United States
Department of
Agriculture

Forest Service

**Pacific
Northwest
Region**

Stickpin Fire

BAER Soils Resource Report

Colville National Forest

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Introduction

The Stickpin Fire is the largest fire within the Kettle Complex on the Colville National Forest. It started on August, 11th, 2015 as the result of a lightning strike east of the town of Malo, WA off Highway 21. As of September 28th, the Stickpin Fire was 82 percent contained and had burned a reported 53,722 acres. Approximately 48,485 acres or roughly 90 percent of the fire area burned on the Colville National Forest.

A Burned Area Emergency Response (BAER) team was assembled on September 23rd to assess the Stickpin Fire portion of the Kettle Complex on the forest. During the period of September 23th – October 2nd, the team conducted an emergency assessment of post-fire resource conditions. The purpose of the burned area assessment was to determine whether or not the fire created emergency watershed conditions and identify the location and extent of those conditions. If an emergency determination is made, the probability of damage and the magnitude of the consequences to the Values at Risk (VARs) drive the development of emergency treatment recommendations.

Objectives

- Identify Values at Risk resulting from post-fire conditions.
- Determine soil burn severity throughout the burned area.
- Determine erosion rates under post-fire conditions.
- Identify areas of severe erosion hazards associated with post-fire conditions.
- Develop treatment recommendations for areas of high risk.

Description of Resource Area

Landscape Characteristics

The Stickpin Fire lies within the Columbia Mountains region of northeast Washington. The landscape of the fire was shaped by long periods of glaciation and fluvial processes. The Mt. Mazama (present day Crater Lake) eruption around 7,700 years ago left an extensive ash mantle that is commonly present to varying depths in the mountainous, forested landscapes today across this region. The ash mantle is deeper and typically coarser-textured near the source (present day

Crater Lake) and becomes thin and finer-textured away from the source. The forested areas encompassing the Colville National Forest contains an ash cap layer that ranges in depth from a couple inches up to as much as 15 to 20 inches.

The terrain varies from steep slopes to rolling hillsides, and gently-sloped river valleys. The general vegetation types within the fire perimeter are best described as mixed conifer forest, ponderosa pine forest, narrow riparian wet meadows, and cottonwood-alder dominated communities in riparian stream corridors. Climatic patterns across the area are generally defined by dry, warm summer months and winters are typically long, with the majority of the mean annual precipitation occurring from late fall, through winter, and into early spring. The mean annual precipitation ranges from 12 to18 inches and mean annual temperature ranges 30° to 85° F (WRCC, 2015). Average annual snowfall ranges from 4 to 15 inches from late fall to early spring and average annual snow depth during the winter months ranges from 5 to 10 inches (WRCC, 2015).

Soils

The soil survey used for the soils analysis during this assessment was created by the Natural Resource Conservation Service and the Forest Service in cooperation with the Washington Agricultural Experiment Station. North Ferry County Soil Survey map unit information can be referenced online at the NRCS's Web Soil Survey Application (USDA-NRCS, 2015). Figure 1 is a display of the map units found within the burn perimeter and a detailed list of map units per watershed can be found in Appendix A.

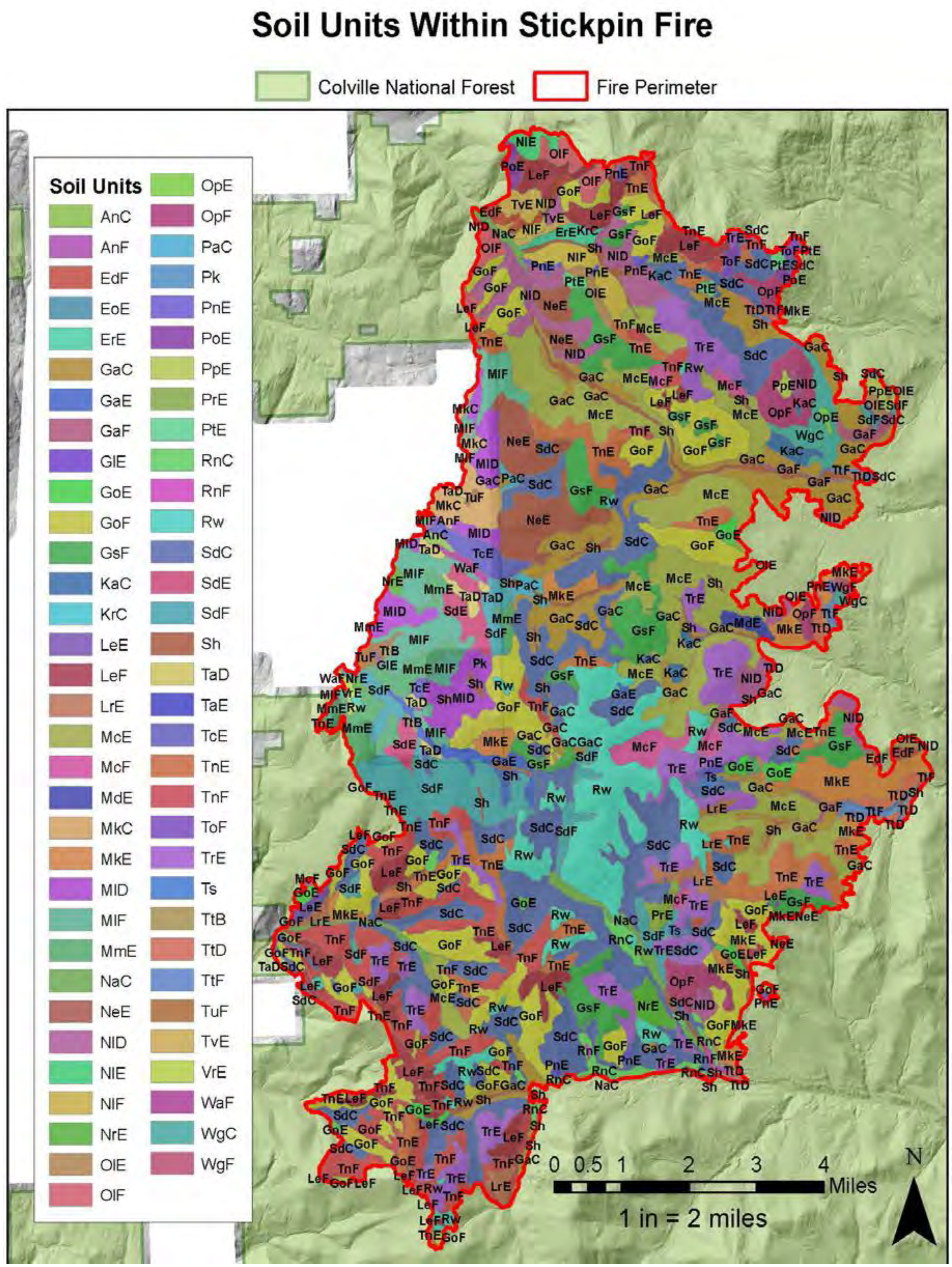

Figure 1: Soil map units within the Stickpin Fire.

In general, soils found within the fire perimeter consist of moderately-well to well-drained soils formed in volcanic ash overlying glacial till or granitic, gneissic, andesitic, rhyolitic, or schist bedrock formations in the higher elevation forested areas. Shallow soils (< 15 inches) and rock outcropping are commonly present and often associated with steeper topography and rock escarpments. Valley bottoms typically include deeper soils (> 40 inches) that are well to excessively-drained, formed in alluvial material derived from a mixture of volcanic ash, glacial till and/or glacial outwash. Surface soil textures range from ashy loams to ashy silt loams to fine sandy loams with some surface textures exhibiting gravelly surface rock fragment modifiers (15 – 35 percent rock fragment content within the soil horizon) in the higher elevations. Valley bottom soils typically exhibit gravelly to very gravelly (35 – 65 percent rock fragment content) sandy loams to loamy sand soil surface textures with a few locations that may have silt loam to loam surface textures and/or ashy characteristics.

Soils formed in or influenced by volcanic ash are important to forest management as these soils represent a valuable resource from both an economic and ecological perspective. Unique properties of ash cap soils such as a very high water holding capacity and inherent fertility are important and are linked to the level of site productivity in the forested ecosystems of this area. Volcanic ash soils exhibit high erodibility due to their fine texture and relatively weak structural development so their susceptibility to loss via erosional processes greatly increases after ground cover is removed and/or the soil surface is disturbed. Volcanic ash soils can also be considered a non-renewable natural resource in the context that if they are lost, they cannot be replaced until another volcanic ash deposition event occurs to the degree in the Mt. Mazama eruption deposited ash. The likelihood of that happening in our lifetime is almost non-existent.

While inherent soil characteristics certainly play a role in how soils erode and deliver sediment after a fire, the largest determinates in overall erosion and sedimentation response post-fire at a landscape scale are: soil burn severity, slope, fire intensity, and weather patterns.

Assessment Protocol

Rapid assessment of soil burn severity classes, including soil water-repellency tests, are necessary for incorporation with other site factors such as soil type, slope, hydrologic characteristics, climate regimes, and potential vegetation types to identify source areas of potential flooding and erosion and locations where critical ecosystem and human resource values may be degraded.

Soil Burn Severity Classes and Soil Water-Repellency are best generalized by the following (Parsons et al., 2010):

Low soil burn severity: Typically less than 20 percent of the pre-fire ground cover may be consumed. Generally, surface organic layers may exhibit some degree of consumption, but are still recognizable. Soil structure is not changed from its unburned condition. Roots are generally unchanged because the heat pulse below the soil surface was not great enough to consume or char any underlying organics. The ground surface, including any exposed mineral soil, may appear brown or black (lightly charred) and the majority of the canopy /understory vegetation will likely appear green.

Moderate soil burn severity: Approximately 20 – 80 percent of the pre-fire ground cover may be consumed. Fine roots (~0.1 inch or 0.25 cm diameter) may be scorched, but are rarely completely consumed over the entire area. The prevailing color of the site is often dull gray and white for the ash component intermixed with brown and black organic material that was not completely consumed. Soil structure is generally unchanged. There may be potential for recruitment of effective ground cover from scorched needles or leaves remaining in the canopy that will soon fall to the ground.

High soil burn severity: All or near complete (greater than 80 percent) consumption of the pre-fire ground cover and surface organic matter (litter, duff, and fine roots) is typically consumed, and charring may be visible on larger roots. Bare soil or ash is exposed and susceptible to erosion, and soil structure may be less stable. White or gray ash up to several centimeters in depth indicates that considerable ground cover or fuels were consumed. Sometimes very large tree roots (> 3 inches or 8 cm diameter) are entirely burned and charred. Soil is often gray, orange, or reddish at the ground surface where large fuels were concentrated and consumed.

Soil Water-Repellency: Soils high in organic matter commonly exhibit natural water repellency (hydrophobicity). Fire-induced hydrophobicity is usually associated with areas experiencing moderate to high burn intensity. Identification of the presence, degree, and spatial extent of hydrophobic layers is important in evaluating post-fire hydrologic response of a burned watershed and associated risks because it can amplify watershed response. The BAER team used the Water Drop Penetration Time (WDPT) method to identify hydrophobicity at varying depths. Water was applied and the time to infiltration was recorded. According to the WDPT method, soil hydrophobicity was categorized based on observed time to infiltration:

- Slight: Less than 10 seconds.
- Moderate: Between 10 to 40 seconds.
- Strong: Greater than 40 seconds.

Understanding the difference between *fire intensity* and *soil burn severity* are critical concepts in the evaluation of burned area conditions. Fire intensity is generally defined by parameters such as flame height, rate of spread, fuel loading, thermal potential, canopy consumption, tree mortality, etc. For example, a high intensity crown fire in a stand replacement event may result in a moderate to low soil burn severity if the residence time of the fire is short on the ground where soil characteristics may not be altered to a large degree. Conversely, a slow moving surface fire with complete consumption of heavily accumulated fuels can spare some high intensity burning on trees but penetrate and heat the soil severely which can have major implications on soil structure and overall aggregate stability at the surface. Soil burn severity, used in this context, is a better indicator of overall watershed response to burning and natural vegetative recovery after the fire than purely vegetation burn intensity. It is also important to note the role soil water repellency plays in a burned watershed. Hydrophobic layers may amplify watershed response and accelerate erosion. However, it is not the presence or absence of fire-induced water repellent layers that will drive the overall watershed response overtime; rather, the driving factor will be the lack of effective ground cover and the loss of raindrop interception via the absence of vegetation canopy cover.

Soil Burn Severity

The initial Burned Area Reflectance Classification (BARC) map was provided on September 23rd from satellite imagery acquired by the Remote Sensing Applications Center (RSAC). A BARC map is a satellite-derived map of pre and post-fire vegetation conditions based on the relative change in near and mid-level infrared reflectance values. The BARC map has four burn intensity classes: high, moderate, low and unburned (Figure 3 and Table 1).

The field verification of soil burn severity took place from September 23th – 27th. It included assessment of ash characteristics, ground cover, roots, soil structure, and soil hydrophobicity. Assessments were stratified in priority areas of high and moderate burn intensity where erosion and sediment production pose a threat to the identified Values at Risk. Access to some of the burn was limited due to continued fire activity within the perimeter and hazard trees. In these cases, the Burn Severity Map was used to justify validations.

Approximately 22,235 acres rated as unburned / low burn severity. A seed source should be present in the topsoil and natural regeneration is expected to occur in these areas. The seed source will likely also help with regeneration in areas that border moderate soil burn severity.

Approximately 11,597 acres rated as moderate soil burn severity. The most notable difference between moderate and high burn severity was the litter/duff remaining on the ground and the potential for effective ground cover from scorched needles or leaves remaining in the canopy in the moderate burn compared to the high burn areas. Moderate soil hydrophobicity was observed in the top 1 to 2 inches of the soil surface.

About 14,635 acres rated as high soil burn severity. Much of the area within the high burn severity areas contained less than 20% ground cover and lacked any canopy cover for future needle cast. Ash is grayish to white in color with small areas of orange where larger fuels were concentrated and consumed. Cover pre-fire, was representative of dense over-stocked forest, some of which was left as jack-strawed material post fire.

Figure 2: Image taken within North Fork- Boulder Creek Watershed.

The lack of direct contact of these burned logs to the soil surface minimizes effectiveness as a ground cover component leaving soils susceptible to erode during heavy storm events. Soil organic matter consumption was also present. Soil structure was altered in some locations due to the extent of surface organic matter consumption in the top 0.25 - 1 inch of the surface leaving loose, unconsolidated structure. Many of the larger rock fragment size classes (stones and boulders) were spalled, which is another indication of intense heating around the surface. Moderate to high soil hydrophobicity was observed in the top 2 to 3 inches of the soil across much of the high severity burned area.

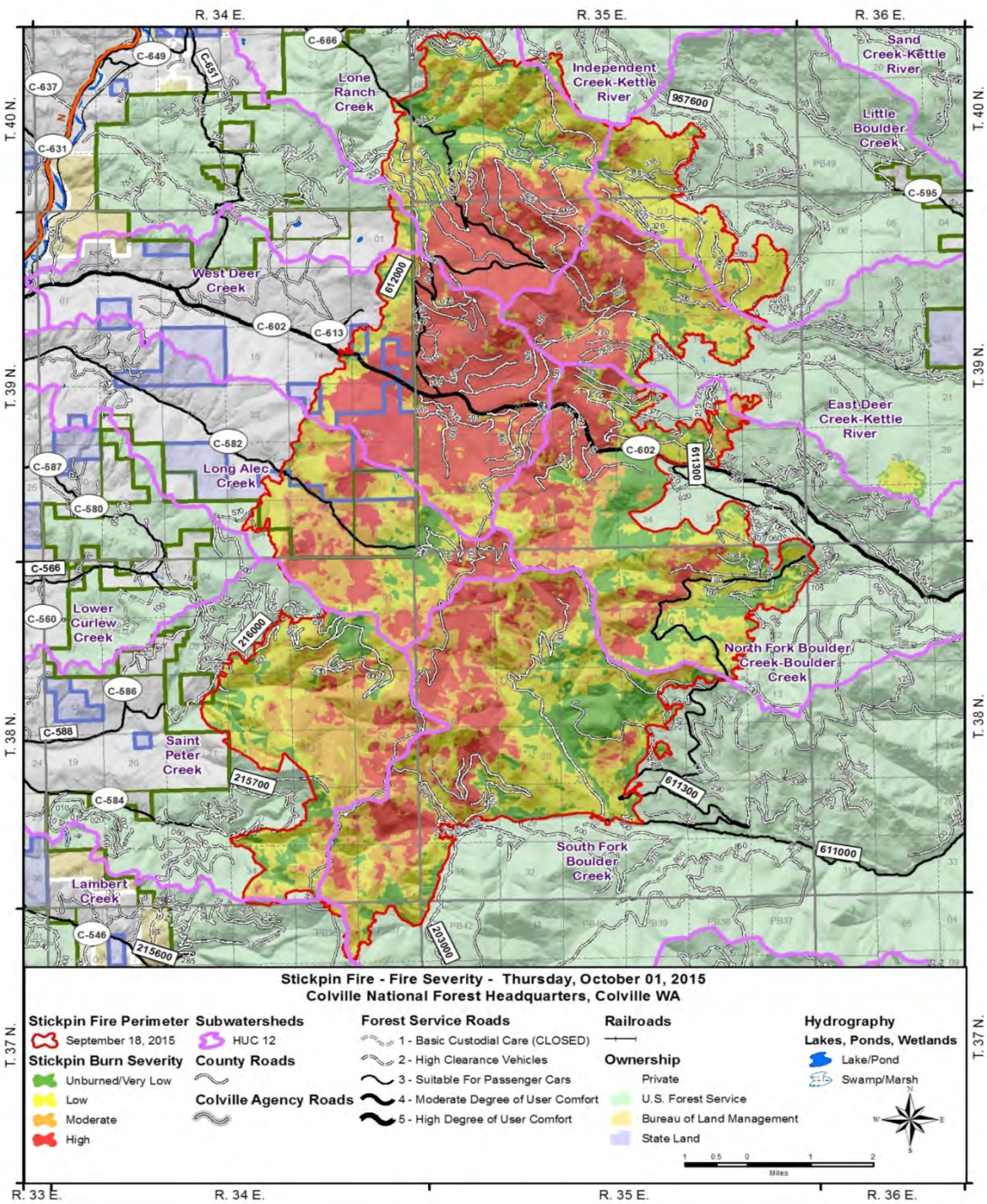

Figure 3: Soil Burn Severity for Stickpin Fire.

Soil Burn Severity	Total Acres	Percent Value

Low/Unburned	22,235	28
Moderate	11,597	24
High	14,635	30
Total	**48,485**	**100**

Table 1: Soil Burn Severity for the Stickpin Fire on USFS Land.

Soil Erosion Hazard Ratings

Generally, soil erodibility tends to increase with greater silt content, steepness of slopes, and loss of organic matter. Conversely, erosion will decrease as sand and clay contents increase, presence of organic matter increase binding strength, and erosion risk will decrease if the infiltration rates are greater than rainfall rates.

Soil Erosion Hazard Ratings indicate the degree of potential erosion for a given soil map unit. The Universal Soil Loss Equation (USLE) provides a framework for factors that affect soil erosion and is used in a large capacity to rate the severity of erosion for a soil map unit. The USLE equation describes a function of rainfall and runoff, soil erodibility, slope length, slope steepness, soil management, and conservation practices (Hairston et al., 2001). Class ratings are slight, moderate, or severe as listed in the Land Management: Erosion Hazard query in Soil Data Explorer for Web Soil Survey (USDA-NRCS, 2015).

An Area of Interest (AOI) spatial extent was set in Web Soil Survey for the soil survey used in this assessment. The erosion hazard class ratings were recorded for each soil unit and cross referenced with the total number of combined high and moderate severity burn acres for those units. The results are listed below:

Soil Erosion Hazard	Acres	Percent of Area
Slight	4,798	22
Moderate	10,401	49
Severe	6,114	29
Total	21,313	100

Table 2: Soil Erosion Hazard Ratings.

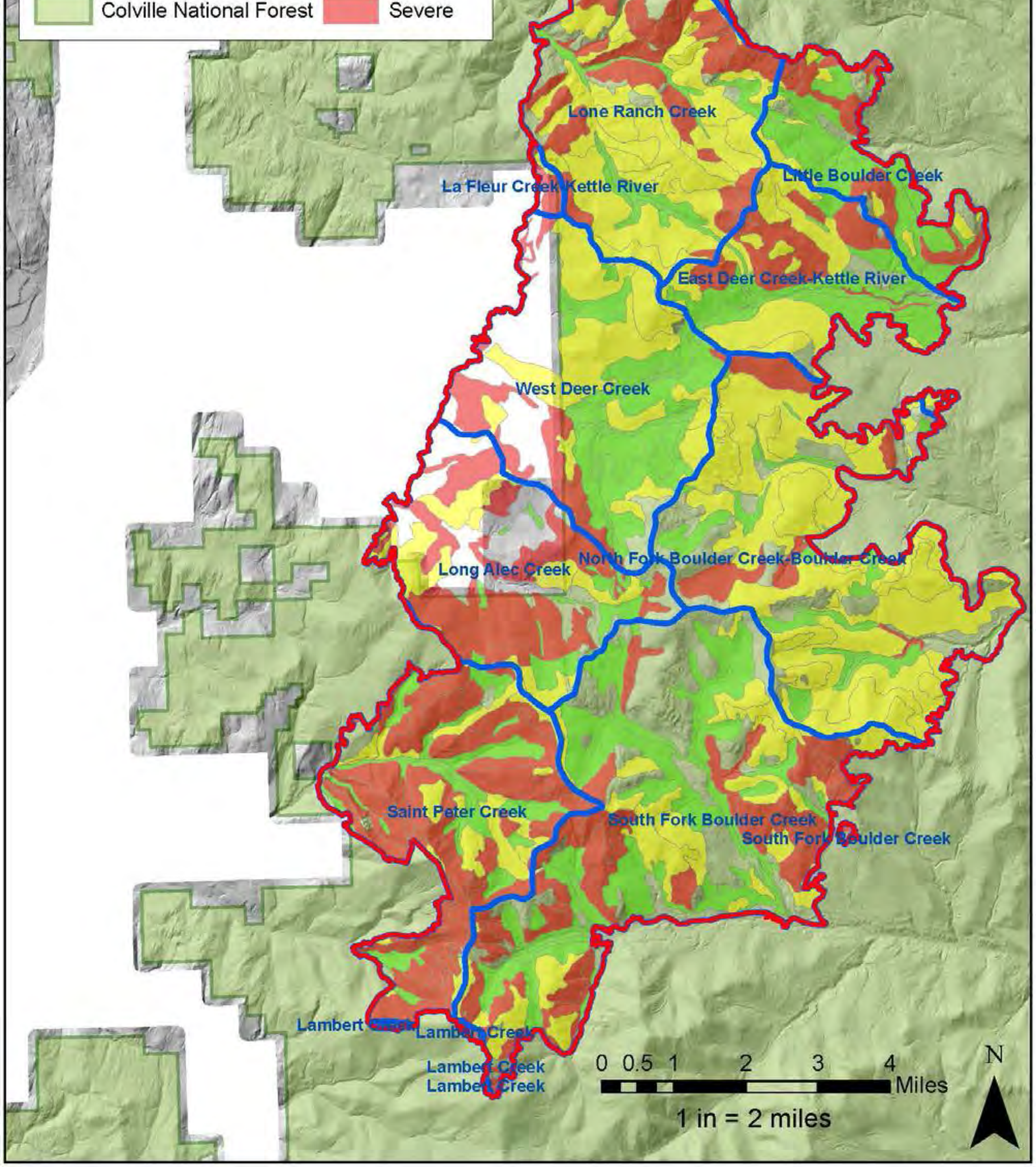

Figure 4: Erosion Hazard Ratings for Stickpin Fire.

Modeling and Analysis

Modeling Pre-Work and Assumptions

A filtering and stratification GIS workflow was used to concentrate on soil map units that would contribute the greatest to overall post-fire erosion and sedimentation response at a watershed level (HUC_12). Watersheds within the Colville National Forest that had some extent within the burn perimeter of the fire were analyzed. The forest's soil layer was then clipped to those watersheds. High and moderate burn severity was then clipped to the soils layer for analysis. Soil units that accounted for more than 0.5 percent spatial extent within the high or moderate burned area in individual watersheds were modeled. A detailed list of the soil units modeled by watershed can be referenced in Appendix A.

The following assumptions were used during the modeling based upon the experience of the BAER soils team:

- Low-burn severity erosion and sedimentation rates are the same or very close to rates under natural, unburned conditions. The overall effect in these areas on hydrologic response at a watershed level is negligible so they were not modeled.
- Map units that occupied less than 0.5% of the total high and/or moderate burned area within a watershed were not modeled as they will not significantly contribute to overall post-fire erosion and sedimentation response in a watershed.
- Natural and fire induced hydrophobicity do occur to some degree and extent but will not be the factor driving post-fire erosion, sedimentation, and hydrologic response.
- Removal of vegetative canopy and ground cover will be the overriding factor driving post-fire erosion, sedimentation, and overall hydrologic response.

Erosion Modeling

WEPP

Erosion modeling to predict erosion and sediment delivery values included the use of the Forest Service Disturbed Water Erosion Prediction Project (WEPP) model. The model utilizes the power of a large, physically based interface that simplifies input data requirements. The general data requirements for Disturbed WEPP are climate data, soil texture, rock fragments, general vegetation type, slope gradient, horizontal slope length and burn severity. The Republic, WA National Oceanic and Atmospheric Administration (NOAA) cooperative climate station was used for the climatic inputs for the model (Table 3). The erosion output values generated by WEPP are based on the average of various storm events within a 30-year period.

Modified Climate Station	Precipitation (in)	Elevation (ft)	Location
Republic, WA +	15.7	2,650	Lat: 48.39° Long: -118.44°

Table 3: Climate parameters for the Republic, WA NOAA cooperative climate station.

Specific input variables used for WEPP included: burn severity, percent slope gradient for an upper and lower section, slope length, ground cover (litter + surface rock fragments + veg. basal area), rock content by percent volume in the soil and soil texture. WEPP does not have a moderate soil burn severity input so the high severity input was used for both high and moderate burn severity runs for each soil unit. Slope gradients were derived from soil map unit slope class ranges.

Erosion and sedimentation runs generate larger values based upon a longer hillslope length. 500 feet was used as the input for the upper section and lower for all runs (1000 ft. total hillslope length) as it represented the longest hillslope length across the burned areas based on various field observations and measurements of slope lengths in ArcMap. Ground cover inputs used were the midpoint value for the range of ground cover present after a high severity and moderate severity, respectively (Parsons et al., 2010) (i.e. 10 percent for high severity and 50 percent for moderate severity). Rock fragment content inputs were derived from soil surface texture rock fragment modifier ranges: no modifier (0-14 percent rock content), gravelly, cobbly, or stony (15-34 percent rock content), very gravelly, very cobbly, or very stony (35-59 percent rock content), and extremely gravelly, extremely cobbly, or extremely stony (60-90 percent rock content). The rock content input requires one value, so the midpoint value for the above ranges was used. Surface soil texture was used for the soil texture input in the model. A detailed spreadsheet of map unit input values can be referenced in Appendix B.

WEPP outputs indicated that the average total erosion potential and total sediment delivery combined for the modeled soil units in high and moderate burn severity within the Stickpin fire is 43 tons/acre and 964 cubic/yards per sq. mile, respectively. Since natural soil erosion potential is generally very low (roughly 1 – 2 tons per acre at most) in most undisturbed forests, 43 tons/acre is significant. An erosion and sediment prediction table from which the above values were derived can be referred to in Table 4**.**

Total Acres OF Burned Watershed (l,m,h)	Total Acres OF Watershed	Total Sed. Del. IN BURN (m,h) (yd3/mi2)	Total Sed. Del. OVER ENTIRE WATERSHED (yd3/mi2)	Average Erosion Potential Mod (t ac-1)	Average Erosion Potential High (t ac-1)	Erosion Potential TOTAL (t ac-1)
East Deer Creek-Kettle River						
4,091.78	23385	502.59	87.94	1.11	6.09	7.20
Independent Creek						
112.00	35,884.47	115.53	0.36	1.50	0.00	1.50
LaFleur Creek						
184.22	42,471.04	21.68	0.09	0.28	0	0.28
Lambert Creek						
73.74	12,254.35	385.31	2.32	5.02	0	5.02
Little Boulder Creek						
2,666.19	13,828.90	97.14	18.73	0.88	0.43	1.31
Lone Ranch Creek						
7,217.18	14,705.46	473.50	232.38	1.30	5.44	6.75
Long Alec Creek						
5,439.28	11,669.35	189.00	88.09	1.14	1.48	2.62
North Fork Boulder Creek						

9,103.25	**21,081.82**	**338.37**	**146.11**	**1.68**	**3.05**	**4.73**
Saint Peter Creek						
6,209.66	**17,634.08**	**360.09**	**126.80**	**4.07**	**0.69**	**4.76**
South Fork Boulder Creek						
11,587.21	**44,071.14**	**223.21**	**58.69**	**1.24**	**1.87**	**3.11**
West Deer Creek – Kettle River						
7,109.03	**13,661.83**	**389.95**	**202.91**	**0.55**	**5.07**	**5.62**
53,794	250,647	3,096	964.44	19	24.12	43

Table 4: Erosion and Sediment Predictions for Stickpin Fire 2015.

ERMiT

The Forest Service Erosion Risk Management Tool (ERMiT) was used to evaluate potential treatments. As it was deemed that low burn severity has little to no effect on post-fire erosion and hydrologic response, treatments weren't considered for any low burn severity areas. Therefore, model runs were only performed for moderate and high burn severity classes.

ERMiT is based on the WEPP model but is used to assess the differences in erosion rates between no treatment and various other treatments to include: mulching at various rates, seeding, log erosion barriers and wattles. In this analysis, ERMiT was used to assess the effectiveness of potential treatments within the burned area and the results used to inform recommendations. Outputs include a comparison of treatment effectiveness for a five-year period post-fire.

Predicted Soil Erosion ERMiT (tons ac-1)

Watershed:Lone Ranch Creek

		Event Sediment Delivery (ton ac-1)					
TOTAL BURNED ACRES OF WATERSHED **7217**	Acres of Highly Erosive Soils Burned in M,H Severity	1st year Untreated (ton ac-1)	1st year Mulch (1ton ac-1)	1st year Sediment Reduction **with** Treatment (%)	2nd year Untreated (ton ac-1)	2nd year Mulch (1ton ac-1)	2nd year Sediment Reduction **with** Treatment (%)
TOTAL	**879**	**168**	**39**	**80**	**112**	**54**	**53**
% RED. OF SED. DELIV. PROVIDED BY TREAT. POLY. FOR BA IN WATERSHED (YR 1)							**10**
% RED. OF SED. DELIV. PROVIDED BY TREAT. POLY. FOR BA IN WATERSHED (YR 2)							**7**
OVERALL % RED IN SED. DELIV. PROVIDED BY TREAT POLY FOR BA OF WS IN 1ST 2 YEARS							**17**

Watershed:East Deer Creek-Kettle River

		Event Sediment Delivery (ton ac-1)					
TOTAL BURNED ACRES OF WATERSHED **4092**	Acres of Highly Erosive Soils Burned in M,H Severity	1st year Untreated (ton ac-1)	1st year Mulch (1ton ac-1)	1st year Sediment Reduction **with** Treatment (%)	2nd year Untreated (ton ac-1)	2nd year Mulch (1ton ac-1)	2nd year Sediment Reduction **with** Treatment (%)
TOTAL	**491**	**149**	**38**	**81**	**103**	**57**	**52**

% RED. OF SED. DELIV. PROVIDED BY TREAT. POLY. FOR BA IN WATERSHED (YR 1)	10
% RED. OF SED. DELIV. PROVIDED BY TREAT. POLY. FOR BA IN WATERSHED (YR 2)	6
OVERALL % RED IN SED. DELIV. PROVIDED BY TREAT POLY FOR BA OF WS IN 1ST 2 YEARS	16

Watershed: West Deer Creek- Kettle River

Event Sediment Delivery (ton ac-1)

TOTAL BURNED ACRES OF WATERSHED **7109**	Acres of Highly Erosive Soils Burned in M,H Severity	1st year Untreated (ton ac-1)	1st year Mulch (1ton ac-1)	1st year Sediment Reduction **with** Treatment (%)	2nd year Untreated (ton ac-1)	2nd year Mulch (1ton ac-1)	2nd year Sediment Reduction **with** Treatment (%)
TOTAL	**493**	**110**	**25**	**82**	**68**	**34**	**54**
% RED. OF SED. DELIV. PROVIDED BY TREAT. POLY. FOR BA IN WATERSHED (YR 1)							**6**
% RED. OF SED. DELIV. PROVIDED BY TREAT. POLY. FOR BA IN WATERSHED (YR 2)							**4**
OVERALL % RED IN SED. DELIV. PROVIDED BY TREAT POLY FOR BA OF WS IN 1ST 2 YEARS							**10**

Watershed: North Fork Boulder Creek

Event Sediment Delivery (ton ac-1)

TOTAL BURNED ACRES OF WATERSHED **9103**	Acres of Highly Erosive Soils Burned in M,H Severity	1st year Untreated (ton ac-1)	1st year Mulch (1ton ac-1)	1st year Sediment Reduction **with** Treatment (%)	2nd year Untreated (ton ac-1)	2nd year Mulch (1ton ac-1)	2nd year Sediment Reduction **with** Treatment (%)
TOTAL	**151**	**54**	**14**	**74**	**38**	**20**	**48**
% RED. OF SED. DELIV. PROVIDED BY TREAT. POLY. FOR BA IN WATERSHED (YR 1)							**1**
% RED. OF SED. DELIV. PROVIDED BY TREAT. POLY. FOR BA IN WATERSHED (YR 2)							**1**
OVERALL % RED IN SED. DELIV. PROVIDED BY TREAT POLY FOR BA OF WS IN 1ST 2 YEARS							**2**

Table 5: Predicted sediment delivery (ERMiT) post fire with and without treatment in the first two years for priority watersheds.

Treatment Rationale and Recommendations

Rationale

The potential loss of soil as a result of the fire may cause irreversible damage to soil quality and has implications on long-term soil productivity. The importance of the volcanic ash cap soils in this area cannot be overstated. These productive volcanic ash cap soils were deposited, and later developed, by an event that took place approximately 7,700 years ago. The ash cap soils on the Colville National Forest are shallower than the volcanic ash soils closer to the source which marks the soil itself as valuable asset to protect. If these soils are lost due to erosion, the site may not recover to pre-fire conditions in our lifetime. Soils would consist of a much shallower or lost ash cap and would continue to develop with the underlying coarser textured granitic parent material. Soils would then have a much lower water holding capacity, higher bulk density, would be shallower to bedrock, and be less fertile. With the change in the soil quality, a change in vegetative outputs can be expected, which could result in a less desirable vegetation type. This could also potentially affect the local economy in the future, which relies on the natural resources available on the forest for the timber industry, recreation opportunities, and overall water quality.

Treatment Recommendations

Based on the erosion modeling outlined above, field reconnaissance and observations, data collection, and collective input from BAER team members, the Lone Ranch, North Fork Boulder Creek, East Deer Creek-Kettle River, and the West Deer Creek-Kettle River watersheds were deemed to have the highest level of unacceptable risk posed by the fire to human life, property, or irreversible damage that may occur to natural or cultural resources. Mulching treatments were recommended for specific locations within the priority watersheds to mitigate erosion and runoff to protect priority VARs, one of which is long-term soil productivity within the treatment areas (Figure 5). Specific information for those particular VARs by watershed can be referenced in the 2500-8 for this fire. The following map depicts the priority watersheds and treatment locations selected by the BAER Team. Watersheds that are excluded from the proposed treatments does not suggest a decrease in risk of erosion, sedimentation, or soil productivity loss rather these watersheds did not meet the criteria of risk established by BAER protocols.

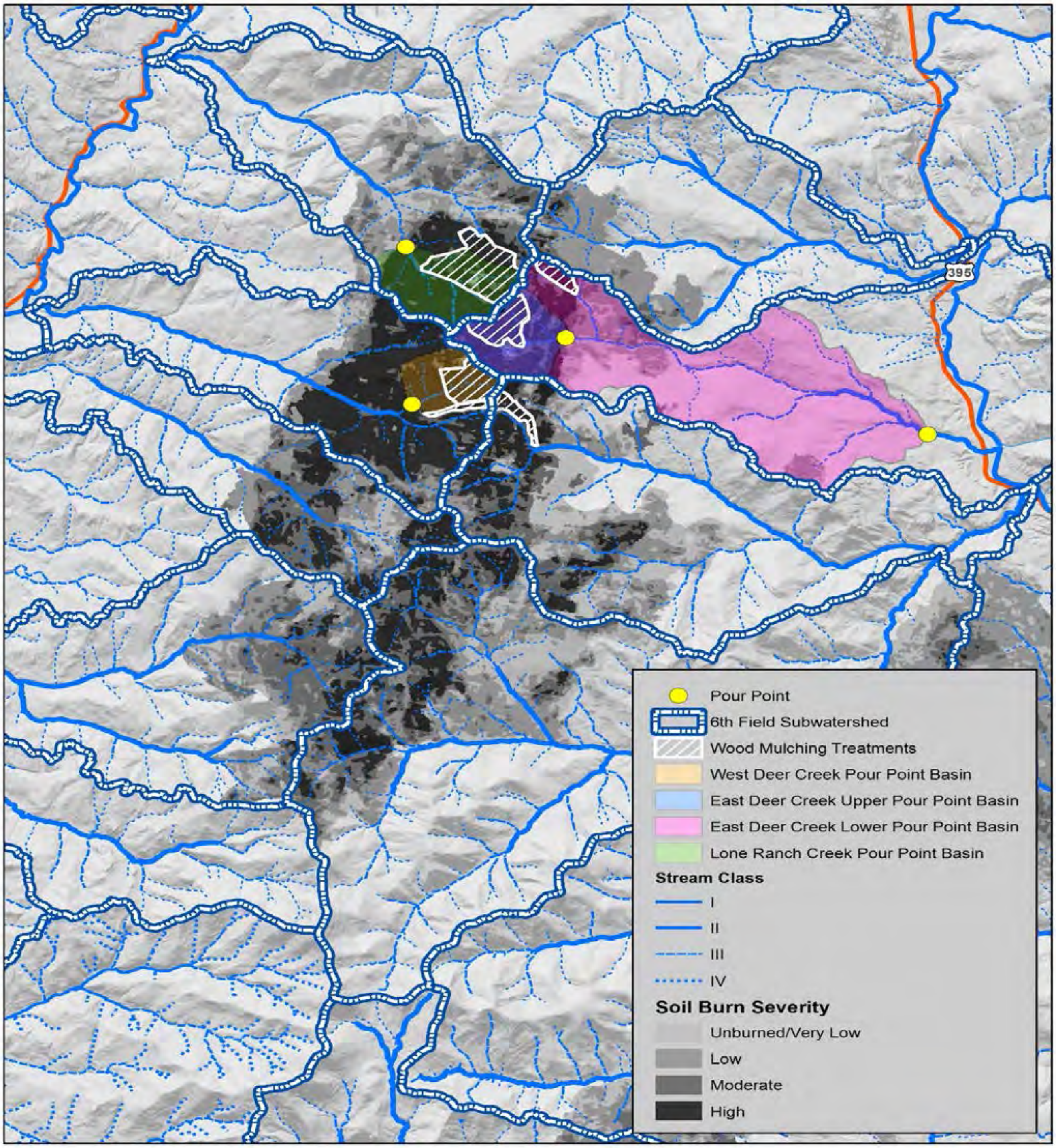

Figure 5: Potential treatment polygons within priority watersheds.

Treatment Type

Wood shred mulching is the recommended treatment for all treatment locations. The purpose of the mulch is to protect soils on steeper slopes from raindrop impaction, to reduce the event energy at the watershed-head source areas, reduce hydrophobicity, increase water infiltration, minimize soil erosion, and promote re-vegetation from seed germination and seedling survival. Although more expensive, it is well documented the benefits of using wood straw mulch instead of agricultural straw. Wood straw is a lot denser material compared to agricultural straw so it is less susceptible to removal from a site by overland flow or wind erosion. Agricultural straw also decomposes much quicker, so the longevity of the material on site is much less compared to wood straw. Agricultural straw has a reputation for bringing in non-native or invasive species although it may be advertised as coming from a certified, weed-free source. There exists a lesser chance of this occurring with the application of wood straw, especially if it can be processed on site. The recommended application rate is 4 tons/acre with an anticipated result of 50 – 70 percent ground coverage.

East Deer Creek-Kettle River Watershed

The East Deer Creek watershed ranked as the Team's top priority watershed and includes 491 acres of treatment within the burn area, comprising 12% of the burned watershed area with severe erosion hazard ratings. The main critical value at risk is a municipal watershed which serves the town of Orient, WA. Although the water treatment facility is located off-forest, the dam associated with the water treatment plant is located on forest and operates under a special use permit. All operations at this dam are completed by hand. Loss of soil productivity is also considered a value at risk within this watershed. Overall reduction in sediment delivery off-site will help mitigate increases in sedimentation into the overall water supply. The potential reduction in sediment delivery provided by the mulch within this treatment is approximately 81% across the treatment area within the first year.

West Deer Creek-Kettle River Watershed

The West Deer Creek Watershed ranked at the Team's second priority and includes 493 acres of treatment which is 7% of the burned watershed area with severe erosion hazard ratings. The main value at risk for this watershed is the Boulder Creek county road and potential safety concerns to those traveling through the area. Secondary, but of equal importance, is the loss of soil productivity. The potential reduction in sediment delivery is approximately 82% for this watershed within the first year.

North Boulder Creek Watershed

The North Boulder Creek Watershed was ranked third and includes 151 acres of treatment which is 2% of the burned watershed area with severe erosion hazard ratings. The main value at risk for this watershed is the Boulder Creek county road and potential safety concerns to those traveling through the area. The treated area would be above the road where the road cut has serious drainage issues causing gullying. A catchment basin exists below this section of the road cut indicating this area is already a problem spot. The potential reduction in sediment delivery is approximately 74% within the first year.

Lone Ranch Watershed

The Lone Ranch Watershed was ranked fourth and includes 829 acres of treatment which is 12% of the watershed. Soil productivity is the main value at risk within the watershed. The 6120 road lies within the treatment area and would also greatly benefit from the mulching treatment. The potential reduction in sediment delivery is approximately 80% within the first year.

Other Watersheds of Concern

The St. Peters Creek Watershed remains as an area of concern from a soil erosion hazard standpoint (Table 4). This watershed has the largest concentration of soil units with severe erosion hazards at the headwaters compared to any other watershed. Although this area exhibited the largest level of concern from a soil erosion perspective, it did not have near the risk to critical values on FS land compared to the other priority watersheds. That being said, the importance of monitoring this area for potential debris flows or landslides during significant precipitation events should not be ignored. It is highly recommended that storm patrols are regularly instituted for this particular watershed as it poses a threat to property and infrastructure off FS land, potentially many miles downstream.

References

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Appendix A

NRCS Soil Map Unit Information

Watershed: East Deer Creek-Kettle River

Map Unit Symbol	Soil Series	Parent Material	Soil Surface Texture	Slope Range	Total Acres within Analyzed Area	Percent within Fire Perimeter
GaC	Gehee	Volcanic ash/ Glacial Till	loam	0-15	218	5.33
GoF	Growden	Volcanic ash/ Colluvium	sandy loam	35-65	596	14.57
GsF	Growden association	Volcanic ash/ Colluvium	sandy loam	15-65	73	1.78
LeF	Leonardo	Volcanic ash/ Loess	sandy loam	35-65	21	0.51
McE	Manley	Volcanic ash/ Glacial Till	silt loam	15-35	609	14.88
OpF	Oxerine-Pepoon complex	Glacial Till	loam	15-35	28	0.68
SdC	Scar	Glacial Till	sandy loam	0-15	241	5.89
TnE	Togo	Volcanic ash/ Glacial Till	silt loam	15-35	222	5.43
TrE	Togo-Rock land Complex	Volcanic ash/ Glacial Till	silt loam	15-50	230	5.62
WgC	Wapal	Glacial Outwash	sandy loam	0-15	66	1.61
McF	Manley	Volcanic ash/ Glacial Till	silt loam	15-35	57	1.39
Sh	Shaskit	Glacial Outwash	silt loam	0	60	1.47

Watershed: Independent Creek-Kettle River

Map Unit Symbol	Soil Series	Parent Material	Soil Surface Texture	Slope Range	Total Acres within Analyzed Area	Percent within Fire Perimeter
LeF	Leonardo	Volcanic ash/ Loess	sandy loam	35-65	1	0.02
TnE	Togo	Volcanic ash/ Glacial till	silt loam	15-35	10	0.24
TnF	Togo	Volcanic ash/ Glacial till	silt loam	35-65	5	0.12

Watershed: La Fleur Creek-Kettle River

Map Unit Symbol	Soil Series	Parent Material	Soil Surface Texture	Slope Range	Total Acres within Analyzed Area	Percent within Fire Perimeter
LeF	Leonardo	Volcanic ash/ Loess	sandy loam	35-65	2	0.05
MlF	Merkel	Volcanic ash/ Glacial till	sandy loam	25-65	3	0.07

Watershed: Lambert Creek						
LeF	Leonardo	Volcanic ash/Loess	sandy loam	35-65	2	0.05
TnE	Togo-Rock land complex	Volcanic ash/ Glacial till	silt loam	15-35	6	0.15
TnF	Togo	Volcanic ash/ Glacial till	silt loam	35-65	19	0.46
Watershed: Little Boulder Creek						
GaF	Gahee	Volcanic ash/ Glacial till	loam	35-65	20	0.49
OpE	Oxerine-Pepoon complex	Glacical Till/ Bedrock	loam	35-65	14	0.34
OpF	Oxerine-Pepoon complex	Glacical Till/ Bedrock	sandy loam	35-65	20	0.49
SdC	Scar	Glacial till	sandy loam	0-15	115	2.81
ToF	Togo Bamber complex	Volcanic ash/ Glacial till	silt loam	35-65	47	1.15
TrE	Togo- Rock land complex	Volcanic ash/ Glacial till	silt loam	15-50	107	2.61
WgC	Wapal	Glacial outwash	sandy loam	0-15	53	1.30
TnF	Togo	Volcanic ash/ Glacial till	silt loam	35-65	15	0.37
Watershed: Lone Ranch Creek						
GaC	Gahee	Volcanic ash/ glacial till	loam	0-15	178	4.35
ErE	Edds- Rock land complex	Volcanic ash/ glacial till	loam	15-50	57	1.39
GoF	Oxerine-Pepoon complex	Volcanic ash/ Colluvium	sandy loam	35-65	235	5.74
GsF	Growden association	Volcanic ash/ Colluvium	sandy loam	15-65	383	9.36
LeF	Leonardo	Volcanic ash/ Glacial till	sandy loam	15-65	236	5.77
McE	Manley	Volcanic ash/ Glacial till	silt loam	15-35	1084	26.49
NeE	Neuske	Glacial till	silt loam	15-35	188	4.59
NlD	Nevine	Volcanic ash/ Glacial till	loam	0-30	278	6.79
TnE	Togo	Volcanic ash/ Glacial till	silt loam	15-35	364	8.90

TrE	Togo-Rock land complex	Volcanic ash/ Glacial till	silt loam	15-50	126	3.08
TvE	Toroda	Volcanic ash/ Glacial till	silt loam	15-35	39	0.95
McF	Manley	Volcanic ash/ Glacial till	silt loam	35-65	47	1.15
MlF	Merkel	Volcanic ash/ Glacial till	sandy loam	25-65	46	1.12
NlF	Nevine	Volcanic ash/ Glacial till	loam	45-65	49	1.20
OlE	Oxerine	Glacial till/ Bedrock	loam	15-35	54	1.32
Sh	Shaskit-Tonata complex	Glacial outwash	silt loam	0	92	2.25
TnF	Togo	Volcanic ash/ Glacial till	silt loam	35-65	118	2.88
Watershed:Long Alec Creek						
MmE	Merkel-Rock land	Volcanic ash/ Glacial till	loam	15-50	32	0.78
Sdc	Scar	Glacial till	sandy loam	0-15	280	6.84
SdF	Shaskit-Tonata comple	Glacial outwash	sandy loam	35-65	805	19.67
TnE	Togo	Volcanic ash/ Glacial till	silt loam	35-65	152	3.71
TnF	Togo	Volcanic ash/ Glacial till	silt loam	35-65	33	0.81
GaC	Gahee	Volcanic ash/ Glacial till	loam	0-15	39	0.95
GsF	Growden association	Volcanic ash/ Colluvium	sandy loam	15-65	43	1.05
Watershed: North Fork Boulder Creek-Boulder Creek						
GaC	Gahee	Volcanic ash/ Glacial till	loam	0-15	159	3.89
GoF	Growden	Volcanic ash/ Colluvium	sandy loam	35-65	177	4.33
GsF	Growden association	Volcanic ash/ Colluvium	sandy loam	15-65	339	8.28
LrE	Leonardo	Volcanic ash/ Glacial till	sandy loam	15-50	45	1.10
McE	Manley	Volcanic ash/ Glacial till	silt loam	15-35	1277	31.21
McF	Manley	Volcanic ash/ Glacial till	silt loam	35-65	243	5.94
MkE	Merkel	Volcanic ash/ Glacial till	silt loam	15-35	186	4.55
Sdc	Scar	Glacial till	silt loam	0-15	266	6.50

TnE	Togo	Volcanic ash/ Glacial till	silt loam	15-35	242	5.91
TrE	Togo	Volcanic ash/ Glacial till	silt loam	15-50	461	11.27
Watershed: Saint Peter Creek						
GoF	Volcanic ash/ Colluvium	Volcanic ash/ Colluvium	sandy loam	35-65	553	13.51
LeF	Leonardo	Volcanic ash/Loess	sandy loam	35-65	172	4.20
McE	Manley	Volcanic ash/ Glacial till	silt loam	15-35	175	4.28
NaC	Nanamkin	Glacial outwash	sandy loam	0-15	38	0.93
SdC	Scar	Glacial till	sandy loam	0-15	581	14.20
TnE	Togo	Volcanic ash/ Glacial till	silt loam	15-35	197	4.81
TnF	Togo	Volcanic ash/ Glacial till	silt loam	35-65	999	24.41
TrE	Togo-Rock land complex	Volcanic ash/ Glacial till	silt loam	15-50	243	5.94
Watershed: South Fork Boulder Creek						
GaC	Gahee	Volcanic ash/ Glacial till	loam	0-15	147	3.59
GoF	Growden	Volcanic ash/ Colluvium	sandy loam	35-65	572	13.98
GsF	Growden association	Volcanic ash/ Colluvium	sandy loam	15-65	213	5.21
LeF	Leonardo	Volcanic ash/ Loess	sandy loam	15-65	114	2.79
Sdc	Scar	Glacial till	sandy loam	0-15	1164	28.45
SdF	Scar	Glacial till	sandy loam	35-65	106	2.59
TnE	Togo	Volcanic ash/ Glacial till	silt loam	15-35	259	6.33
TnF	Togo	Volcanic ash/ Glacial till	silt loam	15-35	456	11.14
TrE	Togo-Rock land complex	Volcanic ash/ Glacial till	silt loam	15-50	398	9.73
Watershed: West Deer Creek – Kettle River						
GaC	Gahee	Volcanic ash/ Glacial till	loam	0-15	769	18.79
GoF	Growden	Volcanic ash/ Colluvium	sandy loam	35-65	121	2.96
GsF	Growden association	Volcanic ash/ Colluvium	sandy loam	15-65	494	12.07

NeE	Neuske	Glacial till	silt loam	15-35	1035	25.29
SdC	Scar	Glacial till	sandy loam	0-15	1160	28.35
TnE	Togo	Volcanic ash/ Glacial till	silt loam	15-35	129	3.15
TnF	Togo	Volcanic ash/ Glacial till	silt loam	35-65	44	1.08
McE	Manley	Volcanic ash/ Glacial till	silt loam	15-35	47	1.15
MkE	Merkel	Volcanic ash/ Glacial till	sandy loam	15-35	100	2.44
MmE	Merkel-Rock land complex	Volcanic ash/ Glacial till	loam	15-50	52	1.27
PaC	Pausant	Glacial deposit	sandy loam	0-15	125	3.05
Sh	Shaskit-Tonata	Glacial outwash	silt loam	0	99	2.42
TcE	Talls	Volcanic ash/ Glacial till	silt loam	0-45	57	1.39

Appendix B

Disturbed WEPP 1.0 and ERMiT INPUTS

Watershed: East Deer Creek-Kettle River

Map Unit/Burn Severity	Surface Texture	Slope Gradient (Upper and Lower %)	Slope Length (ft)	Forest Type	Rock Fragments (surface)	Cover (%)	
						High	Moderate
GaC/M,H	loam	0-15	1000	Forest	8	10	50
GoF/M,H	sandy loam	35-65	1000	Forest	8	10	50
GsF /M,H	sandy loam	15-65	1000	Forest	8	10	50
LeF/M	sandy loam	35-65	1000	Forest	8	10	50
McE/M,H	silt loam	15-35	1000	Forest	8	10	50
OpF /M	loam	15-35	1000	Forest	8	10	50
SdC/M,H	sandy loam	0-15	1000	Forest	8	10	50
TnE/M,H	silt loam	15-35	1000	Forest	8	10	50
TrE/M,H	silt loam	15-50	1000	Forest	8	10	50
WgC/M	sandy loam	0-15	1000	Forest	8	10	50
McF/H	silt loam	15-35	1000	Forest	8	10	50
Sh/H	silt loam	0	1000	Forest	8	10	50

Watershed: Independent Creek- Kettle River

LeF/M	sandy loam	35-65	1000	Forest	8	10	50
TnE/ M	silt loam	15-35	1000	Forest	8	10	50
TnF/M	silt loam	35-65	1000	Forest	8	10	50

Watershed: La Fleur Creek-Kettle River

LeF/M	sandy loam	35-65	1000	Forest	8	10	50
MlF/M	sandy loam	25-65	1000	Forest	25	10	50

Watershed: Lambert Creek

LeF/M	sandy loam	35-65	1000	Forest	8	10	50
TnE/M	silt loam	15-35	1000	Forest	8	10	50
TnF/M	silt loam	35-65	1000	Forest	8	10	50

Watershed: Little Boulder Creek

GaF/M	loam	35-65	1000	Forest	8	10	50
OpE/M	loam	35-65	1000	Forest	8	10	50
OpF/M	sandy loam	35-65	1000	Forest	8	10	50
SdC/M	sandy loam	0-15	1000	Forest	8	10	50
ToF/M	silt loam	35-65	1000	Forest	8	10	50
TrE/M,H	silt loam	15-50	1000	Forest	8	10	50
WgC/M,H	sandy loam	0-15	1000	Forest	8	10	50
TnF/H	silt loam	35-65	1000	Forest	8	10	50

Watershed: Lone Ranch Creek

ErE/M	loam	15-50	1000	Forest	8	10	50
GoF/M,H	sandy loam	35-65	1000	Forest	8	10	50
GsF/M,H	sandy loam	15-65	1000	Forest	8	10	50
LeF/M	sandy loam	15-65	1000	Forest	8	10	50
McE/M,H	silt loam	15-35	1000	Forest	8	10	50
NeE/M,H	silt loam	15-35	1000	Forest	8	10	50
NlD/M,H	loam	0-30	1000	Forest	8	10	50
TnE/M,H	silt loam	15-35	1000	Forest	8	10	50
TrE/M,H	silt loam	15-50	1000	Forest	8	10	50
TvE/M	silt loam	15-35	1000	Forest	8	10	50

McF/H	silt loam	35-65	1000	Forest	8	10	50
MlF/H	sandy loam	25-65	1000	Forest	25	10	50
NlF/H	loam	45-65	1000	Forest	8	10	50
OlE	loam	15-35	1000	Forest	8	10	50
Sh/H	silt loam	0	1000	Forest	8	10	50
TnF/H	silt loam	35-65	1000	Forest	8	10	50

Watershed: Long Alec Creek

MmE/M	loam	15-50	1000	Forest	25	10	50
Sdc/M,H	sandy loam	0-15	1000	Forest	8	10	50
SdF/M,H	sandy loam	35-65	1000	Forest	8	10	50
TnE/M,H	silt loam	35-65	1000	Forest	8	10	50
TnF/M	silt loam	35-65	1000	Forest	8	10	50
GaC/H	loam	0-15	1000	Forest	8	10	50
GsF/H	sandy loam	15-65	1000	Forest	8	10	50

Watershed: North Fork Boulder Creek-Boulder Creek

GaC/M,H	loam	0-15	1000	Forest	8	10	50
GoF/M,H	sandy loam	35-65	1000	Forest	8	10	50
GsF/M, H	sandy loam	15-65	1000	Forest	8	10	50
LrE/M	sandy loam	15-50	1000	Forest	8	10	50
McE/M,H	silt loam	15-35	1000	Forest	8	10	50
McF/M,H	silt loam	35-65	1000	Forest	8	10	50
MkE/M,H	silt loam	15-35	1000	Forest	8	10	50
Sdc/M,H	silt loam	0-15	1000	Forest	8	10	50
TnE/M,H	silt loam	15-35	1000	Forest	8	10	50
TrE/M,H	silt loam	15-50	1000	Forest	8	10	50

Watershed: Saint Peter Creek

GoF/H	sandy loam	35-65	1000	Forest	8	10	50
LeF/M,H	sandy loam	35-65	1000	Forest	8	10	50
McE/M,H	silt loam	15-35	1000	Forest	8	10	50
NaC/M	sandy loam	0-15	1000	Forest	25	10	50
SdC/M,H	sandy loam	0-15	1000	Forest	8	10	50
TnE/M,H	silt loam	15-35	1000	Forest	8	10	50

TnF/M,H	silt loam	35-65	1000	Forest	8	10	50
TrE/M	silt loam	15-50	1000	Forest	8	10	50
Watershed: South Fork Boulder Creek							
GaC/M,H	loam	0-15	1000	Forest	8	10	50
GoF/M,H	sandy loam	35-65	1000	Forest	8	10	50
GsF/M,H	sandy loam	15-65	1000	Forest	8	10	50
LeF/M	sandy loam	15-65	1000	Forest	8	10	50
Sdc/H	sandy loam	0-15	1000	Forest	8	10	50
TnE/M,	silt loam	15-35	1000	Forest	8	10	50
TnF/M,H	silt loam	15-35	1000	Forest	8	10	50
TrE/M,H	silt loam	15-50	1000	Forest	8	10	50
Watershed: West Deer Creek – Kettle River							
GaC/M,H	loam	0-15	1000	Forest	8	10	50
GoF/M,H	sandy loam	35-65	1000	Forest	8	10	50
GsF/M,H	sandy loam	15-65	1000	Forest	8	10	50
NeE/M,H	silt loam	15-35	1000	Forest	8	10	50
SdC/M,H	sandy loam	0-15	1000	Forest	8	10	50
TnE/M,H	silt loam	15-35	1000	Forest	8	10	50
TnF/M	silt loam	35-65	1000	Forest	8	10	50
McE/H	silt loam	15-35	1000	Forest	8	10	50
MkE/H	sandy loam	15-35	1000	Forest	8	10	50
MmE/ H	loam	15-50	1000	Forest	25	10	50
PaC/H	sandy loam	0-15	1000	Forest	8	10	50
Sh/H	silt loam	0	1000	Forest	8	10	50
TcE/H	loam	0-45	1000	Forest	25	10	50