IX. SOILS

Introduction

This section discusses the components of the soil resource that could be affected by the proposed activities. They are:

- Soil productivity
- Soil erosion
- Mass failure

Soil Productivity

Soil productivity is the ability of the soil to supply the water and nutrients needed to sustain plant growth. Characteristics that influence soil productivity include physical soil characteristics, organic matter, and soil biological activity.

Physical Soil Characteristics

These characteristics include soil depth, the amount of pore space in the soil, and bulk density. Changes in soil characteristics occur when ground-based equipment makes repeated passes over the soil (Lull 1959). These activities compress or compact soils and, if soils are wet enough, can cause rutting and puddling. All of these changes to the physical soil characteristics reduce the pore space volume, gas exchange, and water holding capacity. This in turn reduces the infiltration rates and soil drainage, impedes root growth through soils, and reduces plant-available water and nutrients. Physical soil disturbances also alter the amount of carbon dioxide and oxygen in the soil, affecting both plants and soil biota.

Organic Matter

Organic matter in its various forms contributes to soil productivity. Humus is decomposed organic matter. Duff and litter are partially decomposed leaves, needles, and twigs on the surface of soils. Large woody debris consists of woody stems greater than three inches in diameter (Harvey et al. 1994). Decomposed large woody debris supplies moisture to plants after the soils dry out. All organic matter provides water and nutrients for soil organisms and plants. Garrison and Moore (1998) found 85 to 90 percent of the total nutrients in most coniferous trees are contained in the branches, twigs, and foliage. Prescott and Laiho (2002) found the contribution of nutrients from large woody debris to be relatively minor.

Soil Biological Activity

Soil organisms, including fungi and bacteria, drive the nutrient cycling process by decomposing organic matter and releasing the nutrients for use by plants. Soil organisms depend on organic matter for the nutrients they need to carry out their life processes. Decomposed large woody debris provides important habitat for the survival of mycorrhizae fungi. These fungi form a symbiotic relationship with tree roots, increasing water and nutrient uptake by the trees and the fungi (Perry et al. 1990).

Soil Erosion

Soil erosion is the movement of soil particles by water, wind, or ice. In forested sites on steep slopes, water is the most common cause of soil erosion. Erosion is infrequent on undisturbed forest soils for two reasons: (1) abundant organic matter provides a protective blanket on the soil surface that reduces the impacts of raindrops and allows water to infiltrate; and (2) the surface soil below the organic layer is by nature porous, allowing water to move into and through the soil profile (Goldman et al. 1986).

Soil erosion can occur when the surface soil is compacted or when the loose surface soil and its protective layer of organic material are changed by management activities. Compaction, rutting, and puddling reduce the movement of water into the soil, and tend to channel and concentrate water. As a result, run off is increased (overland flow) and carries soil particles with it. Natural occurrences (e.g., fire) can remove organic matter from the soil surface. When organic matter is removed, soil pores can be plugged by impact from raindrops resulting in overland flow and increased rates of soil erosion.

Mass Failure

Mass failures can be caused by natural or man-made disturbances, and they may result from sequences of natural events (for example high-intensity precipitation followed by a trigger such as an earthquake). Some areas are prone to mass failures because of the nature of the geology or soil.

Management activities can saturate soil by channeling water and concentrating it onto a limited area, for example below a road culvert or a rutted skid trail. Mass failures triggered by human causes are detrimental soil disturbances. These disturbances cause long-term changes in soil productivity that may last centuries.

Information Sources

Forest Service Manual Section 2550 and the Region 1 Supplement 2500-99-1 (Firefighter Project File) provide direction for maintaining soil quality. Numerous bulk density samples have been taken from the Flathead National Forest in areas that were managed for timber production. Two statistical analyses of bulk density measurements establish their validity in determining the effects of management on the ground. These reports (‘Comparison of soil bulk density’ report and the ‘New soil disturbance’ report) may be found in the Firefighter Project File (Project File).

A study of soil moisture trends on the Flathead National Forest (Project File) demonstrates the existence of time when soils are sufficiently dry (soil moisture less than field capacity) to reduce soil detrimental disturbances, a practice recommended in literature cited in this document. Literature has been cited that documents the effectiveness of design criteria proposed to reduce anticipated detrimental soil disturbance from the Firefighter Project. In addition, monitoring reports for activities on soils similar to those in the Firefighter Project area (Project File) were used to estimate the effects of the proposed activities. Information gathered from field investigations was used to determine cumulative effects. A summary of the field investigations

are in Table 3-43, and the spreadsheets containing field transect data are located in the Project File (Firefighter Project soil quality monitoring).

The soils in the project area are described in the updated landtype report for the Flathead National Forest (USDA Forest Service 1983). Landtypes are the basis for the soil analysis. All soils are classified according to the system of Soil Taxonomy, a system used to classify soils according to their limitations that affect specific practical purposes. Classification allows soils to be grouped to permit the largest number and the most precise predictions possible about responses to use and management (USDA Natural Resources Conservation Service 1999). This system allows for monitoring results from one taxonomic unit to be related to other, similar taxonomic units.

Analysis Area

The analysis area forms the boundary for the direct, indirect, and the cumulative soils effects analysis. The spatial analysis area consists of the proposed activity areas for Alternative 2 as described in Chapter 2. This analysis area was selected because it is where the effects of implementing the proposed activities would occur. The effects on soils would not extend beyond the units proposed for treatment. The temporal bounds for analysis is at most 70 years, the maximum time mentioned in literature for soil compaction to persist. Our own field investigations have determined effects on skid trails and less disturbed sites from past activities to be difficult to detect after 40 years.

Affected Environment/Existing Condition

Field investigations were conducted to determine the existing condition of soils within the proposed activity areas. The investigations determined if and how existing soil conditions were affected by past management activities and other dispersed activities, such as off-highway vehicle travel and firewood cutting. In addition, places within the proposed activity areas requiring design criteria to address sensitive soil conditions were identified; these included sensitive soils that are wet, steep, lacking adequate soil cover, or had evidence of past harvesting that caused compaction, displacement, rutting, puddling, or soil erosion.

Most soils on the Flathead National Forest, including those within the project area, have a surface that formed in volcanic ash material, thus they are similarly classified. Most soil quality monitoring on the Flathead National Forest has occurred on soils with a volcanic ash surface, so there are a large number of both quantitative density measurements and qualitative ratings that relate to the soils in the project area. This information has two valuable implications:

1. We can estimate the amount of detrimental soil disturbance that exists from past management activities by doing transects and observing the amount of visible detrimental disturbance present.
2. We can estimate the amount of detrimental soil disturbance to expect from proposed management activities on given soil types, and thus estimate the effects on the soil resource.

Soil Quality Evaluations

The Northern Region Soil Quality Monitoring Protocol (USDA Forest Service 2007d) was used to determine the existing condition of all proposed units. This protocol provides a method for systematically quantifying soil conditions based on visual qualities. The Forest Soil Scientist determines which visual classes represent detrimental soil disturbance based on the characteristics of the soils within the project area. For the Firefighter Project Area, where soils are shallower and water holding capacity is lower than in other parts of the Flathead National Forest, visual soil disturbance classes 2 and 3 are detrimental soil disturbances. Classes 0 and 1 are not detrimental.

All soil quality data was collected and entered on a field data logger. Spreadsheets from the field visits are summarized in the Project File, (Firefighter Project soil quality monitoring). Table 3-43 summarizes the results of the field investigation for each proposed unit.

Table 3-43. Percent Detrimental Soil Disturbance for Proposed Units

Unit	Past Harvest Type	Harvest Year	Percent Detrimental Disturbance	Comments
2a	Precommercial thin by hand	1976	3	Old skid trails
2b	Precommercial thin by hand	1976	0	None
3	None	None	0	None
5	None	None	0	None
6	None	None	0	None
7	None	None	0	None
8	None	None	0	None
9b	None	None	0	A few signs of past disturbance
9c	None	None	0	A few old skid trails
11	None	None	0	A few old skid trails
13a	Overstory removal	1957	0	A few old skid trails
13b	Overstory removal	1957	0	A few old skid trails
13c	Overstory removal	1957	0	A few old skid trails
13d	Overstory removal	1957	0	A few old skid trails
13e	Overstory removal	1957	0	A few old skid trails
13f	Overstory removal	1957	0	A few old skid trails
14	None	None	3	Old skid trails
15	None	None	0	None
16	Overstory removal	1969	3	Old skid trails along west edge of unit
18	None	None	0	Roller thinned in south east quarter of unit; a few old skid trails in west portion of unit
19	Precommercial roller thin	1972	0	Most of unit was roller thinned
20	None	None	0	None
21	Salvage	1979	0	Old skid trails in south end of unit

Unit	Past Harvest Type	Harvest Year	Percent Detrimental Disturbance	Comments
23	None	None	0	A few old skid trails scattered throughout the unit
26	None	None	0	None
29	Overstory Removal	1969	2	Northeast edge of unit was roller thinned
	Salvage	1982		
30	None	None	0	None
40	None	None	0	None
41	Precommercial thin by hand	1973	0	A few old skid trails scattered throughout the unit
	Overstory Removal	1980		
43	Overstory Removal	1965	0	A few old skid trails scattered throughout the unit
	Precommercial thin by hand	1973		
47	Overstory Removal	1969	0	A few old skid trails scattered throughout the unit
49	None	None	0	A few old skid trails scattered throughout the unit
50	None	None	0	A few old skid trails scattered throughout the unit
56	Precommercial thin by hand	1976	0	Old skid trails scattered throughout the unit
60a-x	Precommercial roller thin	1964	2	A few old skid trails
61	None	None	0	None
70	Precommercial thin by hand	1977	9	Compacted skid trails and evidence of displacement
	Clearcut	1993		

Field surveys found past disturbance within some units that have no database record. In these cases, the above table shows no previous harvest activity and no date, but it does quantify and describe the amount and type of detrimental soil disturbance found within these units. The units that had past activities but had no measured detrimental soil disturbance might have recovered or were logged in a manner that minimized detrimental soil disturbance.

Trends

Soil quality in the Firefighter Project area is stable to trending upward. Past activities were completed up to 50 years ago. Literature indicates that disturbed soils improve by means of soil organisms, root growth, freeze/thaw cycles, wet/dry cycles, and additions of organic matter. These natural processes effectively ameliorate compacted soils (Lull 1959). Gonsior (1983) reviewed literature and found that compacted soils recover in 10 to 70 years.

Field notes from the investigations for this project indicate that most disturbed soils have abundant organic matter and roots throughout the upper soil layers (‘New soil disturbance…’ report in the Project File). In addition, the pre-harvest surveys of the proposed units show that many old disturbances including skid trails and areas that were thinned are no longer detrimentally disturbed; this indicates that they are recovering and soil quality is trending upward.

Landtypes and Interpretations

Table 3-44 lists landtype map units for the proposed units. It also lists soil interpretations for project-specific effects. This information is from the Soil Survey Report for the Flathead National Forest (USDA Natural Resources Conservation Service 1998). Table 3-45 identifies soil conditions specific to some units.

Table 3-44. Landtypes by Unit

Units	Landtype	Productivity	Sensitive Soils	Erosion Risk	Soil Features
2a, 2b, 3, 6, 7, 8, 11, 19, 20, 21, 23, 26, 29, 40, 50	26J-8	High	Yes	Moderate	Very Gravelly Sandy Loam textures
5	26J-8	High	Yes	Moderate	One-half of this unit is on an historic mass failure (LT* 31). No indicators of current instability are present
	31		No		
9b, 14, 16, 18, 30	24-9	Moderate	No	Moderate	Very Gravelly Fine Sandy Loam textures
9c	24-9	Moderate	No	Moderate	One-quarter of this unit is on a historic mass failure (LT 32). No indicators of current instability are present
	32	High			
15	32	High	No	Moderate	This unit is on a historic mass failure (LT 32). No indicators of current instability are present
13a-x, 60a-x	26C-8	High	No	Moderate	Gravelly Silt textures
41, 43, 47, 49	26L-8	High	No	Moderate	Gravelly Silty Clay Loam
	57-8	Moderate			Very Gravelly Silt Loam textures
	76	Low			Silty textures, steep slopes
61	26J-8	High	No	Moderate	Very Gravelly Sandy Loam textures
	24-8	Moderate			Gravelly Loam textures
70	24-8	Moderate	No	Moderate	Gravelly Loam textures

*LT = landtype

Table 3-45. Special Soil Conditions by Unit

Unit Number	Soil Features
3	Wet spots where Aspen grows
5	Wet draw in center of unit
9c	Ridges on north and east sides of unit have shallow rocky soils
11	Shallow rocky soils on southeast edge of unit
14	Thin soils in east part of the unit
15	Thin soils in upper part of the unit
30	Thin soils on southwest edge of unit

Productivity

Soil productivity in the Firefighter Project area is predominantly high, with a few moderately productive soils. However, all soils within the proposed units, with the exception of a few shallow, rocky inclusions, 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. The high rock content of many of the soils also promotes water movement through the soils. Runoff from these soils is uncommon; however, when the surface volcanic ash layer is disturbed or removed, water erosion is possible on landtype 26L-8. These soils have higher clay content than other soils and have a higher risk of runoff and erosion on disturbed skid trails and landings.

Sensitive Soils

Landtypes 26L and 26J have soils with potential for slow movement of water into compacted skid trails or landings. This characteristic results in the potential for overland flow that causes soil erosion and sediment. Design criteria described in the Design Criteria section of Chapter 2 would reduce the likelihood of rutting skid trails within these units, thus reducing the risk of overland flow and erosion. Proper surface drainage is also necessary on all roads and skid trails that cross these soils. Temporary roads could have low strength and be subject to rutting when wet, increasing the potential for sediment. Operations timed to coincide with the dry season or winter operations are the best options for these Landtypes.

Mass Failure

Soils in Landtype 31 formed in landslide deposit parent material. This landtype is characterized by historic mass failure deposits. One 0.4-mile section of proposed temporary road to Unit 5 would be located on this landtype. Material exposed in cutbanks during road construction tends to slough if the cutbanks are steep, and landslides can damage roads in places. A suitability assessment of this temporary road location was performed and it was determined to be suitable for the intended use. Determination was based on slope evaluations and lack of active landslide activity along proposed route.

Environmental Consequences

Introduction

The analysis of effects for soils assumes that all design criteria outlined in Chapter 2 would be effectively implemented. The analysis will show the expected amount of soil disturbance resulting from the implementation of the alternatives, and will describe the risk that the expected amount of disturbance would be exceeded. Proposed design criteria were implemented in

previous projects and monitored for effectiveness. Monitoring reports are located in the Project File for trail spacing, summer logging on dry soils, the use of excavators, and skyline logging.

The soil analysis process is described in the Soil Analysis Guideline contained in the Project File (Firefighter Project soil quality monitoring). Cumulative effects are discussed in terms of the activity areas. The Forest Service Manual (FSM) R-1 Supplement No. 2500-99-1 (Project File) defines an activity area as a land area affected by a management activity to which soil quality standards are applied. An example of an activity area is a harvest unit or an ecosystem burn unit. Soil quality standards do not apply outside of an activity area.

The soil analysis is based on the current soil condition (the amount of detrimental soil disturbance still in existence) as determined from field visits; it analyzes the expected changes in soil condition caused by implementation of the proposed management activities. Detrimental disturbances are defined in FSM R-1 Supplement No. 2500-99-1 (Project File) as the condition where established soil quality standards are not met and the result is a significant change in soil quality. The FSM states that at least 85 percent of an activity area must have soil that is in satisfactory condition.

The FSM defines the Regional Soil Quality Guidelines in terms of detrimental soil disturbance, which includes:

- Compaction
- Rutting
- Displacement
- Severely-burned Soil
- Surface Erosion
- Soil Mass Movement (Mass Failures)

It is important to consider that not all soil disturbances are detrimental disturbances. Past monitoring of projects on the Flathead National Forest suggests that some soil disturbances create bulk density below the levels that inhibit root growth (‘Comparison of soil bulk density’ report in the Project File). Research by Powers et al. (2005) showed that increased bulk density on coarse textured soils resulted in increased production capacity because of associated increases soil water holding capacity. They also noted that increases in bulk density were not reflected in site production if an understory was absent. In other words, reducing competition from forbs, brush, and trees can leave increased resources for the remaining vegetation, even if soil bulk density increases.

The effects indicators used for soils were changes in:

- Soil productivity
- Soil erosion
- Mass failures

Alternative 1 (No-Action Alternative)

Direct and Indirect Effects

Alternative 1 provides a baseline to evaluate the effects of the Action Alternatives. The effects on soils are discussed as changes over time on soil productivity, soil erosion, and mass failures.

Soil Productivity

Alternative 1 would not cause short-term effects on the soil resource over and above the existing condition. No additional road building, road decommissioning, salvage harvest, or fuels reduction would disrupt the natural soil processes.

Physical Soil Characteristics

Alternative 1 would not cause soil compaction, rutting, puddling, or soil displacement. Undisturbed soils would remain so. Soil productivity in areas where past timber management compacted soils would slowly improve as plant roots, soil organisms, and freeze-thaw events loosen the soil. Most soil disturbances would recover after about 70 years (Gonsior 1983). Sites that were slightly compacted would recover in fewer than 70 years; and displaced, rutted, and puddled soils would have reduced productivity for a longer time than compacted soils.

Organic Matter

With implementation of Alternative 1, standing dead trees would eventually fall over and contribute coarse woody debris. Needles and branches would remain on the site and fall to the ground. Soil organisms would decompose the organic materials, thus adding humus to the soil. Nutrients associated with this material would slowly become available for plant growth. As the tree canopies close and shade the soil surface, decomposition rates would slow, allowing organic matter and nutrients to accumulate on the soil surface. This process would continue until another major disturbance (e.g. fire, windstorm) opens the tree canopy and speeds up the recycling process again.

An intense wildfire is a possibility at some time in the future. This event could reduce the amount of organic matter and associated nutrients on the site, although this change would be temporary. Historically, in the Flathead National Forest, forests regenerate after wildfires.

Soil Organisms

Microorganism populations would fluctuate with the changes in the microclimate and the organic matter on the soil surface. This would be in response to the changing vegetation, which occurred because of natural events such as fire, insect, and disease. Any changes would be buffered by the capability of soil microbial communities to adapt to changing conditions on very short time scales (Schmidt et al. 2007).

Soil Erosion

Alternative 1 would allow any current soil erosion to decrease as vegetation returns to soils that lack plant cover. Wildfires could cause a short-term increase in soil erosion. Soil erosion rates would fluctuate with natural changes in vegetation.

Mass Failures

Alternative 1 would not change the risk of mass failures within the project area.

Alternatives 2 & 3 (Action Alternatives)

Direct and Indirect Effects

Soil Productivity

The following paragraphs are based on our intent to maintain soil quality by designing the skid trails and landings so they occupy less than 15 percent of each activity area, and to use site preparation methods that minimize soil detrimental disturbance. In addition, the implementation of design criteria has the potential to reduce soil impacts further.

Physical Soil Characteristics

Ground-Based Harvest: Ground-based harvesting would cause direct and indirect effects on soil physical characteristics within the boundaries of proposed activity areas. Most detrimental effects would be concentrated on the proposed skid trails, temporary roads, and landings within or associated with timber harvest units. Minimizing the area occupied by landings and skid trails to reduce the detrimental effects on soil productivity from changes in physical soil properties is recommended in several papers (Garland 1997, Williamson and Nielson 2000, Page-Dumroese 1993).

Skid trails and landings would be laid out to occupy less than 15 percent of a unit. The Project File contains an exhibit demonstrating that spacing skid trails 75 and 100 feet apart limits detrimental disturbance to less than 15 percent of the activity area. Garland (1997) noted in a paper on minimizing soil effects from timber harvest, that designated skid trails spaced 100 feet apart impact 11 percent of the harvest area. Monitoring of soil conditions on the Flathead National Forest after timber harvest consistently shows less than 15 percent detrimental soil disturbance from ground based operations that use designated skid trails (Hunger Henry timber sale monitoring report in the Project File).

In addition to using designated skid trails and landings, there is the potential to reduce soil effects further by limiting equipment operation, to the extent possible, on skid trails when the soils are drier than field moisture capacity. Startsev and McNabb (2001), and McNabb et al. (2001) found that soil compaction is reduced when soils are drier than field capacity. Williamson and Nielson (2000) noted that rutting and puddling are most often associated with logging on wet soils. Soil moisture monitoring on the Flathead National Forest has shown that soils are drier than field capacity during the summer dry

period, which begins in early summer and often lasts through October (Project File). Most summer logging would occur when soils are drier than field capacity. Thus, by operating on low soil moisture conditions, we have the potential to reduce the amount of detrimental disturbance on skid trails.

Han (2006) showed that heavy slash (about 40 kg/m2) was effective for buffering the effect of equipment operation on mineral soil. Thus, if cut to length systems are used and heavy slash is maintained on the skid trails, detrimental effects could be reduced. The same research noted that cut to length harvesting systems, which stay on designated skid trails, create detrimental soil disturbance on about 10 percent of the harvested area. Han et al. (2006) noted that logging when soils are drier than field moisture capacity reduced the amount of compaction associated with cut to length logging. Monitoring on the Flathead National Forest Duck Bill Timber Sale showed that 8 units logged with a forwarder all met the soil quality standards with less than 15 percent detrimental soil disturbance (Project File).

Skyline Timber Harvest: This operation would cause direct and indirect effects on soil physical characteristics within the boundaries of the proposed activity areas. However, the effects would be less than from ground-based operations. A literature review by McIver and Starr (2000) found that skyline yarding disturbed 2 to 8 percent of the soil in a unit. Alexander and Poff (1985) state that skyline yarding disturbs from 10 to 40 percent of activity areas. However, they did not differentiate between detrimental and non-detrimental disturbance. Monitoring results on the Flathead National Forest show skyline yarding had consistent levels of detrimental disturbance on less than 15 percent of an activity area.

Monitoring of skyline units on the Riffin Sale on the Tally Lake Ranger District showed 7 to 9 percent detrimental disturbance on ash-cap, glacial till soils, which included the effects from falling and pre-bunching logs with a tracked feller-buncher and a broadcast burn after the harvest (Riffin Salvage timber sale soil monitoring report in the Project File). Pre-bunching of logs with a feller-buncher is equivalent to following skyline yarding with site preparation by an excavator. These are basically the same piece of equipment with a different tool at the end of the mechanical arm. Doogan Dog Sale Units 6A and 6B were skyline yarded and then broadcast burned. Monitoring showed they had 9 percent detrimental impacts, which included impacts from an old road at the bottom of the unit (Project File).

Helicopter Timber Harvest: McIver and Starr (2000) discuss the amount of soil disturbance from various yarding systems. Helicopter yarding avoids all impacts from ground-based equipment within a cutting unit. Less than 1 percent of an activity area is disturbed and it is unlikely to be detrimental. Several acres of soil would be disturbed for use as individual helicopter log landings and service areas. Landings would be located on flat areas away from streams and outside of the cutting units. Helicopter landings would be ripped to lessen compaction and increase movement of water into the soil when they are no longer needed. In some cases, roads would be used for helicopter landings, which would have no effect on soil productivity.

Excavator Piling: Excavator piling of logging slash minimizes changes to physical soil properties. All mechanical slash piling or fuel reduction would be accomplished with excavators. This method reduces the aerial extent of detrimental soil impacts from the site preparation activities (see 1992 Forest Plan Annual Monitoring Report). Excavator effects have been monitored on the Flathead National Forest since the early 1990s. Approximately 200 bulk density samples were collected where excavators had worked. Those samples exhibited minor increases in soil bulk density ('Comparison of soil bulk density' report in the Project File). In addition, when they are used on slopes less than 45 percent, displacement of the topsoil is rare.

Lop and Scatter: Treatment in Unit 70 would cut down lodgepole pine between 2 and 6 inches in diameter. Removal would be accomplished by cutting with chainsaws and hand removal. No detrimental soil disturbance would occur from the hand cutting of trees.

Broadcast Burning: Light and moderately burned areas have minor effects well within the natural range of variability for wildfire. Areas burned under conditions that produce light or moderate burn severity would vegetate quickly because they retain viable seeds or roots that could produce more plants and because the soil contains a complement of microorganisms and nutrients (Ryan and Noste 1983). The effects of light-intensity, short-duration burning that does not result in consumption of the duff layer does not strongly affect soils. Duff acts as an effective insulator, protecting the soil from excessive heating (Hartford and Frandsen 1992). Effects of this type of burning are generally short-lived (Neary et al. 1999), therefore, effects from past burning are not considered to contribute to cumulative effects, and will not be discussed further.

Summary for Physical Soil Characteristics

Local monitoring and literature indicates that Regional Soil Quality Standards can be met using designated skid trails that occupy less than 15 percent of the harvest area. Additional protection of the soil resource would be afforded by operating ground-based equipment when soils are dry; operating in winter on snow or frozen soils; or operating equipment on a dense slash mat. Cut to length harvesting also meets the Regional Soil Quality Standards as indicated by both local monitoring and literature. Literature and local monitoring on soils similar to those in the project area indicate that skyline logging would meet the Regional Soil Quality Standards. The effects from skyline yarding would impact less soil than ground-based equipment when used on the appropriate slopes. Excavators used to treat slash minimize detrimental disturbance levels. Excavator piling was monitored on the Flathead National Forest and was determined to have caused few detrimental impacts ('New soil disturbance' report in the Project File). When excavator piling was used in combination with ground-based logging systems, Region 1 Soil Quality Standards were met.

Organic Matter

Several different treatments are proposed for the Firefighter Project. These treatments would leave varying amounts of soil organic matter (SOM) on the site. Reduced SOM can be

associated with reduced soil nutrient levels. The question would be, has enough SOM been left on the site to maintain long-term soil quality.

The total amount of nutrients on a site would likely be reduced where SOM would be removed or displaced. However, the plant available nutrients (those released from organic matter) would increase due to the increased incoming solar radiation and soil moisture, conditions that accelerate the decomposition of the remaining SOM and the corresponding release of plant-available nutrients in the treated stands (Harvey et al. 1994). After project implementation, competition between trees would be reduced because fewer trees would remain on the sites. This situation could result in more available nutrients and water for the remaining trees. Powers et al. (2005) discussed this possibility along with the result that remaining trees exhibit increased growth, vigor, and disease resistance.

One must also consider that nutrients stored in the soil and SOM are not the only nutrients available to the forest vegetation. Jurgenson et al. (1981) studied logging followed by low severity slash burning in northwestern Montana. The authors concluded there would be no long-term depletion of nitrogen reserves, because lost nitrogen would be more than replenished by inputs from precipitation and by biological nitrogen fixation over a rotation of 100 to 150 years.

Harvey et al. (1994) stated that it is most difficult to resolve the loss of nutrients on sites with high fire potential. The potential result of this proposed project would be to reduce the risk of wildfire by reducing fuels within the activity areas and increasing live tree spacing. More nutrients and organic matter would remain on these treated sites compared to a site burned by a severe wildfire, and thus would remain within the historic range of natural variability for SOM.

All harvest prescriptions would leave a portion of the existing stand on the site. The proposed treatments are described in detail in Chapter 2 of this document. Remaining living trees in stands would serve as potential nutrient sources on the site for sustaining the future forest.

> Regeneration Treatments: These treatments (seedtree, clearcut, and shelterwood harvests) would remove larger amounts of live vegetation and have the potential to remove larger amounts of organic matter than intermediate harvests. The seedtree and clearcut units could also be logged with whole tree yarding, which would remove some branches and needles from the stand to the landing for disposal.
>
> Units proposed for underburning would leave nutrients associated with the slash on the site to be used by the remaining forest vegetation. Site preparation in the units that are not proposed for burning would be delayed for one wet season to reduce the loss of nutrients. This would provide time for nutrients to leach from the organic debris and for needles to fall off as discussed in Garrison and Moore (1998). The units proposed for underburning instead of whole tree yarding would retain nutrients on site, thus a delay is not necessary in those cases.
>
> All harvest prescriptions would leave a portion of the existing stand on the site. The proposed treatments are described in detail within Chapter 2 of this EA. Timber

management that leaves trees on the ground also leaves nutrients on the site for sustaining the future forest.

Thinning Treatments: This treatment would leave a large portion of the existing stand on site, which would maintain more organic matter on the site than the regeneration treatments.

Hand Thinning Treatments: Unit 70 would be treated by hand and have the slash lopped and scattered throughout the unit. Organic matter would not be removed and there would be no measurable ground disturbance associated with this activity.

Excavator Piling: This post-harvest treatment would be used for all mechanical site preparation work. The proposed site preparation activities would reduce organic material on sites while reducing hazardous fuel loads. A variety of organic material would remain on the site after project implementation.

Broadcast Burning: This treatment is proposed to reduce fuels, to prepare the site for planting, and to stimulate browse species for ungulates in some units. It would accomplish these objectives while maintaining residual trees. Burning would occur when soils are moist enough to reduce soil heating. Both excavator fuels reduction and broadcast burning would meet the Regional Soil Quality Guidelines. Harvey et al. (1994) note that careful prescribed burns or mechanical site preparation can be practiced on most sites with relatively little effect on soil organic content. Harvey et al (1994) also state that on sites with fragile organic horizons, productivity would be maintained or improved by conserving as much organic matter as possible.

Summary for Organic Matter

All proposed units would leave some live vegetation. In proposed regeneration treatment units, slashed and unmerchantable material would remain on the site until most of the needles fall off prior to piling and burning or broadcast burning of the material. In addition, much of the living grass, forb, and shrub components would be left behind in all of the proposed units. Many live trees would remain on all of the sites with the fewest trees left on the proposed clearcut and seedtree harvest units. The material that remains in all of the units would provide an active microorganism-rich organic layer on the soil surface.

Carbon Sequestration

One comment related to the projects' anticipated effect on soil organic carbon (SOC) stores was submitted during public scoping. A thorough literature review revealed a broad range of post-harvest SOC densities, which vary greatly over time following timber harvest (Lal 2005). Results from a study in northern hardwood forests (Covington 1981) have driven much of the discussion in this area over the past quarter century. This study showed as much as 50% of SOC in stands was lost within the first 30 years or more following harvest, with a return to pre-harvest SOC levels around 60 years following harvest. Subsequent studies have resulted in findings varying from post-harvest increases in SOC to losses approaching values presented in

Covington. Careful implementation of forest harvesting activities may have minimal or no effect on SOC levels (Lal 2005).

As of 2007, global atmospheric carbon dioxide levels were estimated at 381.2 parts per million (World Meteorological Organization 2007). It is assumed that any loss of SOC within the ranges discussed above resulting from implementation of either Action Alternative would not have a measurable effect on global atmospheric carbon dioxide levels. Given the state of controversy and wide variation in reported levels of post-harvest SOC loss, any conclusion concerning project contributions at this time would be speculative at best.

Soil Microorganisms

Jurgenson et al. (1977) note that post-fire recovery of soil microorganisms occurs rapidly, frequently resulting in population levels greater than before the fire. Borchers and Perry (1990) discussed the important role that less disturbed areas of soil play in inoculating soil lacking or having reduced populations of soil microorganisms. They state that unburned areas within burns, adjacent undisturbed areas, large woody debris, and soils that have only minor amounts of disturbance contain propagules for fungi, bacteria, and other soil organisms; they also state that these propagules can be dispersed by wind, animals, and other agents.
The variety of organic matter left on the proposed harvest areas would benefit soil microorganisms by providing substrate and habitat. All alternatives would leave both dead and live trees on site. All alternatives and all proposed activity areas would have less than 15 percent of the area detrimentally disturbed, and many areas would be undisturbed by equipment. These areas would be a source of propagules for disturbed sites. The amounts of live and dead trees to be left in the proposed harvest areas are described in Chapter 2.

Soil compaction, puddling, rutting, and displacement reduce the ability of soils to exchange oxygen and carbon dioxide, thus affecting the ability of soil microorganisms to survive. Favorable habitat for soil organisms would be maintained because all proposed harvest areas would be designed to reduce soil disturbance to meet Regional soil guidelines.

Summary for Soil Microorganisms

Because the amount of detrimental physical soil changes would be minimized, and because organic matter in various forms would remain on the proposed units, the effects to soil microorganisms would be minor. Soil microorganisms are mobile. They can quickly re-colonize disturbed sites from adjacent, undisturbed sites. A variety of organic matter would remain on all sites, including living trees and other forest vegetation. In addition, the organic layer on the soil surface would be retained over at least 85% of the area, providing habitat and nutrients for soil microorganisms.

<u>Soil Erosion</u>

Where there is a risk of soil erosion, it would be minimized by implementing the following management practices:

- Reducing the area where equipment operates.

- Locating landings on relatively flat ground that can be drained.
- Locating skid trails on slopes less than 35 percent that have soils with a low or moderate erosion hazard.
- Using erosion control features such as water bars, replanting, and placing slash on disturbed soils.

Management activities that leave organic matter on the soil surface reduce soil erosion. Using these management tools in the Firefighter Project would minimize soil erosion. Watershed Erosion Prediction Project estimates (refer to disturbed WEPP results in the Project File) demonstrate that the typical erosion control measures used on skid trails would reduce erosion rates on a 25 percent slope by 80 percent, if slash covered 50 percent cover of the trail and water bars reduced the slope length to 50 feet. Detrimental effects caused by soil erosion are long term. Given the time required for new soil formation, soil loss is effectively permanent.

Soil Erosion would be unlikely to occur because of the hand treatments. If thinning slash is lopped and scattered it would add cover to the soil surface, reducing the risk of erosion.

Mass Failures

The majority of proposed mechanized treatments are planned for a landscape with slopes less than 40 percent, which greatly reduces the risk of mass failures. However, part of the temporary road to Unit 5 is partially located on a landtype map unit characterized by historic mass failures. Application of road best management practices (BMP) would reduce concentrations of road surface drainage, reducing the risk of mass failures associated with road drainage.

Temporary Road Construction

All temporary roads constructed for this project that utilize existing road templates would be reclaimed by any site-appropriate combination of the following:

- Removing any installed culverts or temporary bridges
- Installing erosion control features where needed
- Placing large woody material on the template
- Seeding with the native plant mix as specified by the Forest Botanist.

In addition, all newly constructed temporary roads would be reclaimed after use. Reclamation of new temporary roads would include recontouring the entire road template to natural ground contour, and to the extent feasible, placing the top soil back on the soil surface. These restoration activities would not ameliorate the soil damage immediately, but they would improve soil conditions compared to a temporary road. The establishment of vegetation and associated additions of organic matter would encourage recovery. Recontouring, where it occurs would loosen the soil, further providing a suitable seed bed for native forest vegetation. These conditions would accelerate the recovery of the soil effects related to temporary roads as discussed in the first part of this document.

Much of the predicted increases in detrimental soil impacts are directly related to temporary road construction. Mandatory reclamation of temporary roads would reduce predicted amounts of

detrimental soil impacts in the associated treatment units. Reclamation of new temporary roads would include re-contouring the entire road template to natural ground contour and, to the extent feasible, placing top soil back on the soil surface. Table 3-46 summarizes the predicted reduction of detrimental impacts, by unit, expected from temporary road reclamation.

Table 3-46. Predicted Detrimental Disturbance Ranges Following Temporary Road Reclamation

Unit Number	Pre-Reclamation Disturbance Range	Post-Reclamation Disturbance Range
3	12-16	10-14
5	14-18	9-13
7	9-13	9-13
8	12-16	9-13
20	9-13	9-13
26	16-20	9-13
61	13-17	9-13

Duration of Direct and Indirect Effects

Displacement, the loss of topsoil, is a long-term, and perhaps permanent, loss of soil productivity. However, management practices outlined in the design features would reduce the amount of displacement and all other detrimental impacts to within the Region 1 guidelines.

Compaction lasts 10 to 70 years (Gonsior 1983). Monitoring of 30-year-old activities within this project area showed less than 4% detrimental soil disturbance now, indicating recovery of the compacted soils has occurred.

Reductions in organic matter content reverse quickly as vegetation grows. Organic debris accumulates on the surface, and roots grow and decompose in the soil. These organic materials break down and release nutrients, and improve the quality of the soil by improving its structure and reducing compaction and other detrimental soil disturbances. Loss of organic matter is a short-term change lasting about ten years once vegetation returns to the soil.

Light and moderate severity burned areas have minor effects well within the natural range of variability for wildfire. Areas burned under conditions that produce light or moderate burn severity would vegetate quickly due to viable seeds or roots that could produce more plants and the complement of microorganisms and nutrients remaining on site (Ryan and Noste 1983).

Changes in soil microorganisms are not permanent. Recovery would occur as soon as organic matter is present in the soil, which could be immediately after the proposed management activity.

Soil erosion would be controlled with erosion control measures. In addition, bare soils would naturally recover or be revegetated with native seed. Any erosion that occurs would be short-lived, most likely occurring during the time between the soil disturbance and the implementation of erosion control measures.

Comparison of Alternatives 2 & 3 (Action Alternatives)

The comparison of specific alternatives is based on the information presented in Table 2-11 in Chapter 2, which summarizes treatments by alternative. Alternative 2 has the highest risk of causing detrimental soil impacts because it treats more acres and implements more acres of regeneration harvest. In addition, this alternative would implement more site preparation and post-harvest fuel reduction with mechanical means than would Alternative 3. However, with implementation of the design criteria detailed in Chapter 2, Alternative 2 would meet the Region 1 Soil Quality Standards. Alternative 3 would treat fewer acres than Alternative 2, and with implementation of the design criteria listed in Chapter 2, this alternative would also meet the Regional Soil Quality Standards.

Cumulative Effects

The risks of cumulative effects were assessed within each proposed activity area. Cumulative effects consist of the impacts from all past, present, future, and proposed activities overlapping in time and space with the proposed project area. All units were reviewed on the ground to quantify and qualify the effects from past timber harvest and determine if existing levels of detrimental soil disturbance exceed the Region 1 Soil Quality Guidelines. The estimated cumulative effects for each activity area from implementation of an Action Alternative are displayed in Table 3-47

Table 3-48 displays the total acres of predicted detrimental soil disturbance caused by implementing the proposed activities. The Action Alternatives are designed to reduce the amount of detrimental soil disturbance by implementing the design criteria described in Chapter 2, with the intent of meeting the soil quality standards.

Table 3-47. Soils Cumulative Effects Summary

Unit Number	Percent Existing Detrimental Disturbance	Predicted Percent Project Disturbance by Category		Predicted Percent Cumulative Disturbance Range[2]	
		Logging	Temp Roads[1]	Alt. 2	Alt. 3
2a	3	4-8	0	7-11	7-11
2b	0	10-14	0	10-14	10-14
3	0	8-12	3	12-16[3]	0
5	0	8-12	6	14-18	0
6	0	8-12	0	8-12	0
7	0	8-12	1	9-13	0
8	0	8-12	4	12-16	0
9b	0	8-12	0	8-12	4-8
9c	0	0-2	0	1-3	0
11	0	8-12	0	8-12	4-8
13 a-x	0	8-12	0	11-15	0

Unit Number	Percent Existing Detrimental Disturbance	Predicted Percent Project Disturbance by Category		Predicted Percent Cumulative Disturbance Range[2]	
		Logging	Temp Roads[1]	Alt. 2	Alt. 3
14	3	8-12	0	11-15	7-11
15	0	3-5	0	3-5	0
16	3	10-14	0	13-17	13-17
18	0	8-12	0	8-12	0
19	0	8-12	0	8-12	4-8
20	0	8-12	1	9-13	0
21	0	8-12	0	8-12	4-8
23	0	8-12	0	8-12	4-8
26	0	8-12	8	16-20	12-16
29	2	8-12	0	10-14	6-10
30	0	8-12	0	8-12	4-8
40	0	3-5	0	3-5	3-5
41	0	10-14	0	10-14	10-14
43	0	10-14	0	10-14	10-14
47	0	10-14	0	10-14	10-14
49	0	10-14	0	10-14	10-14
50	0	10-14	0	10-14	10-14
56	0	10-14	0	10-14	10-14
60 a-x	2	8-12	0	11-15	0
61	0	8-12	5	13-17	0
70	9	0-2	0	9-11	9-11

[1]Percentage based on equivalent area of temporary road located outside of unit.
[2]The predicted percent detrimental soil disturbance is based on the soil analysis guide in the Project File ('Guidelines for analyzing environmental effects on soils' report). The actual amount of disturbance could vary. Unless otherwise described in the last column, estimates were made with the assumption that skid trails would be spaced an average of 75' apart and all activities would occur in summer under dry soil conditions. Operation on wet soils would increase it.
[3]Numbers do not add due to rounding.

Table 3-48. Detrimental Soil Disturbance Summary by Alternative

	Alt. 1	Alt. 2	Alt. 3
Total Treated Acres	0	749	355
Existing Acres of Detrimental Disturbance from Past Activities within the Proposed Activity Areas	22	22	20
Estimated Acres of Detrimental Disturbance from Proposed Activities	0	52	15
Total Estimated Cumulative Acres of Detrimental Disturbance following Project Implementation	22	74	35

There is no evidence of past or present domestic grazing within the borders of the project area.

Any off-highway vehicle use through proposed activity areas would have been identified and accounted for during the field surveys, although none was identified in the field notes.

Contrasting Effects of the Proposed Action with Past Actions

The estimated level of detrimental disturbance from this proposed project is less than that associated with harvest activities that occurred prior to 1990. During the past two decades, the level of concern for maintaining soil productivity has increased, which has been backed up by implementation of management practices that protect the soil. These changes include:

- The use of excavators instead of dozers for mechanical site preparation
- Cut to length yarding systems
- Use of designated skid trails
- Operating when soils are dry or when winter conditions would protect soil productivity
- Use of slash layers to reduce effects on skid trails

In addition, timber sales are audited for compliance with BMPs and are monitored as specified in the NEPA decision, both of which contribute to an improved result compared to the past.

Effects of Ongoing and Reasonably Foreseeable Activities

Most ongoing and foreseeable activities would not overlap with either Action Alternative in time or space. Specifically, their effects do not overlap in space as they occur outside of the proposed activity areas.

Combined Effects from Past, Proposed, Ongoing and Foreseeable Activities

Several proposed units in both alternatives would have cumulative effects from the combined past and proposed activities. These effects are displayed in Table 3-47. All proposed activities associated with both Action Alternatives would meet the soil quality standards with the implementation of the design criteria for soils described in Chapter 2.

Special design criteria are necessary to reduce potential, predicted cumulative effects to meet soil quality standards in Units 3, 5, 8, 26, and 61 in Alternative 2, and Unit 26 in Alternative 3.

Post-implementation monitoring of these units would be performed to determine if proposed the units were meeting the Region 1 Soil Quality Standards. The Sale Administrator would monitor all units during management activities to assure that skid trails occupy less than 15 percent of the area and that soil conditions in either winter or summer are adequate to minimize effects.

If monitoring results show soil disturbance in excess of 15 percent, specified restoration activities would occur to move the units back towards improved condition. Additional units that were treated in a similar fashion would also be monitored at this time.

Restoration efforts would be undertaken on these units if post-implementation monitoring indicates that detrimental soil disturbances for these units exceed equal 15 percent. Restoration activities to improve soil conditions would include lightly ripping heavily used skid trails and landings. The goal would be to reduce soil compaction and meet the direction provided in Region 1 Supplement 2500-99-1. Several studies discuss the effectiveness of ripping as a soil restoration activity. Studies cited by Froehlich and McNabb (1983) showed up to 39 percent improved seedling survival and growth after tilling compacted soils.

Dick et al. (1988) found subsoiling (tilling) restored biological processes that were reduced by soil compaction. In general, tilling or scarifying a compacted soil improves productivity by reducing the resistance of soil to root penetration and providing improved soil drainage and aeration to enhance seedling establishment and tree growth (Bulmer 1998). These conditions also improve the environment for soil microorganisms. Soil restoration is not the immediate result of ripping, planting, or any other activity. The goal of soil restoration is to create favorable conditions for impaired soils to begin the recovery process.

Regulatory Framework and Consistency

The soil analysis indicates that all alternatives and all activities proposed by the alternatives would meet the Region 1 Soil Quality Standards through the implementation of management practices outlined in Chapter 2 and restoration of landings and heavily used skid trails, if needed, to reduce the total amount of detrimental soil impacts. All Forest Plan management direction would be met by the proposed alternatives.

Flathead NF Forest Plan Management Direction – Forest-wide standards for soil resources, page II-46, are as follows:

- Ensure that all resource management activities would maintain soil productivity and minimize erosion through implementation of:
    - Management direction presented in the Landtype Guidelines
    - Erosion Prevention Standards (Engineering Handbook Supplement)
- Design or modify all management practices as necessary to protect land productivity.

The Soil and Water Conservation Practices Handbook (USDA Forest Service 1988) is incorporated by reference in the Forest Plan, describing Best Management Practices (BMPs) to be used in the planning and implementation of timber sale and associated activities.

Regional guidance is available from the Region 1 Forest Service Manual for Soil Management FSM 2500-99-1 (USDA Forest Service 1999b). Region 1 policy states “Design new activities that do not create detrimental soil conditions on more than 15 percent of an activity area. In areas where less than 15 percent detrimental soil conditions exist from prior activities, the cumulative detrimental effect of the current activity following project implementation and restoration must not exceed 15 percent.”

The National Forest Management Act (16 U.S.C. 1604) allows for “timber harvested from National Forest System lands...only where soil, slope, or other watershed conditions will not be irreversibly damaged.”

The National Forest Management Act requires that Forest Service regulations implementing NFMA specify guidelines to insure that timber would be harvested from National Forest System land only where "soil, slope, or other watershed conditions will not be irreversibly damaged." 16 USC 1604(g)(3)(E)(i). Region 1 Regional Soil Quality Standards identified as Forest Service Manual (FSM) R-1 Supplement 2500-99-01 (see AR Doc. H-72) were set forth to meet the direction of NFMA to manage Forest Service lands without permanent impairment of land productivity and to maintain or improve soil quality. The policy as stated in the FSM is to:

> Design new activities that do not create detrimental soil conditions on more than 15 percent of an activity area. In areas where less than 15 percent detrimental soil conditions exist from prior activities, the cumulative detrimental effect of the current activity following project implementation and restoration must not exceed 15 percent. In areas where more than 15 percent detrimental soil conditions exist from prior activities, the cumulative detrimental effects from project implementation and restoration should not exceed the conditions prior to the planned activity and should move toward a net improvement in soil quality.