Soils

Introduction

This report describes existing soils conditions and the effects of proposed activities on soils associated with the Hemlock Elk Fuels Reduction and Forest Health Management Project.

The treatment area encompasses approximately 739 acres of federal lands within the Flathead National Forest. This area is located in Missoula County just west of Condon, MT. An estimated 321 acres of the project are located within the wildland urban interface. The project is designed to reduce the associated risk of high-severity landscape wildfire risk within the wildland urban interface (WUI), restore and maintain forest health and provide wood products for local economies.

Analysis Area

Spatial Bounds

For the soil resource, the treatment unit serves as the analysis area, as activities within units would not influence soil characteristics outside of unit boundaries.

Temporal Bounds

On the time scale, this assessment can detect soil disturbance up to 80 years in the past. Effects of the proposed management activities can be estimated to about 60 years into the future.

Data Sources, Methods, and Assumptions Used

During May 2008, two qualified Soil Scientists accompanied by Field Technicians surveyed all treatment units with a history of soils disturbance and many units without any sign of disturbance.

The Region One Soil Tech Guide (USDA draft) was used to establish the existing and potential detrimental soil disturbance. Soil disturbance is considered detrimental when long-term soil productivity is compromised. The FSM 2500 R1 Supplement (1999) establishes thresholds for compaction, displacement, rutting, severely burned soil, surface erosion, soil mass movement, and residual organic matter where detrimental soil disturbance can occur. Where current conditions or estimated cumulative effects exceed 15 percent detrimental soil disturbance across a unit, long-term impacts to soil productivity are likely (if there is less than 15 percent detrimental disturbance, substantial or permanent impairment of productivity is not likely). All potential treatment areas were assessed to determine detrimental disturbance from previous logging and fire. Records and research sources used to determine the type and extent of historic disturbances include (unless otherwise noted files are located at the Swan Lake Ranger District Office):

- Soil Survey of the Flathead National Forest;
- Missoula County Soil Survey;
- Aerial photos;
- Timber sale records;
- Fire history maps (1889 to present);

- Stand exam data (contained in stand files, the Timber Stand Management Record System (TSMRS), and GIS datasets);
- Personal communication with local residents; and,
- Walk-through surveys performed in each of the proposed treatment areas by District Personnel in which evidence of past activity including logging, fuel treatments, old roads, and fires, was noted (see project file).

The R1 Soil Monitoring Guide protocol was used that estimates the amount of detrimental disturbance within each treatment unit. Measurements also included:

- Percent cover by category: rock, wood, vegetation, and litter;
- Down woody debris (tons per acre) using modified Brown's transects;
- Litter and duff depths;
- Percent of rock in the uppermost soil horizon;
- Depth of volcanic ash, and;
- Slope stability issues, erosion concerns and other soil issues.

The natural soil bio-physical resiliency of each unit was assessed to gain insight that ties current conditions to proposed treatments and cumulative effects. Understanding the complex web of processes and elements that maintain how and why the soil is resilient to disturbance is key to sustained soil productivity.

Final information pertinent to, but not included in this report is located in the Hemlock Elk Project File. Information includes all field notes, specific concerns by unit, maps, background information and calculations, and references.

Description of Measurement Indicators

Each unit was inspected and soil conditions were evaluated in consideration of the proposed treatments. Full surveys were performed (outlined below) on all units where machinery could impact the character of the soil.

Surveys were based on a modified Howe's (USFS 2000) soil disturbance assessment, and a modified Brown's woody debris transect. Data was collected for both surveys from plots along a line transect.

The following data was collected:

- Forest Floor Cover (Percent cover, five categories)
- Down Woody Debris (tons/acre)
- Duff Depth
- Coarse Fragments
- Soil Texture
- Soil Disturbance Assessment
  - Compaction (Penetrometer Tests)
  - Vegetation Vigor
  - Organic Horizon Integrity
  - Forest Floor Cover
  - Soil Displacement, Erosion & Mass Wasting

Soil Disturbance Classes

- Class 0 - undisturbed
  - No evidence of past equipment operation
  - No depressions of wheel tracks evident
  - Forest floor layers present and intact
  - No management-generated soil erosion
  - Litter and duff layers not burned. No soil char. Water repellency may be present.
- Class 1
  - Soil Surface
    - Faint wheel tracks or slight depressions evident and are <5 cm. deep.
    - Forest floor layers present and intact
    - Surface soil has not been displaced and shows minimal mixing with subsoil.
    - Burning light: Litter charred, or consumed. Duff largely intact. Water repellency is similar to pre-burn conditions. Depth of char <1cm.
  - Soil Compaction
    - Compaction in the surface soil is slightly greater than observed under natural conditions.
    - Concentrated from 1-10 cm in depth.
  - Observations of soil physical conditions:
    - Change in soil structure from crumb or granular structure to massive or platy structure, restricted to the surface 0-10 cm.
    - Platy structure is non-continuous.
- Class 2
  - Soil Surface:
    - Wheel tracks or depressions are 5 to 10 cm deep.
    - Forest floor layers partially intact or missing.
    - Surface soil partially intact and may be mixed with subsoil.
    - Burning moderate: Duff deeply charred or consumed. Surface soil water repellency increased compared to the pre-burn condition. Depth of char 1-5cm.
  - Soil Compaction:
    - Increased compaction is present from 10 – 30 cm in depth.
  - Observation of soil physical condition:
    - Change in soil structure from crumb or granular structure to massive or platy structure, restricted to the surface 10 – 30 cm.
    - Platy structure is generally continuous.

Large roots may penetrate platy structure, but fine and medium roots may not.

- Class 3
  - Soil Surface:
    - Wheel tracks and depressions highly evident with depth >10 cm.
    - Forest floor layers are missing.
    - Evidence of surface soil removal, gouging, and piling.
    - The majority of surface soil has been displaced. Surface soil may be mixed with subsoil. Subsoil partially or totally exposed.
    - Burning Extreme: Duff and litter layer completely consumed. Surface soil is water repellent. Depth of char > 5 cm. Surface reddish or orange in places.
  - Soil Compaction
    - Increased compaction is deep in the soil profile (>30 cm in depth)
  - Observation of soil physical condition:
    - Change in soil structure from granular structure to massive of platy structure extends beyond 30 cm. in depth.
    - Platy structure is continuous.
    - Roots do not penetrate platy structure.

Any soil disturbance rated 2 or above is designated a long-term detrimental effect.

Affected Environment

Existing Condition

Landtypes and Proposed Management Activities: Table 3-4 lists each soil landtype map unit in the project area and the proposed units within the landtype. It also lists the soil properties important in determining management effects. This information is from the Soil Survey Report for the Flathead National Forest (1998).

TABLE 3-4
LANDTYPES AND UNITS

Landtype	Productivity	Surface Soil Erosion Rating	Soil Features	Units in Landtype
10-3	Moderate	N/A	Loam Texture	1, 2
26C-7	High	Moderate	Silty Textures	3 - 7, 9 - 25,
26D-7	Moderate	Moderate	Sandy Textures	25, 26, 27, and 28

Productivity: Productivity of most soils is high because they are deep and provide adequate plant available nutrients and water. The two exceptions are Landtypes 10-3 and 26D-7, which have moderate productivity because 26D-7 is sandy and holds fewer nutrients and less water than the other soils in the analysis area and 10-3 because of a high water table. However, both these soils do support forest vegetation.

Erosion Risk: The erosion risk for all the soils is moderate because of the relatively gentle slopes and the presence of a volcanic ash surface soil, which has a very high ability to move water into and through the soil. According to the Forest Service Landtype Inventory, runoff

from these soils is uncommon; however, if these soils are compromised by compaction or organic matter removal, runoff and erosion become an issue.

Project Area Description: The proposed project area includes the "Valley Bottom Ecosystem" and transitions through the "Cool, Moist Ecosystem," both described in detail in the Upper Swan Valley Landscape Assessment (Swan Ecosystem Center 2004).

The Valley Bottom Ecosystem includes undulating flatlands with many potholes and wetlands. The topography is complex, created by advancing and retreating glaciers from various directions. The Cool Moist Ecosystem was also strongly influenced by glaciers, and tends to have rolling hills and gentle slopes, with many wet draws and depressions.

The soils in both ecotypes belong to the Jimlake Series, and are classified as Loamy-skeletal, mixed Andeptic Cryoboralfs (Soil Survey of Missoula County 1995). These soils are very deep and well drained, formed mainly from alpine glacial till, primarily from limestone. The upper soil horizons have high volcanic ash content. The average annual precipitation is 30 to 40 inches.

Charcoal was found in the soil in all sites, demonstrating a history of fire throughout this landscape. Soil wood is also common in most sites, except those heavily disturbed by logging over the past 50 years. Soil wood is the decomposition product of brown cubical rot and typically found mostly or entirely buried within the forest floor.

Generally, these soils are very productive, but vulnerable to disturbance, which can adversely influence soil quality.

Volcanic Ash: Most of the proposed treatment units are similar in one aspect: the topmost mineral soil horizon is volcanic ash. Mount Mazama, now Crater Lake, Oregon, experienced a cataclysmic pyroclastic eruption about 7,000 years ago. In the Hemlock Elk Area, the ash is typically between 4 and 10 inches in depth. The "ash cap" imparts both benefits and vulnerabilities to forest soil characteristics. Volcanic ash has a high water-holding capacity and provides an excellent germination substrate for many native plant species. Unfortunately, ash is extremely vulnerable to compaction, displacement and (when laid bare by disturbance) erosion (Page-Dumroese 1993; Johnson et. al. 2007). All soils are more sensitive to disturbance when moist, but ash-capped soils are especially sensitive when moist.

Volcanic ash soils do not provide or hold plant-available nutrients well. Nitrogen (N) mineralization was strongly correlated with the presence of organic matter on ash-capped soils. For this reason, the organic element of the soil in the Hemlock Elk region is especially important (Garrison-Johnston et al. 2007).

Under the objectives outlined in the NFMA, the Forest Service has assembled the North American Long-Term Soil Productivity Research Program (LTSP). The LTSP has focused its attention on two soil properties that are most influenced by timber harvesting and most related to forest integrity within the constraints of climate and topography: (1) soil organic matter, and (2) soil porosity (Powers 1998). Soil nutrients are also an important component to soil productivity.

These issues are also the primary soil concerns for the Hemlock Elk Project Area. Soil organic matter is influenced by fire, silvicultural prescriptions, timber harvests, and decomposition and accumulation rates. Soil porosity is most influenced by mechanical compaction and a lack of bio-physical resiliency.

Soil Organic Matter: Although often overlooked in forest management plans, the importance of soil organic matter cannot be overstated (Okinarian 1996; Jurgensen et al. 1997). This organic component contains a large reserve of nutrients and carbon, and it is dynamically alive with microbial activity. The character of forest soil organic matter influences many critical ecosystem processes, such as the formation of soil structure, which in turn influences soil gas exchange, soil

water infiltration rates and soil water-holding capacity. Soil organic matter is also the primary location of nutrient recycling and humus formation, which enhances soil cation exchange capacity and overall fertility.

These processes have direct and tremendous effect on site productivity and sustainability. Fortunately, organic matter is the one component of the soil resource that, if managed correctly, can actually be improved by human activity. Manipulation of the organic constituents of the soil may be the only practical tool available for mitigating effects of harvesting systems that remove standing trees and dead and down trees, or cause extensive soil disturbance. Of the many organic materials incorporated in a forest soil, the woody component is in many ways the most important. To protect the sustainable productivity of the forest soil, a continuous supply of organic materials must be provided, particularly in harsh environments (Harvey et al., 1987). A clear understanding of fungal processes and the creation of soil organic matter are essential for forest management and forest soil restoration.

Soil Wood:

Brown Cubical Rot: No discussion about forest woody debris and biological activity would be complete without promoting the values of brown cubical rot, and recommendations that may increase the amount of the product of this unique decomposition process across the landscape.

Residue left after advanced brown-rot decay is a brown, crumbly mass composed largely of lignin. In healthy forest ecosystems, especially coniferous forests, the upper-most soil horizon contains a significant portion of brown-rotted wood residues. The sponge-like properties of advanced brown-rotted wood act as a moisture and nutrient sink. Because of the high lignin concentrations, and low carbohydrate rates, it persists in the forest for a long time (Blanchette, 1995).

The lignin product of brown rot is tremendously important in the forests of the West. Since brown rot typically affects only heart wood, it is important that large trees are allowed to die and decompose naturally in the woods. For example, a larch 36 inches in diameter may possess 24 inches of heart wood. This in turn decomposes to a 16-inch zone of brown cubical residue, often referred to as soil wood. Early logging techniques that bulldozed forest debris into piles and then burned the organics significantly reduced the occurrence of soil wood in our forests. Soil wood possesses one key characteristic that makes it important: the ability to hold water. This high water-holding capacity provides:

- Plant-available water, especially during the driest months;
- Excellent underground habitat for all types of soil biological activity;
- Appropriate conditions that cause a hub of mycorrhizae fungi activity.

Replacement of the woody soil components from a site that has lost such may take from 100 to 300 years (Harvey et al., 1981).

To ensure sustained forest use and protect ecosystem integrity, it is important to understand two concepts in regard to the fungal resource. First, the role of fungi is essential for the continuance of many ecosystem processes. Second, with proper awareness and skill, forest practices can be designed to greatly influence fungal processes and potential benefits.

Wood decay fungi in the coniferous forest ecosystem have three major roles:

- Breaking down plant residues and recycling carbon to the soil or the atmosphere;
- Releasing mineral nutrients from plant residues and making the nutrients available to living organisms, and;

- Producing and maintaining the physical character of the soil matrix.

The outcomes of these processes promote soil water infiltration rates, soil water-holding capacity, cation exchange capacity, nutrient availability, nitrogen fixing activity, and habitat for mycorrhizae associations.

Project design can influence fungal processes by considering the effects of silvicultural, harvesting, and slash disposal activities. Silvicultural plans that promote fungal processes will prescribe harvests that preserve a cool, moist microclimate and provide for a continuous source of large woody debris for use by fungi. Harvest techniques should be light on the land, disturbing as little soil as possible. Slash management techniques should emphasize leaving as much debris as is appropriate to the site and the Purpose and Need of the project.

Soil Porosity: Soil porosity refers to the amount and character of void space within the soil. In a "typical" soil approximately 50 percent of the soil volume is void space. Pore space is lost primarily through mechanical compaction. Two fundamental processes are negatively impacted by compromised soil pore space:

- Gas exchange;
- Soil water infiltration rates; and
- Soil bio-physical resiliency

Gas Exchange: Soil oxygen is fundamental to all soil biologic activity. Roots, soil fauna, and fungi all respire, using oxygen while releasing carbon dioxide. When gas exchange is compromised, biologic activity is also compromised. Maintaining appropriate soil biologic activity is paramount when considering long-term forest vitality.

Soil Water Infiltration Rates: Severely compacted soils do not allow appropriate water infiltration, leading to overland flow and associated erosion, sediment delivery, spring flooding, and low summer flows. Some recent advances in logging technology and mechanization have exacerbated the problem, as feller bunchers must travel to each tree and slash is often piled with excavator type, tracked grapple equipment. Skid trails are the longest lasting detrimental disturbance, where many machines travel over the same route. Again, activities on moist soils are especially damaging. Work on dry or frozen soils maintains much more of a soil's natural ability to quickly restore pore spaces.

Soil Bio-physical Resiliency: Though ash-capped soils are sensitive to disturbance, the soils observed were found to be relatively resilient. Observations showed that soil pore space is naturally restored after mechanized disturbance from 60 to 80 years on main skid routes. Where resiliency is high and soil compaction moderate, observations showed natural pore space restoration from 40 to 60 years. For new activities where all appropriate Design Criteria and techniques are employed, it is expected naturally restored soil pore space would occur between 5 and 40 years.

Soil pore space is restored through natural aggregation processes, the result of two primary processes: 1) biologic activity; and 2) freeze-thaw events, or wet-dry events. Understanding the factors that preserve, maintain, or improve natural bio-physical resiliency is key to understanding the relationship between existing conditions and probable environmental impacts from forest treatments.

It is important to be able to predict how much abuse a soil can experience before crossing the threshold where natural aggregation processes are significantly compromised. For example, a soil is relatively resilient after moderate tractor logging and

very resilient after most fires; but the combination of these two disturbances has a synergistic effect that ruins natural restorative processes.

Unfortunately, recognizing and understanding where this threshold lies is difficult. Many factors create a complex web of interrelationships that impart resiliency, or the lack thereof, to the soil resource. As discussed above, design criteria associated with the proposed activities are identified in Table 2-15 that would minimize soil impacts and maintain natural biological resiliency.

Table 3-5 displays the current soil conditions by unit in the project area.

TABLE 3-5
CURRENT CONDITIONS OF THE HEMLOCK ELK PROPOSED UNITS

Unit No.	Acres	Current Down Woody Debris (tons/acre)	Coarse Fragments	Total Organics (cm)	Current Detrimental Disturbance
1	21	31.95	10-35%	4.00	5.0%
2	10	7.33	10-20%	3.25	4.6%
3a	4	11.13	15-30%	4.38	4.5%
3b	8	7.67	15%	4.00	11.1%
5a	10	0.00	5-10%	7.00	6.5%
5b	41	13.32	15%	3.50	11.7%
6	9	1.83	15-20%	2.00	23.3%
7	20	3.36	15-20%	3.60	3.3%
9	22	16.23	5-15%	4.50	0.0%
10	24	37.80	5-10%	5.00	0.0%
11	33	7.18	5-35%	3.60	5.0%
12	29	0.00	0-15%	2.00	14.5%
13	11	0.00	10-20%	2.17	10.0%
14	15	8.10	10-20%	2.63	18.3%
15	134	17.04	5-30%	4.70	2.2%
16	38	15.73	5-45%	5.38	3.3%
17	7	6.95	15-35%	5.17	4.4%
18a	23	4.54	10-30%	4.40	2.7%
18b	2	4.54	10-30%	4.40	2.7%
19	38	7.66	5-25%	6.00	1.5%
20	12	0.00	5-30%	4.33	0.0%
21	22	19.45	5-35%	4.25	0.0%
22	18	26.00	<5-15%	4.67	0.0%
23	100	8.00	5-20%	4.40	5.3%
24a	9	30.80	5-15%	5.13	3.3%
24b	28	31.46	0-15%	4.80	7.3%
25	16	15.07	10-20%	3.50	0.0%
26	10	4.27	15-20%	2.83	0.0%
27	3	15.07	10-20%	3.50	0.0%
28	22	2.08	10-15%	3.63	0.0%

Down Woody Debris and Soil Wood: Woody debris is a great indicator of site bio-physical resiliency and overall forest health. On average, down woody debris should be between 15 and 25 tons per acre (Graham et al. 1994). However, Flathead National Forest Standards recommend leaving 8 tons per acre in the designated wildland/urban interface, which fulfills the Purpose and Need of the proposed project.

Units 2, 3b, 5a, 6, 7, 11, 12, 13, 14, 17, 18a, 18b, 19, 20, 23, 26, and 28 currently have less than the 15 to 25 tons per acre of woody debris.

Many of these stands lacking woody debris are in a natural condition. Treating these stands may remove that portion of the standing wood that has a potential to become forest floor debris. Leaving an appropriate amount of woody debris after treatment protects this natural forest process.

Soil is also used as an indicator of forest ecological integrity. Most of the units have sufficient amounts of soil wood.

Coarse Fragments: The percent of coarse fragments is a measure of rock content in the surface six inches of mineral soil. Rock content is an excellent indicator of the effect of compaction on a specific soil type. Rock content over 35 percent would greatly reduce the effect of mechanical compaction. As Table 3-5indicates, rock content for many of the units is at or below 35 percent, meaning that these soils are especially vulnerable to compaction.

Total Organics: This is a measure of the total depth of the combined litter and duff organic horizons. This measure is another indicator of bio-physical resiliency. The depth and character of the organic horizon influences soil structure, moisture-holding capacity, nutrient cycling, pH, and soil temperature. The organic horizon also imparts information about decomposition and organic accumulation rates.

Organic horizon depths in the range of 1.18 to 1.96 inches (3 to 5 centimeters) are typical for this forest type. As the data indicates, the litter and duff layers are good in the majority of the units. Litter layers in Units 6, 12, and 13 are low. This can be caused by a number of reasons, such as an imbalance between decomposition and accumulation rates, or serve as evidence of a developing litter layer after a disturbance. This would influence how the site recovers after logging.

Detrimental Disturbance: Three units have moderate current soil disturbance (5a, 23, and 24b). These units have more recent harvest activity and skid trails present, but sites are recovering and are resilient. Three units are highly disturbed (3b, 5b, and 12) and two units (6 and 14) have disturbance greater than the 15 percent current disturbance threshold.

Units 6 and 14 require soil restoration. These units experienced a clearcut followed by litter and duff layer removal. Soil wood and other organics were also removed. While scraping the organics into burn piles, a significant portion of the vulnerable ash cap was also dozered off site. In addition to dozer piling and burning, these units possess a network of compacted skid trails.

Environmental Consequences

This section describes the direct, indirect, and cumulative effects of the No Action Alternative and the proposed actions to the Soil Resource.

Alternative A - No Action
Direct and Indirect Effects

For undisturbed to moderately disturbed sites, Alternative A would have no direct or indirect negative influences on forest soils. Indirectly, Alternative A would allow developing litter layers to mature. Untreated, self-thinning stands would contribute woody debris to decompose, adding needed organics and soil wood.

For the two highly disturbed sites (Units 6 and 14), Alternative A would have no direct negative impacts, but would create indirect negative impacts by missing an opportunity to actively restore damaged soils. These sites would naturally recover in time, approximately 60 to 80 years. Active management can accelerate processes to restore function in 40 to 60 years. These numbers are estimates based on field observations in the Swan Region.

No action presents the possibility that when a fire passes through the project area, negative effects of the fire on the soil resource may be increased relative to fire effects in treated stands.

Alternatives B, C and D
Direct Effects

Soils in Units 6 and 14 would be actively restored with the implementation of Alternatives B, C, and D. This active management would accelerate processes to restore function to these sites in 40 to 60 years.

For undisturbed to moderately disturbed units, proposed activities would have long and short-term direct negative effects on forest soils. Effects include:

- Compaction;
- Rutting & displacement;
- Severely burned soils;
- Degradation of the litter layer and soil organic matter caused by increased decomposition rates and lack of appropriate annual litter contributions;
- Lack of large woody debris;
- Possible weed incursions.

Past effects from logging are detectable up to 80 or more years. Proposed activities use techniques that maintain or promote natural soil bio-physical resiliency. The effect of proposed activities should be relatively short compared to techniques used in the past. If all natural elements and processes remain intact, soil impacts would be nearly undetectable within 20 to 40 years based on professional judgment and experience on these soil types. Recovery time in Alternative C for the units proposed for winter logging could be shorter based on the fact that winter logging has less impact on the soil resource (See Table 3-6).

Proposed treatment effects on the soil can be minimized by using techniques and restoration strategies outlined in this report. Proposed treatments and total acres by treatment in the project area by alternative are displayed in Table 3-6. The amount of expected detrimental disturbance would vary greatly with proposed treatments. These estimates of added disturbance come from Niehoff (2002), as well as on-the-ground observations and surveys, and take into account Best Management Practices described in Niehoff (2002). Table 3-6 illustrates expected effects based on a variety of proposed treatments. Units harvested in summer/fall would have 11 percent disturbance from harvesting, while units harvested in winter (Alternative C) would have 8 percent disturbance from harvesting. Alternative B and Alternative C would treat 739 acres and Alternative D would treat 663 acres.

TABLE 3-6.
ACRES BY TREATMENT AND PREDICTED ADDITIONAL DETRIMENTAL DISTURBANCE

	Alternative B	Alternative C	Alternative D	Added Disturbance*
Logging System Acres				
Tractor	668	668	592	8-11%
Mechanical	10	10	10	8-11%
Hand	61	61	61	2%

*Percentages from Neihoff (2002), Flathead National Forest Monitoring Data, and on the ground observations and experience.

The following section discusses the expected direct effects from various logging techniques and silvicultural treatments.

Ground Based Harvest with Excavator Piling

Generally, the effects from ground based harvesting are concentrated on skid trails, temporary roads, and landing areas. Typically, a post-harvest soil disturbance survey would find from 10 to 20 percent detrimental soil disturbance over a treatment unit. The amount of disturbance is dependent on many factors including:

- Soil Moisture
- Soil Characteristics
- Slope
- Operator Skill
- Equipment Used
- Silvicultural Prescriptions

Excavator piling is a slash management technique becoming more popular each year. On dry soil or winter logging, this technique adds from 0 to 5 percent detrimental disturbance (personal observation). In moist conditions excavator piling can add from 5 to 10 percent detrimental disturbance (personal observation). In addition to soil physical damage, piling and either burning or chipping slash removes an important portion of a forest organic matter and nutrient capital.

In areas where ground-based thinning and excavator piling and burning are proposed, excavator piling could push the proposed treatment over the accepted percentage allowed of detrimental disturbance.

Whole Tree Yarding

Whole Tree Yarding is a harvesting and slash management technique typically associated with ground-based, feller-buncher and grapple skidder operations. Whole-tree logging takes the entire tree to a landing to be processed. The limbs and tops are typically chipped for hog fuel or burned. This technique removes a significant portion of the forest biomass. When considering long-term sustainable forest use, whole tree logging has a detrimental influence on forest vitality, especially on silvicultural prescriptions that remove more that 50 percent of the biomass (20 years of observations in the Swan Valley).

Earlier in this report, we emphasized the importance of soil organic matter. Little long-term detrimental disturbance would result if the appropriate amount of woody debris remains on site, and the litter and duff layers are protected. The larger the size of the woody debris left on site, the more beneficial it is for long-term soil stewardship. Please see the Design Criteria in Table 2-15

which displays the amount of woody debris that would be left on site. This is especially important on the units without very much coarse woody debris currently (Units 2, 5a, 7, 11, 14, 17, 18a, 18b, 19, 20, 23, 26, and 28).

Cut-to-length systems that incorporate in-woods harvester/ processors and log forwarding equipment can leave appropriate amounts of slash on the forest floor and do less physical damage.

Clearcut, Patch Clearcut, and Seed Tree with Reserves (Alternatives B and C only)

Clearcut with Reserves Treatments are proposed for Units 10, 20, and 21. Patch Clearcut Treatments with Reserves are planned for Unit 25, and Seed Tree with Reserves are proposed for Units 11, 14, 16, 22, 27, and 28.

In the Swan Valley west side forests, any silvicultural prescription that removes a significant portion of the canopy would influence soil bio-physical attributes (personal observations in the Swan Valley). Clearcuts and Seed Tree Treatments could decrease annual litter contributions, causing an imbalance between accumulation and decomposition. These prescriptions combined with whole tree logging and excavator piling could also diminish nutrient availability and the forest bio-physical resiliency to disturbance. Any physical disturbance caused by logging activities would require a significantly longer period of time to recover relative to partial canopy removal. We estimate 60 to 80 years (personal experience in the Swan Valley). Conversely, select cuts with plenty of woody debris and appropriate annual litter contributions could recover in much less time (20 to 40 years).

Thin from Below – Commercial, Tractor Logging, Whole Tree/Excavator Pile/Chip/Burn

Commercial Thinning from Below typically yields the least direct and indirect impacts to soils. This technique not only maintains appropriate litter contributions, it also preserves those elements and processes that impart bio-physical resiliency to the forest. If the thinning is moderate, whole tree logging would not have the negative effects described with a Clearcut or Seed Tree prescription. The proposed action is moderate, describing a target of 70 to 120 square feet of basal area.

Moist Soils

Most of the proposed units have portions with fragile moist soils where the water table is fairly high. These are very common on the west side of the Swan Valley, making spring, early summer, and late fall inappropriate for treatment activities. This leaves mid summer to early fall and winter for on-the-ground work where units contain such soils.

Winter Logging

In Alternative B, none of the units would be harvested in the winter. In the Swan Valley, we highly recommend winter logging on frozen or snow covered soils when such conditions are available. Working on dry soils is also appropriate in many cases and with some logging techniques.

Alternatives B, C and D
Indirect Effects

Many indirect effects are possible when soil conditions are compromised. Compaction can decrease water infiltration rates, leading to increased overland flow and associated erosion and sediment delivery to streams. Increased overland flow also increases intensity of spring flooding, degrading stream morphological integrity and low summer flows. Compaction decreases gas exchange, which in turn degrades sub-surface biological activity and above-ground forest vitality.

Rutting and displacement cause the same indirect effects as compaction, and also channel water in an inappropriate fashion, increasing erosion potential. Severely burned soils can indirectly influence many forest elements and processes. Expect possible weed incursions, changes in hydrology as described above, and decreased biologic activity and associated events. Loss of organic matter would decrease natural resiliency to disturbance, decrease nutrient cycling and availability, decrease soil water and nutrient-holding capacity, decrease aggregate formation and all benefits associated with aggregation. Lack of large woody debris would influence the forest soil in a similar way as does the loss of organic matter.

Harvest operations remove biomass and site organic matter and thus affect nutrient cycling. Generally, nutrient losses are proportional to the volume of biomass removed from a site. Nutrients are lost during harvesting by removing the stored nutrients in trees, and additional nutrients are lost if the litter layer and woody debris are removed. Whole-tree harvesting, which extracts larger amounts of biomass, especially nutrient-rich foliage, compared to conventional sawlog or thinning operations, removes a larger amount of the nutrients from the site. The exact amount of nutrients lost from a particular site would vary with forest types and particular site conditions (Grier et al. 1989). The amount of nutrients present in the trees would also vary with stand age and development of the humus layer (Grier et al. 1989). Moreover, the greater the proportion of nutrients stored in trees, the greater the potential for site degradation and declines in productivity after harvesting operations. The data suggest that nutrient losses from whole-tree harvesting are considerably greater when compared to conventional sawlog harvesting for all nutrients. Calcium losses were particularly large for whole-tree harvesting due to the high concentrations of calcium present in the wood fiber of twigs, branches, and boles (Adams 1998; Mann et al. 1988).

Prescribed fire could increase available nitrogen for 1 to 2 years following (Choromanska and DeLuca 2002). Burning slash piles could create extremely high temperatures in concentrated areas and would lead to volatilization of nitrogen, loss of phosphorus and potassium (DeBano 1981). If litter layers and organic matter is kept intact throughout the rest of the stand, nutrient losses would be minimal from burning slash and would be localized. Nitrogen-fixing plants could colonize sites following fire and help restore Nitrogen in the ecosystem (Newland and DeLuca 2000; Jurgensen et. al. 1997). Following fire, soil erosion could increase, which could also reduce the nutrient pool (Megahan 1990). Generally, if plants colonize sites following fire, nutrient levels can reach pre-fire levels quickly (Certini 2005). Charcoal deposited following fire also adds carbon to the soil (DeLuca and Aplet 2007).

Indirect effects of soil nutrient loss include reduced growth and yield and increased susceptibility to pathogens, such as root disease (Garrison and Moore 1998; Garrison-Johnston 2003) and insect infestation (Garrison-Johnston et al. 2003 and 2004). Precipitation (Stark 1979) and weathering of rocks would continue to make additional nutrients available on site. Annual needle, leaf, and twig fall, forbs, and shrub mortality would continue to recycle nutrients, as well.

To summarize, by maintaining organic matter and ground cover on at least 85 percent of the site, nutrient cycling and availability should not be altered. The mitigations and Region One Soil Quality Standards are prescribed to achieve this desired outcome. Localized losses may occur under burn piles, at landings, or where severe fire occurs.

Alternatives B, C and D
Cumulative Effects

This section describes how old impacts, expected new impacts from fuel treatments, and foreseeable future events act together to influence long-term soil vitality. As mentioned, proposed treatments would employ low-impact logging techniques that minimize soil disturbance and maintain processes that promote natural soil bio-physical resiliency. Effects of the fuels treatment should not exceed 40 years.

Cumulative Effects of Timber Harvesting

The undisturbed units burned in the early 1900s would experience the least, if any, cumulative effects from ground-based logging. Since litter layer is just now reaching maturity, additional activities that negatively influence soil organic matter would have cumulative influence.

Cumulative effects on moderately disturbed units (6 to 15 percent detrimental disturbance) where ground-based logging and thinning are proposed would likely exceed the Regional Soil Quality Guidelines and thresholds for a short time, perhaps 5 to 10 years. Design Criteria (Table 2-15) would maintain natural biophysical resiliency and allow soils to meet Region One soil standards in a timely fashion.

Proposed mechanized activities on the severely disturbed units would generate similar disturbance patterns as described above. The difference is in the character of cumulative effects. These sites lack a full complement of processes and elements that promote natural soil biophysical resiliency. However, using all appropriate measures designed to minimize soil disturbance and soil restoration techniques, cumulative effects would be drastically minimized, and in some cases, actually aid in soil recovery. Cumulative effects would be relatively short term (~20 years).

In regard to soil nutrient concerns, undisturbed units, typically those burned early in the 1900s, are just now reaching their potential for nutrient capital and efficient nutrient cycling. Treatments that minimize soil disturbance and leave slash on the ground for one season to leach available nutrients would not display cumulative effects. If, however, units are whole-tree logged, or too much slash is used for biomass, or slash piling and burning becomes excessive, or the unit experiences a hot prescribed burn, then nutrient-based cumulative effects would be expected. Design Criteria identified to protect soil and site productivity displayed in Table 2-15 would ensure no cumulative effects.

Units that have experienced a moderate to high amount of detrimental disturbance in the past are vulnerable to cumulative nutrient effects. Past harvest activities have removed considerable amounts of carbon and also decreased annual litter fall for a time. Most important, we must protect those elements and processes that maintain nutrient capital and cycling. Again, employing Design Criteria would ensure no cumulative nutrient-related effects.

Page-Dumroese (2000) found that relatively small levels of disturbance (less than 15 percent of the area) resulted in relatively small losses in carbon, nitrogen, and cation exchange capacity (CEC), ranging between 1 to 13 percent of the available pools. Page-Dumroese (2000) concludes that at these levels of loss, current soil quality guidelines appear to be adequate.

Region One Soil Quality Standards require remaining below 15 percent detrimental soil disturbance over the activity area in each treatment unit. Table 3-7 displays the estimates of expected cumulative detrimental disturbance for Alternatives B and C. These numbers were derived assuming a 59 percent overlap with new disturbance on top of old disturbance. Refer to Table 3-7 for coefficients used to predict potential detrimental disturbance for proposed logging and slash treatment scenarios including burning and piling. The level of disturbance increase also depends on the amount or lack of existing skid trails. Activity units that have had little prior disturbance would show a greater incremental increase in potential detrimental disturbance than those units that already contain a network of existing skid trails. Little to no increase in disturbance is expected in areas already containing a network of existing skid trails because equipment would re-use some if not all existing skid trails. Additionally, many units in Alternative C would be winter logged for further resource protection.

Table 3-8 displays these estimates for Alternative D. The numbers represent on-the-ground conditions where skilled operators employ all applicable techniques that minimize soil disturbance.

Soil Restoration Techniques: Two units (6 and 14) currently exceed the Regional Soil Quality Standard and two units (5b and 12) are predicted to exceed the standard with proposed activities in the action alternatives (See Table 3-7). Unit Units 6 and 14 need restoration to avoid adverse cumulative impacts and improve soil condition. Units 6 and 14 exceed the Regional Standard due to previous logging activity. In areas above 15 percent detrimental disturbance, restoration work is needed to improve the site condition where new activities are proposed. Units 5b and 12 must receive soil restoration treatment after project implementation in addition to minimizing soil disturbance during operations. These units are predicted to exceed the 15 percent standard due to cumulative effects of old and proposed treatments. Restoration treatments are proposed for these units and long-term soil productivity would be maintained within these units following restoration (See Design Criteria, Table 2-15). Soil restoration treatments would include:

1) Mechanical Ripping (on temporary roads and landings);

2) Freeze/Thaw or Wet/Dry Events;

These are natural physical processes which assist in ameliorating compacted soils, especially fine-textured soils.

3) Biologic Activity (on skid trails and other moderately disturbed soils throughout the units)

To use biologic activity to reduce soil compaction:

- Where feasible, place slash on old and new trails at a rate of 25 to 40 tons per acre (TPA).
- An average of 8 tons per acre of coarse woody debris would be left on treatment units within the WUI; 8 to 21 tons per acre of coarse woody debris would be left in treatment units outside the WUI. Where available, 32 pieces average per acre 9 to 20 inches diameter and 15 pieces average per acre greater than 20 inches diameter would be left.

The cumulative detrimental effects from project implementation and restoration would move these units toward a net improvement in soil quality. Refer to the Soils Specialist Report for more detailed information on soil restoration treatments.

Monitoring

The Forest Soil Scientist would monitor post treatment soil conditions. Monitoring would emphasize the effectiveness of Design Criteria included in Chapter 2 and compliance to Forest and Regional Soil Quality Standards. Please refer to Appendix A of this document for a display of monitoring items that would be conducted.

TABLE 3-7.
CUMULATIVE EFFECTS FOR ALTERNATIVES B AND C

Unit #	Silvicultural Prescription	Slash Abatement	Harvest System	Current Detrimental Disturbance (%)	Projected Detrimental Disturbance Alternative B (%)	Estimated Total Detrimental Disturbance Alternative B (%)	Projected Detrimental Disturbance Alternative C (%)	Estimated Total Detrimental Disturbance Alternative C (4%)	Restoration Needed
1	Thin From Below - Commercial	WTY-Excavator Pile/Chip/Burn	Tractor	5.0	11.0	13.5	11.0	13.5	
2	Salvage	WTY-Excavator Pile/Chip/Burn	Tractor	4.6	11.0	13.3	11.0	13.3	
3a	Pre-Commercial Thinning	Hand Piling and Pile Burning	Hand	4.5	2.0	5.5	2.0	5.5	
3b	Pre-Commercial Thinning	Hand Piling and Pile Burning	Hand	11.1	2.0	12.1	2.0	12.1	
5a	Sanitation	WTY – Excavator Pile/Chip/Burn	Tractor	6.5	11.0	14.3	11.0	14.3	
5b	Sanitation	WTY – Excavator Pile/Chip/Burn	Tractor	11.7	11.0	16.9	11.0	16.9	X
6	Pre-Commercial Thinning	Hand Pile and Pile Burning	Hand	23.3	11.0	22.7	11.0	22.7	X
7	Thin From Below – Commercial	WTY – Excavator Pile/Chip/Burn	Tractor	3.3	11.0	12.7	11.0	12.7	
9	Thin From Below – Commercial	WTY – Excavator Pile/Chip/Burn	Tractor	0.0	11.0	11.0	11.0	11.0	
10	Clearcut with Reserves	WTY – Excavator Pile/Burn	Tractor	0.0	11.0	11.0	11.0	11.0	
11	Seed Tree with Reserves	WTY – Excavator Pile/Burn	Tractor	5.0	11.0	13.5	11.0	13.5	
12	Pre-Commercial Thinning	Hand Piling and Pile Burning	Hand	14.5	2.0	15.5	2.0	15.5	X
13	Pre-Commercial Thinning	Hand Piling and Pile Burning	Hand	10.0	2.0	11.0	2.0	12.0	
14	Seed Tree with Reserves	WTY – Excavator Pile/Burn	Tractor	18.3	11.0	20.2	11.0	20.2	X

TABLE 3-7.
CUMULATIVE EFFECTS FOR ALTERNATIVES B AND C

Unit #	Silvicultural Prescription	Slash Abatement	Harvest System	Current Detrimental Disturbance (%)	Projected Detrimental Disturbance Alternative B (%)	Estimated Total Detrimental Disturbance Alternative B (%)	Projected Detrimental Disturbance Alternative C (%)	Estimated Total Detrimental Disturbance Alternative C (4%)	Restoration Needed
15	Thin From Below – Commercial	WTY – Excavator Pile/Chip/Burn	Tractor	2.2	11.0	12.1	11.0	12.1	
16	Seed Tree with Reserves	WTY – Excavator Pile/Burn	Tractor	3.3	11.0	12.7	11.0	12.7	
17	Thin From Below – Commercial	WTY – Excavator Pile/Chip/Burn	Tractor	4.4	11.0	13.2	11.0	13.2	
18a*	Thin From Below – Commercial	WTY – Excavator Pile/Chip/Burn	Tractor	2.7	11.0	12.4	8.0	9.4	
18b*	Thin From Below – Commercial	WTY – Excavator Pile/Chip/Burn	Tractor	2.7	11.0	12.4	8.0	9.4	
19*	Thin From Below – Commercial	WTY – Excavator Pile/Chip/Burn	Tractor	1.5	11.0	11.8	8.0	8.8	
20*	Clearcut with Reserves	WTY – Excavator Pile/Burn	Tractor	0.0	11.0	11.0	8.0	8.0	
21*	Clearcut with Reserves	WTY – Excavator Pile/Burn	Tractor	0.0	11.0	11.0	8.0	8.0	
22*	Seed Tree with Reserves	WTY – Excavator Pile/Burn	Tractor	0.0	11.0	11.0	8.0	8.0	
23*	Thin from Below – Commercial	WTY – Excavator Pile/Chip/Burn	Tractor	5.3	11.0	13.7	8.0	10.7	
24a*	Thin From Below – Commercial	WTY – Excavator Pile/Chip/Burn	Tractor	3.3	11.0	12.7	8.0	9.7	
24b*	Thin from Below – Commercial	WTY – Excavator Pile/Chip/Burn	Tractor	7.3	11.0	14.7	8.0	11.7	
25*	Patch Clearcut with Reserves	WTY – Excavator Pile/Burn	Tractor	0.0	11.0	11.0	8.0	8.0	
26*	Thin From Below – Non-Commercial	WTY – Excavator Pile/Chip/Lop and	Mechanical	0.0	11.0	11.0	8.0	8.0	

TABLE 3-7.
CUMULATIVE EFFECTS FOR ALTERNATIVES B AND C

Unit #	Silvicultural Prescription	Slash Abatement	Harvest System	Current Detrimental Disturbance (%)	Projected Detrimental Disturbance Alternative B (%)	Estimated Total Detrimental Disturbance Alternative B (%)	Projected Detrimental Disturbance Alternative C (%)	Estimated Total Detrimental Disturbance Alternative C (4%)	Restoration Needed
		Scatter							
27*	Seed Tree with Reserves	WTY – Excavator Pile/Burn	Tractor	0.0	11.0	11.0	8.0	8.0	
28	Seed Tree with Reserves	WTY – Excavator Pile/Burn	Tractor	0.0	11.0	11.0	13.0	13.0	

WTY – Whole Tree Yard

* = Winter Logged Units in Alternative C

^ These numbers were calculated assuming a 59% overlap with new disturbance on top of old disturbance. When old disturbance was high and expected disturbance was low, a much higher overlap was expected.

Rounding errors may occur.

TABLE 3-8.
CUMULATIVE EFFECTS FOR ALTERNATIVE D

Unit #	Silvicultural Prescription	Slash Abatement	Harvest System	Current Detrimental Disturbance (%)	Projected Detrimental Disturbance-Alternative D (%)	Estimated Total Detrimental Disturbance Alt D (%)^	Restoration Needed
1	Thin From Below - Commercial	WTY-Excavator Pile/Chip/Burn	Tractor	5.0	11	13.5	
2	Salvage	WTY-Excavator Pile/Chip/Burn	Tractor	4.6	11	13.3	
3A	Pre-Commercial Thinning	Hand Piling and Pile Burning	Hand	4.5	2	6.5	
3B	Pre-Commercial Thinning	Hand Piling and Pile Burning	Hand	11.1	2	13.1	
5A	Sanitation	WTY-Excavator Pile/Chip/Burn	Tractor	6.5	11	14.3	
5B	Sanitation	WTY-Excavator Pile/Chip/Burn	Tractor	11.7	11	16.9	X
6	Pre-Commercial Thinning	Hand Piling and Pile Burning	Hand	23.3	11	22.7	X
7	Thin From Below - Commercial	WTY-Excavator Pile/Chip/Burn	Tractor	3.3	11	12.7	
9	Thin From Below - Commercial	WTY-Excavator Pile/Chip/Burn	Tractor	0.0	11	11.0	
10	Salvage	WTY-Excavator Pile/Chip/Burn	Tractor	0.0	11	11.0	
11	Thin From Below – Commercial	WTY – Excavator Pile/Chip/Burn	Tractor	5.0	11	13.5	

TABLE 3-8.
CUMULATIVE EFFECTS FOR ALTERNATIVE D

Unit #	Silvicultural Prescription	Slash Abatement	Harvest System	Current Detrimental Disturbance (%)	Projected Detrimental Disturbance-Alternative D (%)	Estimated Total Detrimental Disturbance Alt D (%)^	Restoration Needed
12	Pre-Commercial Thinning	Hand Piling and Pile Burning	Hand	14.5	2	15.5	X
13	Pre-Commercial Thinning	Hand Piling and Pile Burning	Hand	10.0	2	11.0	
15	Thin From Below – Commercial	WTY – Excavator Pile/Chip/Burn	Tractor	2.2	11	12.1	
17	Thin From Below – Commercial	WTY – Excavator Pile/Chip/Burn	Tractor	4.4	11	13.2	
18a	Thin From Below – Commercial	WTY – Excavator Pile/Chip/Burn	Tractor	2.7	11	12.4	
18b	Thin From Below – Commercial	WTY – Excavator Pile/Chip/Burn	Tractor	2.7	11	12.4	
19	Thin From Below – Commercial	WTY – Excavator Pile/Chip/Burn	Tractor	1.5	11	11.8	
20	Thin From Below – Commercial	WTY – Excavator Pile/Chip/Burn	Tractor	0.0	11	11.0	
21	Thin From Below – Commercial	WTY – Excavator Pile/Chip/Burn	Tractor	0.0	11	11.0	
22	Thin From Below – Commercial	WTY – Excavator Pile/Chip/Burn	Tractor	0.0	11	11.0	
23	Thin From Below – Commercial	WTY – Excavator Pile/Chip/Burn	Tractor	5.3	11	13.7	
24a	Thin From Below – Commercial	WTY – Excavator Pile/Chip/Burn	Tractor	3.3	11	12.7	

TABLE 3-8.
CUMULATIVE EFFECTS FOR ALTERNATIVE D

Unit #	Silvicultural Prescription	Slash Abatement	Harvest System	Current Detrimental Disturbance (%)	Projected Detrimental Disturbance-Alternative D (%)	Estimated Total Detrimental Disturbance Alt D (%)^	Restoration Needed
24b	Thin From Below – Commercial	WTY – Excavator Pile/Chip/Burn	Tractor	7.3	11	14.7	
26	Thin From Below – Non-Commercial	WTY – Excavator Pile/Chip/Burn/Lop and Scatter	Mechanical	0.0	11	11.0	
27	Salvage	WTY – Excavator Pile/Chip/Burn	Tractor	0.0	11	11.0	
28	Thin From Below – Commercial	WTY – Excavator Pile/Chip/Burn	Tractor	0.0	11	11.0	

^ These numbers were calculated assuming a 59% overlap with new disturbance on top of old disturbance. Where old disturbance was high and expected disturbance was low, a much higher overlap was expected.

Cumulative Effects of Road Maintenance

All developed roads built in the past have a lasting effect on soil productivity due to compaction and displacement. Their maintenance for residence access, recreation, and vegetation management calls for ongoing use, which results in compaction and displacement throughout the project area.

Proposed road maintenance may increase short-term sediment movement from road surface runoff initially but should be minimal, especially at road locations higher on the slope that are at a relatively low gradient and provide for sufficient buffer zones. Road maintenance includes culvert installation, blading, and brushing, and typically improves drainage and decreases erosion from water channeling down the road surface in the long run. For a detailed analysis and information on roads and related issues, please see the Specialist's Report on Hydrology.

Cumulative Effects from Recreation

Disturbance from general motorized use and recreational access has been occurring and will continue throughout the project area indefinitely. With the exception of possible potential increased illegal ATV and trail bike use, no changes are anticipated in the existing recreation profile. Other recreational activities that occur off the developed roads, such as the gathering of miscellaneous forest products and hunting, is generally carried out on foot and should have no additional effects on soils in the activity areas.

Four-wheel and two-wheel motorcycle use is rapidly increasing throughout many Forest Service lands. A portion of this use is off-road and illegal, sometimes causing significant detrimental soil disturbance. Forest thinning can increase illegal off-road activity, as site distances increase; the temptation to illegally travel cross-country travel becomes great. Leaving an appropriate amount of woody debris on the ground greatly discourages cross-country motorized use. Temporary roads would be reclaimed which includes placing woody material on the road template (See Design Criteria, Table 2-15). This would help curb illegal off-road motorize traffic. Cumulative effects are not expected from this use.

Cumulative Effects of Fire and Fire Suppression

In the late 1800s and again in 1926, a large percentage of the project area burned over in hot, fast-moving fires. Since 1926, the only large fire in the project area was the Crazy Horse Fire in 2003. Though the fire was in the general project area it did not affect any of the proposed harvest units and should have no cumulative effect to soils within treatment units. For the most part fire suppression efforts have kept fires relatively small. The affected areas have recovered and no observable lasting effects to soils were found.

Active fire suppression has protected much of the Hemlock Elk Area over the past decades, but has resulted in increased fuel loading. The proposed harvest would aid future suppression activities by reducing current levels of infected dead and dying trees, thereby reducing the potential for larger scale fires. The benefits of fires with lower intensity and severity would include a reduced potential of excessive soil heating and sterilization as well as hydrophobic conditions that tend to increase sediment movement, flooding, and possible slope instability (deDios Benavides-Soloria and McDonald 2005; Neary et al. 2005).

On small wildfires, disturbance from fire suppression activities is usually limited to hand tools; most hand fire-line construction has only minor (insignificant) impacts to the soil resource. During fire suppression, closed roads may be reopened for access and incorporated as fire line. As part of the post-fire work, the areas of disturbance are rehabilitated and the roads returned to their previous condition in most cases.

Cumulative Effects of Grazing

No past, present, or foreseeable cattle grazing occurs on NFS lands within the project area.

National Forest Management Act (NFMA)

Noxious weed monitoring and treatment would occur as needed and would follow guidelines established in the NIWC EA (USDA 2001). Effects to soil resources were analyzed in the document and its adaptive strategy. No additional effects to soils beyond what was analyzed for and disclosed in the EA are expected to occur.

Cumulative effects of Ongoing and Reasonably Foreseeable Activities

The known ongoing and foreseeable activities in the area would not overlap in space with the current proposed activities and, therefore, would not have cumulative soil impacts.

Regulatory Framework and Consistency

As stated above, two units (6 and 14) currently exceed the Regional Soil Quality Standard and two units (5b and 12) are predicted to exceed the standard with proposed activities (See Table 3-7). Restoration treatments are proposed for these units and long-term soil productivity would be maintained within these units following restoration. The cumulative detrimental effects from project implementation and restoration would move these units toward a net improvement in soil quality. Several other units are approaching the 15 percent standard. Design Criteria, such as harvesting on dry or frozen conditions, maintaining 100-foot spacing between skid trails, and reusing existing skid trails would reduce cumulative impacts and maintain soil productivity.

Design Criteria would protect those processes and elements that maintain soil biophysical resiliency. For example, retain appropriate litter and duff layers by using light-on-the land logging techniques, retaining enough standing trees for annual litter contributions, burning under appropriate conditions, and allowing recommended volumes of large woody debris to stay on site.

All Forest Plan management direction would be met by the proposed alternatives.