Libby Asbestos Superfund OU3
DRAFT Fire Behavior/Fuels Report

February 4, 2016

Introduction

Purpose

The EPA has asked the Forest Service to assist in identifying areas where fuels treatments, fire mitigation activities, and other fire protection activities would reduce the risk of fire in the most heavily contaminated area (Grace's Proposed OU3 Area, roughly approximated by the dashed black/white line in Figure 1), thereby enhancing the protection of the CERCLA remedy of OU3. The intent is to maximize suppression effectiveness because fires will occur and resources will be limited, and resource benefit objectives are not a consideration due to the re-suspension risk.

End State: Utilize professional experience and fire modeling to assist the agencies in identifying an area around the most heavily contaminated areas where a combination of fuel treatments (past and proposed), improved road access, and other activities that would maximize fire suppression effectiveness. The modeling effort will show the potential extent of wildfire spread into, around, and from the Grace's Proposed OU3 Area (Area of Concern). The process, assumptions, and decisions will be well-documented and repeatable.

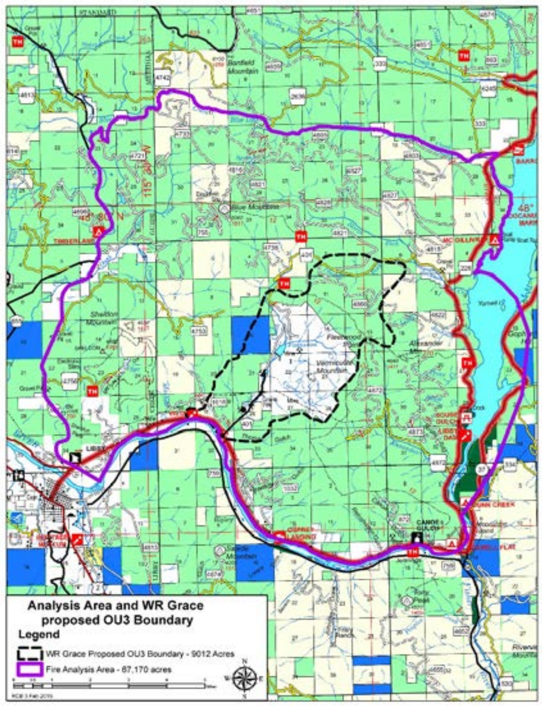

Figure 1. WR Grace Proposed OU3 Boundary and analysis area.

Analysis Area

The initial analysis area was large (Figure 1) and included the existing southern OU3 boundary on the Kootenai River and along the western edge of Lake Koocanusa heading north to Baron Creek then west along Blue Creek Road # 615 to its intersection with the Pipe Creek Road #68 and finally south back to the Kootenai River. The area selected had to be large enough to capture large fire scenarios generated in the fire modeling. The area also had to include the portions of Grace's Proposed OU3 Area that extends beyond the original OU3 boundary (known locally as FMU3).

The analysis area can generally be described as a largely forested heterogeneous landscape with a mix of species and a variety of age classes from past harvest. Ownerships within this area include US Forest Service, WR Grace Mine site and surrounding property, Plum Creek Timberlands, State Lands and several inclusions of private property. The Alexander Creek Roadless Area covers approximately 6600 acres in the SE corner of the analysis area.

Executive Summary

The Kootenai National Forest assembled a team with experience managing long-term wildfires in the Northern Rockies. Individuals were selected based on their extensive fire behavior and modeling experience as well as knowledge of fires in regional fuels and weather conditions. The planning team was comprised of two long term fire analysts, a geographic information system specialist, a strategic operational planner and an Incident Commander as the team leader. Fire and forest managers with local knowledge and many years of experience on the Kootenai National Forest were also consulted, provided valuable information on vegetation, distribution, stand characteristics as well as fire behavior and fuel treatments that proved essential to the integrity of this project.

Large fires ignite, move, and burn on the Kootenai National Forest. Under average fire season conditions, fires are successfully attacked and extinguished; therefore, it is the fire behavior in the above-normal years that is of most concern. Fire behavior exceeding control tactics occurred most recently in 2015 and the frequency of these above-normal fire years is expected to increase. The planning team assembled a large fire history and examined spread events to illustrate the potential for fire spread. The lack of recent large fires in the immediate vicinity of the mine does not indicate a lack of fire potential. Natural stand succession, without any disturbance, has resulted in denser canopies, multi-storied structures with ladder fuels and lower crown base heights that create conditions for an increase in fire intensity and susceptibility to crown fire.

Full suppression in the analysis area is the planned response. Fuel treatment locations were designed based on an assessment of where fires would move with intensities that challenge resistance to control operations. We adopted general guidelines on how to treat surface and canopy fuels to meet objectives from previous forest planning documents and current literature, recommending that these are further refined with ground verification and silvicultural prescriptions tailored to individual stand characteristics. Seventy-three treatment units over 6,000 acres in and around Grace's Proposed OU3 Area (the planning team referred to this in documentation as the "Area of Concern") were identified.

Operational application of fire behavior models by the team aided the design of proposed fuel treatment areas by confirming what fire and fuels experts delineated on maps (NAIP imagery). Landscape fire spread models were used to examine how fuel treatment patterns change spatial patterns that impact burn probability and large fire spread pre- and post-treatment. Fire behavior modeling was only used to support and verify what team members and local fire managers recommended.

Overall, the collection of treatments across the landscape show reduction in fire size, fire intensity, crown fire potential, and spotting. Reduction in fire intensity will improve suppression effectiveness, which will help meet suppression objectives in the overall area. Proposed treatments link or connect past vegetative treatments. The explanation seems straightforward given our collective experience in fighting wildfires, conducting prescribed burns and designing fuels treatment throughout our careers. Areas in the models that exhibited problematic fire behavior such as high flame lengths (greater than 4 feet), crown fire potential and spotting were those same areas identified on imagery that have not had any disturbance within the last 50 years.

In addition to vegetative fuel reduction treatments, the planning team made other recommendations that enhance fire suppression effectiveness, such as opening roads that are currently impassable, and applying connectivity to past treatment areas.

Team Members

The forest used the team approach in conducting this analysis. They assembled a group of experts from the Northern Rockies Wildland Fire Management Team and local resource specialists as listed in the table below.

Table 1. Team Members

Core Analysis Team	Position
Diane Hutton	Incident Commander-Team Leader
Mary Taber	Long Term Fire Behavior Analyst
Tonja Opperman	Long Term Fire Behavior Analyst
Byron Bonney	Strategic Operational Planner
Ray Backstrom	GIS Specialist
Local Resources	
Ed Morgan	District GIS Specialist
Nikia Hernandez	District Fire Management officer (FMO)
Dan Rose	Forest FMO
Jeff Stevenson	Forest Assistant FMO
Tim Bumgarner	Fuels Specialist
Grant Rider	District AFMO/operations
Seth Cole	District Timber/Vegetation staff officer
Ron Hvizdak	Fire Management Officer-retired
Glenn Gibson	Fire Management Officer-retired
Wyatt Frampton	DNRC-Libby Unit Fire Supervisor

Fire Occurrence

There has been a total of 77 fires within the Wildfire Response Zones in FMU3 in the past 24 years with an average annual fire occurrence of 4 fires per year and a total of 90.5 acres for an average of 4 acres per year. The highest concentration of fire starts is in the Canoe Gulch, Em Kayan, Rainey Creek Restricted, and Fleetwood Point Wildfire Response Guide Zones. All of these areas with higher wildfire occurrence are located to the south and east of Grace's Proposed OU3 Area.

Table 2. Fire Occurrence

Fire Occurrence 1992-2015											
Wildfire Response Zone from KNF OU3 Wildfire Response Guide	# of Fires	# of Acres Burned	# Fires by Cause								
			1	2	3	4	5	6	7	8	9
Rainey Creek – Restricted	11	12.4	9			2					
Em Kayan	15	2.6	9		1	1				1	3
Canoe Gulch	19	17.4	11	1		1	1				5
Alexander Creek	7	1.6	7								
Fleetwood Point	12	4.1	12								
S. Fk. Jackson Creek	5	26.3	3			1	1				
Blue-Sheldon Mtn.	8	26.1	5			2					1
Total	77	90.5	56	1	1	7	2	0	0	1	9

Fire Cause Descriptions: 1-Lightning; 2-Equipment Use; 3-Smoking; 4-Campfire; 5-Debris Burning; 6-Railroad; 7-Arson; 8-Children; 9-Miscellaneous.

While it is not possible to predict when or where a fire will occur, fire weather forecasters do forecast when lightning storms may occur and will predict the lightning activity level of those storms. Most lightning fires occur during July and August. Person-caused fires are much more difficult to predict because they can occur any time at any location. A fire season ending rain event traditionally occurs between the third week of August and the third week of September. The exceptional years when this rain event does not occur will see the fire season extending into mid to late October.

Table 3. Fire history in KNF FMU3.

# Fires & # Acres per Year – 1992-2015					
Year	# Fires	# Acres	Year	# Fires	# Acres
1992	4	26.1	2004	8	11.6
1993	0	0	2005	1	0.6
1994	10	28.5	2006	10	11.4
1995	0	0	2007	11	2.5
1996	2	0.2	2008	4	2.3
1997	4	0.5	2009	1	0.1
1998	4	0.5	2010	3	1.2
1999	5	1.8	2011	2	0.2
2000	0	0	2012	1	2.1
2001	0	0	2013	0	0
2002	2	0.2	2014	1	.1
2003	2	0.2	2015	2	.4
Total	31	57.8	Total	46	32.7
Total # Fires		77	Total # Acres Burned		90.5
Avg. # Fires/Year		4	Avg. # Acres Burned/Year		4

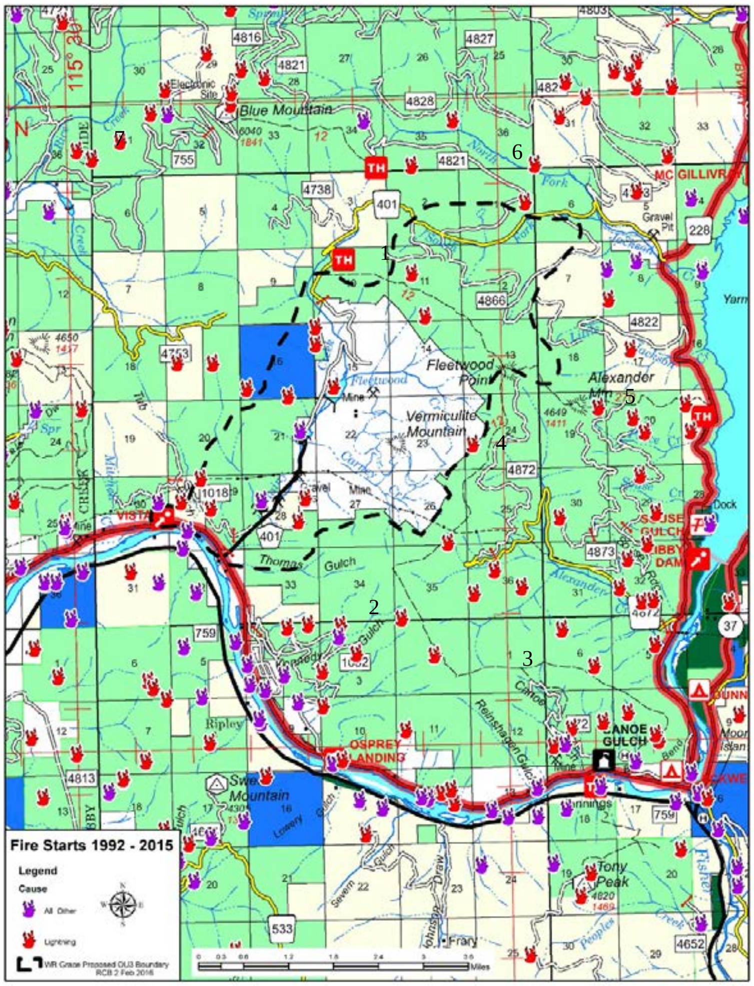

Figure 2. Fire ignitions from 1992-2015.

Large Fire History and Fire Potential

Characterizing the type of fire that is of concern in the area must be understood in order to mitigate large fire potential. We assembled information based on fire weather and fire occurrence records for the Kootenai National Forest spanning 1991-2015, a map of fire ignitions from 1992-2015, information in the Wildland Fire Decision Support System for large fires in 2015, the Kootenai NF Pocket Card, Remote Automated Weather Stations (RAWS), a fire history map of final sizes, and—most importantly—conversations with local active and retired fire management personnel, and their own experience modeling fire behavior in the Northern Rockies (most recently on the Clark Fork Complex, 2015 on the Kootenai and Idaho Panhandle NFs).

The following table shows the history of recent large wildfires (over 1,000 acres) on the Kootenai National Forest from 1991 through 2015. There have been 33 large fires on the forest since 1991 that have burned over 127,000 acres on the forest in this 25-year period. This is an average burned acreage of over 5,000 acres per year. These fires ranged in size from 1,000 acres to 11,115 acres.

Table 4. Large Fire History.

Fire Name	Origin Date	Total Acres Burned	Fire Name	Origin Date	Total Acres Burned
Keystone	10/16/91	7,869	Kopsi	9/2/98	1,060
Arbo	10/16/91	3,551	Stone Hill	8/11/00	11,115
N. Fk. Big Creek	8/15/94	9,000	Upper Beaver	8/11/00	9,425
Sheep Range 3	8/15/94	5,897	Cliff Point	8/10/00	6,660
Little Wolf	8/15/94	4,500	Lydia Mountain	8/11/00	5,895
Webb Knob	8/15/94	3,500	Kelsey Creek	8/11/00	2,768
Scenery 1	8/15/94	3,245	Taylor Creek	8/10/00	1,311
Upper Fowler	8/15/94	2,470	Lawrence Mountain	9/2/09	2,400
Pulpit	8/15/94	2,023	Napoleon 1	8/13/15	8,967
17 Mile	8/14/94	1,715	Marston	8/11/15	7,552
Studebaker	8/16/94	1,592	Klatawa	8/14/15	5,538
Smith Peak	8/15/94	1,522	Berray Mountain	8/13/15	4,966
Fish Fry	8/22/94	1,420	Sawtooth	8/15/15	2,680
High One	8/15/94	1,300	Napoleon 3	8/13/15	UNK
Scenery 2	8/15/94	1,245	Teepee Mountain	8/14/15	1,018
Roberts	8/15/94	1,000	Poplar Point	8/14/15	UNK
Dome	9/2/98	3,340			

The historical record does not show any recent large fires in the Grace's Proposed OU3 Area (Area of Concern). The last large wildfire in this area (>1,000 Acres) was in 1910 that burned an area of approximately 11,000 acres. There have been about 10 smaller fires (10-100 acres) within the area. The most recent of these 10 smaller fires was in 2004 burning 25 acres. A map of large fire history can be found in Appendix C.

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Problematic fire conditions occur when multiple ignitions take place over a short period of time under conditions that support large fire spread. This occurs most often from July 22-August 28 when the Energy Release Component (ERC-G) is above 50 (*ERC is a number describing available energy per square foot of fuel based on fuel dryness and recent moisture and is used as the most common indicator of local fire danger*). This occurred most recently when 14 large fires were ignited August 14-22, 1994; when 6 large fires were ignited on August 10-11, 2000; and when 8 large fires were ignited during August 11-15, 2015. More information is available in Appendix B Topic, "Weather Data and Fire Statistics".

Spread Events in Surrounding Area

Several fires in the area have exhibited spread characteristics and fire behavior with high resistance to control due to terrain, fuels, spotting, resource shortages, and wind events. Some of those details are presented here. More detailed information is provided in Appendix B, "Historic Spread Events". Even without any fire modeling, it is apparent that fires in this area start, move, and get large. Many such fires have occurred on the Kootenai NF when it is impossible to control the head of the fire. These examples give a good indication of fire potential in the area of interest.

We reviewed recent fires to determine fire spread in similar fuels, on similar terrain within 40 miles of the project area. Those fires include: Lawrence Mountain (2009), Brush Creek (2007), Marston Fire (2015), and Klatawa Fire (2015). This information is detailed in Appendix B topic: "Historic Fire Spread Events" and we recommend more of these fire events are examined to establish further evidence regarding how fires spread and move and under what conditions these events occur. Much of the data needed for this analysis is in fire documentation boxes in paper format, or on archived hard drives.

Depletion of firefighting resources often occurs during these multiple ignition events if fuels are dry across the Northern Rockies Geographic areas and other forests are also experiencing large fires. Firefighter drawdown levels are a concern when high intensity wildfire conditions are present over the greater area because firefighting resources are controlled by the Northern Rockies Geographic Area Coordination Center (NR-GACC) when widespread and problematic fires occur and there are not enough firefighting resources to staff every single fire adequately.

Even if more firefighting resources were available, the types of fires that occurred in 1994, 2000, 2015, and other years could not likely be extinguished. This situation is most apparent in California, which has the largest wildfire fighting force in the U.S. and yet continues to have unprecedented wildfires [Rough Fire (2015), Valley Fire (2015), Rim Fire (2013), Station Fire (2009)] every few years. Since fires burn as a result of the fuels, weather and topography it would be best to focus on changing the fuel composition across the landscape to mitigate problematic fire behavior.

Defining Unacceptable Fire Behavior

Based on Leader's Intent and through further discussion with local Kootenai National Forest fire and resource staff, local wildland fire experts and EPA Superfund Project Manager Christina Progess, the team defined "unacceptable fire behavior." These items are discussed in more detail in this section.

The group concluded that the unacceptable fire behavior that would threaten the remedy within Grace's Proposed OU3 Area (Area of Concern) and limit suppression effectiveness would be defined as:

- crown fire within the Area of Concern;
- flame lengths that limit effective suppression within the Area of Concern;
- and spotting within approximately 1 mile of the Area of Concern.

Crown fire within the Grace’s Proposed OU3 Area (Area of Concern)

Crown fires are highly resistant to control. *Passive crown fires* burn vertically up individual trees or small groups of trees from the surface fuels below; passive crown fires are often referred to as “torching.” *Active crown fires* burn the entire tree canopy and spread horizontally through the canopy from crown to crown; they are dependent on heat from surface fires for continued spread. [Kootenai NF Flower Creek Fuels project file—Fire and Fuels write-up, unpublished]. Crown fire—particularly active crown fire—can cause surface and canopy fuels and other materials associated with them to be convectively lifted into the air and deposited downwind, or even in all directions under extreme fire behavior conditions.

Flame Lengths that limit effective suppression within Grace’s Proposed OU3 Area (Area of Concern)

Flame length is determined by the rate of spread and the heat per unit area of the fire (Andrews and Rothemel 1981). It is a rough approximation of fireline intensity that is routinely used as a visual indicator to determine which suppression resources would be effective in suppressing a wildland fire. As flame length increases, suppression options increase in complexity and cost, from low flame lengths easily controlled by ground crews building handline, to moderate flame lengths on which heavy equipment and aircraft can be effective, to fires with longer flame lengths and greater fireline intensity on which any control effort at the head of the fire will be ineffective. Flame length and fireline intensity can be interpreted in terms of suppression capabilities as shown below. (Flame length refers to the flame length for surface spread, not crown fire flame length).

Table 5. Fire suppression interpretations of flame length and fireline intensity (Andrews and Rothermel 1981).

Flame length		Fireline intensity		Interpretation	
ft	m	Btu/ft/s	kJ/m/s		
< 4	< 1.2	< 100	<350		• Fires can generally be attacked at the head or flanks by persons using hand tools. • Hand line should hold the fire.
4 – 8	1.2 – 2.4	100 – 500	350 – 1700		• Fires are too intense for direct attack on the head by persons using hand tools. • Hand line cannot be relied on to hold the fire. • Equipment such as dozers, pumpers, and retardant aircraft can be effective.
8 – 11	2.4 – 3.4	500 – 1000	1700 – 3500		• Fires may present serious control problems—torching out, crowning, and spotting. • Control efforts at the fire head will probably be ineffective
> 11	> 3.4	> 1000	> 3500		• Crowning, spotting, and major fire runs are probable. • Control efforts at head of fire are ineffective.

Spotting within 1 mile of Grace's Proposed OU3 (Area of Concern)

A wildland fire is said to be "spotting" when it produces sparks or embers that are carried by the wind and start new fires beyond the zone of direct ignition by the main fire. Ember production from torching trees and crown fire can rapidly advance the fire front, increasing its growth and allowing it to cross natural or artificial barriers, compromising suppression effectiveness, access routes and firefighter safety (Albini 1979; "18 Watchout Situations"). In order to protect the EPA remedy within the Area of Concern, the Area of Concern must be protected from fire starts due to spotting from outside the Area of Concern. [Detailed documentation for the determination of spotting distance is found in Appendix B]. Fire brands more readily ignite fuel when the Probability of Ignition (POI) is high. Conditions under which fires are likely to escape initial attack efforts are when 1-hr fuel moisture is low and air temperatures are high. The POI table shows high POI when 1-hour fuel moistures are less than 7%.

Table 6. Probability of Ignition output table.

Probability of Ignition from a Firebrand (%)

1-h Moisture %	Air Temperature oF 70	80	90	100
1	100	100	100	100
4	70	73	76	78
7	46	48	50	52
10	29	31	32	34
13	18	19	21	22

Fire Behavior Modeling

Fire Ignition Scenarios

Through discussions with local Forest staff, three specific fire start scenarios were identified that would be expected to represent the greatest potential threat to Grace's Proposed OU3 Area (Area of Concern). Each ignition was modeled for 3 hours using Near Term Fire Behavior to simulate extreme conditions with failed initial attack. The resulting fire size was used as a starting ignition for additional, long-term modeling. The Lawrence Creek wildfire north of the mine area grew over 100 acres for each of the first three days when it was unable to be extinguished upon discovery (see Appendix B).

Scenario 1 is an ignition along the road in private property west of the Rainy Creek drainage. This location has steep slopes and grass fuels. An atlas of recent fire ignitions (human and lightning-caused) indicates ignitions along the road are common in this particular portion of the landscape. A 160-acre shapefile was then created as the ignition for 3-day projections in the Near Term Fire Behavior model and simulating 7-day burn probabilities with the Fire Spread Probability model.

Scenario 2 is an ignition approximately 2 miles north of Scenario 1 in a forested area with 3 lightning strikes since 1992 according to the fire occurrence database. This ignition was modeled for 3 hours to represent ineffective initial attack suppression efforts. The resulting 32-acre fire footprint was created as the ignition for 3-day projections in the Near Term Fire Behavior model and simulating 7-day burn probabilities with the Fire Spread Probability model.

Scenario 3 is an ignition in the Alexander Creek Inventoried Roadless Area east of Rainy Creek and north of Highway 37. This ignition would pose added complexity due to a lack of roads in the area. This location has steep slopes and grass fuels. A 130-acre shapefile was created as the ignition for 3-day projections in the Near Term Fire Behavior model and simulating 7-day burn probabilities with the Fire Spread Probability model.

More information is available in Appendix B, "Fire Ignition Scenarios".

Modeling the Pre-Treatment Condition

Modifying the Landscape Files: LANDFIRE 2012 v 1.3.0 derived from within the Wildland Fire Decision Support System (WFDSS) was used for the modeling. Discussion with local fire staff and examination of fire behavior analyses performed during the 2015 fire season supported converting a prevalent grass-and-shrub fuel model (GS2 or 122) to less active fuel models, and reducing the canopy cover in one fuel model (165). This landscape file was then used in all of the pre-treatment fire behavior analyses. See Appendix B topic, "Modifications to Landfire 2012 to Represent Existing Condition".

Identifying Vegetation Types ("Fuel Models") that Exhibit Unacceptable Fire Behavior

After the landscape was edited and verified by local fire managers and fire behavior specialists, simple fire behavior modeling was used to characterize fire behavior across the greater area by defining weather scenarios, fuel moisture scenarios, and running Basic Fire Behavior (which is the same as Behave Plus 5, but calculated geospatially).

Defining the weather scenarios. Weather information was, for the most part, taken from real weather streams and not invented. In some cases, to test specific spread scenarios, for example, a wind azimuth showing at the Libby RAWS as easterly in the middle of the burn period, was changed to 225 to represent a SW wind vector in the model. All such instances of modifying weather variables are disclosed in Appendix B, "Defining the Weather Scenarios".

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Based on the ERC analysis, 2007 weather data represents a recent, dry, seasonal scenario. It is likely that the past does not adequately dictate the future; fire seasons are getting longer, available burnable area has increased, and fires may become more problematic in the future (Jolly and others 2015). The year 2007 was chosen to represent daily weather and fuel moisture conditioning. The Big Creek Baldy RAWS was used for representative winds that are not significantly impacted by terrain. Although this station has data gaps in recent years, there are several data points that create a windrose that is similar to most other ridgetop wind data in the area. Libby RAWS is an extremely sheltered station that often shows winds of 0-3 mph in the middle of the burn period when winds affecting fire spread are 2-4 times greater at higher elevations where fires occur.

Fuel Moisture Scenarios. Based on analysis of fire behavior modeling done on area wildfires in 2015, weather data from 2007 (to ensure that we were designing treatments resistant to extreme but actual conditions), records of field sampling of live fuel moistures, and input from WR Grace analysts, the fuel moisture scenarios used for the analyses were:
Dead Fuel Moisture
1-hour: 3%
10-hour: 4%
100-hour: 8%
Live Fuel Moisture
Herbaceous: 60%
Woody: 90%

Detailed documentation of the justification for the live fuel moisture scenario is found in Appendix B, "Live Fuel Moisture Inputs".

In order to locate the areas that could experience unacceptable fire behavior over a large landscape, Basic Fire Behavior analyses (BFB –the equivalent of FlamMap within the WFDSS user interface) were used to derive common characteristics of those problematic areas. The above fuel moisture scenarios were used with a gridded wind of 30mph; Libby RAWS was used for fuel conditioning (7 days) for an 8/1/2007 run.

Figure 3. Short-duration crown fire runs would be expected when wind, slope, and heavy fuels are aligned. This photo taken on the Clark Fork Complex west of mine site on Kootenai NF, 2015. The black area in the photo represents how the "red" pixels in Basic Fire Behavior are expected to burn.

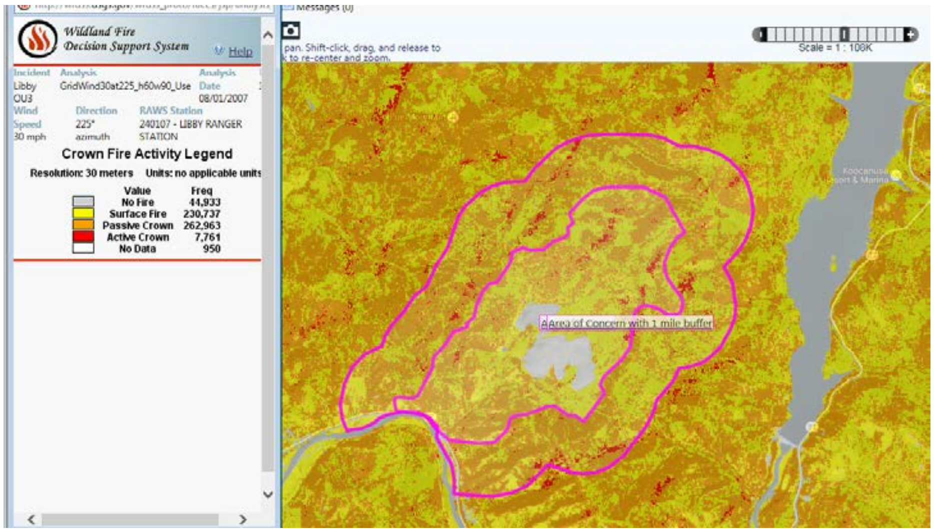


Figure 4. Crown fire output for southwest wind under existing conditions.

The "Haul Chart" output within the WFDSS interface was used to examine suppression effectiveness, as the Haul Chart is a commonly-used tool for this purpose (Andrews and Rothermel 1982; Andrews et. al. 2011). Areas in blue can be effectively attacked by handcrews; green denotes areas where heavy equipment, wider control lines and aerial resources may be necessary; yellow areas are expected to challenge suppression effectiveness with torching, short crown runs and spotting; orange and red areas depict areas where under the given conditions, major crown runs and other extreme fire behavior can be expected, and control efforts are unlikely to be successful. (Flame length refers to the flame length for surface spread, not crown fire flame length).

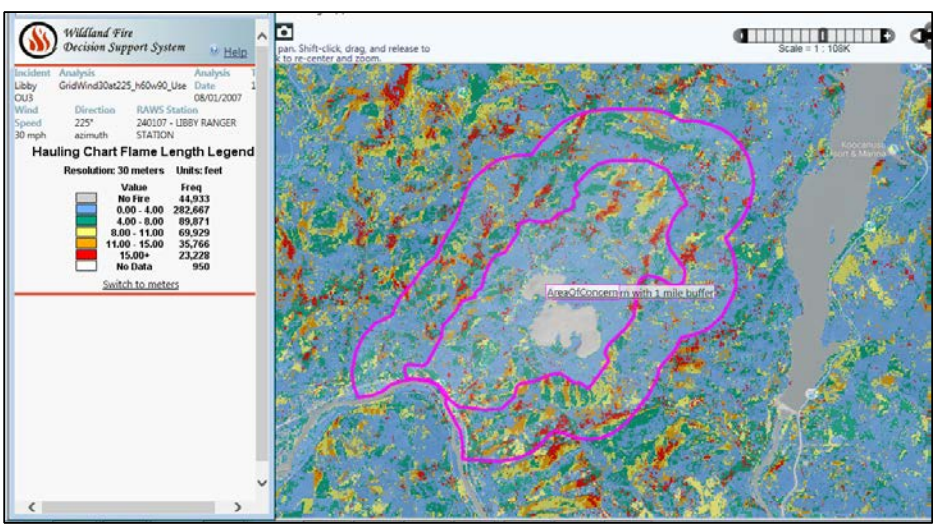


Figure 5. Haul Chart/Flame Length output for southwest wind for existing conditions.

After completing BFB analyses for three representative wind directions (135º, 315 º, and 45 º), the outputs were examined by a group of fire behavior and fuels specialists in order to identify commonalities of areas exhibiting unacceptable fire behavior (active crown fire or flame lengths in excess of 11'). This was done using printed maps, NAIP imagery, a map of previously treated areas and ownerships, and BFB output grids.

It was readily apparent to all members of the analysis team that the problematic areas were primarily defined by the FM165 vegetation structure (Very High Load, Dry Climate Timber Shrub). This vegetation type is easily seen on imagery or in Google Earth. Further investigation revealed a lesser but still significant problem with areas Identified as FM201 (Low Load Activity Fuels) and FM188 (Long-Needle Litter/Ponderosa Pine). [Fuel Models 165 and188 appeared on the native LANDFIRE 2012 fuel model layer; Fuel Model 201 was the result of a fuel model lyer edit—see Appendix B: Modifications to Landfire 2012 to Represent Existing Conditions.] After this analysis, we consulted Nikia Hernandez as well as several Forest planning documents from local fuels projects (Flower Creek, East Reservoir) and confirmed that independent analysis by local fire personnel had identified fuel models 165, 188, and 201 as areas in need of treatment to reduce unacceptable potential fire behavior.

Conclusion: Fuel Models 165 (primarily), 188, and 201 represent the existing vegetation stand structure and fuel loadings that produce unacceptable fire behavior; these areas should be located within the analysis area and evaluated for treatment.

Determining Maximum Spotting Distance

Under extreme weather conditions in the Northern Rockies, spotting distance has been anecdotally reported to exceed several miles. Extreme fire behavior phenomena such as fire whirls and plume-dominated fire may loft firebrands hundreds of feet into the air to be carried miles away by prevailing winds (Albini 1979). It is unlikely that prevention or significant reduction of spotting from these distances into Grace's Proposed OU3 Area (Area of Concern) is realistic; however, spotting distance derived from models created for use under steady-state fire spread is expected to define an area that will address a significant proportion of lofted embers.

Spotting was modeled using the BEHAVE Plus5 Spotting Distance module and FlamMap Maximum Spotting Distance; detailed documentation of this analysis is in Appendix B, "Justification for Buffer Zone Around Area of Concern Based on Spotting Distance". Using either model, the output indicates that the maximum spotting distance is approximately 1 mile within Grace's Proposed OU3 Area (Area of Concern) analysis landscape. Therefore, reducing spotting potential within 1 mile of Grace's Proposed OU3 Area (Area of Concern) by treatments targeted at mitigating active crown fire activity is expected to address the majority of potential spotting into Grace's Proposed OU3 Area (Area of Concern), but torching trees within one mile and extreme fire behavior phenomena within several miles of the Area of Concern could still potentially loft embers into the Area of Concern. Maximizing suppression effectiveness within Grace's Proposed OU3 Area (Area of Concern) is critical to mitigating this possibility.

Conclusion Fuel treatments should be designed to limit crown fire within approximately one mile of Grace's Proposed OU3 Area (Area of Concern).

Minimum Travel Time Analysis

Short Term Fire Behavior (STFB) within the WFDSS user interface was used to model Minimum Travel Time (MTT) travel paths. STFB is a two-dimensional fire growth model and is similar to the FlamMap's MTT module, which is a desktop application. STFB calculates spread rates and maximum spread direction at each cell. Using one set of wind and fuel moisture conditions, STFB provides potential fire spread (arrival times and major paths) for a user-defined length of time. STFB calculates fire growth and behavior by searching for the set of pathways with minimum fire spread times from an ignition source.

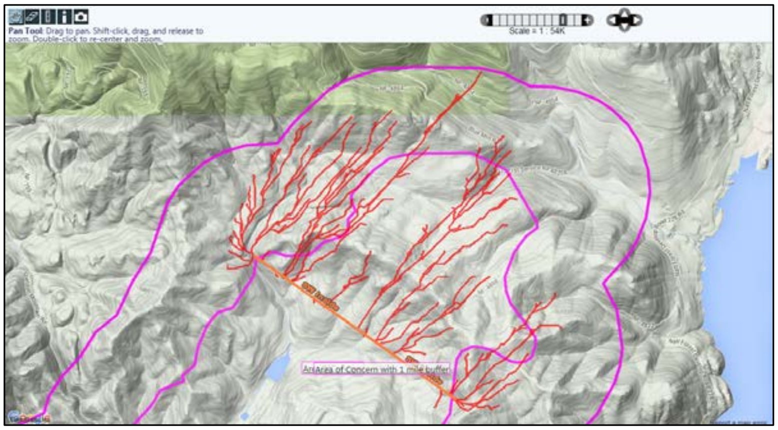


Figure 6. Example of Minimum Travel Time output showing travel paths.

Proposed Fuel Treatment Units

Process

The following information was used in identifying and designing the proposed treatment units:

- Review of the Minimum Travel Time modeling outputs. The various fire spread pathways were reviewed to understand what areas might be impacted by fire, and assessed topography and fuels in Google Earth to verify these outputs based on fire management experience. The MTT paths assisted in determining the location of proposed harvest/fuel reduction units in areas of highest probability of unacceptable fire entering and/or exiting Grace's Proposed OU3 Area (Area of Concern).
- Review of the Basic fire behavior outputs:
    - Crown Fire Activity – Active and Passive Crown Fire. This fire characteristic was assessed in order to reduce the probability of active crown fire in critical areas that may impact Grace's Proposed OU3 Area (Area of Concern).
    - Flame Length (>4 feet) was evaluated in order to understand the areas where the resistance to control may be too great for hand crews to safely suppress a fire and where fire may transition from 4-foot flame lengths to higher fire intensities.
    - Rate of Spread was considered to a lesser extent but was reviewed to understand if a proposed fuel treatment may block the spread pathway of a fire from entering or escaping Grace's Proposed OU3 Area (Area of Concern).
- Local experts; with several decades of experience in wildfire suppression, designing fuel treatments through vegetative manipulation (regeneration harvest, intermediate harvest, and thinning), and prescribed burning on the Kootenai National Forest were used as consultants.
    - Their knowledge of how fire behaves on this landscape was critical in designing the strategic placement of fuel treatment units to take advantage of topography as well as changes in fuel and vegetation types.
    - They were relied upon to review and validate the fire behavior minimum travel time and fire behavior characteristic outputs.
- The past harvest units in and surrounding Grace's Proposed OU3 Area (Area of Concern) provided additional opportunities to increase effectiveness by linking or connecting the proposed treatment units with existing past vegetative treatments.

Recommended Vegetation Treatments to Reduce Unacceptable Fire Behavior

If the objective on some lands is to reduce the threat of unwanted wildland fire, then fires will be suppressed in those areas. If a fire starts in a suppression zone, firefighters are directed to suppress that fire.

The shorter the fire's duration, the less potential exists for adverse weather changes or extreme fire conditions that can narrow a firefighter's margin of safety, and there is potentially less firefighter exposure to environmental hazards. Experience has shown that firefighters can more safely fight a fire if it stays small (low rate of spread; largely determined by small fuels), has lower intensities (determined by fuel structure, fuel moisture and accumulation), has relatively little spotting potential (determined by potential firebrand sources, how far theytravel, and probability of ignition upon landing), and low resistance to control (suppression force required to control a unit of fire perimeter; determined by amount of dead and down fuels). Fire behavior is complex with many contributing factors, all of which fall into the categories of topography, weather, and fuels (Agee, 2005). These three elements comprise the fire environment.

Modifying any one of these elements has a direct result on fire behavior, which is basically described by rate of spread and intensity. Rate of spread is readily observed in the field, and intensity is estimated by observed flame length. These two observations can be assessed by firefighters to determine whether conditions are conducive to spotting and crowning. Favorable conditions for crown fires include heavy accumulations of dead and downed litter, conifer reproduction and other ladder fuels, and continuous conifer tree forest (Rothermel, 1991). A reduction in surface fuels can limit fireline intensity and can help to lower fire severity. Fuel characteristics affecting fire behavior are vegetative density, species composition, amount of surface fuel, arrangement of fuels and moisture content (Rothermel,1983, Graham et al., 2004). Fuels contribute to the rate of spread of a fire, the intensity/flame length of the fire, how long a fire is held over in an area, and the size of the burned area (Rothermel, 1983; Agee, et al., 2000). The following table succinctly describes why certain conditions are important to mitigating fire behavior.

Table 7. Principles of fire-resilient forests (adapted from Agee, 2002).

OBJECTIVE	EFFECT	ADVANTAGE	COMMENTS
Reduce surface and ladder fuels	Reduces potential flame length	Fire control easier, less torching	Surface disturbance less with fire than other techniques
Increase canopy base height	Requires longer flame length to ignite tree crowns	Less torching	Opens understory, may allow surface wind to increase
Decrease crown density	Makes independent crown fire less probable	Reduces crown fire propagation	Surface wind may increase, surface fuels may be drier

In a national survey, nearly 80% of all wildland firefighters identified fuel reduction as the single-most important factor for improving their margin of safety on wildland fires (Tri-Data 1998). Firefighters have no control over the weather or topography but they can manage fuels. Therefore, fuel reduction can play an important part in increasing firefighter and public safety by modifying fire behavior in the fire environment through a reduction in fire intensity and severity (Pollet and Omi, 1999).

Fuel treatments can increase the probability of modifying fire behavior during most weather conditions. However, designing treatments that would be effective during extreme weather conditions is probably not possible; short of converting the entire area of concern to an unburnable condition. A realistic objective of fuel treatments is to reduce the probability of crown fire and other fire behavior that would mitigate undesirable future conditions, not to guarantee elimination of crown fire. As Graham (2004) notes, fuel treatments cannot guarantee benign fire behavior but can reduce the probability that extreme fire behavior will occur.

After identifying the areas where the vegetation that was predicted to produce unacceptable fire behavior occurred on the analysis landscape, the analysts examined the fire behavior characteristics in those stands and focused on fuelbed and canopy characteristics that contributed to those characteristics. According to Graham (2004), the most effective strategy for reducing crown fire occurrence and severity is to (1) reduce surface fuels, (2) increase height to live crown, (3) reduce canopy bulk density, and (4) reduce continuity of the forest canopy. These same treatments are expected to maximize suppression effectiveness as well. In addition to using BEHAVE outputs, Kootenai National Forest fire planning files and a fuels management EIS were consulted to develop the recommended fuelbed and canopy characteristics. The values developed as inputs to the modeling to test the effectiveness of the proposed treatments were:

- Convert FM165 and FM188 to FM183
- Convert FM201 to FM102
- Increase the Canopy Base Height to a minimum of 10 feet
- Decrease the Canopy Bulk Density to a maximum of .06 kg/m^3
- Decrease Canopy Cover to a maximum of 40%

Detailed documentation for developing these parameters are in Appendix B, "Canopy Characteristic Standards for Treatment Areas."

The tables displayed below are a summary of the proposed units that were generated as a result of this analysis effort.

Table 8. Acres of proposed treatments by geographic location.

Grace's Proposed OU3 Area Proposed Fuel Treatment Units	
Total # of Proposed Fuel Treatment Units	73 Units
Total Acres of Proposed Fuel Treatment Units	6,036 Acres
Total Acres inside Buffer including Grace's Proposed OU3 Area	23,156 Acres
Total Acres of Grace's Proposed OU3 Area	9,012 Acres
Total Acres within the Buffer	14,144 Acres
Total Acres of Proposed Fuel Treatment Units inside the. Grace's Proposed OU3 Area	2,723 Acres 30% of this area
Total Acres of Proposed Fuel Treatment Units within the Buffer	3,313 Acres 23% of this area
Total Acres of Past Fuel Treatments inside Grace's Proposed OU3 Area	
Total Acres of Past Fuel Treatment Units within the Buffer	

Table 9. Proposed fuel treatment units by ownership.

Proposed Fuel Treatment Units by Ownership		
Ownership	# Units	Total Acres
U. S. Forest Service	48	4,809 Acres
Plum Creek Timberlands	14	759 Acres
W.R. Grace	5	290 Acres
State of Montana	4	160 Acres
Private Land	2	18 Acres
Total	73	6,036 Acres

The majority of the proposed units in the table have not been verified on the ground so on-site conditions could vary from what is recommended here. Unit placement was not constrained by land management allocation, resource concerns, property ownership or unit size. Refer to Appendix A for detailed proposed fuel treatment unit information.

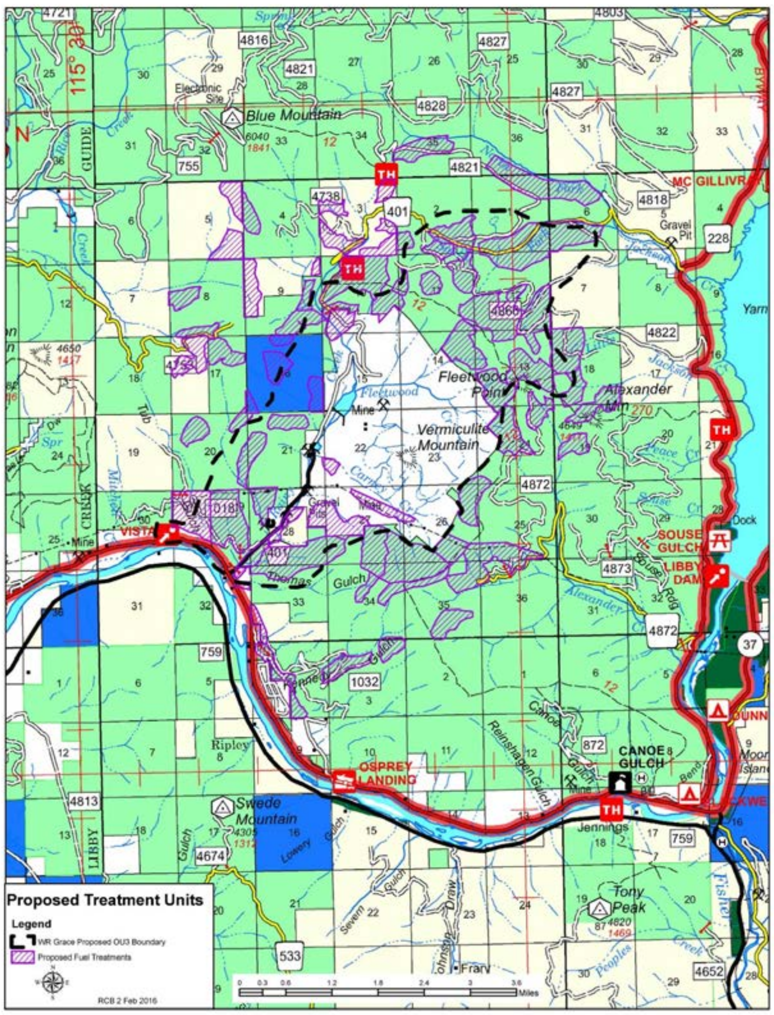


Figure 7. Proposed treatment units in Grace's Proposed OU3 Area and vicinity.

The proposed fuel treatment units took advantage of areas where past fuel treatment activities occurred and often shared boundaries with past fuel treatment areas. The main reason for designing the proposed treatment areas in this way was because the experience and knowledge of local fire managers indicated that many of the past fuel treatment areas exhibit reduced spread rates and do not contribute to crown fire initiation. In these cases, they further indicated that these past treatment units exhibit fire characteristics similar to a fuel model 8 which produces low surface rates of spread and low fire intensities.

Fuel treatments that alter forest structures and fuel characteristics can help modify fire behavior sufficiently so that most wildfires can be suppressed more easily. Subsequent, sustained fuel treatments can maintain these conditions. The degree of risk reduction will depend to some degree on the level of investment, economic and technologic feasibility of applying these treatments, and concurrent consideration of other resource values. Models and observations of landscape scale fire behavior and the effects of fuel treatments clearly suggest that a landscape approach is more likely to have significant overall impacts on fire spread, intensity and suppression effectiveness than an approach that treats individual isolated stands (Graham, 2004).

The teams recommendation for the proposed treatments represent only part of the solution (remedy) and is contingent upon the inclusion of connecting the past treatment areas to facilitate suppression actions and effectively alter unwanted fire behavior characteristics across a larger area. Treatment longevity must also be addressed at the individual stand level and will vary by treatment type, fuel model, species and time since treatment. Fuels and vegetation managers will have to evaluate the past treatment areas to determine when and how they should be maintained.

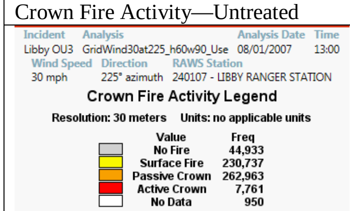
Evidence of treatment effectiveness can be seen on the forest as well as across the country in the aftermath of landscape scale wildfires. Many treatments, as seen on real fires, act as areas to slow fire spread, drop crown fires to the ground and places where firefighters can safely accomplishment containment objectives The following pictures were taken after the Camp 32 fire on the Eureka Ranger District in 2005 and show a distinct difference in fire behavior between treated and untreated timber stands Fuel treatment effectiveness database is also a place where fire managers have just recently started documentation on the interactions between fuel treatments and wildfires.

Modeling Effectiveness of Treatments

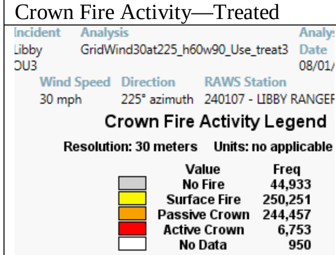
Treatment effectiveness was tested by re-running the initial Basic Fire Behavior analyses after applying the treatment eidt rules to the landscape treatment polygons (the Landscape Editor rules for the modeled treatments are found in Appendix B).

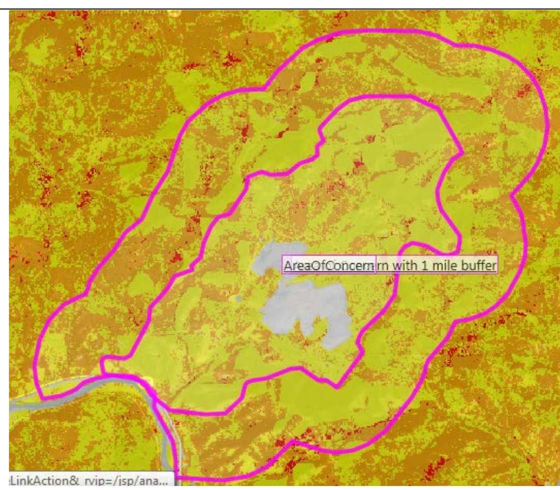
The difference in the amount of crown fire activity and undesirable flame lengths is shown graphically and numerically in the following two images.

Crown Fire Activity—Untreated



Crown Fire Activity—Treated



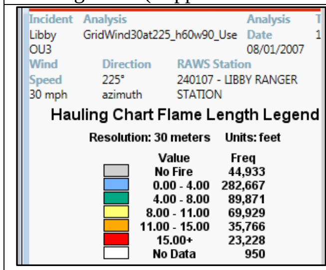


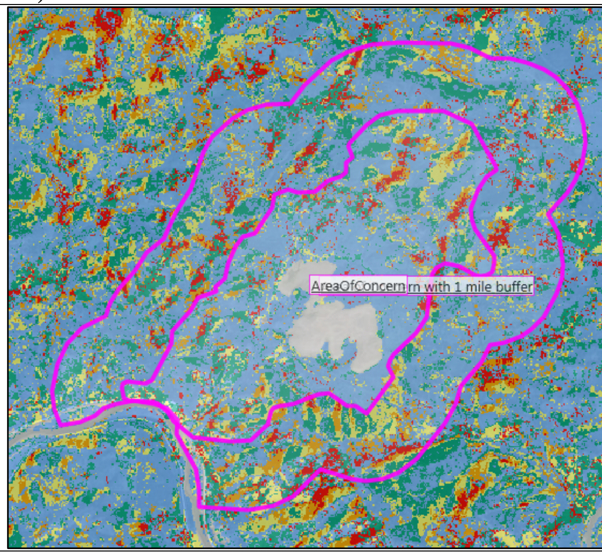
Difference in **Active Crown Fire** acreage = approx. 250 fewer acres burned as active crown fire after treatment.

Difference in **Passive Crown Fire** acreage= approx. 4500 fewer acres after treatment.

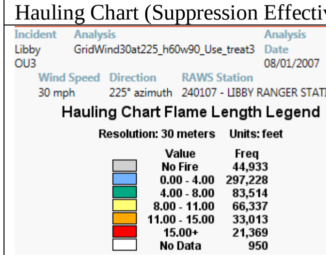
Figure 8. Modeled crown fire activity pre- and post-treatment.

Hauling Chart (Suppression Effectiveness)—Untreated





Hauling Chart (Suppression Effectiveness)—Treated



Difference in **Flame Lengths greater than 4 feet** = approx. 3700 fewer acres after treatment.

Difference in **Flame Lengths greater than 11 feet** = approx. 1000 fewer acres after treatment (this is a subset of the 3700 acres reported above).

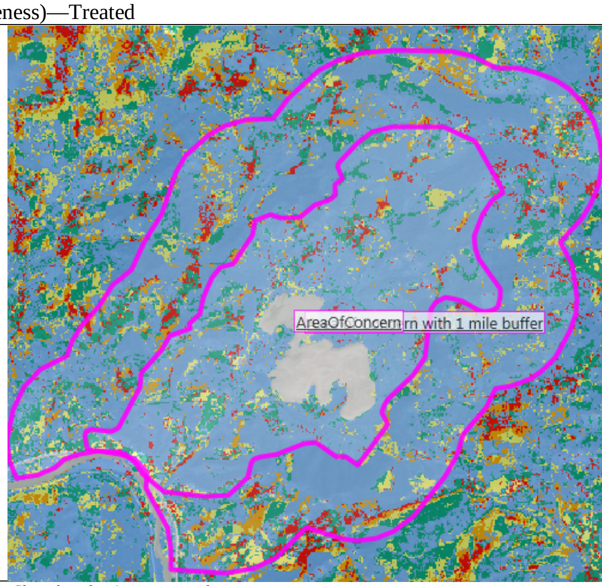


Figure 9. Modeled flame lengths with Hauling Chart breakpoints, pre- and post-treatment.

Fire Spread Analysis in Treated Areas

Near Term Fire Behavior (NTFB) and Fire Spread Probability (FSPro) modeling systems within the WFDSS Interface were used to model and compare fire spread under the Fire Behavior Scenarios described earlier in this section. NTFB is similar to FARSITE; FSPro produces an ensemble of multiple FlamMap-Minimum Travel Time (MTT) runs and a probability surface of the ensemble.

Near Term (NTFB) The Near Term Fire Behavior deterministic fire modeling system with spotting (stochastic) was used to model expected fire behavior pre- and post-treatment under early August, dry, windy conditions after failed initial attack efforts. The same ignition and weather conditions are used in pre- and post-treatment scenarios. The fire footprints shown here assume NO SUPPRESSION since that cannot be modeled accurately. Suppression effectiveness is assumed to be more effective with lower flame lengths and reduced passive/active crown fire that produces embers to ignite spot fires.

Fire Spread Probability (FSPro) FSPro is a geospatial probabilistic modeling system that predicts fire growth, and is designed to support long-term decision-making (more than 5 days). FSPro calculates two-dimensional fire growth and maps the probability that fire will visit each point (cell) on the landscape of interest under the following conditions:

- during the specified time (in this analysis, seven days)
- in the absence of suppression
- based on the current fire perimeter or ignition point (in this case based on the developed scenarios).
- FSPro can provide insight for strategic decision-making by helping answering questions such as the following:
    - What is the probability a fire will reach a point of concern on the landscape during a specific
    - period of time (7 days)?
    - How large might the fire get?
    - What is the expected fire size distribution?

Like all model systems, FSPro has numerous assumptions and limitations specific to each model it uses. It is important to be familiar with these when viewing model results. FSPro uses the same underlying fire models as BehavePlus5, FARSITE, and FlamMap. The assumptions and limitations of those models are also inherent in FSPro (e.g., uniform fuels, etc). Some additional assumptions and limitations of FSPro include the following:

- FSPro results assume no suppression action (other than the inclusion of barriers to simulate effective fireline construction).
- Limited fine-scale temporal variability in weather. This means that the weather is constant for the entire day (1 ERC value and related fuel moistures, 1 wind speed and wind direction).
- The peak burning period is assumed because the ERC, fuel moisture, and wind are obtained at that time.
- There is no correction of fuel moisture for elevation or aspect (forthcoming).
- The FSPro model uses 100% for foliar moisture content. This value cannot be edited.
- Winds and fuel moistures are independent.
- No climate change prediction is available (assumes historic climate).
- The extremely rare event may or may not be represented by the simulation.
- Model output is contingent on model input and modeler expertise. FSPro can only be as accurate as the data used as inputs to the model. The following two data sources should be critiqued:
    - Landscape: Needs to be up to date (often the landscape will need to be edited to provide realistic modeling results); use of the landscape editor might be needed [see Stratton, 2009].

RAWS: One or two can be selected and need to be representative of the analysis area for both ERC values, as well as wind values.

Most importantly, the resulting burn probability maps are easily misinterpreted as a fire progression, such as in FARSITE (**FSPro results show probability contours NOT daily progression perimeters!**).

FSpro analyses were performed for a 7-day period to compliment the NTFB scenarios, which were run for three days. The FSPro analyses extend the scenarios to 7 days, representing that under extreme fire conditions when fires escape intial attack, it is often several more days to a week before a strategy with enough resources and an adequate management structure can be put in place to begin effective suppression. NTFB is not considered an appropriate model for periods of more than 3-5 days, at which point, probabilistic models such as FSPro are considered more appropriate. Because FSPro does not model suppression well, longer periods of time for the FSPro analysis period were not used.

For each of the three scenarios, a portion of the FSPro output—emphasizing Grace's Proposed OU3 Area (Area of Concern)—is shown. Fire spread was reduced in Grace's Proposed OU3 Area (Area of Concern) after treatment, but the reduction is often difficult to discern in the visual mapped output, so a graph depicting the reduction in acres by probability class **within Grace's Proposed OU3 Area (Area of Concern)** is included after the map output.

Scenario 1: Human Ignition Along Highway 37

Expected Flame Lengths are shown here. Reductions in flame length are shown north of the Kootenai River west of Rainy Creek Road and the fire does not spread as extensively along the west side of Rainy Creek Road, nor does it spot across the Rainy Creek Road. Fire size is expected to be smaller. Passive Crown fire (not shown here) has similar results.

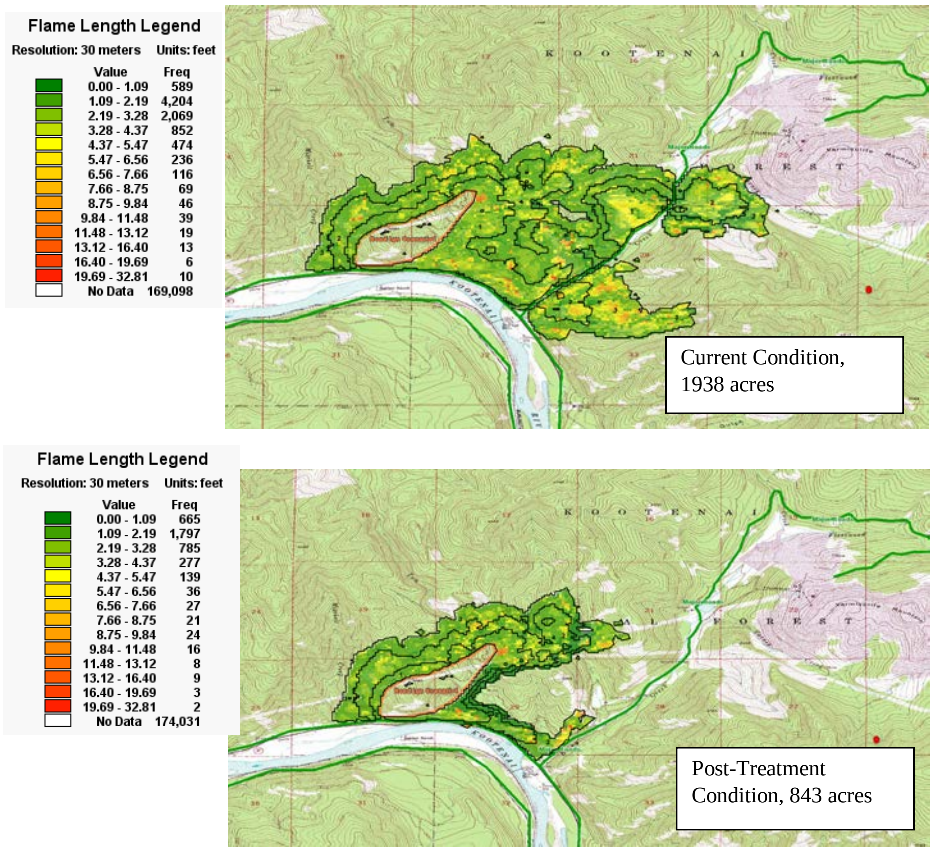
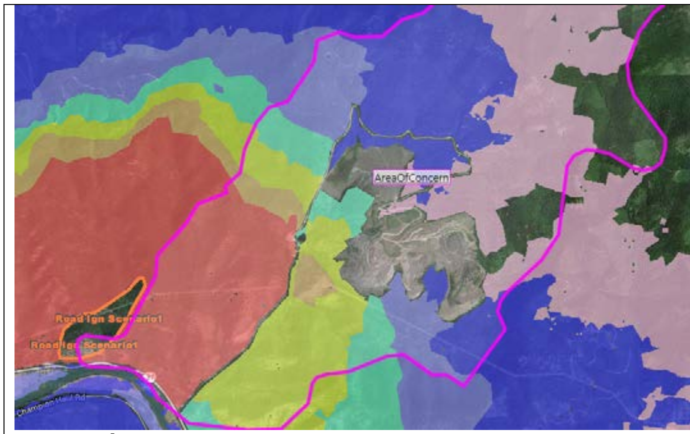
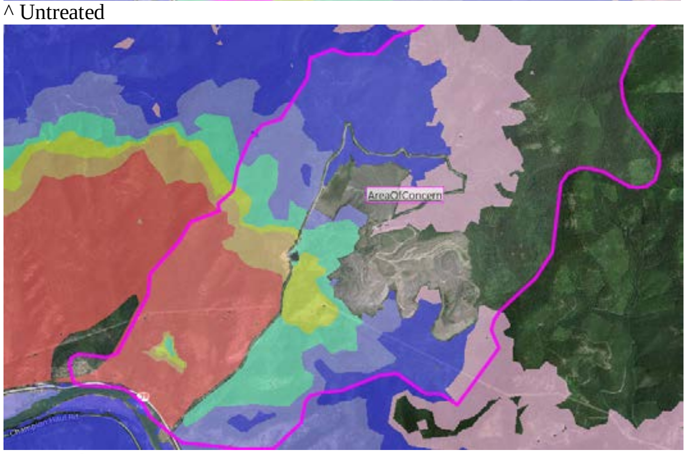


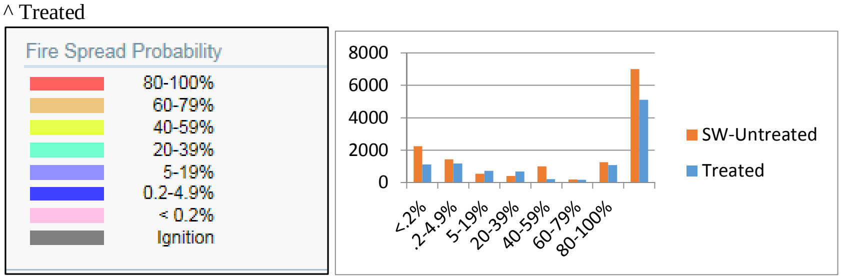
Figure 10. Near Term flame length output for 3 burn periods.



^ Untreated



^ Treated



Acres within each probability class within the Area of Concern

Figure 11. FSPro (fire spread probability) output for Scenario 1.

The FSPro analysis for Scenario 1 shows a slight decrease in acres that experienced fire and a slight overall shift to a lower probability of experiencing fire. In the analysis of the untreated landscape, 7005 acres appear within the probability surface; in the treated landscape, 5117 acres are within the probability surface. Most of the effect is in the corridor to the east of Rainy Creek Road, where treatments show effectiveness in reducing probability of spread by spotting over the road.

Scenario 2: Lightning Ignition West of Area of Interest

Expected Flame Lengths are shown here. Reductions in flame length occur east of the original ignition and the fire does not travel as quickly toward Grace's Proposed OU3 Area (Area of Concern) (pink line). Fire size is expected to be smaller. Passive Crown fire (not shown here) has similar results.

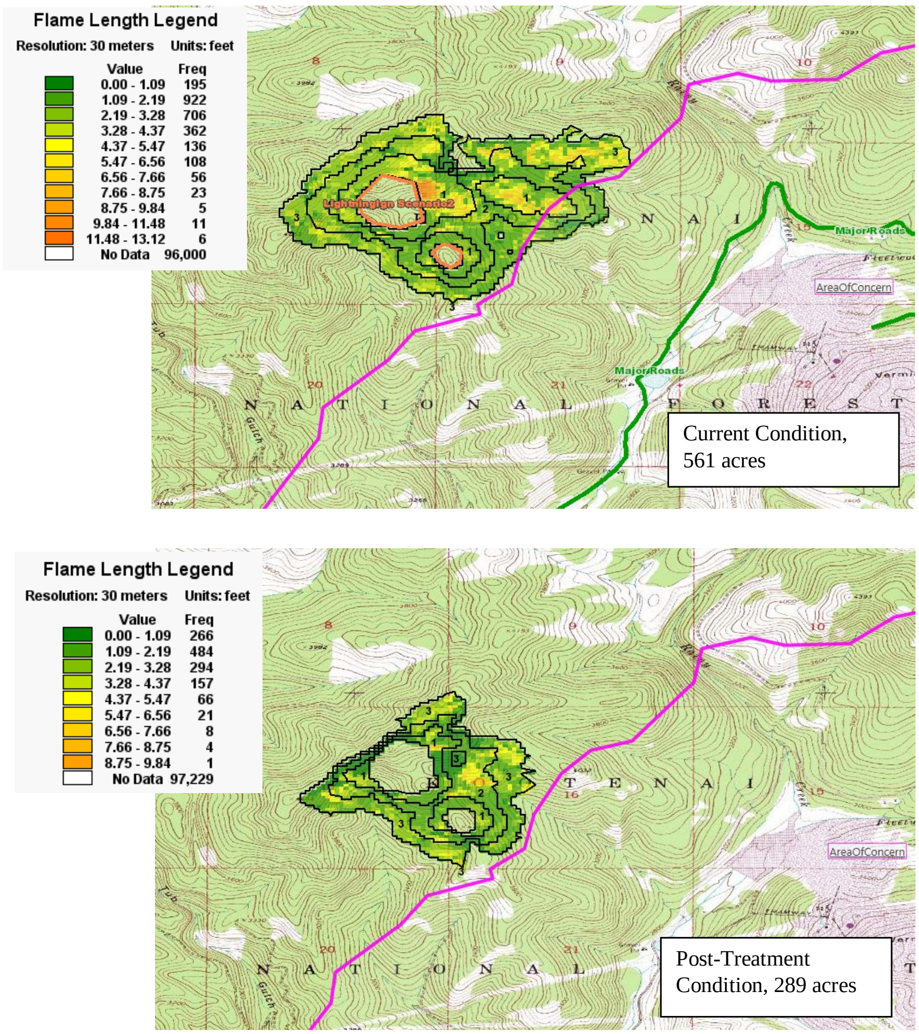


Figure 12. Near Term Fire Behavior output for 3 days, flame length output.

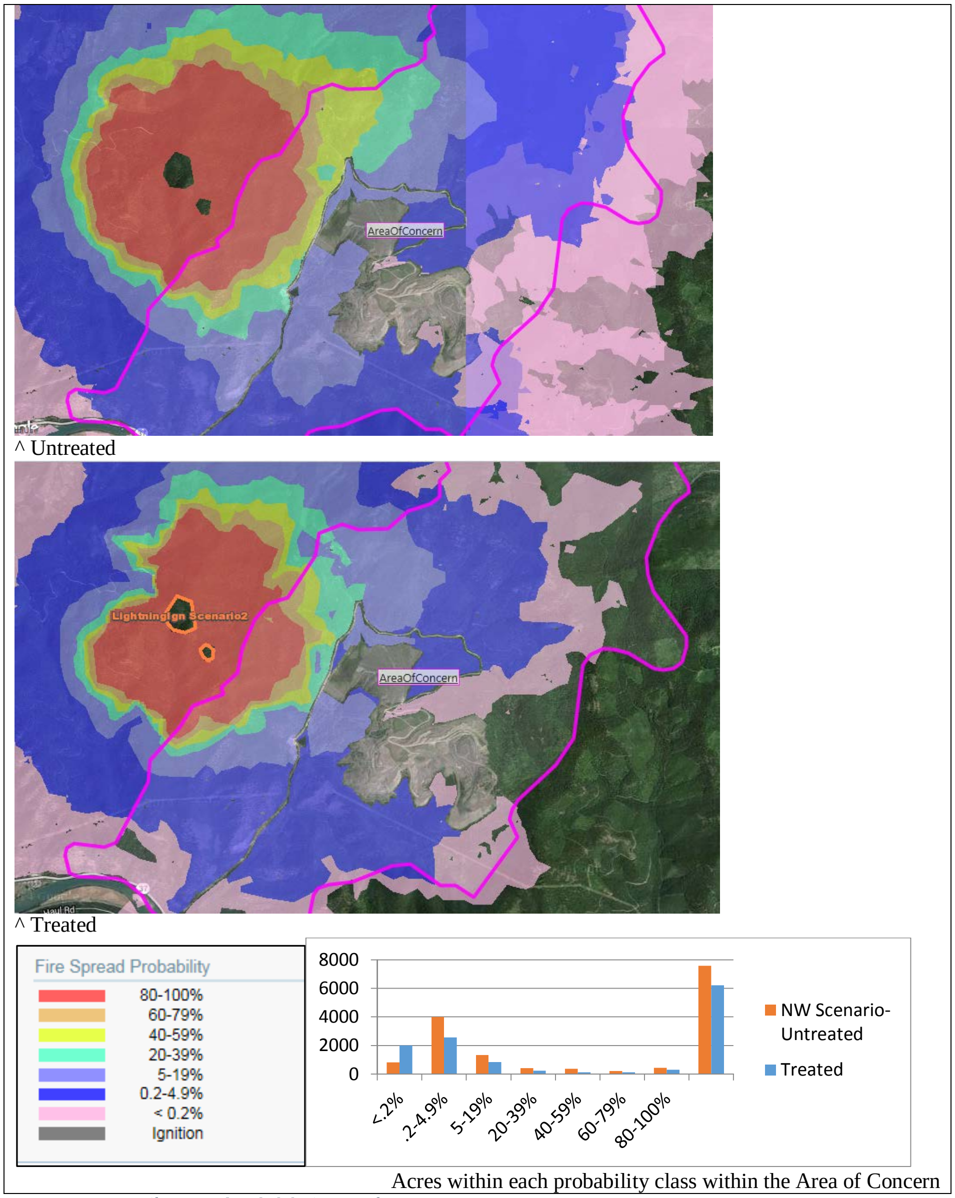


Figure 13. FSPro (fire spread probability) output for Scenario 2.

The FSPro analysis for Scenario 2 also shows a slight decrease in acres that experienced fire and a slight overall shift to a lower probability of experiencing fire. . In the analysis of the untreated landscape, 7579 acres appear within the probability surface; in the treated landscape, 6211 acres are within the probability surface. The effects of treatment are seen mainly in the corridor west of Rainy Creek Road, where treatments reduce the probability of the fire reaching the road, and to the west of the ignition within the buffer.

Scenario 3: Inventoried Roadless Ignition

Expected Flame Lengths are shown here. Reductions in flame length are shown north of the ignition and the fire does not spread as extensively toward Grace's Proposed OU3 Area (Area of Concern) (pink line). Fire size is expected to be reduced, but most spread is not in the direction where treatments were placed. Lack of access in the Inventoried Roadless Area is expected to hamper suppression efforts. Passive Crown fire (not shown here) has similar results. The model handles spotting as a stochastic process; the post-treatment run shows a spot fire in grass by chance. The treatment does not increase the chance of spotting into the grass, the run just happened to launch an ember in that direction during the run.

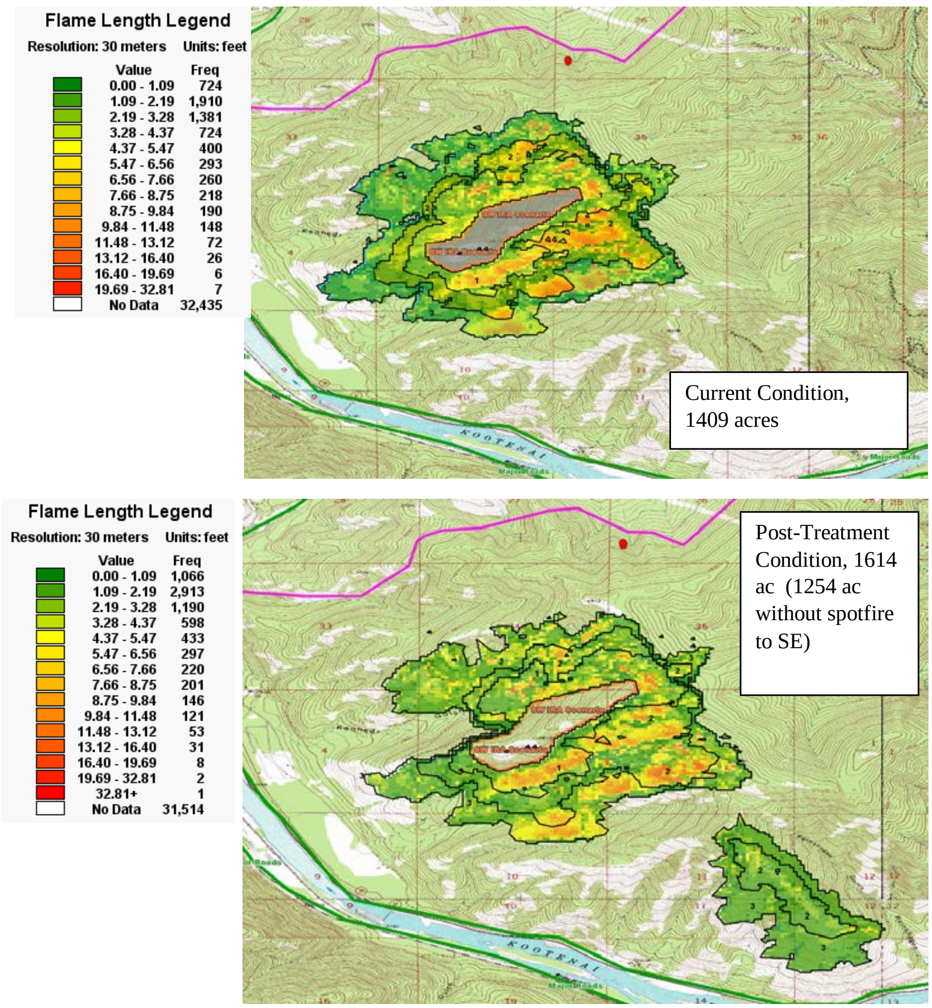
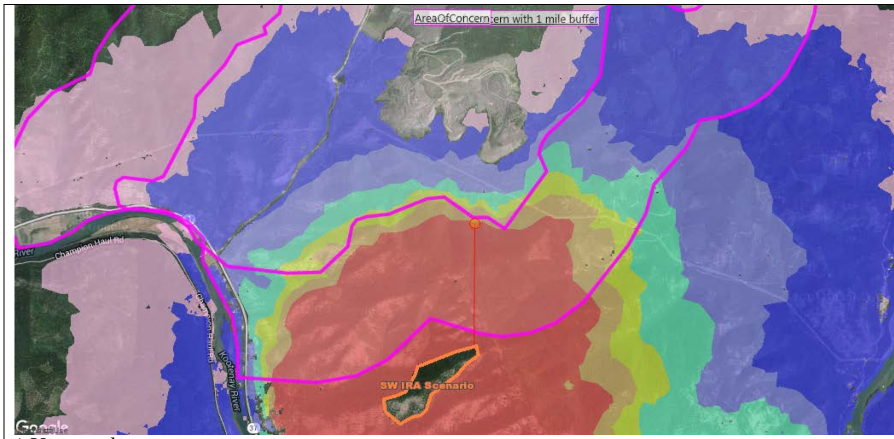
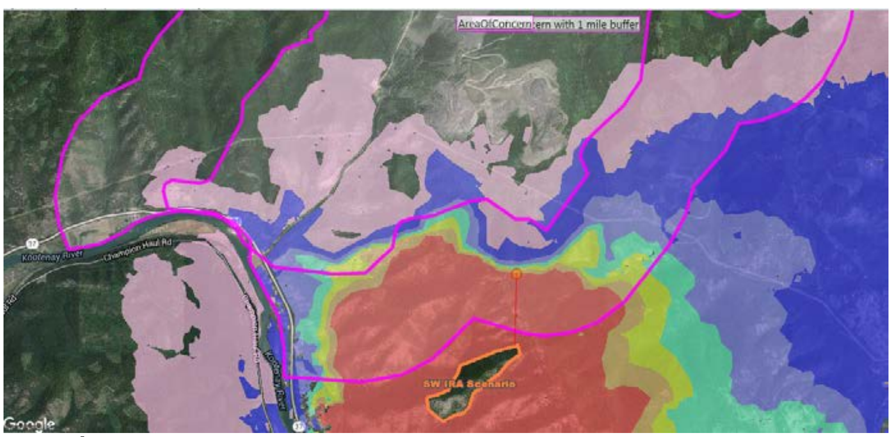


Figure 14. Near Term fire behavior output for 3 days of spread showing flame lengths.



^ Untreated



^ Treated

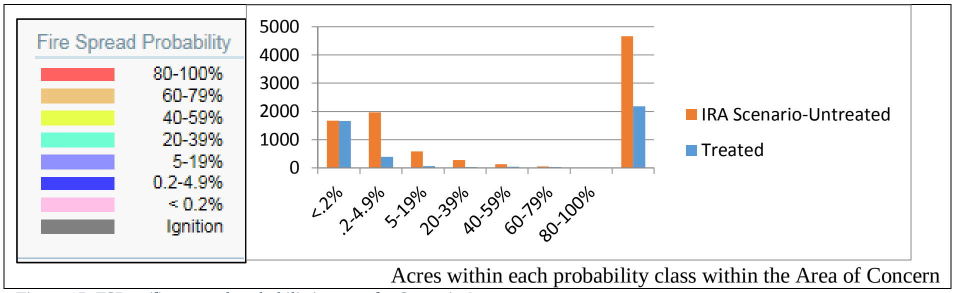


Figure 15. FSPro (fire spread probability) output for Scenario 3.

The FSPro analysis for Scenario 3 shows a more significant decrease in acres that experienced fire and an overall shift to a lower probability of experiencing fire. In the analysis of the untreated landscape, 4664 acres appear within the probability surface; in the treated landscape, 2183 acres are within the probability surface. The effects of treatment are evident in the probability of fire spreading both within the buffer and within the Area of Concern.

Conclusion to Fire Spread Analysis As anticipated, the proposed treatments have had a lesser impact on rates of spread than on the other targeted fire behavior characteristics, such as flame length. If further reductions in fire spread are desired under extreme fire weather conditions, treatments that further reduce spotting (such as reduction in passive crown fire activity) may be warranted. Grass fuel models (102) also contribute significantly to rate of spread in dry, windy conditions, but are challenging to treat due to treatment longevity.

Further Recommendations

- Recommendation Open roads that are currently impassible to provide improved access for firefighters, which will increase firefighting effectiveness. Currently, many of the roads within and outside Grace's Proposed OU3 Area (Area of Concern) are overgrown, limiting where firefighters can gain fast and effective access into areas where fires may occur. Many of the gated roads are impassible. It may be very beneficial to consider opening roads that have been closed for a number of years if the road surface is adequate and will lead into critical areas for fire suppression. This would also be an important consideration on Plum Creek Timberlands property.
- Recommendation **Ground truth proposed unit locations.** Gather pertinent data to help identify adequate treatments to meet desired stand characteristics. Not every acre within all proposed treatment units will necessarily be treated but only those areas within the units that will meet the objectives. Unit boundaries may need to be adjusted after field verification because the analysis used to determine the location of these units relied on local knowledge of the area and various GIS tools to determine the most critical areas to locate proposed treatments. Specific fuel treatment prescriptions for each area should be completed by a fire/fuels specialist and a silviculturist.
- Recommendation Identify and maintain past treatment areas in approximately a one mile buffer around Grace's Proposed OU3 Area (Area of Concern) to retain or improve stand characteristics to achieve firefighting effectiveness objectives. Many of the past fuel treatment areas are beneficial for reduction of fire intensities and fire spread because these areas have fragmented the continuity of the fuels profile across the landscape. The regeneration treatment units have provided some of the best fuel breaks during past fire events. Consider all methods (prescribed burning, thinning w/slash treatment, mastication, etc.) for the maintenance of these areas.
- Recommendation **Consider a treatment schedule that would be coordinated with all affected stakeholders.** It is understood that all the proposed fuel treatment units would not occur simultaneously. Therefore, it is critical that all stakeholders coordinate their treatments because several of the units on different ownerships are adjacent to each other.

Table 10. Team Members and contact information.

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Appendices

APPENDIX A

Proposed Fuel Treatment Units within the
Grace's Proposed OU3 Area (Area of Concern)

The following table shows the rationale and characteristics considered for the selection of proposed fuel treatment units within Grace's Proposed OU3 Area (Area of Concern) and the area outside this area of concern. In this document, whenever Proposed OU3 Area, OU3 Area, or area of concern terms are used, they are referring to Grace's Proposed OU3 Area. The purpose of proposing fuel treatment areas is to reduce flame lengths, active and passive crown fire, and spotting potential that may impact Grace's Proposed OU3 Area (Area of Concern) thus increasing suppression effectiveness. The fuel treatment areas are designated in areas where the problem fuel models appear across the landscape. The main fuel models that produce high flame lengths, active crown fire and spotting potential are 165 (timber/understory with very high fuel load), 188 (Timber/Long needle litter) where canopy base height is low and/or canopy bulk density is high, and 201 (low load activity fuel/blowdown).

The proposed treatment unit fire characteristics shown in this table are rated as low, moderate or high. The following are the parameters for subjectively rating the pre-treatment characteristics applied to the following table for flame length and rate of spread. The ratings were developed by the fire analysts on the team using basic fire behavior modeling in the Wildland Fire Decision Support System.

Flame Length: Low: < or = 4 feet; Moderate: > 4 feet to 8 feet; High: 8-11 feet; Extreme: 11+ feet

Rate of Spread: Low: < or = 10 chains/hour; Moderate: > 11-20 chains/hour; High: 20-40 chains/hour; Extreme: 40+ chains/hour

Wind event column refers to wind event direction that could cause unacceptable fire behavior.

Fire and forest managers with local knowledge and many years of experience on the Kootenai National Forest in the area of this analysis were also consulted. They provided valuable information on vegetation, distribution, stand characteristics as well as fire behavior and fuel treatments that proved essential to the integrity of this project. The Kootenai National Forest worked with a fire/fuels specialist several years ago on a specific project to identify (field verification and mapping the units) proposed fuel treatment units to meet the objectives of improving firefighting effectiveness by reducing fire size, fire intensity, crown fire potential, and spotting. This information was relied upon as a starting point for the identification of proposed fuel treatment areas in this analysis. Proposed treatments link or connect past vegetative treatments to reduce pathways where fire might spread into the highly contaminated area.

There are roads present on all Plum Creek Timberland, private land, WR Grace Property, and some roads on National Forest in areas where the proposed units were designated. Some roads may need to be opened up in order to gain access for increasing firefighter effectiveness. There is no access to any of the units on the State of Montana land. The following tables will show whether a unit has roads or is un-roaded. This would be a major consideration in determining firefighter effectiveness.

The majority of the proposed units in the table have not been verified on the ground so on-site conditions could vary from what is recommended here. Unit placement was not constrained by land management allocation, resource concerns, property ownership or unit size.

<table>
<tr><th colspan="10">Grace's Proposed OU3 Area Fuel Treatment Unit Selection Rationale</th></tr>
<tr><th>Ownership</th><th>Unit #</th><th>Ac.</th><th>OU3 Area</th><th>Roaded</th><th>Wind Event</th><th>Crown Fire</th><th>FL</th><th>ROS</th><th>Minimum Travel Time</th></tr>
<tr><td>Plum Creek</td><td>1</td><td>174</td><td>In/Out</td><td>Yes</td><td>SW & NW</td><td>Passive</td><td>M</td><td>M</td><td>Major SW wind Multiple Pathways into Grace's Proposed OU3 Area</td></tr>
<tr><td colspan="10">This is a south aspect unit above the Highway 37 corridor. Person-caused fires are a high risk. Light fuels along highway will cause fast spreading fire upslope into and beyond the unit on this south aspect into areas that could produce more active crown fire. Fire spread would also be in alignment with the drainages in the area with a SW wind. Treatment of this unit would provide protection of the major powerline above the unit.</td></tr>
<tr><td colspan="10"></td></tr>
<tr><td>Plum Creek</td><td>2</td><td>16</td><td>In</td><td>Yes</td><td>SW & NW</td><td>Passive</td><td>M</td><td>M</td><td>Major SW wind pathway straight up Rainey Creek toward the mine site.</td></tr>
<tr><td colspan="10">This unit is in the drainage bottom and is aligned with the strong SW wind. This is in a corridor that would be a safety problem for firefighters and others traveling the road up Rainey Creek in the event of a fire spreading up canyon.</td></tr>
<tr><td colspan="10"></td></tr>
<tr><td>Plum Creek</td><td>3</td><td>15</td><td>In</td><td>Yes</td><td>SW</td><td>Passive</td><td>L-M</td><td>M</td><td>Major SW wind pathway straight up Rainey Creek toward the mine site.</td></tr>
<tr><td colspan="10">This unit is in the drainage bottom and is aligned with the strong SW wind. This is in a corridor that would be a safety problem for firefighters and others traveling the road up Rainey Creek in the event of a fire spreading up canyon.</td></tr>
<tr><td colspan="10"></td></tr>
<tr><td>Plum Creek</td><td>4</td><td>20</td><td>Out</td><td>Yes</td><td>NW & NE</td><td>Active & Passive</td><td>H</td><td>M-H</td><td>Major NW wind multiple pathways through the unit.</td></tr>
<tr><td colspan="10">This unit is located on a ridge oriented with a NW cold frontal passage or strong NE wind. Strong winds from NW or NE would cause upslope spread toward Grace's Proposed OU3 Area.</td></tr>
<tr><td colspan="10"></td></tr>
<tr><td>Plum Creek</td><td>5</td><td>50</td><td>Out</td><td>Yes</td><td>NW & NE</td><td>Active & Passive</td><td>H</td><td>M-H</td><td>Major NW wind multiple pathways through the unit.</td></tr>
<tr><td colspan="10">This unit is located on a slope oriented with a NW cold frontal passage. The unit is located from the ridgetop to the drainage bottom. Strong NW winds would cause upslope spread toward Grace Grace's Proposed OU3 Area.</td></tr>
<tr><td colspan="10"></td></tr>
</table>

Ownership	Unit #	Ac.	OU3 Area	Roaded	Wind Event	Crown Fire	FL	ROS	Minimum Travel Time

Plum Creek	6	57	Out	Yes	NW	Active & Passive	H	M-H	Major NW wind multiple pathways through the unit.
The unit lies on a high elevation south aspect. Due to the unit location on the highest ridge in the area with a southerly and southwesterly aspect, it will receive strong NW winds. Fire in this unit will burn actively lofting embers to the E and SE toward Grace's Proposed OU3 Area. The unit is adjacent to a Forest Service fuel treatment unit (FS 32). This unit is located the furthest to the NW of any proposed unit. Any fire to the west or northwest threatening this area would burn with heightened intensity due to the extremely steep and timbered slopes toward this unit and Grace's Proposed OU3 Area.									
Plum Creek	7	74	Out	Yes	NW	Passive & Active	M-H	M-H	Major NW wind multiple pathways through the unit.
This unit is high elevation on a west aspect exposed directly to a strong NW wind. Fire spreading into this unit from the west/northwest has the potential to loft embers into the drainage to the east. Spot fires in this drainage have the potential of fast upslope spread to the Grace proposed OU3 boundary with a continued strong NW cold frontal passage.									
Plum Creek	8	87	Out	Yes	NW	Active & Passive	H-E	M-H	Major NW wind pathway through this unit.
The unit lies high on a major ridge line about ¾ mile to the west of Grace's Proposed OU3 Area. It is a west aspect in direct alignment with a strong NW frontal passage wind. As in the case with unit PC 7, it too would have a high probability of lofting embers toward Grace's Proposed OU3 Area into areas with M-H ROS and H flame lengths. There would be a high probability of fire spread upslope into Grace's Proposed OU3 Area.									
Plum Creek	9	30	Out	Yes	SW	Passive	M-H	H-E	The MTT ignition line begins at the bottom of this unit.
This unit is immediately above the private land at the bottom of the steep W aspect. This area is in direct alignment with a strong SW wind. Fire starting at the bottom of this slope would spread rapidly through the location of this unit toward the top of the ridge that lies 2,000 vertical feet above this unit.									
Plum Creek	10	69	Out	Yes	NW	Active & Passive	H	M-H	Major NW wind pathway through the unit into Grace's Proposed OU3 Area.
Unit is a south and southwest aspect and is within .6 miles of Grace's Proposed OU3 Area. There is a high potential of spotting from this unit across the drainage onto a NW aspect. During a strong NW cold frontal passage, spotting in that area would cause fire to become established in an area that has high-extreme flame lengths, a high rate of spread, and potential for major upslope crown fire runs continuing with spotting into Grace's Proposed OU3 Area.									
Ownership	**Unit #**	**Ac.**	**OU3 Area**	**Roaded**	**Wind Event**	**Crown Fire**	**FL**	**ROS**	**Minimum Travel Time**
Plum Creek	11	33	Out	Yes	NE NW	Passive & Active	H-E	M	Major NE & NW wind pathway through the unit.

<table>
<tr><td colspan="10">Unit is a south and southwest aspect and is within .5 miles of Grace's Proposed OU3 Area and lies in the middle to upper 1/3rd of the slope. This unit is dominated by fuel model 165, 201 intermixed with 188. There is a high potential of spotting from this unit across the drainage to the south onto a NW aspect into high risk Plum Creek Timberland Units. During a strong NW cold frontal passage, spotting in that area would cause fire to become established in an area that has high-extreme flame lengths, a high rate of spread, and potential for major upslope crown fire runs causing additional spotting into Grace's Proposed OU3 Area.</td></tr>
<tr><td colspan="10"></td></tr>
<tr><td>Plum Creek</td><td>12</td><td>31</td><td>Out</td><td>Yes</td><td>NW</td><td>Passive</td><td>M-H</td><td>M</td><td>Major NW & NE wind pathway through the unit.</td></tr>
<tr><td colspan="10">Unit is a combination of aspects from south to east aspects and is .8 miles of Grace's Proposed OU3 Area. This unit is dominated by fuel model 201 (blowdown) with intermixed 165. There is a saddle on the ridgeline in this unit. There is a high potential of spotting from this unit across the drainage to the south onto a NW aspect into high risk Plum Creek Timberland Units. During a strong NW cold frontal passage, spotting in the adjacent Plum Creek area would cause fire to become established in an area that has high-extreme flame lengths, a high rate of spread, and potential for major upslope crown fire runs causing additional spotting into Grace's Proposed OU3 Area</td></tr>
<tr><td colspan="10"></td></tr>
<tr><td>Plum Creek</td><td>13</td><td>12</td><td>Out</td><td>Yes</td><td>NW</td><td>Passive & Active</td><td>H-E</td><td>M-H</td><td>Major NW wind pathway near the unit.</td></tr>
<tr><td colspan="10">Unit lies on both sides of a ridge with northwest and southeast aspects and is within .4 miles of Grace's Proposed OU3 Area. Unit is dominated by fuel model 165 with 161 intermixed within the unit. Spotting from a fire within this unit under extreme conditions lofting embers onto a NW aspect that is aligned with a strong NW wind impacting Grace's Proposed OU3 Area. This area also exhibits active crown fire characteristics further threatening additional acreage within Grace's Proposed OU3 Area.</td></tr>
<tr><td colspan="10"></td></tr>
<tr><td>Plum Creek</td><td>14</td><td>91</td><td>Out</td><td>Yes</td><td>NW</td><td>Active & Passive</td><td>H-E</td><td>M-H</td><td>Major NW wind pathways through the unit toward Grace's Proposed OU3 Area.</td></tr>
<tr><td colspan="10">Unit has north and northwest aspects and is within .9 miles of Grace's Proposed OU3 Area. The unit is steep and heavily timbered with the dominant fuel models 165 and 188. This unit is in direct alignment with a strong NW cold frontal passage wind. A fire behavior within this unit under extreme conditions would cause spotting into Grace's Proposed OU3 Area onto south aspect slopes that would produce high ROS and high flame lengths.</td></tr>
<tr><td colspan="10">Total - 14 Plum Creek Timberland Units = 759 Acres</td></tr>
<tr><td>WR Grace</td><td>1</td><td>6</td><td>In</td><td>Yes</td><td>SW</td><td>Passive on upper slopes</td><td>L-M</td><td>M-H</td><td>Major SW wind pathway through the unit.</td></tr>
<tr><td colspan="10">The unit is located in the bottom of Rainey Creek that is oriented in direct alignment with a strong SW wind. Active fire behavior in this unit may compromise firefighter and public safety that travel this road. Fire established in this area would have a tendency to become established on both sides of the drainage and spread not only up slope on both sides of the drainage but further to the NE toward the mine site.</td></tr>
<tr><td colspan="10"></td></tr>
<tr><td>Ownership</td><td>Unit #</td><td>Ac.</td><td>OU3 Area</td><td>Roaded</td><td>Wind Event</td><td>Crown Fire</td><td>FL</td><td>ROS</td><td>Minimum Travel Time</td></tr>
<tr><td>WR Grace</td><td>2</td><td>137</td><td>In</td><td>Yes</td><td>SW &</td><td>Passive & Active</td><td>H-E</td><td>M-H</td><td>Major SW & NW wind multiple pathways</td></tr>
</table>

					NW				through the unit.
The unit is located mid-slope on the SE side of Rainey Creek and is .3 miles south of the mine site. The dominant fuel model is 165 with smaller amounts of 188. The unit is very steep so any fire on this slope would spread rapidly upslope to the SE toward the OU3 boundary. Spotting potential would be high further into Grace's Proposed OU3 Area but with a strong SW wind over the ridge above the unit, the embers would travel to the mine site and areas surrounding mine site that have less active fire behavior characteristics.									
WR Grace	3	59	In	Yes	NW & SW	Passive w/slight areas of Active	M	L-M	Major SW wind multiple pathways through the unit.
This unit is in the bottom of a side drainage to Rainey Creek somewhat sheltered from a strong SW wind but spotting from other sources from another location to the SW could cause spotting into this unit that is located next to the mine site. Strong SW wind has a probability of spreading fire across the drainage to the mine site. Treatment of this unit would provide protection of the major powerline adjacent to this unit.									
WR Grace	4	69	In	Yes	NW & SW	Passive	M	M	Major SW wind pathway and multiple NW pathways through the unit.
The unit is a southwest aspect on steep slope in direct alignment with the strong SW wind. This unit is also across the drainage on a northeast aspect that would be exposed to a strong NW wind. Fuel models 165 and 188 lie within this unit. It is also located on an aspect in a steep dissected drainage that is aligned with a strong NW cold frontal passage. Fire spread could be combination of upslope and/or laterally depending on the wind direction. A strong NW wind would spread fire in this area further into Grace's Proposed OU3 Area north of the mine site. A strong SW wind would spread rapidly upslope toward the OU3 boundary sending embers over the ridge to the NE onto National Forest inside and outside Grace's Proposed OU3 Area.									
WR Grace	5	19	In	Yes	NW & SW	Most of unit area is Passive	H-E	L-M	No major pathways through this unit.
The unit lies on the point of a ridge next to the mine site above Rainey Creek. It is a north aspect with dense timber on steep slopes dominated by fuel model 165. The unit is partially sheltered from a strong SW wind flow but is adjacent to some extreme ROS slopes to the SW of the unit. Fire becoming established in this unit would spread upslope under high to extreme conditions and be too intense for effective suppression action.									
Total – 5 W.R. Grace Units = 290 Acres									

Ownership	**Unit #**	**Ac.**	**OU3 Area**	**Roaded**	**Wind Event**	**Crown Fire**	**FL**	**ROS**	**Minimum Travel Time**
Forest Service	1	200	In	No	SW	Passive	L-E	M-E	Major SW wind multiple pathways through the unit from the lower slopes.
This unit is on a south aspect about .2 miles above Highway 37 dominated by fuel model 188. The main fire problem with this unit are fires starting below the unit and rapidly spreading upslope into the unit through fine fuels. There are also fast spreading fuels within the eastern portion of this unit and outside the unit. Spotting would occur further into Grace's Proposed OU3 Area with a high potential of igniting spot fires on other south									

and west facing slopes to the NE on the west side of Rainey Creek. Treatment of this unit would provide protection of the major powerline above the unit.									
Forest Service	2	66	In	Yes	SW	Most of unit area is Passive	M-H	M-E	Major SW wind multiple pathways through the unit and NW pathway through the top of the unit.
Unit is a west aspect surrounded by slopes that show high to extreme spread rates and high to extreme flame lengths in fine fuels. Fuel model 188 is the most prevalent fuel model with some 165 and 102. Spotting would occur further into Grace's Proposed OU3 Area with a high probability of igniting spot fires under extreme conditions. Treatment of this unit would provide protection of the major powerline above the unit.									
Forest Service	3	41	In	Yes	SW	Active & Passive	H	M-H	Major SW wind pathways through the area.
The unit is located in the bottom of Rainey Creek that is oriented in direct alignment with a strong SW wind. Fuel models 165 and 188 lie within this unit. Active fire behavior in this unit may compromise firefighter and public safety that travel this road. Fire established in this area would have a tendency to become established on both sides of the drainage and spread not only up slope on both sides of the drainage but further to the NE toward the mine site.									
Forest Service	4	251	In/Out	Yes	SW & NW	Active & Passive	H	M-H	Major SW & NW wind multiple pathways through the unit.
This unit has a combination of N to W to S aspects on the east side of Rainey Creek. It is in the lower and mid-slopes and contains heavy dense timber with most of the unit in fuel model 165 and 188. Fire spread from a SW wind would cause major spread further into Grace's Proposed OU3 Area with long-range spotting. Firefighter effectiveness under high to extreme conditions and the fact the area is inaccessible would be low.									
Forest Service	5	120	Out/In	No	SW & NW	Active & Passive	H	M-H	Major SW wind multiple pathways through the unit.
The unit is in the top 1/3rd and along a main ridge. It is inaccessible on a steep N to W aspect in heavy dense timber characterized by fuel model 165. This unit is particularly susceptible to receiving spots from a fire to the south above the river and has a high potential of passive and active crown fire. A strong SW wind with a fire in this area has a high probability of spotting further into Grace's Proposed OU3 Area. Due to these factors firefighter effectiveness would be low.									
Ownership	**Unit #**	**Ac.**	**OU3 Area**	**Roaded**	**Wind Event**	**Crown Fire**	**FL**	**ROS**	**Minimum Travel Time**
Forest Service	6	120	Out/In	Yes	SE & SW	Active & Passive	H	M-H	Major SE and SW wind multiple pathways through the unit.
This unit contains multiple aspects (S, W, NW). It lies along the main ridge east of the mine site. There is a road along the southern boundary of the unit but there is no other access within the unit. Fire within this unit with a SW or SE strong wind would spread into Grace's Proposed OU3 Area. There are past harvest units to the east and downslope from this unit which would retard fire spread from any fire that may threaten entering this									

area from the east. The dominant fuel model in this unit is 165 with some 188.									
Forest Service	7	60	Out	Yes	SE	Active & Passive	H	M-H	Major NE, SW, & SE wind multiple pathways through the unit.
The unit is on S to E aspects below the main ridge in heavy dense timber in alignment with any strong winds from the SE or SW. It is surrounded by past harvest units but there are Minimum Travel Time pathways into the unit from the SE. Fire in this unit would have a tendency to loft embers to Grace's Proposed OU3 Area onto west aspects over the ridge. Fuel models are a combination of 165 and 161. The unit is relatively accessible with roads in the bottom and top of the unit.									
Forest Service	8	134	In	No	SE & NE	Active & Passive	H	M-H	Major NE, SW, & SE wind multiple pathways through the unit.
The unit is on a combination of aspects from W to N to NE in heavy dense timber characterized by the dominant 165 fuel model with lesser amounts of 188 and 161. It lies on the main ridge between Rainey Creek and Jackson Creek drainages. This unit would be mainly impacted by mainly strong NE and SE winds but can also be impacted by a strong SW wind flowing through WR Grace property in the Rainey Creek basin. Fire in this unit that is impacted by NE and SE winds could loft fire brands into the Rainey Creek basin. The unit inaccessible.									
Forest Service	9	148	Out/In	Yes	SE & NE	Active & Passive	H	M-H	Major NW wind multiple pathways through the unit.
Unit is on a NE and E aspect in heavy dense timber with the dominant fuel model of 165 with lesser amounts of 183 and 161. Heavy timber canopy is consistent across the landscape from E to W leading into Grace's Proposed OU3 Area. This would cause any fire within this area to spread and crown fires would loft embers into Grace's Proposed OU3 Area from strong SE or NE winds.									
Ownership	**Unit #**	**Ac.**	**OU3 Area**	**Roaded**	**Wind Event**	**Crown Fire**	**FL**	**ROS**	**Minimum Travel Time**
Forest Service	10	136	In/Out	Yes	NE, NW & SE	Active & Passive	H	M-H	Major NE and SE wind multiple pathways through the unit. NW wind also impacts the unit.
This unit is on a NW aspect in heavy dense timber with 165 as the dominant fuel model. Strong SE, NE, and NW winds would affect fire behavior on any fire in this unit with a high probability of active crown fire with profuse spotting into other areas surrounding this unit and within Grace's Proposed OU3 Area. This is particularly critical in Grace's Proposed OU3 Area with a strong NE wind.									
Forest Service	11	224	In	Yes	NW & SW	Passive & Active	H	M-H	Major NW & SW wind multiple pathways through the unit.
Aspects in this unit are NE, N, and NW in heavy dense timber stands with 165 as the dominant fuel model. Fire spread from a strong SW or NW wind would impact additional acreage in Grace's Proposed OU3 Area. There is a high potential of crown fire and spotting within this unit to those areas surrounding the unit.									

Forest Service	12	59	Out/In	Yes	SE & NE	Active & Passive	H	M-H	Major SE & NE wind multiple pathways through the unit.
This unit lies in the head of a drainage to the top of the main ridge on E, NE, and SE aspects. The dominant fuel model is 165 with less amounts of 161 and 188. This unit is in direct alignment with SE and NE winds which would cause fire in this unit to impact Grace's Proposed OU3 Area. Due to the heavy dense fuel model 165 fire spread from this unit has a high potential of active crown fire creating profuse spotting and spreading further impacting Grace's Proposed OU3 Area.									
Forest Service	13	368	In/Out	Yes	NE, NW & SW	Active & Passive	H	M-H	Major NE, NW, and SW wind multiple pathways through the unit.
This unit lies on a slope from the drainage bottom to the ridge on N, NE, and NW aspects. The dominant fuel model is 165. This unit is in direct alignment with NE and NW winds to impact Grace's Proposed OU3 Area. Due to the heavy dense fuel model 165 fire spread from this unit has a high potential of active crown fire creating profuse spotting and spreading further impacting Grace's Proposed OU3 Area.									
Forest Service	14	236	Out	Yes	NE & NW	Active & Passive	H-E	H-E	Major NW and NE wind multiple pathways through the unit.
This unit lies on a slope from the drainage bottom to the ridge on N aspect outside Grace's Proposed OU3 Area. The dominant fuel model is 165. This unit is in direct alignment with NE and NW winds that would impact Grace's Proposed OU3 Area. Due to the heavy dense timber fuel model 165 fire spread from this unit has a high potential of active crown fire creating profuse spotting and high rate of spread toward Grace's Proposed OU3 Area.									
Ownership	**Unit #**	**Ac.**	**OU3 Area**	**Roaded**	**Wind Event**	**Crown Fire**	**FL**	**ROS**	**Minimum Travel Time**
Forest Service	15	78	In	Yes	NE, NW & SW	Active & Passive	H	M-H	Major NE, NW, and SW wind multiple pathways through the unit.
This unit lies on the lower and middle third of the slope on N aspect inside Grace's Proposed OU3 Area. The dominant fuel model is 165. This unit is in direct alignment with NE and NW winds that would impact Grace's Proposed OU3 Area. Strong NE winds would show the highest probability of producing high intensity active crown fire runs due to fuel model 165 dominating the unit. Fire exhibiting this behavior would has a high potential of active crown fire creating profuse spotting and high rate of spread into the Rainey Creek basin further into Grace's Proposed OU3 Area.									
Forest Service	16	40	In	Yes	NE, NW & SW	Passive & Active	H	M-H	Major NW wind multiple pathways through the unit.
This unit lies on the lower third of the slope on N aspect inside Grace's Proposed OU3 Area. The dominant fuel model is 165. This unit is in direct alignment with NE and NW winds that would impact Grace's Proposed OU3 Area. Strong NE winds would show the highest probability of producing high intensity active crown fire runs due to fuel model 165 dominating the unit. Fire exhibiting this behavior would has a high potential of active									

Ownership	Unit #	Ac.	OU3 Area	Roaded	Wind Event	Crown Fire	FL	ROS	Minimum Travel Time
crown fire creating profuse spotting and high rate of spread into the Rainey Creek basin further into Grace's Proposed OU3 Area.									
Forest Service	17	42	In	Yes	NE, NW & SW	Active & Passive	H	M-H	Major NW and NE wind multiple pathways through the unit.
This unit lies on the upper third of the slope to the top of the main ridge dividing Rainey and Jackson Creek drainages. It is on a N aspect inside Grace's Proposed OU3 Area. The dominant fuel model is 165. This unit is in direct alignment with NE and NW winds that would impact Grace's Proposed OU3 Area. Strong NE winds would show the highest probability of producing high intensity active crown fire runs due to fuel model 165 dominating the unit. Fire exhibiting this behavior would has a high potential of active crown fire creating profuse spotting and high rate of spread into the Rainey Creek basin further into Grace's Proposed OU3 Area.									
Forest Service	18	27	In/Out	Yes	NE, NW & SW	Active & Passive	H	M-H	Major NE and NW wind multiple pathways through the unit.
This unit lies on the upper third of the slope to the top of the main ridge dividing Rainey and Jackson Creek drainages. It is on a N aspect inside and outside Grace's Proposed OU3 Area. The most prevalent fuel model is 165. This unit is in direct alignment with NE and NW winds that would impact Grace's Proposed OU3 Area. Strong NE winds would show the highest probability of producing high intensity active crown fire runs due to fuel model 165 dominating the unit. Fire exhibiting this behavior would has a high potential of active crown fire creating profuse spotting and high rate of spread into the Rainey Creek basin further into Grace's Proposed OU3 Area.									
Ownership	**Unit #**	**Ac.**	**OU3 Area**	**Roaded**	**Wind Event**	**Crown Fire**	**FL**	**ROS**	**Minimum Travel Time**
Forest Service	19	213	Out	Yes	NW, NE & SW	Passive & Active	H-E	M-H	Major NW and SW wind multiple pathways through the unit.
This unit lies from the bottom of the drainage to the top of the main ridge dividing Rainey and Jackson Creek drainages. It goes over that ridge into the Rainey Creek drainage. It is on a N and NW aspect on the Jackson Creek side and a S to SW aspect on the Rainey Creek side of the ridge. The most prevalent fuel model is 165 with some 161 and 188. This unit is in direct alignment with NE and NW winds that could impact Grace's Proposed OU3 Area if a fire originated in this unit or spread into this unit from adjacent stands. Strong NE and NW winds would show the highest probability of producing high intensity active crown fire runs due to fuel model 165 dominating the unit. Fire exhibiting this behavior would has a high potential of active crown fire creating profuse spotting and high rate of spread into the Rainey Creek basin further into Grace's Proposed OU3 Area.									
Forest Service	20	29	In	Yes	NW	Passive & Active	H-E	M-H	Major NW wind multiple pathways through the unit.
The unit lies on a S and SW aspect along the Rainey/Jackson Creek divide following the ridgetop into the bottom of the drainage. The most prominent fuel model in this unit is 165 with some 161 and 188. The OU3 boundary is a common boundary with the N and NW side of the unit. Fire in this unit with a strong NW frontal passage has a high probability of spreading further into Grace's Proposed OU3 Area.									

Ownership	Unit #	Ac.	OU3 Area	Roaded	Wind Event	Crown Fire	FL	ROS	Minimum Travel Time
Forest Service	21	62	In	Yes	NW & SW	Passive & Active	H-E	M-H	Major NW and SW wind multiple pathways through the unit.
This unit is in the Rainey Creek drainage below the Rainey/Jackson divide. It is in the upper third of the slope, very steep and inaccessible. Fuel model 165 is the most dominant fuel model with some 188 and 161. Fire spreading into or out of this unit has a high probability of crown fire runs upslope and laterally further impacting Grace's Proposed OU3 Area with a high rate of spread and spotting within the Rainey Creek basin as well as over the divide into the Jackson Creek drainage.									
Forest Service	22	131	In	No	NW & SW	Active & Passive	H-E	M-H	Major NW and SW wind multiple pathways through the unit.
This unit is in the Rainey Creek drainage below the Rainey/Jackson divide. It is in the upper third of the slope, very steep and inaccessible. Fuel models include 165, 188 and 161 with some 201 (blowdown). Fire spreading into or out of this unit has a high probability of crown fire runs upslope and laterally further impacting Grace's Proposed OU3 Area with a high rate of spread and spotting within the Rainey Creek basin as well as over the divide into the Jackson Creek drainage.									
Ownership	**Unit #**	**Ac.**	**OU3 Area**	**Roaded**	**Wind Event**	**Crown Fire**	**FL**	**ROS**	**Minimum Travel Time**
Forest Service	23	30	Out	Yes	NW & SW	Passive & Active	M-H	M-H	Major NW and SW wind multiple pathways through the unit.
This unit is on a low flat ridge between two drainages. Fuel models include 165 and 161. Fire spreading into or out of this unit has a probability of high fire intensity runs with a strong NW or SW wind. A strong NW wind could cause fire spread into Grace's Proposed OU3 Area further into the Rainey Creek drainage. Strong SW winds would could cause major spread to the NW outside Grace's Proposed OU3 Area.									
Forest Service	24	76	Out	Yes	NW	Passive & Active	H-E	M-H	Major NW wind multiple pathways through the unit.
This unit lies from the drainage bottom to the ridgetop on a N-NW aspect. A small portion of the lower part of this unit is a NE aspect. The fuel model in the unit is primarily 165 with some 161. Fire spreading into or out of this unit has a high probability of producing crowning runs with a strong NW wind. This strong NW wind could cause fire spread into Grace's Proposed OU3 Area further into the Rainey Creek drainage. Strong SW winds could cause major spread to the NW outside Grace's Proposed OU3 Area.									
Forest Service	25	233	Out	No	SW & NW	Passive w/some Active	H	M-H	Major SW wind multiple pathways through the unit.
This unit in the middle and upper third of the slope. It is tops out on the main ridge dividing the Kootenai River and Rainey Creek. It is on a NE-NW aspect on an extremely steep slope heavily timbered slope that is primarily fuel model 165. This unit is partially sheltered from a strong SW wind but eddying will occur on the lee side in this unit. A fire on the river face south of this unit has a high probability of depositing embers in this unit and with the eddying effect, would probably cause fire spread upslope back to the south toward the ridgetop. There is a high probability of fire in this unit producing crowning runs with a strong NW wind. This strong NW wind could cause fire spread away from Grace's Proposed OU3 Area.									

Ownership	Unit #	Ac.	OU3 Area	Roaded	Wind Event	Crown Fire	FL	ROS	Minimum Travel Time
Forest Service	26	56	In	Yes	SW & NW	Passive w/some Active	H-E	M-H	Major SW and NW wind multiple pathways through the unit.
This unit lies from the lower to middle third of the slope on a steep, heavily timbered in fuel models 165 and 188. A strong SW wind would spread fire further into Grace's Proposed OU3 Area. Fire in this unit would threaten other areas in Grace's Proposed OU3 Area that also have a high probability of producing extreme fire behavior characteristics in a strong SW wind. A fire in this unit with a strong NW wind has a high potential of compromising the main road leading to the mine and spreading toward the mine. The mine site is only about .25 miles from the bottom of this unit.									
Forest Service	27	84	In	Yes	SW & NW	Passive & Active	H-E	H-E	Major SW and NW wind multiple pathways through the unit.
This unit lies from the bottom of the drainage to the top of the ridge on a very steep, heavily timbered slope. The main fuel models in this unit are 165 and 188. A fire spreading through or from this unit by a strong SW or NW wind would cause fire spread well into Grace's Proposed OU3 Area with high intensity crown fire runs, lofting fire brands further into Grace's Proposed OU3 Area. This unit is approximately 1 mile west of the mine site.									
Ownership	**Unit #**	**Ac.**	**OU3 Area**	**Roaded**	**Wind Event**	**Crown Fire**	**FL**	**ROS**	**Minimum Travel Time**
Forest Service	28	57	Out	Yes	NW & SW	Passive & Active	H-E	M-H	Major SW and NW wind multiple pathways through the unit.
The unit is located in the middle and top third of the slope. It is heavily timbered and is about 1.25 miles north of Highway 37. The main fuel models in this unit are 165 and 188. Lightning starts are always a problem throughout Grace's Proposed OU3 Area but this unit's location adds some additional complexity. The reason is because of the person-caused fire threat along the highway. Fire starting on the fast spreading fuels on the slopes below this unit could spread rapidly up through this area.									
Forest Service	29	80	Out	Yes	NW	Active & Passive	H-E	H-E	Major NW wind multiple pathways through the unit.
The unit lies from the bottom of the drainage on the north to the top of the main ridge. All aspects are present in this unit because the unit lies on both sides (north and south) of the main ridge. It is heavily timbered on very steep slopes. The entire unit is predominantly fuel model 165. The unit is about ½ mile west of Grace's Proposed OU3 Area. A strong NW cold frontal passage would be of major concern for spreading toward the area of concern. Because of the high probability of active crown fire which would launch embers easily into the area of concern. The northern portion of this unit is in the head of a drainage that is aligned directly with a NW cold frontal passage.									
Forest Service	30	39	Out	Yes	NW	Active & Passive	H-E	H-E	Major NW wind multiple pathways through the unit.
The unit is on the lower portion of the slope. It is heavily timbered that is mostly fuel model 165. The unit is about .9 miles west of the Proposed OU3 boundary. A strong NW cold frontal passage would be of major concern for spreading toward the area of concern. Because of the high probability of active crown fire which would launch embers easily into the area of concern and would cause fire to spread up canyon to FS unit #29									

that also has a high potential of exhibiting extreme fire behavior. The northern portion of this unit is in a drainage that is aligned directly with a strong NW cold frontal passage.									
Forest Service	31	51	Out	Yes	NW	Active & Passive	H-E	H-E	Major NW wind multiple pathways through the unit.
This unit is on a low ridge and lies from the bottom of a drainage to the ridgetop and is also a heavily timbered fuel model 165. As with FS unit #30, because of the high probability of active crown fire, fire spread and lofted embers from a strong NW cold frontal passage would enter areas that would also have a high probability of exhibiting extreme fire behavior. This unit is in a drainage that is aligned directly with a strong NW cold frontal passage.									
Ownership	**Unit #**	**Ac.**	**OU3 Area**	**Roaded**	**Wind Event**	**Crown Fire**	**FL**	**ROS**	**Minimum Travel Time**
Forest Service	32	51	Out	Yes	NW	Active & Passive	H-E	H-E	Major NW wind multiple pathways through the unit.
This is a ridgetop unit heavily timbered with a combination of fuel model 165, 188, and 161. This unit is located about 1.25 miles on one of the highest ridges NW of Grace's Proposed OU3 Area. Due to the high probability of active and passive crown fire, fire spread and lofted embers from a strong NW cold frontal passage would have a high probability of entering areas that would also exhibit a high probability of extreme fire behavior.									
Forest Service	33	67	Out	No	SW	Passive	M-H	M	Major SW wind multiple pathways through the unit.
This unit is aligned along the highest ridge on the divide between the Kootenai River and Rainey Creek. It will provide a break in the fuels from any fire originating on the steep, inaccessible south aspect river face. The unit contains a combination of 165, 161, and 188 fuel models. This unit would assist in retarding surface fire spread over the ridge into areas that have a higher crown fire potential closer to Grace's Proposed OU3 Area.									
Forest Service	34	49	Out	No	SW	Active & Passive	E	E	Major SW wind multiple pathways through the unit.
This unit is aligned with a strong SW wind event on the upper third of the slope in a heavily timbered fuel model 165. It lies on a NW aspect. A fire burning upslope from the river toward the main divide between the Kootenai River and Rainey Creek would have a high probability of high intensity active crown fire runs directly aligned with the strong SW wind event producing long-range spotting over the main ridge into other areas that would support active crown fire (Units FS25 and FS37) near Grace's Proposed OU3 Area. This unit sits above an area that has a history of person-caused fires along Highway 37 and on private land.									
Forest Service	35	73	Out	Yes	SW	Passive w/some Active	M-H	M-H	Major SW wind multiple pathways through the unit.
This unit has similar fire characteristics as FS Unit #34 and the same person-caused fire problem but is below this unit on the middle third of the slope. Crown fire potential, flame length and rate of spread are less than FS Unit #34. Fire in this unit location would contribute to fire becoming established in FS #34 and the head of the drainage.									

Forest Service	36	90	Out	Yes	SW	Active & Passive	E	H-E	Major SW wind multiple pathways through the unit.
This unit is located in the bottom upslope from the private land near the Kootenai River. It is mainly fuel model 188 with some 165 and 102. Due to the elevated risk of person-caused fires on private land and along Highway 37 this unit will provide protection from fire spreading upslope toward Grace's Proposed OU3 Area through fuels that would greatly increase the threat to the area of concern.									
Ownership	**Unit #**	**Ac.**	**OU3 Area**	**Roaded**	**Wind Event**	**Crown Fire**	**FL**	**ROS**	**Minimum Travel Time**
Forest Service	37	67	Out	No	SW	Passive	H	L-M	Major SW wind multiple pathways through the unit.
This unit is located adjacent to the Proposed OU3 boundary on steep, heavily timbered fuel model 165 on the upper third of the slope. The top of the unit is on the main ridge that divides the Kootenai River and Rainey Creek. It is on a NW aspect. Fire in this unit has a high probability of spreading downslope into the area of concern and along the ridge to the NE impacting additional areas with higher crown fire potential and fire intensities which could further involve areas within Grace's Proposed OU3 Area. Treatment of this unit would provide protection of the major powerline adjacent to this unit.									
Forest Service	38	223	Out	Yes	SE & SW	Passive & Active	H-E	M-E	Major SW and SE wind multiple pathways through the unit.
This unit is on a S to SE aspect on the upper third of the slope on the ridge dividing the Kootenai River and Rainey Creek on the SE side of Grace's Proposed OU3 Area. It is located about .3 miles from the area of concern. It contains a mixture of fuel models 165, 188, 161, and 201 (blowdown) on steep slopes that are accessible by road. Fire in this area would spread rapidly up slope and laterally with strong SW and SE winds with a high probability of producing spotting in Grace's Proposed OU3 Area as well as in other areas with high fire potential. Treatment of this unit would provide protection of the major powerline adjacent to this unit.									
Forest Service	39	100	Out	Yes	SE & SW	Passive w/some Active	H-E	M	Major SE and SW wind pathways near the unit.
This unit lies adjacent to the Proposed OU3 boundary on the upper third of the slope in predominantly fuel model 165. This unit is on a very steep slope inaccessible by road. Fire in this area with a strong SW wind would spread fire along the ridge to the NE impacting other areas with high fire potential further risking the area of concern along its eastern boundary. A strong SE wind with fire in this unit would cause eddying on the lee side of the ridge which would allow fire to spread back upslope, laterally and downslope toward the area of concern. Due to the elevated spread rates fire could easily enter Grace's Proposed OU3 Area.									
Forest Service	40	103	In/Out	No	SW	Active & Passive	M-E	M-H	Major SW wind multiple pathways through the unit.
The unit is located on the upper third of the slope on the ridge dividing Rainey Creek and Jackson Creek in a mixture of fuel models 165 and 188 with some 161. This unit is on a very steep inaccessible area. Fire with a strong SW wind would spread over the ridge and loft embers further into Grace's									

Proposed OU3 Area to north aspects that would support active and passive crown fire.									
Forest Service	41	28	Out	No	SW	Active	E	E	Major SW wind multiple pathways through the unit.
The unit lies in the upper third of the slope directly aligned with a strong SW wind. The top of the unit is on the main ridge dividing the Kootenai River and Rainey Creek. Fuel model 165 is the main fuel model in the area. It is heavily timbered on a very steep inaccessible slope which shows that it will produce high intensity crown fire with extreme spread rates and flame lengths. The fire behavior in this area will produce long-range spotting over the main ridge toward Grace's Proposed OU3 Area and into other areas outside the area of concern that would also have a high probability of exhibiting intense fire behavior.									

Ownership	**Unit #**	**Ac.**	**OU3 Area**	**Roaded**	**Wind Event**	**Crown Fire**	**FL**	**ROS**	**Minimum Travel Time**
Forest Service	42	74	Out	No	SE & SW	Active & Passive	H-E	H-E	Major SW wind multiple pathways through the unit.
This unit is located in the Inventoried Roadless Area on the upper third of the slope with the dominant fuel model of 165. This unit is about .75 miles SE of Grace's Proposed OU3 Area. A strong SE wind would have a high probability of causing fire spread toward the area of concern through long-range spotting, surface fire spread and crown fire spread.									
Forest Service	43	52	Out	Yes	SE & SW	Passive w/some Active	H	M-H	Major SE wind multiple pathways through the unit.
This unit lies from the top of the ridge to the bottom of the drainage on a W aspect on a steep, heavily timbered slope that is mainly a mixture of 165 and 161. It is about ½ mile from the Proposed OU3 boundary that is to the N/NW. The unit is aligned with a drainage that, during a strong SW wind, will funnel the wind directly toward the area of concern. Fire in this unit has a high potential of producing crown fire runs with long-range spotting to the NE with a strong SW wind or to the NW with a strong SE wind. There are numerous past harvest units in the area that may inhibit surface fire spread but spotting can occur past these units into areas that would threaten fire entering the area of concern.									
Forest Service	44	92	Out	Yes	SE & NE	Passive w/some Active	H	M-H	Major SE and NE wind multiple pathways through the unit.
This unit lies from the top of the ridge to the bottom of the drainage on N and NE aspects on a steep, heavily timbered slope that is mainly a mixture of 165, 161, and 183. It is about ¼ mile from the Proposed OU3 boundary that is to the N/NW. The unit slope is aligned with a strong NE wind that has the potential of spreading fire toward the area of concern. Fire in this unit has a high potential of producing crown fire runs with long-range spotting to the NW and SW with strong SE or NE winds. There are numerous past harvest units in the area that may inhibit surface fire spread but spotting can occur past these units into areas that would threaten fire entering the area of concern.									
Forest Service	45	90	In	Yes	NW & NE	Passive w/some Active	M-H	M-H	Major NW and NE wind multiple pathways through the unit.
This unit lies in the lower and middle third of the slope in a heavily timbered area that is mainly fuel model 165. Fire in this unit has a high potential									

of producing crown fire runs with long-range spotting to the SE and SW with strong NW or NE winds. There are numerous past harvest units in the area that may inhibit surface fire spread but spotting can occur past these units into areas that would threaten fire spreading further impacting the area of concern.									
Ownership	**Unit #**	**Ac.**	**OU3 Area**	**Roaded**	**Wind Event**	**Crown Fire**	**FL**	**ROS**	**Minimum Travel Time**
Forest Service	46	102	Out	Yes	NW & NE	Mainly Active w/some Passive	E	E	Major NW and NE wind multiple pathways through the unit.
This unit lies from the bottom of the drainage to the top of the main ridge on the slope with a N aspect in a heavily timbered area that is mainly fuel model 165. Fire in this unit has a very high potential of producing active crown fire runs with long-range spotting to the SE and SW with strong NW or NE winds. There are some past harvest units in the area that may inhibit surface fire spread but due to the long-range spotting problem from this unit the area of concern would be threatened.									
Forest Service	47	29	In/Out	Yes	NW & NE	Passive	M-H	M	Major NW wind multiple pathways through the unit.
This unit lies upper third of the slope on an E aspect in a heavily timbered area that is mainly fuel model 165. Fire in this unit has a potential of producing crown fire runs with spotting to the SE and SW with strong NW or NE winds. There are some past harvest units in the area that may inhibit surface fire spread but due to the spotting problem from this unit to loft embers into other areas that could exhibit elevated fire potential that would further threaten the area of concern.									
Forest Service	48	28	In/Out	No	NW	Passive w/some Active	H-E	M-H	Major NW wind multiple pathways adjacent to the unit.
This unit lies on the upper third of the slope to a main ridge above the Rainey Creek drainage on a W/NW aspect in direct alignment with a strong NW wind in predominantly fuel model 165. This unit is adjacent to the State Unit #4. A strong NW wind would spread fire down into Rainey Creek into Grace's Proposed OU3 Area toward the mine site.									
Total – 48 Forest Service Units = 4,809 Acres									
State	1	23	Out	No	NW	Active & Passive	H	M-H	Major NW wind multiple pathways through the unit.
This unit lies on the upper third of the slope to a main ridge above the Rainey Creek drainage on a S/SW aspect in predominantly fuel models 165 and 188. This unit is adjacent to the FS Unit #24. The unit is less than ¼ mile NW from Grace's Proposed OU3 Area. A strong NW wind would spread fire down into Rainey Creek into Grace's Proposed OU3 Area toward the mine site.									
State	2	68	Out/In	No	NW	Passive	H	M	Major NW wind multiple pathways through the unit.
This unit lies on the upper third of the slope to a main ridge above the Rainey Creek drainage on a combination of N/W/S facing aspects in predominantly fuel models 165 and 188. This northern side of this unit is in a drainage that is in direct alignment with a strong NW wind. A strong									

NW wind would spread fire down into Rainey Creek into Grace's Proposed OU3 Area toward the mine site.									
Ownership	**Unit #**	**Ac.**	**OU3 Area**	**Roaded**	**Wind Event**	**Crown Fire**	**FL**	**ROS**	**Minimum Travel Time**
State	3	50	In	No	NW & SW	Active & Passive	H	M-H	Major NW and SW wind multiple pathways through the unit.
This unit lies from the bottom of the slope to a main ridge directly above Rainey Creek on a S aspect in predominantly fuel models 165 and 188 with some 161. The unit is less than 1/10th mile from the Rainey Creek road which is directly adjacent to the mine site. A strong NW or SW wind would spread further into Grace's Proposed OU3 Area toward the mine site and surrounding areas around the mine site. There is a high potential for mid to long range spotting to the SE and N/NW from the NW and SW strong winds.									
State	4	19	Out	No	NW & SW	Active & Passive	H	M-H	Major NW and SW wind multiple pathways through the unit.
This unit lies on the upper third of the slope in direct alignment with a strong NW cold frontal passage wind.in a combination of fuel models 188 and 165. This unit has a common boundary with the FS Unit #48. It is adjacent to Grace's Proposed OU3 Area, therefore any fire in this unit would have a tendency to spread into Grace's Proposed OU3 Area to the SE with a strong NW wind. A fire in this unit influenced by a strong SW wind would spread fire along Grace's Proposed OU3 Area further threatening other areas to the NE along that boundary. Spotting from any fire in and around this unit would be into the area of concern.									
Total – 4 State of Montana Units = 160 Acres									
Private	1	9	Out/In	Yes	SW	Passive & Active	H	H	Major SW wind multiple pathways through the unit.
This unit lies in the mouth of Rainey Creek on private land at the bottom of a steep slope on a N aspect. The main fuel models are 188 and 165 with some blowdown (201). A strong SW wind event would spread a fire up Rainey Creek compromising the safety along the Rainey Creek road leading to the mine site. Fire would also have a high probability of becoming established on the east side of the drainage on the upper slopes that would produce fast spreading active crown fire toward the top of the main ridge dividing the Kootenai River from the Rainey Creek drainage. Any fire in the crowns from active or passive would loft embers up Rainey Creek further threatening the area of concern and could possibly involve both sides of the Rainey Creek drainage which would definitely compromise the safety of firefighters, mine employees, and public along the road corridor.									
Private	2	9	In/Out	No	SW	Passive and Active	H	H-E	Major SW wind multiple pathways through the unit.
This unit lies in the mouth of Rainey Creek on private land at the bottom of a steep slope on a W aspect. The main fuel models are 188 and 165. A strong SW wind event would spread a fire up Rainey Creek compromising the safety along the Rainey Creek road leading to the mine site. Fire would also have a high probability of becoming established on the west side of the drainage on the upper slopes that would produce fast spreading surface fires in the fine fuels and active crown fire toward the upper slopes above Rainey Creek. Any fire in the crowns from active or passive would loft embers up Rainey Creek further threatening the area of concern and could possibly involve both sides of the Rainey Creek drainage which would									

definitely compromise the safety of firefighters, mine employees, and public along the road corridor.
Total – 2 Private Land Units = 18 Acres

Forest Fuels Modification
to Reduce Fire Size, Fire Intensity, Crown Fire & Spotting Potential

Key Points

Wildland fire behavior is influenced by fuels, weather and topography. The only factor that can be modified to reduce fire size, fire intensity, crown fire potential and spotting probability is fuels. Therefore, it is critical in a forested environment in areas where fire suppression is designated that the fuels profile be managed to reduce the probability of large, catastrophic wildfires. These large wildfires can cause threats to human life and property, tremendous resource damage, threaten and damage values at risk.

- Forested areas within Grace's Proposed OU3 Area are comprised of dense timber stands that have a high probability of producing high fire intensities with crown fire and spotting potential.
- The fuel model that dominates these timber stands is most characterized by fuel model 165 (TU5) and to a lesser degree by fuel model 188 (TLS).
- These timber stands were identified as target stands for proposed fuel treatment areas within Grace's Proposed OU3 area and the Buffer surrounding this area.

- The proposed treatments link or connect past vegetative treatments.
- Fire and forest managers with local knowledge and many years of experience on the Kootenai National Forest were also consulted, provided valuable information on vegetation, distribution, stand characteristics as well as fire behavior and fuel treatments that proved essential to the integrity of this project.

Appendix B

Fire Behavior Appendix Contents

Assumptions, Limitations, Data Gaps, for Fire Behavior Analyses

Assumption: The analyses are based on current landscape conditions and assume that recommended treatments will be implemented concurrently. Vegetation may be altered in the future by normal growth, natural succession, or disturbance (fire, pathology, and management actions); these analyses may not be valid under future conditions, and the treatments may be less effective if implemented individually over an extended time period. Recommended treatments are expected to lose effectiveness over time and will require repeated treatment. Other tools such as Forest Vegetation Simulator/Fuels and Fire Extension may be useful in modeling future conditions to estimate future costs of maintaining landscape treatments.

Limitation: The fire behavior inputs were created based on local expert knowledge of fuels and fire behavior, satellite imagery, modeling experience during the 2015 fire season, and limited field observations during the month of January. The analysts did not have the opportunity to calibrate the inputs by observing a burning wildfire in the analysis area. However, overall fire history and behavior in the greater area indicates fire potential.

Assumption: The suggested treatments primarily focus on forested areas with heavy surface fuels, trees that torch to produce spot fires, and areas where wind/slope align with these fuels. Experience managing fires in the Northern Rockies verifies that these are the fuels conditions that are problematic for fire suppression. This vegetation was modeled as Fuel Model 165 (Very High Load, Dry Climate Timber-Shrub). The treatment of these stands could increase rate of spread due to less wind reduction at the mid-flame level when the canopy is removed, but lower overall flame lengths and open conditions would enhance firefighting capabilities. The rate of spread is expected to be modified to levels significantly less than Fuel Model 165. Flame lengths, potential for crown fire and resistance to control will be significantly reduced immediately after treatment and these conditions will remain as long as the units are maintained in the recommended fuels condition. Treatments were verified and supported through modeling, but treatment location and design was based on experience and judgment regarding fire behavior and movement in these fuels and on these landscapes.

Limitation: The fuel treatment design presented here was accomplished during a 14-day period. Time constraints limited the number of iterations between treatment design and modeling for effectiveness testing. Four evolving versions of the treatment design were analyzed, but further modeled testing is warranted as fuels are ground-truthed.

Assumption: The mask created around the Mine Site delineates denuded ground that will remain in an unburnable condition in the future.

Data Gap: Updated stand data would be necessary for Forest Vegetation Simulator/Fire Fuels Extension (FVS-FFE) analysis that can simulate growing vegetation and treatments over time.

Limitation: Under the most extreme weather scenarios from the weather record (1994, 2007, 2015), fires can still spread toward and within the Area of Concern; however, the fire behavior characteristics (flame length, crown fire activity, spotting distance, intensity) will be significantly reduced, leading to greater suppression effectiveness. Rate of spread may be reduced less significantly, or may increase slightly after treatment.

Limitation: The model outputs are subject to all limitations and assumptions common to all Rothermel-based fire behavior models (BEHAVE, FlamMap, FARSITE and all modeling systems that bundle these models in the WFDSS interface).

Modifications to Landfire 2012 to Represent Existing Conditions

Landscape Source and Extent: The .lcp file for the Libby OU3 fire modeling projects was derived from the WFDSS landscape generator using Landfire 2012 1.3.0 with a resolution of 30 meters. The Fuel Model layer uses the Scott/Burgan 40. The standard landscape extent was defined by the coordinates below; however, minor adjustments were made on individual runs if the standard landscape was not adequate or was excessive.

Landscape Extent

N 48.5442	
W 115.5603	**E** 115.2539
S 48.3489	

Landscape Edits: After examination of the landscape layers and consultation with local fire personnel, several edits were made to the landscape layers

Fuel Model 122 (GS2): Fuel Model 122 occurs across approximately 20-25% of the OU3 landscape in the unedited LANDFIRE 2012 Fuel Model layer, including much of the denuded area surrounding the Mine Site and a large percentage of previously treated/logged units. The denuded areas surrounding the Mine Site are devoid of sufficient vegetation to support fire spread. The treated/logged areas have not been observed to support the rate of spread and flame lengths associated with FM122 based on input from experienced fire managers and local fire staff; furthermore, FM122 was deemed inaccurate for use in the logged units on Plum Creek lands that contain low loads of activity fuels.

Photo: Treated/logged units on east side of mine area with Mine Site in background.

Local Knowledge

On January 25, the following local experts were consulted, and they collaboratively concluded that FM122 should be corrected to FM161(Low Load Dry Climate Timber-Grass-Shrub) to better represent the fuel loading and fire behavior observed in the OU3 regen units:

Glenn Gibson

Dan Rose

Seth Cole

Jeff Stevenson

Wyatt Frampton

On January 26, we met with Glenn Gibson, Ron Hvizdak and Dan Rose. The discussion concluded that northfacing slopes in the treated/logged areas originally classified as FM122 would be even more resistant to fire spread than represented by FM161; they recommended changing the northfacing slopes to FM183 (Moderate Load Conifer Litter). They also added descriptions of observed fuels in Plum Creek logging units that included light loads of activity fuels; they matched their knowledge of the units and observed fire behavior on past fires to FM185 (High Load Conifer Litter) on north-facing slopes and FM201 (Low Load Activity Fuel) on south-facing slopes.

Conclusions

1) The denuded area surrounding the Mine Site was converted to Fuel Model 99 (Bare Ground).
2) FM122 on southfacing slopes was converted to Fuel Model 161 (Low Load Dry Climate Timber-Grass-Shrub); FM122 on northfacing slopes was converted to Fuel Model 183 (Moderate Load Conifer Litter).
3) Logging units on Plum Creek land that were modeled as FM122 were converted to FM185 (High Load Conifer Litter) on northfacing slopes and FM201 (Low Load Activity Fuel).

These conversions are expected to significantly slow the rate of spread and decrease flame length as compared to FM122.

The resulting landscape edit rules for the untreated fuel model layer are:

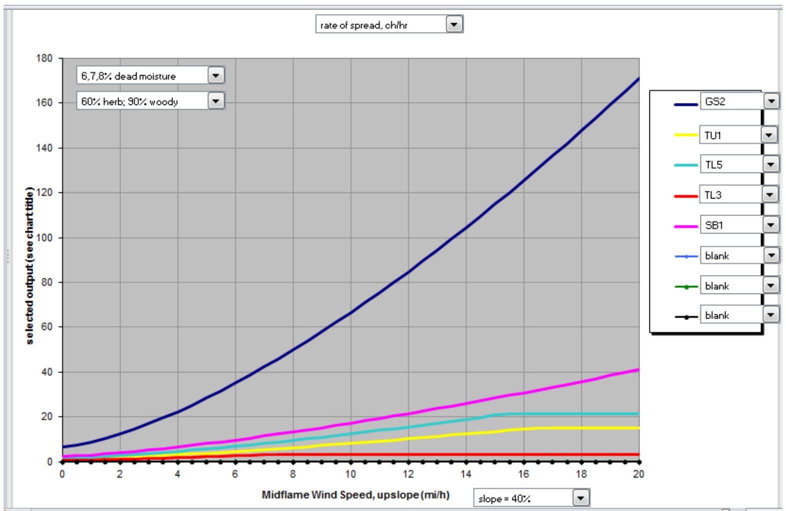
Landscape File Editor

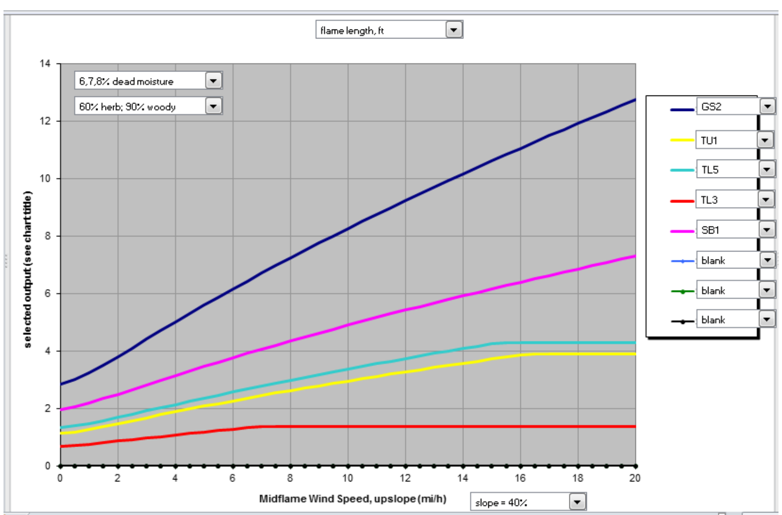
Attribute	Rule Description
Fuel Model	If (LCP intersects Mine Site Low Fuel) Set Fuel Model to 99
Fuel Model	Else If (Fuel Model is 122) AND (Aspect is between 135 and 225) AND (LCP intersects PlumCreek) Set Fuel Model to 201
Fuel Model	Else If (Fuel Model is 122) AND (LCP intersects PlumCreek) Set Fuel Model to 185
Fuel Model	Else If (Fuel Model is 122) AND (Aspect is between 135 and 225) Set Fuel Model to 161
Fuel Model	Else If (Fuel Model is 122) Set Fuel Model to 183
Canopy Cover	If (Fuel Model is 165) Multiply Canopy Cover by 0.7

Add Edit Move Up Delete...

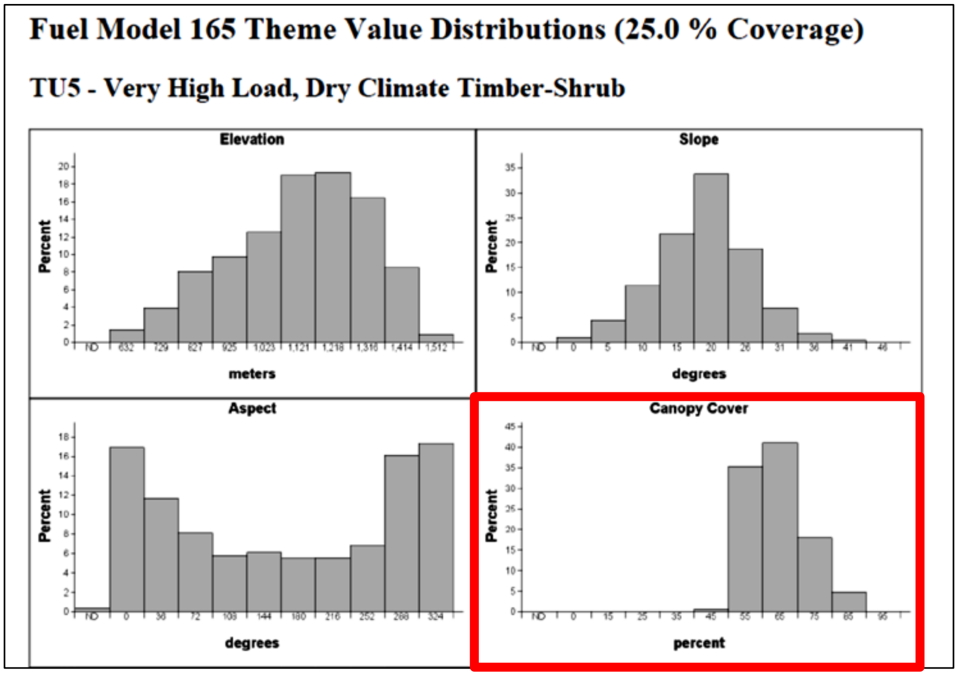
Compare4 Graphs comparing Rate of Spread and Flame Length for the discussed Fuel Models appear on the next page.

Compare4 Graphs comparing Rate of Spread and Flame Length of FM122 (GS2), FM161 (TU1), FM183 (TL3), FM185 (TL5), and FM201 (SB1) under low fuel moisture scenarios on a 40% slope:





Canopy Cover: The Landscape Critique for the analysis area reveals an unrealistically high value for Canopy Cover (CC) within Fuel Model 165 (Very High Load, Dry Climate Timber-Shrub):



According to Stratton (2009), CC rarely exceeds 70% even in so-called closed-canopy forests. Further, the LANDFIRE website (2016) states:

Background:

Some external review suggests LANDFIRE forest canopy cover (CC) estimates are too high. This is difficult to verify given the lack of reliable field-based canopy cover observations in forest systems, but the effect on potential fire behavior can be substantial.

Advice:

Reduction in LANDFIRE forest canopy cover should be performed on a case-by-case basis. In general, we recommend reducing canopy cover more intensely on the higher end than on the lower of the potential range in an area. One option is to reduce canopy cover by 30% between 95 - 55% and by 15% between 25 - 45%.

This overestimation of Canopy Cover was only seen in FM165 on this landscape, so the landscape edit rule of “If Fuel Model=165, multiply Canopy Cover by .7” was applied to the landscape. This rule was also consistent with analyses performed by LTANs Opperman and Taber on the Clark Fork Complex in 2015.

Conclusion: Literature supports reducing Canopy Cover by 30% in Fuel Model 165 on this landscape.

References

Stratton, Richard D. 2009. Guidebook on LANDFIRE fuels data acquisition, critique, modification, maintenance, and model calibration. Gen. Tech. Rep. RMRS-GTR-220. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 54 p.

LANDFIRE website: http://landfire.gov/notifications16.php <accessed Jan 24, 2016>

Justification for Buffer Zone Around "Area of Concern" Based on Spotting Distance

A wildland fire is said to be "spotting" when it produces sparks or embers that are carried by the wind and start new fires beyond the zone of direct ignition by the main fire. Ember production from torching trees and crown fire can rapidly advance the fire front, increasing its growth and allowing it to cross natural or artificial barriers, compromising suppression effectiveness, access routes and firefighter safety (Albini 1979; "18 Watchout Situations"). In order to protect the EPA remedy within the Area of Concern, the Area of Concern must be protected from fire starts due to spotting from outside the Area of Concern.

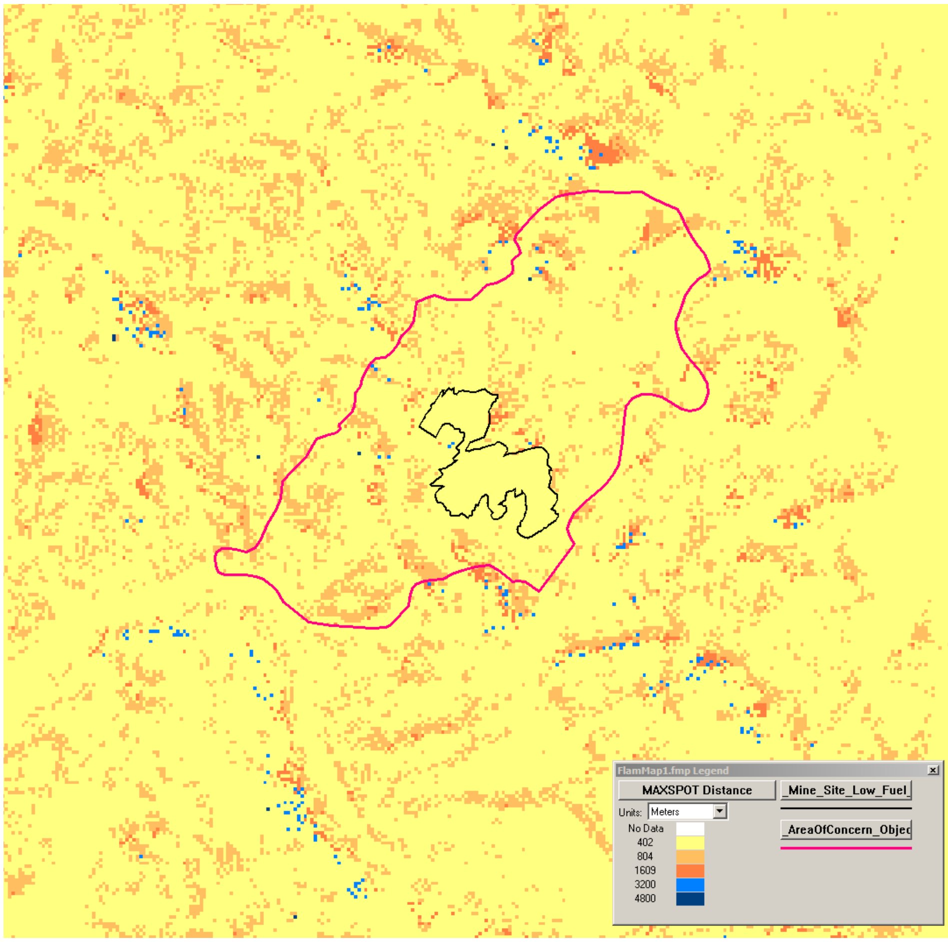
Under extreme weather conditions in the Northern Rockies, spotting distance has been anecdotally reported to exceed several miles. Extreme fire behavior phenomena such as fire whirls and plume-dominated fire may loft firebrands hundreds of feet into the air to be carried miles away by prevailing winds (Albini 1979). Prevention or significant reduction of spotting from these distances into the Area of Concern is unrealistic; however, spotting distance derived from models created for use under steady-state fire spread is used with success when managing actual fires and planning suppression actions. The estimated spotting distance is expected to define an area that will address a significant proportion of lofted embers.

Spotting was modeled using the BEHAVE Plus5 Spotting Distance module. FlamMap Maximum Spotting Distance grids display this same calculation geospatially, varying inputs based on landscape data. The underlying model for both of these modules is the same, but there are different data sources for each of the modules.

BEHAVE: Some of the inputs for the BEHAVE run were chosen from values found in the .LCP layers in the OU3 landscape file. Because values vary across the landscape, and BEHAVE requires the input of a single value, analyst judgement is needed to select which value to use from within the range shown in the .LCP file (histograms below). The "Spot Tree Species" is not available in the .LCP layer; Ponderosa Pine and Douglas-fir at varying DBHs were selected to represent the spotting scenarios from FM188 and FM165. The topography to the northwest of the Area of Concern was evaluated for topographical inputs, as this area has been identified as having the potential to produce spots that would be lofted toward the Area of Concern during a "Cold-Front Passage" weather scenario. The maximum number of torching trees was chosen based on the high amount of passive crown fire expected in the untreated areas outside the treatment boundary. The weather scenario used in both analyses was the August 2007 scenario used in OU3 analyses. The BEHAVE inputs/outputs are attached. The output is for a single set of variables; i.e., one spot on the landscape under a single weather scenario.

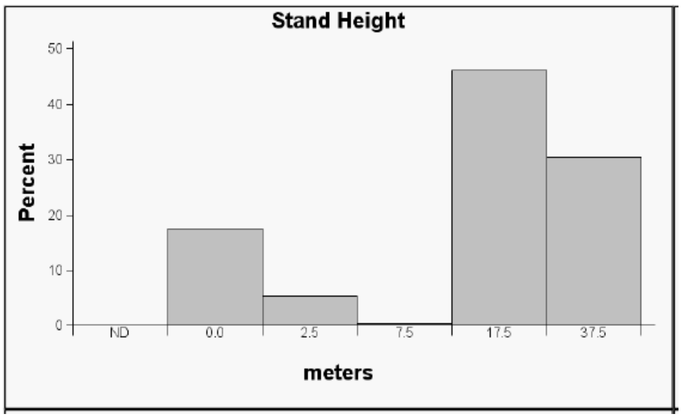
FlamMap: Maximum Spotting Distance from each pixel on the Landfire 2012 landscape (fuels were modified to represent the current condition for the analysis (see LCP Rules). The landscape is 30m resolution, winds are gridded with Wind Ninja at 60m resolution using a 225 input azimuth and 30mph wind speed. Fire behavior is calculated for each node on a 30m fixed grid, and when the node shows passive or active crown fire, 16 incrementally-sized embers are lofted and "followed". Embers travel distances based on lofting heights determined with Crown Fraction Burned as a surrogate for "number of torching trees". Maximum spotting distance and azimuth are calculated using canopy cover, crown fraction burned, elevation, and wind to create this theme. Units are shown in meters broken at 402 (0.25mi), 804 (0.50 mile), 1609 (1 mile), 3200 (2 mile), and 4800 (3+mile). Most of the landscape shows spotting distances of 1 mile or less.

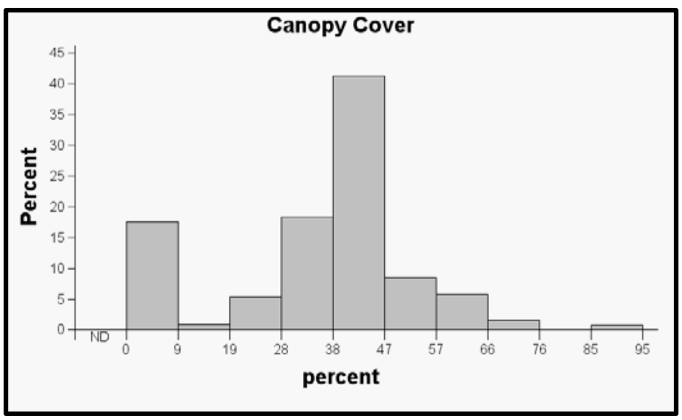
The FlamMap spatial output for the OU3 analysis landscape is below:



Conclusion: Using either model, the output indicates that the maximum spotting distance is approximately 1 mile within the OU3 analysis landscape. Therefore, reducing spotting potential within 1 mile of the Area of Concern is expected to address the majority of potential spotting into the Area of Concern, but extreme fire behavior within several miles of the Area of Concern could still potentially loft embers into the Area of Concern.

Values for Untreated (but modified to represent current condition) LCP (in meters); used as inputs in BEHAVE for spotting module.





BehavePlus 5.0.5 (Build 307)

Spotting Distance from Torching Trees
Mon, Feb 01, 2016 at 10:12:50

Input Worksheet

Inputs: CROWN, SPOT, IGNITE

Input Variables	Units	Input Value(s)
Fuel/Vegetation, Overstory		
Downwind Canopy Height	ft	120
Torching Tree Height	ft	120
Spot Tree Species		PINPON, PSEMEN
D.B.H.	in	12, 14, 16, 18, 20, 22, 24
Fuel Moisture		
1-h Moisture	%	3
Weather		
20-ft Wind Speed (upslope)	mi/h	30
Air Temperature	oF	90
Fuel Shading from the Sun	%	60
Terrain		
Ridge-to-Valley Elevation Difference	ft	1500
Ridge-to-Valley Horizontal Distance	mi	1.5
Spotting Source Location		RT
Fire		

Number of Torching Trees	30

Notes

Run Option Notes

None

Results for: Spot Dist from Torching Trees (mi)

Spot Tree	D.B.H.						
Species	in						
	12	14	16	18	20	22	24
PINPON	0.9	0.9	0.9	0.9	1.0	1.0	1.0
PSEMEN	0.9	1.0	1.0	1.0	1.0	0.9	0.9

Results for: Probability of Ignition from a Firebrand (%)

Spot Tree	D.B.H.						
Species	in						
	12	14	16	18	20	22	24
PINPON	86	86	86	86	86	86	86
PSEMEN	86	86	86	86	86	86	86

Literature Cited

ALBINI, F. A.1979. Spot fire distance from burning trees--a predictive model. USDA For. Service. Gen. Tech. Rep. INT-56, 73 p. Intermt. For .and Range Exp. Stn, Ogden, Utah

Live Fuel Moisture Inputs

Live fuel moistures are notoriously difficult to pin down for modeled analyses—field samples from the same site on the same day from the same species have been documented to exhibit standard deviations as high as 47% (Jolly 2007). On wildfire incidents, the single input values (one value each for herbaceous and woody fuel moisture) required by fire behavior models are informed by field sampling data, field observations of plant phenology, calibration to observed fire behavior, and wildland fire modeling experience.

The 30% herbaceous/60% woody live fuel moisture scenario was commonly used for fire behavior analyses in WFDSS on the Kootenai NF fires of 2015. One analyst (not a member of the current analysis team) noted in her FSPro run for the Napoleon 1 fire "The dead and live fuel moistures were adjusted to district measurement," and the live fuel moistures inputs referred to were 35% for the herbaceous fuel moisture and 70% for the woody live fuel moisture in the 97th percentile bin (the ERCs during the analysis period were above the 97th percentile) (S. Miller 2015); we will attempt to find the data this note was based on. An analysis of 2015 fire behavior analyses in WFDSS for fires on the Kootenai NF yielded 8 fire behavior analyses that were accepted ("completed") by analysts in the days surrounding August 1 (the chosen date for our analyses). The average herbaceous fuel moisture used was 36.2% (range=30-50%), and the average woody fuel moisture was 68.7% (range=60-90%).

Furthermore, using the 30/60 scenario in the 97th percentile bin and the "Libby OU3" landscape edits in a 7-day FSPro analysis completed during this 2016 modeling effort, we generated outputs roughly consistent with the spread of the first week of 2007 Brush Creek Fire before effective suppression efforts were implemented; i.e., the largest fire sizes and daily acres were consistent with the progression of the Brush Creek fire, which burned under greater than 97th percentile conditions. While this method of analysis is admittedly a "stretch" for FSPro in isolation, it is one method among several that analysts routinely use to evaluate the "reasonableness" of an FSPro output and calibrate the model.

All that said, our evaluation of the specific fuel models across the analysis landscape (figure below) indicates that there is a low relative sensitivity to changes in live fuel moisture (Jolly 2007).

Fuel Model Legend

Resolution: 30 meters

Value	Freq	Value	Freq
91 - NB1	9,764	188 - TL8	149,859
92 - NB2	2	201 - SB1	8,062
93 - NB3	14	No Data	950
98 - NB8	27,961		
99 - NB9	7,192		
101 - GR1	3,598		
102 - GR2	40,930		
121 - GS1	4,492		
142 - SH2	387		
143 - SH3	2		
145 - SH5	73		
147 - SH7	5,382		
161 - TU1	56,589		
162 - TU2	453		
165 - TU5	143,144		
181 - TL1	100		
182 - TL2	367		
183 - TL3	67,691		
185 - TL5	16,684		
186 - TL6	3,648		

Using a "Low" live fuel moisture scenario (60% for herbaceous and 90% for woody) as opposed to a "Very Low" fuel moisture scenario (30% for herbaceous and 60% for woody) does not result in large-scale changes to the outputs that would affect our recommendations—the problem areas we are proposing to treat are still identified in the higher-LFM scenario. As a show of good faith, we will use the 60%/90% live fuel moisture scenario.

Literature Cited

Jolly, Matt (2007) Sensitivity of a surface fire spread model and associated fire behaviour fuel models to changes in live fuel moisture. International Journal of Wildland Fire, 2007, 16, 503–509.

Canopy Characteristic Standards for Treatment Areas

The canopy characteristics developed for this project were based on values contained in Forest fuels planning documents as well as critical values computed in the BEHAVE Plus 5 program.

From the East Reservoir EIS (Kootenai National Forest):

Table 3.74 – Pre- and Post-Treatment Stand Characteristics Used for Fire Behavior Modeling

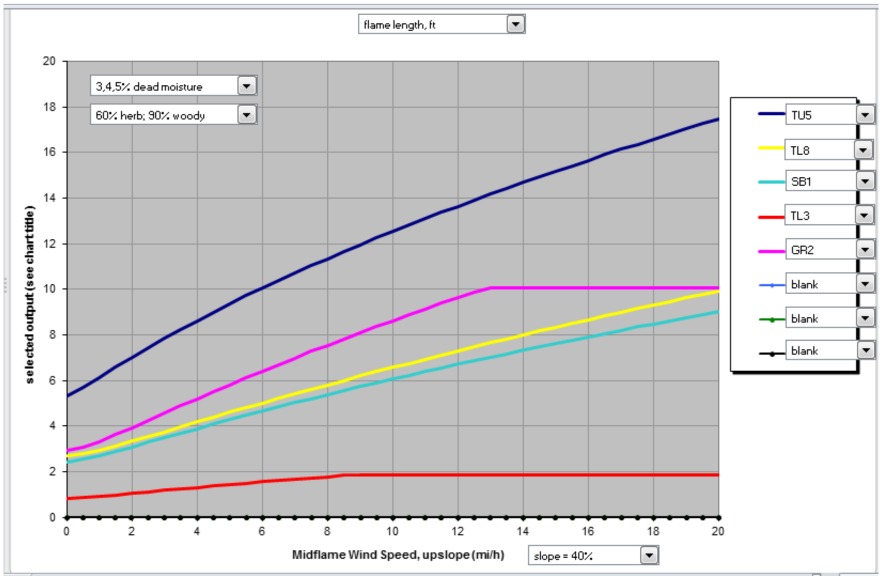
	REGENERATION HARVEST		IMPROVEMENT HARVEST		FUEL REDUCTION ONLY		UNITS
	PRE-TREATMENT	POST TREATMENT	PRE-TREATMENT	POST TREATMENT	PRE-TREATMENT	POST TREATMENT	
Fuel Model	TU1(161), TU5(165), TL4(184), TL8(188)	TU1(161), TL3(183), TL4(184), TL8(188)	TU1(161), TU5(165), TL4(184), TL8(188)	TU1 (161), TL3 (183), TL4 (184), TL8 (188)	GR2(102), GS2(122), TU1(161), TU5(165), TL4(184), TL8(188)	GR2(102), GS2(122), TU1(161), TL4(184), TL5(185), TL8(188)	Fuel Model Number
Canopy Bulk Density*	0.10-0.290	0.020-0.030	0.080-0.20	0.040-0.10	0.020-0.290	0.020-0.220	Kg/m^3
Canopy Base Height**	1-10	20-30	1-10	10-30	1-10	6-15	feet
Canopy Cover	40-60	10-20	40-60	30-40	40-60	30-50	Percent
Crown Fire Potential	Yes	No	Yes	No	Yes	Limited to passive crown fire	

* Canopy Bulk Density is the mass of available canopy fuel per unit of canopy volume (Scott and Reinhardt 2001).
**Canopy Base Height is the lowest height above the ground at which there is a sufficient amount of canopy fuel to propagate fire vertically into the canopy. It is an effective value that incorporates ladder fuels such as shrubs and understory trees (Scott and Reinhardt 2001).

Canopy Base Height (CBH)

CBH is a critical factor in crown fire initiation. Firefighters routinely “limb up” firelines or fuel treatment areas to prevent surface fire from getting into the canopy fuels. We verified with current and retired local fire managers that the stands modeled as FM 165 on the landscape are likely to have low canopy base heights. Fundamentally, if the fuel model and fire environment produce flame lengths greater than the CBH, crown fire will be initiated, and passive crown fire (individual and group tree “torching”) will occur. Much of the treatment areas have a CBH of 0-3 feet; very low flame lengths are required to initiate passive crown fire. By raising CBH to 10 feet (consistent with a conservative value from a current Forest EIS for the East Reservoir EIS), crown fire initiation can be greatly reduced in the treated units. The recommended conversions of fuel models (165 and 188 to 183, and 201 to 102) will result in flame lengths less than this Canopy Base Height, preventing crown fire activity from initiating.

Flame lengths for pre- and post- treatment fuel models:



Canopy Bulk Density

Canopy Bulk Density will be reduced by virtue of tree removal during treatment; it is otherwise difficult to measure (Scott and Reinhart 2005). The critical Canopy Bulk Density was determined to be .004 lbs/ft^3 (.06407 kg/m^3); this is consistent with a mid-point value in a conservative harvest scenario in the EIS. Further reduction of modeled post-treatment CBD may be warranted. Most importantly, the actual prescription for any of the proposed treatments must have a fire/fuels specialist evaluate distance among standing trees, spacing on slopes, and other local factors to determine actual tree spacing so that fire does not travel from crown to crown and become difficult to control.

BehavePlus 5.0.5 (Build 307)

Critical Crown Fire Values for 165
Fri, Jan 29, 2016 at 11:21:34

Input Worksheet

Inputs: SURFACE, CROWN

Input Variables	Units	Input Value(s)
Fuel/Vegetation, Surface/Understory		
Fuel Model		TU5
Fuel/Vegetation, Overstory		
Canopy Cover	%	40
Canopy Height	ft	120
Canopy Base Height	ft	0
Canopy Bulk Density	lb/ft3	0.001, 0.002, 0.003, 0.004, 0.005, 0.006, 0.007, 0.008
Fuel Moisture		
1-h Moisture	%	3
10-h Moisture	%	4
100-h Moisture	%	8
Live Herbaceous Moisture	%	30
Live Woody Moisture	%	60
Foliar Moisture	%	100
Weather		

20-ft Wind Speed (upslope)	mi/h	30

Terrain

Slope Steepness	%	40

Notes

Most fuel characteristic and topographic inputs were derived from the landscape layers used in the Basic Fire Behavior output LibbyERC97th_GridWind30at225_2007Final. Weather inputs were derived from the 97th percentile scenario defined for the overall modeling effort. Critical CBD for FM165 was determined to be approximately between .003 and .004 lb/cu. ft. or .06407 kg/cu. meter.

Run Option Notes

Maximum reliable effective wind speed limit IS imposed [SURFACE].

Calculations are only for the direction of maximum spread [SURFACE].

Fireline intensity, flame length, and spread distance are always for the direction of the spread calculations [SURFACE].

Wind is blowing upslope [SURFACE].

Results

Canopy Bulk Dens	ROS (max)	Flame Length	Critical Surf Int	Trans Ratio	Transition to Crown?	Crown Fire ROS	Critical Crown ROS	Active Ratio	Active Crown?	Fire Type
lb/ft3	ch/h	ft	Btu/ft/s			ch/h	ch/h			
0.001	11.6	8.8	2	418.64	Yes	149.0	558.6	0.27	No	Torching
0.002	11.6	8.8	2	418.64	Yes	149.0	279.3	0.53	No	Torching
0.003	11.6	8.8	2	418.64	Yes	149.0	186.2	0.80	No	Torching

0.004*	11.6	8.8	2	418.64	Yes	149.0	139.6	1.07	Yes	Crowning
0.005	11.6	8.8	2	418.64	Yes	149.0	111.7	1.33	Yes	Crowning
0.006	11.6	8.8	2	418.64	Yes	149.0	93.1	1.60	Yes	Crowning
0.007	11.6	8.8	2	418.64	Yes	149.0	79.8	1.87	Yes	Crowning
0.008	11.6	8.8	2	418.64	Yes	149.0	69.8	2.13	Yes	Crowning

*The "lbs/ft^3" used above must be converted to a "kg/m^3" for use in WFDSS; .004 lbs/ft^3 = .06407 kg/m^3

Canopy Cover

Canopy Cover is expected to be reduced by some amount when trees are removed during treatment. A maximum value of 40% remaining post-treatment canopy cover was determined from the most conservative value in the EIS table. Additional reduction in Canopy Cover exposes fuels to less shading and more exposure to wind, causing increased drying of fuels and can increase surface fire spread.

The resulting landscape edit rules were:

Landscape File Editor

Attribute	Rule Description
Fuel Model	If (LCP intersects Mine Site Low Fuel) Set Fuel Model to 99
Fuel Model	Else If (Fuel Model is 122) AND (Aspect is between 135 and 225) AND (LCP intersects PlumCreek) Set Fuel Model to 201
Fuel Model	Else If (Fuel Model is 122) AND (LCP intersects PlumCreek) Set Fuel Model to 185
Fuel Model	Else If (Fuel Model is 122) AND (Aspect is between 135 and 225) Set Fuel Model to 161
Fuel Model	Else If (Fuel Model is 122) Set Fuel Model to 183
Fuel Model	Else If (Fuel Model is 165 or 188) AND (LCP intersects treat3_Feb1) Set Fuel Model to 183
Fuel Model	Else If (Fuel Model is 201) AND (LCP intersects treat3_Feb1) Set Fuel Model to 102
Canopy Base Height	If (Canopy Base Height <= 3.0) AND (LCP intersects treat3_Feb1) Set Canopy Base Height to 3.0
Canopy Bulk Density	If (Canopy Bulk Density >= 0.06) AND (LCP intersects treat3_Feb1) Set Canopy Bulk Density to 0.04
Canopy Cover	If (Canopy Cover >= 40) AND (LCP intersects treat3_Feb1) Set Canopy Cover to 40
Canopy Cover	Else If (Fuel Model is 165) AND (Canopy Cover <= 39) AND (LCP intersects treat3_Feb1) Multiply Canopy Cover by 0.7
Canopy Cover	Else If (Fuel Model is 165) Multiply Canopy Cover by 0.7

Add Edit Move Up Delete...

Literature Cited

Graham, Russell T.; McCaffrey, Sarah; Jain, Theresa B. (tech. Eds.) 2004. Science Basis for Changing Forest Structure to Modify Wildfire Behavior and Severity. Gen. Tech. Rep. RMRS-GTR-120. 43 p.

Graham, R.T., Harvey A.E., Jain, T.B., and Tonn, J.R. 1999. The effects of thinning and similar stands treatments on fire behavior in western forests. USDA FS Pacific NW Research Station General Technical Report PNW-GTR-463: Portland, OR.

Scott, Joe H.; Reinhardt, Elizabeth D. 2005. Stereo photo guide for estimating canopy fuel characteristics in conifer stands. Gen. Tech. Rep. RMRS-GTR-145. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 49 p. plus stereoscope.

Weather Data and Fire Statistics

Wildfires under "average" weather conditions can often be successfully extinguished with initial attack (IA) resources, including crews, engines, aircraft and heavy equipment. These fires typically have flame lengths less than 4 feet and do not breach control lines through mid- or long-range spotting. The majority of these fires are successfully extinguished within a few burn periods. When these types of fires escape IA, it is usually due to a dry lightning storm that starts several fires at once, requiring managers to prioritize life and property during the initial response. As the fire grows larger, it can move into areas that are less accessible and make control more difficult.

In the Northern Rockies, dry cold fronts and dry thunderstorms with high winds have the potential to cause significant spread events (winds of 25-35 mph. Fires under these conditions, especially if the season has been warm and dry, will have fast rates of spread, long spotting distances, and can ground firefighting aircraft. Fires under these conditions can exhibit behavior that renders firefighting resources (including aircraft), ineffective, or present conditions (high winds, falling trees, fast rates of spread, long-range spotting) that are too dangerous to deploy personnel.

Both lightning-caused and human-caused fires occur across the greater area surrounding the mine. Areas where human-caused fires would be expected are Forest roaded areas where recreation is prevalent, steep grassy slopes behind developed areas along Highway 37, any area along Highway 37 where fine fuels are adjacent to forested lands, and Pipe Creek Road. Additionally, 2015 had an arsonist starting fires. See map of fire ignitions (1992-2013) to indicate spatial arrangement of ignitions (reference).

This is summarized on the Kootenai National Forest Pocket Card, which gives the following local thresholds for large fire growth and resistance to fire control:

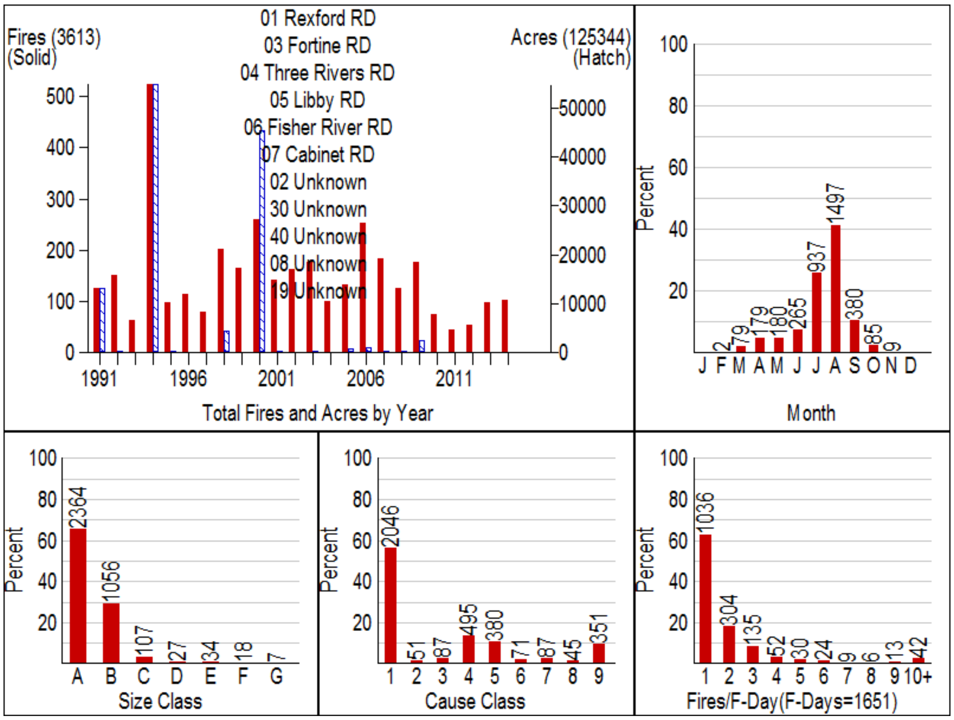
- 20' WS >15mph
- RH <25%
- Temp >85F
- 1000 TLFM <15%
- Multiple ignitions
- 10 Days without Rain

Several RAWS stations were evaluated in the local area. Station attributes are presented in a table. A Fire Family Plus database (Libby_OU3.mdb) was created with station information as shown in the table.

Name	ID#	Current Type	Elev (ft)	Distance (mi)	Aspect/Terrain	Data Availability	Use/FF+
Libby	240107	Satellite	2070	6	Flat/Valley Bottom	1954-2016	Fuel moisture conditioning; station winds are sheltered.
Swede	240116	Manual	4080	5	Flat/Ridgetop	1964-2015	1300 observations only; no gusts reported.
Fisher	240118	Satellite	2160	7	South/Valley Bottom	1984-2015	Only 1300 wx. Wind rose strong N component.
Big Creek Baldy	240119	Satellite	4300	15	Southwest/ MidSlope	1985-2015	Used in many 2015 analyses on real fires. Only 1300 weather through 2012; 2015 has hourly.
Swaney	240227	Satellite	4975	31	Southeast/ MidSlope	2013-2015	Only 1400 Observations; wind rose has strong E/NE
Yaak	240120	Satellite	3000	36	Flat/Valley Bottom	2001-2015	Valley bottom station not representative
Magee Peak	100425	Satellite	4720		Flat/Ridgetop	2005-2015	Wind Rose is strong South
Zonolite	mzon	Satellite—non RAWS	4204	0	Flat/Ridgetop	2007-2015	Not a fire-sited RAWS; very windy due to exposure

Fire Associations in Fire Family Plus

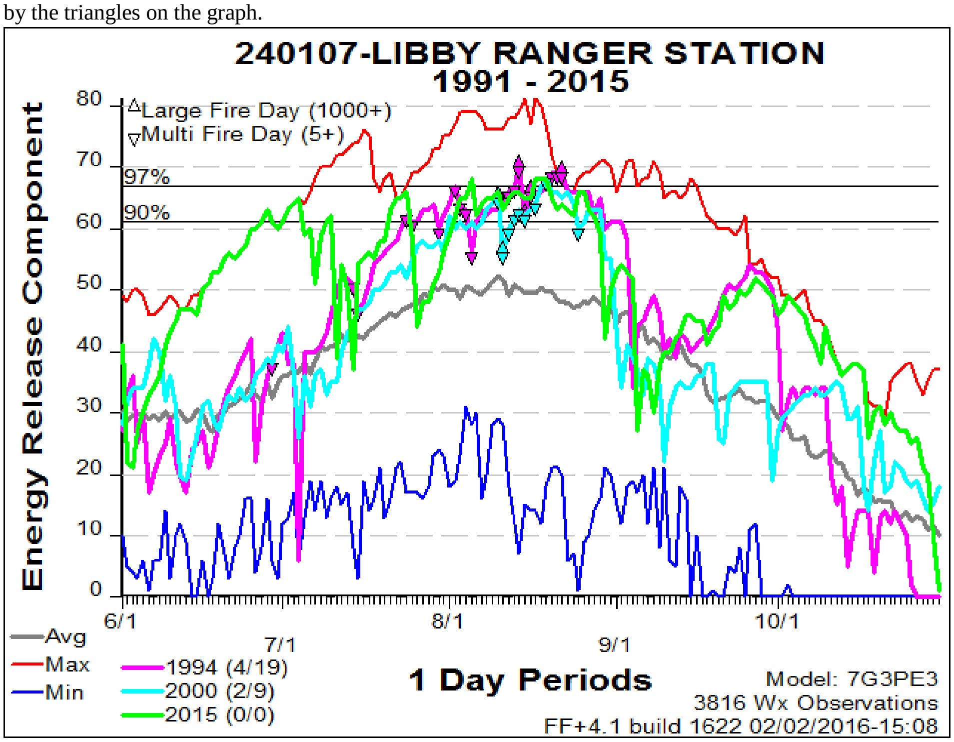
The fire occurrence database for the Kootenai National Forest was limited to 1991-2015 for this analysis. Years with the highest burned area are 1994 (54,642 acres), 2000 (45,295 acres), and 1991 (13,252 acres). 2015 total acres exceeded 31,000 based on large fires input in WFDSS. Some years have more than 80 ignitions across the forest, but 40 is more common. On 94 fire days from 1991-2014, there were more than 6 starts in a day. Fires tend to start in June, July, and August. 60% of fires start by lightning and the remainder are human-caused or "unknown". The second largest cause of wildfires is campfires. The 99th percentile for fire size is 610 acres for all fires since 1991. The largest recorded fire on the KNF in recent history was 13,051 acres (Dry Fork Fire in 1988). (Reference: KNF_FireOccurrenceSummaryReport.txt and KNF_FireOccurrenceSummaryGraph1991-2014.bmp and Size&CauseDefinitions.txt).



A list of all fires from 1991-2014 was exported from FireFamilyPlus, and 2015 fires over 1000 acres were added from a WFDSS search. The tabular output is available in "FireSummaryOver1000acres1991-2015.xlsx" and summarized in the graph where each dot represents a single fire. Large fires tend to occur together, as seen in 1994, 2000, and 2015. This same pattern is evident in years prior to 1991, but the analysis was limited to 25 years to characterize only the current situation.

ERC Analysis in Fire Family Plus

Energy Release Component (ERC) is a commonly used to evaluate the availability of fuels to burn. ERC is completely independent from wind, nevertheless, it is a valuable indicator of fire danger. Years with elevated ERCs and several fires larger than 1000 acres were: 1994, 2000, and 2015. In 2007, many of the highest ERC values were recorded and 2007, therefore, is characterized by much of the red line in the graph. Occurrence of large fires (over 1000 acres) and multiple fires (more than 5 per day) are indicated by the triangles on the graph.

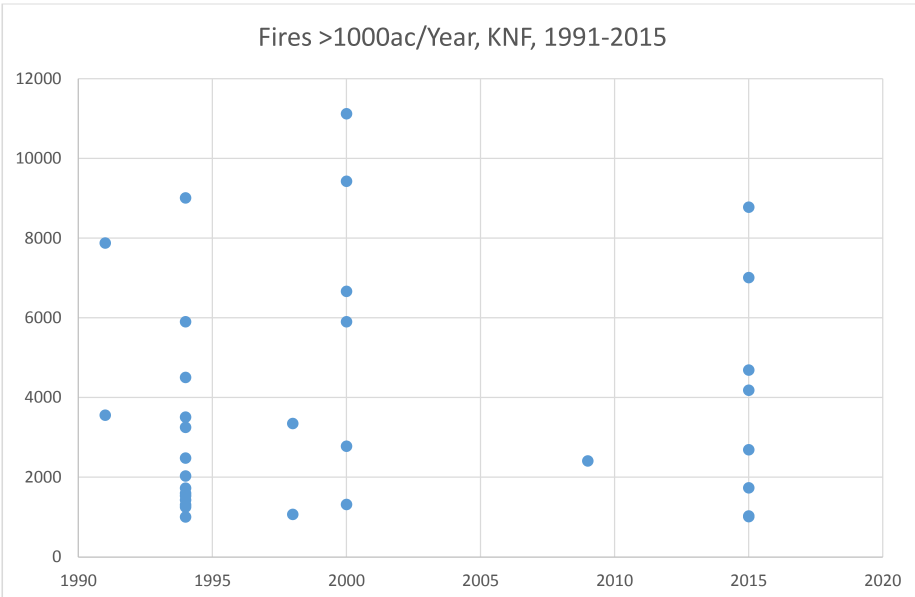


Conclusions:

This information presented here illustrates that problematic fire conditions have occurred around the August 1 date in 1994, 2000, and 2015 when weather/wind was conducive to large fire spread and/or there were multiple ignitions over a short period of 1-3 days. Other years with higher than average ERC values for an extended period were 2001, 2003 when fires occurred sporadically, but did not get large; 2005 when there was only one large fire; 2006 when the season's fires were of mixed sizes; 2007 when ERCs were at all time maximums (this year still represents the maximum ERC year) and there were a lot of fires but no large fires; 2008 when there were no large fires.

2015 fire records were not yet in the fire database, therefore the ERC graph does not show the fires for 2015, only the ERC.

ERC graphs of fire danger illustrate that fire danger and the risk of large fire occurrence is typically most extreme from 7/22-8/28 when ERCs are above 50. Under these conditions, multiple fire ignitions increase the chance that fires will grow large.

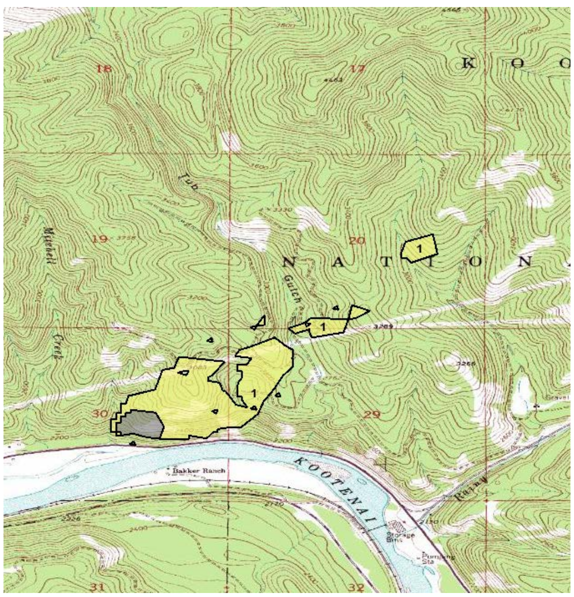


2007 represented a year with extremely dry fuels. 2015 had more moisture, but still supported six large fires across the forest in August. We compared the two years and found that although 2015 had less than 90th percentile values for ERC through most of the summer, it still had high temperatures and low relative humidities. One noticeable difference was a small amount of rain on 8/10/15 while no rain was observed in 2007.

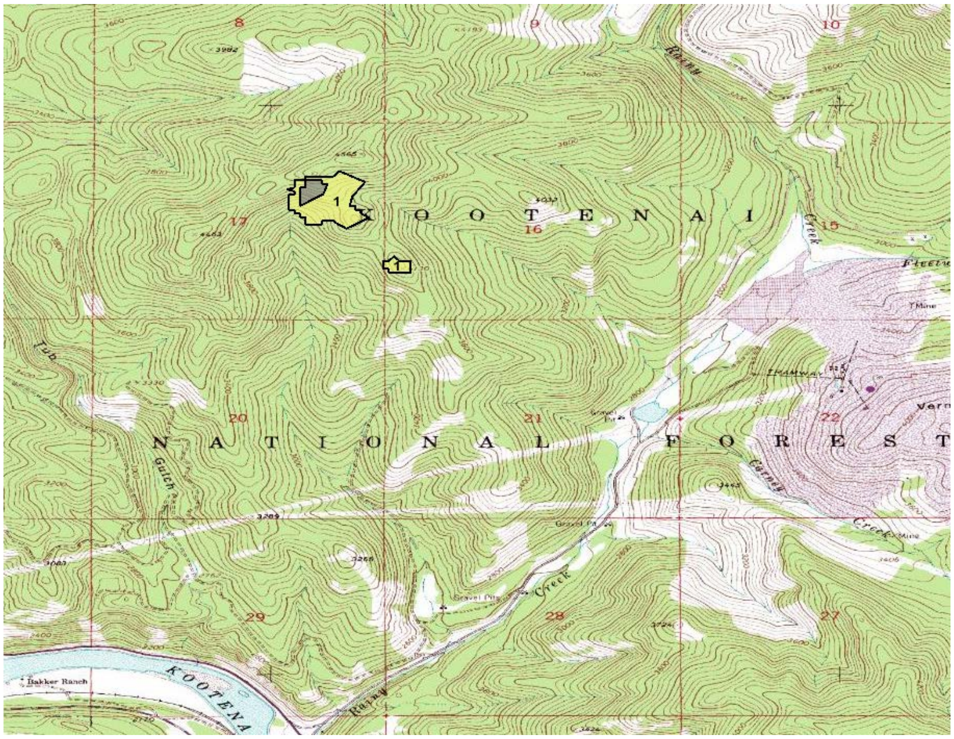
Fire Ignition Scenarios

Scenario 1 is an ignition along the road in private property west of the Rainy Creek drainage. This location has steep slopes and grass fuels that would be mostly cured (60% live herbaceous fuel moisture) on August 1. An atlas of recent fire ignitions (human and lightning-caused) indicates ignitions along the road are common in this particular portion of the landscape. Fires starting here have travel paths to the area of concern within the first burn period when the fire escapes initial attack efforts. Assuming an ignition burned for 3 hours under hot, dry, windy conditions experienced in this area, and assuming initial attack is unsuccessful, the fire would reach the Tub Gulch area. A 160-acre shapefile was then created as the ignition for 3-day projections in the Near Term Fire Behavior model and simulating 7-day burn probabilities with the Fire Spread Probability model.

3-hour NTFB Projection to Simulate Escaped Initial Attack Fire Size and Location (below)



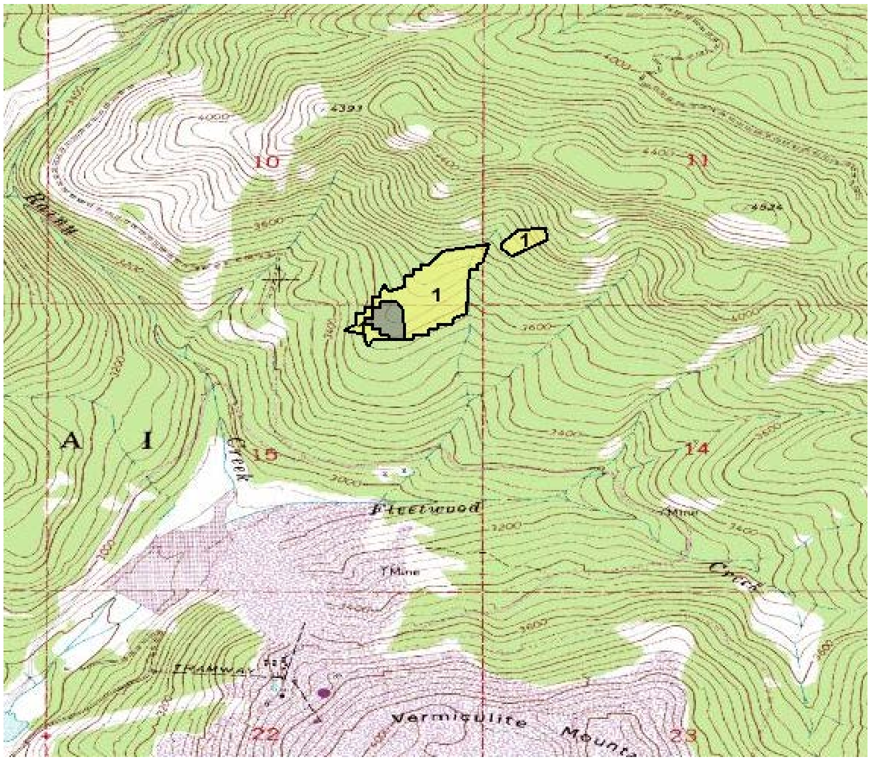
Scenario 2 is an ignition approximately 2 miles north of Scenario 1 in a forested area with 3 lightning strikes since 1992 according to the fire occurrence database. There was a small fire here in 1994, so this area was avoided for placement of the scenario ignition, since fuels were modified by that fire. A 2-acre ignition under the influence of high NW winds and 30% live herbaceous, and 60% live woody fuel moisture represents an active fire ignition. This ignition was modeled for 3 hours to represent ineffective initial attack suppression efforts. The resulting 32-acre fire footprint was created as the ignition for 3-day projections in the Near Term Fire Behavior model and simulating 7-day burn probabilities with the Fire Spread Probability model.



Scenario 3 is an ignition in the Alexander Creek Inventoried Roadless Area east of Rainy Creek and north of Highway 37. This ignition would pose added complexity due to a lack of roads in the area. This location has steep slopes and grass fuels that would be mostly cured (60% live herbaceous fuel moisture) on August 1. An atlas of recent fire ignitions (human and lightning-caused) indicates seven ignitions on this slope have occurred since 1992. Assuming an ignition burned for 3 hours under hot, dry, windy conditions experienced in this area, and assuming initial attack is unsuccessful, the fire would reach the top of the ridge. A 130-acre shapefile was created as the ignition for 3-day projections in the Near Term Fire Behavior model and simulating 7-day burn probabilities with the Fire Spread Probability model.

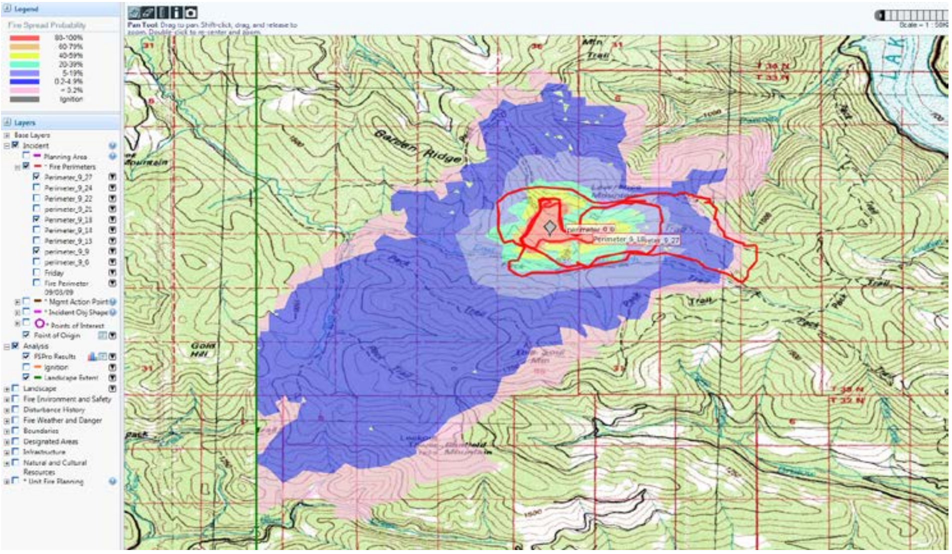
Scenario 4 was a fire ignition inside of the area of concern, a mile north of Vermiculite Mountain.

This location has steep slopes with fuels that would be mostly cured (60% live herbaceous and 90% live woody fuel moisture) on August 1. The slope is in alignment with prevailing SW winds. An atlas of recent fire ignitions (human and lightning-caused) indicates two lightning ignitions on this slope since 1992. Assuming an ignition burned for 3 hours under hot, dry, windy conditions experienced in this area, and assuming initial attack is unsuccessful, the fire would almost reach the top of the ridge. A 33-acre shapefile was created as the ignition for 3-day projections in the Near Term Fire Behavior model and simulating 7-day burn probabilities with the Fire Spread Probability model.


10
11
15
14
22
23
1
1
A
I
Creek
Fleetwood
Creek
Mine
Mine
Tramway
Vermiculite
4524
4397

Historic Fire Spread Events

Lawrence Mountain Fire, 2009



Lawrence Mountain Fire, 2009, 12 miles north of Vermiculite Mountain.

Spread Events:

9/2/09: discovered

9/3/09: 13 acres (grew 12)

9/4/09: 118 acres (grew 105)

9/9/09: 226 acres (grew 108) FSPro Analysis, 14 days, estimated average fire size of 983 on 9/22 and largest fire of 14,105 acres. Actual fire size on 9/22 was 1183, which would be considered a reasonably close estimate.

9/13/09: 412 acres (grew 186)

9/14/09: 490 acres (grew 78)

9/18/09: 910 acres (grew 420) Large daily spread event on this fire.

9/21/09: 1052 acres (grew 142)

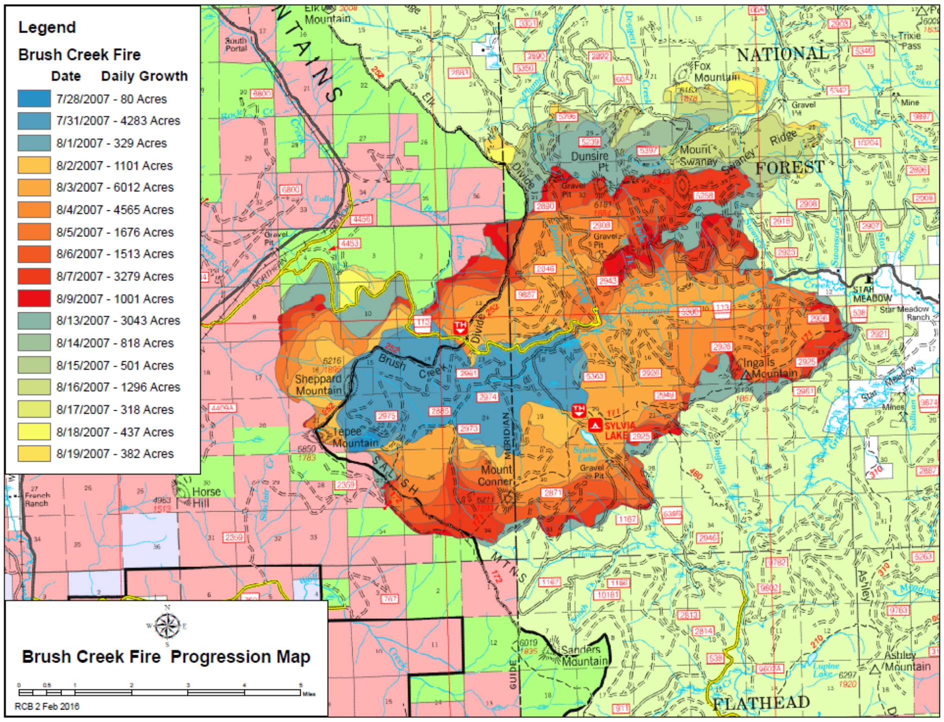
9/22/09: 1183 acres (grew 131)

9/24/09: 1562 acres (grew 379) Large daily spread event on this fire.

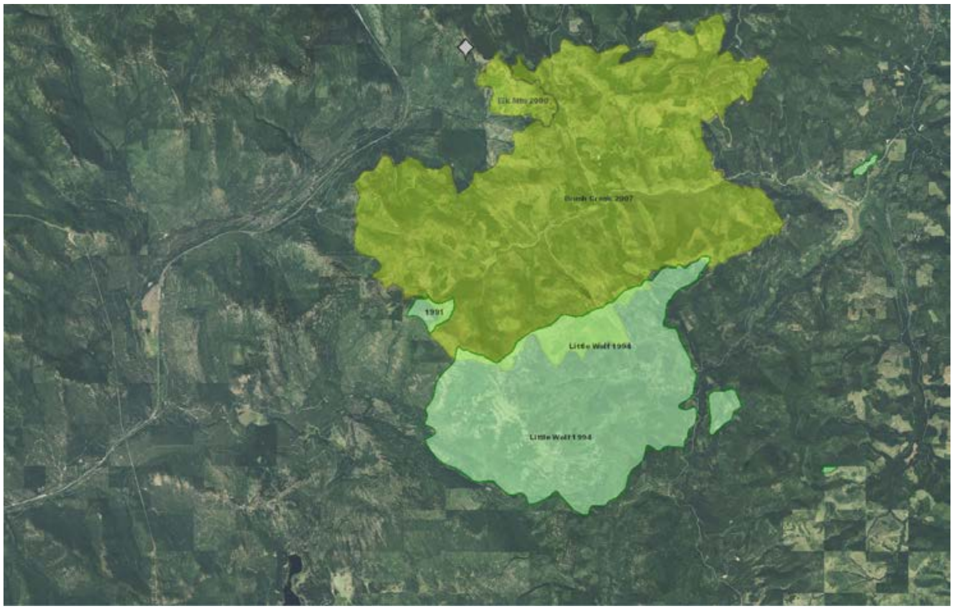
9/27/09: 2356 acres (grew 794) Largest daily spread event on this fire.

Brush Creek Fire, 2007

This fire was 24 miles west of Vermiculite Mountain on Kootenai/Flathead NFs



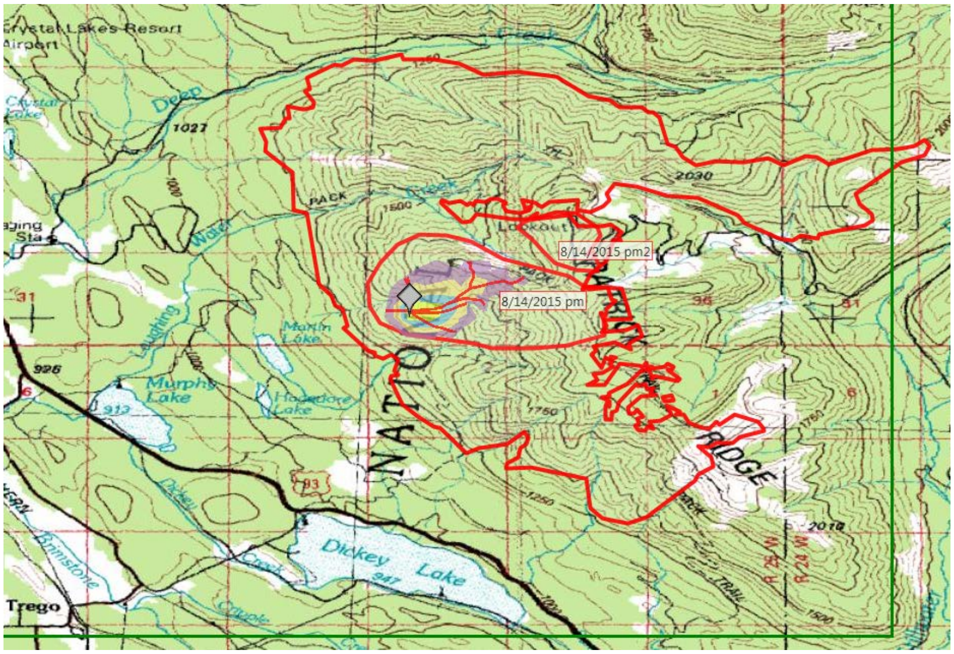
Spread Events: The Brush Creek Fire made several runs of over 1 mile per day with the largest run of 3+ miles occurring on 8/2. The fire burned at 3500-4500 feet elevation in a landscape similar to the forested area around the Vermiculite Mountain area in regards to tree species and a highly dissected landscape where forest management activities and a high road density exist. The fire did not move south presumably due to the Little Wolf Fire in 1994. For a rough scale, the longest axis of the Brush Creek Fire is 10 miles.



Daily Growth for largest growth days:
7/27/07: Discovered
7/31/07: Grew 4283 acres
8/3/07: Grew 6012 acres
8/4/07: Grew 4565 acres
8/7/07: Grew 3279 acres
8/13/07: Grew 3043 acres

Marston Fire, 2015

This fire was 36 miles NE of Vermiculite Mountain. Burned from 4000-7000 feet in heavy forested fuels without as dissected a landscape as appears around Vermiculite Mountain. Exhibited spotting of 0.25 miles on 8/13. Significant N/S spread event on 8/24 where it burned 1.5 miles North and 1 mile South on the same day. A short term fire behavior run using a 7 mph wind speed input significantly under-predicted fire spread over the next 12 hours. Graphic shows estimated 8/14 fire footprint, two interior red perimeters show actual 8/14 perimeter, and largest red polygon is final fire size (approx. 6800 acres).



Spread Events:

8/14/15: Fire spread from approximately 100 acres in size to 1200 acres in size, spotting across a drainage a minimum of 0.25 miles. Represents 1100 acres of growth in one day.
8/24/15: Fire spread approximately 1.5 miles north and 1.0 miles south along the face of the ridge, in alignment with slope/valley winds.
8/28/15: Fire spread approximately 1.7 miles east from strong westerly winds during a cold front.

Klatawa Fire, 2015

This fire burned 14 miles SW of Vermiculite Mountain.

Spread Events:
8/26/15: Fire spread approximately 1 mile downslope—canyon aligned with westerly/southwesterly winds.
8/28/15: Fire crossed drainage bottom and moved 1.5 miles upslope to ridgetop.
8/29/15: Fire was pushed down the drainage 1.5 miles.

Additional local fires should be added to this list with their respective fire spread events:
Dry Fork, 1988
Banfield #2, 1994
Sheep Range 3, 1994
Scenery 1, 1994
Dome, 1998

Defining the Weather, Wind, and Fuel Moisture Scenarios

1. Recent Weather Seasons to use for Weather Values
    a. Years:
        i. 2007: This year was chosen based on an ERC analysis that indicates 2007 represents the highest ERC season on record for the Kootenai NF. The KNF uses the Libby RAWS for the National Fire Danger Rating System elements. Analysts used the Libby RAWS and graphed all ERCs from 1991-2015 to evaluate fire danger for each year. ERC considers fuel dryness and fire potential but is completely independent from wind. See ERC graph in Appendix B, “Weather Data and Fire Statistics”. The hourly 2007 weather stream for precipitation, temperature, relative humidity, wind speed, and wind direction was used to condition fuel moistures for scenarios.
        ii. 2015: This year was chosen because it is the most recent active fire year on the Kootenai NF. The ERCs are elevated for 2015, but not extreme. 2015 data was used for daily wind speed and wind directions (average and gusts) during the burn period because the Big Creek Baldy RAWS located only 15 miles from the area of interest, had hourly data from a ridgetop location that is not strongly affected by terrain winds. Although there are some gaps in the 2015 record, there were consistent daily values for the fire modeling period for simulations that began on August 1.
2. Model Burn Date: August 1 was chosen for the modeling burn date in ST/Basic, NT, and FSPro. This date was chosen because daily weather was available from Libby RAWS and Big Creek Baldy for the days immediately before and after this date. August 1 is a date in the fire season where fires are typically burning (between July 22 and August 28).
3. Live and Dead Fuel Moisture values (see section about Fuel Moistures in this Appendix).
4. Spotting values (percent): the default for an active burn day using FSPro is 0.15. When modeling real-world fires, this value is rarely modified. Although there can be good reasons to do so when there is a real fire that can be used to calibrate the model, most of the time analysts do not change this value. The Brush Creek Fire in 2007 was burning in this area under the highest ERC season on record (since 1991). When we ran FSPro (ensemble fire spread model) with a 2007 season, fire spread was modeled using the 0.15 spotting value in the highest bin. The results of FSPro indicate that a 7-day model output was reasonably similar to the real fire size after 7 days. Therefore, we concluded that this default spotting value was sufficient. Basic does not utilize spotting. Short Term only uses spotting for MTT, and since FSPro uses MTT, spotting was set the same at 0.15 in ST. NT uses a different method for lofting embers. We used 0.01, the lowest setting possible, for NT spotting potential. Setting spotting to 0 would be unrealistic for modeling these types of fires. Spotting in NT was tested at .05 and .03 but exceeded our expectations of fire spread under high-wind scenarios.
5. Barriers: We used major paved roads as barriers to surface fire spread. Unpaved forest roads were not made into barriers since fires burning under conditions that are of interest do not usually stop on roads, but easily spot over them as a function of regular forward fire spread (not necessarily long-range spotting).
6. Wind Speeds: Gridded winds were run using Wind Ninja in the background of Basic/ST using a 30mph input. Local expertise suggested that a wind speed of 25-35 mph was not uncommon under scenarios where fires escaped IA. In these cases, winds were usually set to a cardinal direction. Other wind speeds/directions for NT were set according to hourly Big Creek Baldy RAWS gusts. See spreadsheet with wind scenarios created for NT:

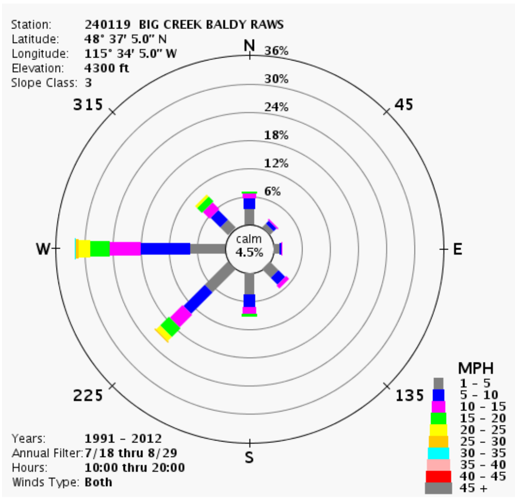
"weather_inputs_fms_all_models.xlsx". This spreadsheet has 3 tabs with modeling input information. The W/SW Gust Scenario for 3 days is shown here:

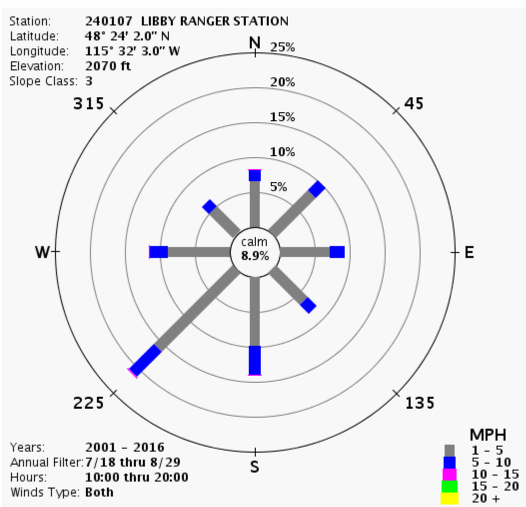
W/SW Gust Scenario--3 Days High

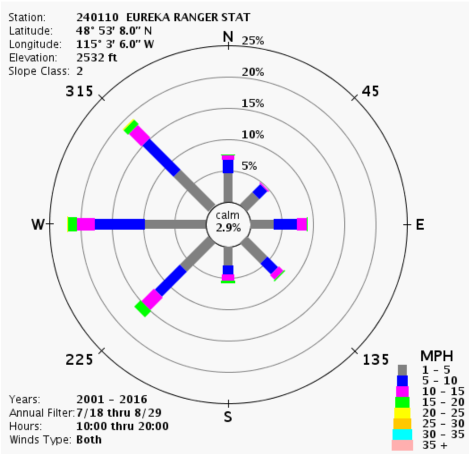
	1-Aug		2-Aug		3-Aug	
	WS	WD	WS	WD	WS	WD
1300	22	241	10	222	8	138
1400	19	278	11	247	10	187
1500	19	304	15	256	13	237
1600	17	245	11	220	12	303
1700	19	279	13	250	11	216
1800	15	246	13	291	11	243

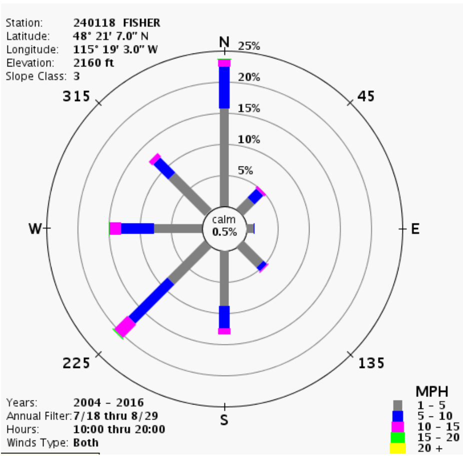
Description: Values here are taken from Big Creek Baldy RAWS in 2015 using Wind Gust and Wind Gust Azimuth from August 1 to model cold front that occurred and was recorded in the wind stream. August 2-3 are Wind Gust and Wind Gust Azimuth as reported at the station on August 9 and 10 2015.

7. Precipitation, Temp, RH, Cloud Cover: Libby 2007 weather data. This data was interpolated by the National Weather Service since Libby had 1300 observations.
8. Burn period: 6 hours; the burn period is usually estimated to be longer for operational planning, but in modeling, 6 hours of burning represents a typical high probability burn day.
9. Periods: short term and near term model used 3 days of burning since that is typically the limit of weather information. FSPro used 7 days, which is a typical setting.
10. Conditioning Days: set to 7, which is commonly used when modeling fires with terrain.
11. Crown Fire Method: the Finney model adequately represents crown fire occurrence based on experience of modelers in the Northern Rockies under these scenarios. This is the default.
12. Start/End hours for NT: 1300, 1900 because this represents the active burn period on real fires in this area.
13. Landscape resolution: used 30m for most modeling. This is the default and native resolution for Landfire data. We used Landfire 2012, the most recent version available in WFDSS. Landscape edits were made. Those rules are explained elsewhere.
14. ERCs for FSPro used Libby RAWS since it is consistent with Fire Danger Ratings in the area. Observed ERCs were not used during the simulation.
15. The ERC wind rose was created using Big Creek Baldy RAWS. That RAWS wind rose is shown below along with other RAWS in the area that could have also been used but that are further away or not representative of winds influencing fire spread based on experience modeling fire spread in the Northern Rockies. The hours used in FSPro simulations were from 1000-2000 hours and "both" average and gusts were selected for the probability matrix. All wind roses are showing the same time period and "both" gusts and 10-minute average winds, but note that the percentage scales in the concentric rings are scaled differently in each. Libby and Fisher are extremely sheltered stations for use in predicting fire spread. Swede Mountain Lookout is not available for use in FSPro because it only has manually observed 1300 winds.


Station: 240119 BIG CREEK BALDY RAWS
Latitude: 48° 37' 5.0" N
Longitude: 115° 34' 5.0" W
Elevation: 4300 ft
Slope Class: 3
N
45
E
135
S
225
W
315
36%
30%
24%
18%
12%
6%
calm
4.5%
MPH
1 - 5
5 - 10
10 - 15
15 - 20
20 - 25
25 - 30
30 - 35
35 - 40
40 - 45
45 +
Years: 1991 - 2012
Annual Filter: 7/18 thru 8/29
Hours: 10:00 thru 20:00
Winds Type: Both


Station: 240107 LIBBY RANGER STATION
Latitude: 48° 24' 2.0" N
Longitude: 115° 32' 3.0" W
Elevation: 2070 ft
Slope Class: 3
N
45
E
135
S
225
W
315
25%
20%
15%
10%
5%
calm
8.9%
MPH
1 - 5
5 - 10
10 - 15
15 - 20
20 +
Years: 2001 - 2016
Annual Filter: 7/18 thru 8/29
Hours: 10:00 thru 20:00
Winds Type: Both


Station: 240110 EUREKA RANGER STAT
Latitude: 48° 53' 8.0" N
Longitude: 115° 3' 6.0" W
Elevation: 2532 ft
Slope Class: 2
N
25%
20%
15%
10%
5%
45
315
W
E
calm
2.9%
225
135
S
Years: 2001 - 2016
Annual Filter: 7/18 thru 8/29
Hours: 10:00 thru 20:00
Winds Type: Both
MPH
1 - 5
5 - 10
10 - 15
15 - 20
20 - 25
25 - 30
30 - 35
35 +


Station: 240118 FISHER
Latitude: 48° 21' 7.0" N
Longitude: 115° 19' 3.0" W
Elevation: 2160 ft
Slope Class: 3
N
25%
20%
15%
10%
5%
45
315
W
E
calm
0.5%
225
135
S
Years: 2004 - 2016
Annual Filter: 7/18 thru 8/29
Hours: 10:00 thru 20:00
Winds Type: Both
MPH
1 - 5
5 - 10
10 - 15
15 - 20
20 +

Appendix C—Maps

Map of large fire history.