# Mad Roaring Mills: Soil Effects Analysis

Prepared by: Tracy Christopherson, North Zone Soil Scientist
For: Entiat Ranger District, Okanogan-Wenatchee National Forest
Date: December, 2021

## Issues Addressed

There are few activities conducted on National Forest System lands that do not have the potential to affect soil resources in some way. Application of sound soil conservation practices is essential if we are to sustain the health, diversity and productivity of national forests and grasslands. This section includes issues pertaining to soils that have been identified for detailed analysis. An issue is "a statement of cause and effect linking environmental effects to actions" (FSH 1909.15).

Issue 1: The use of Ground Based Harvesting (GBH) equipment in Unit 200 may cause detrimental soil conditions (e.g., soil compaction, rutting, puddling, or erosion) that exceed the National and Region 6 Soil Standards.

Issue 2: Burning debris piles and prescribed fire may result in adverse short-term soil conditions (e.g., hydrophobicity resulting from a high-severity burn).

Issue 3: Conversion of a closed road segment to a motorized trail could increase dust and localized soil erosion.

## Methodology

The spatial boundaries for analyzing the direct, indirect, and cumulative effects to the soil resource are treatment units. This is because the effects to soil are on a site and treatment specific basis. The temporal boundaries for analyzing the same effects are years (five or more), because detrimental soil compaction, rutting, puddling, and/or erosion can persist on the landscape. This time scale is based on the most limiting expected detrimental soil disturbance (DSD), subsoil compaction, which has been shown to persist following heavy equipment traffic for five or more years, depending on soil texture (Hakansson et al., 1987).

Qualitative field surveys for pre-existing DSD were restricted to Unit 200 since that is the only Vegetation Management unit that will require the use of GBH equipment. The Soil Scientist and Hydrologist walked an intuitively controlled transect through Unit 200 on November 13th, 2021 to document the existing soil condition. A Dickey-John 30" steel soil compaction tester was used to identify and record soil compaction. When compaction was encountered along the transect it ranged from approximately 4–9" below the soil surface. Based on penetrometer readings on the transect, and evidence of soil recovery at prior compacted sites (e.g., granular soil structure above platy compacted structure), consensus was reached that this unit was below the Forest Service Management Plan threshold of <20% DSD.

Additionally, Issue 1 (Unit 200) was analyzed for applicable land management suitability and limitations using targeted soil interpretations produced by the Natural Resources Conservation Service (NRCS) (Soil Survey Staff, 2021). Analyses included the potential for puddling, compaction, rutting hazard, and fire damage susceptibility (Table 2).

Issue 2 was analyzed using a NRCS soil interpretation for fire damage susceptibility for all Vegetation Management proposed action units (Appendix 1) (Soil Survey Staff, 2021). Burned Area Emergency

Response reports (e.g., 2021 Twentyfive Mile fire) from the region were also used for understanding impacts to the soil resource following a low-, moderate-, and high-severity fire.

Issue 3 was analyzed using a NRCS soil interpretation for potential vulnerability for soil displacement from unsurfaced roads and trails (Appendix 2) (Soil Survey Staff, 2021). Field data is lacking to verify the accuracy of the NRCS interpretation report for erosion hazards on unsurfaced motorized trails.

## Resource Indicators and Measures

The following soil resource indicators provide us with the best field metrics to define and assess what long-term soil productivity is and how our management actions would affect these soil properties.

**Table 1. Resource indicators and measures for assessing effects, Mad Roaring Mills Draft EA, Okanogan-Wenatchee National Forest, Washington, 2022.**

| Issue | Indicator | Measure | Source |
|---|---|---|---|
| 1) Detrimental Soil Conditions from Ground Based Heavy Equipment | Puddling potential, compaction potential, soil rutting hazard, heavy equipment operability, and fire damage susceptibility. | Percent of Treatment Unit | USDA-NRCS Web Soil Survey |
| 2) Potential for damage to soil nutrient, physical, and biotic soil characteristics by fire. | Surface organic matter loss caused by a high-severity fire. | Percent of Treatment Unit | USDA-NRCS Web Soil Survey |
| 3) Soil erosion on motorized trail. | Soil loss based on K factor, slope, and content of rock fragments. | Percent of Motorized Trail | USDA-NRCS Web Soil Survey |

# Environmental Consequences

Soils in the project area formed primarily in colluvium and residuum weathered from schist, gneiss, or granite, on mountain slopes and hillslopes. Alluvium is present on floodplains, terraces, and alluvial fan landforms. Volcanic ash is present throughout the study area, and is primarily mixed with colluvium (3–44” thick) on mountain and hillslopes. A discrete ash cap may form in areas less prone to disturbance (e.g., toeslope) up to 23 inches thick. Soils tend to be well drained with a water table depth 200 cm below the soil surface. The most common soil orders are humus-rich Mollisols, weakly-developed Inceptisols, and Andisols that have formed in volcanic tephra.

Soil productivity is defined as the capacity of soil, in its normal environment, to support plant growth (Grigal, 2000). Soil productivity is reflected in the growth of forest vegetation or the volume of organic matter produced on a site. A decrease in soil productivity could affect the rate of future forest growth and the level of timber harvesting the forest can sustain. Maintaining soil productivity sustains forest soils in a condition that favors regeneration, survival, and long-term growth of desired forest vegetation. In addition to terrestrial vegetation, soils sustain and govern key ecosystem services such as, nutrient cycling, site stability, the storage of water, and the regulation of atmospheric gases (Busse, et al., 2014).

## Alternative 1: No Action

Past soil disturbance is responsible for the existing baseline soil condition and is visible as compacted soils, soil erosion from the road network, and bare soil areas. Activities that created these conditions

include, but are not limited to, historical timber harvest, road construction and lack of road maintenance, motorized and non-motorized recreation, and fires.

### Direct and Indirect Effects of No Action

The resource indicator values described above would remain relatively unchanged for Issue 1 until a disturbance event such as wildfire occurred. Were a natural or human caused fire to occur in Unit 200 in absence of a fuels reduction treatment, 100% of that unit is expected to have a moderate or high likelihood of damage resulting from wildfires (e.g., loss of surface organic material) (Table 2). Potential detrimental soil conditions associated with the use of heavy equipment would be entirely avoided for Alternative 1.

Were no action taken for Issue 2, and natural or human-caused wildfires were to occur on the Vegetation Management units, they would cause consumption of the protective litter and duff layer on the soil surface. While this could also happen with Alternative 2 (see below), mitigation measures would not be in place to reduce the likelihood of a high-severity crown fire. Low-severity fires would not be expected to cause large mud or debris flows. High- and moderate-severity burns that result in hydrophobic soil properties would be vulnerable for soil erosion and mass movement, depending on storm intensity and duration (Parrett et al., 2003). Based on the NRCS soil interpretation for potential damage by fire, 76.1% of the Vegetation Management units have a moderate or high potential for wildfires that are intense enough to remove the duff layer and consume organic matter in the surface layer (Appendix 1). Loss of productive organic horizons through fire consumption would adversely impact soil productivity.

The resource indicator values described above would remain relatively unchanged for Issue 3 since erosion from road prisms throughout the project area would continue to some extent with this alternative. The section of trail analyzed for this report is officially closed yet it has semi-regular motorized traffic. Just over 90% of the soils along the proposed motorized trail are ranked as severely limiting. This class indicates significant erosion is expected, that the trail may require frequent maintenance, and that costly erosion-control measures are expected (Appendix 2) (Soil Survey Staff, 2021). Despite the NRCS mapping the dominant soil condition as severely limiting for this land use, a No Action for Alternative 1 for Issue 3 is expected to cause an increased degree of soil erosion since trail improvements to USFS standards would not be completed and motorized use is expected to continue.

## Alternative 2: Environmental Consequences

### Direct and Indirect Effects of the Proposed Action

Direct and indirect effects to the soil resource would occur as a result of machine thinning trees, prescribed fire, and upgrading, decommissioning, or closing roads. The direct and indirect effects of the proposed action for Issue 1 are summarized in Table 2. Increased surface water run-off or debris flows from compaction or high-severity burned soils could result from a high-intensity storm event. These direct and indirect effects would be reduced or eliminated by following the soil design criteria and mitigation measures described in the Design Features section.

The effects to soils from the use of heavy equipment are not expected to cause widespread puddling or rutting, with the exception of the Ardenmont soil type, which is vulnerable to rutting. The Ardenmont and Kloochman soils are poorly suited for heavy equipment operations. Both components primarily occur on steep slope gradients (30–60%), the majority of which exceed the slope severity threshold for Best Management Practices (BMPs) (which will reduce heavy equipment traffic in those units). The Tillicum component is the most abundant (35.7%) soil component in Unit 200, and combined with the Chumstick soil (1.8%), are both well-suited for heavy equipment on lower slope gradients (<30%). There is a

medium compaction potential for 98.2% for Unit 200 which would be mitigated by operating on unsaturated soils, over slash, and avoiding more than one pass over the same area whenever possible (see Design Features). In addition, implementing specific erosion control measures such as constructing water bars, placing slash on bare soils, and vegetating disturbed soils would conserve the soil resource.

**Table 2. Predicted Direct and Indirect impacts of Vegetation Management objectives conducted in Unit 200, Mad Roaring Mills Draft EA, Okanogan-Wenatchee National Forest, Washington, 2022.**

| Dominant Component (NRCS Soil Series Name) | Puddling Potential | Compaction Potential | Soil Rutting Hazard | Heavy Equipment Operability | Fire Damage Susceptibility | Area (acres) | Cover (%) |
|---|---|---|---|---|---|---|---|
| Ardenmont | Low | Medium | Severe | Poorly suited | Highly susceptible | 48.6 | 29.0 |
| Chumstick | Low | Low | Moderate | Well suited | Moderately susceptible | 3.0 | 1.8 |
| Kloochman | Low | Medium | Moderate | Poorly suited | Highly susceptible | 56.1 | 33.5 |
| Tillicum | Low | Medium | Moderate | Well suited on slopes <30%; Poorly suited slopes >30% | Highly susceptible | 59.7 | 35.7 |
| | | | | | | **167.3** | **100.0** |

The Vegetation Management units' susceptibility to fire damage ranges from low to high across the study area. The direct and indirect effects of the proposed action for Issue 2 are summarized in Appendix 1. Over half of the study area is moderately susceptible to nutrient, physical, and biotic soil damage caused by fire. Soil carbon and organic matter losses from mineral soil are nominal unless the burning is severe (Busse et al., 2014). The Vegetation Management proposed actions in Alternative 2 would, 1) reduce the likelihood of a crown fire by thinning, and 2) apply a controlled burn in a managed setting to maximize low-severity burn conditions. Mineral soil is a poor conductor of heat, so damage (if any) is usually limited to the top few centimeters for all but high-severity burns (Busse et al., 2014). The design criteria to cover bare soil with slash has numerous effects, including, replaces organic material for microbial populations, protects the soil surface from raindrop impact, dissipates the energy of overland flow, binds soil particles together, and dampens soil temperature extremes and daily fluxes (Graham, 1994 and Robichaud and Hungerford, 2000). Soil micro-organisms are killed across a wide range of temperatures; however, even severe burning does not sterilize the soil (Busse et al., 2014).

The direct and indirect effects to the soil resource from converting a closed road segment to a designated motorized trail include increased soil displacement in the form of dust and sediment run-off. This trail has historic use, so bare soil is the present existing condition for the length of the proposed trail analyzed for Issue 3. Bare ground is expected to increase with Alternative 2 by as much as 50%, as the trail will need to be widened in some sections to meet National Forest Standards. Over 90% of the proposed trail occurs on soils with a severe hazard rating for soil loss from an unsurfaced trail (Appendix 2). Highly Erosive Soils (HES) on the Okanogan-Wenatchee National Forest are known to occur on steep slopes (>35%) which formed in ash-capped (<20” thick) soils over loosely compacted glacial till. None of the dominant soil types in this study presently meet the criterion for known HES on the Forest. Project design features to mitigate erosion, such as using a mini excavator and hand tools to install tread block to armor corners, will help shed water that encroaches on the trail from above.

### Cumulative Effects of the Proposed Action

The cumulative effects for soils resources include the combined direct and indirect impacts described above, as well as, past and potential future impacts from year-round recreation (e.g, dispersed camping, hiking, snow machining, etc.), hunting, firewood gathering, off-road vehicle use, timber management, human and natural caused fires, road maintenance, and sheep grazing. These activities can diminish soil productivity and soil resilience by causing detrimental soil conditions (e.g., compaction), removal of coarse woody debris, and create bare areas, all of which can contribute to loss of ground cover, soil compaction, erosion, rutting, and puddling.

The actions above overlap in time and space with proposed activities in this project and may slightly increase sediment delivery. However, after timber harvest or thinning and prescribed burning, sediment levels would return to normal after a few years, and the risk of catastrophic wildfire adjacent to USFS lands will be reduced. These activities have no measurable effect on any resource indicators used in this analysis within the project area. Grazing does impact sediment delivery in the project area, but the effects are on-going as described for the existing condition in Alternative 1 and comply with the relevant allotment management plans.

Proper grazing techniques can enhance future site productivity and nutrient cycling, causing a positive growth response from native vegetation, whereby roots improve soil structure and help stabilize the soil resource (Veen et al, 2014). The effect of repeated prescribed fire treatments on soil is not well studied, which moderates our confidence in quantifying cumulative effects (Busse et al, 2014). Subsoil compaction from primary skid trails and roads result in significant reduction of the productive capacity of the soils directly beneath them, but decompaction techniques with a subsoiler (Kees, 2008) can promote native plant establishment (Archuleta and Baxter, 2008). Proposed road decommissioning (not an issue analyzed in this report as it reduces soil disturbance) will occur as authorized by the EA. These transportation actions, and those analyzed in this report, would have a cumulative beneficial long-term negligible effect on these resource indicators within the project area because closing and decommissioning roads, improving motorized trails to standards, and removing or upsizing culverts, improves all the resource indicators.

# Relevant Laws, Regulations, and Policy

## Regulatory Framework

### Land and Resource Management Plan

The Okanogan National Forest Land and Resource Management Plan (LRMP; USDA Forest Service 1989) provides standards and guidelines for long-term soil productivity.

- LRMP Standards and Guidelines 13-9: Reduce soil displacement, ground yarding systems should not be used on sustained slopes in excess of 35 percent.
- LRMP Standard and Guidelines 13-10: Ground yarding systems shall be restricted to meet regional guidelines for soil compaction, displacement, and puddling. No more than 15 percent of the area shall be in a puddled, displaced, or compacted condition following completion of management activities.

### Desired Condition

Design and implement management practices which maintain or improve soil and water quality, and to emphasize protection over restoration. Design new activities that do not exceed detrimental soil

conditions on more than 20 percent of an activity area. (This includes the permanent transportation system.)

In areas where less than 20 percent detrimental soil conditions exist from prior activities, the cumulative detrimental effect of the current activity following project implementation and restoration must not exceed 20 percent.

In areas where more than 20 percent detrimental soil conditions exist from prior activities, the cumulative detrimental effects from project implementation and restoration must, at a minimum, not exceed the conditions prior to the planned activity and should move toward a net improvement in soil quality.

## Federal Law

- National Forest Management Act of 1976: To comply with NFMA, the Chief of the Forest Service has charged each Forest Service Region with developing soil quality standards for detecting soil disturbance and indicating a loss in long-term soil productivity where it occurs. The following Forest Service Manual and supplement directions assure compliance with this requirement:
    - Forest Service Manual (FSM) 2500 Chapter 2550: Soil Management directive establishes the framework for sustaining soil quality and hydrologic function while providing goods and services outlined in forest and grassland management plans.
    - Region 6 Supplement (2500-98-1) to FSM 2500: Design and implement management practices which maintain or improve soil and water quality, and to emphasize protection over restoration.
- Clean Water Act – Project design criteria is implemented to reduce or eliminate erosion into surface waterways in the project area. This would comply with CWA.
- 2. 3 - State and Local Law
- State Clean Water Act - Project design criteria are implemented to reduce or eliminate erosion into surface waterways in the project area. This would comply with SCWA.
- 2. 4 - Other Policy, Guidance, or Recommendations
- <u>FSM 2500-98-1: Detrimental Soil Conditions:</u> The Region 6 Supplement to the FSM 2500 states the following:

<u>Soil Quality Standards</u>: The following regional standards are thresholds beyond which soil quality is adversely impacted. Leave a minimum of 80% of an activity area in an acceptable soil quality condition. Detrimental conditions, as defined below, also include landings and system roads. Detrimental soil quality conditions and the accompanying criteria for determining when and where these conditions occur include: Compaction, Displacement, Puddling, and Severely Burned.

- <u>Detrimental Compaction.</u>
    - <u>Volcanic Ash/Pumice Soils (Soils with Andic Properties)</u>. An increase in soil bulk density of 20 percent, or more, over the undisturbed level.
    - <u>Other Soils</u>. An increase in soil bulk density of 15 percent, or more, over the undisturbed level, a macrospore space reduction of 50 percent or more, and/or a reduction below 15 percent macro porosity.

Assess changes in compaction by sampling bulk density, macro porosity, or penetration resistance in the zone in which change is relatively long term and that is the principal root development zone. This zone is commonly 4 to 12 inches in depth.

- Detrimental Puddling. Detrimental puddling is where the depth of ruts or imprints is six inches or more. Soil deformation and loss of structure are observable and usually bulk density is increased.
    - Detrimental Displacement. Detrimental displacement is the removal of more than 50 percent of the A horizon from an area greater than 100 square feet, which is at least 5 feet in width.
    - Detrimental Burned Soil. Soils are considered to be detrimentally burned when the mineral soil surface has been significantly changed in color, oxidized to a reddish color, and the next on-half inch blackened from organic matter charring by heat conducted through the top layer. The detrimentally burned soil standard applies to an area greater than 100 square feet, which is at least five in width.

## Conclusion

Alternative 1 would not add to cumulative soil effects unless, or until, a high-severity fire occurred. That is due to unauthorized traffic by motorized vehicles contributing to the existing condition. Alternative 1 would also avoid detrimental soil conditions in Unit 200 since ground-based equipment would not be used, and existing noxious weed populations would persist (except where currently authorized treatments reduce them).

In contrast, Alternative 2 would produce additional soil disturbance that overlaps in time and space with the existing soil conditions. This disturbance would be minor to moderate immediately after project implementation. Using BMPs and design criteria would help ensure that these impacts are short-term (5 years or less). Future wildfires, OHV use, firewood gathering, grazing, and road maintenance activities are the most likely on-going and reasonably foreseeable actions that would cumulatively affect soil resources in treatment units.

Compared to Alternative 1, Alternative 2 would have a lasting beneficial effect on reducing erosion from unauthorized motorized trail use, and better protect the soil resource from damage caused by a high-severity fire. A low-severity prescribed fire is an effective tool for reducing fire hazard and restoring forest health by replenishing available soil nutrients, stimulating plant growth, improving wildlife habitat, and maintaining biological diversity (Reinhardt et al. 2008).

## References Cited

Archuleta, J.G. and Baxter, E.S., 2008. Subsoiling promotes native plant establishment on compacted forest sites. Native Plants Journal, 9(2), pp.117-122.

Busse, Matt D.; Hubbert, Ken R.; Moghaddas, Emily E. Y., 2014. Fuel reduction practices and their effects on soil quality. Gen. Tech. Rep. PSW-GTR-241. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station. 156 p.

Forest Service Handbook (FSH). 2010. 1909.15.12.41 Available at http://www.fs.fed.us/cgi-bin/Directives/get_dirs/fsh?1909.15. Accessed January 5, 2022.

Graham, R.T., 1994. Managing coarse woody debris in forests of the Rocky Mountains (No. 477-480). US Department of Agriculture, Forest Service, Intermountain Research Station.

Grigal, D.F., 2000. Effects of extensive forest management on soil productivity. Forest Ecology and Management, 138(1-3), pp.167-185.

Håkansson, I., Voorhees, W.B., Elonen, P., Raghavan, G.S.V., Lowery, B., Van Wijk, A.L.M., Rasmussen, K. and Riley, H., 1987. Effect of high axle-load traffic on subsoil compaction and crop yield in humid regions with annual freezing. Soil and tillage research, 10(3), pp.259-268.

Kees, G., 2008. Using subsoiling to reduce soil compaction. Technology & Development Program, pp.0834-2828.

Parrett, C.; Cannon, S.H.; Gartner, J.E.; Parise, M., 2003. Wildfire related debris flow generation through episodic progressive sediment bulking processes, western United States.: Debris Flow Hazards Mitigation, Mechanics, Prediction, and Assessment. 71-82 p.

Reinhardt, E.D.; Keane, R.E.; Calkin, D.E.; Cohen, J.D., 2008. Objectives and considerations for wildland fuel treatment in forested ecosystems of the interior western United States. Forest Ecology and Management. 256: 1997–2006.

Robichaud, P.R. and Hungerford, R.D., 2000. Water repellency by laboratory burning of four northern Rocky Mountain forest soils. Journal of Hydrology, 231, pp.207-219.

Soil Survey Staff. 2021. Natural Resources Conservation Service, United States Department of Agriculture. Web Soil Survey. Available at: https://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm (Accessed November 23, 2021).

Veen, G. F. (C. et al.), 2014. "Grazing-Induced Changes in Plant-Soil Feedback Alter Plant Biomass Allocation," Oikos, 123(7), pp. 800–806. doi: 10.1111/j.1600-0706.2013.01077.x.

## *Appendix 1. Vegetation Management Objective, Potential for Damage by Fire, Mad Roaring Mills Draft EA, Okanogan-Wenatchee National Forest, Washington, 2022.*

The ratings in this interpretation indicate the potential for damage to nutrient, physical, and biotic soil characteristics by fire. The ratings involve an evaluation of the potential impact of prescribed fires or wildfires that are intense enough to remove the duff layer and consume organic matter in the surface layer. The soils are described as having a "low," "moderate," or "high" potential for this kind of damage. "Low" indicates that fire damage is unlikely. Good performance can be expected, and little or no maintenance is needed. "Moderate" indicates that fire damage can occur because one or more soil properties are less than desirable. Fair performance can be expected, and some maintenance is needed. "High" indicates that fire damage can occur because of one or more soil properties and that overcoming the unfavorable properties requires special design, extra maintenance, and costly alteration.[1]

| Map Unit Symbol | Map Unit Name | Fire Damage Susceptibility | Area (acres) | Percent Cover (%) |
|---|---|---|---|---|
| 2 | Almac fine sandy loam, 3 to 30 percent slopes | Low | 225.3 | 2.1 |
| 3 | Almac fine sandy loam, 30 to 60 percent slopes | Moderate | 1218.5 | 11.3 |
| 17 | Anatone-Rock outcrop complex, 30 to 60 percent slopes | Moderate | 10.5 | 0.1 |
| 27 | Ardening stony loam, 30 to 60 percent slopes | Moderate | 5.0 | 0.0 |

| | | | | |
|---|---|---|---|---|
| 28 | Ardenmont coarse sandy loam, 8 to 30 percent slopes | High | 18.2 | 0.2 |
| 29 | Ardenmont coarse sandy loam, 30 to 60 percent slopes | High | 497.2 | 4.6 |
| 30 | Ardenmont coarse sandy loam, 60 to 90 percent slopes | High | 9.3 | 0.1 |
| 31 | Ardenmont-Swakane complex, 60 to 90 percent slopes | High | 9.4 | 0.1 |
| 32 | Ardenvoir stony fine sandy loam, 30 to 60 percent slopes | Moderate | 25.0 | 0.2 |
| 33 | Ardenvoir stony fine sandy loam, 60 to 90 percent slopes | Moderate | 16.7 | 0.2 |
| 34 | Azwell-Rock outcrop complex, 30 to 60 percent slopes | Moderate | 136.8 | 1.3 |
| 35 | Bagmont gravelly loam, 40 to 90 percent slopes | Moderate | 136.9 | 1.3 |
| 37 | Billyridge gravelly sandy loam, 0 to 8 percent slopes | Low | 5.3 | 0.0 |
| 53 | Burnscreek stony sandy loam, 3 to 30 percent slopes | Moderate | 1.2 | 0.0 |
| 58 | Chapot extremely bouldery loam, 30 to 60 percent slopes | High | 56.8 | 0.5 |
| 72 | Choralmont cindery sandy loam, 30 to 60 percent slopes | Low | 1183.6 | 11.0 |
| 76 | Chumstick stony sandy loam, 3 to 30 percent slopes | Moderate | 12.7 | 0.1 |
| 77 | Chumstick stony sandy loam, 30 to 60 percent slopes | Moderate | 148.1 | 1.4 |
| 78 | Chumstick stony sandy loam, 60 to 90 percent slopes | Moderate | 55.8 | 0.5 |
| 91 | Dinkelman gravelly sandy loam, 30 to 60 percent slopes | Low | 257.6 | 2.4 |
| 92 | Dinkelman gravelly sandy loam, 60 to 90 percent slopes | Low | 121.0 | 1.1 |
| 93 | Dinkelman-Rock outcrop complex, 30 to 90 percent slopes | Low | 30.9 | 0.3 |
| 98 | Domkey sandy loam, 30 to 60 percent slopes | High | 63.8 | 0.6 |
| 100 | Dragoon fine sandy loam, 30 to 60 percent slopes | Low | 1.2 | 0.0 |
| 101 | Dragoon loam, 30 to 60 percent slopes | Low | 303.5 | 2.8 |
| 114 | Georgecreek fine sandy loam, 15 to 30 percent slopes | Low | 8.2 | 0.1 |

| | | | | |
|---|---|---|---|---|
| 115 | Georgecreek fine sandy loam, 30 to 60 percent slopes | Low | 27.2 | 0.3 |
| 142 | Inkler stony fine sandy loam, 30 to 60 percent slopes | High | 573.2 | 5.3 |
| 152 | Kloochman gravelly fine sandy loam, 3 to 30 percent slopes | Low | 29.4 | 0.3 |
| 153 | Kloochman gravelly fine sandy loam, 30 to 60 percent slopes | Moderate | 158.7 | 1.5 |
| 157 | Kloochman-Rock outcrop complex, 45 to 75 percent slopes | Moderate | 377.5 | 3.5 |
| 167 | Loneridge stony loam, 3 to 30 percent slopes | Low | 19.6 | 0.2 |
| 169 | Loneridge very stony loam, 30 to 60 percent slopes | Low | 0.8 | 0.0 |
| 180 | McCree stony fine sandy loam, 30 to 60 percent slopes | Moderate | 6.2 | 0.1 |
| 184 | McCree-Rock outcrop complex, 45 to 90 percent slopes | Moderate | 19.4 | 0.2 |
| 185 | Mippon gravelly fine sandy loam, 0 to 3 percent slopes | Low | 28.5 | 0.3 |
| 191 | Morical-Dragoon complex, 30 to 60 percent slopes | Low | 63.9 | 0.6 |
| 192 | Morical-Dragoon fine sandy loams, 3 to 30 percent slopes | Low | 0.3 | 0.0 |
| 193 | Morical-Dragoon fine sandy loams, 30 to 60 percent slopes | Low | 19.7 | 0.2 |
| 220 | Palmich cindery sandy loam, 15 to 30 percent slopes | Low | 0.4 | 0.0 |
| 221 | Palmich cindery sandy loam, 30 to 60 percent slopes | Moderate | 216.2 | 2.0 |
| 223 | Palmich-McCree association, 30 to 60 percent slopes* | Moderate | 52.0 | 0.5 |
| 232 | Ramparter stony sandy loam, till substratum, 30 to 60 percent slopes | High | 10.2 | 0.1 |
| 235 | Ramparter very fine sandy loam, 30 to 60 percent slopes | Moderate | 125.6 | 1.2 |
| 236 | Ramparter-Wilma complex, 30 to 60 percent slopes | Low | 9.4 | 0.1 |
| 242 | Rock outcrop-Chumstick-Icicle complex, 45 to 90 percent slopes | Moderate | 331.6 | 3.1 |
| 249 | Safety stony sandy loam, 60 to 90 percent slopes | Moderate | 15.7 | 0.1 |
| 270 | Shamel sandy loam, 30 to 60 percent slopes | Low | 30.4 | 0.3 |

| | | | | |
|---|---|---|---|---|
| 295 | Surgh fine sandy loam, 30 to 60 percent slopes | High | 646.1 | 6.0 |
| 296 | Surgh fine sandy loam, 60 to 90 percent slopes | High | 99.6 | 0.9 |
| 299 | Swakane stony sandy loam, 60 to 90 percent slopes | High | 0.7 | 0.0 |
| 300 | Swakane, granitic substratum-Rock outcrop complex, 40 to 90 percent slopes | Moderate | 755.6 | 7.0 |
| 301 | Swakane-Rock outcrop complex, 45 to 90 percent slopes | High | 16.1 | 0.1 |
| 304 | Switchback gravelly fine sandy loam, 60 to 90 percent slopes | Low | 111.1 | 1.0 |
| 319 | Tillicum sandy loam, 30 to 60 percent slopes | Moderate | 316.7 | 2.9 |
| 320 | Tillicum fine sandy loam, 8 to 30 percent slopes | Moderate | 58.5 | 0.5 |
| 321 | Tillicum fine sandy loam, 30 to 60 percent slopes | Moderate | 318.4 | 2.9 |
| 335 | Tyee gravelly loamy coarse sand, 30 to 90 percent slopes | High | 162.7 | 1.5 |
| 337 | Tyee gravelly sandy loam, 30 to 90 percent slopes | Low | 95.0 | 0.9 |
| 360 | Wedge cindery fine sandy loam, 8 to 30 percent slopes | Moderate | 25.1 | 0.2 |
| 361 | Wedge cindery fine sandy loam, 30 to 60 percent slopes | Moderate | 320.3 | 3.0 |
| 365 | Wilma stony fine sandy loam, 30 to 60 percent slopes | Moderate | 1093.0 | 10.1 |
| 366 | Wilma-Rock outcrop complex, 30 to 60 percent slopes | Moderate | 101.0 | 0.9 |
| | | **Grand Total** | **10794.3** | **100.0** |

| **Summary Rating** | **Acres in AOI** | **Percent of AOI** |
|---|---|---|
| Moderate | 6,058.7 | 56.1% |
| Low | 2,572.2 | 23.9% |
| High | 2,163.4 | 20.0% |
| **Total for Area of Interest (AOI)** | **10,794.3** | **100.0%** |

[1]Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture. Web Soil Survey. Available online at the following link: http://websoilsurvey.sc.egov.usda.gov/. Accessed (November 23, 2021).

## *Appendix 2. Transportation Objective, Erosion Hazard (Trail/Road), Mad Roaring Mills Draft EA, Okanogan-Wenatchee National Forest, Washington, 2022.*

The ratings in this interpretation indicate the hazard of soil loss from unsurfaced roads and trails. The ratings are based on soil erosion factor K, slope, and content of rock fragments. The hazard is described as "slight," "moderate," or "severe." A rating of "slight" indicates that little or no erosion is likely; "moderate" indicates that some erosion is likely, that the roads or trails may require occasional maintenance, and that simple erosion-control measures are needed; and "severe" indicates that significant erosion is expected, that the roads or trails require frequent maintenance, and that costly erosion-control measures are needed.[1]

| Map Unit | Map Unit Name | Parent Material | Slope RV (%) | Dominant Component Ash Cap Thickness (in) | Erosion Hazard (Road, Trail) | Length (miles) | Cover (%) |
|---|---|---|---|---|---|---|---|
| 17 | Anatone-Rock outcrop complex, 30 to 60 percent slopes | volcanic ash and loess mixed with colluvium and residuum from basalt and andesite | 45 | 0 | Severe | 0.4 | 2.9 |
| 29 | Ardenmont coarse sandy loam, 30 to 60 percent slopes | residuum and colluvium weathered from schist mixed with volcanic ash and loess | 45 | 23 | Severe | 1.7 | 13.3 |
| 30 | Ardenmont coarse sandy loam, 60 to 90 percent slopes | residuum and colluvium weathered from schist mixed with volcanic ash and loess | 75 | 23 | Severe | 2.1 | 16.9 |
| 31 | Ardenmont -Swakane complex, 60 to 90 percent slopes | residuum and colluvium weathered from schist mixed with volcanic ash and loess | 75 | 23 | Severe | 1.8 | 13.8 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 32 | Ardenvoir stony fine sandy loam, 30 to 60 percent slopes | residuum and colluvium weathered from gneiss and schist mixed in the surface with loess and volcanic ash | 45 | 0 | Severe | 3.1 | 24.3 |
| 33 | Ardenvoir stony fine sandy loam, 60 to 90 percent slopes | residuum and colluvium weathered from gneiss and schist mixed in the surface with loess and volcanic ash | 75 | 0 | Severe | 0.6 | 5.1 |
| 77 | Chumstick stony sandy loam, 30 to 60 percent slopes | colluvium and residuum from granite, gneiss, and schist mixed with volcanic ash and loess | 45 | 0 | Severe | 0.2 | 1.9 |
| 167 | Loneridge stony loam, 3 to 30 percent slopes | residuum and colluvium from basalt or andesite mixed with loess and volcanic ash | 17 | 0 | Severe | 0.3 | 2.5 |
| 198 | Nahahum loam, 30 to 60 percent slopes | colluvium and residuum from schist or gneiss mixed with volcanic ash and loess | 45 | 16 | Severe | 0.8 | 6.6 |
| 294 | Surgh fine sandy loam, 3 to 30 percent slopes | Residuum, colluvium and alluvium from gneiss, schist and granite, with a mantle of volcanic ash colluvium derived from schist and/or alluvium derived from graphitic schist and/or residuum weathered | 17 | 3 | Severe | 0.0 | 0.2 |
| 295 | Surgh fine sandy loam, 30 to 60 | residuum, colluvium and alluvium from gneiss, schist and granite, with a | 45 | 3 | Severe | 0.2 | 1.8 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | percent slopes | mantle of volcanic ash colluvium derived from schist and/or alluvium derived from graphitic schist and/or residuum weathered | | | | | |
| 299 | Swakane stony sandy loam, 60 to 90 percent slopes | residuum, colluvium and slope alluvium from gneiss, schist and granodiorite mixed with volcanic ash and loess | 65 | 0 | Slight | 1.1 | 8.5 |
| 320 | Tillicum fine sandy loam, 8 to 30 percent slopes | volcanic ash over residuum and colluvium from schist or gneiss | 19 | 24 | Severe | 0.3 | 2.2 |
| | | | | | **Grand Total** | **12.7** | **100.0** |

| **Summary Rating** | **Miles in AOI** | **Percent of AOI** |
|---|---|---|
| Severe | 11.6 | 91.5 |
| Slight | 1.1 | 8.5 |
| **Total for Area of Interest (AOI)** | **12.7** | **100.0** |

[1]Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture. Web Soil Survey. Available online at the following link: http://websoilsurvey.sc.egov.usda.gov/. Accessed (November 23, 2021).