NATURAL RESOURCES

WILDFIRE SEASON 2021 - WORK OF WILDFIRE ASSESSMENT

Forest Health Science Team
Forest Resilience Division

This report provides a rapid evaluation of the effects of the 2021 wildfires on the forest landscape resilience and wildfire risk reduction objectives of the 20-Year Forest Health Strategic Plan: Eastern Washington

MARCH 2022

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Wildfire Season 2021 - Work of Wildfire Assessment

EXECUTIVE SUMMARY

Throughout the western US, 2021 was a very challenging fire season that impacted communities and strained wildland fire management resources. In eastern Washington, wildfires affected 679,761 total acres, including 463,345 acres of forest that burned with a wide range of effects across different forest types. Many communities experienced heavy smoke impacts, evacuations, and damage to property and other resources. These fires also had substantial effects on forested landscapes and the many benefits they provide to people.

In 2017, the Washington State Department of Natural Resources (DNR) launched the 20-Year Forest Health Strategic Plan: Eastern Washington (20-Year Plan) to accelerate work on landscape-scale wildfire risk reduction, restoration, and climate adaptation across all lands. Over the past four years, WA DNR staff have collaborated with many partners to prioritize planning areas, determine landscape treatment needs, implement treatments, and develop a monitoring program to track changes in landscape conditions as well as treatment effectiveness.

To better understand the impacts of the 2021 fire season, the DNR Forest Health Science Team piloted a rapid assessment to evaluate the work of wildfire – i.e., the degree to which fire effects were consistent with the landscape resilience and wildfire risk reduction objectives of the 20-Year Plan. We present the results of this pilot project in four related themes: (1) Summary of 2021 fires; (2) Effects of individual fires; (3) Forest health treatments; (4) Wildland fire operations. We note that all 2021 wildfires in this report were managed for suppression objectives and that our results are based on preliminary burn severity maps that may change due to delayed tree mortality and other factors. Key findings from this pilot assessment include the following:

The 2021 wildfires had both positive and negative effects on resilience and wildfire risk reduction objectives.

Uncharacteristically severe impacts occurred in dry forests and portions of moist forests. High-severity fire (>75% tree mortality) occurred across an estimated 125,000 acres of dry and moist forests, including 85,000 acres in medium and large patches (>100 acres). High-severity fire reduced large tree habitats, seed sources for natural regeneration, and soil stability, compounding the impacts of previous large fires and diminishing options to restore more resilient landscapes and lower wildfire risks.

Fires likely had beneficial effects on landscape resilience and wildfire risk in many locations. Low- and moderate-severity fire (<75% tree mortality) occurred across an estimated 230,000 acres of dry and moist forests. Fires reduced fuels and tree densities in these areas, thereby mitigating fire risk and facilitating management of future fires, particularly if resilient conditions are maintained by future treatments. This total compares to 210,000 footprint acres of mechanical and prescribed fire treatments over the prior four years across eastern Washington (2017-2020).

Individual wildfire events spanned a wide range of forest conditions across eastern Washington.

Each large fire exhibited distinct spatial patterns of burn severity (i.e., tree mortality), with corresponding implications for landscape resilience goals. The Schneider Springs Fire was the largest overall (97,320 forested acres), while the Cub Creek 2 Fire included the most high-severity fire in dry forests (21,646 acres). The Cedar Creek Fire produced a variety of outcomes, illustrating many of the overall patterns of the 2021 fires. For example, the Cedar Creek Fire included uncharacteristically large patches (>1,000 acres) of high-severity fire in dry forests as well as low- and moderate-severity fire that partially addressed treatment needs in priority landscapes.

Forest health treatments burned at low, moderate, and high severity.

The 2021 wildfires included many examples where prior treatments burned at low severity (<25% tree mortality) and gave fire managers more options to directly engage and safely manage fires. However, exceptionally hot and dry weather, high winds, and other factors led to moderate and high severity in other treatments. Based on limited field observations, treatments that included prescribed fire or piling and burning to reduce surface fuels were more likely to be effective, whereas mechanical only treatments often experienced higher tree mortality.

Wildfire managers utilized some forest health treatments to manage wildfires more effectively and safely.

Wildfire incidents are dynamic, and the utility of prior treatments for wildland firefighting operations depends on fire weather, resource availability, and strategic considerations specific to each fire. As such, not all treatment units are directly used in fire operations. In the Cedar Creek Fire, fire managers utilized some treatment units to reduce fire spread and severity while accomplishing work faster and with fewer resources. Where treatments were used operationally, fire managers were able to protect communities, infrastructure, forest resources, and other highly valued resources.

In addition to these key findings, the 2021 wildfire season demonstrated numerous lessons for future assessments. Given recent trends and climate projections, wildfires are likely to continue to be a major disturbance agent shaping forest health and landscape resilience. Despite the sharp increase in total acres burned since 2014, the 10-year average is below estimated historical levels that maintained resilient landscapes. Evaluating the positive and negative effects of wildfires, forest health treatments, and wildfire operations will become increasingly important for climate adaptation strategies like the 20-Year Plan.

INTRODUCTION

Across the western US, the need for large-scale intentional management actions to increase the resilience of landscapes to increasing drought and wildfire activity has been clearly established (Hagmann et al. 2021, Hessburg et al. 2021, Prichard et al. 2021). Although the pace and scale of mechanical and prescribed fire treatments are increasing, wildfires are affecting many communities and landscapes before or during implementation of restoration and risk reduction efforts. Thus, in parallel with efforts to increase the pace of forest health treatments, fire management resources are increasing to address the many negative impacts of wildfires on communities, human heath, infrastructure, recreation, and natural resources (Infrastructure Investment and Jobs Act of 2021, WA State House Bill 1168, 2021).

In addition to the widespread social, economic, and environmental impacts of wildfires, fires often have effects – such as reduced tree densities and surface fuel loadings – that lower risks from, and increase resilience to, future wildfires and drought (Fettig et al. 2019, Ager et al. 2022, Cansler et al. 2022). Wildfires also can enhance wildlife habitat and aquatic systems, including increasing snow pack and stream flow (Kennedy and Fontaine 2009, Rieman et al. 2012, Wine et al. 2018). Managers, scientists, and stakeholders are thus developing methods to integrate this positive "work" of wildfire into landscape restoration efforts while also mitigating the negative impacts of fires (National Cohesive Wildland Fire Strategy, Dunn et al. 2020, Ager et al. 2022, Larson et al. 2022).

In 2017, the Washington State Department of Natural Resources (DNR) launched the 20-Year Forest Health Strategic Plan: Eastern Washington (20-Year Plan) to accelerate work on landscape-scale wildfire risk reduction, restoration, and climate adaptation work across all land ownerships. Over the past four years, WA DNR staff have collaborated with many partners to prioritize planning areas, determine landscape treatment needs, implement forest health treatments, and develop a monitoring program to track changes in landscape conditions as well as treatment effectiveness. This report builds on multiple prior and ongoing efforts that have evaluated fire effects and the utility of treatments for multiple objectives (Appendix A).

The 2021 wildfires had major impacts on the objectives of the 20-Year Plan in eastern Washington. Exceptionally dry fuels caused by early season drought and a record-breaking heat wave led to the third largest fire season (679,761 acres) in recent history (Figure 1). Large wildfires occurred across Eastern Washington (Figure 2), imparting a wide range of fire effects (Figure 3). By altering forest structure and fuels, the 2021 fires changed treatment needs and priorities across multiple landscapes and ownerships. These fires also burned through many forest health treatments, and treatments were utilized by fire managers during suppression operations. Additionally, all fires assessed in this report were managed for suppression objectives following a directive from the USDA Forest Service (USFS). The 2021 wildfire season thus provided an opportunity to evaluate wildfire outcomes and summarize lessons learned. Importantly, the total acres burned in 2021 is just one component of wildfire impacts (Figure 3), and these fires enable researchers and managers to unpack the range of outcomes across a gradient of fire effects, forest types, and management objectives.

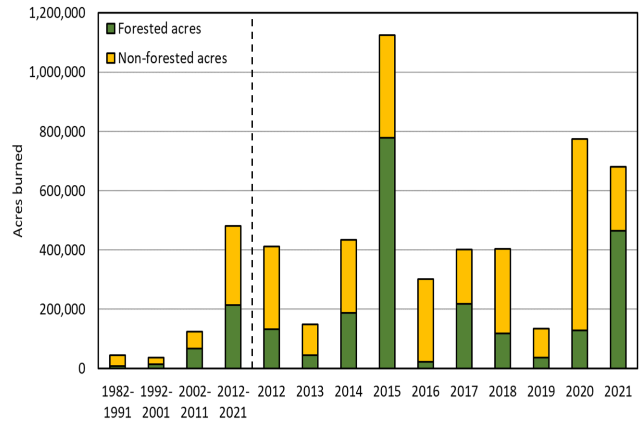

Figure 1. Average annual acres burned in eastern Washington State from 1984 to 2021 by decade and individual year (2012-2021; bars to the right of the dashed line). Large fire perimeters include all events over 100 acres and are compiled by the WA DNR Wildland Fire Management Division. 2015, 2020, and 2021 have been the largest fire years to date.

This report presents results of the first WA DNR Work of Wildfire Rapid Assessment. The overall goal of this effort was to develop a rapid, data-driven assessment of the effects of the 2021 wildfires across all lands in eastern Washington. Collaborating with many partners within and outside of DNR, the Forest Health Science Team quantified how fires moved landscapes towards and away from the resilience, risk reduction, and climate adaptation objectives of the 20-Year Plan. We also tested and developed methods to update treatment needs for planning areas, assess how fires burned in treated areas, and evaluate how treatments were utilized in wildfire management operations.

Our report is intended to provide complementary information to the annual wildfire season report that is prepared by the WA DNR Wildfire Division, which focuses on fire operations, economic costs, and damage to structures and resources (available online). Here, we present the results of the 2021 pilot project in the following themes related to the 20-Year Plan: (1) Summary of 2021 fires; (2) Effects of individual fires; (3) Forest health treatments; (4) Wildland fire operations. We present quantitative results for the first two themes. For the next two, we describe our field observations and information gathered from partners, as well as next steps and refined methods for future analyses.

METHODS TO QUANTIFY FIRE EFFECTS

To enable a comprehensive and rapid assessment of fire effects, we adapted the USFS Region 6 mapping approach using Google Earth Engine, pre- and post-fire Sentinel-2 satellite imagery, and field-based observations of tree mortality (Reilly et al. 2017) to map low-, moderate-, and high-severity fire corresponding to 0-25%, 25-75%, and 75-100% tree basal area mortality (See Appendix B for a detailed methods). This approach is similar to the RAVG program (https://burnseverity.cr.usgs.gov/ravg/) but allowed us to assess all fires in one workflow. We used fire perimeters from the National Interagency Fire Center (https://ftp.wildfire.gov/). We combined burn severity maps with vegetation type (dry, moist, and cold forests, plus non-forest vegetation) and land ownership maps developed for the 20-Year Plan.

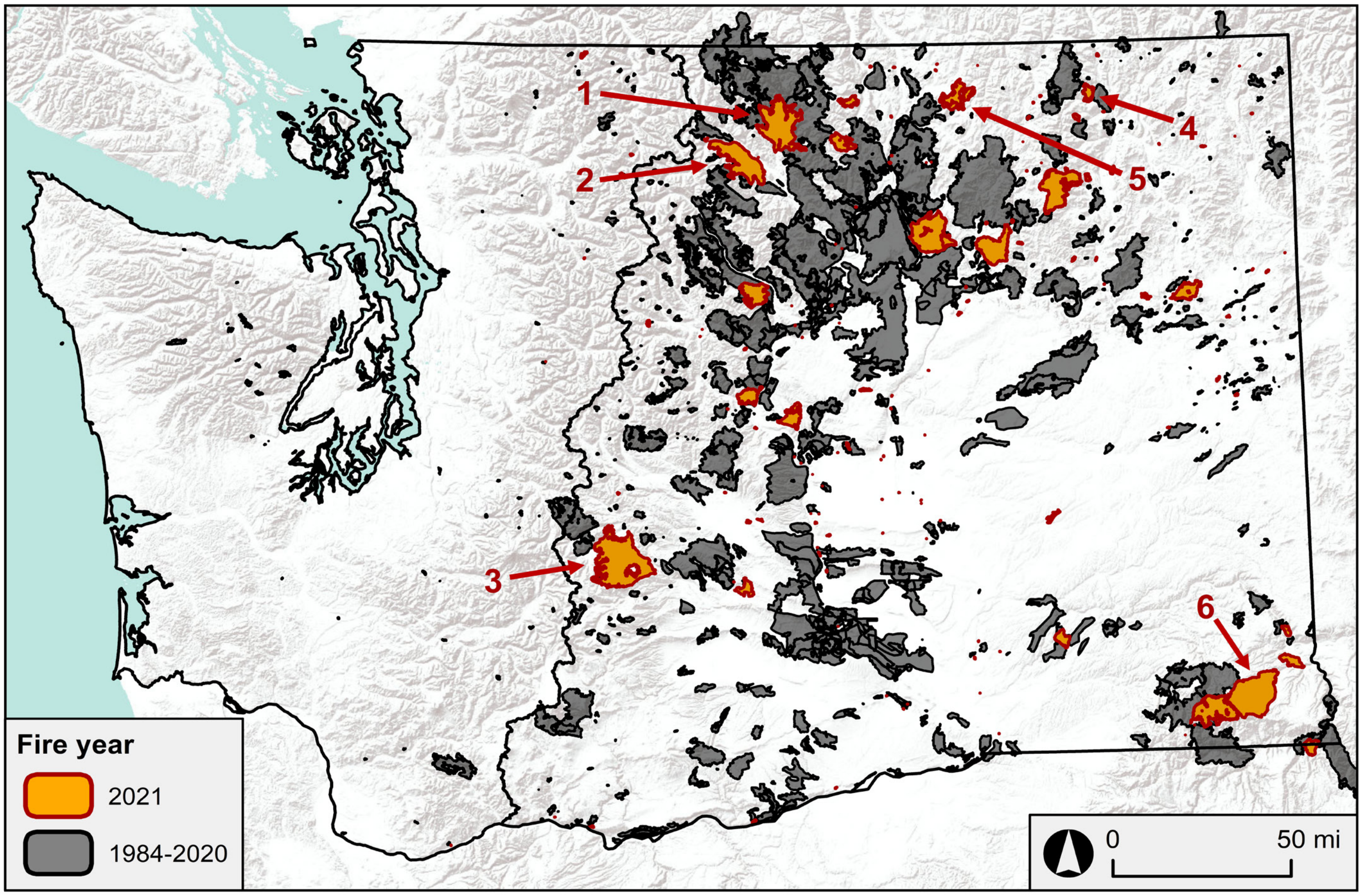

Figure 2. Wildfires across Washington State from 1984 to 2021. Large fire perimeters include all events over 100 acres and are compiled by the WA DNR Wildfire Division. The vast majority of burned areas have occurred in eastern Washington, delineated by the crest of the Cascade Range (black line). Red arrows and numbers indicate individual large fires highlighted in this report: 1: Cub Creek 2; 2: Cedar Creek; 3: Schneider Springs; 4: Bulldog Mountain; 5: Walker Creek; 6: Lick Creek. Service layer credits: Esri, USGS, NOAA.

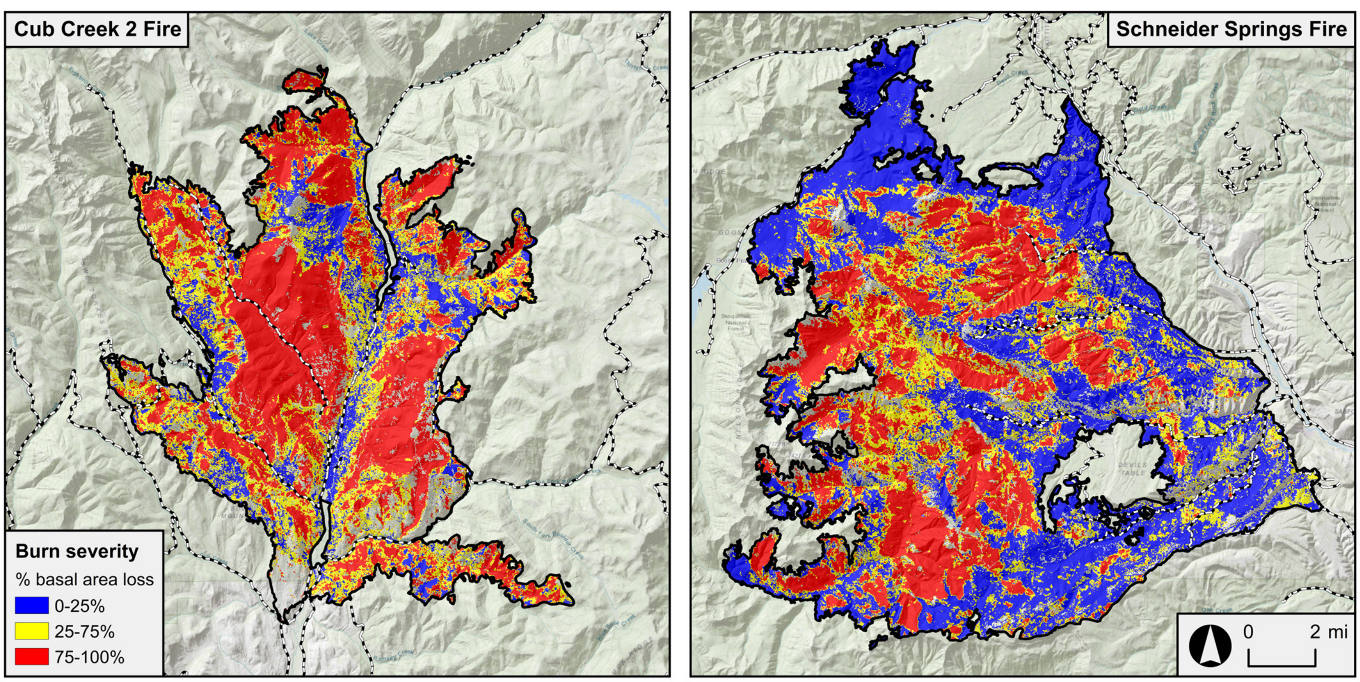

Figure 3. Preliminary burn severity patterns across forested portions of two major 2021 wildfires. Left panel: Cub Creek 2 had very large patches of high-severity fire. Right panel: Schneider Springs was the largest 2021 fire and exhibited a balance of severity classes that varied with elevation and past treatment activity. Preliminary burn severity maps of the 14 largest fires are included in Appendix D. Basemap: ESRI World Topographic Map.

Note that our burn severity maps are preliminary and do not capture delayed mortality. We thus anticipate that severity estimates will increase in subsequent years (Cansler et al. 2020). Given the need for timely adaptive management information and the possibility that 2022 could be another big fire year, we decided that using preliminary fire information was acceptable. However, we plan to work with partners to produce new severity maps following the summer of 2022 and update these results where there are major changes in our 2022 report to the Washington State Legislature.

To assess the work of wildfire – the degree to which fires moved landscapes towards landscape resilience and wildfire risk reduction goals – we compared the observed proportions of low-, moderate-, and high-severity fire for dry, moist, and cold forests with historical fire severities from Haugo et al. (2019), which are based on the LANDFIRE 2016 Biophysical Settings Review (http://www.landfirereview.org/) and refined simulation methodology from Blankenship et al. (2015). These historical severity levels maintained landscape conditions that were resilient to a wide range of disturbances and climatic fluctuations, while providing a wide range of ecological functions (Keane et al. 2009, Hessburg et al. 2019). These historical estimates thus represent reference ranges that are most likely to maintain landscapes that provide desired ecosystem services over time, including lower fuel loads and wildfires that are less difficult to manage. These ranges are provided in Appendix B.

We focused our evaluation of fire effects on severity levels in dry and moist forests. Amounts of high-severity fire in dry, and to a lesser extent moist forests, in contemporary fires are often greater than historical levels (Reilly et al. 2017, Parks et al. 2018). This can set back landscape resilience and wildfire risk reduction objectives (Churchill et al. 2022). Especially concerning are large high-severity patches that can homogenize landscapes (Cassell et al. 2019), setting them up for future high-severity fires, insect outbreaks, and increasing likelihood of climate-driven type conversion to landscapes dominated by young forest, grassland and shrubland (Kemp et al. 2019, Coop et al. 2020). Small to medium patches of high-severity fire did occur historically in dry and especially moist forests, and these can play an important role in restoring and maintaining a mosaic of forest age classes and grasslands and shrublands that provide important wildlife habitat (Hessburg et al. 2019, Swanson et al. 2011).

Low-severity fire, in contrast, consumes surface fuels and ladder fuels (i.e., small trees, tall shrubs, and lower branches of larger trees), thereby accomplishing some wildfire risk reduction goals for 10-20 years (Cansler et al. 2022). Moderate-severity fires also reduce canopy bulk density (overstory tree densities) and can shift species composition towards fire- and drought- tolerant species, thereby increasing drought resistance. While these effects are often similar to thinning treatments, moderate-severity fire also generates high levels of dead fuels 5-15 years post-fire that can increase the risk of high-severity fire (Peterson et al. 2015, Johnson et al. 2020, Larson et al. 2022).

In contrast to dry and moist forests, fire effects are more challenging to evaluate in cold forests, as high-severity fire is more characteristic, landscape treatment needs are generally much lower, and delayed mortality can be higher, which makes preliminary fire severity maps less reliable.

Definitions (See WA DNR online glossary)

Burn severity: This report focuses on satellite-based estimates of tree mortality, a common metric of the ecological effects of fire. Low-, moderate-, and high-severity fire classes correspond to 0-25%, 25-75%, and 75-100% tree basal area mortality.

Landscape resilience: The ability of a landscape (or ecosystem) to sustain desired ecological functions, robust native biodiversity, and critical landscape processes over time and under changing conditions. Management activities or natural disturbances increase resilience where they reduce departure of current conditions and desired conditions based on historical and future ranges of variation (HRV, FRV).

Forest health: The condition of a forest ecosystem reflecting its ability to sustain characteristic structure, function, and processes; resilience to fire, insects and other disturbance mechanisms; adaptability to changing climate and increased drought stress; and capacity to provide ecosystem services to meet landowner objectives and human needs.

Forest health treatment: Treatments that reduce tree density, alter forest structure, and reduce surface and ladder fuels through mechanical (commercial and non-commercial) and fuel reduction (prescribed fire, piling and burning, etc.) techniques to achieve forest health and/or resilience objectives.

Forest structure

Large tree: Overstory diameter >20 inches.
Medium tree: Overstory diameter 10-20 inches.
Small tree: Overstory diameter <10 inches.
Dense canopy: Greater than 40% tree canopy.
Open canopy: Less than 40% tree canopy.

Fuels: Shrubs, grasses, small trees, litter, duff, and dead wood.

Vegetation types

Cold forest: Upper elevation mixed-conifer forests with high-severity fires every 80-200+ years.

Dry forest: Ponderosa pine and Douglas-fir dominated forests that historically had surface fires every 5-25 years.

Moist forest: Forests that historically had mixed-severity fires every 30-100 years and were composed of fire-resistant (western larch, Douglas-fir) and fire-intolerant (grand fir) trees.

Non-forest: Grasslands and shrublands that may have oak woodlands or ≤10% conifer cover.

Work of wildfire: The degree to which fire effects are consistent with science-based landscape resilience and wildfire risk reduction objectives.

SUMMARY OF 2021 WILDFIRE EFFECTS ON FORESTS ACROSS EASTERN WASHINGTON

Exceptionally dry fuels caused by early season drought and record-breaking heat waves led to another very challenging fire season in 2021. Many communities experienced long-duration smoke impacts, evacuations, and damage to property and other resources, although structure losses were low compared to recent years in Washington State. Landowners with economic objectives suffered substantial losses. In eastern Washington, 2021 had extreme fire danger values (e.g., energy release component) throughout the early fire season and similar peak values to the record-setting 2015 fire season (Appendix C). Wildland firefighting resources were overextended, but fire management operations were still effective despite the extreme drought and logistical challenges due to the Covid-19 pandemic.

In total, 73 large fires (>100 acres) occurred across eastern Washington (Figure 2), affecting multiple forest types and landowners (Table 1, Table 2). 2021 was the second largest fire season since 1984 in terms of forested acres burned (463,345) and third largest in terms of total acres (679,761; Figure 1). This total equates to 4.6% of the forested area in eastern Washington. The 2021 fires also burned 1,822 acres in western Washington, but these fires and their effects are not included in this report. For context, 84,328 acres have burned in western Washington since 1984. Although the 2021 wildfires affected many different land owners, the majority of fire in forested areas occurred on Federal lands (338,175 acres; 73%) and Tribal lands (79,248 acres; 17%) (Table 2).

In terms of the landscape resilience and wildfire risk reduction goals associated with the 20-Year Plan, the 2021 wildfires had both positive and negative effects, depending on forest type, fire extent and severity, and departure from historical reference conditions (Figure 3, Figure 4). In dry forests, 2021 fire extent was similar to the historical average (251,689 vs. 251,690 acres, respectively) but included a much higher percentage of moderate- and high-severity fire (respectively 37% and 38% in 2021 vs. 21% and 10% historically) (Figure 4). Conversely, in moist and cold forests, 2021 fire extent exceeded the historical average but had similar severity proportions (Figure 4). For example, the 2021 fires burned 102,153 acres of moist forest, which is 3.6 times higher than the historical average (28,332 acres).

Based on our assessment of burn severity patterns among forest types, many fires had uncharacteristically severe impacts compared to historical estimates, especially in dry forests and portions of moist forests. High-severity fire (>75% tree mortality) occurred across an estimated 125,000 acres of dry and moist forests, including 85,000 acres in medium and large patches greater than 100 acres (Table 2). High-severity fire reduced forest habitats with large trees and dense canopies, seed sources for natural regeneration, and soil stability, compounding the impacts of previous large fires. Collectively, these fire impacts diminish options for landscape restoration and climate change adaptation.

Table 1. 2021 wildfire extent and severity by potential vegetation type. Estimates are preliminary and will change due to delayed tree mortality and other factors. Low- and moderate-severity fire likely had beneficial effects across ~230,000 acres of dry and moist forest.

Forest	High	Moderate	Low	Total
Dry	94,795	92,642	64,253	251,689
Moist	29,637	38,604	33,912	102,153
Cold	45,614	35,434	28,454	109,503
Total	170,046	166,679	126,619	463,345

Despite some uncharacteristic fire effects, the 2021 wildfires likely had beneficial outcomes for forest health objectives in many locations. Low- and moderate-severity fire (<75% tree mortality) occurred across an estimated 230,000 acres of dry and moist forests (Table 1). In these areas, wildfires consumed fuels and lowered tree densities, reducing ladder fuels and canopy bulk density. This potentially beneficial work of wildfire could facilitate management of future wildfires and reduce fire impacts to communities. However, future fire or mechanical treatments will be needed in many of these areas to reduce surface accumulation of fire-generated fuels.

The total acreage of low- and moderate-severity fire in dry and moist forests (230,000 acres) is very similar to the cumulative total of mechanical and prescribed fire treatments accomplished over the prior four years across eastern Washington (210,000 footprint acres from 2017 to 2020; https://foresthealthtracker.dnr.wa.gov/). Although total annual fire extent has increased since 2014, the 10-year average (2012-2021) is below estimated historical levels that maintained resilient landscapes across all severities and forest types (Figure 4).

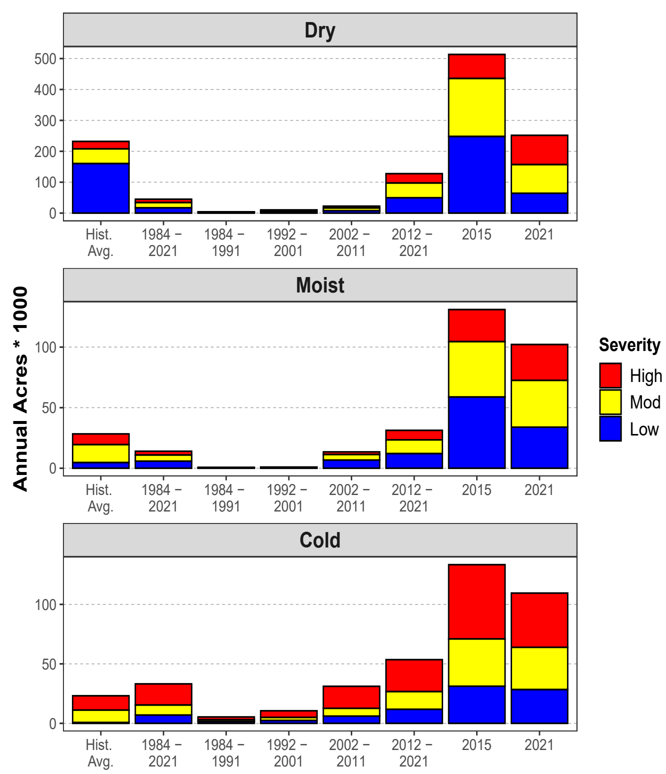

Figure 4. Preliminary burn severity across forested areas of Washington State from 1984 to 2021 and historically by potential vegetation type (Haugo et al. 2019). Low-, moderate-, and high-severity classes correspond to 0-25%, 25-75%, and 75-100%, respectively. Note the larger *Y*-axis range for dry forests.

Table 2. 2021 wildfire extent and severity by potential vegetation type and ownership. The vegetation map is based on USFS Forest Service layers compiled by WA DNR. The ownership map is based on 2019 WA county tax parcel data and public land ownership data (WADNR 2020). Severity estimates are preliminary and will change due to delayed tree mortality and other factors. The 2021 fires affected economic objectives most directly in high-severity portions of Tribal, DNR Trustlands, small private, and industrial lands (approximately 45,000 acres).

Forest	Burn severity	Federal	Tribal	DNR Trustlands	Small Private	Industrial	Other State	Unknown/ Total	Total
Dry	High	57,838	23,083	4,504	5,393	2,404	1,465	108	94,795
	Low-Mod	96,624	32,971	13,833	9,536	1,733	1,960	237	156,895
Moist	High	26,988	1,567	415	306	83	250	28	29,637
	Low-Mod	67,577	3,017	871	415	133	454	50	72,516
Cold	High	38,396	6,786	348	79	5	0	0	45,614
	Low-Mod	50,752	11,824	1,120	188	5	0	0	63,888
Total forest		338,175	79,248	21,091	15,917	4,362	4,129	424	463,345
Non-forest		60,040	65,387	15,898	33,697	906	17,909	22,579	216,416
Total		398,215	144,635	36,898	49,614	5,268	22,038	23,002	679,761

FOREST HEALTH EFFECTS OF INDIVIDUAL LARGE FIRES

To more fully evaluate the work of the 2021 wildfires, we analyzed the largest 14 of the 73 fires that occurred in eastern Washington (Table 3). These 14 fires each burned more than 5,000 acres of forest, and together totaled 96% of the 463,345 acres of forest that burned in 2021. The outcomes of each wildfire varied widely and depended on multiple factors, including fire weather, fuel conditions, fire management operations, past treatments, and terrain. Fire effects occurred under suppression objectives for all fires. Managed wildfires, or resource benefit fires, did not occur in Washington in 2021. With the exception of the Bulldog Mountain Fire, the amount of high-severity fire in dry forests exceeded the desired ranges from historical reference conditions. Many fires greatly exceeded the desired ranges for high severity (e.g., 35-55% of dry forests burned at high severity vs. the historical range of 5-18%). See methods for details and rationale for using historical ranges to evaluate current fire effects.

For each fire, we assessed the following key indicators of positive vs. negative forest health outcomes.

1. **Burn severity in dry and moist forests.** We quantified the proportion of low-, moderate-, and high-severity fire relative to historical reference ranges (See methods).

2. **High-severity fire patch sizes in dry and moist forests**. We analyzed the amount of high-severity acres in large (>1000 acres), medium (100-1000 acres), and small patches (<100 acres). Large patches of high-severity fire in dry and moist forests were rare historically (Hagmann et al. 2021). They can reduce large tree structure, hinder tree regeneration, and set landscapes up for a cycle of repeating high-severity fire (Cassell et al. 2019). Small to medium patches of high-severity fire were common historically in dry and especially moist forests, and these can play an important role in restoring and maintaining a mosaic of forest age classes, grasslands, and shrublands (Hessburg et al. 2019).

3. **Potential seed source limitation for tree regeneration.** We calculated the proportion of the fire extent (forested acres) in high-severity patches that is now greater than 500 feet from residual live trees in unburned, low-, or moderate-severity areas. This distance is a common threshold for seed dispersal beyond which tree regeneration drops off, particularly for ponderosa pine (Povak et al. 2020, Stevens-Rumann and Morgan 2019). Other tree species, such as Douglas-fir, have longer dispersal distances.

4. **Mortality of large trees.** We tabulated the severity of forested areas with large trees (greater than 20” in diameter) using remotely sensed datasets (Table 4). Large trees are resistant to fire, and are thus the backbone of resilient landscapes (Agee and Skinner 2005, Hessburg et al. 2015). Mortality of large trees from wildfires can be a major setback to wildfire risk reduction and resilience objectives, as they take multiple decades to centuries to regrow.

5. **The amount of low-, moderate-, and high-severity fire in stream-adjacent forests.** This analysis provides a starting place to gauge the impacts, both positive and negative, of fires on riparian and aquatic systems (Table 4).

In addition to these five attributes, we conducted a post-fire landscape evaluation and prioritization of post-fire treatments for landscapes in which the Cedar Creek and Walker Creek Fires burned. These more in-depth analyses were requested by USFS managers and collaborative partners. This analysis will be repeated for the WA DNR Methow Valley priority planning area in the fall of 2022, incorporating updated severity maps that capture delayed mortality, which could be exacerbated by drought stress. The landscape evaluation for this planning area will then be updated based on the fire effects. The Methow Valley was the only DNR priority planning area that experienced a major fire in 2021 and already had a completed landscape evaluation. Here, we provide results for the Cedar Creek Fire. We include summaries of the 13 other large fires in Appendix D.

Table 3. Total acres, forested acres, and acres burned by forest type and burn severity for the 14 large fires that burned over 5,000 acres of forest. Bold italic numbers indicate that the amount of high-severity fire was higher than would be expected under historical/characteristic conditions. Historical severity proportions are from Landfire as applied by Haugo et al (2019). Historical comparisons are not shown for low- and moderate-severity fire in all forest types nor for high-severity fire in cold forests.

Fire Name	Total Acres	Forested Acres	Dry Forest		Moist Forest		Cold Forest	
			High	Low-Mod	High	Low-Mod	High	Low-Mod
Schneider Springs	107,337	97,320	***8,704***	33,254	6,407	15,811	12,395	20,750
Cub Creek 2	70,248	62,214	***21,646***	23,479	***1,266***	884	7,517	7,421
Cedar Creek	55,235	47,576	***7,695***	16,490	***1,064***	896	10,702	10,729
Summit Trail	49,595	47,568	***9,652***	16,226	1,515	2,896	6,449	10,830
Lick Creek	80,426	46,340	***7,920***	8,217	7,315	22,146	74	668
Green Ridge	43,719	41,659	***1,750***	4,749	9,479	24,849	77	757
Walker Creek	23,765	20,595	***4,068***	8,360	457	737	3,570	3,402
Twentyfive Mile	22,118	17,907	***4,028***	8,931	209	650	869	3,221
Whitmore	58,279	16,758	***6,821***	9,742	51	115	4	25
Chuweah Creek	36,753	13,383	***6,568***	5,512	0	0	333	970
Ford Corkscrew	15,718	12,639	***6,642***	5,490	***254***	246	5	3
Muckamuck	13,312	8,680	***3,015***	3,804	***431***	512	289	629
Bulldog Mountain	6,214	5,652	419	2,149	584	1,777	119	304
Chickadee Creek	5,859	5,455	***1,294***	2,368	148	246	315	1,084

Cedar Creek Fire

This fire burned 55,235 acres in the Methow Valley in north-central Washington. It started on July 8, 2021 with several lightning strikes, following a record-setting heat wave that contributed to extremely low fuel moistures and high fire danger. Although most of the fire occurred in steep, roadless terrain on USFS land, it burned through private land and forced level 3 evacuations in parts of the Methow and Twisp River valleys, as well as long-duration smoke impacts throughout the area. Much of the fire extent occurred during days and nights of high winds that resulted in large patches of high-severity fire (Figure 5). However, 60% of the fire burned at low and moderate severity, most notably near the southern side of Highway 20.

EFFECTS OF HIGH-SEVERITY FIRE

The proportion of high-severity fire in dry and moist forests was significantly higher than estimated historical levels (Figure 6), setting back resilience and wildfire risk reduction objectives in a number of ways. Large high-severity patches were common, particularly within drainages and in patches that burned under strong winds, with close to half of the 8,795 high severity acres in dry and moist forests occurring in large patches over 1,000 acres (Figure 6). Tree regeneration is likely to be limited by lack of seed trees in these large patches where very few, if any, trees survived (Figure 6, Figure 7). An estimated 8% of the forested acres (3,800 acres) may experience delayed tree regeneration due to the lack of seed sources. In addition, 2,875 acres of dry forest that contained large, old ponderosa pine and Douglas-fir trees burned at high severity (Table 4, Figure 6), which is 36% of the total acres with large trees.

The number of high-severity acres and large patch sizes of the Cedar Creek Fire (and the nearby 2021 Cub Creek 2 Fire; Figure 3) are especially concerning because much of the Methow and Twisp Valleys have experienced similar fires over the past 20 years (See StoryMap by University of Washington researchers). Cumulatively, these fires are shifting large portions of this landscape towards large patches of young trees, shrubland, and grassland (Figure 7), with only scattered patches of older forest remaining. Within 10-30 years, downed woody fuel accumulations from the fire-killed trees, combined with grass and shrub fuels, could increase reburn severity, which could hinder forest regeneration and contribute to vegetation type conversion (Prichard et al. 2017). The landscape could be on a trajectory towards a repeating cycle of high-severity fire, which will make it very challanging to restore patches of fire-resistant forest with large trees (Steel et al. 2021).

Although high-severity patches provide important habitat for many wildlife species and can increase stream flow and aquatic system productivity, they are currently over-represented in forest types relative to historical conditions (see Twisp River Landscape Evaluation, WA DNR 2020). If future fires continue to burn with uncharacteristic level of high severity fire and reduce large tree structure, the functions associated with large and old trees, such as carbon storage, fire resistance, wildlife habitat, genetic diversity, recreational opportunities, and aesthetic values (Jones et al. 2021, Lutz et al. 2012), will continue to decline, and early-seral habitat will become more overabundant.

EFFECTS OF LOW- AND MODERATE-SEVERITY FIRE

In dry and moist forests, 6,063 acres burned at low severity, and 11,323 acres burned at moderate severity. Low-severity fire consumed surface fuels and killed small trees (ladder fuels), while moderate-severity fire also reduced overstory densities (Figure 7). Fires are less likely to spread across these areas (~17,000 acres) for ~15 years (Cansler et al. 2022), providing fire managers

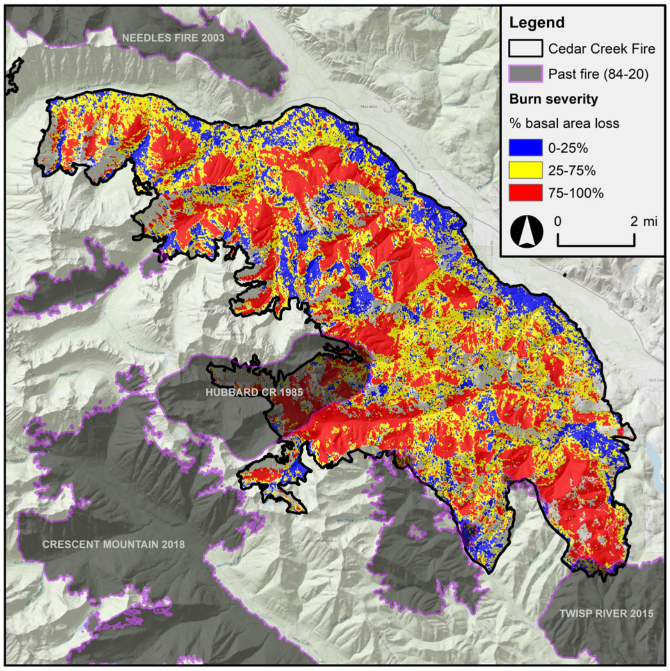

Figure 5. Preliminary burn severity of forested portions of the Cedar Creek Fire and recent fire perimeters. Basemap: ESRI World Topographic Map.

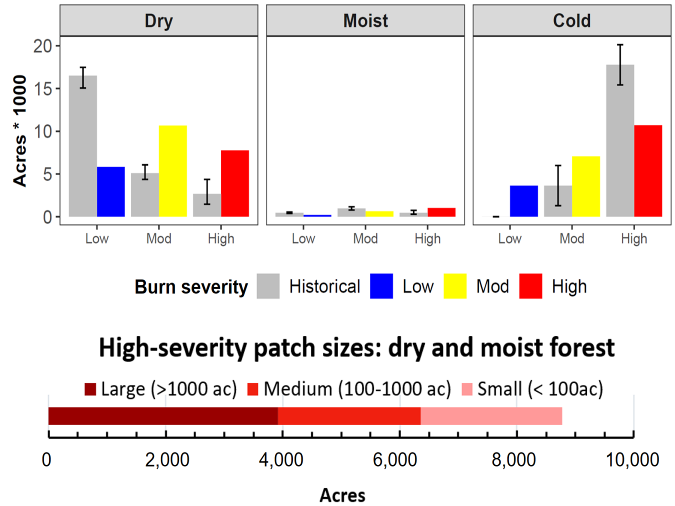

Figure 6. Top panel: Preliminary burn severity of forested portions of the Cedar Creek Fire by forest type compared with estimated historical reference ranges (Haugo et al. 2019). Bottom panel: Patch size distribution of high-severity fire in dry and moist forests. Large (>1,000 acres) and medium (100-1,000 acres) patches were rare in dry forests with active, frequent fire regimes and relatively rare in moist forests historically (Hagmann et al. 2021).

potential control locations for future fire management operations. Potential fire spread from the Cedar Creek Fire footprint into adjacent communities and private parcels with homes will be lower for this period of time, thus reducing fire risk. However, fire risk is still high in many parts of the Methow Valley.

The fire also burned through a number of previously treated units on USFS and DNR land. In areas where prescribed-fire was conducted, the Cedar Creek Fire acted as a maintenance treatment. In areas that were mechanically thinned but not treated with follow-up prescribed fire or piling and burning, fire effects were more variable. In areas that burned under moderate weather conditions, the fire burned at low severity and effectively treated surface fuels. Conversely, areas that burned during periods of low relative humidity and higher wind speeds experienced high tree mortality.

Although low-severity fire reduces forest density, these areas often still contain overabundant live trees relative to historical levels and landscape resilience goals, and they may be vulnerable to drought strees and insect disturbances, especially on drier sites. Managers have some time to plan treatments in these areas to reduce density and restore forests with large trees and open canopies that were commonly found in frequent-fire forests (Hagmann et al. 2021). In contrast, moderate-severity fire generally reduces overstory tree density and corresponding canopy bulk density but generates high levels of dead fuels 5-15 years post fire (Larson et al. 2022). Where feasible, thinning treatments that mimic treatments in unburned forest can be done as soon as possible after the fire to "finish the job" by removing dead trees and additional green trees if necessary, which will facilitate future maintenance treatments. Alternatively, fire-only and/or mechanical treatments can be conducted 10-20 years post-fire to reduce high fuel loads, although prescribed burning and/or mechanical treatment in these situations can be challenging and expensive.

Wildfires have short- and long-term effects on aquatic systems. They can have large impacts on water quantity, quality, and temperature; sediment budgets and flows; large wood inputs; productivity; and fish habitat quality (Kennedy and Fontaine 2009, Luce et al. 2012, Rieman et al. 2012, Flitcroft et al. 2016, Wine et al. 2018). While some short-term impacts can be negative, most long-term effects are positive. However, the cumulative effects of multiple, high-severity fires in a warming climate are unknown (Jager et al. 2021). On the Cedar Creek Fire, burn severity in stream-adjacent forests was relatively balanced (Table 4), although some long segments of high-severity fire did occur along fish bearing streams.

CHANGES TO LANDSCAPE DEPARTURE AND TREATMENT NEED

The Cedar Creek Fire burned through a portion of the WA DNR Twisp River planning area, thus changing the underlying vegetation structure and composition, departure from target reference conditions, and treatment needs that were quantified in the 2020 Landscape Evaluation (WA DNR 2020). The Okanogan-Wenatchee National Forest was in the process of planning a large restoration project in the area and had prepared a draft Environmental Assessment. The area burned before the project could be implemented, which is an increasingly common trend in eastern Washington.

During the fall of 2021, the DNR Forest Health Science Team worked with USFS managers and the North Central Washington Forest Health Collaborative to assess how the fire changed restoration treatment needs and to prioritize locations for post-fire treatments. This in-depth evaluation applied and refined the conceptual framework and toolset for post-fire management

Figure 7. Top panel: Mosaic of low- and moderate-severity-fire in the Methow Valley, just south of Highway 20 between Mazama and Winthrop. The Cedar Creek Fire burned downhill during moderate fire weather, creating a mosaic of burn severities. Fire risk in this area will be relatively lower for the next ~15 years. Middle panel: Large patch (>1,500 acres) of high-severity fire on Thompson Ridge at the southeastern end of the Cedar Creek Fire. Natural regeneration may be limited by the lack of live seed trees. Bottom panel: Three successive fires in the Little Bridge Creek (foreground) and Twisp River Valley (background) that are shifting this landscape towards a landscape dominated by young forest, shrubland, and grassland, with scattered patches of medium and large trees. The fires include the 2014 Little Bridge Creek Fire, the 2018 Crescent Mountain Fire, and the 2021 Cedar Creek Fire (bottom right corner).

Table 4. Burn severity of riparian forests and forests with large trees. Note that these acres overlap, as riparian forests often contain large trees. Riparian forests were mapped using the WA DNR Stream layer with 150 foot buffers for fish bearing streams, 75 foot buffers for non-fish bearing streams, and 50 foot buffers for intermittent streams. Large trees were mapped using a LiDAR-derived 95th percentile height layer (30-m pixel resolution) with a height cutoff of 100 feet for large trees. WA DNR Forest Inventory and GNN data (Ohmann et al. 2011) were used to fill in areas where LiDAR data were not available.

Area (acres)	Fire Severity		
	High	Moderate	Low
Riparian	1,978	1,967	1,065
Large tree	2,875	3,319	1,685

developed for a Joint Fire Science Program research project called NEWFIRE (Larson et al. 2022, Churchill et al. 2022), which is based on landscape evaluations in unburned landscapes (Hessburg et al. 2013). We conducted this post-fire landscape evaluation for the whole Little Bridge Creek sub-watershed (Figure 8), including both burned and unburned portions. We also included small parts of the Thompson Creek and Wolf Creek sub-watersheds. This area is the only part of the Twisp River planning area that was affected by the Cedar Creek Fire.

Overall, the post-fire landscape evaluation and prioritization show that the Cedar Creek Fire accomplished some landscape treatment needs but also created new ones. High-severity fire converted approximately 6,000 acres of dense forest into early-seral conditions. Prior to the fire, closed-canopy, medium- to large- size forest structure was over-represented relative to target reference ranges (Figure 9). The fire shifted the amount of this forest type into the target ranges, although it is still on the high end, especially on dry sites. The amount of open canopy, large tree forest is also below target ranges. While the fire reduced the need for density and fuel reduction treatments by 2,000 - 2,500 acres, treatments are still needed in the unburned portions of this landscape. Treatments are also needed in low-severity areas to reduce tree density, although fire probability in these areas will remain lower for 10-20 years. To guide location of these treatments, we re-ran the landscape treatment prioritization from the 2020 Landscape Evaluation while incorporating the effects of the fire (Figure 8).

In contrast, the amount of early-seral vegetation is now over-represented, consistent with the conclusions drawn from the burn severity analysis in the prior section. Natural regeneration is likely to be abundant in moist and cold forests (Povak et al. 2020), and thus a significant amount of this early-seral type may transition to young forest within several decades. However, as discussed above, seed source limitations in large patches, ongoing climate warming, and reburns are likely to limit establishment of new forests, especially on drier sites. Post-fire tree planting is thus warranted to improve chances of re-establishing forest in key locations and with climate adapted tree species and planting stock (Larson et al. 2022). We conducted a prioritization analysis to guide reforestation efforts (Figure 8). In addition, prescribed fire and explicit management of wildfires to protect planted areas will likely be necessary to give seedlings and saplings enough time to reach more fire-resistant size classes (Stevens et al. 2021).

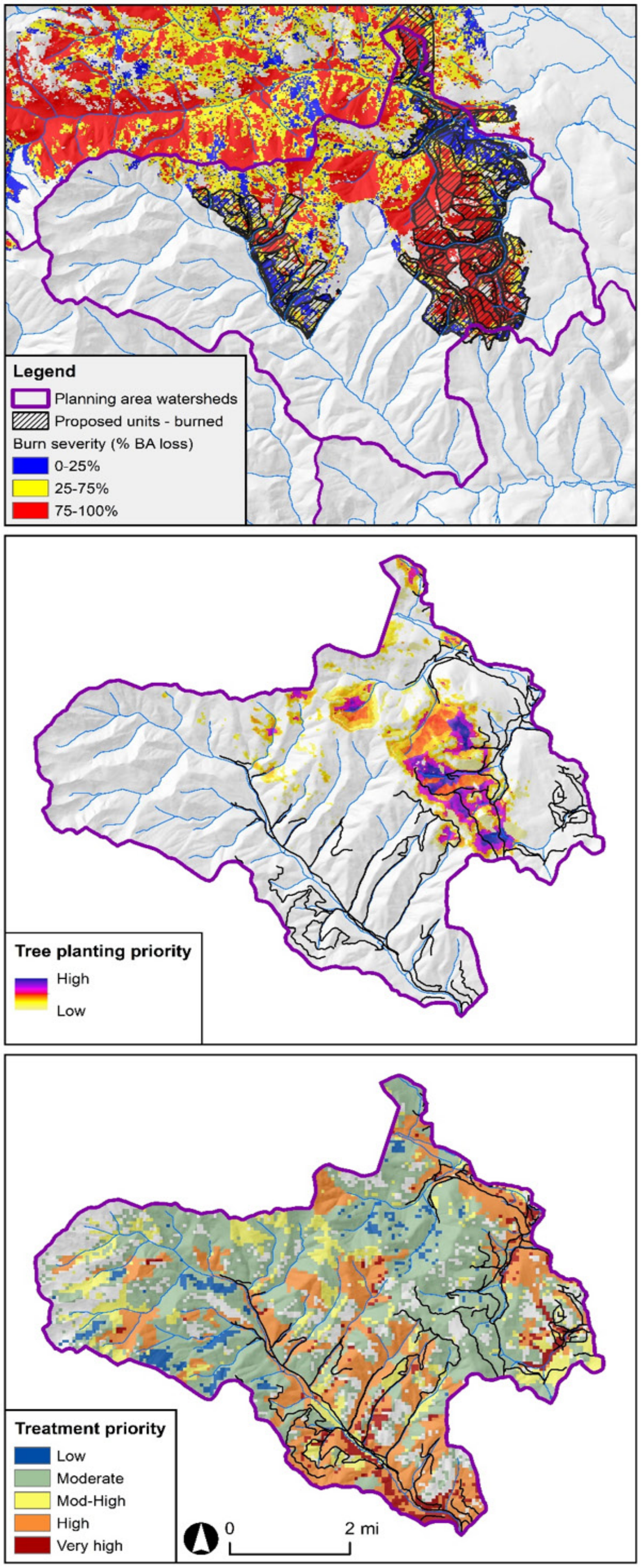

Figure 8. Top panel: Section of the WA DNR Twisp River planning area that burned in the Cedar Creek Fire. Burn severity and units proposed for treatment prior to the fire are shown. Middle panel: Prioritization for tree planting based on severity, distance to surviving trees, and higher moisture deficits (Larson et al. 2022). Bottom panel: Post-fire landscape treatment prioritization for density and fuel reduction treatments (see WA DNR 2020 for methods).

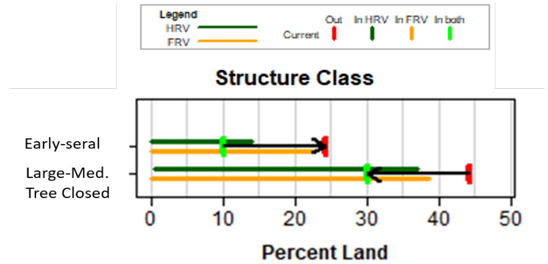

Figure 9. Effects of the Cedar Creek Fire on landscape departure from historical and future ranges of variation (HRV and FRV). The black arrow indicates the change from pre- to post-fire conditions. Red and bright green indicate conditions outside and inside the HRV and FRV range, respectively. HRV and FRV ranges for landscape-level vegetation conditions were derived from early to mid-century aerial photographs. See Hessburg et al. 2013 for details (Larson et al. 2022).

FOREST HEALTH TREATMENT INTERACTIONS WITH 2021 WILDFIRES

Interactions of forest health treatments with wildfires are a major topic for research and management in western North America (e.g., Hudak et al. 2011, Safford et al. 2012, Martinson and Omi 2013, Prichard et al. 2020). Forest health treatments encompass a wide range of management activities. Here, we define treatments broadly to include activities that address forest health and fuel management objectives, which depend on location and landowner goals. Specific management approaches can include commercial and non-commercial thinning, regeneration harvests to address species composition mismatches, piling and burning of surface fuels, prescribed fire, and managed wildfire. The effects of these treatments on forest structure, composition, and pattern can vary widely, depending on pre-treatment conditions and treatment type.

Wildfire outcomes also span a wide range of impacts and associated metrics, including fire behavior, severity, and utility for wildland firefighting operations. Importantly, fire behavior is influenced by fuels, weather, and topography, so fire outcomes are strongly influenced by factors other than past treatments (Cansler et al. 2022). Thus, evaluating the effect of forest health treatments on wildfire outcomes requires attention to specific conditions, such as treatment type, location, and timing, as well as other drivers of fire behavior and effects, such as fuel moisture, wind speed, and slope (Prichard et al. 2020).

Reducing fire intensity and severity is one of many objectives of forest health treatments, and forest health benefits are realized whether or not fire intersects a given treatment. In addition, treatments that burn at moderate or even high severity are not necessarily failures, as extreme fire weather and surrounding conditions can overwhelm the best designed treatments. Treatments should instead be evaluated on a relative basis. For example, did they result in lower burn severity compared with surrounding untreated areas? Another key aspect of effectiveness is the extent to which they assisted fire management operations.

Remote sensing and field-based assessments can provide an immediate and informative estimate of burn severity within treatments and how this compares with untreated areas. However, truly understanding fire outcomes of treatments and determining

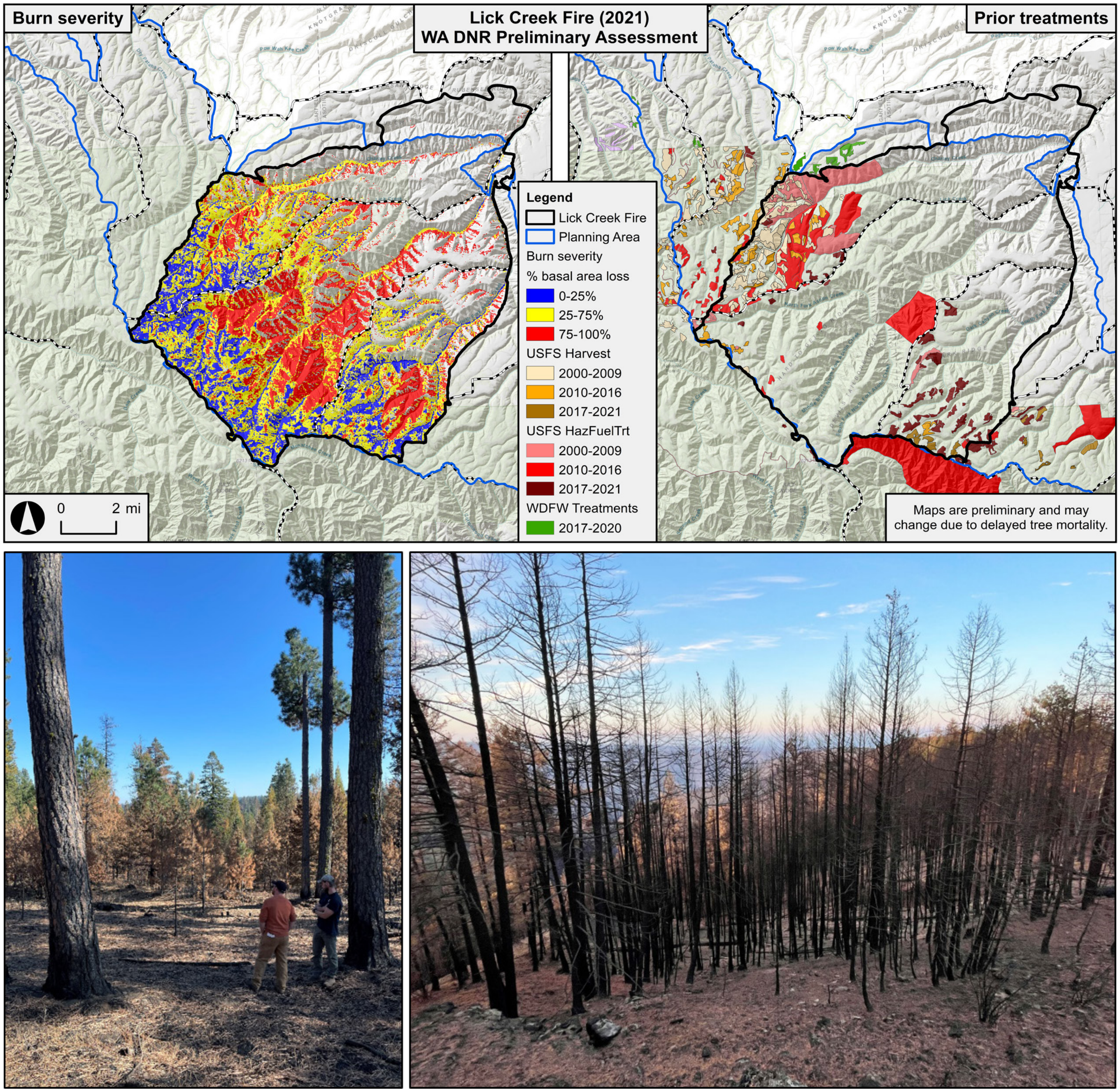

Figure 10. Fire effects and treatments examples from the Lick Creek Fire. Top panel: Preliminary burn severity in forested areas (left) and recent forest management activities (right) in the WA DNR Asotin Planning Area (blue outline). Bottom left: Example of recent treatment that supported wildfire operations. Bottom right: Example of untreated, high-severity area. Basemap: ESRI World Topographic Map.

effectiveness requires a robust statistical analysis and detailed information on pre-treatment conditions, fire spread, and fire weather. Thus, only a portion of forest health treatments in each fire year can realistically be evaluated robustly, and multiple years of wildfire and treatment data will provide a more comprehensive perspective.

Recognizing that other entities have led multiple prior and ongoing efforts to evaluate treatment interactions with wildfires (Appendix A), the intent of this report is to complement these efforts and identify critical gaps for ongoing work. In future years, we will be better positioned to quickly assess treatments more systematically. Below, we highlight specific examples from 2021. Based on limited field observations by the Forest Health Science Team and insights from partners, the following three themes emerged:

1. Treated areas experienced low-, moderate-, and high-severity fire effects (i.e., tree mortality). Relatively low-severity fire occurred in many treated areas, especially where treatments were more recent and where prescribed fire was implemented prior to the wildfire.

2. Scale matters: In general, less high-severity fire and more low- and moderate-severity occurred in locations with more extensive treatments vs. smaller and/or isolated treatments.

Figure 11. Example fire effects in treated areas. Top panel: Low severity on the Cedar Creek Fire on Virginia Ridge. Middle panel: Moderate severity on the Cub Creek 2 Fire near Ramsey Creek. Bottom panel: High severity on Cedar Creek Fire on Virginia Ridge.

3. Treating surface fuels is critical: Burn severity was variable in treatments where surface fuels had not been treated with prescribed fire or piling and burning. In many cases, these units burned at moderate- to high-severity due to extremely low fuel moistures combined with wind. Fuel profiles that managers were accustomed to seeing burn at low severity often resulted in higher than expected severity due to the drought conditions. Unburned landing piles and higher surface fuel loading also made it more challenging to utilize these treatments for wildland firefighting operations.

The Lick Creek Fire (Figure 10) and Schneider Springs Fire (Figure 3) demonstrated several success stories where areas with extensive recent forest health treatments met restoration objectives, including contributing to relatively low-severity fire in some areas and providing locations where wildland firefighters were able to engage strategically. Recent treatments that were supported by the WA DNR resulted in beneficial outcomes on the Lick Creek Fire. Across eastern Washington, there were numerous other examples of treatments experiencing relatively low-severity fire and more mixed effects (Figure 11), which will be the basis for ongoing work towards a more comprehensive synthesis.

Next steps for analyzing wildfire and forest health treatment interactions

We have initiated a robust statistical analysis of how forest health treatments affected fire behavior and severity in the Schneider Springs Fire. This event burned more forested acres than any other fire in 2021 in a location where much of the landscape had been treated before the fire, including several recent large prescribed fires. Despite its negative impacts on air quality in Yakima and surrounding communities, the Schneider Springs Fire offers a key opportunity to learn and provide important adaptive management information to managers and other partners.

Rapid burn severity mapping in recently treated and untreated areas is another important topic for ongoing refinement. Using 2022 satellite imagery, we will assess initial vs. extended approaches, delayed tree mortality in different forest types, fire effects on other attributes including soils, and the influence of different sensors, timing, and thresholds, especially in locations with relatively open canopies and low surface fuels. A key lesson from this pilot year is that clean, well-organized treatment records and GIS data for all landowners are necessary to accurately evaluate treatments for a particular fire and more broadly.

DNR Forest Resilience staff have developed an extensive database and GIS layers for treatments from 2017 onwards for the Forest Health Tracker (https://foresthealthtracker.dnr.wa.gov/). Recognizing the need for longer-term records, we are exploring the availability of older datasets and the use of satellite-based change detection methods to catalog forest management and forest health treatment layers going back to 2005 or earlier.

2021 WILDLAND FIRE OPERATIONS AND FOREST HEALTH TREATMENTS

WADNR is required to spatially prioritize forest health treatments that have the dual benefit of forest health and wildfire operations in priority landscapes identified in the 20-Year Plan. The analytical process underlying this prioritization is the Forest Health Assessment and Treatment Framework, which has been thoroughly described in previous work (WADNR 2020).

This section focuses on the fire operations benefits of forest health treatments (mechanical and prescribed fire), recognizing that wildfire managers also utilize previous fire perimeters. Pre-existing treatments can provide multiple benefits for fire operations by providing strategic locations for fire engagement where fuel structure and loads have been reduced before a fire occurs. Strategic locations are those that provide the best chances of successfully controlling wildfire. Prior treatments allow for operations to conduct faster preparation for burnouts, safer direct engagement, and easier and faster mop-up. In successfully treated areas, reduced fuel loads lead to lower fireline intensity and torching potential, which reduces chances of fire spotting across control lines. Treatments provide opportunities that would not otherwise exist or would have to be created during a fire when resources may be scarce or unavailable, timelines are constrained, and objectives are limited to emergency management of the incident.

The direct benefits of forest health treatments to wildfire operations are conditional on whether fire and treatments interact. If and when fire-treatment interactions occur, several factors can combine to determine whether the treated unit can be used operationally. These include fuel conditions, fire weather, resource availability, and access to the treatment area (Syphard et al. 2011). Establishing metrics of operational benefit and appropriate baselines is challenging. For example, to assess the effects of forest health treatments on forest resilience and departure, one can measure tree mortality and post-fire forest structure. These provide tangible, measurable metrics of fire effects in treated areas that can be compared with neighboring untreated areas that burned under similar weather conditions. In contrast, understanding the specific, direct benefits of treatments to fire operations requires approaches that rely on qualitative data from surveys and interviews with fire managers to capture information that is subjective in nature.

In this section, we describe DNR's pilot project to explore two alternative approaches to assess the benefits that forest health treatments provide to fire operations. We also provide an overview of existing work by other agencies on monitoring treatment effectiveness with an operational component. The purpose of the DNR pilot is to explore the feasibility of each approach and make a recommendation of a preferred approach for integration into DNR's monitoring program and the programmatic needs such integration would require.

DNR's pilot project will run from September 2021 through December 2022. This work is driven by the legislative requirement to monitor whether the implementation of the 20-Year Plan is meeting its goals. It is also driven by the need to better understand under what conditions fire operations benefit from established forest health treatments and to use that information to strengthen the alignment between forest management and fire management (Dunn et al. 2020, Ager et al. 2022). This will contribute to resilient forests, safer firefighters, and safer communities. We also hope our results can help better communicate to the public and stakeholders the stories of the hard work of fire operations staff and the resulting losses averted on the fireline - made possible by the foresight of our foresters, in many cases several years before a fire occurs.

US Forest Service Fuel Treatment Effectiveness Monitoring

Every year, the USFS conducts a fuel treatment effectiveness monitoring (FTEM) assessment. FTEM collects data that documents the effectiveness of fuel treatments on wildland fire behavior when treatments are intersected by fire. The program focuses exclusively on federal lands.

The FTEM program measures the benefit of treatments to protect firefighters and the public from wildland fire, reduces the loss of structures and investments, and documents the need to continue to invest in vegetation management programs. Data are collected either during or after the fire season and before winter conditions make it prohibitive to do so.

Information collected as part of FTEM is integrated into the Interagency Fuel Treatment Decision Support System (IFTDSS), which facilitates data management and monitoring. IFTDSS collects fuel treatment information for activities in FACTS (USFS) and NFPORS (DOI). In Region 6 (Oregon and Washington), all activities up to 20 years are subject to FTEM. During the fire season, fire information is uploaded nightly, including point (Integrated Reporting of Wildland Fire Information (IRWIN)) and perimeter (National Incident Feature Services (NIFS)) data.

Within IFTDSS users have access to a streamlined process to select and monitor treatments. Data on treatment effectiveness are also displayed publicly (See online dashboard), and an individual summary report is created for specific fires (Appendix A). The FTEM approach focuses on comprehensive data collection at treatment sites, but it does not include information about what fire operations took place at specific sites, nor does it explore the decision process of why specific treatment units were not used operationally, which is the main focus of the WADNR approach.

A DNR pilot project to assess forest health treatment benefits to fire operations

The objective of this pilot project is to explore two approaches to collect qualitative data on where, when, and how forest health treatments provide benefits to fire management. Differences in the two approaches are based on whether information is collected during or after the fire season. The Forest Health Science Team is collaborating with USFS scientists to develop a set of questions that can be adapted to both approaches and tailored for the ArcGIS Survey123 application.

APPROACH 1: SPECIFIC AND OFF-SEASON

Approach 1 collects data on interactions between specific fires and specific treatment units, and it is conducted retrospectively after a given fire season. This work will typically be completed between October and February and will involve overlaying fire perimeter and fire progression data on treatment data to identify when and where treatments were breached. This will include any treatment catalogued on the DNR's Forest Health Tracker (https://foresthealthtracker.dnr.wa.gov/).

The pilot project will not include previous wildfires or fuel breaks (primary or contingent) installed as part of the emergency management response to the fire. Future implementations of this work may include past fires as capacity allows for it. Fire weather information for the days of the breach will then be collected from incident Remote Automated Weather Stations (iRAWS), preferably, or RAWS. This will be done to characterize relative humidity and wind speed during the days in which the fire-treatment interaction occurred. Incident information including maps and daily briefings will be used to help establish a narrative. Local fire management officers, resource advisors or other fire management personnel with specific knowledge

Figure 12. Burnout operations in the Cedar Creek Fire. Source: INCIWEB.

of each interaction will be interviewed to gather information about operational activities and benefits, and their answers will be summarized in an annual report.

We piloted this approach on the 2021 Cedar Creek Fire and four fire-treatment interactions that took place during that event, including burnout operations (Figure 12). We present results of this analysis in the Cedar Creek Diaries (Appendix E).

APPROACH 2: SPECIFIC AND ON-SEASON

Approach 2 collects data on interactions between specific fires and specific treatment units, but it will be conducted during the fire season. As such, data collection will take place between June and September and potentially extend into the fall. During the fire season, wildfires in eastern Washington will be monitored daily for interaction with forest health treatments in the Forest Health Tracker to identify when treatments are breached by fire.

We will pilot Approach 2 during the 2022 fire season if the right opportunity presents itself. As such, data collection during the pilot will be opportunistic and rely on the ability to place an interviewer with and Incident Management Team managing an incident where fire-treatment interactions have occurred or are expected to occur based on projected fire spread. DNR Forest Resilience staff will connect with fire staff, including resource advisors, field observers, agency liaisons, and division supervisors to conduct the same set of interviews as in Approach 1.

Depending on the fire and staff availability, interviews will be conducted by DNR staff working on the incident or DNR Forest Resilience Division staff in Olympia. When personnel are not available to be interviewed, contact information will be collected for an off-season interview. As with Approach 1, this pilot analysis will not include previous wildfires that have been used as containment lines or fuel breaks installed as part of emergency management response to the fire. Fire weather information for the days of the breach will be collected from iRAWS used in the incident, preferably, or RAWS. This will be done to characterize relative humidity and wind speed during the fire-treatment interaction. Incident information, including progression maps and daily briefings, will be used to help establish a narrative of the incident and the fire-treatment interactions. Results from this analysis will be made public as part of an annual report.

CONCLUSIONS AND LESSONS LEARNED

In eastern Washington, 2021 was the second largest in terms of forested acres burned (463,345 acres) and third largest fire season in recent history in terms of total acres burned. Many communities suffered from smoke and evacuations, although fortunately impacts to homes and structures were minimal.

In terms of the landscape resilience and forest health goals associated with the 20-Year Plan, 2021 fires had beneficial outcomes in many places while moving conditions in the wrong direction in others. Specific outcomes of each wildfire depended on management objectives, fire weather, fuel conditions, fire management operations, past forest health treatments, and terrain.

This report presented a rapid, data-driven, pilot process to assess the work of the 2021 wildfires in the context of the 20-Year Plan. Collaborating with many partners within and outside of DNR, the Forest Health Science Team explored and developed initial methods to quantify fire effects, update forest health and wildfire risk reduction treatment needs, inform post-fire management, assess wildfire interactions with forest health treatments, and evaluate how treatments influenced wildfire management operations. We learned much about the work of wildfires and our process for evaluating them during this pilot year, and we have a clear plan for assessments of future fire seasons. Key takeaways from this assessment are listed below. Note that these results are based on limited field observations and preliminary burn severity results that likely will change due to delayed tree mortality and other factors.

The 2021 wildfires had both positive and negative effects on resilience and wildfire risk reduction objectives.

Uncharacteristically severe impacts occurred in dry forests and portions of moist forests. High-severity fire (>75% tree mortality) occurred across an estimated 125,000 acres of dry and moist forests, including 85,000 acres in medium and large patches (>100 acres). High-severity fire reduced large tree habitats, seed sources for natural regeneration, and soil stability. Some areas, like the Methow Valley and northern Blue Mountains, have experienced multiple large fires in recent years, and high-severity fire patches in the 2021 fires likely will compound the impacts of previous large fires, diminishing options to restore more resilient landscapes and reduce wildfire risks.

Fires likely had beneficial effects on landscape resilience and wildfire risk in many locations. Low- and moderate-severity fire (<75% tree mortality) occurred across an estimated 230,000 acres of dry and moist forests. Fires consumed fuels and lowered tree densities in these areas, thereby facilitating management of future wildfires and reducing fire risk and potential impacts to communities. Future fire or mechanical treatments will be needed in some of these areas, however, to reduce surface accumulation of fire-generated fuels. The total footprint of low- and moderate-severity fire in dry and moist forests (230,000 acres) compares to 210,000 footprint acres of mechanical and prescribed fire treatments over the prior four years across eastern Washington (2017-2020). Despite the increase in acres burned since 2014, the 10-year average (2012-2021) is still below estimated historical levels that maintained resilient landscapes.

Individual wildfire events spanned a wide range of forest conditions across eastern Washington.

Each large fire exhibited distinct proportions and spatial patterns of burn severity, with corresponding implications for landscape resilience goals. The Schneider Springs Fire was the largest fire overall (97,320 forested acres), while the Cub Creek 2 Fire included the most high-severity fire in dry forests (21,646 acres). The Cedar Creek Fire produced a variety of outcomes, illustrating many of the overall patterns of the 2021 fires. For example, the Cedar Creek Fire included uncharacteristically large patches (>1,000 acres) of high-severity fire in dry forests, as well as low- and moderate-severity fire that partially addressed treatment needs in priority landscapes.

Forest health treatments burned at low, moderate, and high severity.

The 2021 wildfires included many examples where prior forest health treatments burned at low severity (<25% tree mortality) and gave fire managers more options to directly engage and safely manage fires. However, exceptionally hot and dry weather, high winds, and other factors led to moderate and high severity in other treatments. Treatments that were more recent and that included prescribed fire or piling and burning to reduce surface fuels were more likely to be effective, whereas mechanical only treatments often experienced higher tree mortality.

Wildfire managers utilized some forest health treatments to manage wildfires more effectively and safely.

Wildfire incidents are dynamic events, and whether a given treatment provides benefits to operations depends on a variety of factors, including fire weather, resource availability, and strategic considerations that are specific to each fire. As such, not all treatment units or prior wildfire perimeters are directly used in fire operations. In the Cedar Creek Fire, fire managers utilized some treatment units to reduce fire spread and severity while accomplishing work faster and with fewer resources. Where forest health treatments were used operationally, fire managers were able to protect communities, infrastructure, forest resources, and other highly-valued resources.

In addition to these key findings, the 2021 wildfire season demonstrated numerous lessons for ongoing work. Moving forward, we will collaborate with partners to interpret and contextualize the effects of the 2021 fires while preparing for future fire seasons. For example, we will refine our methods for rapid burn severity mapping and compare initial maps with subsequent imagery to quantify delayed mortality. Building on the in-depth analysis of the Cedar Creek Fire illustrated in this report, we will expand our assessment of other large fires (Appendix D) to aid partners in planning post-fire reforestation and treatment prioritization. In addition, we will continue to build out a forest health treatment database to enable a more comprehensive synthesis of how treatments influence fire behavior and effects, wildland fire operations, and subsequent fire risk and landscape resilience.

As wildfire activity continues to increase across western North America, major fire years like 2021 will occur more frequently in Washington State, even within moister forest types. It is important to recognize the full range of tools available to influence wildfire outcomes. Although wildfires are an inherently blunt restoration tool with both positive and negative impacts on landscape resilience (Churchill et al. 2022), forest and fire management approaches that recognize the potentially beneficial effects of wildfire will become increasingly important. Given recent warming trends and climate projections, we are in a race against time to reduce wildfire risk to communities and to help landscapes adapt to increasing drought and wildfire activity. The only realistic way to treat forest landscapes fast enough - and maintain them over time - is by harnessing the beneficial work of wildfires in the appropriate places and under safe conditions, while suppressing fires that threaten resources and communities. Over time, restored landscapes will provide managers more flexibility to manage wildfire to protect communities, achieve forest health objectives, and maintain these fire-dependent ecosystems.

LIST OF APPENDICES

Appendix A. Summary of complementary efforts

Appendix B. Detailed methods and data

Appendix C. Energy release component for eastern Washington

Appendix D. Effects of individual large fires

Appendix E. Cedar Creek Diaries

ACKNOWLEDGMENTS

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Appendix A. Summary of complementary efforts related to the WA DNR Work of Wildfre Assessment

Table A1. Summary of existing programs related to post-fire assessment and forest health/fuel treatments. USFS: USDA Forest Service.

Program	Agency	Description	Link/Citation
Burn Severity Mapping			
BAER soil burn severity	USFS	Burned Area Emergency Response	National fire list and downloads
BARC	USFS	Burned Area Reflectance Classification	National fire list and downloads
RAVG	USGS	Rapid Assessment of Vegetation Mortality	RAVG home page
Region 6 Google Earth Engine (provides some BARC/BAER)	USFS	Google Earth Engine vegetation mortality mapping	
MTBS	USFS/ Interagency	Longer-term record of burn severity using one-year post-fire imagery (1984-2019)	MTBS home page
Fire effects and fuel treatments			
R6 fuels treatment effectiveness monitoring (FTEM)	USFS	Congressional mandate to evaluate treatments on all large fires	Dashboard
Fire Behavior Assessment Team (FBAT)	USFS	On-call module that measures pre-, active-, post-fire to improve knowledge about fuels, behavior, firefighter safety, etc	FBAT home page
Rapid Assessment Team (RAT)	USFS	Focus on post-fire management alternatives	
Fire perimeters (preliminary, infrared is best)	USFS	Public FTP of fire perimeters and other GIS data	WA 2021 Incidents
Fire monitoring and assessment (NWCC)	Interagency	Northwest Interagency Coordination Center, including annual report	NWCC website
Fire weather from MesoWest	University of Utah	Weather and climate data, including RAWS and iRAWS	Data interface
ICS-209 (external - all large fires, daily submission; IAP is internal)	USFS	Daily incident reports, use to connect with fire behavior, fire progression, weather, personnel to interview	PNW large fire list
Fire situation bindersWA	WA DNR	Monthly summary & outlook from WF Division	
Sycan Marsh	The Nature Conservancy	Rapid post-fire assessment of Bootleg Fire	
Fire Effects Monitoring	National Park Service		Home page
FIREMON (CBI/dNBR)	Interagency	Methods for remote sensing and field assessment (composite burn index)	CBI description

Appendix B. Detailed methods and data for the WA DNR Work of Wildfire Assessment

1. BURN SEVERITY MAPPING

To enable a comprehensive and rapid assessment of fire effects, we adapted the US Forest Service Region 6 (R6) mapping approach using Google Earth Engine. We used fire perimeters from November 2021 from the National Interagency Fire Center (https://ftp.wildfire.gov/) and pre- and post-fire Sentinel-2 satellite imagery. We computed the commonly used RdNBR spectral index (details below) and classified low-, moderate-, and high-severity fire corresponding to 0-25%, 25-75%, and 75-100% tree basal area mortality with the following thresholds from Reilly et al. (2017): low: <235.195, moderate: 235.195-648.725, high: >648.725. This method is similar to the approach of the US Forest Service RAVG program (Rapid Assessment of Vegetation Conditions; https://burnseverity.cr.usgs.gov/ravg/) but allowed us to assess all fires rapidly in one workflow.

Note that our burn severity maps are preliminary and do not capture delayed mortality. We anticipate that severity estimates will increase in subsequent years, especially in cold forests that are with fire-intolerant, thinned-barked species (Cansler et al. 2020). Moving forward, we will work with partners to update burn severity maps following the summer of 2022.

We developed this method after evaluating two primary approaches during the 2021 fire season. Specifically, we considered methods from (1) R6 that compare composite satellite imagery from the year of fire with imagery the year prior to the fire and (2) the USFS RAVG program, which compares individual images pre- and immediate post-fire. We evaluated both approaches for accuracy during field visits to the Methow Valley (Cedar Creek & Cub Creek 2 Fires) and the Blue Mountains (Lick Creek & Green Ridge Fires). Burn severity estimates from all three methods were created using Google Earth Engine (Gorelick et al. 2017) and R (R Core Team, 2021).

In addition to the three methods evaluated, we also tested both Landsat and Sentinel-2 satellite data for use in the algorithms. Sentinel imagery has a finer resolution than Landsat (20m vs. 30m), but the regressions used to estimate basal area mortality from satellite reflectance are not tuned to those data. As such, Landsat may be more accurate than Sentinel in some cases. Additionally, the two satellites are collected on different dates, meaning that cloud cover and shadows may also differ. We chose to use Sentinel data for estimating 2021 severity because it was more consistent with the R6 method.

The RAVG and R6 methods have several key differences. For the RAVG approach, severity maps are based on two clear images: a pre-fire image from the year prior to the fire, and a post-fire image the year of the fire. The images are selected to have similar spectral and vegetation characteristics, to be relatively close in date, and to be clear of clouds, smoke, and other contamination. Relative differenced Normalized Burn Ratio (RdNBR; Miller and Thode 2007, Parks et al. 2014) is then calculated using the two images. Benefits of the RAVG approach include minimal effects due to climatic differences between pre- and post-fire dates, and a lack of cloud, cloud shadow, smoke, or snow contamination. Additionally, the RAVG regression equations have been modified to better fit immediate post-fire conditions, rather than year-after-fire conditions (Miller and Quayle 2015). However, the method requires much more hands-on time to calculate, and the imagery dates differ by fire, creating the potential for inconsistency among fires.

With the R6 method, RdNBR is calculated using composites of imagery from June through the end of October for the year prior to the fire and the year of the fire. Different end dates may be used, but the end of October produced the most accurate results for our analysis. This method is fast and easy to run for many fires, and is relatively consistent across all fires. Some date inconsistencies are still present due to different dates of imagery being excluded for each fire due to smoke or cloud contamination, but overall the imagery dates among fires with the R6 method are more consistent across fires than with the RAVG method. That being said, the approach is often less accurate than RAVG until several good post-fire images may be obtained, resulting in a slight delay in the availability of results. Additionally, there may be areas of falsely low severity for some time after the fire for the same reasons. Finally, the R6 method is also somewhat more prone to differences in climate and vegetation greenness between pre- and post-fire images because it does not explicitly match vegetation conditions between years. If the growing season (June-October) is consistently drier the year of the fire, severity may be artificially high in the results.

While both RAVG and R6 burn severity maps are available externally, the DNR Forest Health Science Team decided to create our own maps using one of these methods in order to produce consistent severity maps for all fires in eastern Washington. The R6 approach creates severity maps for many large fires across the region, but smaller fires and fires not on USFS lands are usually excluded. Similarly, the RAVG program creates severity data for many fires across the United States, but typically only for larger fires or fires or special interest to the USFS. Additionally, because the RAVG program is responsible for maps across a much larger area, data are often not available until later in the fall or early winter.

We evaluated data produced using both the R6 method and from the RAVG program in the field. Both aligned well with on-the-ground observations, although there were discrepancies between the maps themselves as well as conditions on the ground. In particular, areas of lower severity according to RAVG tended to be mapped as slightly higher severity on average using the R6 method. Additionally, the R6 method was more prone to errors due to cloud contamination.

We decided to use the R6 method to determine immediate post-fire burn severity for several reasons. First, the R6 method is much less computationally intensive than the RAVG method.

Second, the R6 method uses composite imagery rather than individual images, theoretically making it a better representation of overall post-fire conditions. Last, while the R6 approach tended to slightly overestimate the proportion of low-moderate burn severity areas relative to low severity, these classes were combined in many of the analyses. We were focused primarily on the prevalence and patterns associated with high burn severity, so this issue was relatively minor.

There are several concerns that arise from using the R6 method that should be noted. In addition to the overestimation of burn severity in lower severity zones, this approach also improves in accuracy later in the season as more smoke- and cloud-free post-fire imagery becomes available. The issue with overestimation of burn severity could potentially be reduced by applying an offset to the RdNBR values. Offsets are values determined from adjacent unburned areas to account for year-to-year changes in vegetation spectral conditions (e.g., due to differences in climatic conditions or phenology). This is a standard alteration to similar severity calculations that allows for better comparisons among fires (Miller and Thode 2007, Parks et al. 2014). A final issue with this approach is that the burn severity estimates are based on regression equations using field data collected at least one year post-fire at sites in Washington and Oregon. Creating a new regression with data only from Washington would potentially improve the accuracy for fires in the state. We plan to address several of these issues with ongoing work. We will test an offset by altering the R6 code and will work with researchers at the University of Washington (Saberi et al. 2020) to improve the regression equations relating immediate RdNBR and basal area mortality and the composite burn index (similar to Miller and Quayle 2015). These changes should make the product more consistent across fires and increase the accuracy for low- and moderate-severity areas.

2. COMPARING BURN SEVERITY WITH HISTORICAL FIRE REGIMES ASSOCIATED WITH FOREST TYPES

To assess the extent to which fires moved landscapes towards landscape resilience goals, we first combined burn severity with a vegetation type layer developed for the 20-Year Plan that is based on an updated version of ILAP 2012, see Appendix B in the WA DNR Forest Health Assessment and Treatment Framework 2020 report (available online; WA DNR 2020). Potential vegetation types (PVTs) were grouped into more general vegetation classes (dry, moist, and fold forests, plus non-forest vegetation) (Table B1). The observed proportions of low-, moderate-, and high-severity fire for dry, moist, and cold forest were then calculated for each fire.

Ranges for historical reference fire severities (5th percentile, 50th percentile, and 95th percentile) were calculated for dry, moist, and cold forests for each fire using values from Haugo et al. (2019), which are based on LANDFIRE 2016 Biophysical Settings Review (www.landfirereview.org) and refined simulation methodology from Blankenship et al. (2015). We used a crosswalk from Haugo et al. (2019) to match our PVTs to Landfire Biophysical Settings. These values are provided in Table B1. For fires with more than one PVT within a vegetation type (e.g., dry ponderosa pine and dry mixed-conifer PVTs, which are both in the Dry Forest vegetation type), we calculated weighted averages for the historical ranges using the area of each PVT within the fire perimeter. The final step was to compare the observed severity proportions for each fire by vegetation type with the historical ranges. Non-forest types (shrublands, grassland) were not included in this analysis.

3. HIGH-SEVERITY FIRE PATCH SIZES IN DRY AND MOIST FORESTS

For the 14 largest fires (>5,000 acres of forest burned), we calculated the amount of high-severity acres in large (>1,000 acres), medium (100-1,000 acres), and small patches (<100 acres) for moist and dry forests. Patches were generated from a combined raster of the 30-m resolution burn severity and vegetation type data described in the previous section using an 8 nearest neighbor rule. High-severity dry and moist forest pixels were combined for this analysis. To avoid artificially breaking up high-severity patches by forest type, cold forest pixels within these patches were also included to delineate patches and calculate patch sizes. However, only dry and moist forest pixels were counted when calculating the number of acres in each patch size bin: (large, medium, small).

4. POTENTIAL SEED SOURCE LIMITATION FOR TREE REGENERATION

For the 14 largest fires (>5,000 acres of forest burned), we calculated the amount and proportion of acres in high-severity patches greater than 150 meters (500 feet) from residual live trees. This distance was based on ponderosa pine seed dispersal (Stevens-Rumann et al. 2019, Povak et al. 2020). We used the high-severity patches described in the previous section, calculating the distance to the nearest unburned, low-, or moderate-severity pixel. Non-forest pixels were excluded based on a forest mask covering eastern Washington (WA DNR 2020). We summed the area of pixels with values >150 m to generate the total acres. Distances were calculated from pixel center to pixel center

5. MORTALITY OF LARGE TREES

We tabulated the severity of forested areas with large trees (greater than 20” in diameter) using LiDAR information that covers most of eastern Washington. Areas with large trees were mapped using a 95th percentile height (P95) layer (30-m pixel resolution) with a height cutoff of 100 feet. Prior modeling using tree lists from over 600 field plots (location mapped with high accuracy GPS) in eastern Washington indicated that P95 values of ≥100 feet generally correspond with an overstory quadratic mean diameter (QMD) of ≥20” from field plots (WA DNR 2020). An overstory QMD of 20” is a common definition of large tree structure in eastern Washington. Overstory QMD is calculated using the top 25th percentile of trees by diameter in a plot. In areas where LiDAR data were not available, we used QMD of trees greater than 6” diameter from WA DNR’s forest inventory (based on Digital Area Photogrammetry using NAIP imagery; see WA DNR 2020) or QMD of the top 25th percentile of trees by height from GNN (Ohmann et al. 2011)

6. THE AMOUNT OF LOW-, MODERATE-, AND HIGH-SEVERITY FIRE IN STREAM-ADJACENT FORESTS

Stream-adjacent forest were mapped using the WA DNR stream layer with buffers of 250 feet for rivers, 150 feet for fish bearing streams, 75 feet for non-fish bearing, and 50 feet for intermittent. The distances are not from DNR or USFS regulatory buffers, but based on forest-stream ecological interactions. Burn severity layers described above were used to tabulate the number of stream adjacent acres in each severity class (low, moderate, high).

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Table B1. Historical burn severity distributions for potential vegetation types of eastern Washington. Source: Haugo et al. (2019), based on LANDFIRE 2016 Biophysical Settings Review (www.landfirereview.org) and refined simulation methodology from Blankenship et al. (2015). ILAP: Integrated Landscape Assessment Project (https://ecoshare.info/ilap/about-ilap/).

Potential Vegetation Type	Forest Type	ILAP Code 2012	Fire Regime Group	Burn Severity Percentiles								
				Low			Moderate			High		
				5th	50th	95th	5th	50th	95th	5th	50th	95th
Oak Pine	Dry	WEC_fop	I	0.75	0.8	0.86	0.01	0.02	0.03	0.12	0.17	0.23
Ponderosa Pine	Dry	WEC_fpd	I	0.68	0.76	0.83	0.13	0.19	0.24	0.03	0.05	0.08
Dry Mix Conifer	Dry	WEC_fmd	I	0.61	0.67	0.72	0.18	0.21	0.25	0.06	0.11	0.18
Moist Mix Conifer	Moist	WEC_fmm	III	0.2	0.24	0.29	0.39	0.5	0.61	0.16	0.26	0.37
Silver Fir	Cold	WEC_fsi	III	0	0	0	0.42	0.54	0.65	0.35	0.46	0.58
Mtn Hemlock	Cold	WEC_fmh	V	0.11	0.17	0.24	0.21	0.28	0.36	0.46	0.55	0.64
Subalpine Parklands	Cold	WEC_fal	III	0	0	0	0.73	0.81	0.9	0.1	0.19	0.27
Ponderosa Dry	Dry	WNE_fpd	I	0.67	0.75	0.83	0.14	0.19	0.25	0.04	0.06	0.1
Dry Mixed Conifer	Dry	WNE_fdd	I	0.62	0.68	0.72	0.18	0.21	0.25	0.06	0.11	0.18
NRM Mixed Conifer	Moist	WNE_fcm	III	0.2	0.24	0.29	0.41	0.51	0.61	0.15	0.24	0.39
W Red Cedar	Moist	WNE_frn	III	0	0	0	0.48	0.56	0.66	0.34	0.44	0.52
Subalpine - Lodgepole	Cold	WNE_fes	IV	0	0	0	0.06	0.17	0.28	0.72	0.83	0.94
Subalpine - Spruce	Cold	WNE_fcd	IV	0	0	0	0.05	0.18	0.35	0.65	0.82	0.95
Subalpine Fir	Cold	WNE_faf	IV	0.07	0.11	0.15	0.08	0.13	0.17	0.68	0.76	0.81
Subalpine Parklands	Cold	WNE_fal	III	0	0	0	0.05	0.18	0.35	0.65	0.82	0.95
Xeric Ponderosa pine	Dry	WBM_fxp	III	0.28	0.34	0.43	0.39	0.47	0.56	0.12	0.19	0.28
Dry Ponderosa pine	Dry	WBM_fdp	I	0.69	0.75	0.82	0.14	0.19	0.24	0.03	0.05	0.08
Dry Douglas-fir	Dry	WBM_fdd	I	0.62	0.68	0.75	0.18	0.21	0.25	0.05	0.11	0.18
Warm-Dry Grand fir	Dry	WBM_fdg	I	0.62	0.68	0.75	0.18	0.21	0.25	0.05	0.11	0.18
Cool-Moist Grand fir	Moist	WBM_fcm	III	0.19	0.24	0.29	0.43	0.51	0.59	0.16	0.25	0.34
Cold-Dry Subalpine fir	Cold	WBM_fcd	IV	0	0	0	0.05	0.16	0.31	0.69	0.84	0.95

Appendix C. Energy Release Component for eastern Washington

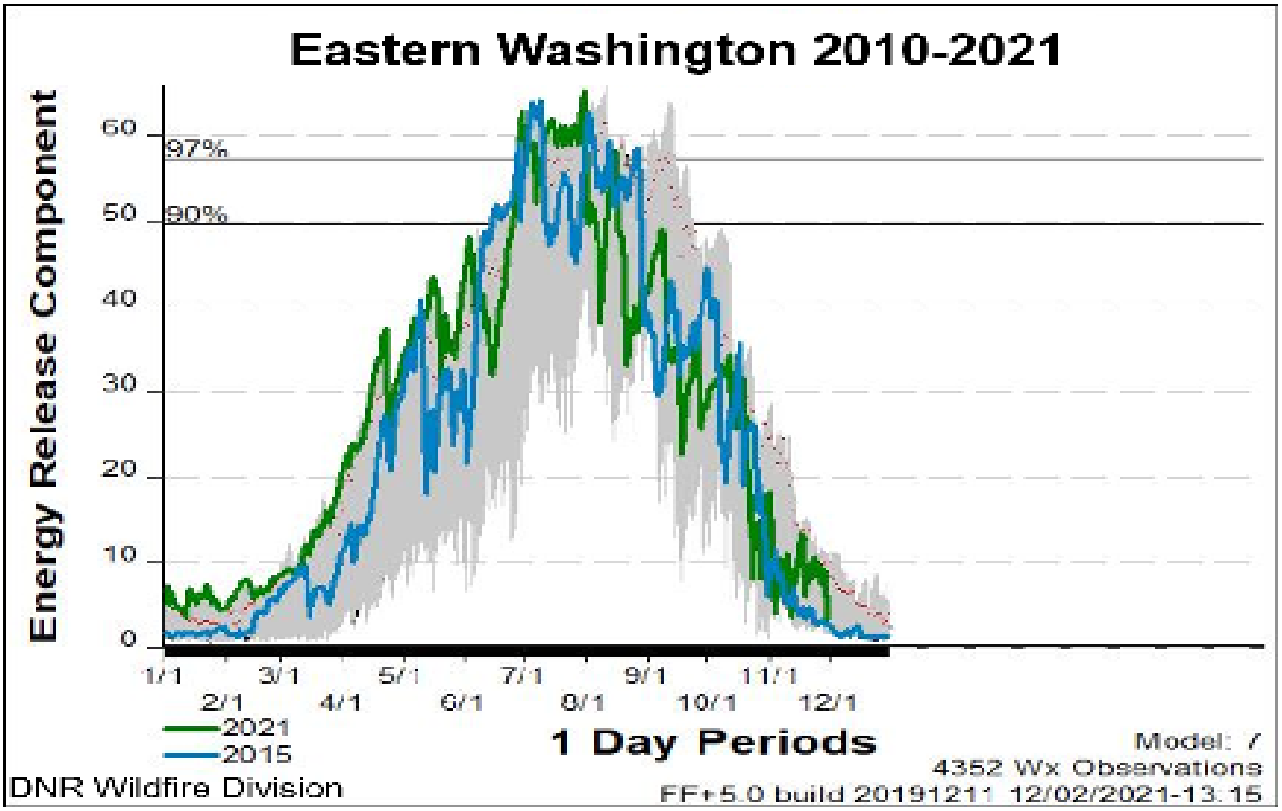

Figure C1. Energy Release Component (ERC) for eastern Washington. ERC is a commonly used indicator of fire danger based on fuel moisture. Image courtesy of Vaughn Cork (WA DNR Wildland Fire Management Division). In eastern Washington, 2021 had extreme ERC values throughout the early fire season and similar peak values to the 2015 fire season, essentially doubling the amount of time of extreme fire danger compared to a typical fire season. Additional background information is available online.

Appendix D. Effects of individual large 2021 fires in eastern Washington

OVERVIEW

This appendix summarizes the effects of the 14 largest fires on forest landscapes in eastern Washington (main report Figure 1, Table 3). Following an overview map (Figure D1), there is a one-page summary for each fire in decreasing order of forested acres burned. These 14 fires each burned more than 5,000 acres of forest, together accounting for 96% of the 463,345 acres of forest that burned in 2021. The outcomes of each wildfire varied widely and depended on multiple factors, including fire weather, fuel conditions, fire management operations, past treatments, and terrain. Fire effects occurred under suppression objectives for all fires.

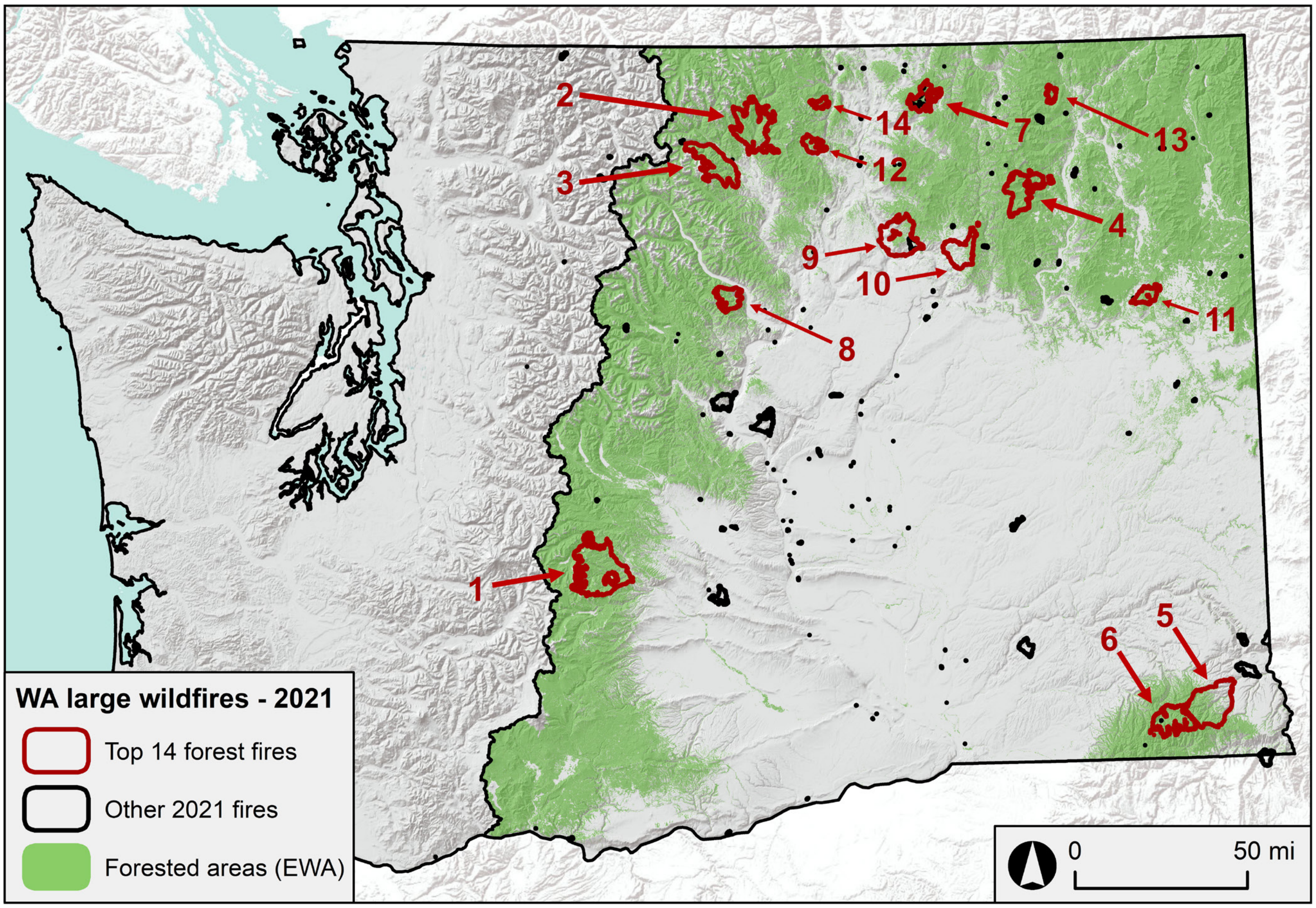

Figure D1. 2021 wildfires across Washington State. Large fire perimeters include all events over 100 acres and are compiled by the WA DNR Wildland Fire Management Division. The vast majority of 2021 large fires occurred in eastern Washington, delineated by the crest of the Cascade Range (black line). Green areas indicated forested portions of eastern WA based on a forest mask maintained by the WA DNR Forest Health Science Team. Red arrows and numbers indicate individual large fires in decreasing order of forested acres burned: 1: Schneider Springs; 2: Cub Creek 2; 3: Cedar Creek; 4: Summit Trail; 5: Lick Creek (Dry Gulch); 6: Green Ridge; 7: Walker Creek (Spur); 8: 25 Mile; 9: Whitmore; 10: Chuweah Creek; 11: Ford Corkscrew; 12: Muckamuck; 13: Bulldog Mountain; 14: Chickadee Creek. Service layer credits: Esri, USGS, NOAA.

Schneider Springs Fire

The Schneider Springs Fire was the largest fire in 2021, and it burned through many acres and types of past treatments. Despite some very large high-severity patches, overall burn severity proportions were similar to historical estimates.

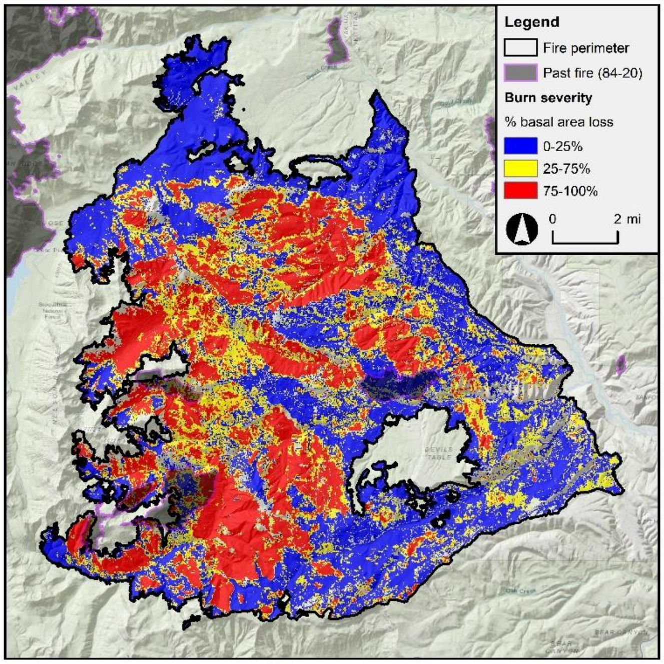

Figure D2a. Preliminary burn severity of forested areas. Basemap: ESRI World Topographic Map.

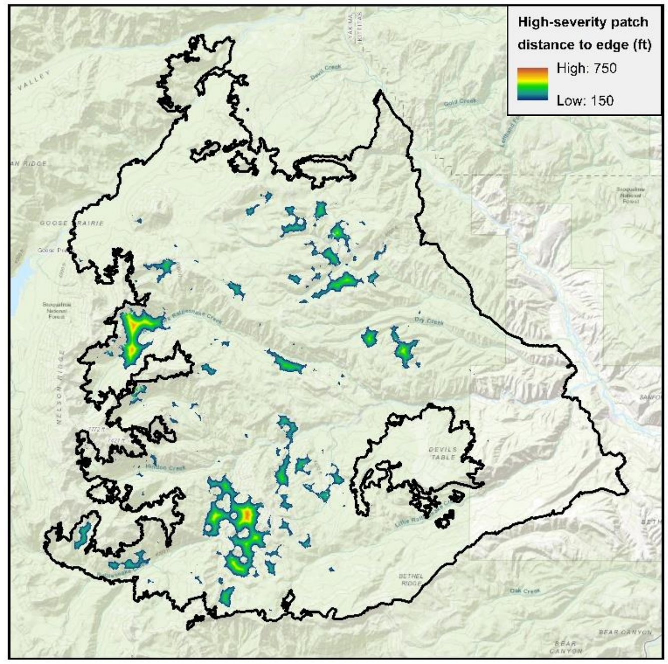

Figure D2b. Distance to edge in high-severity patches (6,023 acres). A total of 6% of the forested area that burned is >150m from potential seed sources in residual live trees.

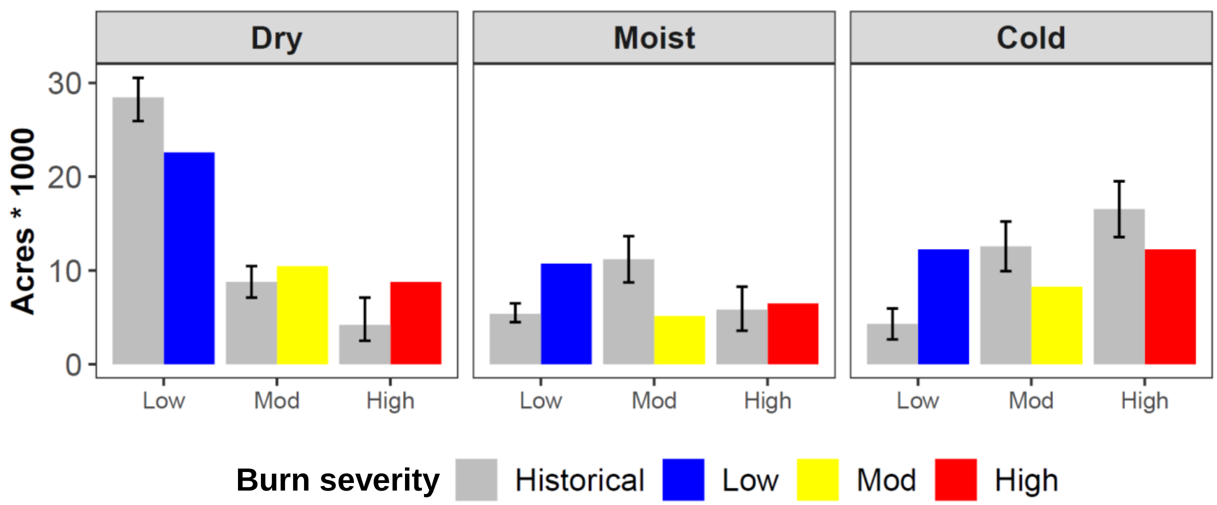

Figure D2c. Preliminary burn severity and historical estimates for potential vegetation types across forested portions (97,320 acres) within the Schneider Springs Fire (107,337 total acres).

Table D2a. 2021 wildfire extent and severity by forest type, including a subset of riparian forest and large trees, which often overlap.

Burn severity	Dry	Moist	Cold	Non-forest	Riparian	Large tree	Total
High	8,704	6,407	12,395	0	2,078	5,914	27,505
Moderate	10,559	5,041	8,336	0	2,340	4,094	23,936
Low	22,694	10,770	12,415	0	4,750	9,585	45,879
Total	41,957	22,218	33,145	10,017	9,167	19,594	107,337

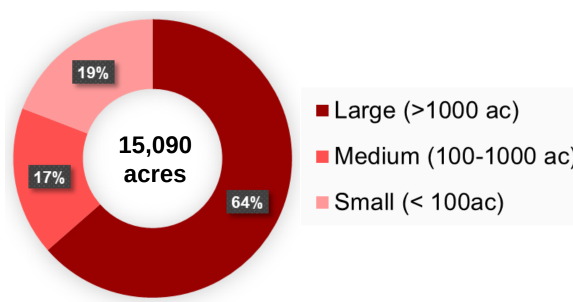

Figure D2d. Patch sizes of high-severity fire in dry and moist forests (15,090 total acres).

Cub Creek 2 Fire

The Cub Creek 2 Fire had very large patches of high-severity fire and more extreme effects than the nearby Cedar Creek Fire. Prior wildfires played a key role in the management, spread, and severity of the Cub Creek 2 Fire.

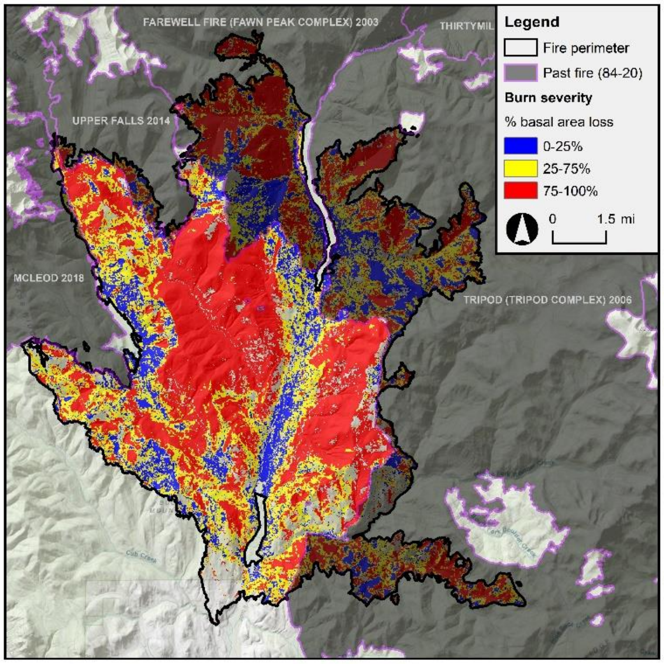

Figure D3a. Preliminary burn severity of forested areas. Basemap: ESRI World Topographic Map.

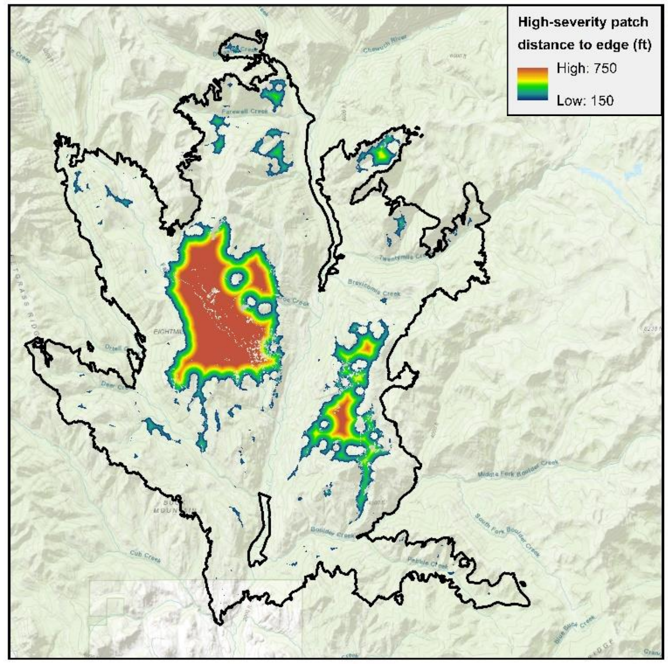

Figure D3b. Distance to edge in high-severity patches (11,575 acres). A total of 19% of the forested area that burned is >150m from potential seed sources in residual live trees.

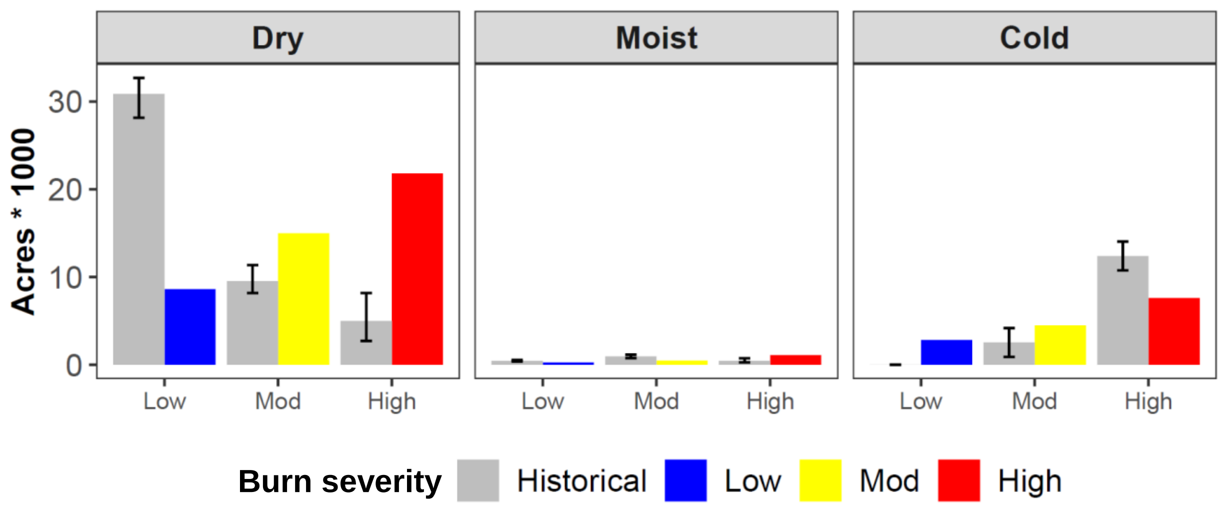

Figure D3c. Preliminary burn severity and historical estimates for potential vegetation types across forested portions (62,214 acres) within the Cub Creek 2 Fire (70,248 total acres).

Table D3a. 2021 wildfire extent and severity by forest type, including a subset of riparian forest and large trees, which often overlap.

Burn severity	Dry	Moist	Cold	Non-forest	Riparian	Large tree	Total
High	21,646	1,266	7,517	0	2,975	2,293	30,430
Moderate	14,869	553	4,524	0	2,138	2,043	19,946
Low	8,610	330	2,898	0	1,273	1,396	11,838
Total	45,125	2,150	14,939	8,034	6,385	5,731	70,248

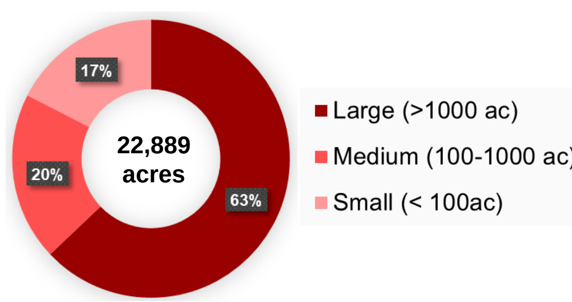

Figure D3d. Patch sizes of high-severity fire in dry and moist forests (22,889 total acres).

Cedar Creek Fire

Much of the fire extent occurred during days and nights of high winds that resulted in large patches of high-severity fire. However, 60% of the fire burned at low and moderate severity, most notably on the southern side of Highway 20.

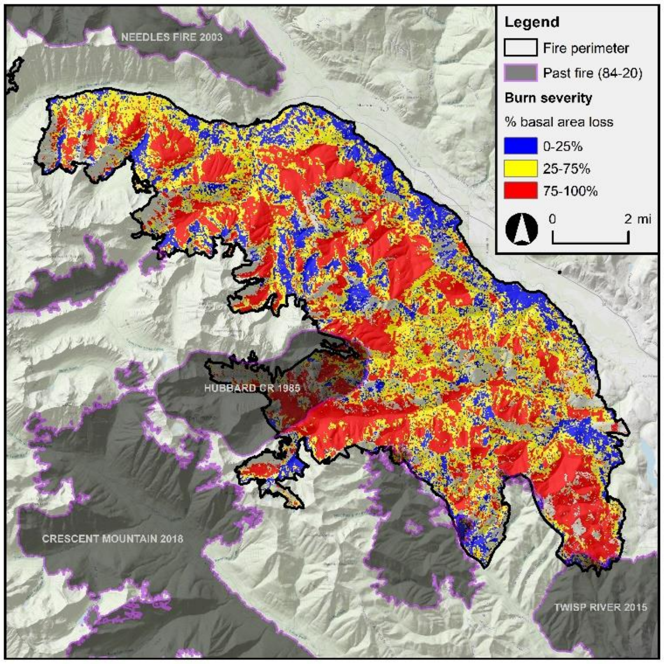

Figure D4a. Preliminary burn severity of forested areas. Basemap: ESRI World Topographic Map.

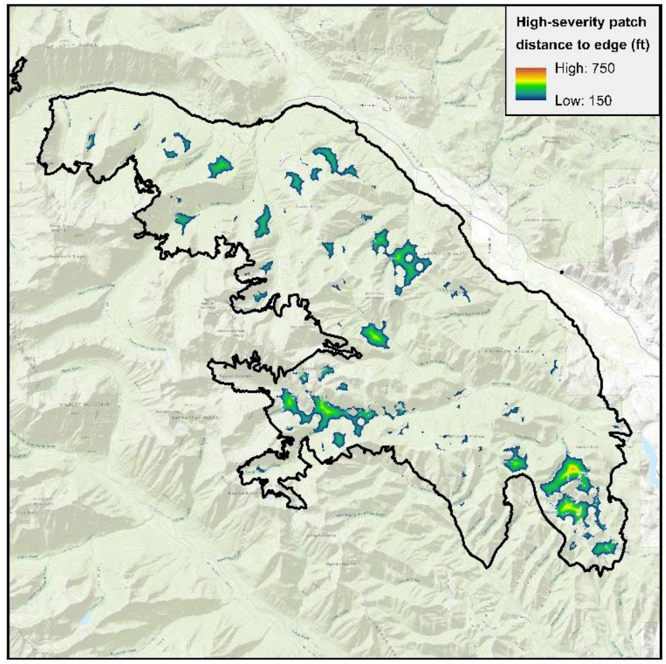

Figure D4b. Distance to edge in high-severity patches (3,896 acres). A total of 8% of the forested area that burned is >150m from potential seed sources in residual live trees.

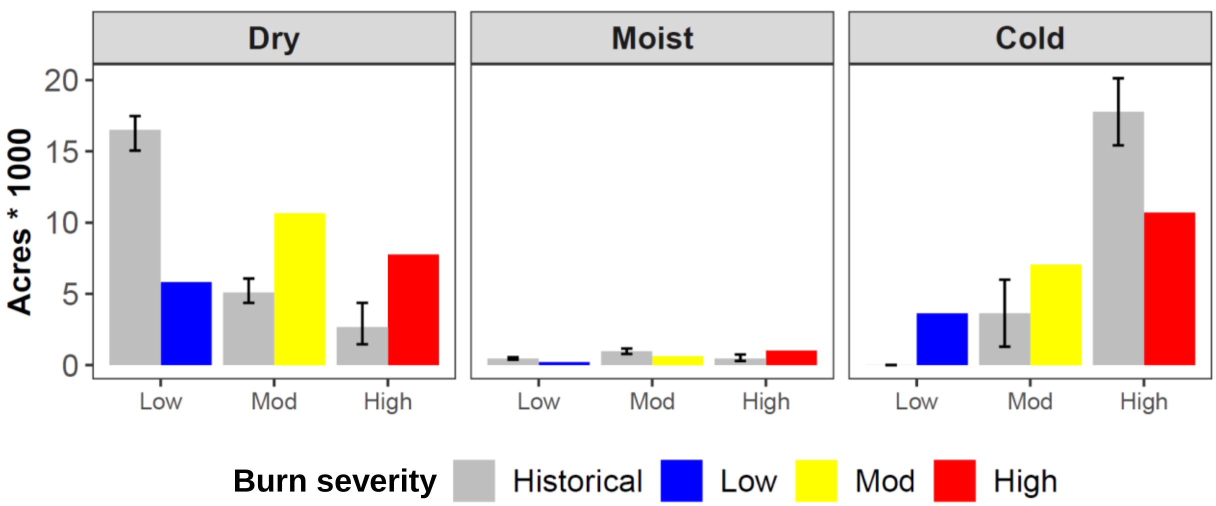

Figure D4c. Preliminary burn severity and historical estimates for potential vegetation types across forested portions (47,576 acres) within the Cedar Creek Fire (55,235 total acres).

Table D4a. 2021 wildfire extent and severity by forest type, including a subset of riparian forest and large trees, which often overlap.

Burn severity	Dry	Moist	Cold	Non-forest	Riparian	Large tree	Total
High	7,695	1,064	10,702	0	1,978	2,875	19,461
Moderate	10,652	671	7,159	0	1,967	3,319	18,482
Low	5,838	225	3,570	0	1,065	1,685	9,633
Total	24,185	1,961	21,430	7,660	5,010	7,879	55,235

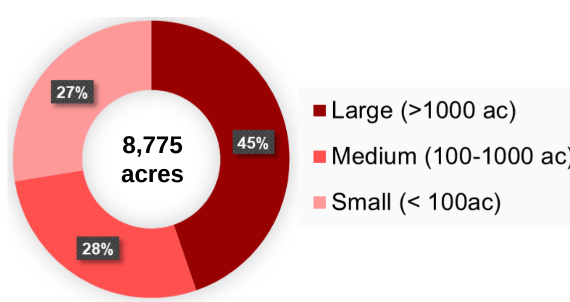

Figure D4d. Patch sizes of high-severity fire in dry and moist forests (8,775 total acres).

Summit Trail Fire

The Summit Trail Fire burned on the Colville Reservation. It exhibited uncharacteristically large high-severity patches, particularly in dry forests.

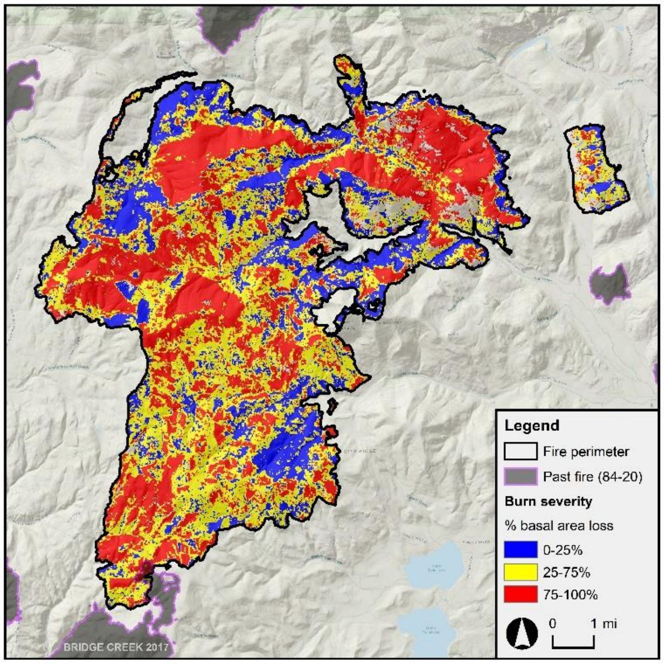

Figure D5a. Preliminary burn severity of forested areas. Basemap: ESRI World Topographic Map.

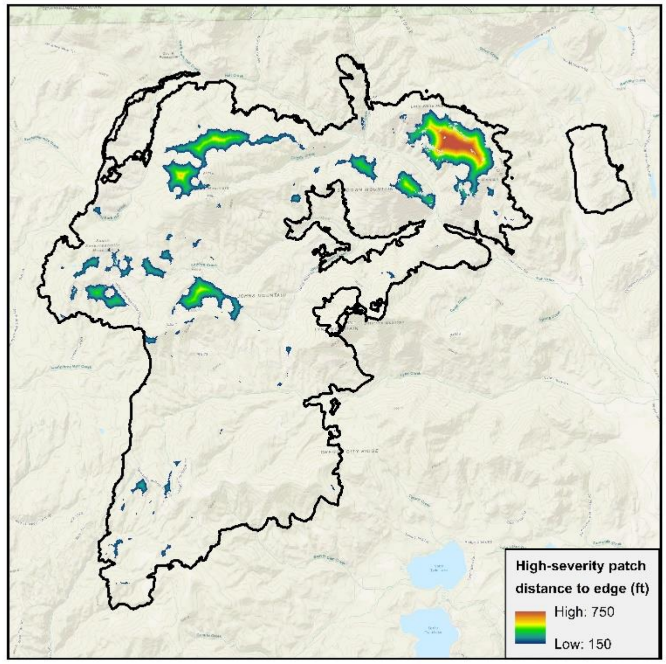

Figure D5b. Distance to edge in high-severity patches (3,774 acres). A total of 8% of the forested area that burned is >150m from potential seed sources in residual live trees.

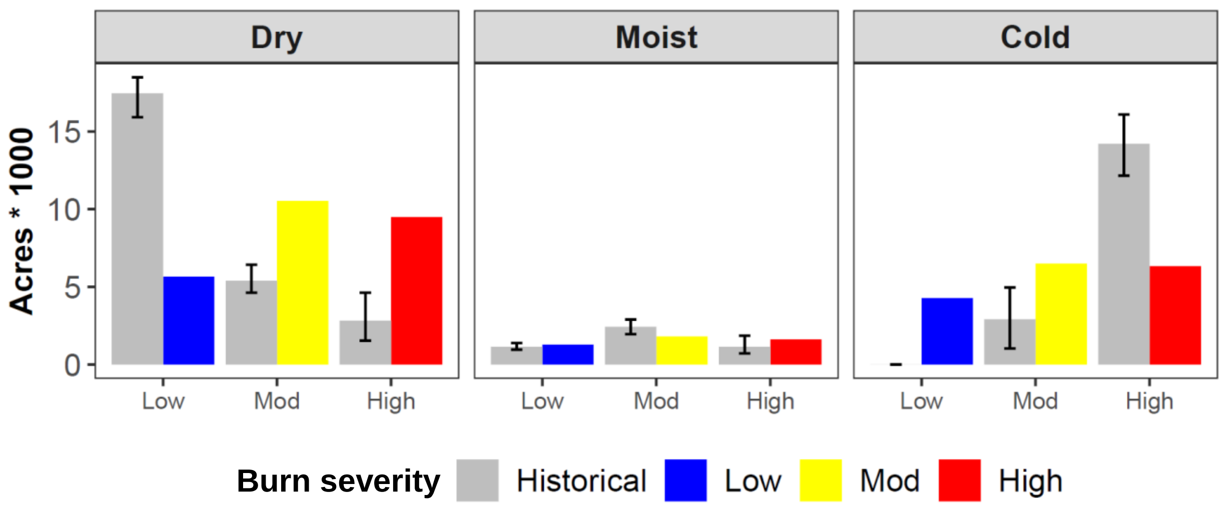

Figure D5c. Preliminary burn severity and historical estimates for potential vegetation types across forested portions (47,568 acres) within the Summit Trail Fire (49,595 total acres).

Table D5a. 2021 wildfire extent and severity by forest type, including a subset of riparian forest and large trees, which often overlap.

Burn severity	Dry	Moist	Cold	Non-forest	Riparian	Large tree	Total
High	9,652	1,515	6,449	0	1,836	1,920	17,615
Moderate	10,568	1,682	6,546	0	2,372	2,708	18,796
Low	5,658	1,215	4,284	0	1,756	1,796	11,157
Total	25,878	4,411	17,279	2,027	5,964	6,423	49,595

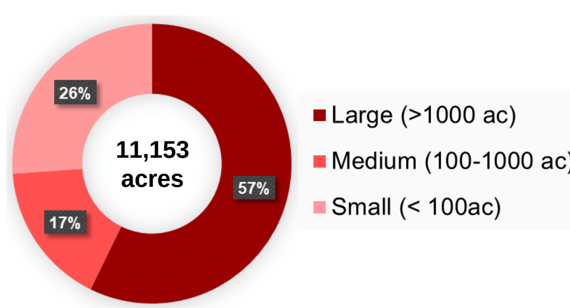

Figure D5d. Patch sizes of high-severity fire in dry and moist forests (11,153 total acres).

Lick Creek Fire (Dry Gulch)

The Lick Creek Fire spread rapidly from low, non-forest areas up to forested ridges, where burn severity was lower. Burn severity was uncharacteristically high in dry forests but consistent with historical estimates in moist forests.

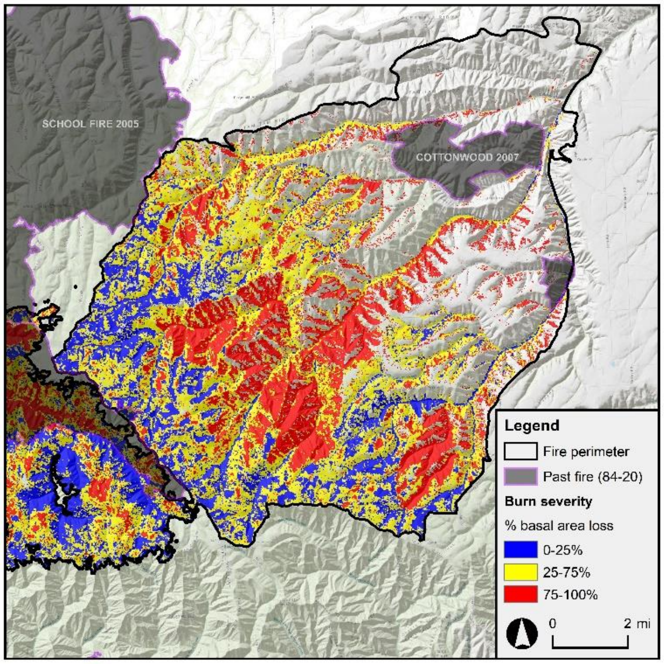

Figure D6a. Preliminary burn severity of forested areas. The Green Ridge Fire occurred directly to the southwest. Basemap: ESRI World Topographic Map.

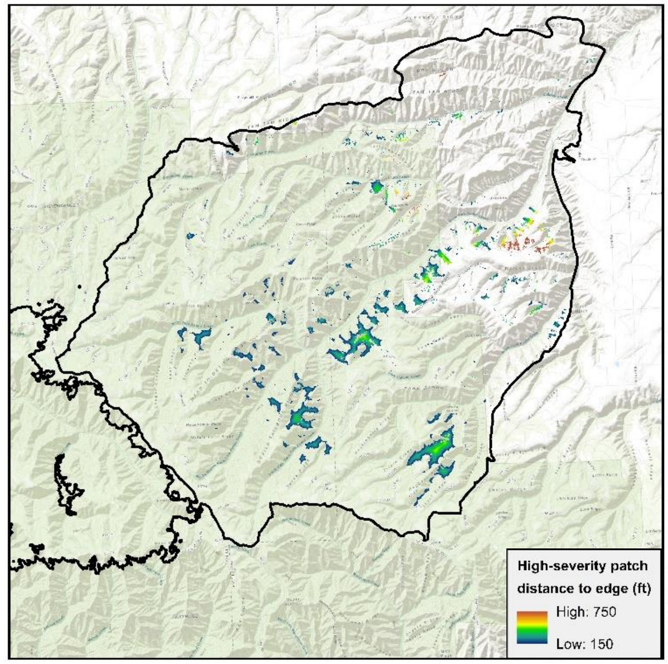

Figure D6b. Distance to edge in high-severity patches (2,427 acres). A total of 5% of the forested area that burned is >150m from potential seed sources in residual live trees.

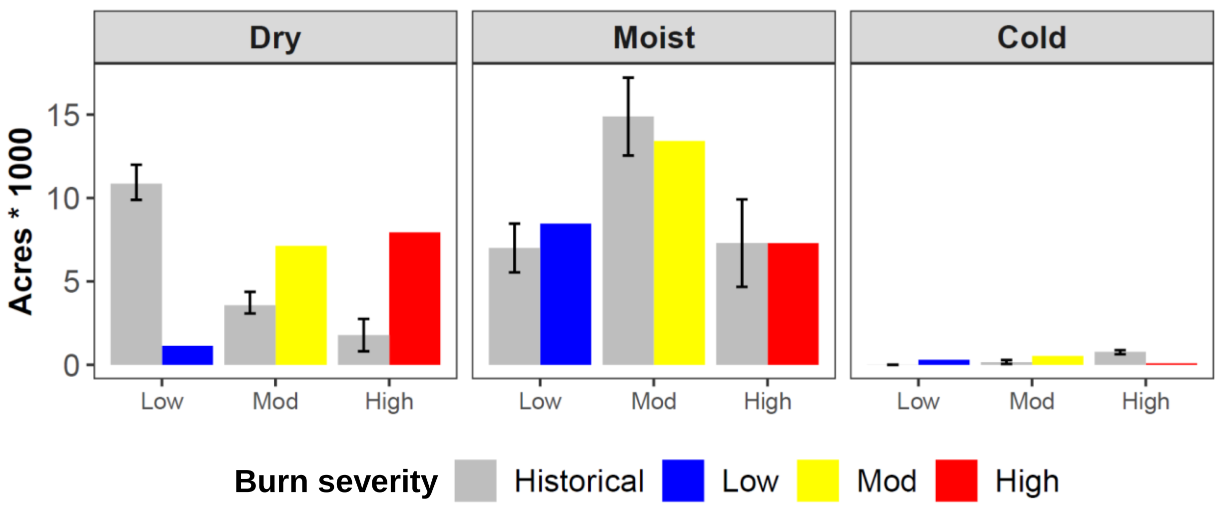

Figure D6c. Preliminary burn severity and historical estimates for potential vegetation types across forested portions (46,340 acres) within the Lick Creek Fire (80,426 total acres).

Table D6a. 2021 wildfire extent and severity by forest type, including a subset of riparian forest and large trees, which often overlap.

Burn severity	Dry	Moist	Cold	Non-forest	Riparian	Large tree	Total
High	7,920	7,315	74	0	6,779	1,970	15,309
Moderate	7,132	13,541	419	0	4,648	2,390	21,092
Low	1,085	8,605	249	0	2,606	1,521	9,939
Total	16,137	29,461	742	34,086	14,032	5,881	80,426

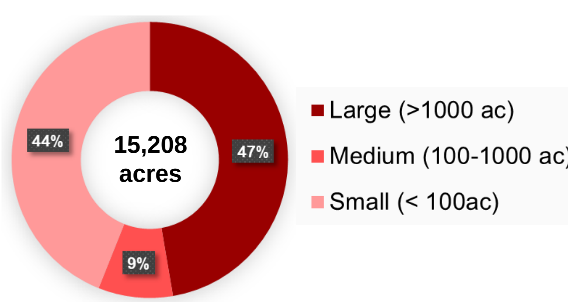

Figure D6d. Patch sizes of high-severity fire in dry and moist forests (15,208 total acres).

Green Ridge Fire

The Green Ridge Fire occurred mostly in roadless and wilderness areas, overlapping substantially with prior wildfires. Burn severity proportions were consistent with historical estimates, and many acres with large trees burned.

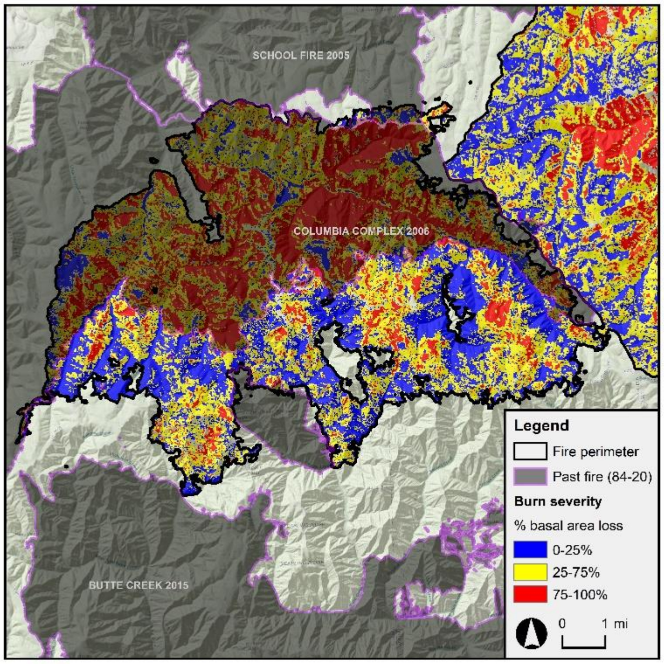

Figure D7a. Preliminary burn severity of forested areas. The Lick Creek Fire occurred directly to the northeast. Basemap: ESRI World Topographic Map.

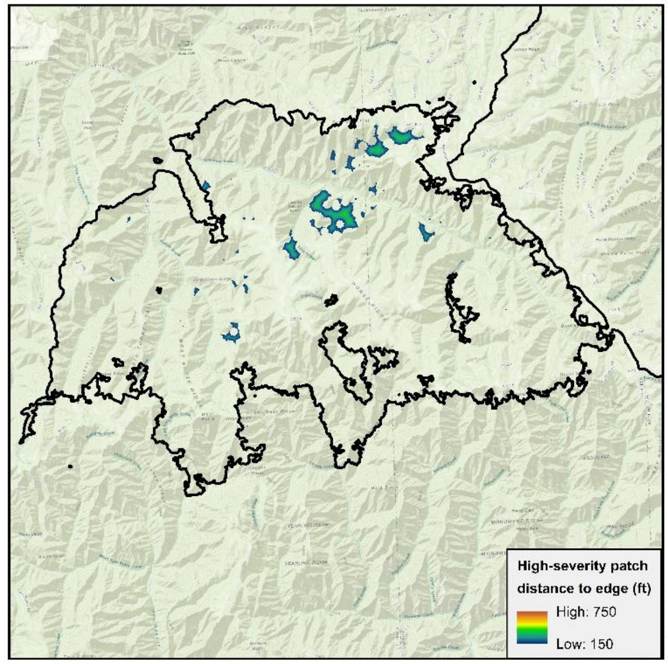

Figure D7b. Distance to edge in high-severity patches (857 acres). A total of 2% of the forested area that burned is >150m from potential seed sources in residual live trees.

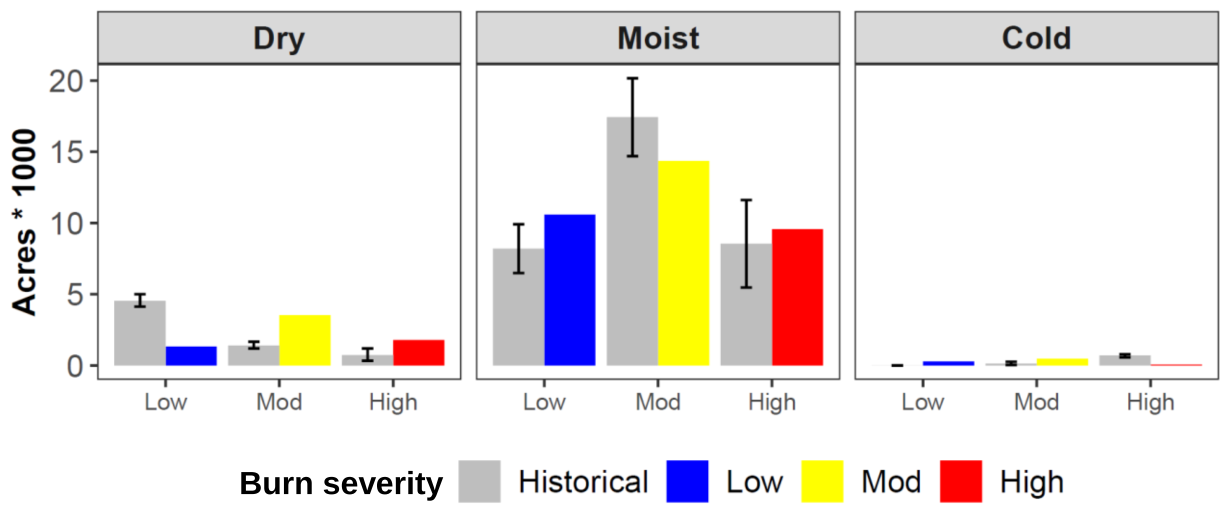

Figure D7c. Preliminary burn severity and historical estimates for potential vegetation types across forested portions (41,659 acres) within the Green Ridge Fire (43,719 total acres).

Table D7a. 2021 wildfire extent and severity by forest type, including a subset of riparian forest and large trees, which often overlap.

Burn severity	Dry	Moist	Cold	Non-forest	Riparian	Large tree	Total
High	1,750	9,479	77	0	1,222	3,089	11,305
Moderate	3,409	14,236	476	0	1,275	3,840	18,121
Low	1,340	10,612	281	0	1,711	5,363	12,233
Total	6,498	34,327	834	2,060	4,208	12,292	43,719

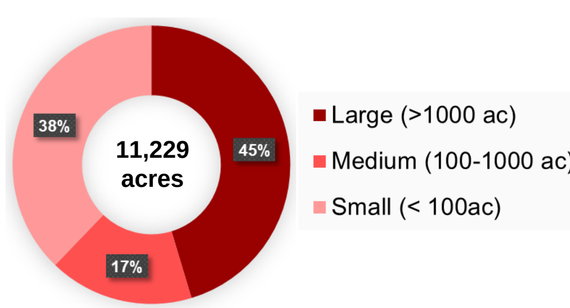

Figure D7d. Patch sizes of high-severity fire in dry and moist forests (11,229 total acres).

Walker Creek Fire (Spur)

The Walker Fire encompasses the Spur Fire. A large patch of high-severity fire occurred on the southeast side of Mount Bonaparte, mostly in cold forest. The fire burned through a number of past treatments on the Colville National Forest.

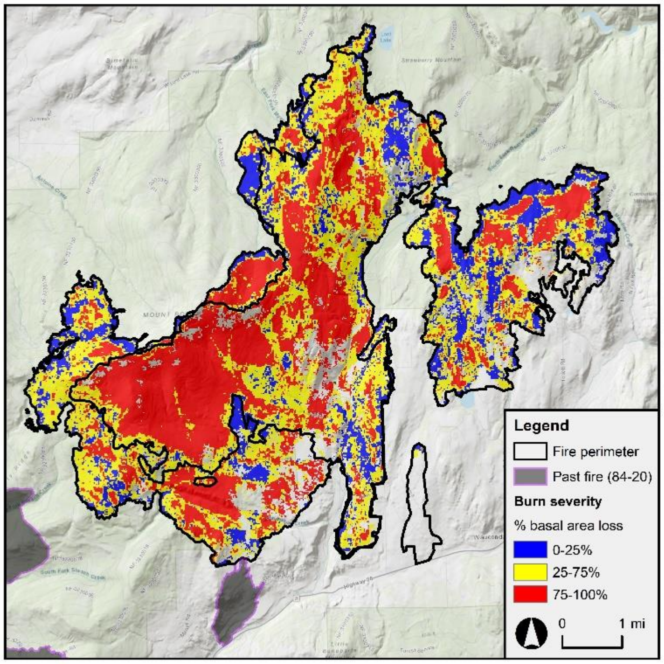

Figure D8a. Preliminary burn severity of forested areas. Basemap: ESRI World Topographic Map.

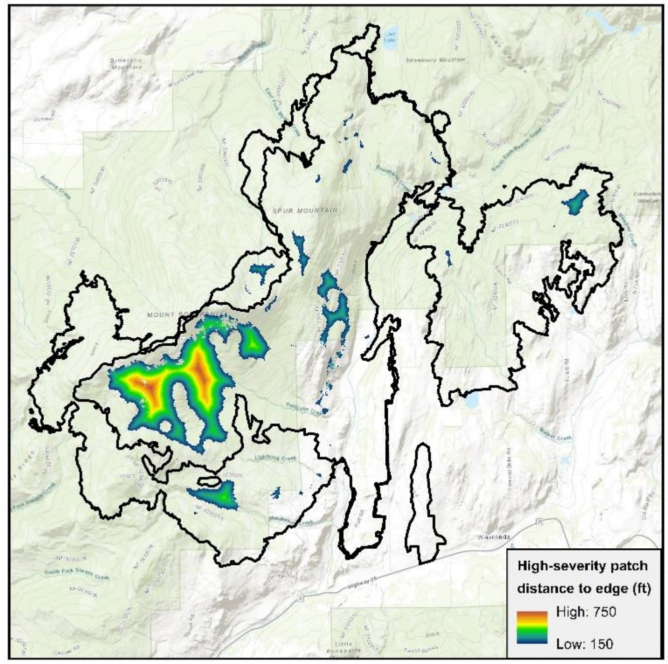

Figure D8b. Distance to edge in high-severity patches (2,140 acres). A total of 10% of the forested area that burned is >150m from potential seed sources in residual live trees.

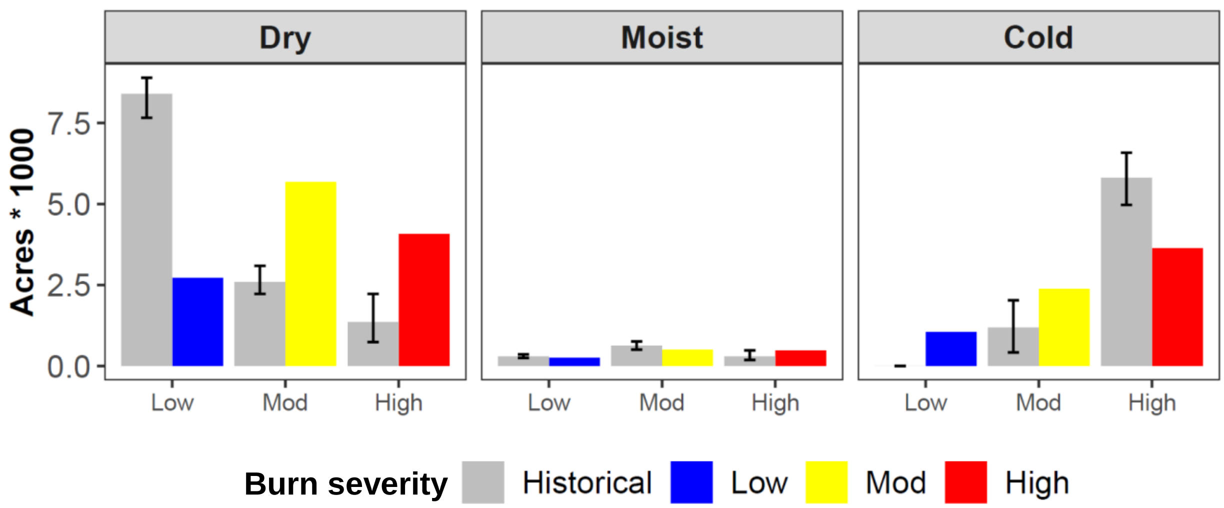

Figure D8c. Preliminary burn severity and historical estimates for potential vegetation types across forested portions (20,595 acres) within the Walker Creek Fire (23,765 total acres).

Table D8a. 2021 wildfire extent and severity by forest type, including a subset of riparian forest and large trees, which often overlap.

Burn severity	Dry	Moist	Cold	Non-forest	Riparian	Large tree	Total
High	4,068	457	3,570	0	700	929	8,096
Moderate	5,656	484	2,358	0	762	882	8,497
Low	2,704	253	1,045	0	304	357	4,002
Total	12,429	1,194	6,973	3,169	1,766	2,168	23,765

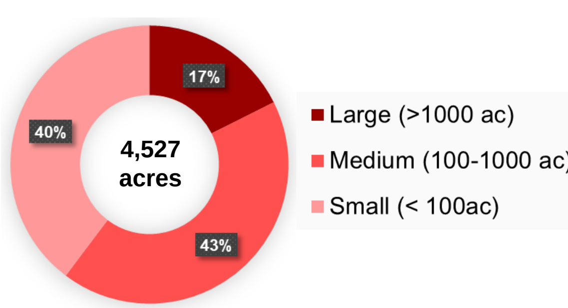

Figure D8d. Patch sizes of high-severity fire in dry and moist forests (4,527 total acres).

Twentyfive Mile Fire

The Twentyfile Mile Fire occurred near Lake Chelan, overlapping substantially with prior wildfires. Burn severity was uncharacteristically high in dry forests but consistent with historical estimates in moist and cold forests.

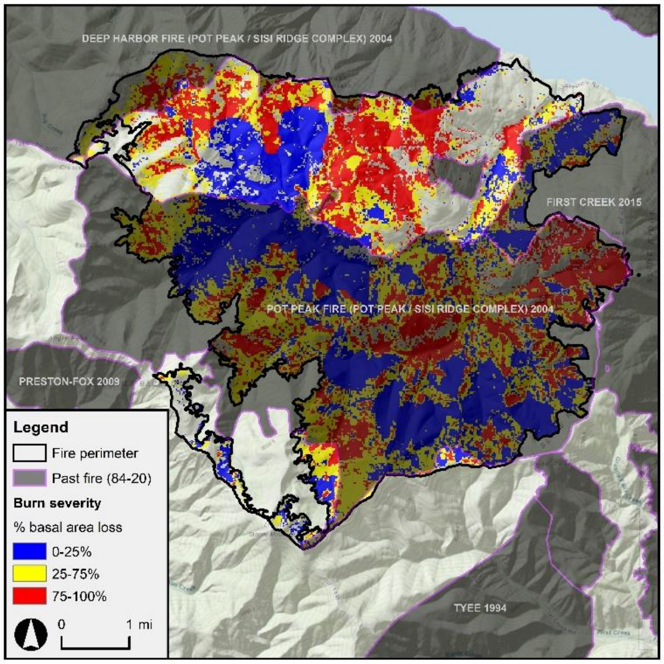

Figure D9a. Preliminary burn severity of forested areas. Basemap: ESRI World Topographic Map.

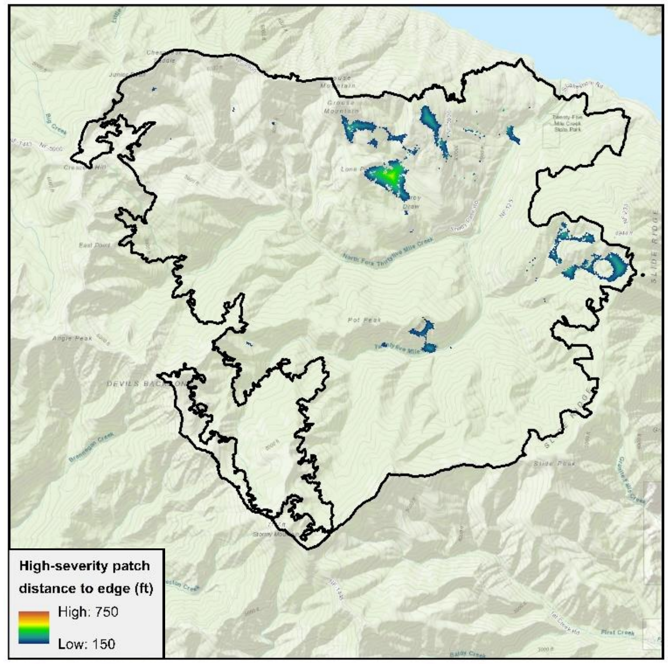

Figure D9b. Distance to edge in high-severity patches (477 acres). A total of 3% of the forested area that burned is >150m from potential seed sources in residual live trees.

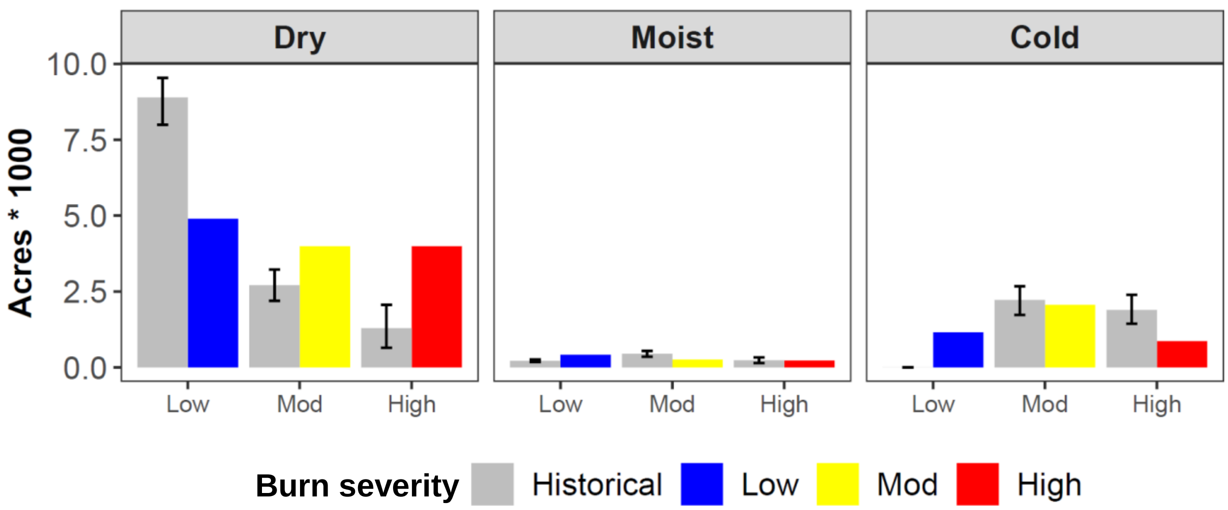

Figure D9c. Preliminary burn severity and historical estimates for potential vegetation types across forested portions (17,907 acres) within the Twentyfive Mile Fire (22,118 total acres).

Table D9a. 2021 wildfire extent and severity by forest type, including a subset of riparian forest and large trees, which often overlap.

Burn severity	Dry	Moist	Cold	Non-forest	Riparian	Large tree	Total
High	4,028	209	869	0	1,610	787	5,105
Moderate	4,049	247	2,064	0	1,582	1,272	6,360
Low	4,882	403	1,157	0	1,733	759	6,442
Total	12,959	859	4,090	4,211	4,924	2,818	22,118

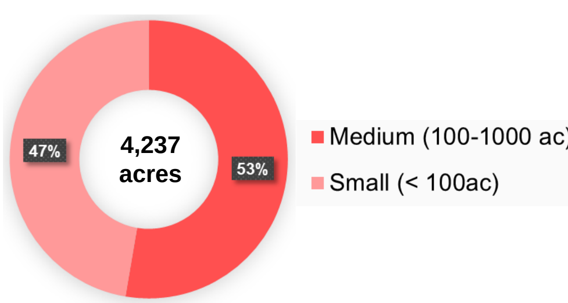

Figure D9d. Patch sizes of high-severity fire in dry and moist forests (4,237 total acres).

Whitmore Fire

The Whitmore Fire burned on the Colville Reservation, overlapping substantially with prior wildfires. This fire affected only dry forests, which burned with uncharacteristically high severity compared to historical estimates.

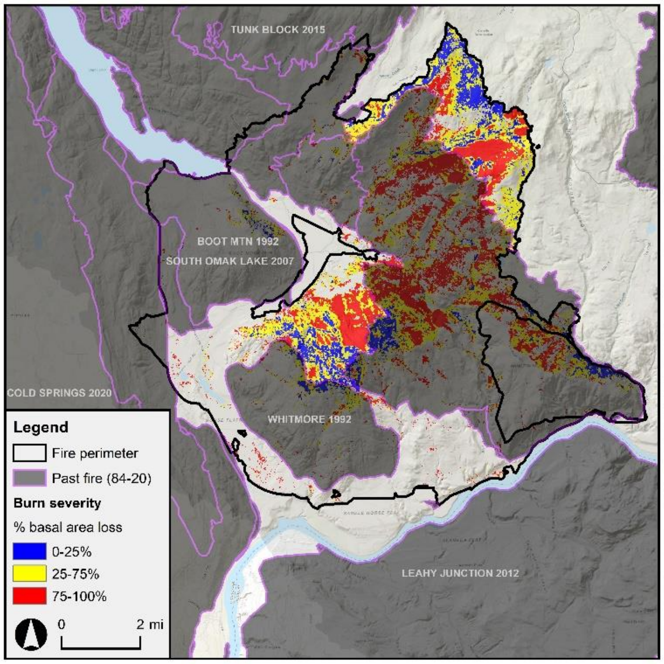

Figure D10a. Preliminary burn severity of forested areas. Basemap: ESRI World Topographic Map.

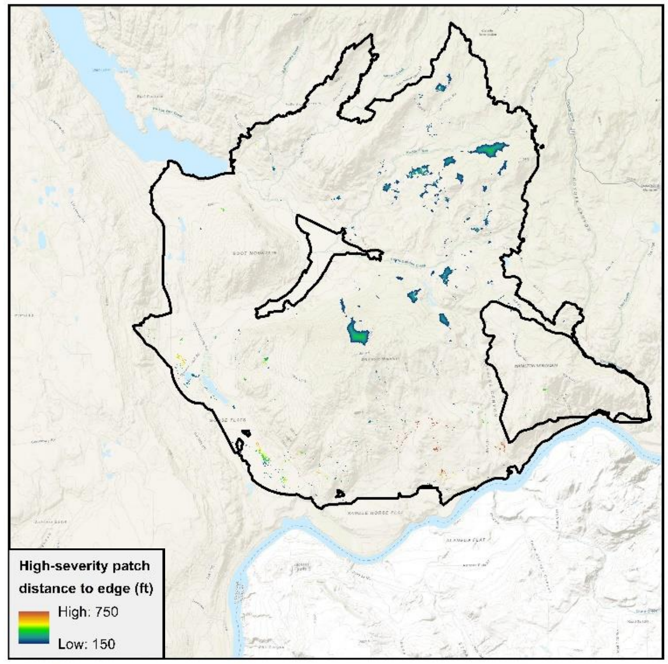

Figure D10b. Distance to edge in high-severity patches (879 acres). A total of 5% of the forested area that burned is >150m from potential seed sources in residual live trees.

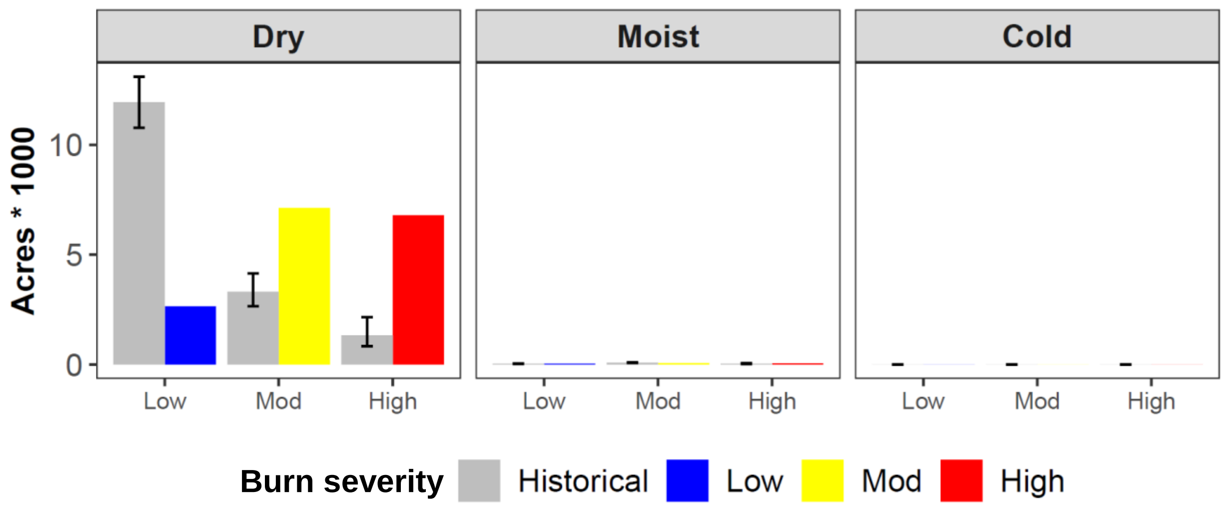

Figure D10c. Preliminary burn severity and historical estimates for potential vegetation types across forested portions (16,758 acres) within the Whitmore Fire (58,279 total acres).

Table D10a. 2021 wildfire extent and severity by forest type, including a subset of riparian forest and large trees, which often overlap.

Burn severity	Dry	Moist	Cold	Non-forest	Riparian	Large tree	Total
High	6,821	51	4	0	4,022	306	6,877
Moderate	7,117	69	11	0	1,790	545	7,197
Low	2,624	46	14	0	323	162	2,684
Total	16,563	166	29	41,521	6,134	1,013	58,279

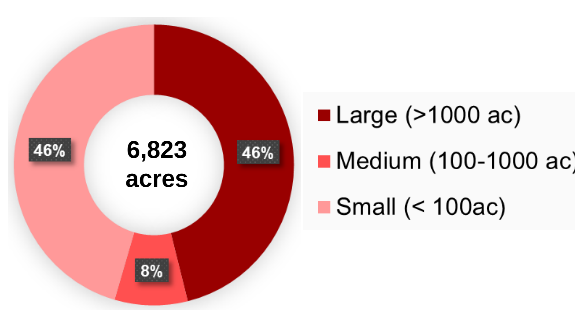

Figure D10d. Patch sizes of high-severity fire in dry and moist forests (6,823 total acres).

Chuweah Creek Fire

The Chuweah Creek Fire burned on the Colville Reservation. This fire affected mostly dry forests, which burned with uncharacteristically high severity compared to historical estimates.

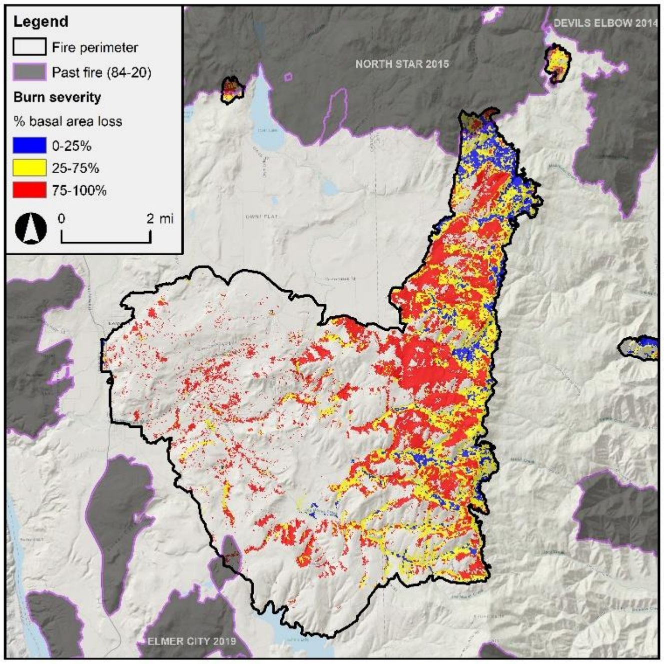

Figure D11a. Preliminary burn severity of forested areas. Basemap: ESRI World Topographic Map.

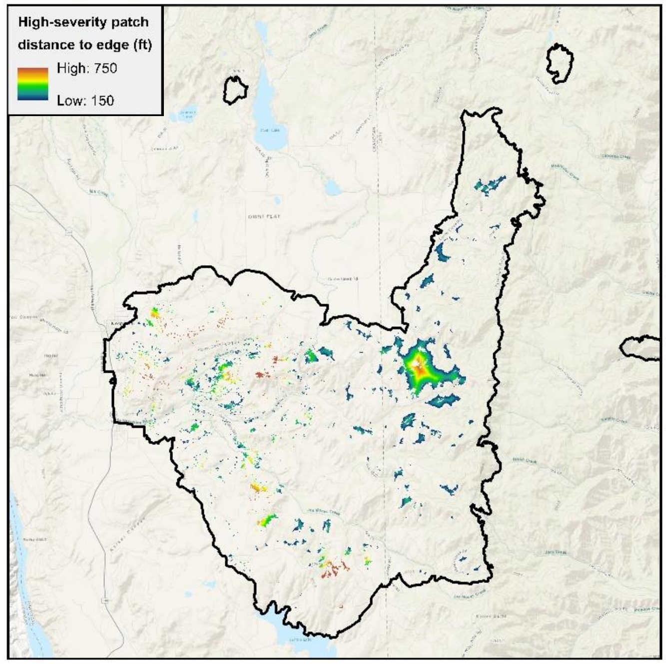

Figure D11b. Distance to edge in high-severity patches (1,815 acres). A total of 14% of the forested area that burned is >150m from potential seed sources in residual live trees.

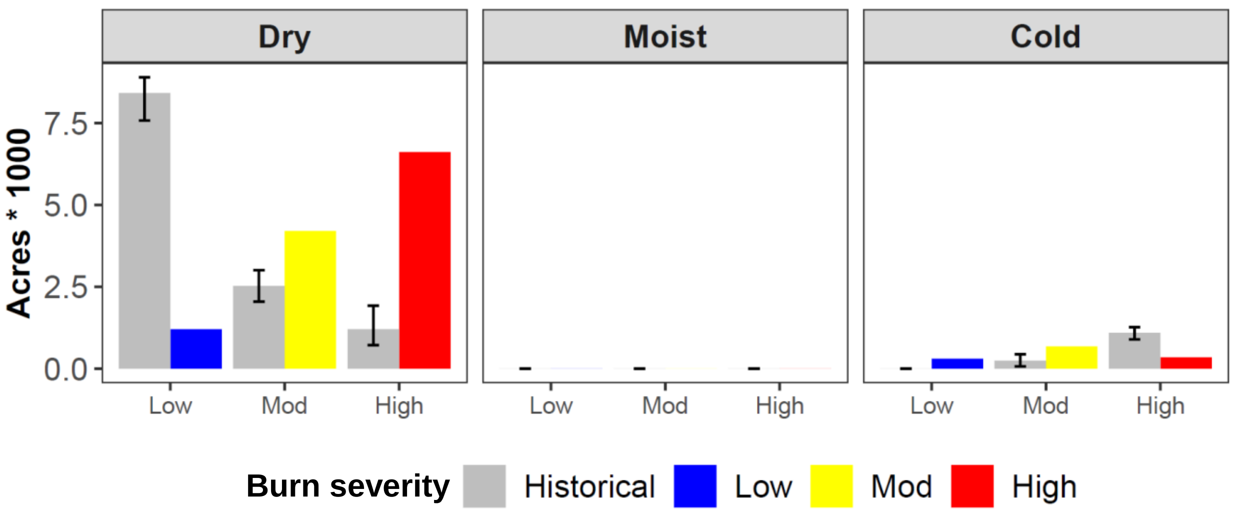

Figure D11c. Preliminary burn severity and historical estimates for potential vegetation types across forested portions (13,383 acres) within the Chuweah Creek Fire (36,753 total acres).

Table D11a. 2021 wildfire extent and severity by forest type, including a subset of riparian forest and large trees, which often overlap.

Burn severity	Dry	Moist	Cold	Non-forest	Riparian	Large tree	Total
High	6,568	0	333	0	5,036	223	6,901
Moderate	4,238	0	669	0	1,558	392	4,908
Low	1,274	0	300	0	377	224	1,574
Total	12,080	0	1,303	23,370	6,971	839	36,753

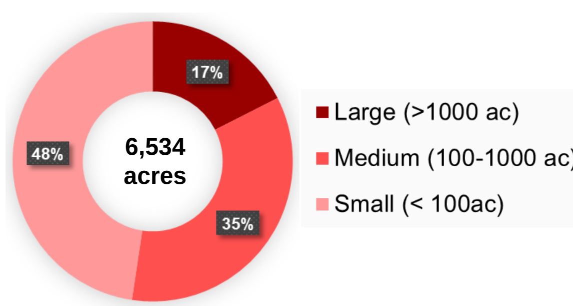

Figure D11d. Patch sizes of high-severity fire in dry and moist forests (6,534 total acres).

Ford Corkscrew Fire

The Ford Corkscrew Fire affected mostly dry forests, which burned with uncharacteristically high severity compared to historical estimates.

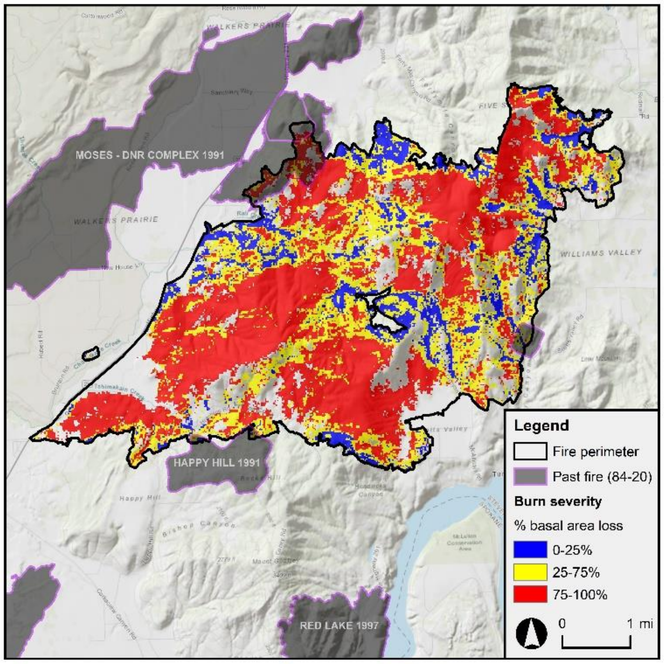

Figure D12a. Preliminary burn severity of forested areas. Basemap: ESRI World Topographic Map.

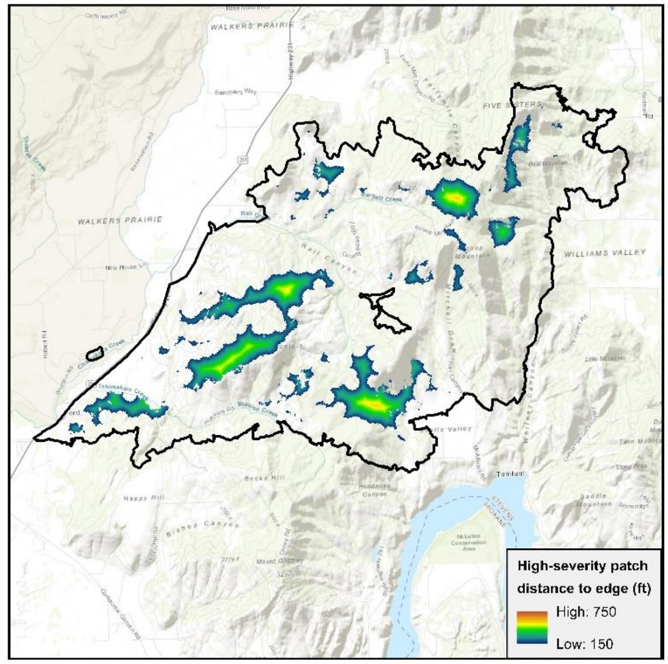

Figure D12b. Distance to edge in high-severity patches (1,996 acres). A total of 16% of the forested area that burned is >150m from potential seed sources in residual live trees.

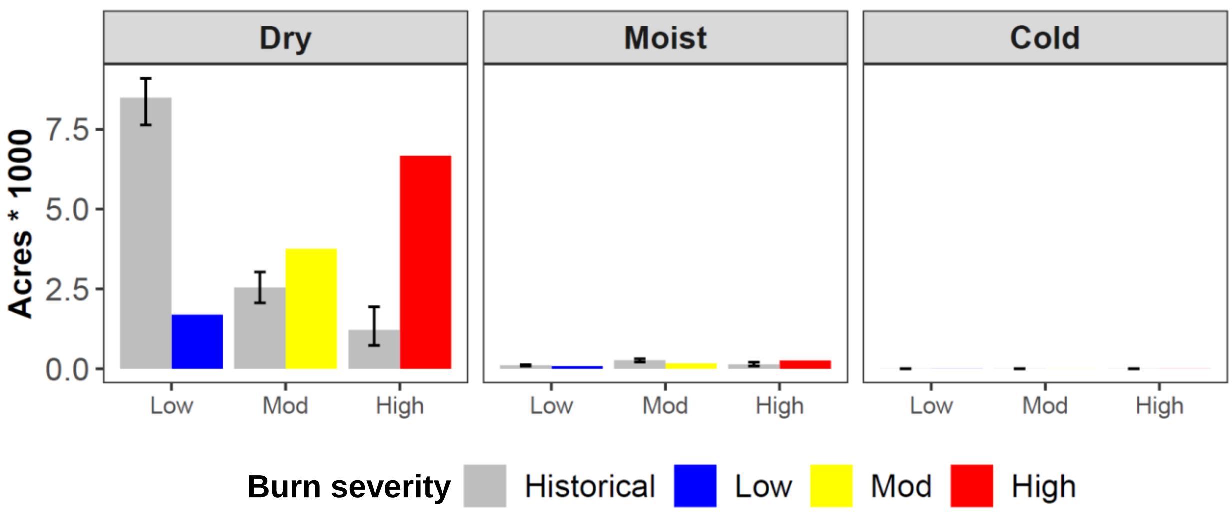

Figure D12c. Preliminary burn severity and historical estimates for potential vegetation types across forested portions (12,639 acres) within the Ford Corkscrew Fire (15,718 total acres).

Table D12a. 2021 wildfire extent and severity by forest type, including a subset of riparian forest and large trees, which often overlap.

Burn severity	Dry	Moist	Cold	Non-forest	Riparian	Large tree	Total
High	6,642	254	5	0	866	330	6,900
Moderate	3,817	166	2	0	541	208	3,985
Low	1,673	80	1	0	335	95	1,754
Total	12,131	500	8	3,079	1,742	632	15,718

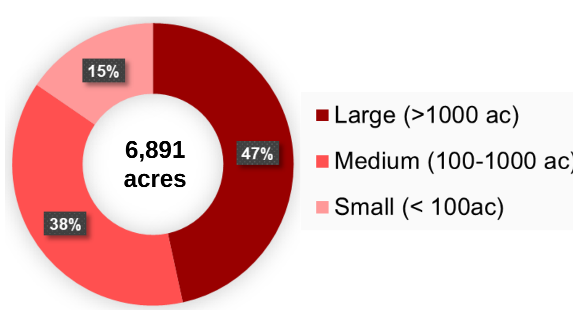

Figure D12d. Patch sizes of high-severity fire in dry and moist forests (6,891 total acres).

Muckamuck Fire

The Muckamuck Fire surrounded the community of Conconully, causing evacuations and long-lasting smoke. The fire affected mostly dry forests, which burned with uncharacteristically high severity compared to historical estimates.

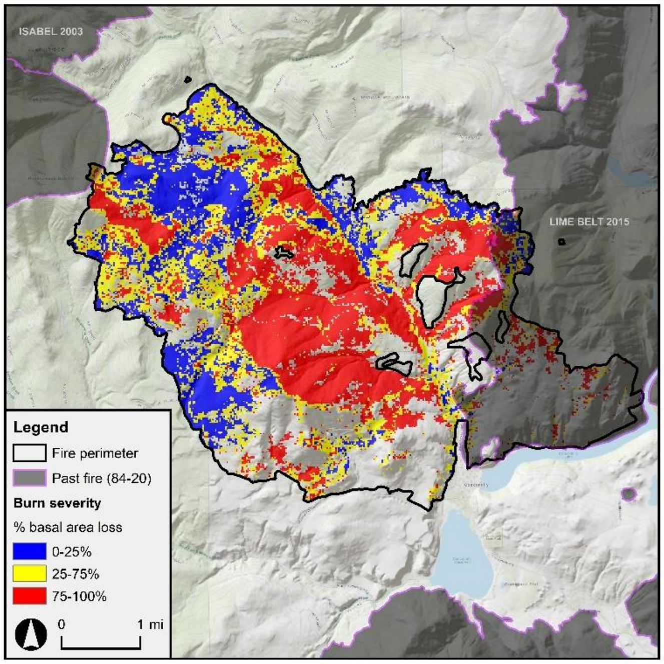

Figure D13a. Preliminary burn severity of forested areas. Basemap: ESRI World Topographic Map.

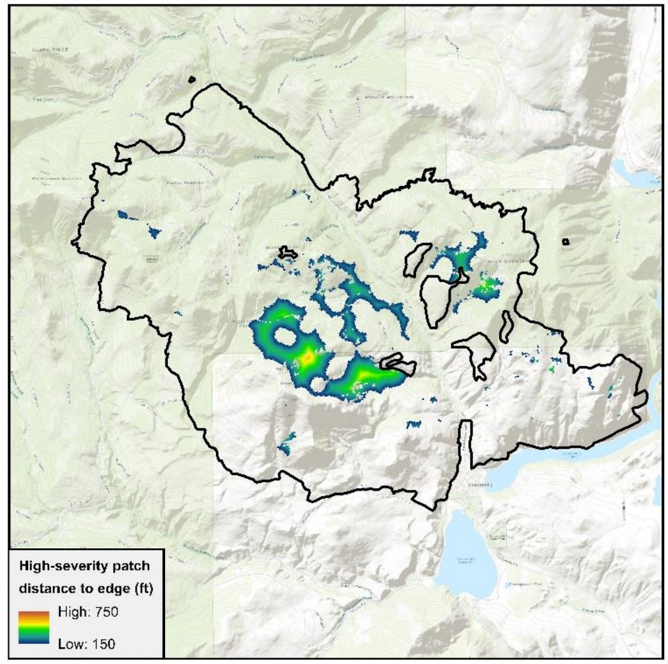

Figure D13b. Distance to edge in high-severity patches (1,066 acres). A total of 12% of the forested area that burned is >150m from potential seed sources in residual live trees.

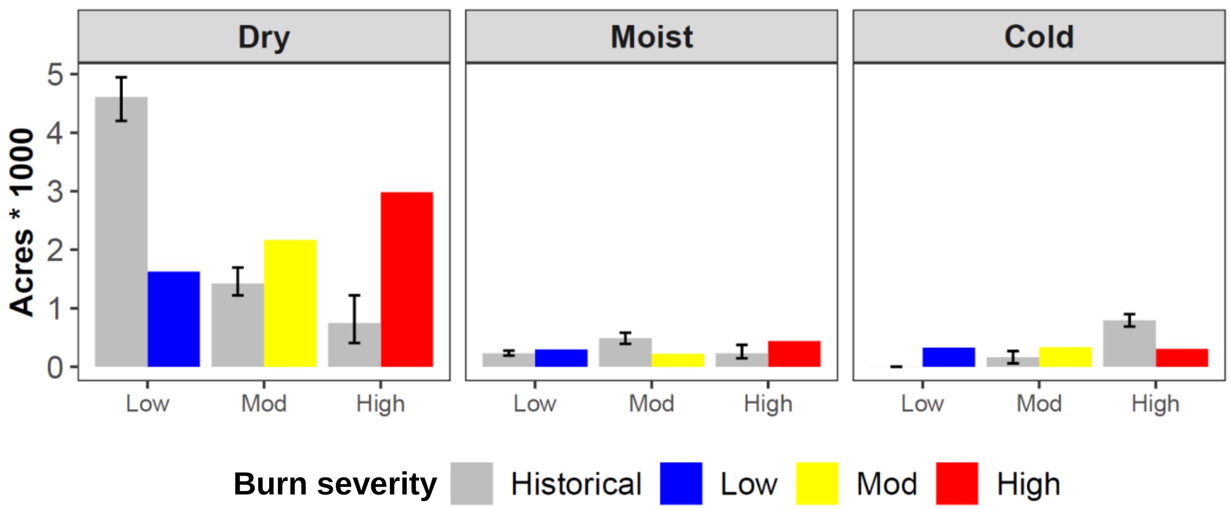

Figure D13c. Preliminary burn severity and historical estimates for potential vegetation types across forested portions (8,680 acres) within the Muckamuck Fire (13,312 total acres).

Table D13a. 2021 wildfire extent and severity by forest type, including a subset of riparian forest and large trees, which often overlap.

Burn severity	Dry	Moist	Cold	Non-forest	Riparian	Large tree	Total
High	3,015	431	289	0	951	204	3,735
Moderate	2,160	215	319	0	499	169	2,695
Low	1,643	297	310	0	335	154	2,250
Total	6,819	943	918	4,632	1,785	526	13,312

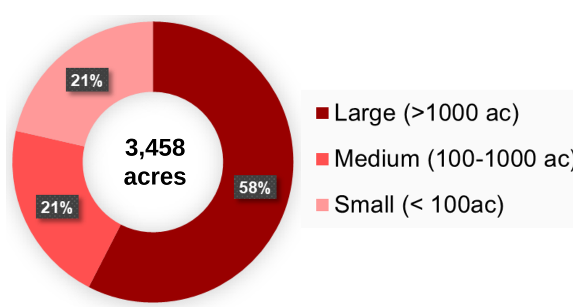

Figure D13d. Patch sizes of high-severity fire in dry and moist forests (3,458 total acres).

Bulldog Mountain Fire

This fire burned on the Colville National Forest during moderate weather conditions. It burned mostly at characteristic severity and affected a large area where a prescribed fire and other treatments were planned but had not been completed.

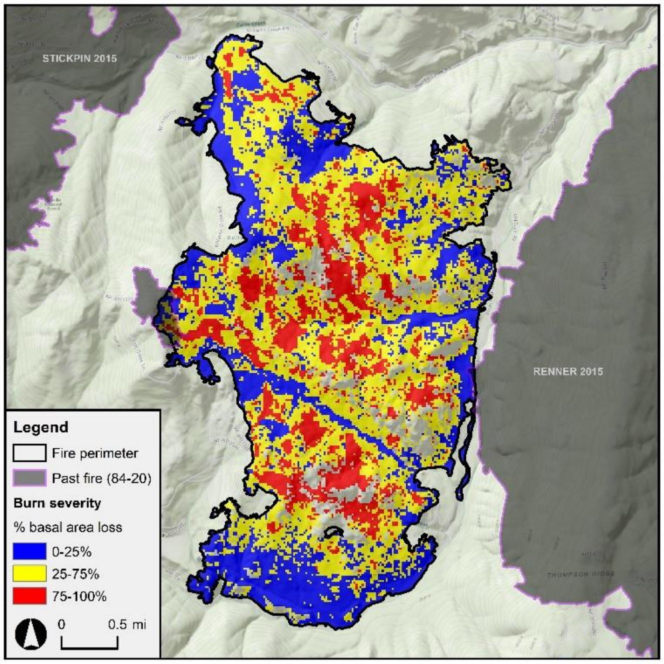

Figure D14a. Preliminary burn severity of forested areas. Basemap: ESRI World Topographic Map.

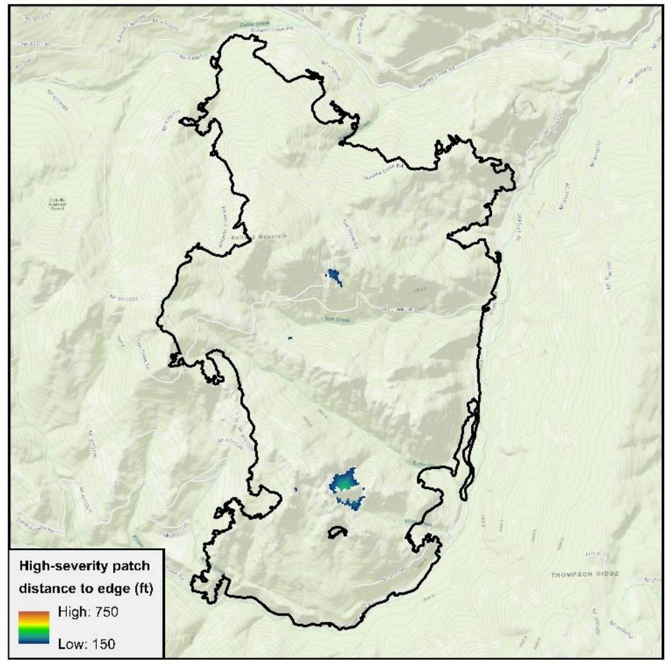

Figure D14b. Distance to edge in high-severity patches (34 acres). A total of 1% of the forested area that burned is >150m from potential seed sources in residual live trees.

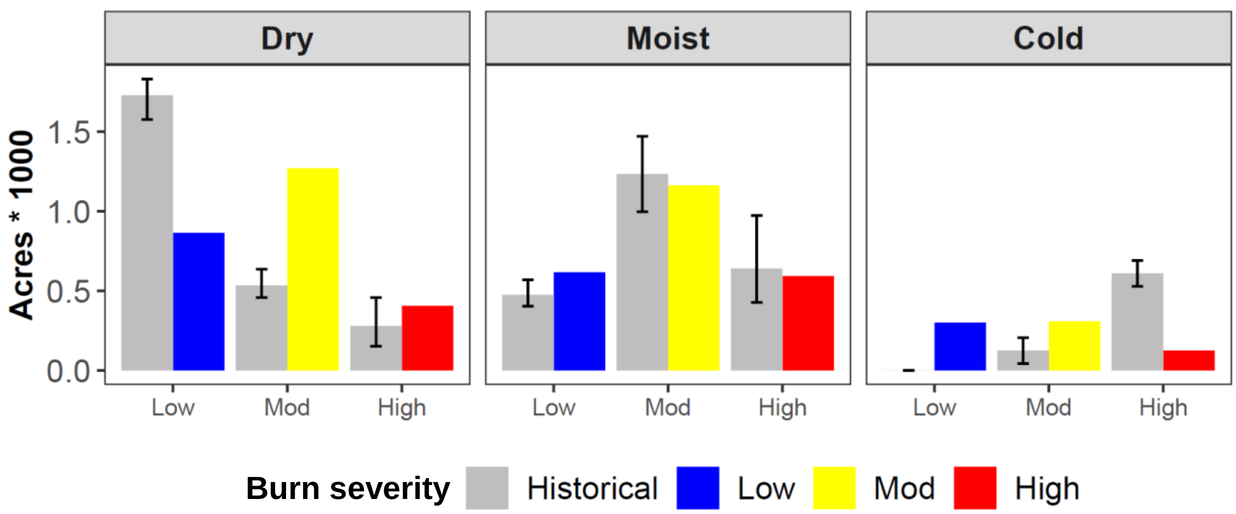

Figure D14c. Preliminary burn severity and historical estimates for potential vegetation types across forested portions (5,652 acres) within the Bulldog Mountain Fire (6,214 total acres).

Table D14a. 2021 wildfire extent and severity by forest type, including a subset of riparian forest and large trees, which often overlap.

Burn severity	Dry	Moist	Cold	Non-forest	Riparian	Large tree	Total
High	419	584	119	0	130	324	1,122
Moderate	1,289	1,147	306	0	227	985	2,742
Low	860	630	298	0	253	678	1,788
Total	2,568	2,361	723	562	610	1,986	6,214

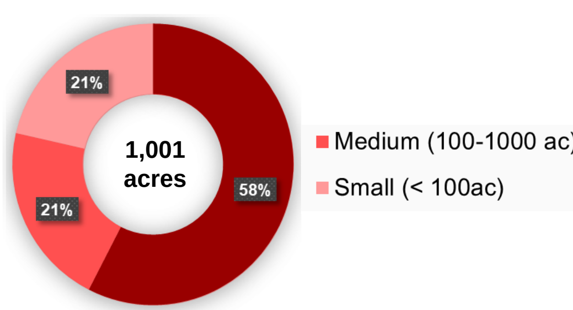

Figure D14d. Patch sizes of high-severity fire in dry and moist forests (1,001 total acres).

Chickadee Creek Fire

The Chickadee Creek Fire affected mostly dry forests, which burned with uncharacteristically high severity compared to historical estimates. The majority of high-severity fire occurred in large patches >1,000 acres.

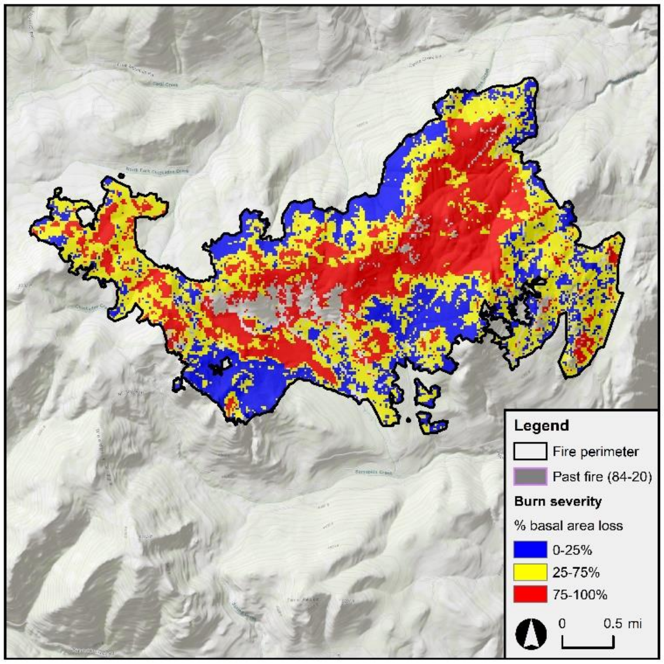

Figure D15a. Preliminary burn severity of forested areas. Basemap: ESRI World Topographic Map.

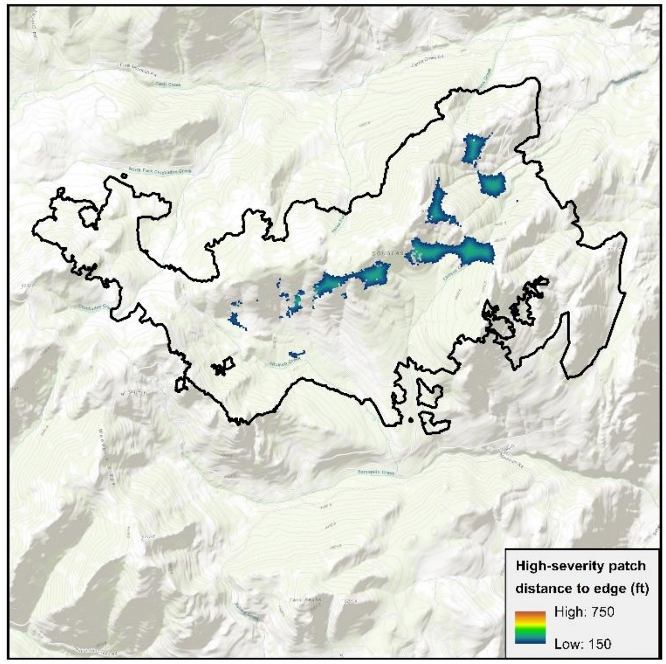

Figure D15b. Distance to edge in high-severity patches (282 acres). A total of 5% of the forested area that burned is >150m from potential seed sources in residual live trees.

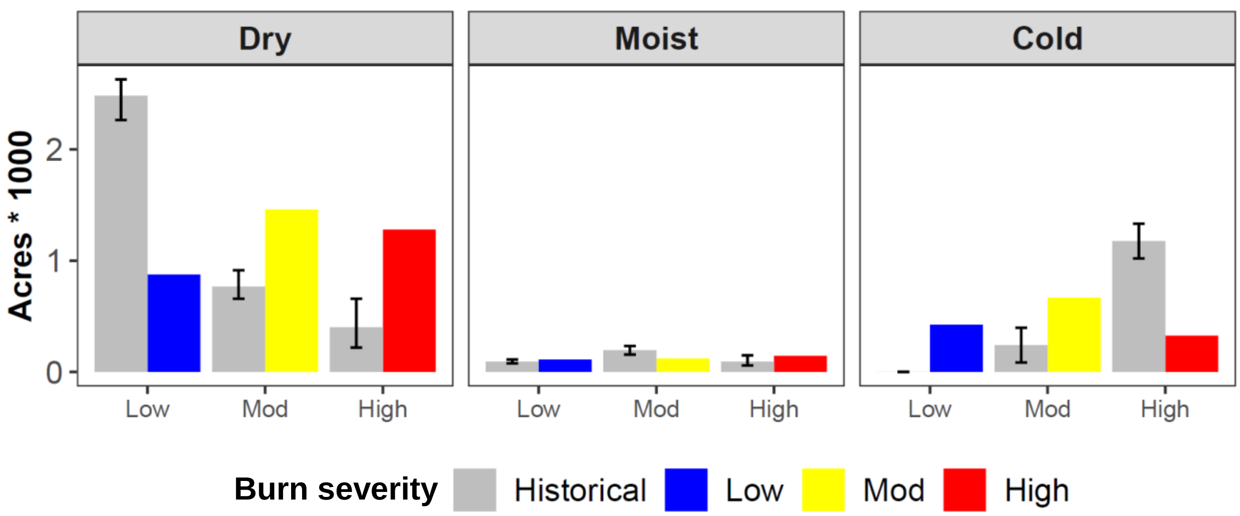

Figure D15c. Preliminary burn severity and historical estimates for potential vegetation types across forested portions (5,455 acres) within the Chickadee Creek Fire (5,859 total acres).

Table D15a. 2021 wildfire extent and severity by forest type, including a subset of riparian forest and large trees, which often overlap.

Burn severity	Dry	Moist	Cold	Non-forest	Riparian	Large tree	Total
High	1,294	148	315	0	130	171	1,757
Moderate	1,478	129	651	0	165	217	2,258
Low	890	117	433	0	129	273	1,440
Total	3,662	394	1,399	405	424	661	5,859

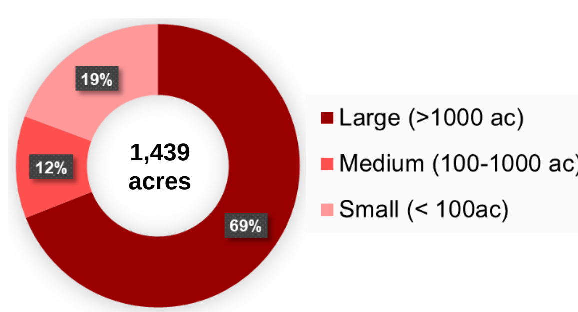

Figure D15d. Patch sizes of high-severity fire in dry and moist forests (1,439 total acres).

Appendix E. The Cedar Creek Diaries

CEDAR CREEK DIARIES

by Forest Health Science Team[1]

[1]Washington Department of Natural Resources
Forest Resilience Division
MS 47307
Olympia WA 98504-7007

CEDAR CREEK FIRE 2021

The Cedar Creek Fire was caused by lightning after a thunderstrom that rolled thorough north-central Washington on July 8 and ignited the Delancy, Cedar Creek and Varden Fires. The fires burned in steep and rocky terrain with heavy fuels, and on July 15 the Varden and Cedar Creek Fires merged into a single fire named after the latter. The newly formed Cedar Creek Fire, located roughly 3 miles southwest of Mazama, continued to progress towards the southeast in steep terrain with difficul access and working conditions. In higher elevation, the fire burned through timber with large amounts of dead and down biomass. In lower elevation, the fire burned grass and cured shrubs. On July 16 the Cub Creek2 fire was ignited on the opposite side of the Methow Valley and diverted resources from the Cedar Creek. Meanwhile the Cedar Creek Fire continued to burn on steep and rugged terrain that made direct attack by ground resources difficult. During most of July and early August, suppression objectives focused on structure point protection and holding indirect containment line where probabilities of success were highest. This resulted in long suppression timelines. The fire threatened federal, state and private land inholdings and infrastruture in the Methow Valley, Highway 20, campgrounds and trails along Twisp River among other highly-valued resources. The majority of area burned was in USDA Forest Service land (97%) followed by WA State (2%) and private (1%) land. There was no loss of life, and no structures were destroyed or damaged. Portionsof the area burned by the Cedar Creek Fire received hazardous fuel treatments in the past. These treatments included a combination of pre-commercial and commercial thining, timber harvest, broadcast burning, piling, pile burning, and the construction of fuel breaks around the wildland-urban-interface in the Methow Valley. We interviewed fire and forest managers involved in the Cedar Creek Fire, collected and analyzed official public information made available during the incident and fire weather data to tell the stories of when, were and how some of these treatments were used by fire operations from a fire operations lens. This work is not a exaustive analysis of *all* the treatment-fire interactions in the Cedar Creek Fire or *all* of their stories.

Figure E1. Fire personnel unwrapping a portal sign for the Okanogan National Forest on North Cascades Scenic Highway (State Route- 20) , August 15, 202. Source: Inciweb.

LOST DRIVEWAY UNIT 14

The Lost Driveway project in the vicinity of Mazama consisted of a 2,856-acre hazard fuels reduction project including thinning, pruning, handpiling, burning hand piles, underburning, firewood collection, and hand fireline construction on the Okanogan Wenatchee National Forest. The Cedar Creek Fire breached Unit 14, located just below the ridgeline alongside FS road 150. The unit (113 acres) had a pre-commercial thinning and piling of fuels in 2016 with piles burned 2018, almost 3 years before the Cedar Creek Fire.

Fire weather during breach

Unit 14 was breached between July 20 and 25 as the fire was backing towards Highway 20 and 20 days after the fire started. Data collected from the incident RAWS positioned at Sun Mountain for the 5-day period when the Cedar Creek Fire burned through Unit 14, showed that daily minimum relative humidity varied between 13 and 22% and maximum relative humidity (night time) varied between 37 and 45%. Recorded 6-foot wind blew predominantly from the north-northwest averaging between 4 and 6 mph with max gusts between 19 and 30 mph.

Was Unit 14 used in fire operations?

No. Unit 14 was not used directly in fire operations due to the lack of time and resources for preparing and burning the unit.

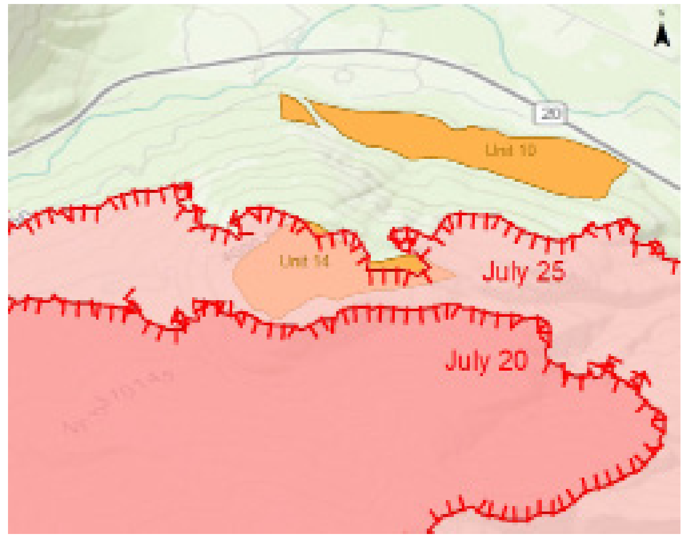

Figure E2. Lost Driveway Unit 14 was burned by the Cedar Creek Fire between July 20th and July 25th (fire edge shown in red dashed line). The unit was not directly used by fire operations.

LOST DRIVEWAY UNIT 10

Relative to Unit 14, Unit 10 is at a lower elevation and along NF road 100. Previous treatments in Unit 10 (134 acres) included thinning of hazardous fuels followed by burning of piles in 2017.

Fire weather during breach

After burning through Unit 14, the fire continued to burn downhill until it reached Unit 10 on July 27. Fire progression maps show no significant fire growth along the Unit 10 control line after July 30. Analysis of weather data for the period between July 27 and July 30 showed that minimum relative humidity varied between 14 and 21% and maximum relative humidity (night time) between 32 and 48%. Recorded 6-foot wind blew from all cardinal directions with a dominant east-southeast component alternating with east-northeast. Windspeeds averaged 4.8 mph with max gusts between 16 and 26 mph. The control line along Unit 10 was declared contained on August 8.

Was Unit 10 used in fire operations?

Yes. Unit 10 was prepped over the course of two weeks. This included handline and dozer line. The unit was burned and monitored post-fire until it was cool to the touch.

Did the treatment provide a benefit to fire management?

Because fuel loads were reduced it was safer and faster to work with fewer resources. Being able to safely back down the Fire into the Unit 10 led to less severe fire behavior than what it would have been if the treatment was not in place. The unit was strategically placed along the road in the interface between USFS and private land. One cannot understate the value of Unit 10 from an operational and safety standpoint. It provided more options to engage safely.

What highly-valued resources would be in the path of fire progression?

Multiple. Approximately 40-60 homes, a lodge, resort, fire station. Also private land, timberland, fisheries, livestock, alfafa fields, ranches, utilities along the highway. If the fire had require closing the highway that would also have economic costs.

What would have been the next available option?

Highway 20. But if the fire jumped the highway managers would not have been able to use the riparian corridor because of the pattern of winds and how they funnel in that area.

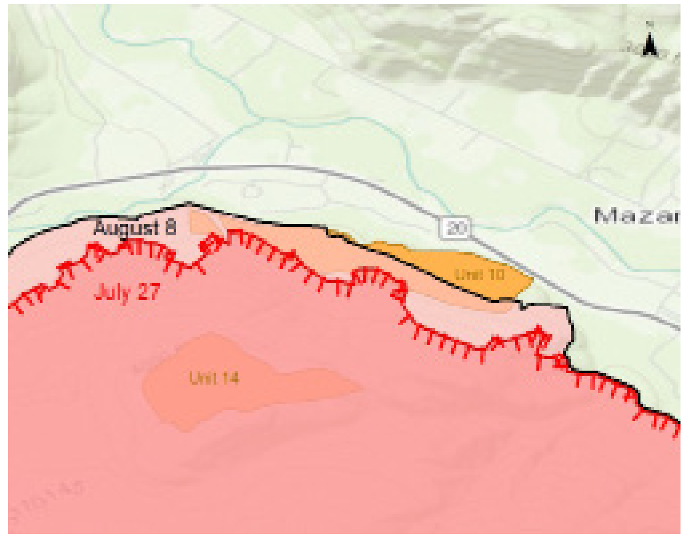

Figure E3. Lost Driveway Unit 10 was used by fire operations to control the Cedar Creek Fire along NF road 100. Containment used dozer line, handline and backburning to harden the control line. Black line shows fire edge as contained. Red dashed line shows edge of the uncontroled Fire on July 27 as it entered the unit. Highway 20 shown north of the control line was the likely next best option for containment had the control line on Unit 10 not held.

VIRGINIA RIDGE UNIT 2

The Virginia Ridge project was a 2019 DNR State Trust Lands timber sale that included specific considerations in the prescriptions to integrate forest health and resiliency stand improvements and public comments. Unit 2 (265 acres) was treated in 2019. Pre-fire fuel conditions were a 50/50 mix of ponderosa pine and Douglas-fir at approximately 40 trees per acre of 7+ inches in diameter. Surface fuels consisted of a light loading of logging slash. Activity piles remained on site.

Fire weather during breach

Unit 2 burned between July 25 and 27 as the fire head moved towards the southeast. For those three days, humidity stayed very low between 13 and 15% with little recovery at night (38 to 40%). For the first two days, 6-foot wind speeds averaged 5 mph with max gusts between 16 and 30 mph, predominantly blowing from the northwest, pushing the head fire into the Unit.

Was Unit 2 used in fire operations?

No. As of March 17 2022 we were not able to identify or interview fire staff with specific knowlege of the interactions between Unit 2 and the Cedar Creek Fire.

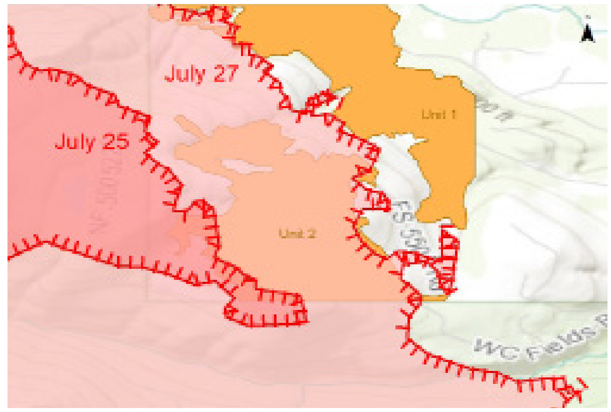

Figure E4. Virginia Ridge Unit 2 was not used by fire operations during the Cedar Creek Fire. The fire entered the unit on July 25 and by July 27 it had burned entirely. Fire progression data for July 26 are not available.

Figure E5. Virginia Ridge Unit 2 before the treatment.

Figure E6. Virginia Ridge Unit 2 in 2020, after the treatment..

Figure E7. Virginia Ridge Unit 2, March 2022, nine months after the Fire.

VIRGINIA RIDGE UNIT 1

The Virginia Ridge project was a 2019 DNR State Trust Lands timber sale that included specific considerations in the prescriptions to integrate forest health and resiliency stand improvements and public comments. Unit 1 (392 acres) was treated in 2019. Pre-fire fuels were a 50/50 mix of ponderosa pine and Douglas-fir at approximately 40 trees per acre of 7+ inches in diameter. Surface fuels consisted of a light loading of logging slash. Activity piles remained on site.

Fire weather during breach

After it burned through Unit 2 the Fire continued to back downhill until it reached Unit 1 on July 27. Analysis of available fire progression maps shows no fire growth after July 30. During that four day period minimum relative humidity varied between 14 and 21% and maximum relative humidity (night time) between 32 and 48%. Recorded 6-foot wind blew from all cardinal directions with a dominant east-southeast component alternating with east-northeast. These wind patterns likely favored firing operations and successfully holding the line as wind pushed fire into the burned area. Windspeeds averaged 4.8 mph with max gusts between 16 and 26 mph. The control line along Unit 1 was declared contained on August 1.

Was Unit 1 used in fire operations?

Yes. Burning was conducted overnight by the Zig Zag Interagency Hotshot Crew utilizing indirect dozer line and the Wolf Creek Road. Fuel treatments allowed firing to commence with minimal preping work. Unit prepping before burning took approximately two days and it involved dozer line and tree cutting with a feller buncher. The unit was used to light a fire along Wolf Creek Road and the 800 Rd that runs through the middle ot the Unit. The firing happened under night operations conditions, which had more favorable relative humidity, temperature, fuel temperature, fine fuel moisture. These conditions, coupled with the prior fuels treatment, led to favorable burn conditions that had a high likelihood of control as well as a good amount of consumption. This fuels consumption from the burnout led to assisting with the control of the fire in the vicinity of Virginia Ridge.

Did the treatment provide a benefit to fire management?

Fire behavior was kept to a minimum and the fire stayed within the control lines. The treatment, along with how the fire backed down the slope, definitely helped reduce resource loss. Overall operations went well and damage to timber was minimal. If the same fire would've burned in the area without a treatment, fire intensity would've been greater and more timber would have been killed. It required less people to contain that part of the fire. It was safer, required less mop-up, and kept damage to the existing stand of timber to a minimum. The treatment area was in a beneficial location based on its location to road systems and the Methow River. As the team proceeded with firing operations we came into an area outside the fuels treatment project. This area had an immediate change with an increase in fire intensity, duration, and difficulty of control. This fire behavior change was directly related to the difference in fuel loading and arrangement between the treated and untreated fuels.

What highly-valued resources would be in the path of fire progression?

Numerous homes along Wolf Creek Road and approximately 5,000 board feet of timber.

What would have been the next available option?

Methow River.

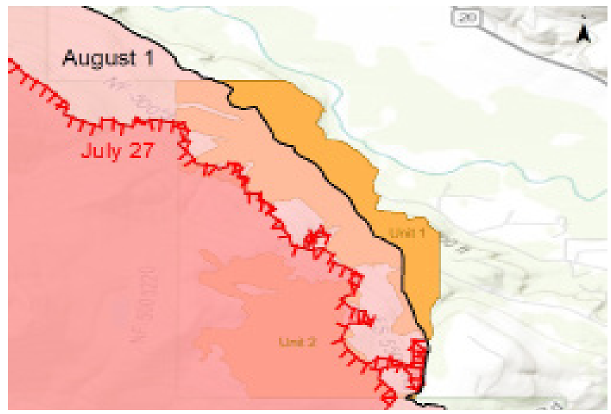

Figure E8. Virginia Ridge Unit 1. Black line shows fire edge as contained. Red line shows uncontained fire progression as the Cedar Creek Fire was approaching Unit 1. North of the containment line is the Methow River which would be a likely option to control the fire had the line along Unit 1 not held.

Figure E9. Example of pre-fire conditions in Virginia Ridge Unit 1.

Figure E10. Post-fire conditions in Virginia Ridge Unit 1. The treated unit provided firefighers with a place to start a burnout. A burnout is a tactical operation that involves purposefully igniting surface fuel between a control line and the fire's edge to help control the fire as it moves towards the containment line. The area of the burnout needs to be prepared by reducing fuel loads prior to firing operations. This is done to reduce the risk of spot fires during the operation and keep the lit fire at lower intensities.

FIRE MANAGERS INTERVIEWED

Jake Townsend

Jake is a Silviculture Forester with the Washington Department of Natural Resources and was a resource advisor for the Cedar Creek Fire when Virginia Ridge Unit 1 was used operationally.

ZigZag Interagency Hotshot Crew

Superintendent Devin Parks and Assistant Superintendent Sandra Sperry provided information regarding firing operations in Virginia Ridge Unit 1.

Matt Ellis

Matt Ellis is the USDA Forest Service Methow Valley Ranger District Fire Management Officer and provided information regarding the interactions of the Cedar Creek Fire with units 14 and 10 of the Lost Driveway project.

PHOTO CREDITS

Figure E1: USFS via Inciweb
Figure E5: Jake Townsend WADNR
Figure E6: Ana Barros WADNR
Figure E7: Ken Bevis, WADNR
Figure E9: Ana Barros, WADNR
Figure E10: Chuck Hersey, WADNR