie fire and August Complex accounted for 18% and 17% of carbon volatilized, respectively or over 7.4 million metric tons each (Appendix 2).

Table 18. Carbon volatilization from standing trees to the atmosphere by landowner and fire severity in millions of metric tons.

	Severity				
Landowner	**Low (MMt)**	**Med (MMt)**	**High (MMt)**	**All Severities (MMt)**	**% of total emissions**
BLM	0.2	0.3	0.4	1.0	2%
Other Federal	0.6	0.5	0.7	1.7	4%
Private	2.1	1.9	3.6	7.5	17%
State and Local	0.1	0.1	0.1	0.3	1%
Tribal	0.1	0.1	0.0	0.2	0%
National Forest	10.2	7.8	15.0	33.0	76%
Total	**13.3**	**10.6**	**19.8**	**43.7**	**100%**

[21] Pers. Comm. Nadia Tase, Climate Change and Forest Inventory Specialist, CAL FIRE, 9/30/2022

[22] California's CO_2 equivalent emissions in 2019 were 418.2 million metric tons (CARB 2021).

Table 19. Carbon volatilized from standing trees to the atmosphere from fires by CAL FIRE vegetation zone.

CAL FIRE vegetation zone	Carbon emissions (MMt)	% of total emissions
Central Coast and Interior Ranges	<0.1	<1%
Eastside	0.3	1%
Klamath/Interior Coast Ranges	20.2	46%
North Coast	0.8	2%
Sierra/Cascades	22.5	51%
Total	**43.7**	**100%**

Table 20. Carbon volatilized from standing trees to the atmosphere from fires by High Hazard Zone tier.

High Hazard Zone Tier	Carbon emissions (MMt)	% of total emissions
1	0.1	0%
2	31.3	72%
3	1.4	3%
4	11.0	25%
Total	**43.7**	**100%**

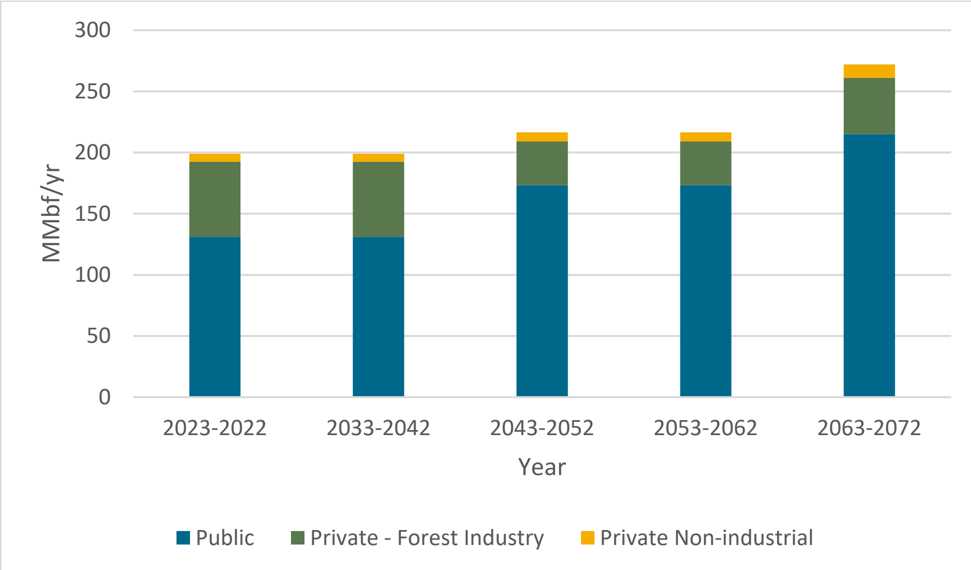
Future timber harvest volume loss

The potential future harvest volume lost due to fires over 10,000 acres from 2018 through 2021 is 11,032 MMbf across the project area over the next 50 years (Table 21, Figure 7). Nearly 75% of the lost potential harvest volume comes from public lands even though the harvestable area assumed in this analysis excludes areas with no harvest or highly restricted harvest due to current policies, as well as all lands greater than 0.25 miles from a road. (Table 6). Among private land ownership groups, most potential future harvest loss is on forest industry lands.

Table 21. Potentially harvestable volume lost in fires over 10,000 acres from 2018 through 2021, by decade (MMbf/yr), and total over 50 years (MMbf).

Decade	Private – Forest Industry (MMbf/yr)	Private – Non-industrial (MMbf/yr)	Public (MMbf/yr)	Total (MMbf/yr)
2023-2032	61	7	131	199
2033-2042	61	7	131	199
2043-2052	36	7	173	217
2053-2062	36	7	173	217
2063-2072	46	11	215	272
	Private – Forest Industry (MMbf)	**Private – Non-industrial (MMbf)**	**Public (MMbf)**	**Total (MMbf)**
Total volume over 50 years	2,403	389	8,240	11,032

Figure 7. Potentially harvestable volume lost in fires over 10,000 acres from 2018 through 2021, by decade (MMbf/yr).



Value of lost future timber harvest

The economic value of the potentially harvestable timber lost in the large fires is $12.7 billion (2022 dollars) over 50 years, assuming current primary wood product values. Assuming a 3% discount rate,[23] the present value of the economic loss is $6.5 billion.

Employment impacts

In 2016, forestry, logging, and wood products manufacturing provided 33,951 direct jobs in California, or 21.6 jobs per MMbf (Marcille et al., 2020). At that rate, the potential harvest volume lost in large fires from 2018 through 2021 would have supported an average 4,800 jobs annually, ranging from a low of 4,300 fewer people employed from 2023 through 2042 to a high of 5,900 fewer people employed in the sector from 2063 through 2072. In addition to direct job impacts, indirect and induced jobs will be affected as well. Marcille et al (2020 pg. 52) report that for every wood products manufacturing job another 1.3 jobs are supported in related sectors and that $1.50 in labor income is generated for every $1 of wood product manufacturing labor income.

Employment impact estimates do not include any impacts to forestry support services, secondary wood products, indirect or induced jobs. Nor do they include impacts of any programs to increase timber harvest or forestry management, such as the Million Acres Strategy,[24] responses by other market participants, or impacts of technology on productivity in the sector.

Availability of timber is not the only limitation to forest industry employment. Competition from other sectors for staff is also a significant factor in retaining and recruiting staff into the industry to maintain current capacity. Mill capacity is also a factor. Marcille et al. (2020) report California's forest products industry's capacity to process sawtimber has decreased

[23] 3% is described as "the rate at which 'society' discounts future consumption flows to their present value" in the Office of Management and Budget's OMB Circular A-4.

[24] The Million Acres Strategy is a plan from the Governor's Office California Wildfire & Forest Resilience Task Force to perform forest health and fuels treatments on minimum of 1 million acres annually by 2025. https://wildfiretaskforce.org/wp-content/uploads/2022/04/roadmap-to-million-acres_2022.pdf

from 6,000 MMbf in the late 1980s to 1,870 MMbf. This mill capacity puts a ceiling on the demand for sawtimber and other forest products.

Long-term effects of lost harvest volume

Fires over 10,000 acres from 2018 through 2021 will have lasting impacts on forests and the forest products industry in California. Future potential timber harvest levels will be reduced by an average of 221 MMbf less timber available annually over the next 50 years, the equivalent of about 14% of the average of 1,543 MMbf harvested annually from 2018 through 2021, or about seven years' worth of harvest. Without structural changes in forest management in California, this decline in timber projection could contribute to a decline in forest products infrastructure by reducing the supply of timber and the economic viability of logging operators and sawmills. Loss of this infrastructure could further limit the ability of landowners to manage forestland for timber and revenue production as well as fire hazard reduction, resilience, and amenity values. Plans such as the Million Acre Strategy could make up for some or all of the lost potential harvest volume and support industry capacity.

Land manager survey

Registered Professional Forester

The RPFs interviewed reported that small forestland owners face difficulties throughout the planning and harvesting process, including:

1) THPs can be uneconomical for small landowners.
2) Loggers are difficult to find.
3) Access to markets is limited after a fire.
4) Seed and seedlings can be difficult to acquire.
5) Net income from harvests is low.

The RPFs noted that the lack of loggers or other operators and the lack of markets for the logs are the top issues for small forest landowners planning forest management. They also said that due to fires, some landowners are considering selling their properties, particularly landowners adjacent to federal lands, due to concern of fires spreading from federal lands.

In many cases, landowners are only able to manage on a reactive basis following fires, and are limited by lack of operators, markets for logs, and in some cases, seedlings. When fire does occur, many forestland owners choose to aggressively salvage. They do so for several reasons, including the relative ease and lower cost of filing an Emergency Notice to salvage compared to a THP, and the desire to remove dead and hazardous trees and replant. However, the lack of loggers and adequate markets means forestland owners are not always able to salvage as planned. Some RPFs noted that landowners are interested in reducing fuel loading and reducing fire risk prior to a fire occurring but are similarly constrained by lack of operators and markets for logs.

The RPFs interviewed reported that the CFIP, Natural Resources Conservation Service grants, and other grants and cost share programs, are widely used by small forestland owners. Some landowners manage their lands specifically to be eligible for one or more of the various programs. Due to the high costs of operations and low value of timber, small forestland owners depend on various grant programs to pay for management and reforestation. Without additional operators and markets, this dependence is likely to continue.

The results of the survey of RPFs highlight that large fires impact small forestland owners' ability to plan and manage their lands for values they desire, such as amenity or timber production. Together, the factors discussed above are causing some landowners to question whether continuing to own forest land is desirable or whether lands should be converted to other uses, such as housing, potentially resulting in more homes in fire prone areas.

Private industrial forestland managers

The private forest industry land managers all reported that portions of the land they manage had been burned in fires over 10,000 acres between 2018 and 2021, with some noting impacts of large and small fires outside of that time period. One land manager reported that over 40% of the company's forestlands had been burned in the large fires included in this study.

All land managers reported undertaking salvage harvest and replanting following the fires. The extent of these activities depended on economic feasibility. Salvage was more likely to occur in areas of high fire severity and higher site quality. All expressed the objective of returning lands to timber production where it is economical.

Long-term impacts of the fires varied by landowner, depending on the extent and severity of the fires on their lands. Most reported that there will be a decline in long-term timber harvest after an initial spike in volume from salvage harvest. On some lands, damage to roads was identified as a concern, particularly following heavy rain. However, managers noted that salvage harvests and the resulting revenue provided an opportunity to reinvest in roads, including moving roads to better locations, controlling erosion, and installing larger culverts. Managers of lands that are intermingled with federal lands reported that delayed repair of federal roads hindered access following fire. These impacts negatively affect land managers' ability to achieve management objectives for their lands.

In response to large fires, and the increase in fires in general, land managers report building, or planning to build fuel breaks. They also report increasing collaboration with neighbors to better plan treatments, fuel breaks, and wildfire response. The fires also have caused some managers to rethink the use of uneven-aged management. One manager noted that after thinning, retained trees are at risk of fire under the prevailing fire conditions. They are considering whether more intensive removals or even-aged management might provide better returns and reduce risk. However, all managers expressed a commitment to continue to manage timber in California, with some interested in expanding the area under management.

The land managers noted that public data such as RAVG and public grants have helped in the post-fire response to large fires. They also credit qualified professional foresters and operations staff. They report a need for more qualified staff, logging operators, truckers, and mills to support increased salvage and green timber harvest. One manager noted the need for more firefighters and more accountability in the firefighting response.

USFS

USFS noted issues similar to those facing small forest landowners, as well as some unique challenges and opportunities. Like lands owned by small forest landowners, post-fire salvage has replaced planned uneven-aged management for some stands. However, USFS has been able to access operators and markets for both post-fire salvage sales and sale of green timber in unburned areas. USFS attributes this to long duration contracts that give operators flexibility to work on post-fire salvage activities without losing green timber contracts.

USFS also faces challenges in adequately staffing contract and procurement offices. Following fires, USFS frequently has access to federal disaster recovery funding, but this funding creates significant workload for procurement staff.

USFS post-fire salvage response is more limited than that of small private landowners. Typically, on National Forest System lands, salvage is limited to hazard tree removal in high severity burn areas near roads as well as some trails and campgrounds. The salvage operation is then followed by reforestation and rehabilitation, such as erosion control, road repair, bridge repair, facilities repair, and fuel reduction. The planning process for salvage activities is slow, with some plans taking so long to complete that what might have been salvageable timber becomes commercially non-viable. This can result in USFS paying operators to remove timber that could have otherwise been part of a commercial sale and not require a subsidy. Funds used to pay for removal of burned timber reduces the budget available for other salvage, rehabilitation, and reforestation activities.

Conclusion

From 2018 to 2021, California experienced some of the largest fires in recent decades with some burning over 1 million acres. These fires burned 20% of the forestland in the North Coast, Cascades, and Sierras, and created 668,000 acres of large high severity burn patches where forest regeneration will be slow or unsuccessful due to lack of seed sources. This increases the risk of long-term land cover changes to shrubland or other vegetation. In addition to affecting forest cover, large fires and a lack of timber operators and adequate log markets have affected the ability of small forestland owners to manage their forests. Many are unable to proactively manage their forests prior to fires occurring, and instead are likely to attempt to salvage harvest and replant following fires. This results in a change in silviculture from planned uneven-aged pre-fire treatment to even-aged post-fire salvage. Small forestland owners frequently utilize CAL FIRE's CFIP or another landowner assistance program to help pay for post-fire operation and restoration because salvage harvest may not generate enough revenue to pay for these activities.

The impact of these fires will be apparent for decades and will affect the local forest products industry. The fires have reduced potential harvest volume by 11,032 MMbf over the next 50 years or an average 221 MMbf per year. Harvest of 221 MMbf per year would have supported 4,800 jobs and produced primary forest products valued at $253 million. The loss of this harvest, if not replaced by increased forest and fuels management activities in other areas, will result in a contraction of the forest industry infrastructure, including logging operators, mills, and support services. Industry infrastructure is already a limiting factor for management in California and an impediment to forest landowners trying to achieve their management objectives, including increasing forest resilience and hazardous fuels reduction. Further contraction will only exacerbate the challenges facing forestland owners in the state.

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Appendix A: Detailed Methods

Overview

Wildfire impacts in California are distributed across political boundaries, biomes, ownership, land use, and forest types. For this study, the combination of all spatial factors, including forest inventory, are called a Land Type (LT)[25], denoting the unique set of biophysical and management factors that have influenced past land use patterns.

Spatial Data Sources

Data was acquired from multiple federal and state sources (Table A-1). All data layers were set to the same extent and snapped to the resolution and coordinate reference system of the Landscape Ecology, Modeling, Mapping & Analysis[26] LEMMA forest type layer. Layers with total coverage (Counties, TVA, California Vegetation Zones, ownership, firesheds) were unmodified. Layers with partial coverage (LEMMA, fire severity[27,28], HHZ, silviculture) were augmented with a non-null value to indicate no data so that the resulting combined raster would retain complete coverage. Layers acquired in vector format were converted to raster format for this analysis.

Table A-1. Spatial data sources, purpose, Land Type sub-deliverable file name, and current web source.

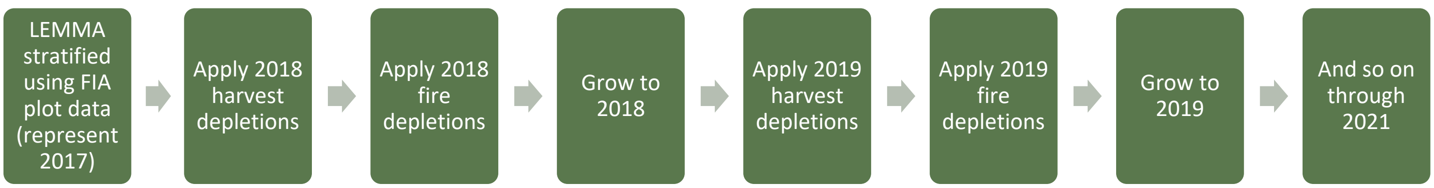
Component	Data Element	Web Source
Fire Severity	Fire Name	MTBS (https://www.mtbs.gov/); RAVG (https://burnseverity.cr.usgs.gov/ravg/)
	Fire Year	As above
Geographic Areas	County	https://gis.data.ca.gov/maps/CDEGIS::california-counties-3
	Marketing areas	https://www.cdtfa.ca.gov/lawguides/vol4/tytr/tytr-all.html#1020
	CALVEG zones	https://data.fs.usda.gov/geodata/edw/datasets.php
Ownership and Land Use	CA Ownership (public)	https://frap.fire.ca.gov/media/hvwoh30t/ownership22_1-gdb.zip
	NWFP LUA	https://www.fs.usda.gov/r6/reo/library/downloads/maps/nwfp_lua_2013.zip
	National Roadless Areas	https://data.fs.usda.gov/geodata/edw/edw_resources/fc/S_USA.RoadlessArea_2001.gdb.zip
	Wilderness	https://data.fs.usda.gov/geodata/edw/edw_resources/fc/S_USA.Wilderness.gdb.zip
High Hazard Zones	High Hazard Zone	https://frap.fire.ca.gov/media/0hubucvy/highhazardzones21_2.zip
Firesheds	USFS crisis strategy firesheds	https://www.fs.usda.gov/rmrs/projects/firesheds-and-fireshed-registry
Harvest Depletions	CA THP	https://hub-calfire-forestry.hub.arcgis.com/maps/CALFIRE-Forestry::cal-fire-timber-harvesting-plans-all-ta83/about
	USFS timber harvests	https://data.fs.usda.gov/geodata/edw/edw_resources/fc/S_USA.Activity_TimberHarvest.gdb.zip

[25] USFS and BLM Northwest Forest Plan uses the term, "Land Use Allocation" (LUA) to define the set of allowed management practices on federal forest land. The federal LUA is one component of the Land Type definition. All lands in the project area have a Land Type; only lands in the NWFP have a LUA.
[26] https://lemma.forestry.oregonstate.edu/
[27] https://www.mtbs.gov/
[28] https://burnseverity.cr.usgs.gov/ravg/

Inventory

The most recent LEMMA data release occurred in 2020, representing inventory year 2017. Although the LEMMA program had provided tree lists for prior iterations at least through 2016, beginning with this latest release, tree lists are no longer made available publicly. This project delivers acreage and carbon estimates, which can be done directly from LEMMA with reasonable accuracy. However, this project also requires growth from 2017, which would be unavailable without a model-grown inventory. Merchandized timber for the economic assessments would also not be possible without an inventory based on tree lists. The inventory is constructed from USFS FIA plots and stratified according to the LEMMA protocol, grown in FVS, with annual harvest and fire depletions, and merchandising done using proprietary MBGTools Software (Figure A-1).

Figure A-1. Diagram of the inventory development process from FIA plot stratification through the 2021.



The FORTYBA forest type layer from LEMMA was the basis for stratification. This layer is a forest type constructed from the relative BA of dominant tree species in the 2017 vegetation. The FORTYPBA protocol[29] classified plots into conifer-dominant (fraction of hardwood BA < 20%), mixed hardwood/conifer (20% <= hardwood BA fraction < 65%), and hardwood-dominant (hardwood BA >= 65%). In mixed plots, the type was defined as both the top conifer and top hardwood species by BA, with the greater BA listed to the first (leftmost). In conifer-dominated plots, where a single conifer species accounted for more than 80% of the total BA, the type consisted solely of that species. If no single species exceeded 80%, the type included the top two species. The same method was applied for hardwood-dominated plots. If total canopy cover was less than 10%, the type was classified as a remnant and translated to FIA non-stocked.

LEMMA FORTYPBA rules were applied to all USFS FIA P2[30] plots in the in the California database.[31] This identified 5,554 distinct PLOT_CN (plot-year combinations) from which to construct inventory strata. The final strata comprised USFS FIA forest type (FORTYPCD) with several possible combinations of BA and trees per acre (TPA). A 'complete' FORTYPCD stratum, with four BA quartiles and four TPA quartiles within each BA quartile, requires 96 plots, equitably distributed over each BA and TPA combination. If at least 48 FIA plots were available in a FORTYPCD, but fewer than 96, two BA groups were used, with two TPA groups in each. For FORTPYCD with between 16 and 48 plots, there are no BA groups but two TPA groups. With fewer than 16 FIA plots, no further strata beyond FORTPYD were designated; this never impacted commercial species. For each LEMMA grid cell, BA and TPA quartile was assigned from LEMMA layers BA_GE_3 and TPH_GE_3. LEMMA provides a reasonably unbiased estimate of BA, but generally an upward-biased TPA estimate. LEMMA BA and TPA were mapped to FIA BA and TPA by quartile rather than by a direct comparison of magnitude. Of 58,369 original combinations of LEMMA FORTYPBA x BA x TPA, only a few hundred could not be matched directly to an FIA plot. For the unmatched, a sequential replacement strategy was used. First, the first and second species were switched, and a new match sought. Second, if both species together did not work, single species were tried in dominance order. Finally,

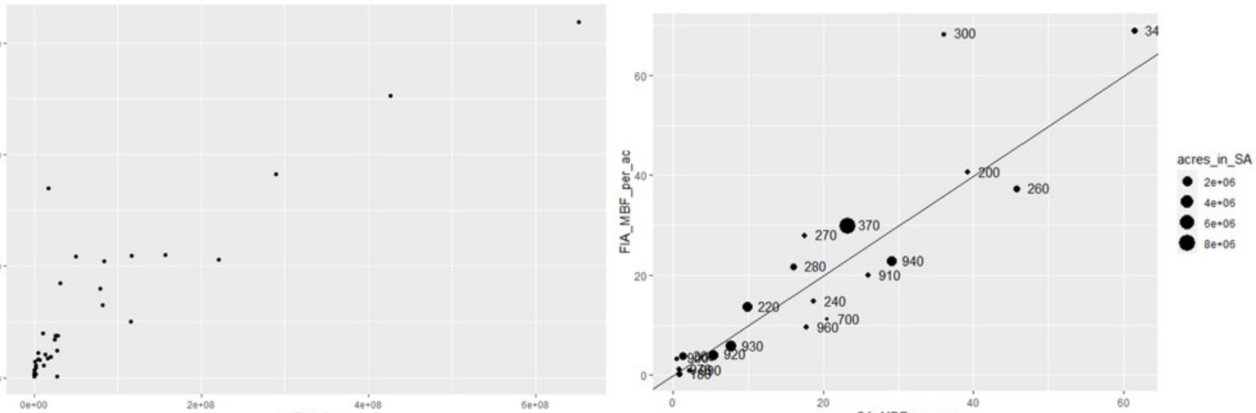
[29] https://lemma.forestry.oregonstate.edu/data/structure-maps
[30] https://www.fia.fs.usda.gov/library/field-guides-methods-proc/docs/2022/core_ver9-2_9_2022_SW_HW%20table.pdf
[31] https://apps.fs.usda.gov/fia/datamart/datamart.html

the 40 remaining LEMMA groups that could not match directly or with substitution were manually assigned the FIA FORTYPCD most similar or commonly used by adjacent LEMMA FORTYPBA.

All LEMMA FORTYPBA groups translated into 41 USFS FIA FORTPYCD. The LEMMA product was developed in large part from FIA, so in principle a reverse translation should be accurate. The FIA plot count is proportional to LEMMA cell count within translated FORTYPCD (Figure A-1). Following the plot count rationale above, those 41 FORTYPCD expanded further into 382 individual strata representing unique combinations of forest type, BA, and TPA. Every LEMMA grid cell from FORTYPBA was reassigned to one of these 382 USFS FIA FORTYPCD-BA-TPA strata. Volume (Mbf per acre) and carbon (metric tons per acre) were calculated over the plots in each stratum weighted by their FIA expansion factor. A 383rd non-forested stratum was introduced to enable complete acreage reporting; this was distinct from the FIA non-stocked stratum.

To assess validity of the stratification, MB&G reconstructed regional inventory using the stratified LEMMA raster assigned the USFS FIA board-foot volume projected to 2018. The basis of comparison was the county-level 2018 population evaluation group FIA summary of gross board-foot volume. The live tree volume in 21.7 million acres in the study area using this stratification is 402 Bbf. Calculating the sum of FIA gross volume in all the counties in the study area, the volume is 536 Bbf on 28.8 million acres. Note that stratified quantity was merchandized in Scribner decimal C short scale, while the FIA native unit is International ¼ inch.[32] In other work MB&G has found near parity between short-scale Scribner and International ¼ inch, typically these scales differ by less than 2%. The LEMMA results in 18.49 Mbf per acre (Scribner) or 18.13 Mbf per acre (International), while the FIA reports 18.56 Mbf per acre (International) or 18.93 Mbf per acre (Scribner). Comparing on the same unit scale, the recovered stratified LEMMA result differs from the FIA regional result by 2.3%. Most individual FORTYPCD strata groups followed a strong positive linear relationship with FIA (Figure A-1). A single stratum, the Sitka Spruce group, under-estimated FIA by about *two-thirds*, but this stratum encompassed only 36,000 acres in LEMMA (19,000 acres in FIA), about 0.1% of the study area.

Figure A-2. FIA plot (PLOT_CN) count of FORTPYCD assigned LEMMA FORTYPBA (left). Reconstructing the study area inventory from stratified LEMMA assigned 2018 FIA projections from a common 2017 start date results in less than 0.5% difference in regional inventory and strong positive linear correlation between LEMMA and FIA (right).



Species groups retained for inventory reporting reflect California taxation groups: Ponderosa pine, hem/fir, Douglas-fir, incense cedar, redwood, Port Orford cedar. Other species (hardwoods, non-commercial species) were retained in 'other

[32] Log scale rules provide a mathematical method for estimating timber volume. Both Scribner decimal C and International ¼ provide estimates in units of board feet, or the quality of lumber that can be produced, based on a set of assumption about production. These assumptions differ, resulting in different estimates of volume.

softwoods' or 'other hardwoods' groups. All species, including non-commercial, were merchandized on a short-log scale with maximum log length 16 feet and minimum log length 10 feet using MBGTools. Only trees with at least 4.6" DHB were merchandized, and to a minimum top diameter of 2.6 inches with 2.5% trim and a stump height of 1 foot. Aboveground live carbon was calculated for species groups and in total using the Jenkins equations as implemented in the FVS keyword CARBCALC.

Composite Burn Index: Fire Severity

The Composite Burn Index (CBI) is available from two data sources, the MTBS and the RAVG. For the study area and focal time period, neither dataset contained all fires. Where both MTBS and RAVG provided data, MTBS was used. Specifically, MTBS …dnbr6.tif files, and RAVG …cbi4.tif files are used in this analysis. These both represent the CBI converted into four categories: 1 unburned within fire perimeter, 2 "low severity", 3 "medium severity", and 4 "high severity". The MBTS data also report a value 5 representing areas that increased greenness after fire—these are treated as unburned. A category 6 in MTBS reflects data errors and are unattributed in this analysis. The RAVG data do not include green-up or unknown categories. In the mosaic raster containing all MBTS and RAVG data, values outside fire perimeters were set to null.

County, Timber Value Area, and California Vegetation Zone

These layers were grouped together because they share a similar spatial scale. Timber Value Area is coincident with counties except where Interstate 5 divides Shasta, Siskiyou, and Tehama Counties. California vegetation zones span up to several counties, or somewhat smaller than a single county in certain instances. The combined raster value represents each unique combination of County, TVA, and CVZ, and there were 65 unique values. These combinations are a complete coverage.

Ownership and Land Use Allocations

A public land ownership layer was provided to MB&G for this project by CAL FIRE. Lands in the National Forest System, BLM, and tribal lands retain their original designation. All other federal lands are grouped into a category "Other Federal". The public lands layer included land owned by NGO's, which are grouped with private land. Other groups include CAL FIRE, several State agencies, and Local or Municipal governments—these are merged into a State and Local category for reporting but retained in their original form in intermediate raster sub-deliverables. Report tables will therefore be organized, alphabetically, as: BLM, other federal, private, tribal, state and local, and national forest. For some analyses private industrial lands are identified by a layer provided by the California Forestry Association. In others, all private lands are grouped to maintain confidentiality.

There are several land use categories within federal ownership that are relevant to forest management, including those from the Northwest Forest Plan (NWFP), the National Roadless Areas, and Federal Wilderness designation. These areas are included in the spatial data used in this analysis. There were minor inconsistencies (<3,000 acres) or overlap of non-federal ownership with NWFP areas. The public ownership layer from CAL FIRE is treated as definitive. Any private ownership with a land use area (LUA) was considered a spatial inaccuracy and eliminated. Federally designated Wilderness or National Roadless areas could occur on any federal lands, National Forest, BLM, or Other Federal. There were again some minor spatial inaccuracies of a few thousand acres where wilderness or roadless areas on private land were eliminated. Each unique combination of ownership and land use was encoded as a raster with 92 unique values.

High Hazard Zones and Firesheds

Acres and carbon volatilized by tree mortality by High Hazard Zone (HHZ) and fireshed are reported. These layers were acquired from publicly available sources (Table 1).

There are two damage tiers in HHZ, Tier 1, where excessive tree mortality coincides with infrastructure, and Tier 2, excessive tree mortality in areas where watersheds are prioritized for forest restoration. Where Tiers 1 and 2 overlap, they are designated as HHZ value 3. Areas without HHZ designation are set to value 4 to allow for complete coverage.

Firesheds are a contiguous layer with 211 complete or partial firesheds within the study area.

Timber Harvest Depletion

Timber harvest layers included National Forest System timber harvests and the California THP database (Table 1). The method to estimate carbon volatilized to the atmosphere due to wildfire applied conversion factors from Maestrini et al. (2015) to current standing live carbon. However, carbon volatilized from wildfire are lower in areas where forest management recently removed timber volume. To account for impact of harvest on pre-fire standing live carbon, MB&G reduced inventory each year in areas that had received harvests after 2017 but before the date of any fire. Where harvest and fire were concurrent, the harvest was applied first.

Management action descriptions from the silviculture layers were interpreted as even-aged, uneven-aged, thinning, or no removal (Table 2). Even-aged management was assumed to remove 80% of volume and carbon, reflecting residuals to accommodate CA harvest regulations and riparian area management requirements. Uneven-aged management was assumed to remove 40% of volume and carbon, while thinning would remove 20%. These depletion factors were multiplied by merchantable volume and standing live carbon to produce a pre-fire estimate. Where no fire occurred, depletion was multiplied by the inventory grown to 2021. Depleted inventory—merchandized volume or standing live carbon—was the final input before representing combustion by the Maestrini et al. (2015) factors.

Table A-2. Silviculture activity translated to regime category, even-aged, uneven-aged, thinning, or none.

Activity	Category	Depletion Factor
Group Selection Cut (UA/RH/FH)	Even-aged	0.8
Harvest without Restocking	Even-aged	0.8
Patch Clearcut (EA/RH/FH)	Even-aged	0.8
Patch Clearcut (with leave trees) (EA/RH/FH)	Even-aged	0.8
Permanent Land Clearing	Even-aged	0.8
Seed-tree Final Cut (EA/NRH/FH)	Even-aged	0.8
Seed-tree Preparatory Cut (EA/NRH/NFH)	Even-aged	0.8
Seed-tree Seed Cut (with and without leave trees) (EA/RH/NFH)	Even-aged	0.8
Shelterwood Removal Cut (EA/NRH/FH)	Even-aged	0.8
Shelterwood Removal Cut (with leave trees) (EA/NRH/FH)	Even-aged	0.8
Stand Clearcut (EA/RH/FH)	Even-aged	0.8
Stand Clearcut (with leave trees) (EA/RH/FH)	Even-aged	0.8
Two-aged Patch Clearcut (with res) (2A/RH/FH)	Even-aged	0.8
Two-aged Shelterwood Establishment Cut (with res) (2A/RH/NFH)	Even-aged	0.8
Two-aged Stand Clearcut (with res) (2A/RH/FH)	Even-aged	0.8
Coppice Cut (with leave trees) (EA/RH/FH)	Uneven-aged	0.4
Improvement Cut	Uneven-aged	0.4
Overstory Removal Cut (from advanced regeneration) (EA/RH/FH)	Uneven-aged	0.4
Salvage Cut (intermediate treatment, not regeneration)	Uneven-aged	0.4
Sanitation Cut	Uneven-aged	0.4
Shelterwood Establishment Cut (with or without leave trees) (EA/RH/NFH)	Uneven-aged	0.4
Shelterwood Preparatory Cut (EA/NRH/NFH)	Uneven-aged	0.4
Single-tree Selection Cut (UA/RH/FH)	Uneven-aged	0.4
Special Products Removal	Uneven-aged	0.4
Two-aged Preparatory Cut (with res) (2A/NRH/NFH)	Uneven-aged	0.4
Commercial Thin	Thinning	0.2
Natural Changes (excludes fire)	Thinning	0.2
Administrative Changes	None	0
Permanent Flooding	None	0

Raster Combination

Data retained for the raster combination included each of the sub-deliverables above: FIA-derived inventory stratified according to LEMMA FORTYPCD and attributed to the LEMMA raster, County-TVA-Veg Zone, CBI severity, Ownership and land use, tree mortality High Hazard Zones, Firesheds, and silviculture factors for inventory depletion. All possible combinations of these factors produced a raster with 474,606 unique combinations. The raster attribute table of this combined layer was exported from ArcGIS Pro as a .csv file for further operations. Where the raster attribute value directly encoded a meaningful quantity (stratum, fire severity, HHZ), those values were suitably named. Where further interpretation was required, field values were either parsed into their correct meaning, or linked to other attribute tables. An intermediate tabular data product representing all unique combinations with their recovered meaning, but prior to rejoining yields or calculating depletion, was produced.[33]

[33] calfire_combined_attribs_MEANING_RECOVERED.csv

Yields and Carbon Losses by Fire Severity

Stratified yields were linked to the combined raster by stratum ID and by fire year. Yields for 2018 were linked to fires in 2018, etc.; where no fire occurred, the 2021 yields were used. Timber volume and carbon were modeled in FVS. Timber harvest volume was merchandized in MBGTools.

The carbon emissions work of Maestrini et al. (2015) was the source for carbon and merchandized volume reduction as a result of fire combustion. Results suggested that in high severity fires, 29.03% of standing live and dead tree carbon would be converted into atmospheric emissions. In low or medium severity fires, the combusted fraction was the same for each, at 22.58%. These were strictly conversions to atmospheric carbon released, not CO2 equivalents or the other particulate matters or carbonaceous compounds released during a fire. The same fractions are applied to the standing merchantable inventory to estimate residual inventory on burned areas based on fire severity data from MTBS, or RAVG where MTBS data was not available. Depleted Mbf and C were also multiplied by the appropriate emissions factors for the fire severity level to estimate (a) volume inventory lost to combustion and (b) carbon converted to emissions. A residual factor, the emissions fraction subtracted from 1, was also multiplied by the depleted inventory to represent the remaining volume or standing carbon. The final tabular output therefore contains an estimate of both the remaining Mbf or C, and the loss of Mbf or C to combustion.

High Severity Patches

Fire severity mosaics were sourced from the same MTBS and RAVG locations as in the acreage and carbon summary (Table A-1). Only fires with more than perimeter 10,000 acres interior to the study area were processed for high severity. For fires spanning the study area border, portions outside the border were removed. The six-class CBI was used for fires from MTBS, and the four-class CBI for fires from RAVG. All fires were assigned a sequential numeric identifier and corresponding English name; these designations are identical to the content in the acre and carbon summary. Each fire was resampled to eliminate isolated cells of locally inconsistent severity. The ArcGIS tool Focal Statistics was used to modify cell severity values, taking on the majority value of the nine cells surrounding each focal cell.

A patch was defined as any area connected by at least 200m width of a shared severity level. Areas connected by thin extensions (‘stringers’) were to be excluded from adjacent patches. Each resampled fire raster was converted to a vector retaining solely the high severity patches. To eliminate stringers, the vectorized high severity patches were buffered by negative 100 m, converted the resulting vector layer to a multi-polygon, and assigned new polygon ID. This result was dissolved, and any stringers connected by areas with width less than 200m were eliminated. This vector result represents the high area of high severity patches greater than 100m to unburned, low, or moderate severity fir; each polygon was assigned a unique ID. The polygon high severity patches were rasterized, with the raster value of the unique ID.

Estimating future timber harvest loss

Prescriptions and mechanizing

The raster layer described above was converted to a vector layer for further analysis. It was added to a data layer showing ownership of industrial forestlands and buffered roads by quarter mile on National Forest System lands. The layer was dissolved on stratum, based on BA and trees per acre values identified when developing the inventory. Then the layer was joined with the tabular data from this layer and harvest volume data produced in MBGTools for a series of modeled prescriptions and assumed landscape-scale harvest intensities (Tables 3 and 4). In MBGTools, the appropriate FVS variant for each stratum based on location information for the FIA plots was used to develop tree lists for each stratum. Tree lists were modeled in 5-year timesteps and merchandized the results in each timestep into log size categories in Table (A-3). Timber was merchandized into 16-foot logs, with 8-foot minimum logs. Initial results showed large changes in apparent harvest levels due to the simplified prescriptions and lack of constraints on change in harvest level from period to period in the model. As a result, the results were averaged across three time periods: 2023 through 2042, 2043 through 2062, and 2063 through 2072. For reporting, results are provided by decade instead of by 5-year period. Additionally, for reporting, the largest two log size classes were combined as were the smallest two size classes.

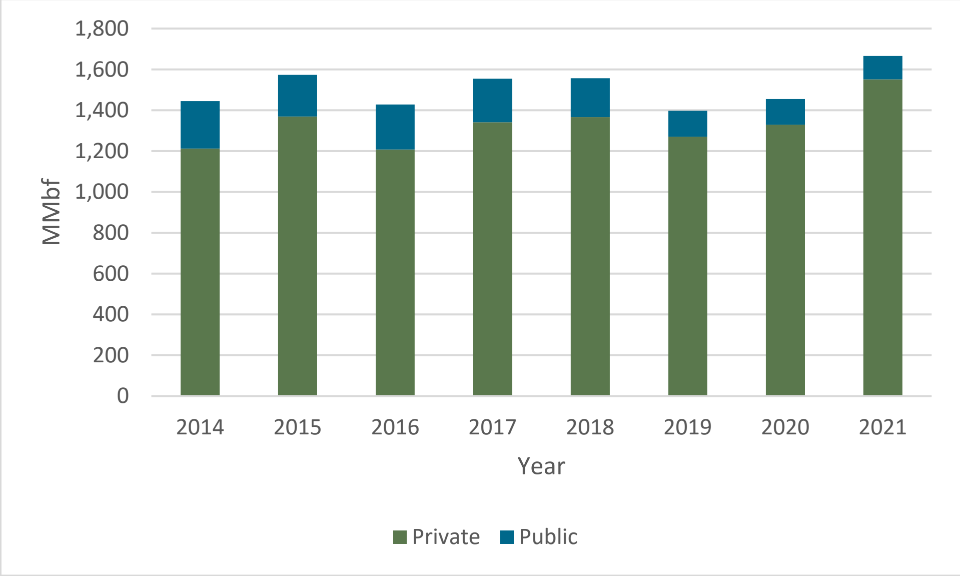
Table A-3. Log diameter specifications for merchandizing.

Log small end inside the bark diameter (inches)	Reporting group
24+	2S and better
12-24	2S and better
8-12	3S
6-8	4S
5-6	4S

Landscape harvest intensity

A landscape harvest intensity was used to adjust harvest volumes produced in modeling to better reflect actual harvest levels based on tax data.[34] Total annual harvest from 2014 to 2021 stayed within a narrow range from 1,400 to 1,650 MMbf. Total harvest appears relatively unaffected by the amount of salvage, likely due to salvage replacing non-salvage harvest and not in addition to non-salvage harvests. This is consistent with the RPF interviews indicating that industry infrastructure is a limiting factor to harvest, not available of harvestable timber.

Figure A-3. Timber harvest by year from public and private lands from counties within the project area.



Different harvest intensities were used for different landowners or landowner groups, based on the following assumptions about management by each of the landowners or owner groups:

- BLM: Managed at the same intensity as National Forest System lands. Wilderness areas and other reserves on BLM lands are excluded from the analysis.

[34] Available at: https://www.cdtfa.ca.gov/dataportal/dataset.htm?url=PropTaxTimberProductionStats

- Local: No harvest on local lands. No data were available showing harvest rates on these lands, local ownership constitutes less than 1% of the total forest area, so it is not a significant contributor of timber harvest volume.
- Private Forest Industry: Based on the survey of forest industry staff, intensity reflects only the estimated impacts of riparian buffers, leave tree requirements, and other regulatory impacts. Lower intensity in mesic forest types due to higher stream density and wider buffers due to larger buffers for salmon streams.
- Private (other): Based on the survey of RFPs, management by small forestland owners is limited by the cost of THP preparation, lack of logging operators, lack of access to mills, and poor economic performance. Further, based on data from Marcille (2019), non-industrial and tribal lands account for about 13% of the total harvest volume in California. Harvest by small forestland owners is scaled to a low level, assuming that tribes have more active timber management programs and to account for the limited volume production from these lands.
- State: An active harvest program on state lands in dry forest types, though with less intensity than private forest industry lands but more intensity than federal lands, reflecting multiple management objectives. No harvest in mesic forest types reflecting current limited harvest activity. As the large fires had little impact on state lands in mesic forests, the impact of this assumption on the projections of lost timber harvest is negligible.
- Tribal: In this report tribal land refers only to reservation lands. These lands are managed at different levels of intensity. This report assumes active harvest programs on tribal lands in dry and mesic forest types, that is less intensity than private forest industry lands but more intensity than federal lands. As tribal lands as whole account for a 0.6% of the total forest area in the analysis area and 0.3% of the total burned area, the volume of potential future timber harvest from tribal lands is small.
- National Forest System: The intensity of harvest on National Forest System lands is scaled to reflect actual recent harvest levels. Wilderness areas and other reserves, as well as lands more than a quarter mile from a road are excluded from the analysis, based on input from USFS staff.

Appendix B: Additional Data Tables

Figure B-1. Forest and total burned acres by fire based on MTBS or RAVG data.

Fire name	Forested acres burned	Total acres burned
Antelope	107,885	147,679
August Complex	810,132	1,035,352
Caldor	187,289	225,149
Caldwell	15,015	81,602
Camp	56,601	68,907
Carr	169,368	223,264
Castle	129,539	171,653
Claremont	279,687	303,215
Creek	289,623	372,282
Delta	56,521	61,694
Dixie	786,922	973,065
Donnell	26,844	36,152
Ferguson	78,072	95,466
French	18,550	20,310
Glass	47,301	68,049
Gold	17,982	22,018
Haypress	170,211	202,911
Hennessey	54,685	133,754
Hirz	43,522	45,845
Kincade	41,055	77,076
Klamathon	10,962	35,839
KNP Complex	79,076	88,792
Lava	19,126	26,913
Lions	9,947	13,240
Loyalton	9,564	45,483
McCash	80,650	95,761
McFarland	49,705	75,966
Monument	201,878	225,529
Mountain View	5,083	11,957
Natchez	29,173	34,019
North	38	2,652
Ranch	250,078	423,020
Red Salmon Complex	126,645	148,308
River	23,646	48,919
Salt	12,093	12,823
Sheep	19,532	28,766
Slater	98,418	112,168
Slink	13,902	26,439
Stone	25,815	39,640
Sugar	62,348	108,334
Tamarack	32,437	55,794

Fire name	Forested acres burned	Total acres burned
Tennant	9,580	11,612
Tucker	622	14,128
W-5 Cold Springs	14,915	70,197
Walker	41,676	54,333
Wallbridge	46,252	55,195
Whaleback	16,344	18,641
Windy	83,113	93,993
Zogg	11,130	18,990
Total	**4,770,552**	**6,404,061**

Table B-2. Forested area burned by severity and landowner, by year.

Year	Ownership	Severity			Total	% of ownership's forest burned
		Low (ac)	Moderate (ac)	High (ac)		
2018	BLM	21,000	31,000	22,000	75,000	8%
	Other Federal	6,100	11,000	20,000	38,000	4%
	Private	64,000	68,000	51,000	183,000	2%
	State and local	2,300	1,400	700	4,300	1%
	Tribal	2	10	57	69	0%
	National Forest	167,000	160,000	106,000	434,000	4%
2019	BLM	350	720	410	1,500	0%
	Other Federal	8	2	-	10	0%
	Private	17,000	9,100	4,700	31,000	0%
	State and local	180	200	140	520	0%
	Tribal	20	6	-	27	0%
	National Forest	16,000	10,000	8,000	34,000	0%
2020	BLM	15,000	17,000	12,000	44,000	5%
	Other Federal	9,900	6,000	2,000	17,000	2%
	Private	107,000	111,000	134,000	353,000	4%
	State and local	8,800	9,400	6,000	24,200	6%
	Tribal	2,100	640	310	3,060	2%
	National Forest	460,000	408,000	469,000	1,337,000	12%
2021	BLM	3,200	3,600	5,900	13,000	1%
	Other Federal	48,000	37,000	34,000	120,000	12%
	Private	77,000	62,000	111,000	251,000	3%
	State and local	1,100	900	1,100	3,100	1%

	Tribal	7,200	5,400	2,500	15,000	11%
	National Forest	402,000	323,000	578,000	1,304,000	12%
Total		1,437,000	1,277,000	1,570,000	4,284,000	

Table B-3. Percent forested area burned by severity and landowner, by year.

		Severity			
Year	**Ownership**	**Low (ac)**	**Moderate (ac)**	**High (ac)**	**Total**
2018	BLM	28%	42%	30%	100%
	Other Federal	16%	30%	54%	100%
	Private	35%	37%	28%	100%
	State and local	53%	32%	15%	100%
	Tribal	3%	15%	83%	100%
	National Forest	39%	37%	25%	100%
2019	BLM	24%	49%	28%	100%
	Other Federal	82%	18%	0%	100%
	Private	56%	29%	15%	100%
	State and local	35%	38%	27%	100%
	Tribal	77%	23%	0%	100%
	National Forest	47%	31%	23%	100%
2020	BLM	34%	38%	27%	100%
	Other Federal	57%	34%	10%	100%
	Private	30%	32%	38%	100%
	State and local	36%	39%	25%	100%
	Tribal	69%	21%	10%	100%
	National Forest	34%	30%	35%	100%
2021	BLM	25%	28%	47%	100%
	Other Federal	40%	31%	29%	100%
	Private	31%	25%	44%	100%
	State and local	37%	28%	36%	100%
	Tribal	48%	36%	17%	100%
	National Forest	31%	25%	44%	100%
Total		34%	30%	37%	100%

Table B-4: Carbon volatilized from standing trees to the atmosphere by fire.

Fire Name	**Year**	**Carbon volatilized (metric tons, thousands)**	**% of total carbon volatilized**
Dixie	2021	7,725	18%
August Complex	2020	7,458	17%
Claremont	2020	3,583	8%
Creek	2020	2,420	6%
Caldor	2021	2,171	5%
Monument	2021	1,762	4%
Ranch	2018	1,751	4%
Haypress	2021	1,591	4%
Slater	2020	1,443	3%

Fire Name	Year	Carbon volatilized (metric tons, thousands)	% of total carbon volatilized
Carr	2018	1,438	3%
Red Salmon Complex	2020	1,367	3%
Castle	2020	1,149	3%
Windy	2021	887	2%
Antelope	2021	807	2%
McCash	2021	729	2%
KNP Complex	2021	727	2%
Delta	2018	625	1%
Ferguson	2018	568	1%
Camp	2018	537	1%
McFarland	2021	507	1%
Wallbridge	2020	408	1%
Hirz	2018	398	1%
Natchez	2018	361	1%
Sugar	2021	359	1%
Glass	2020	334	1%
Walker	2019	283	1%
Hennessey	2020	255	1%
Kincade	2019	233	1%
Tamarack	2021	232	1%
Donnell	2018	227	1%
French	2021	179	0%
Sheep	2020	171	0%
River	2018	137	0%
Lava	2021	131	0%
Salt	2021	107	0%
Stone	2018	93	0%
Slink	2020	83	0%
Lions	2018	73	0%
Gold	2020	65	0%
W-5 Cold Springs	2020	60	0%
Zogg	2020	54	0%
Whaleback	2018	53	0%
Loyalton	2020	52	0%
Tennant	2021	49	0%
Caldwell	2020	45	0%
Klamathon	2018	36	0%
Mountain View	2020	12	0%
Tucker	2019	1	0%
Grand Total		**43,735**	**100%**

Table B-5. Area in high severity patches> 40 acres by fire.

Fire name	Fire year	Area of high severity patches > 40 acres	% of total high severity patches >40 acres area
Dixie	2021	196,965	29%
August Complex	2020	94,308	14%
Claremont	2020	68,265	10%
Caldor	2021	44,972	7%
Slater	2020	44,354	7%
Antelope	2021	32,710	5%
Sugar	2021	31,184	5%
Carr	2018	23,860	4%
Haypress	2021	23,054	3%
Tamarack	2021	10,833	2%
McFarland	2021	10,070	2%
Ranch	2018	10,029	2%
Creek	2020	9,811	1%
Delta	2018	9,745	1%
Lava	2021	7,389	1%
Monument	2021	7,356	1%
Windy	2021	6,598	1%
Red Salmon Complex	2020	4,537	1%
McCash	2021	3,930	1%
Castle	2020	2,919	0%
Donnell	2018	2,820	0%
Sheep	2020	2,570	0%
Glass	2020	2,354	0%
Tennant	2021	2,249	0%
French	2021	1,849	0%
Walker	2019	1,531	0%
Zogg	2020	1,519	0%
KNP Complex	2021	1,454	0%
Wallbridge	2020	1,253	0%
Loyalton	2020	1,194	0%
Caldwell	2020	943	0%
Kincade	2019	905	0%
Salt	2021	772	0%
Camp	2018	602	0%
Whaleback	2018	558	0%
Stone	2018	527	0%
Hennessey	2020	470	0%
Ferguson	2018	455	0%
Natchez	2018	442	0%
Hirz	2018	246	0%
Klamathon	2018	205	0%
River	2018	112	0%

Fire name	Fire year	Area of high severity patches > 40 acres	% of total high severity patches >40 acres area
Slink	2020	99	0%
W-5 Cold Springs	2020	78	0%
Gold	2020	75	0%
Lions	2018	0	0%
Mountain View	2020	0	0%
Tucker	2019	0	0%
Total		668,170	100%

Table B-6. Volume loss by species and grade by decade.

	Species and grade (MMbf/year)		
Decade	**Douglas-fir 2S or better**	**Douglas-fir 3S**	**Douglas-fir 4S**
2023-2032	46	13	2
2033-2042	46	13	2
2043-2052	25	13	3
2053-2062	25	13	3
2063-2072	40	16	3
	Incense-cedar 2S or better	**Incense-cedar 3S**	**Incense-cedar 4S**
2023-2032	7	4	1
2033-2042	7	4	1
2043-2052	8	5	1
2053-2062	8	5	1
2063-2072	15	8	2
	Mixed pine† 2S or better	**Mixed pine 3S**	**Mixed pine 4S**
2023-2032	31	6	1
2033-2042	31	6	1
2043-2052	28	9	2
2053-2062	28	9	2
2063-2072	44	11	2
	Ponderosa pine 2S or better	**Ponderosa pine 3S**	**Ponderosa pine 4S**
2023-2032	16	4	1
2033-2042	16	4	1
2043-2052	17	7	1
2053-2062	17	7	1
2063-2072	24	9	2
	Red fir 2S or better	**Red fir 3S**	**Red fir 4S**
2023-2032	9	2	1
2033-2042	9	2	1
2043-2052	9	4	1
2053-2062	9	4	1
2063-2072	9	3	1
	Western redcedar 2S or better	**Western redcedar 3S**	**Western redcedar 4S**
2023-2032	0.3	0.1	0.0

2033-2042	0.3	0.1	0.0
2043-2052	0.1	0.0	0.0
2053-2062	0.1	0.0	0.0
2063-2072	0.2	0.0	0.0
	Whitewood‡ 2S or better	**Whitewood 3S**	**Whitewood 4S**
2023-2032	29	19	4
2033-2042	29	19	4
2043-2052	36	40	8
2053-2062	36	40	8
2063-2072	51	27	5

† Mixed pine includes Jeffery pine, lodgepole pine, sugar pine, and western white pine, depending on the region FVS variant.

‡ Whitewood includes fir species, hemlock species, and spruce species.

Table B-7. Volume loss by county by decade.

County	Decade	Public (MMbf/yr)	Private (MMbf/yr)	Total (MMbf/yr)
Alpine	**2023-2032**	1.1	0.0	1.2
	2033-2042	1.1	0.0	1.2
	2043-2052	0.1	0.1	1.7
	2053-2062	1.7	0.1	1.7
	2063-2072	2.2	0.1	2.3
Amador	**2023-2032**	0.0	0.0	0.0
	2033-2042	0.0	0.0	0.0
	2043-2052	0.0	0.0	0.0
	2053-2062	0.0	0.0	0.0
	2063-2072	0.0	0.0	0.0
Butte	**2023-2032**	6.1	8.5	14.6
	2033-2042	6.1	8.5	14.6
	2043-2052	4.7	4.7	11.1
	2053-2062	6.4	4.7	11.1
	2063-2072	8.3	6.1	14.4
Colusa	**2023-2032**	0.3	0.0	0.3
	2033-2042	0.3	0.0	0.3
	2043-2052	0.0	0.0	0.7
	2053-2062	0.7	0.0	0.7
	2063-2072	0.8	0.0	0.9
Del Norte	**2023-2032**	1.3	0.6	1.9
	2033-2042	1.3	0.6	1.9
	2043-2052	0.3	0.3	1.8
	2053-2062	1.5	0.3	1.8
	2063-2072	1.7	0.4	2.0
El Dorado	**2023-2032**	12.9	2.9	15.8
	2033-2042	12.9	2.9	15.8
	2043-2052	2.7	2.7	13.7
	2053-2062	11.0	2.7	13.7
	2063-2072	16.4	3.5	19.9
Fresno	**2023-2032**	4.1	0.2	4.3
	2033-2042	4.1	0.2	4.3
	2043-2052	0.3	0.3	4.6

County	Decade	Public (MMbf/yr)	Private (MMbf/yr)	Total (MMbf/yr)
	2053-2062	4.3	0.3	4.6
	2063-2072	6.3	0.5	6.8
Glenn	**2023-2032**	3.0	0.1	3.1
	2033-2042	3.0	0.1	3.1
	2043-2052	0.1	0.1	6.2
	2053-2062	6.1	0.1	6.2
	2063-2072	6.5	0.1	6.6
Humboldt	**2023-2032**	0.7	0.0	0.7
	2033-2042	0.7	0.0	0.7
	2043-2052	0.0	0.0	1.5
	2053-2062	1.5	0.0	1.5
	2063-2072	1.4	0.0	1.4
Kern	**2023-2032**	0.7	0.0	0.7
	2033-2042	0.7	0.0	0.7
	2043-2052	0.0	0.0	0.8
	2053-2062	0.8	0.0	0.8
	2063-2072	1.2	0.0	1.2
Lake	**2023-2032**	2.6	0.3	2.8
	2033-2042	2.6	0.3	2.8
	2043-2052	0.5	0.5	5.9
	2053-2062	5.4	0.5	5.9
	2063-2072	6.4	0.6	7.0
Lassen	**2023-2032**	3.0	4.9	7.9
	2033-2042	3.0	4.9	7.9
	2043-2052	2.9	2.9	7.2
	2053-2062	4.4	2.9	7.2
	2063-2072	5.7	4.3	10.0
Madera	**2023-2032**	4.9	0.0	4.9
	2033-2042	4.9	0.0	4.9
	2043-2052	0.0	0.0	6.2
	2053-2062	6.2	0.0	6.2
	2063-2072	9.0	0.0	9.0
Mariposa	**2023-2032**	1.4	0.0	1.5
	2033-2042	1.4	0.0	1.5
	2043-2052	0.0	0.0	1.9
	2053-2062	1.8	0.0	1.9
	2063-2072	2.6	0.1	2.7
Mendocino	**2023-2032**	2.9	0.5	3.4
	2033-2042	2.9	0.5	3.4
	2043-2052	0.4	0.4	6.3
	2053-2062	5.9	0.4	6.3
	2063-2072	5.7	0.5	6.2
Modoc	**2023-2032**	0.1	0.0	0.1
	2033-2042	0.1	0.0	0.1
	2043-2052	0.0	0.0	0.3
	2053-2062	0.3	0.0	0.3
	2063-2072	0.5	0.0	0.5
Mono	**2023-2032**	0.0	0.0	0.0
	2033-2042	0.0	0.0	0.0

County	Decade	Public (MMbf/yr)	Private (MMbf/yr)	Total (MMbf/yr)
	2043-2052	0.0	0.0	0.0
	2053-2062	0.0	0.0	0.0
	2063-2072	0.1	0.0	0.1
Napa	2023-2032	0.0	0.2	0.2
	2033-2042	0.0	0.2	0.2
	2043-2052	0.4	0.4	0.4
	2053-2062	0.0	0.4	0.4
	2063-2072	0.0	0.5	0.6
Plumas	2023-2032	29.8	22.4	52.2
	2033-2042	29.8	22.4	52.2
	2043-2052	13.8	13.8	57.0
	2053-2062	43.2	13.8	57.0
	2063-2072	52.8	17.5	70.3
Shasta	2023-2032	3.5	4.5	8.0
	2033-2042	3.5	4.5	8.0
	2043-2052	3.6	3.6	9.9
	2053-2062	6.3	3.6	9.9
	2063-2072	7.0	4.7	11.7
Sierra	2023-2032	0.0	0.1	0.1
	2033-2042	0.0	0.1	0.1
	2043-2052	0.1	0.1	0.1
	2053-2062	0.1	0.1	0.1
	2063-2072	0.1	0.1	0.2
Siskiyou	2023-2032	12.9	1.1	13.9
	2033-2042	12.9	1.1	13.9
	2043-2052	1.0	1.0	19.4
	2053-2062	18.4	1.0	19.4
	2063-2072	21.8	1.7	23.5
Sonoma	2023-2032	0.0	0.4	0.4
	2033-2042	0.0	0.4	0.4
	2043-2052	0.7	0.7	0.7
	2053-2062	0.0	0.7	0.7
	2063-2072	0.0	0.8	0.8
Tehama	2023-2032	4.6	5.2	9.8
	2033-2042	4.6	5.2	9.8
	2043-2052	2.4	2.4	9.8
	2053-2062	7.4	2.4	9.8
	2063-2072	8.2	3.4	11.6
Trinity	2023-2032	20.6	2.6	23.2
	2033-2042	20.6	2.6	23.2
	2043-2052	2.0	2.0	30.3
	2053-2062	28.3	2.0	30.3
	2063-2072	33.1	2.8	35.9
Tulare	2023-2032	12.3	2.0	14.3
	2033-2042	12.3	2.0	14.3
	2043-2052	1.0	1.0	10.3
	2053-2062	9.3	1.0	10.3
	2063-2072	13.8	1.7	15.5
Tuolumne	2023-2032	1.0	0.0	1.0

County	Decade	Public (MMbf/yr)	Private (MMbf/yr)	Total (MMbf/yr)
	2033-2042	1.0	0.0	1.0
	2043-2052	0.0	0.0	1.0
	2053-2062	1.0	0.0	1.0
	2063-2072	1.4	0.0	1.4

Appendix C: Landowner Survey

Questions – Private landowners

1) **Demographic information**
    a. **Type of landowner**
        i. **Family/individual**
        ii. **Industrial**
        iii. **Other (e.g. consulting forester)**
    b. **Where are the lands you own or manage located (North Coast, North Interior, North Sierra, Central Sierra, South Sierra, Great Basin)?**
    c. **What is the primary species or species mix on the lands you own or manage?**
    d. **How many acres do you own or manage?**
    e. **How many acres of the lands you own or manage were burned severely enough to change previously anticipated management?**

2) **What are the management objectives for your forest lands?**

3) **What are your management objectives in areas burned in large fires (e.g.; restore/retain access, timber production, erosion control, maintain water quality, carbon credits)?**

4) **How have the fires affected:**
    a. **Planned harvest levels over the next 10 years**
    b. **Road infrastructure**
    c. **Silviculture plans**
    d. **Investments to maintain current infrastructure on existing lands in California**
    e. **Investments in new infrastructure on existing lands in California**
    f. **Purchase of additional lands in California**

5) **When a stand is partially damaged by a fire, how do you decide what management actions to take?**

6) **Is there a burn area threshold below which do you not consider salvage? If so, what percent of the stand needs to burn to consider salvage (e.g., if below a quarter of the stand is burned, no salvage is conducted)?**

7) **For areas not salvaged, is there a burn area threshold below which do you not consider reforestation? If so, what percent of the stand needs to burn to consider reforestation (e.g., if below a quarter of the stand is burned, no salvage is conducted)?**

8) **How do larger fires affect your long-term forest management planning?**

9) **What resources helped you most in making decisions about responding to the wildfire(s) that affected lands you own or manage?**

10) **What resources did you need that you were unable to access in a timely manner after wildfire(s) occurred?**

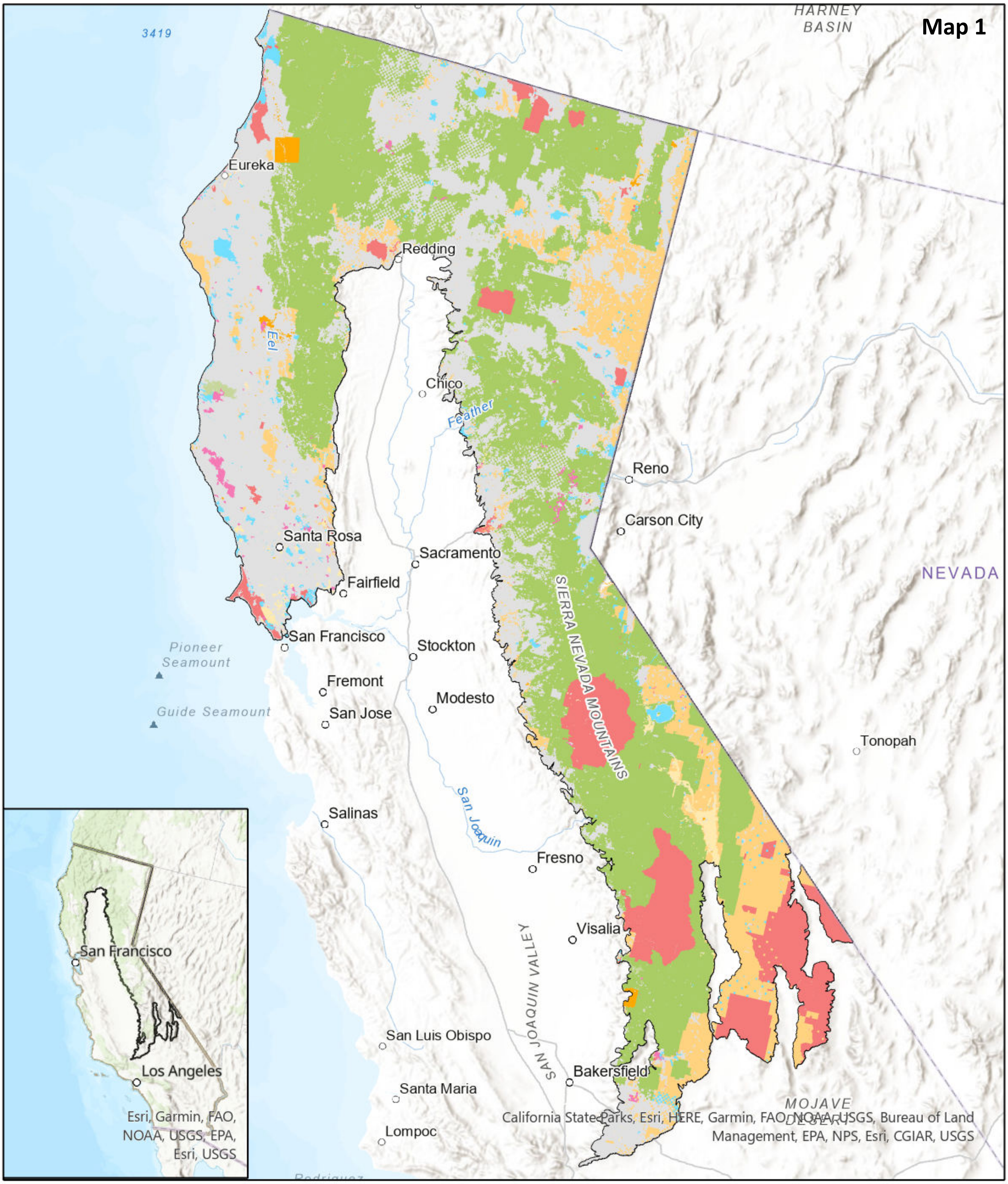
Additional questions for forest industry land managers

1) **What are typical harvest prescriptions used by other large private land landowners in your area?**
    a. **The response should note even or uneven-aged management, timing, and intensity of removal.**
2) **What are factors that limit the area of harvest in your area (e.g., riparian buffers, potentially unstable slopes etc.)?**
3) **In general, for other large landowners in your area, roughly how much area is unavailable for harvest in due to these factors?**

Additional question for federal land managers

1) **How many acres that burned would have likely been harvested over the next 50 years?**

Appendix D: Maps



California Land Ownership by Category

Ownership Category

- BLM
- CA Forest & Fire
- Local
- NGO
- Other Federal
- Other State
- Private
- Tribal
- USFS
- Project Area

N

0 30 60 120 Kilometers

0 30 60 120 Miles

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Basemap: ESRI World Terrain
Coordinate System: NAD 83, UTM Zone 10N
10/19/2022
CAFireMapping_2022_SH

Forested Land Inside Project Area

Forested Land

Forested

Project Area

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Coordinate System: NAD 83, UTM Zone 10N

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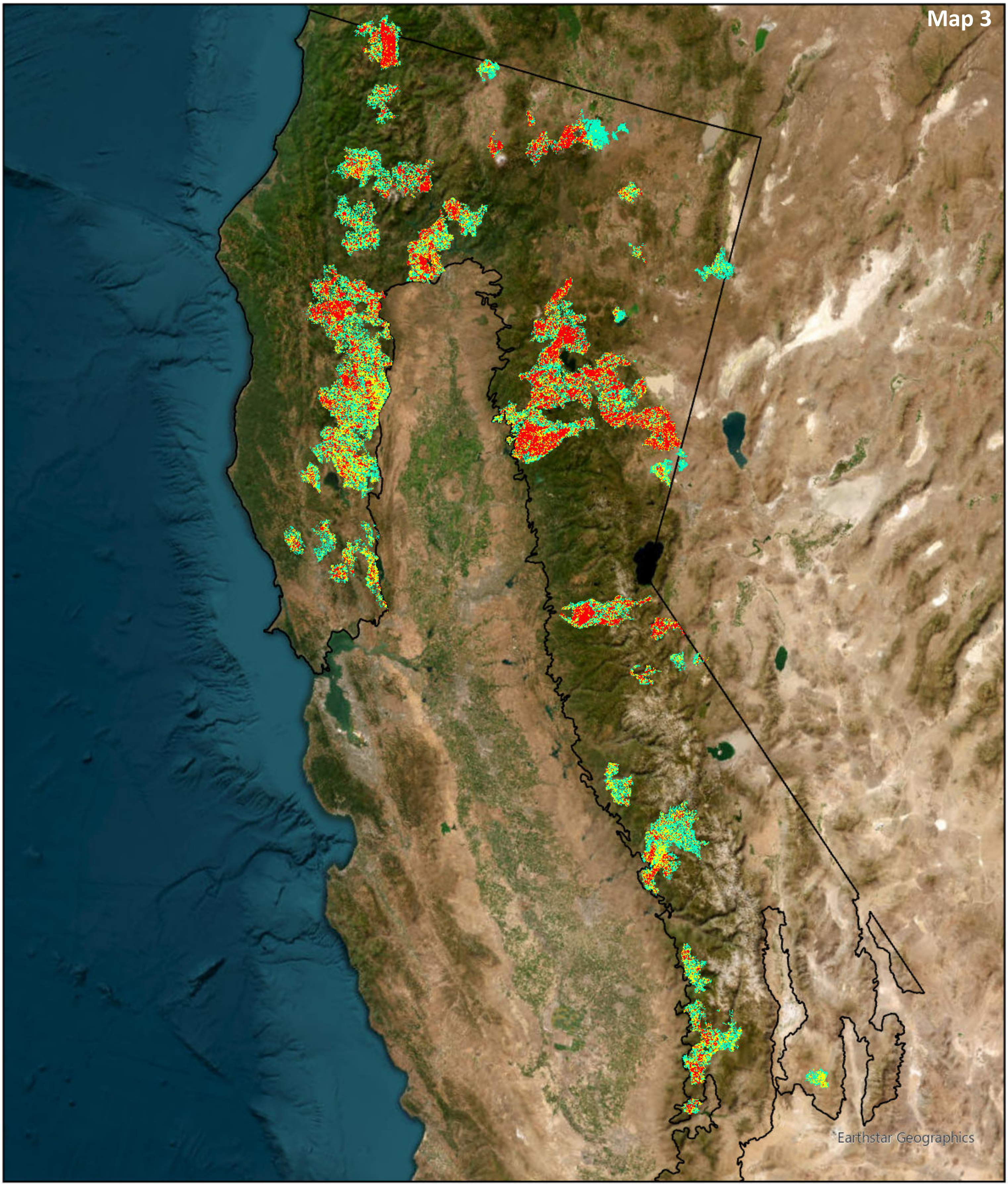
CAFireMapping_2022_SH



All Large Fires in Project Area

N

0 25 50 100 Kilometers

0 30 60 120 Miles

Low (CBI: 0.1 - > 1.25)

Moderate (CBI: 1.25 - > 2.25)

High (CBI: 2.25 - > 3)

Project Area

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Coordinate System: NAD83, UTM Zone 10N

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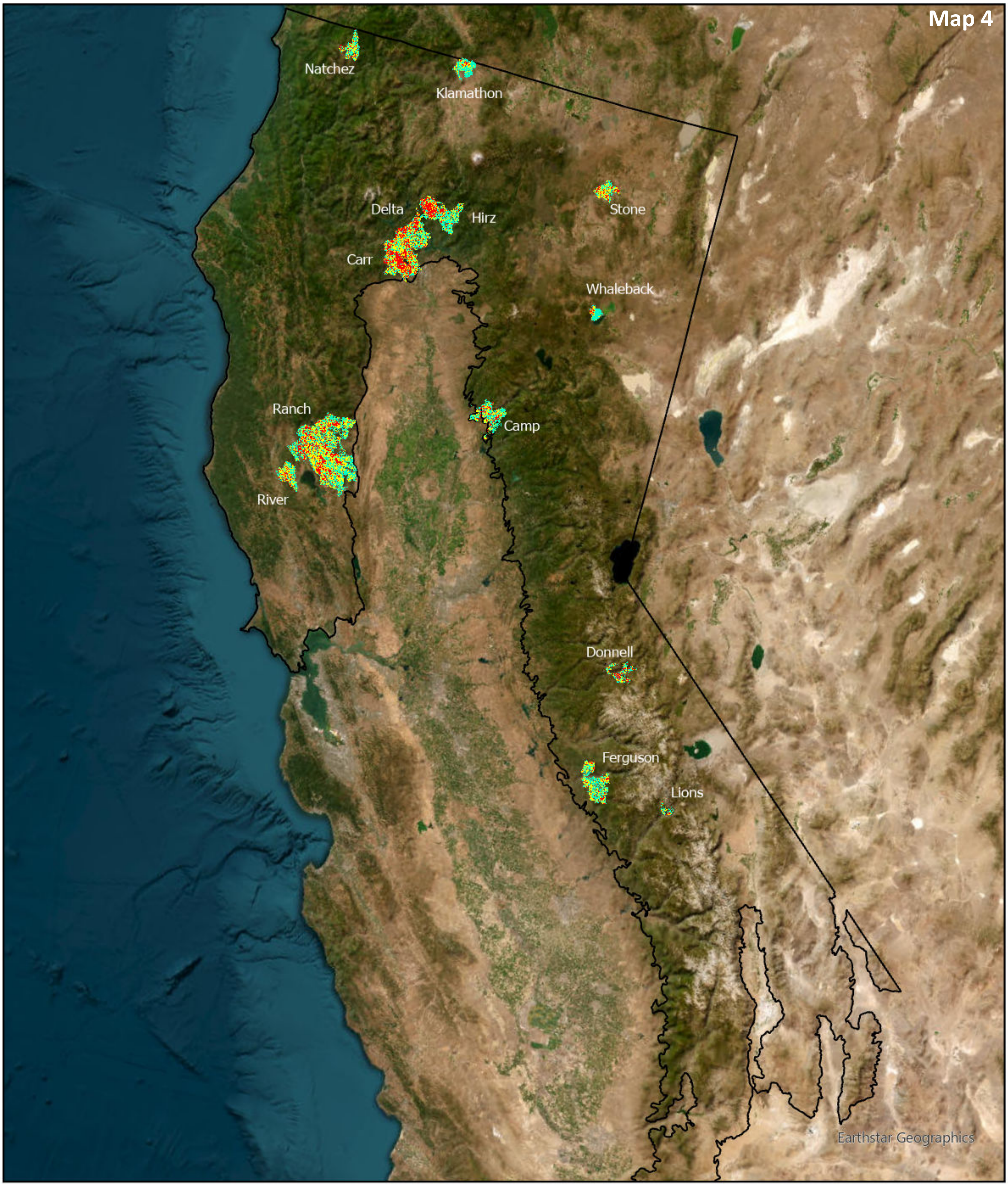

2018 Large Fires in Project Area

N

0 25 50 100 Kilometers

0 30 60 120 Miles

- Low (CBI: 0.1 - <1.25)
- Moderate (CBI: 1.25 - <2.25)
- High (CBI: 1.25 - < 3)
- Project Area

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2019 Large Fires in Project Area

N

0 25 50 100 Kilometers

0 30 60 120 Miles

- Low (CBI: 0.1 - < 1.25)
- Moderate (CBI: 1.25 - < 2.25)
- High (CBI: 2.25 - < 3)
- Project Area

MASON BRUCE & GIRARD

Basemap: ESRI World Terrain
Coordinate System: NAD83, UTM Zone 10N

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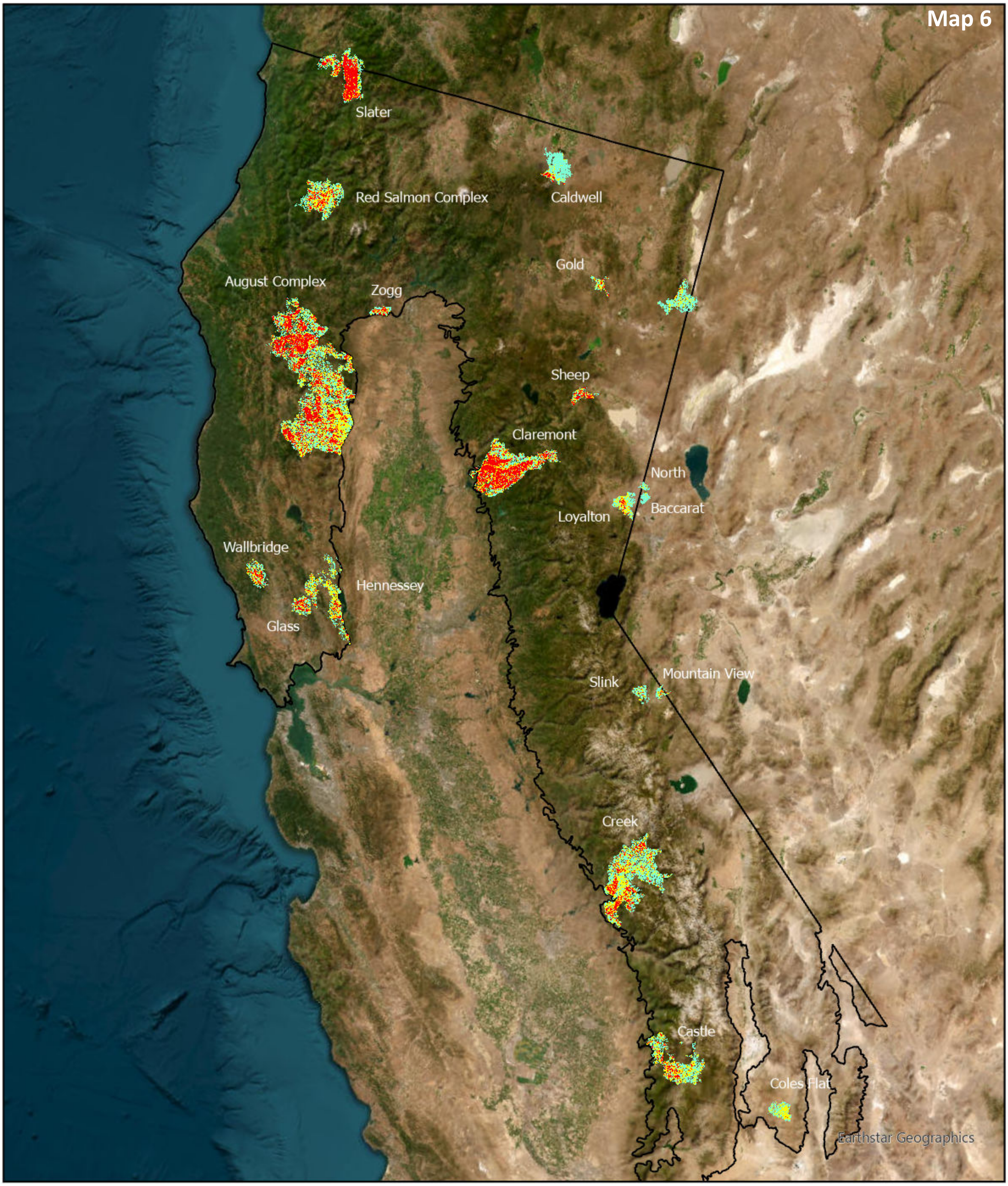

2020 Large Fires in Project Area

N

0 25 50 100 Kilometers

0 30 60 120 Miles

- Low (CBI: 0.1 - <1.25)
- Moderate (CBI: 1.25 - <2.25)
- High (CBI: 2.25 - <3)
- Project Area

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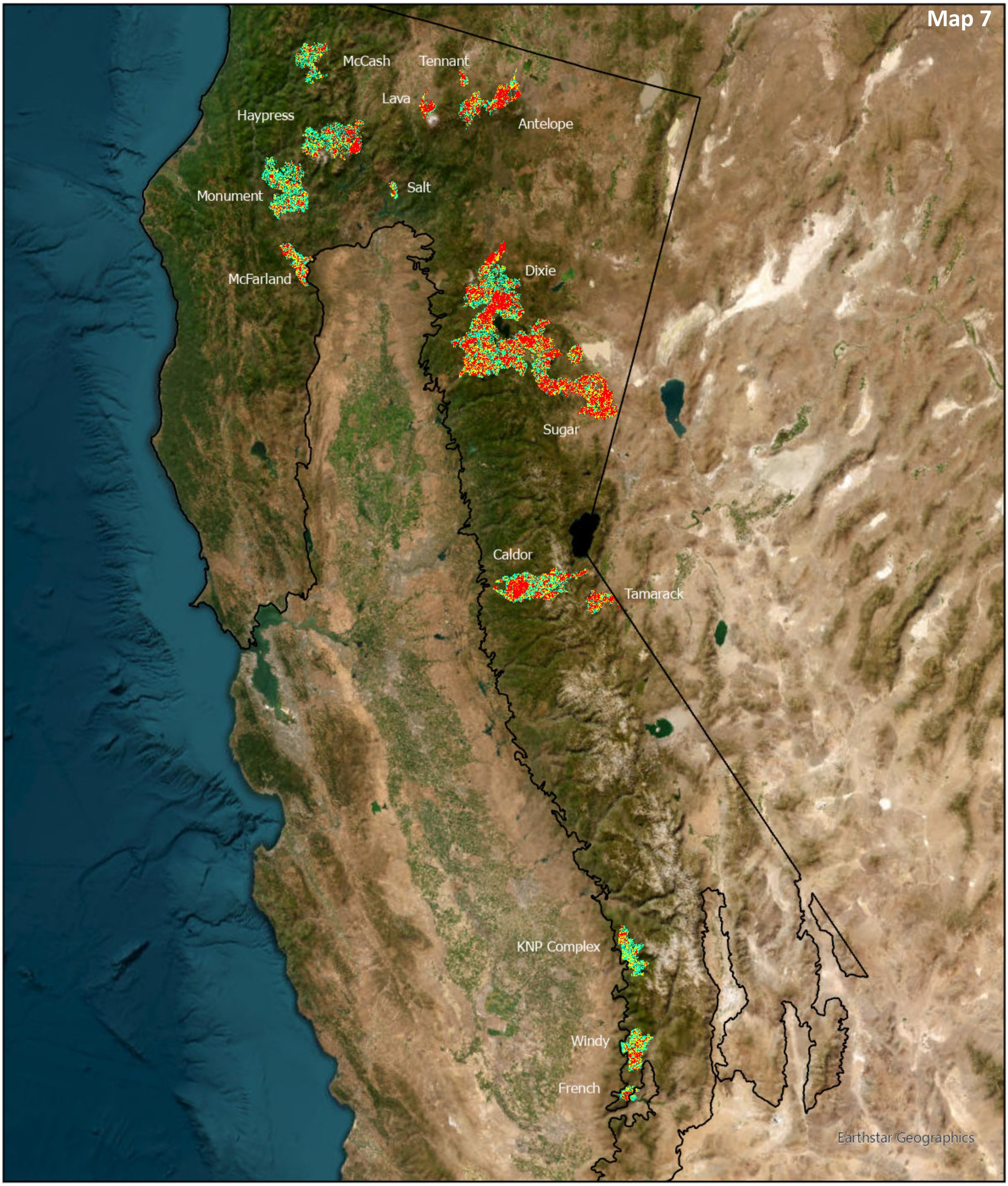

2021 Large Fires in Project Area

Low (CBI: 0.1 - <1.25)
Moderate (CBI: 1.25 - <2.25)
High (CBI: 2.25 - < 3)
Project Area

N

0 20 40 80 Kilometers

0 30 60 120 Miles

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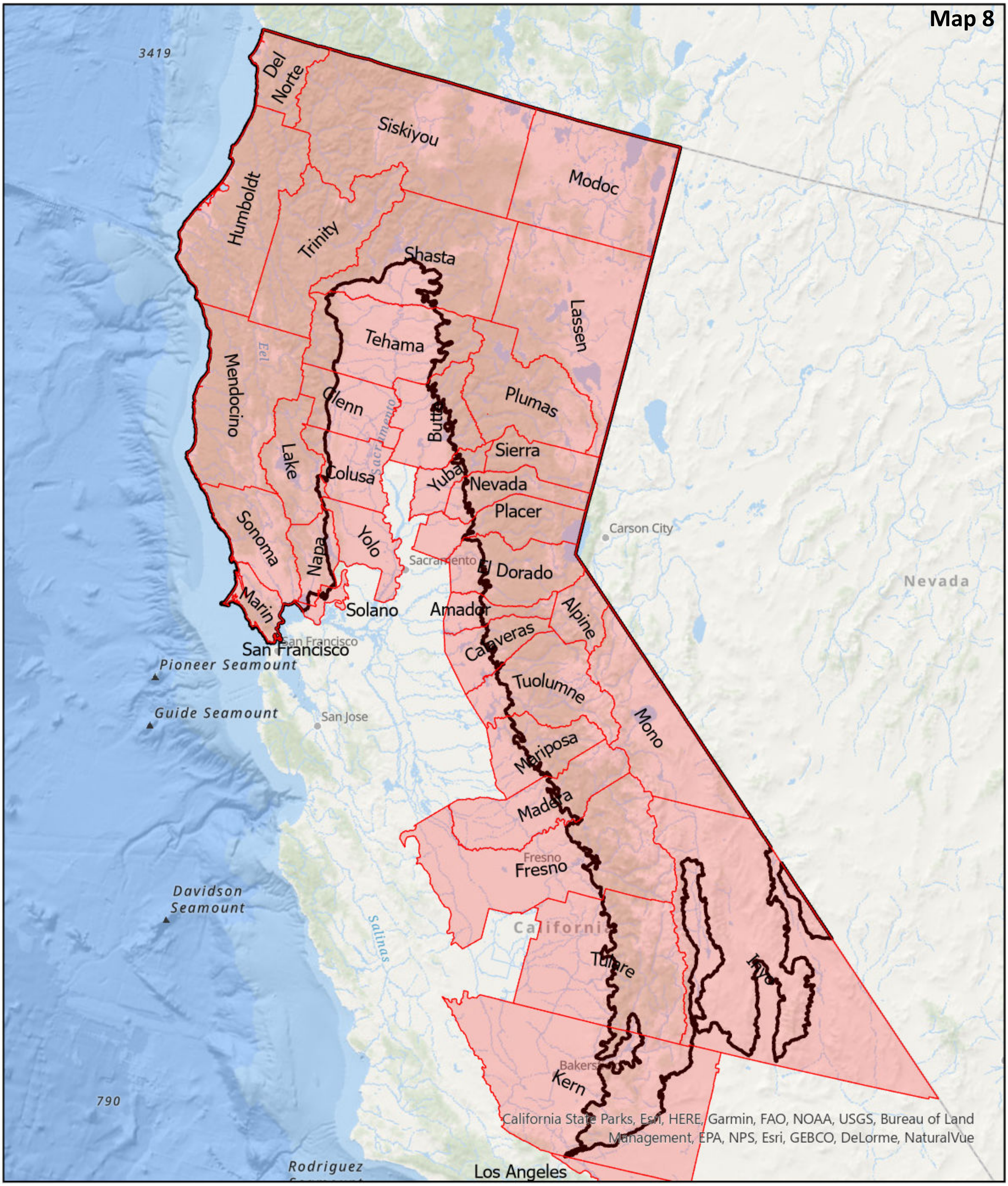

Counties in Project Area

Counties

Project Area

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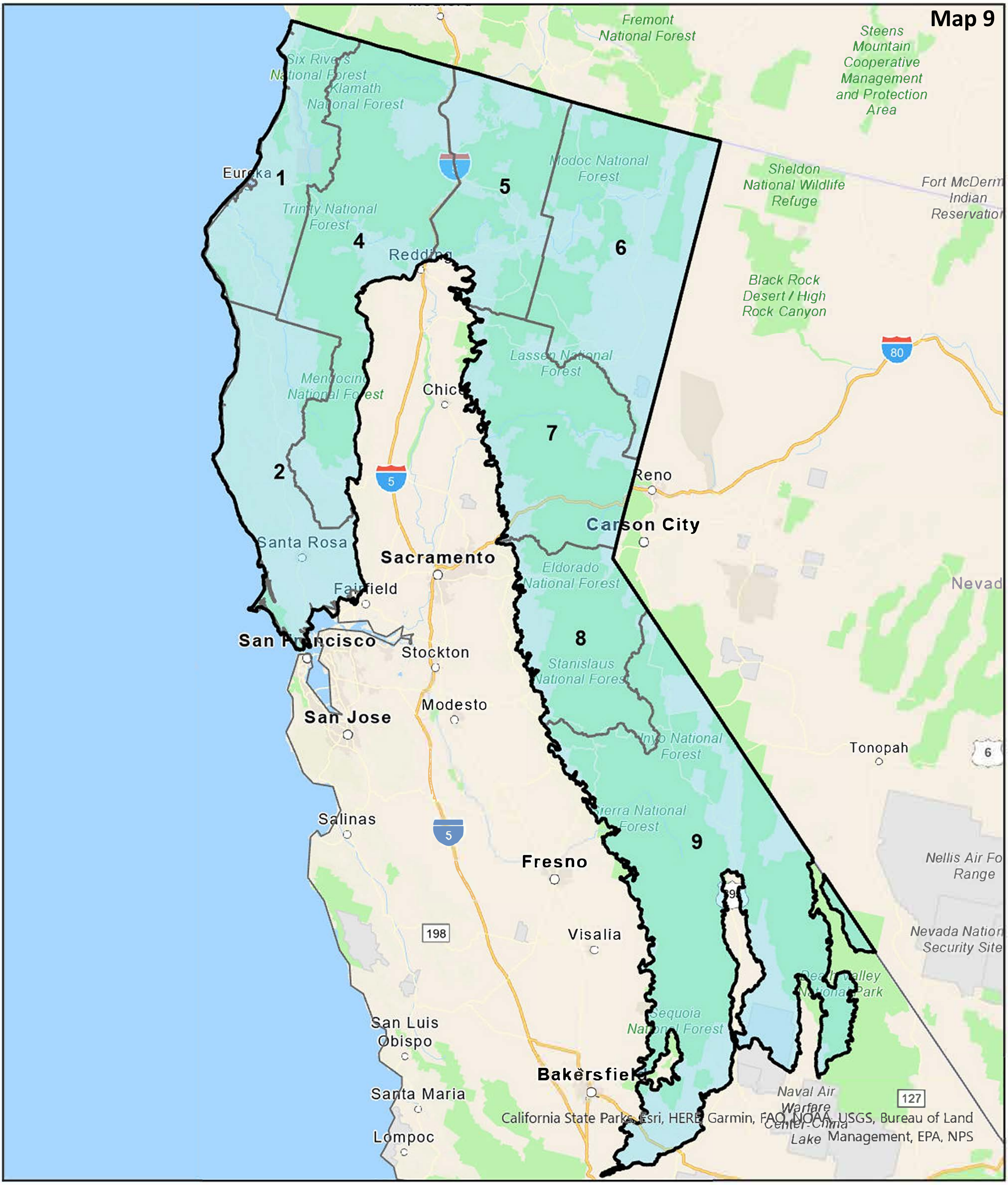

Timber Value Areas (TVA) Inside Project Area

N

0 45 90 180 Kilometers

0 30 60 120 Miles

Project Area

TVA

CA State Boundary

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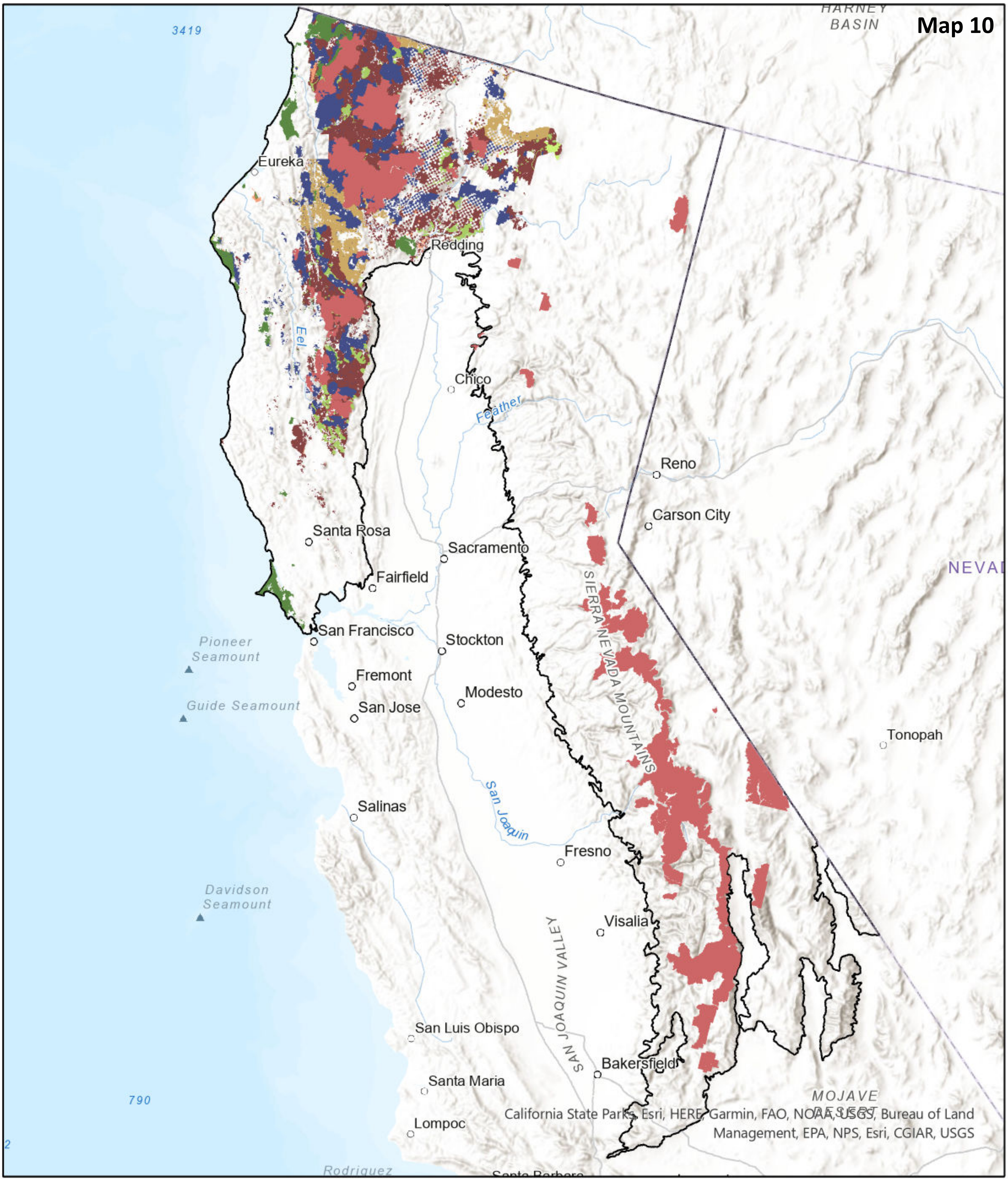

Land Use Allocation Inside Project Area

Land Use Allocation
- Adaptive Management Area
- Administratively Withdrawn Area
- Congressionally Reserved Area
- Late Successional Reserve
- Managed Late Successional Area
- Not Designated
- Other: Matrix, Riparian, Unmapped
- Wilderness Area
- Project Area

0 30 60 120 Kilometers
0 30 60 120 Miles

N

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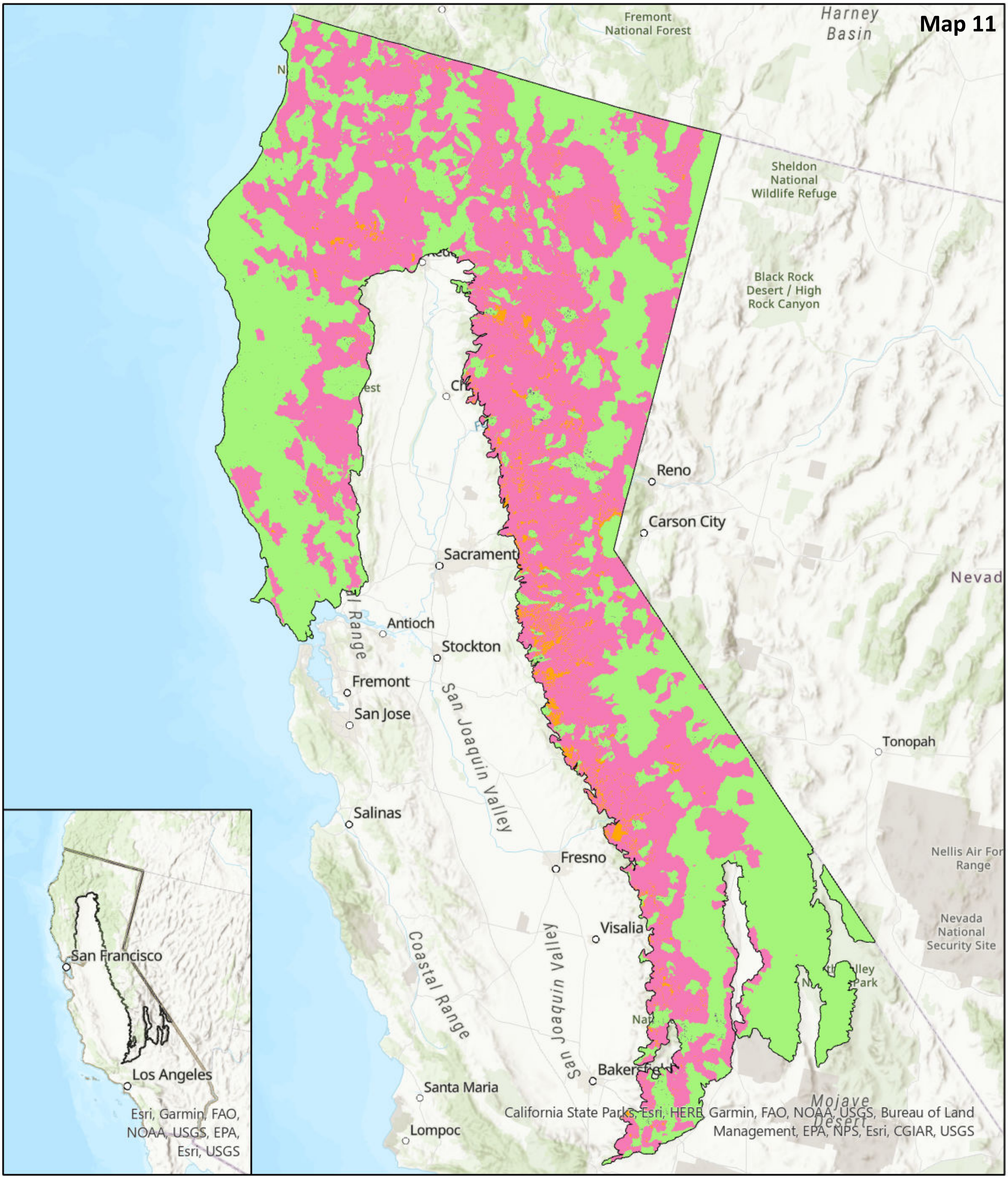

High Hazard Zones Inside Project Area

N

0 30 60 120 Kilometers

0 30 60 120 Miles

- Project Area
- Tier 1
- Tier 2
- Tier 3
- Tier 4

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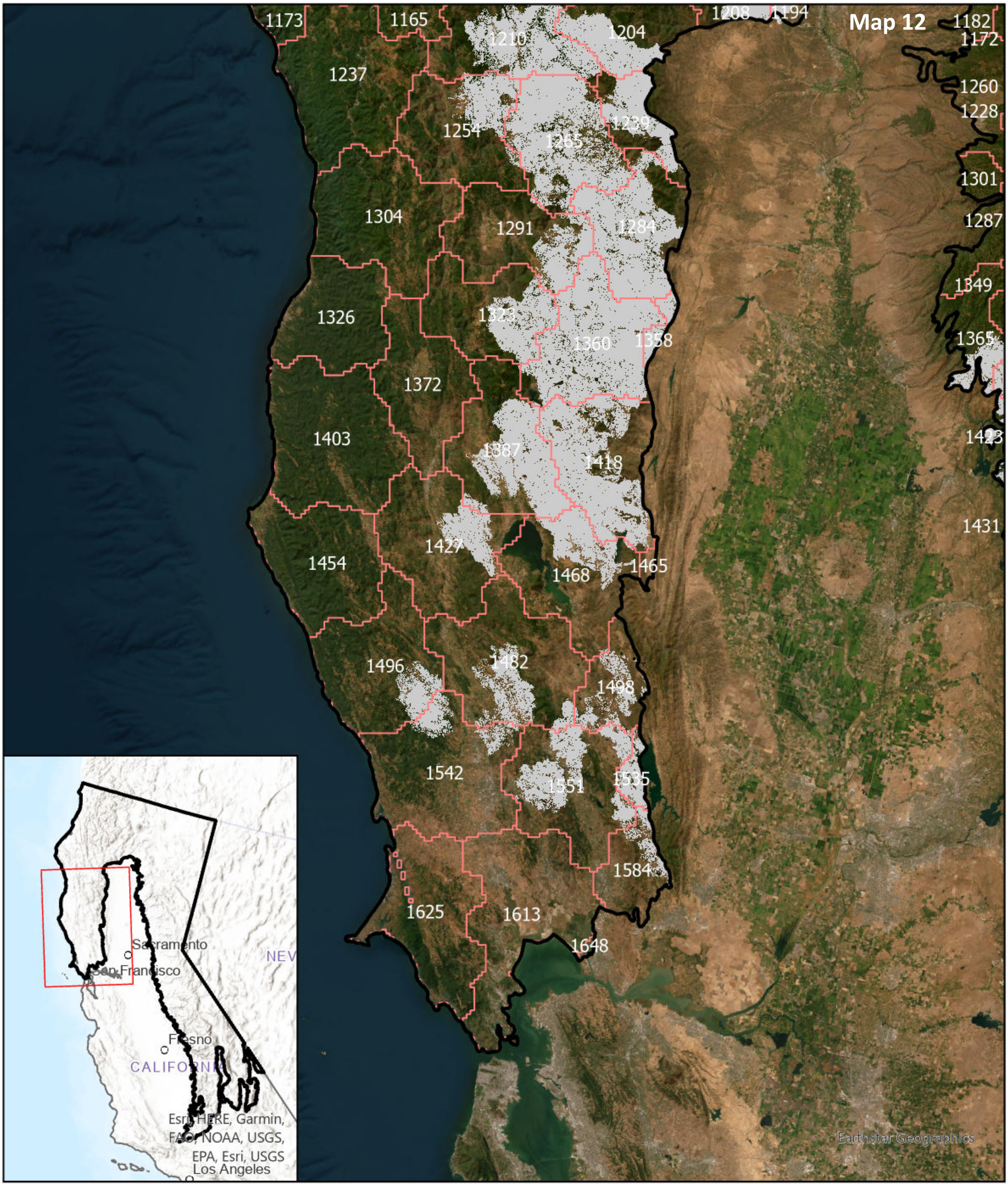
10/28/2022
CAFireMapping_2022_SH_1



Firesheds in Project Area

N

0 10 20 40 Kilometers

0 10 20 40 Miles

Project Area

Firesheds

Large Fires

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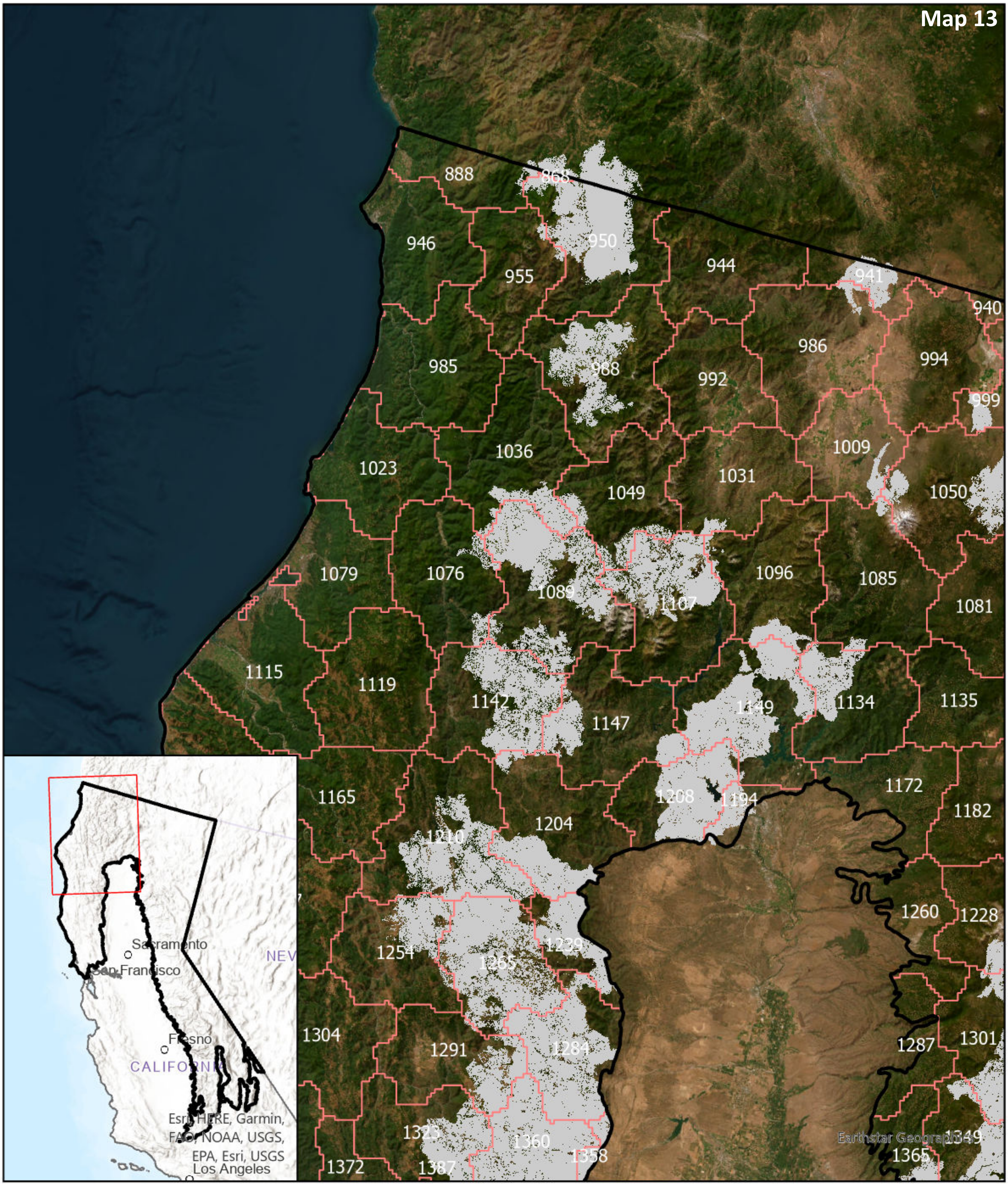
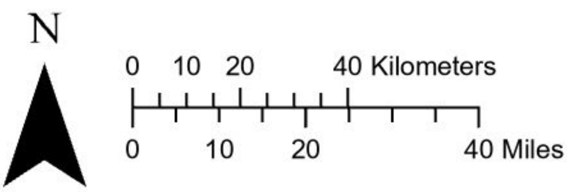


Firesheds in Project Area



Project Area

Firesheds

Large Fires

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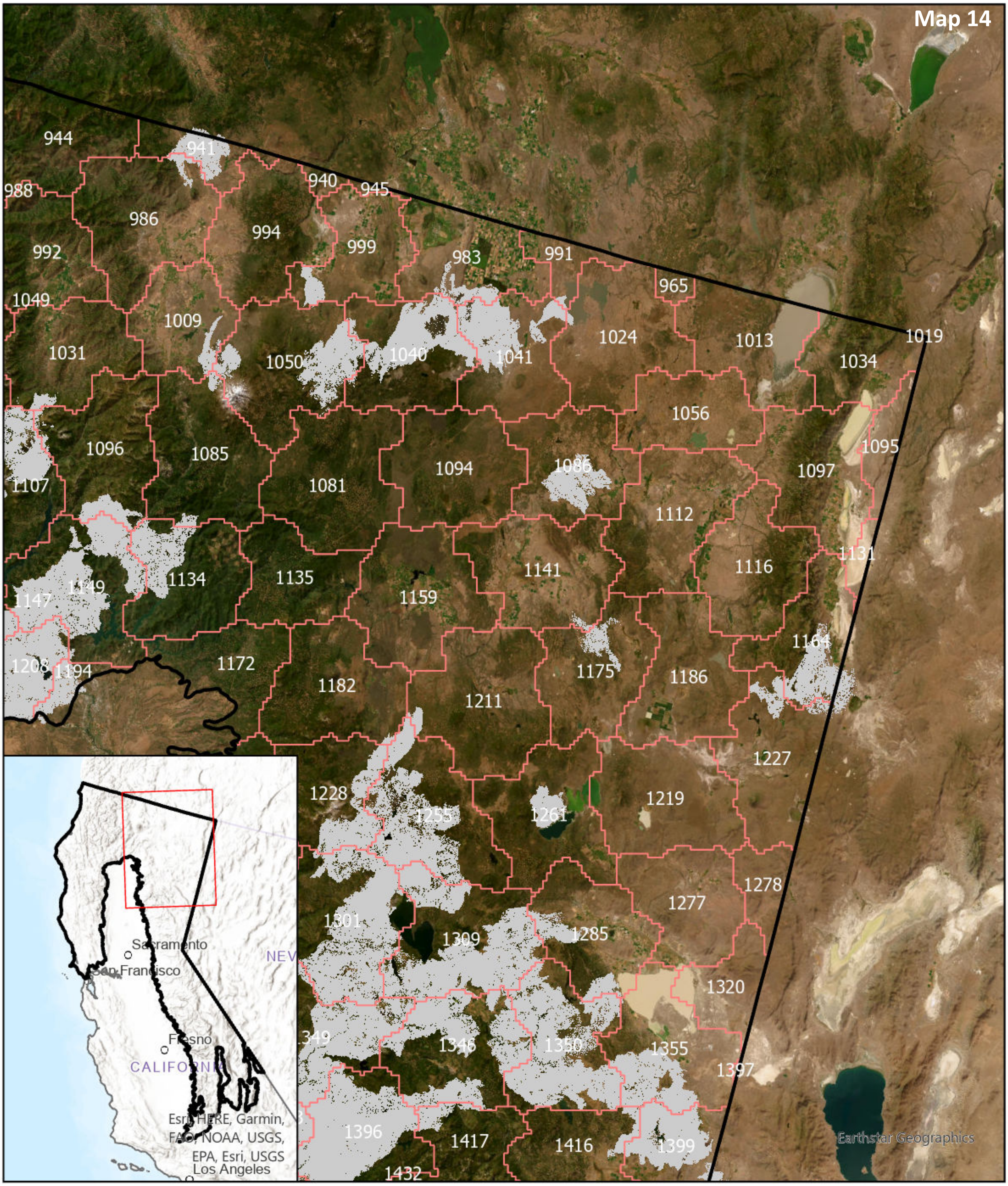

Firesheds in Project Area

N

0 10 20 40 Kilometers

0 10 20 40 Miles

Project Area

Firesheds

Large Fires

MASON BRUCE & GIRARD

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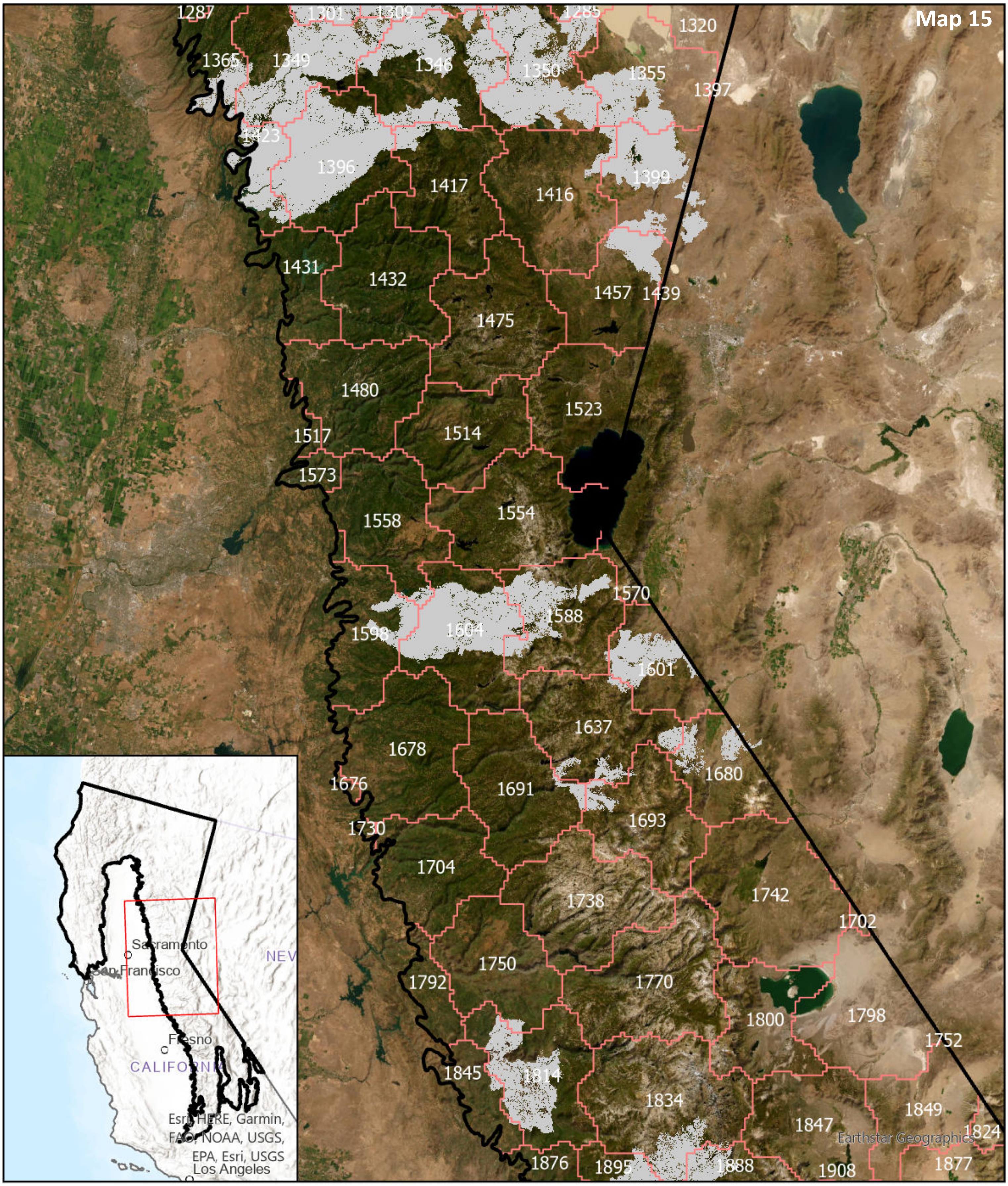

Firesheds in Project Area

N

0 10 20 40 Kilometers

0 10 20 40 Miles

Project Area

Firesheds

Large Fires

MASON BRUCE & GIRARD

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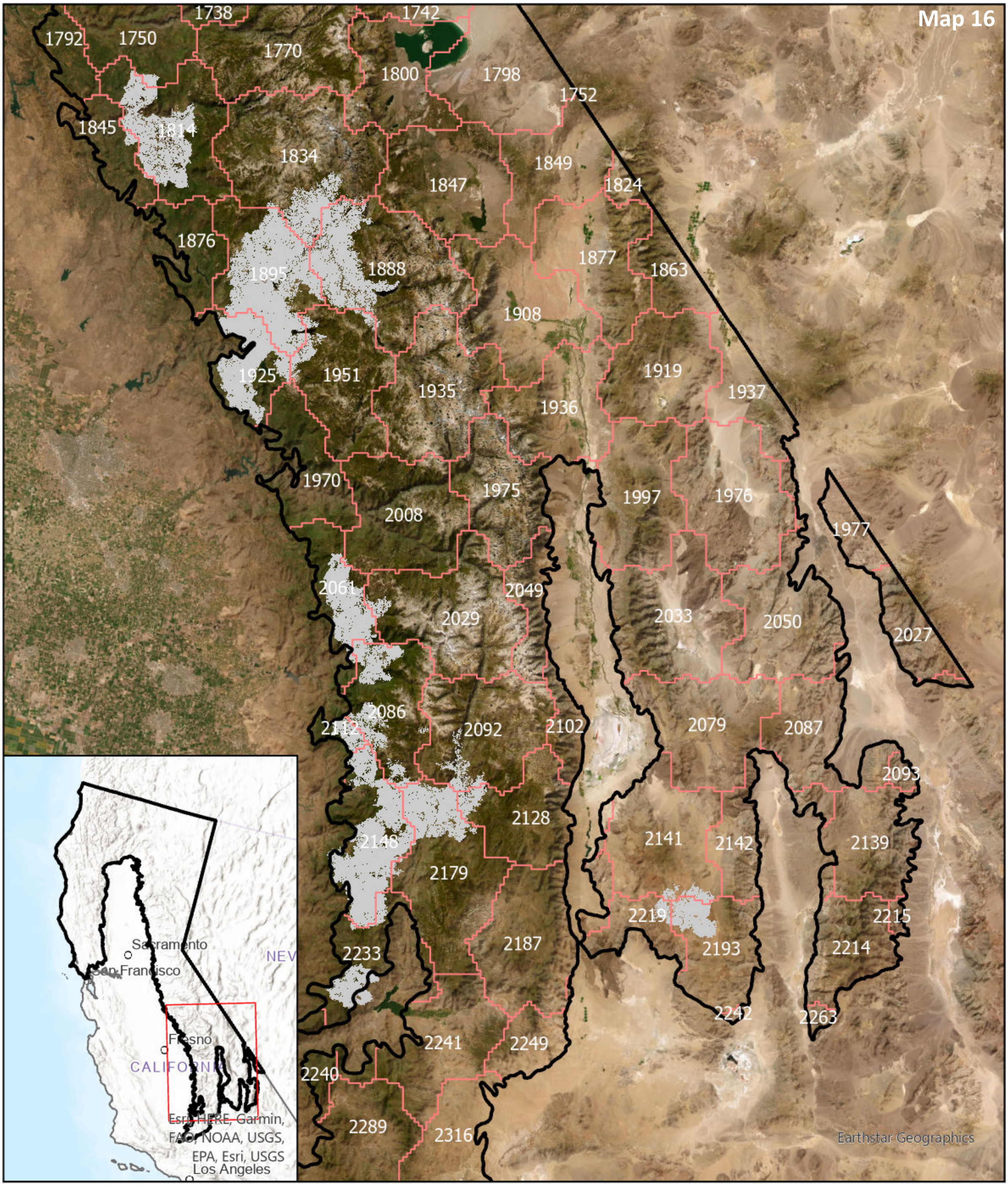

Firesheds in Project Area

N

0 10 20 40 Kilometers

0 10 20 40 Miles

Project Area

Firesheds

Large Fires

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Basemap: ESRI World Terrain
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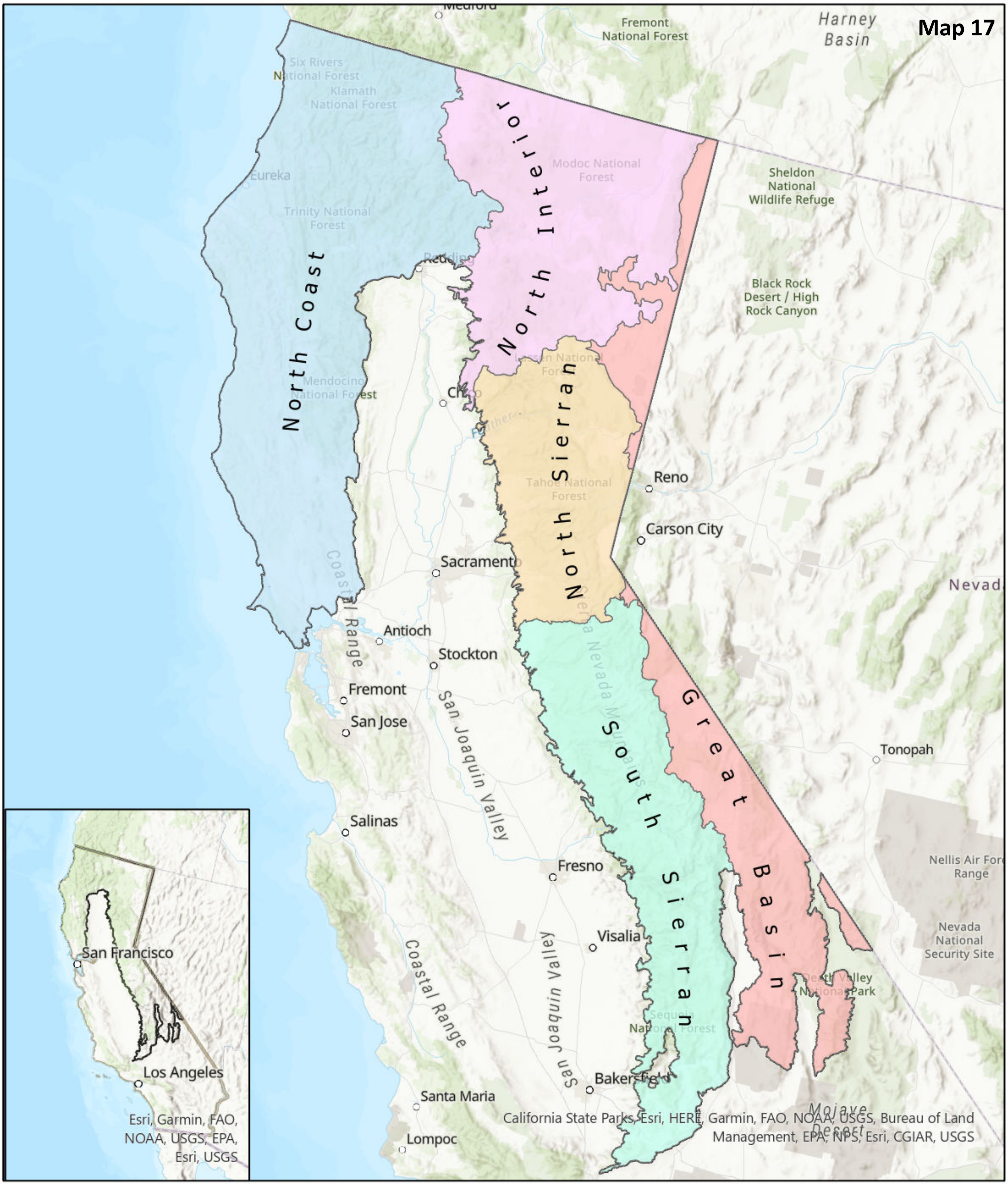

Vegetation Zones Inside Project Area

N

0 30 60 120 Kilometers

0 30 60 120 Miles

Vegetation Zone
- Great Basin
- North Coast
- North Interior
- North Sierran
- South Sierran
- Project Area

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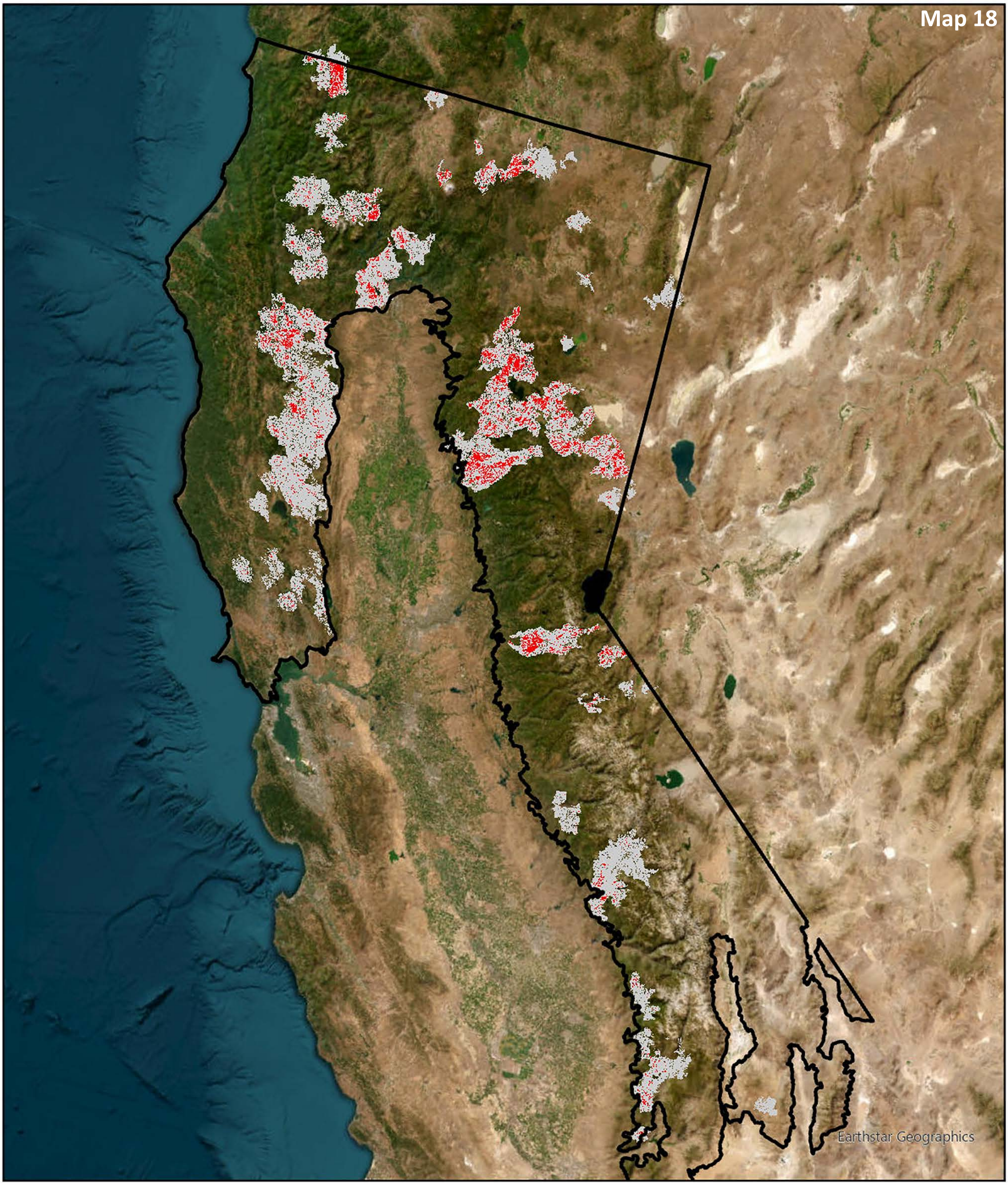

High Severity Patches in Large Fires in Project Area

N

0 25 50 100 Kilometers

0 30 60 120 Miles

Project Area

High Severity Patches

Large Fires

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