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Zigzag Integrated Resource Project

Soil Resource Report

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for:
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Introduction

This is the specialist report that addresses effects to soil resources that will be incorporated into the Zigzag Integrated Environmental Analysis (EA). In this report are described the existing conditions, and an analysis of the environmental consequences to soil resources that could be expected as a result of No Action, or by implementing the Proposed Action (as it is defined in Section 2 of the EA).

Protecting and conserving soil resources has long been a designated integral objective of managing natural resources on National Forest System Lands. Direction has been in place for decades in Forest Service Manual 2550 that, depending on the region, translates into specific standards and guidelines that are defined in the Land and Resource Management Plans (LRMP) of individual National Forests.

These objectives are generally aimed at maintaining or enhancing long-term site productivity so that the inherent capability and function of soil resources to support forest or range plant communities and provide for ecosystem services (ex. nutrient cycling or water storage) is enduring. Evaluating the potential effects to soil quality and productivity from activities on Forest Service lands is essential to achieving those objectives.

It is helpful to understand several fundamental terms common to the consideration of land use on forest soils: 1) soil quality, and 2) soil productivity. They often are used interchangeably.

> Soil Quality: The capacity of a specific kind of soil to function, within natural or managed ecosystems, to sustain plant and animal productivity, maintain or enhance water and air quality, and support human health and habitation.
>
> Soil Productivity: The inherent capacity of the soil resource to sustain appropriate site-specific biological resource management objectives, which includes the growth of specified plants, plant communities, or a sequence of plant communities to support multiple land uses. (Forest Service Manual 2550.5).

Soil quality and productivity are dynamic. Soil properties can change depending on how it is managed. Management choices can affect soil organic matter, soil structure, soil depth, and water and nutrient holding capacity. Soils respond differently to management depending on the inherent properties of the soil and the surrounding landscape.

Analysis Framework

The emphasis of this analysis has been based upon potential effects to soil resources that could be anticipated as a result of ground disturbing activities. The analysis also evaluates the project's consistency with agency plans and directives aimed at conserving or enhancing long-term forest productivity and managing soil quality in a sustainable manner for desired future conditions.

Actions addressed here include those associated with proposed timber harvest activities, silvicultural and forest health treatments, habitat enhancement, road use and management, and recreational uses.

Interpretations and descriptions contained in this specialist report rely heavily on local information derived from the Mt Hood National Forest's Soil Resource Inventory (SRI, Howes, 1979) and digital spatial data in the Forest Service's corporate Geographic Information System (GIS). These information sources were used along with topographic maps, aerial photographs, silvicultural reports, field-based reconnaissance and sampling, various related project reports, and agency directives to characterize local conditions and support analysis used to predict environmental consequences of the Alternatives.

Resource Indicators and Measures

The analysis of effects to soil resources in this EA has been focused on the project areas and the individual units proposed for treatment. Select standards and guidelines (S&Gs) from the Mt Hood National Forest LRMP (USDA 1990) serve as the basis for analyzing the effects of each of the alternatives (Table S1).

Table S1. Key indicators and measures to be used for assessing effects to soil resources

Resource Indicator	Measure	LRMP Forestwide Standards and Guidelines
Extent of Detrimental Soil Conditions	Percent Detrimental Condition	FW-022, 023
Soil Erosion Hazard Class	Percent Effective Ground Cover	FW-025
Amount of Surface Organic Matter	Tons per Acre	FW-031 to 037

Extent of Detrimental Soil Condition: LRMP standards and guidelines FW-022 and FW-023 state that the extent of detrimental soil conditions should not exceed 15 percent in an activity area (i.e., treatment unit) following project completion to maintain and conserve site productivity. Detrimental soil conditions include heavy compaction, displacement, puddling, accelerated erosion, excess loss of organic material, and severely burned soils (for definitions see Forest Service Manual, section 2520.98-1, 1998).

Not all ground disturbance is considered to be detrimental. Impacts from disturbance where the extent and magnitude are severe enough to diminish soil quality and soil productivity to the degree that soil processes are not fully functional over the long-term are considered to be detrimental.

Soil Erosion Hazard Class: LRMP standards and guidelines FW-025 and FW-026 prescribe that, depending upon the erosion hazard rating for a particular soil type, an effective percentage of ground cover should be established after ground disturbing activities to prevent and minimize accelerated erosion. Accelerated erosion has the potential to degrade on-site productivity due to soil loss, as well as affect water quality off-site from runoff and sedimentation. Effective groundcover is key to reducing or eliminating the potential for accelerated erosion.

Amount of Surface Organic matter: LRMP standards and guidelines FW-031 and FW-036 stipulate the retention of sufficient quantities of post-project dead and downed woody material so that the contribution of organic matter to soil productivity is maintained. Expressed quantities are considered to be a proportion of the total potential biomass that a representative ecotype could inherently produce. Retention of surface organic matter is a means for maintaining the function of soil biological systems, and mutually beneficial forest nutrient and carbon cycling.

Methodology

Analysis of the anticipated effects to soil resources was conducted using a methodology that is essentially qualitative, but with a quantitative component. The quantitative extent of detrimental soil conditions was estimated using sampling data, field reconnaissance, GIS analysis, and aerial photographic interpretation; which also functioned as the basis for deriving and validating assumptions and inferences. Effects to soil resources were determined qualitatively based upon select physical and biological properties fundamental to the sensitivity and resilience of soils to certain types of disturbances. Factoring both the quantitative extent of detrimental soil conditions with the qualitative assessment of response to disturbance served as the method for predicting the potential effects to soil quality and productivity.

Due to the variability of past ground disturbance in the project area, the quantitative extent of detrimental soil conditions was characterized for this analysis by categorizing them into classes. Soil condition classes represent a range of the aerial extent of detrimental soil conditions. Expressed as a percentage of an individual treatment or activity unit, three soil condition classes were defined, they are:

- Soil Condition Class 1: less than 5 percent detrimental soil conditions
- Soil Condition Class 2: 5 to 10 percent detrimental soil conditions
- Soil Condition Class 3: greater than 10 percent detrimental soil conditions

These three stratifications were based upon the sensitivity of data to be able to estimate the gradations of detrimental soil conditions and their extent. They serve as a means for assessing the relative risk of a particular treatment or activity to increase the extent of detrimental soil conditions to a level that compromises soil quality and long-term site productivity. Units estimated to have a high proportion of their acreage in the uppermost condition class were identified as having the greatest potential for incurring a level of detrimental soil impacts that put at risk the productivity standards set forth in the LRMP.

There is an important prospect regarding soil condition classes to be mindful of: though they convey an estimate of the range of detrimental soil conditions that extend across an activity area, they also passively imply the extent of soil conditions that are not detrimental. If for example an activity area is designated to be in soil condition class 2, meaning detrimental soil conditions comprise less than 10 percent of its area, then the converse is that soil conditions across at least 90 percent of that unit's area are in good functioning condition. This reflects the variability of effects that is typical after ground disturbance, whereby detrimental conditions are associated with the intensity of the impact. For ground-based operations, detrimental soil impacts are inextricably tied to the routes and repetitiveness of travel by heavy equipment such as the network of roads, landings, and skid trails needed for logging.

Erosion hazard rating and organic matter indicators have also been assessed qualitatively using a cause and effect precept. Spatial extent of potential effects will have been estimated using GIS to relate soil inventory data with stand structure information and proposed treatments. Characteristics of affected soil types have been evaluated to interpret expected response of proposed treatments given forest structural conditions. Potential outcomes take into account the capability, sensitivity, and resilience of individual soil types.

Cumulative effects were analyzed qualitatively. They were assessed by evaluating existing detrimental soil conditions in relation to where proposed activities would occur. Cumulatively the past, present, and reasonably foreseeable actions in the project area where ground-disturbing activities will have overlapped one another constitute the basis and scale for analysis. Ameliorative factors such as avoidance, mitigation (ex., subsoiling, fertilization, mulching, etc.), and recovery have been factored in. Simplistically, the cumulative assessment can be represented as a qualitative sequence to evaluate the probability and magnitude of overlapping effects both spatially and temporally.

> (existing + predicted + future impacts) – (avoidance + minimization + mitigation + natural recovery) = potential cumulative effects

The analysis of effects to soil resources considered the following assumptions:

- Prescribed Best Management Practices (BMPs) and Project Design Criteria (PDC) would be effective at avoiding or minimizing potential detrimental effects to soil resources. They would be requisite for, and during project implementation.
- Existing landings, non-system roads, and skid trails would be reused where feasible.
- Existing non-system roads or landings not used during the project would remain in a detrimental condition.
- Ground-based skidding on steep slopes would be avoided. Skidding would be limited to slopes 40 percent or less.
- New primary skid trails would average 12 feet in width.
- New temporary roads would average 10 feet in width.

- Skidding and yarding patterns would be arranged to minimize their extent within a treatment unit to only what is necessary.
- Detrimental soil impacts have long-lasting effects to soil productivity.
- Detrimental soil impacts resulting from wildfires that occurred in the early 1900s are no longer detectable in proposed treatment units.

Existing Conditions

The Soil Resource Inventory (SRI) of the Mt Hood Nat. Forest identifies the distribution and character of the many soil types across the landscape (USDA 1979). It provides basic soil and landform information useful for land management planning. In it are descriptions of soil types that occur on the Forest, maps of their spatial extent, some of their chemical and physical properties, and interpretations of their capabilities and limitations. It also contains some general information about climate, geology, and vegetation. The SRI has been used to determine the soil types in the project area and serves as the foundation supporting the analysis of effects.

Soil Characteristics and Distribution

There are two separate areas in the Zigzag Integrated project where treatments are proposed, one named “Horseshoe” and the other “Mud”. Terrain, landform, vegetation, and climatic characteristics differ somewhat between the two. Thus, soil properties do too. The capability, limitation, sensitivity, and resilience of different soil types is dependent upon their individual properties. These properties are fundamental for predicting the response of soils that could be expected as a consequence of ground disturbing activities from the past, as well as those being proposed for this project.

The Horseshoe area of the project is representative of the Western Cascades physiographic province as described by Franklin and Dyrness (1973). Landforms are typified as rugged, highly dissected glaciated mountains and valleys with gentle to very steep relief. The underlying geologic formations of these landforms consist chiefly of volcanic and pyroclastic flow strata that are older than the terrain of the Cascade crest immediately to the east. The elevation range of the Horseshoe area is 2,000 to 3,500 feet.

The Horseshoe landscape is dominated by temperate coniferous forest types. Mean annual temperature (41 to 45 degrees F) is moderated from extremes by maritime influence, which also provides ample precipitation. Precipitation averages between 90-110 inches per year. Summers are generally moist and warm, while winters are wet and cool. A persistent winter snowpack several feet deep typically develops at the mid and higher elevations that lasts until mid-spring. The frost-free period averages about 45 to 100 days, and at the lower and mid-elevations the typical growing season lasts from March to November. The soil temperature regime is categorized as frigid, being consistently cool below the topsoil horizons and mostly freeze-free.

Soils underlying treatment units in the Horseshoe area have developed from glacial till. They are well drained soils that exhibit moderate to high productivity, and are capable of supporting a dense forest. Generally, they are moderately deep to deep, rocky and very rocky loams. They are considered to be somewhat well developed with fairly dark and thick topsoil horizons that can be rather rich in organic material. Litter and duff layers are also thick with a highly decomposed layer at their base.

Limitations associated with these soil types are few, and they are not considered to be sensitive. Depending upon the severity of slope, the erosion potential is inherently moderate to high. Because of the texture and high rock content, these soils are not highly susceptible to heavy compaction. But since they are coarse loamy textures, the potential for displacement when dry is high.

Overall, these soil types are fairly resilient. Because they are relatively high in organic matter, fairly deep and productive, precipitation is abundant, soil temperatures are cool, and the growing season is long they are capable of recovering from ground disturbance considerably well.

In comparison, the Mud area is characterized as the High Cascades province. (Franklin and Dyrness 1973). It is higher in elevation, ranging from 3,500 to 4,500 feet. The landform is a glaciated upland characterized by rolling, somewhat dissected mountainous terrain. Relief is gentle to moderate with several stream valleys. Underlying bedrock formations are comprised of geologically young volcanic flows, overlain by glacial till.

The Mud landscape is dominated by the cool, upper elevational, temperate coniferous forest that is situated just below subalpine environs. Mean annual temperatures are a bit lower than the Horseshoe area (38 to 42 degrees F), as are wintertime lows. Total precipitation is a little lower too, averaging between 70 to 90 inches annually.

Summers are generally moist and warm, while winters are wet and cold. A winter snowpack averaging between 4 and 5 feet deep typically develops and persists into late spring. The frost-free period averages about 45 to 60 days, and the typical growing season lasts from April through September. The soil temperature regime is categorized as cryic, being persistently cool to cold below the topsoil horizons and subject to prolonged winter freezing near the surface.

Soils underlying treatment units in the Mud area have developed from glacial till. Generally, they are shallow to moderately deep, rocky and very rocky, sandy and loams. They are well drained soils that exhibit low to moderate productivity, but that are capable of supporting a dense forest. They are considered to be somewhat poorly developed with lightly colored and modestly thin topsoil horizons that are leached and low in organic material. Litter and duff layers are thin to moderately thick and compact from seasonal snowpack. They are acidic and exhibit a relatively low nutrient status.

Despite their relatively low nutrient status, cryic temperature regime, excessive rock content, and a fairly short growing season, these soils are not considered to be sensitive. Their erosion potential is inherently slight to moderate because the terrain is relatively gentle. The susceptibility for heavy compaction is low because the rock content is so high and the texture is coarse. But the coarse texture means that cohesion is low, so the potential for displacement is moderate to high when dry.

Overall, they are considered to be somewhat resilient. Soils in the Mud area are capable of recovering from ground disturbance fairly well with time. The abundant rainfall that supports the prolific forest growth offsets to a degree their inherent limitations. The forest types that occupy these soils are well-adapted to their properties, which can also be somewhat resistant to ground disturbance.

Resource Indicator and Measure 1, Extent of Existing Detrimental Soil Conditions

A little more than half (52%) of the units being proposed for treatment would occur in forested stands that have been previously managed (i.e., plantations). The remaining percentage would occur in stands that had been burned over, and since grown back. Overall, the extent of detrimental soil conditions is predominantly low (74% of the total treatment acreage) throughout the project area. The extent of detrimental soil impacts remaining from past management in the proposed treatment units is greatest in previously managed stands that had been logged using ground-based methods.

In the Horseshoe area, nearly all of the previously managed stands being proposed for treatment were logged using cable, or skyline methods. Soil conditions in the Horseshoe treatment area are considered to be in good condition. The majority (82%) of the acreage proposed for commercial treatments has been determined to be in Soil Condition Class 1. None of the proposed treatment units were identified to exhibit Soil Condition Class 3.

A handful of stands in the Horseshoe area that are being proposed for treatment were thinned in the late 1980s and early 1990s. Originally clearcut harvested, they were light, intermediate thinning using skyline logging methods. Long-term ground impacts were slight. Evidence today of those second entries is barely recognizable.

Detrimental soil impacts that linger from past logging occur in the form of old landings and spur roads, and old skid trail and yarding corridors. Heavy compaction or displacement can be observed where these features are located. Nearly all were detected in previously managed stands. Table S2 summarizes the estimated extent of these residual soil impacts in the Horseshoe treatment area.

Table S2. Existing Soil Condition Class - Percent of Total Horseshoe Acreage Proposed for Commercial Treatments

Soil Condition Class	Fire-Originated Stands	Plantations	Total
Soil Condition Class 1 (0-5% detrimental soil conditions)	41	41	82
Soil Condition Class 2	0	18	18

Soil Condition Class	Fire-Originated Stands	Plantations	Total
(5-10% detrimental soil conditions)			
Soil Condition Class 3 (>10% detrimental soil conditions)	0	0	0
Total	41	59	100

In the Mud area, all of the previously managed units being proposed for treatments had once been logged using ground-based methods. Soil conditions in the Mud treatment area are considered to be in mostly good condition too. The majority (69%) of the acreage proposed for commercial treatments has been determined to be in Soil Condition Class 1. But there is a notable amount of acreage in Soil Condition Class 2 (31%) as a result of the ground-based logging that had occurred previously. None of the proposed treatment units were identified to exhibit Soil Condition Class 3.

Detrimental soil impacts that linger from past logging have been detected in the form of old spur roads and primary skid trails, and landings. Heavy compaction or displacement can be observed where these features are located. Nearly all were detected in previously managed stands. Table S3 summarizes the estimated extent of these residual soil impacts in the Mud treatment area.

Table S3. Existing Soil Condition Class - Percent of Total Mud Acreage Proposed for Commercial Treatments

Soil Condition Class	Fire-Originated Stands	Plantations	Total
Soil Condition Class 1 (0-5% detrimental soil conditions)	51	18	69
Soil Condition Class 2 (5-10% detrimental soil conditions)	1	30	31
Soil Condition Class 3 (>10% detrimental soil conditions)	0	0	0
Total	53	47	100

Nearly all of the previously managed stands in the project area were once clear-cut harvested, followed by site preparation such as broadcast burning, or brush disposal before they were replanted. The action and movement of heavy equipment to conduct these activities and the log removal would have been far less contained than today's standards. Aerial photo imagery from the 1970s suggest that nearly the entire acreage of previously clear-cut stands was disturbed as a result. Effects to organic matter, effective ground cover, and soil porosity and structure at and near the surface could have been pervasive.

Likewise, soil effects in fire-originated stands were presumably widespread. Some of these stands were salvage logged afterward and then replanted, and some were not. But these disturbances occurred long ago in the early 1900s, and their effects are not readily detectable, and no longer considered to be detrimental.

Owing to these past disturbances, and that none of the stands proposed for treatments were determined to exhibit Soil Condition Class 3, suggests that there has been a high degree of natural recovery that has occurred since prior ground disturbance. These soils display a measure of resiliency, and an intrinsic ability to recover from detrimental soil impacts.

Along with natural recovery in the proposed treatment units, there have been restorative activities that benefited soil conditions and enhanced soil quality. Tree planting was mandatory in units that were clear-cut, and reforestation was widespread across the two treatment areas to hasten post-wildfire recovery. Other beneficial post-harvest activities included erosion control seeding of bare surfaces to prevent soil loss, and restoration projects such as road decommissioning that have offset some of the detrimental conditions that remain.

Due to their productive capability and resilience, soils in the treatment units continue to retain their function despite previous disturbance from management, serving as a growing medium, storing and cycling nutrients and water, producing biomass, and supporting or regenerating a contiguous forest cover. Currently, conditions in all of the units proposed for treatments are consistent with the LRMP Forestwide S&Gs FW-022 and 023 for soil productivity.

Resource Indicator and Measure 2, Existing Soil Erosion Hazard Class

As indicated in Table S4, nearly all of the acreage proposed for treatment is categorized to be the low to moderate soil erosion hazard class as defined by the LRMP (1990). Properties of the soils underling the majority of both treatment areas exhibit high infiltration rates and are well drained. They also are heavily vegetated with a dense forest cover. Runoff potential is inherently low except where steeper slopes prevail and rock content is lower.

Table S4. Soil Erosion Hazard Class – Percent of Total Acres Proposed for Commercial Treatment

Treatment Area	Low to Moderate	Severe	Very Severe	Not Rated (rock outcrops, etc)
Horseshoe	88	5	0	7
Mud	96	0	0	4

Erosion rates are not currently accelerated to a noteworthy degree as a result of past activity in proposed treatment units. Natural re-establishment of grasses, forbs, brush, tree regeneration, and reforestation has acted to effectively provide ground cover. The average extent of effective ground cover in all of the proposed units exceeded 95 percent. Evidence of accelerated erosion resulting from residual detrimental soil impacts and past ground disturbance was slight. Accelerated erosion that was observable can be attributed primarily to the existing road system. Currently, conditions in all of the units proposed for treatments, are consistent with the LRMP Forestwide S&G FW-025 for effective ground cover and soil productivity.

Resource Indicator and Measure 3, Amount of Existing Surface Organic Matter

Organic matter is ubiquitous across each of the treatment areas. A contiguous organic layer of litter and duff covers the forest floor of all of the proposed units. The dense forest cover has been generating litter-fall for the forest floor annually for decades, contributing fine needles and small branches, larger limbs and stems from dead and decaying trees and brush.

Although the total amount of surface organic matter is considered to be sufficient, the diversity of the types and sizes is rather uniform within the majority of previously managed stands and sapling plantations. The amount and distribution of downed coarse woody debris (CWD) in these treatment units is considered to be low. In the fire-originated stands conditions are the opposite. The profile of organic materials is diverse and their distribution heterogeneous. There is an abundance of CWD of variable sizes and density.

In both stand types, the recruitment potential of future CWD is high. Growth and mortality of the existing forest cover and individual trees is expected to remain persistent, generating biomass continually. Soils function to support tree growth that transmogrifies to the production and storage of CWD in the live standing forest. The low amount of CWD existing in the plantations will continue to steadily increase in response to competition and/or disturbance induced mortality, but remain concentrated in the smaller diameter classes.

Environmental Consequences

Scope of this analysis is to evaluate impacts to soil resources that could be expected as a result of either implementing or not implementing forest management activities being proposed in the Zigzag Integrated project area. Activities analyzed include those associated with mechanized commercial treatments of the forest overstory and understory, as well as hand treatments in young sapling plantations. Findings predict the direct, indirect, and cumulative effects based upon scientific analysis, relevant research, professional judgment, and well-established cause-and-effect relationships between natural resource management and soil response on the Mt Hood National Forest.

Analysis of the direct and indirect effects was conducted at the treatment unit scale. Units are considered to be individual stands of trees or larger delineations of multiple stands where similar treatments are proposed. Units are the areas where ground impacting activities would occur. Cumulative effects were also analyzed at the unit scale. But they were also considered at the project area scale, particularly in relation to soil function to discern potential effects to ecosystem services across the landscape.

Effects of No Action

Under the No Action alternative, ground-disturbing activities related to the proposed treatments would not occur. Measurable increases in the extent of detrimental soil conditions as a direct result of mechanical ground-based operations would not happen. Soil quality would not be expected to be diminished further on disturbed sites, but would remain compromised where existing detrimental soil conditions prevail such as old spur roads, previously used landings, and former primary skid routes.

Soil quality would remain degraded where detrimental soil conditions persist, and long-term site productivity would be diminished on those sites. The consequence of which, is indirectly a reduced rate of tree growth.

Other than the extent of existing detrimental soil conditions, soil quality across the majority of the project area would remain in good condition (i.e., the extent of detrimental soil conditions would remain below 10 percent in 100% of the proposed treatment units) despite the level of prior management. Natural recovery from past impacts would slowly continue to occur unabated.

The opportunity to optimize soil quality by treating young sapling plantations would not occur. Without thinning, growth rates and soil productivity in the sapling plantations would decline as competition for nutrients, light, and growing space increased. Vertical and horizontal differentiation of trees would remain sluggish, and stand diversity would be delayed until competition and/or disturbance occurred naturally.

The ability to enhance growth and capitalize upon inherent soil productivity through active timber management would not be captured. Soil productivity would continue to be heavily utilized to support the dense quantity of stems, and resilience under-utilized for enhanced structure development. Soil function would be committed to supporting a stagnant stand condition at risk of loss or reversion to poor forest health, rather than the hastened development of a young stand into a vigorous mid-aged structural stage.

Similarly, inherent soil productivity in the dense homogeneous outer riparian zones proposed for treatment would also remain committed to an overstocked condition. The ability to enhance riparian diversity and health would not be captured in the near-term. Soil function would not be committed to hastening large-tree development and promoting old growth characteristics. Instead, soil function would be committed to supporting dense stand conditions where the overstocked understory would be in competition with overstory development.

There would be no new temporary roads created, and no closed roads temporarily re-opened. The extent of the disturbance footprint would not increase for the purposes of forest management. Rehabilitation of temporary roads would not be necessary.

Road maintenance and repair would continue at the current level and improvements to primary access routes or problem sites would only be pursued on a site-by-site basis as funding became available. Certain segments of secondary roads with drainage control problems could remain unrepaired for years. Accelerated erosion would continue during periodic runoff events from certain road segments.

Except for the sites where detrimental conditions remain, soils across the majority of the project area would continue functioning fully to support and maintain long-term site productivity. Detrimentally disturbed sites or those that support densely stocked stands where growth has slowed will remain in a status of either slow recovery or stasis. Other than those sites however, the inherent productivity and resilience of the soils will help to maintain their functional capacity to serve as a growing medium, storing and cycling nutrients and water, producing biomass, and supporting or regenerating a contiguous forest cover of various plant communities.

Direct and Indirect Effects of Proposed Action

The proposed action would entail harvest using heavy equipment. A little more than half (57%) of the total acreage would be logged using ground-based methods, where the potential for incurring detrimental soil impacts is greatest. Because of steep slopes, about 23 percent of the acreage would be logged using cable methods, which proffer a moderate risk of detrimental ground disturbance. The remainder (20%) would be logged using aerial methods, which pose the least amount of risk to soil resources.

Non-commercial vegetation treatments like sapling thinning would be conducted by hand, while brushing would mostly be done by mastication equipment. The potential for detrimental impacts to result from these activities would be very slight, so they are not further analyzed.

Resource Indicator and Measure 1, Extent of Detrimental Soil Conditions

As a direct result of conducting mechanized commercial treatments, detrimental soil impacts could be expected to occur. The potential for the extent to increase above 15 percent is greatest on about 18 percent of the Horseshoe treatment area, and 31 percent of the Mud area. These include about 9 and 21 treatment units respectively, where the extent of existing detrimental soil conditions is already Condition Class 2 (i.e., 5-10% detrimental soil conditions). All are previously managed stands, of which all but 5 are to be treated using ground-based methods (see Table S5).

Table S5. Proposed Treatments Designated Soil Condition Class 2 (i.e., 5-10% detrimental soil conditions)

Treatment Area	Acres	Units	Units Proposed for Ground-based Logging Methods
Horseshoe	144	9 total (12, 13, 14, 46, 56, 58, 69, 82, 96)	4 total (14, 58, 69, 96)
Mud	335	21 total (102, 104, 116, 118, 120,122, 128, 134, 136, 139, 140, 142, 143, 146, 150, 154, 156, 160, 162,165, 170)	21 total
Total	479	30 units	25 total

The risk of diminishing soil quality is the greatest in these units, potentially reducing indirectly the long-term productivity of the site and the capability of the soil to support a fully stocked healthy forest cover. Primary skid trails and landings would be where detrimental soil impacts would be the greatest, and the heaviest disturbance expected. Application of BMPs/PDCs to limit the extent of the skid trail system would be necessary to contain the extent of detrimental soil impacts, and minimize their post-harvest effects that could indirectly lead to a decline of productivity.

Within treatment units prescribed for variable-density thinning, leave patches called, "skips" would be free from potential ground disturbance. On average they would amount to about 10 percent of a variably-thinned treatment. There would not be any accrual of detrimental soil impacts expected in these patches.

Nearly 11 miles of temporary roads would be needed to provide ingress/egress for logging. Approximately 4 miles would be new, and placed across soils that have been relatively undisturbed. These surfaces would constitute a detrimental impact that would remain through the life of the project. They would be rehabilitated within 5 years after project completion when they would no longer be needed. Rehabilitation would entail measures to hasten recovery of soil function by de-compacting their surface, dispersing slash and organic materials over the top, and hiding or barricading their entry. It could be expected that the soil status of rehabilitated temporary roads would remain in a detrimental condition for at least an estimated 5 to 10 years after treatment.

About 2.3 miles of road segments would be decommissioning (both passive and active). These surfaces would be restored and converted from a nonproductive status back to a growing medium. Decommissioning these former system roads would offset to a small degree, detrimental soil impacts incurred as a result of logging.

Resource Indicator and Measure 2, Soil Erosion Hazard Class

As a result of mechanized logging methods, ground disturbance would be expected to remove effective ground cover and expose soils to erosive forces. For ground-based methods, these would include primary skid trails. For cable logging, the yarding corridors would be most prone. Landings and temporary roads associated with any logging system would also expose soils.

Because the majority of the project area is considered to be in the low to moderate soil erosion hazard class, soil exposure would not be expected to directly result in extensive soil loss. The potential for soil loss would be greatest where exposure occurs on steep slopes. Exposure would be intended to be minimal for a short period of time. Implementation of BMPs/PDCs would be expected to minimize erosion and nurture the reestablishment of an effective ground cover of at least 60 percent the first year following completion of treatments.

Alterations to soil properties such as porosity and bulk density would only be expected on heavily used skid trails, landings, and temporary roads. The extent of these features would be limited and controlled. They would not be widespread. An alteration in the overall soil erosion hazard class for the project area would not be expected.

Limiting the duration of soil exposure would minimize surface erosion. The amount of soil loss that could be transported off-site to indirectly effect water sources would be limited by erosion control measures and the establishment of an effective ground cover. Protection buffers along water ways would also prevent the potential for sedimentation from exposed soils. Natural recovery and the inherent capability and resilience of soils underlying the project area would support further new growth and vegetative response. Bare soils would not be expected to remain exposed for a prolonged time.

About 8.8 miles of system roads would be either decommissioned or closed and stormproofed. An effective ground cover would soon reestablish on their exposed surface. Runoff and erosion from these road segments would be expected to abate.

Resource Indicator and Measure 3, Amount of Surface Organic Matter

Surface organic material can be expected to be disturbed in treatment units as a result of heavy logging equipment. It would be completely removed and denuded from primary skid trails, portions of yarding corridors, landings, and temporary roads. The extent of these features would be controlled and limited, so that the majority of the ground would be less disturbed and still covered by a nearly contiguous layer of litter and duff.

Tree removal resulting from timber harvest would decrease total on-site biomass for a short time. Slash comprised of discarded limbs and needles however, would remain on-site and constitute a large immediate influx of fine and medium organic inputs to the forest floor. Standing or downed dead material would also be left on-site. Densely stocked patches of intact forest called, “skips” would be left across about 10 percent of variably-thinned treatment units.

Once opened up, new growth of understory seedlings, brush and vegetation would become profuse. The residual forest cover left on-site would continue to generate litter-fall for the forest floor, contributing fine needles, small branches, and larger limbs and stems. The rate at which biomass accumulates would rebound relatively quick, escalating rapidly in successive growing seasons to eventually match or surpass rates prior to thinning (Ares 2010). The total amount of surface organic matter to remain after treatment would be sufficient for supporting the function of soil biota that facilitate site productivity.

The distribution of the types and sizes of surface organics would be re-apportioned, particularly from the canopy to the forest floor. Competition-induced mortality in the un-thinned patches would remain greater for a time than those in newly thinned ones, and concentrated in smaller diameter classes. In the short-term, the amount and distribution of downed CWD in thinned plantations would remain low. In the fire-originated stands, there would remain an abundance of CWD of variable sizes and density.

In both stand types, the recruitment potential of future CWD would remain high. The thinning response would correlate to an increase of growth and the production and storage of future available CWD in larger diameter classes. Growth of the residual forest and individual trees would temporarily exceed mortality, continually generating biomass. In the long-term, growth would become more balanced with mortality, and the eventual source of CWD from the residual stand more consistent. The amount of biomass on the ground and stored in the standing live trees would remain abundant, and serve as a perpetual source of surface organic matter in the treatment units. Organic substrate supporting the proliferation and functionality of soil biota would likewise continue, perpetuating long-term site productivity.

Cumulative Effects

Cumulative effects to soil resources were analyzed qualitatively by evaluating the past, present, and reasonably foreseeable actions in the project area where ground-disturbing activities would overlap one another in time and space. Effects were assessed at two scales, the unit and the project area. Focally, and at the unit scale these would be sites where multiple activities would, or would have affected the same piece of ground. Equally to be factored, are sites where restoration activities would occur that could compensate or offset the accrual of detrimental impacts in a different place and time of the proposed treatments. Because detrimental soil impacts are considered to be long-lasting, multi-decadal timescales are the temporal context of cumulative effects to soil resources.

Projects that have been considered include:

- The Tamarack Loop Fish log Project
- The Upper Sandy River Watershed Restoration Action Plan
- Ongoing dispersed (non-developed) recreation
- Past road decommissioning
- Past timber harvest

Most of the proposed treatments would enter stands that have been treated previously. For this reason, the potential for cumulatively accruing detrimental soil conditions is likely. Treatment units that exhibit Soil Condition Class 2 would be at the greatest risk, where containment of detrimental soil effects could be a challenge to limit. Close coordination between contract administrators and operators to implement BMPs/PDCs would be needed to contain the extent of detrimental soil impacts.

Adjacent to proposed treatments in the Mud area would occur the removal of selected individual trees from the roadside to be used as material for in-stream restoration of fish habitat. The degree of ground disturbance associated with the activity would be very limited to an individual site. The activity would closely associated with existing road access, and not expected to result in detrimental soil impacts of consequence.

There have been several key roads in both treatment areas that have been decommissioned. Their surfaces have been converted back to a growing medium. Most of the segments had been restored more than 10 years ago. The growth and reestablishment of vegetation has been ongoing, and an effective ground cover has developed. Organic matter continues to accumulate, and site productivity continues to recover. The extent of exposed soils has declined on these features, so surface erosion from them has diminished.

Both treatment areas have within them, sites that have been heavily used for dispersed camping for decades. Some of these sites have been subject to notable degrees of accelerated erosion, the expansion of heavily compacted surfaces, and exposed soils. These sites can be considered to have been converted to a non-forest condition, and several such as the "Airstrip" are multiple acres in size. Many of the most popular of these sites would be expected to remain in the project area. About a half-dozen of these sites however, could be expected to be restored to more natural conditions. The Upper Sandy Watershed Restoration Plan identified specific sites where restoration of some of these heavily used sites would occur, decreasing their disturbance footprint and effect to soil resources.

Consistency with Management Direction

The Proposed Action as planned would be considered consistent with the LRMP Standards and Guidelines (S&Gs) for soil productivity (FW-022 to FW-037). BMPs/PDCs will be the principle tools and measures to be employed during implementation to achieve consistency. Post-harvest restoration projects would also be pursued, and could be deemed compensatory measures to partially offset ground effects.

Table S6. Key indicators and measures used for assessing soil resource protection

LRMP Forestwide Standards and Guidelines	Measure	Principle Means of Consistency
FW-022, 023	Percent Detrimental Condition	Contract administration: • containment of the extent of landings, primary skid trails, and temporary roads • minimizing repetitive travel off primary skid trails • Post-harvest rehab. of primary skid trails and landings Restoration projects: • road decommissioning/closures • ongoing watershed restoration
FW-025	Percent Effective Ground Cover	Contract administration: • containment of the extent of landings, primary skid trails, and temporary roads Natural recovery • revegetation, continuing litter fall

<table>
<tr><th>LRMP Forestwide Standards and Guidelines</th><th>Measure</th><th>Principle Means of Consistency</th></tr>
<tr><td>FW-031 to 037</td><td>Tons per Acre</td><td>Contract administration:
• retention of residual on-site biomass
• overstory green-tree retention
Natural recovery
• renewable supply in overstory
• growth response
• understory re-growth
• continuing litter fall
• eventual mortality in larger diameter classes</td></tr>
</table>

Proposed treatments are also intended to be consistent with the S&Gs of the Northwest Forest Plan (NWFP). The intended consistency would also be achieved by employing the BMPs/PDCs.

Table S7. Northwest Forest Plan Consistency

<table>
<tr><th>NWFP Standards and Guidelines</th><th>Measure</th><th>Principle Means of Consistency</th></tr>
<tr><td>Page C-40</td><td>Amounts of CWD</td><td>Contract administration:
• retention of residual on-site biomass
• overstory green-tree retention
Natural recovery
• renewable supply in overstory
• growth response
• understory re-growth
• continuing litter fall
• eventual mortality in larger diameter classes</td></tr>
<tr><td>Page C-44</td><td>Minimize soil and litter disturbance</td><td>Contract administration:
• containment of the extent of landings, primary skid trails, and temporary roads
• minimizing repetitive travel off primary skid trails
• Post-harvest rehab. of primary skid trails and landings</td></tr>
</table>

Summary of Effects

As a direct result of conducting mechanized commercial treatments, detrimental soil impacts could be expected to occur. The potential for the extent to increase above 15 percent is greatest on about 18 percent of the Horseshoe treatment area, and 31 percent of the Mud area. These include about 9 and 21 treatment units respectively, where the extent of existing detrimental soil conditions is already Condition Class 2 (i.e., 5-10% detrimental soil conditions). All are previously managed stands, of which all but 5 are to be treated using ground-based methods (see Table S8).

Table S8. Proposed Treatments Designated Soil Condition Class 2 (i.e., 5-10% detrimental soil conditions)

Treatment Area	Acres	Units	Units Proposed for Ground-based Logging Methods
Horseshoe	144	9 total (12, 13, 14, 46, 56, 58, 69, 82, 96)	4 total (14, 58, 69, 96)
Mud	335	21 total (102, 104, 116, 118, 120,122, 128, 134, 136, 139, 140, 142, 143, 146, 150, 154, 156, 160, 162,165, 170)	21 total
Total	479	30 units	25 total

The risk of diminishing soil quality is the greatest in these units, potentially reducing indirectly the long-term productivity of the site and the capability of the soil to support a fully stocked healthy forest cover. Primary skid trails and landings would be where detrimental soil impacts would be the greatest, and the heaviest disturbance expected. Application of BMPs/PDCs to limit the extent of the skid trail system would be necessary to contain the extent of detrimental soil impacts, and minimize their post-harvest effects that could indirectly lead to a decline of productivity.

As a result of mechanized logging methods, ground disturbance would be expected to remove effective ground cover and expose soils to erosive forces. For ground-based methods, these would include primary skid trails. For cable logging, the yarding corridors would be most prone. Landings and temporary roads associated with any logging system would also expose soils.

Because the majority of the project area is considered to be in the low to moderate soil erosion hazard class, soil exposure would not be expected to directly result in extensive soil loss. The potential for soil loss would be greatest where exposure occurs on steep slopes. Exposure would be intended to be minimal for a short period of time. Implementation of BMPs/PDCs would be expected to minimize erosion and nurture the reestablishment of an effective ground cover of at least 60 percent the first year following completion of treatments.

Surface organic material can be expected to be disturbed in treatment units as a result of heavy logging equipment. It would be completely removed and denuded from primary skid trails, portions of yarding corridors, landings, and temporary roads. The extent of these features would be controlled and limited, so that the majority of the ground would be less disturbed and still covered by a nearly contiguous layer of litter and duff.

Tree removal resulting from timber harvest would decrease total on-site biomass for a short time. Slash comprised of discarded limbs and needles however, would remain on-site and constitute a large immediate influx of fine and medium organic inputs to the forest floor.

Standing or downed dead material would also be left on-site. Densely stocked patches of intact forest called, “skips” would be left across about 10 percent of variably-thinned treatment units.

Once opened up, new growth of understory seedlings, brush and vegetation would become profuse. The residual forest cover left on-site would continue to generate litter-fall for the forest floor, contributing fine needles, small branches, and larger limbs and stems. The rate at which biomass accumulates would rebound relatively quick, escalating rapidly in successive growing seasons to eventually match or surpass rates prior to thinning. The total amount of surface organic matter to remain after treatment would be sufficient for supporting the function of soil biota that facilitate site productivity.

Cumulative Effects

Most of the proposed treatments would enter stands that have been treated previously. For this reason, the potential for cumulatively accruing detrimental soil conditions is likely. Treatment units that exhibit Soil Condition Class 2 would be at the greatest risk, where containment of detrimental soil effects could be a challenge to limit. Close coordination between contract administrators and operators to implement BMPs/PDCs would be needed to contain the extent of detrimental soil impacts.

Consistency with Plans

The Proposed Action as planned would be considered consistent with the LRMP Standards and Guidelines (S&Gs) for soil productivity (FW-022 to FW-037), as well as the NWFP pages C-40 and C-44. BMPs/PDCs will be the principle tools and measures to be employed during implementation to achieve consistency. Post-harvest restoration projects would also be pursued, and could be deemed compensatory measures to partially offset ground effects.

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