Soil

Introduction

This section covers the analysis of the soil resources as part of the Easy Fire Recovery Project, Environmental Impact Statement. Proposed actions include fire salvage regeneration, fuels reduction, construction of temporary roads and maintenance of system roads.

Regulatory Framework

The Malheur National Forest Plan meets all legal and regulatory requirements for soil conservation. The Forest Plan Goal for soils is to “Manage the soil resource of the Forest by using management practices that will maintain or enhance its productive properties (Goal 30; page IV-3).

Forest Service Manual R6 Supplement No. 2500.98-1, section 2520.2 says objectives of soil management are "To meet direction in the National Forest Management Act of 1976 and other legal mandates. To manage National Forest System lands ... without permanent impairment of land productivity and to maintain ... soil ... quality. .... Soil quality is maintained when soil compaction, displacement puddling, burning, erosion, loss of organic matter and altered soil moisture regimes are maintained within defined standards and guidelines." Therefore, where an action maintains detrimental impacts within the standards and guidelines of the Forest Plan, legal requirements for soil conservation would be met. Forest-Wide Standards state:

101. Harvest timber from slopes that are less than 35% using ground skidding equipment and from slopes greater than 35% using cable or aerial systems. Approve exceptions through the environmental analysis process, including a logging feasibility analysis.

125. Evaluate the potential for soil displacement, compaction, puddling, mass wasting, and surface soil erosion for all ground-disturbing activities.

126. The total acreage of all detrimental soil conditions shall not exceed 20% of the total acreage within any activity area, including landing and system roads. Consider restoration treatments if detrimental conditions are present on 20% or more of the activity area. Detrimental soil conditions include compaction, puddling, displacement, severely burned soil, and surface erosion.

127. Meet minimum percent ground cover levels following management activities (See Table S-6).

128. Seed all disturbed soil occurring within 100 to 200 feet of a stream or areas further than 200 feet that could erode into a stream.

129. Seed all skid trails positioned on slopes greater than 20%.

To further meet the appropriate guidelines in the project area, additional measures as listed in Chapter 2 “Management Requirements, Constraints, and Mitigation Measures” for soils and watershed resources would be applied. These include designating spaced skid trails; subsoiling skid trails; and seeding skid trails that are steeper than 10 percent on moderate or severe burn severity, or skid trails that are located on slopes steeper than 20 percent. Other measures are limiting tractor yarding to dry, frozen or snow-packed conditions, and avoiding skidding up or down draw bottoms. These additional measures plus others, along with the above standards are appropriate for soils found in the project area and will maintain soils to meet guidelines.

Analysis Methods

Information sources used to describe the existing condition of the Easy Fire area include the following:

- Burned Area **Emergency Rehabilitation** (BAER) documents
- Upper Middle Fork John Day River Watershed Analysis
- Mossy Analysis Area – Environmental Assessmen**t**
- Clear Creek Environmental Assessment
- Malheur National Forest Soil Resource Inventory
- Malheur National Forest (MNF) Geographic Information System Database
- Post-fire surveys of detrimental soil conditions
- Post-fire reconnaissance of **streams/ephemeral draws**
- Post-fire information from other resource personnel, including the fish biologist, silviculturist, fuels, logging systems and engineering (roads).
- Post-fire aerial photos.

Quantifiable soil disturbance assessments (transect or walk-through field reconnaissance) were completed during the fall of 2002 throughout the analysis area, with a District Soil Scientist working with the survey crew to provide quality control on the collected data. All proposed activity areas were field assessed, with the exception of a portion of the proposed tractor harvest units (170 acres - low to moderate burn severity). Results from these field assessments, which show that 51 of the 58 areas surveyed had less than 10% detrimental impacts and no areas had more than 15% detrimental impacts (Table S-8), were used to estimate the percent detrimental impacts for the non-inventoried areas. These estimates were based on representative field assessments from areas of similar soils, slopes, and previous land management activities (information from GIS data and photos). The portion of proposed tractor harvest units was estimated at 13% detrimental impacts.

The definitions and categories for detrimental soil impacts were based on Forest Service regional guidelines in Forest Service Manual 2500, Region 6 Supplement 98-1 (1998). See the Appendix C for the definitions and categories of detrimental soil conditions, and for the procedure that was used for the data collection.

The conclusions on effects of non-action and proposed activities are based on information on the specific project area (including the above listed information sources), field trips, scientific literature listed in the Reference section of FEIS, and discussion and contacts with other soil and resource professionals. Four documents (Davis et al. 2001; McNeil, R. 1996; McNeil, R. 1999; and McNeil, R. 2001) have had a central part in the discussion and conclusions reached on the effects of alternatives.

Two of the documents were field reviews or studies of activities after the Summit Fire, which burned on the Malheur and Umatilla National Forests. The two remaining documents contained studies conducted on the Malheur National Forest. These documents were utilized for the analysis since they covered areas close to the Easy Fire project. One limitation of these documents is the small sample size and short-term duration of the monitoring of management effects, as expressed by one of the public comments. Information from McIver and Starr (2000) regarding erosion studies is included in the section on “Erosion and Sediment.” Also, public information sources have stated that in some areas of the Summit Fire project, adverse effects from erosion and sediment were above projected levels from management activities.

Much of the discussion in this report is qualitative, with some quantitative effects. However, the quantitative effects cannot be precisely predicted. In addition, effects of management are influenced by other variables such as weather and details of implementation. The WEPP model and Disturbed WEPP interface were used to predict amounts of increased sediment produced from proposed management activities two years (fall 2004) after the Easy Fire. According to Elliot, Hall and Scheele (2000), any predicted runoff or erosion value from this model will be, at best, within plus or minus 50 percent of the true value. Erosion rates are highly variable, and most models can predict only a single value.

Spatial boundaries for soil effects are proposed and past unit boundaries and their immediate surrounding area. Unless otherwise stated, effects are described for the time period immediately after the proposed actions, when effects are maximized.

Severity of burn was analyzed using two methods: 1) BAER burn severity, and 2) vegetation severity. BAER burn severity describes damage to the soils and ground vegetation. Vegetation severity describes damage to the forest vegetation. This is the reason that acres burned by severity category are not the same for both methods. Also, total acres burned do not match between the two methods because the fire perimeter used in the mapping was not the same for each method. The fire perimeter for the BAER burn severity map (Figure 5, Map Section) was drawn from remote sensing (satellite imagery) and is not as accurate as the vegetation severity map (Figure 6, Map Section), which was based on observations on the ground. The “official” total acreage for the project area (5, 839 acres) was derived from the vegetation severity map.

Existing Conditions

Subwatersheds

The Easy Fire occurred within four subwatersheds – Bridge Creek, Clear Creek, Dry Fork and Reynolds Creek. Most of the fire occurred in the Clear Creek subwatershed, where 3,002 acres burned. Clear Creek subwatershed also had the largest number of acres burned at high severity (800 acres). Only a small number of acres (30 acres) were burned within the Dry Fork subwatershed. In the Reynolds Creek subwatershed, most of the acres were assessed at low burn severity, and only 35 acres were burned at high severity. The table below lists the acres of the various BAER (Burned Area Emergency Rehabilitation) burn severities in the subwatersheds, HUC 6^{th} field (Bright et al. 2002).

Table S-1: Burned Acres by Subwatershed.

Subwatershed (HUC 6th Field)	Total SWS Acres	Unburned Acres in Easy Fire Area	*BAER Burn Severity (acres)* Low	Moderate	High	Total Acres Burned	% of subwatershed burned. (*)
Bridge Creek	12,149	256	311	158	172	641	5 (1)
Clear Creek	12,484	605	1,226	976	800	3,002	24 (6)
Dry Fork	11,219	6	24	5	1	30	<1 (<1)
Reynolds Creek	19,915	265	702	127	35	864	4 (<1)
Total	55,767	1,132	2,263	1,266	1,008	4,537	8 (2)

*Percent of subwatershed with high burn severity in parentheses.

Figures revised April 2003 to reflect new subwatershed boundaries.

The initial intensive soil and water analysis is focused on the three subwatersheds: Bridge Creek, Clear Creek and Reynolds Creek where most of the fire burned. The fire only burned 30 acres in the Dry Fork subwatershed, and no activities are proposed for those acres.

Soils

Most of the Easy Fire area has silt loam surface soils derived from volcanic ash over subsoils derived from volcanic rock, mostly basaltic andesite. The andesitic rock types are fine-grained, generally hard and competent, and moderately to highly fractured. These rock types are stable, with a strong resistance to mass movement (SRI, Malheur N.F. 1974). The northeast portion of the fire area contains areas with non-ash soils, which are loamy, forested soils, developed from competent andesite, basalt, and interflow tuff material.

The best soil description and map available is the Soil Resource Inventory (SRI). Information about soil types from the SRI forms the basis for the discussion of potential effects. The SRI mapping was made for large-area planning. However, the field investigations of the project area and the analysis of the aerial photos indicate that the SRI mapping is essentially accurate for the soil and landscape information, except for small areas of slope categories. Refinements were made to the acres in the various slope categories and the associated SRI soil landtypes. These refinements are reflected in soil tables S-2 and S-3, which show SRI landtypes in the BAER burn severity acres, and the soil management ratings

Ash and Non-Ash Soils

In general, the ash-derived soils are less erosive and more productive than non-ash soils, since the ash soil layer is very porous with a high water infiltration rate, and can retain more water. Thus, there is less overland water flow to cause soil erosion. With a higher water holding capacity, the vegetation on ash soils re-establishes more quickly, thus minimizing the erosion potential. With the high soil porosity, ash soils (SRIs 142, 148, 158 and 159) are less susceptible to soil compaction than are non-ash soils (SRIs 141 and 143).

However, with the low soil bulk density of the ash layer, the surface soils are more easily detached and disturbed from water erosion if ground cover is removed. Also, with no ground cover, these soils are more susceptible to soil displacement and mixing from management activities, especially when the surface soils are dry. If water is allowed to concentrate on these exposed soils on steep slopes, erosion can occur.

Slopes within the fire area are predominantly in the 0-30%, and 31-60% slope range. (Only a few areas are in the very steep slope range of 61-90%+.) Given these conditions and others (e.g. factors concerning soil, bedrock and topographic features, no ground cover), the ash soils have an erosion potential of low to moderate, or high to very high, depending on steepness of slope. In most cases, the erosion hazard would be lower, since some amount of ground cover would remain in the burned areas. The most sensitive areas would be the steeper areas that burned at high burn severity, and lost virtually the entire vegetative and litter layer. Remaining plant crowns, woody debris, and coarse rock fragment would still help to protect against soil erosion.

With the non-ash, loamy forested soils, the erosion hazard on slopes over 30 percent is the dominant management concern (SRI 143). If the protective vegetative cover is removed, then rill and accelerated sheet erosion can occur on these steeper slopes. The loamy soils also have a moderate to high detrimental compaction hazard (SRI, Malheur N.F. 1974).

The table below lists the management ratings for the ash and non-ash soils in the fire area. The soil land types are grouped in either the ash or non-ash soil group.

Table S-2: Soil Management Ratings

Slope Group	SRI Soil Landtypes	Surface Soil Erosion Potential	Subsoil Erosion Potential	Compaction Hazard	Mixing & Displacement Hazard	Potential Source for Turbidity [1]
Ash Soils – Main component of Fire Area						
0-30% slope	142, 158	Low - Moderate	Low - Moderate	Moderate	High	Moderate
31-60% slope	148, 159	High – Very High	High	Moderate	High	Moderate
Non-ash Soils – Minor component of Fire Area						
0-30% slope	141	Low – Moderate	Low – Moderate	Moderate – High	Low – Moderate	Low - Moderate
31-60% slope	143	High	High	Moderate – High	Low – Moderate	Low - Moderate

[1]Rated for surface soil.

The “potential source for turbidity” relates to the level of turbidity and longevity of the turbidity that can be expected from soil material, once the material enters a stream course from erosion or other activities. For all of the soil landtypes, the expected sediment size would be sand and silt.

Post-Fire Conditions

BAER Burn Severity

The Burned Area Emergency Rehabilitation (BAER) Severity map (Figure 5, Map Section) shows the areas that burned at low, moderate, or high burn severity in the fire area. These burn severity ratings are drawn from the BAER ratings, which were based on satellite imagery after the fire, along with some ground verification (Burned Area Report 2002; TenPas & McNeil 2002). The BAER burn severity is an indication of fire effects on the ground as related to fuel loading and impacts to the soil. The BAER burn severity is different from fire vegetation severity, which considers the fire-killed and fire-damaged vegetation.

The high burn BAER severity areas are burned areas that typically have less than 20% remaining ground cover. Moderate burn severity areas have from 20 to 50% remaining ground cover. Low burn severity areas generally have more than 50% remaining ground cover. The term “burn severity” is distinguished in this report from “fire intensity” or “burn intensity” in that “burn severity” relates to the effects of the fire duration on the soil and ground cover. Fire intensity often refers to the amount or rate of heat released from burning materials at a specific time, but not the duration.

There were very few locations where fire actually burned to the water edge along perennial streams. Intermittent streams (Category 4) and ephemeral channels were the channels most affected by the fire.

The table below lists the acres of moderate and high burn severity according to slope categories and soil groups (ash and non-ash). The ash soils make up the main component of the moderate and high burn severity areas.

Table S-3: Moderate and High Burn Severity Acres by Slope Category and Soil Group

Slope Category	Soil Group - SRI	BAER Burn Severity Acres	
		Moderate burn severity	High burn severity
0-30% slopes	Ash – 142, 158	721	561
	Ash & Non-ash complex 141/142	67	4
31-60% slopes	Ash – 148, 159	397	427
	Ash & Non-ash complex 143/148	65	4
61-90% slopes	Ash - 159	2	3

High Burn Severity Areas

The Easy Fire burned with high severity in the upper reaches of Easy Creek (intermittent stream, Category 4), and in several tributaries (Category 4) to Clear Creek (Category 1). The figures below list the acres of water repellent soils in the fire burn area (Burned Area Report –

Malheur Complex Fire 2002), and the surface erosion potential for the soils. This erosion rating is based on climate, slope gradient and length, soil characteristics (including partial ground cover), topography, and the bedrock material.

Table S-4: Water Repellent Soils in Easy Fire Area (figures are in acres):

	Non-repellant	Low	Moderate	High
Water Repellant Soils (acres)	4,400	1,250	250	0

(Based on BAER burn severity boundary.)

Table S-5: Soil Erosion Hazard Rating in Easy Fire Area (figures are in acres):

	Low	Moderate	High
Soil Erosion Hazard Rating[1]	2,221	3,278	340

(Based on project area boundary.)

1 This rating is based on partial ground cover remaining.

Examination of the soils by BAER team members in August 2002 in the high burn severity areas showed that the effects on the soils were not as severe as the effects on the vegetation. Hydrophobicity was predominantly in the "low" or "no water repellency" class, with little strong repellency except at the surface. Some scattered points of medium or high repellency were found in burns and also in unburned areas. The soils were generally moist at 2 inches with unburned, uncharred roots.

In high burn severity areas, the duff cover was mainly reduced to less than 10%, with up to 15% of rock fragment cover and variable amounts of coarse and fine woody debris (TenPas & McNeil 2002).

In the low BAER burn severity areas and in some of the moderate burn areas, the resultant needle-fall (from fire scorch) has added from 1/16 to 3/16 inch of organic litter material, depending on the remaining fire-killed needles in the tree crowns.

Fire Suppression Effects

During the fire suppression activities in July and August 2002, approximately 7.4 miles of hand line and 15.2 miles of machine-constructed fire lines were built. This includes fire lines both inside and outside the project area boundary. Safety zones (12), drop points and staging areas were also established. Portions of machine-constructed fire lines were constructed within RHCAs in the Clear Creek subwatershed. Hand fire lines crossed at several places along intermittent streams and along the lower end of Clear Creek along the fire boundary.

Rehabilitation in the summer and fall 2002 on dozer lines consisted of knocking down the berm created by the dozer, creating cross ditches (similar to waterbars), and scattering slash, logs, large rocks and other debris on the fire lines to both reduce potential for sediment movement and to blend the fire lines with the landscape. Along hand lines, water bars were constructed by hand and materials spread over disturbed areas. Damage at stream crossings was also repaired. Erosion control seeding was not recommended on the fire lines to allow for natural regeneration.

Fire Effects on Soil Productivity

The BAER Team determined that long-term soil productivity was not at risk from this fire event. The Team used results from on-the-ground surveys for soil erosion hazard ratings, in addition to the Water Erosion Prediction Project (WEPP) model for soil erosion. The WEPP model is a physically-based soil erosion model that can provide estimates of soil erosion and sediment yield considering the specific soil, climate, ground cover, and topographic conditions. It was developed by an interagency group of scientists including the U.S. Department of Agriculture's Agricultural Research Service (ARS), Forest Service, and Natural Resources Conservation Service; and the U.S. Department of Interior's Bureau of Land Management and Geological Survey.

Disturbed WEPP is an interface to the Water Erosion Prediction Project soil erosion model (WEPP) to allow users to describe numerous disturbed forest and rangeland erosion conditions. Disturbed WEPP gives both an average annual erosion, and the probability of a given annual erosion rate following a disturbance. To estimate an average annual erosion, Disturbed WEPP generates a stochastic (random) climate for the climate selected, for the number of years specified. The WEPP model then runs a daily simulation for the specified period of time, and calculates the average annual runoff, erosion, and sediment yield values.

The Easy Fire area had several tributary watersheds to Clear Creek and one to Easy Creek that were identified as focus areas for WEPP because of higher percentages of severely burned area. These areas were expected to experience erosion on the order of 2 to 4 tons/acre in the first two years following the fire. The higher than normal burn intensity over a larger contiguous area was attributed to the higher fuel loadings before the fire from fire suppression.

Over several fire return intervals however, this incident is not likely to significantly alter or affect soil productivity. A return to a more normal fire regime would help conserve these soils. Downstream affects were not expected to be significant because of the relatively small area of the watershed affected. Fisheries resource specialists did not expect the affects to significantly affect T & E fish. (TenPas & McNeil 2002).

Fire Effects on Watershed and Water Quality

After their ground survey and analysis in August 2002, the BAER Team watershed personnel reached the following conclusions regarding the effects of the fire on the soil resources (Bright et al. 2002):

- Ample amounts of woody material on hill slopes exist to reduce erosion and trap sediment. Also, substantial subsurface roots are available to bind soil.
- Burn is a mosaic with vegetative filter among more severely burned sites.
- No substantial flood source areas identified – very little hydrophobicity was found in areas mapped as high intensity.
- Re-sprouting grass and sedges exist especially on road shoulders.

In summary, the BAER team determined there were no emergency situations related to the fire for soil/watershed conditions. There were no recommendations such as grass seeding or contour log felling to treat emergency resource conditions in the fire.

Overall, both runoff and sedimentation are expected to increase within those subwatersheds that were influenced by high intensity fire, such as the Clear Creek subwatershed. This is likely to continue until ground cover can be established. However, less than 5% of the area of the fire experienced significantly reduced infiltration, which should minimize the amount of increased runoff (also expected to be about 5-10%), (Bright et al. 2002).

There is the potential for some short-term effects from sediment delivery into streams from storm events. However field survey determinations identified that sufficient down wood on open slopes and along stream banks would minimize this effect and eliminate the "emergency" situation under BAER guidelines. In addition, the fire did not burn intensely within riparian zones leaving live streamside vegetation to buffer and filter potential sediment. A storm event would tend to move sediment through the system and onto flood plains and not deposit in stream channels and impact spawning gravel.

Recovery of Protective Ground Cover

Soils would continue to erode at accelerated levels until adequate ground cover returns, tree downfall is in contact with the soil surface, or new vegetation grows. Recovery of ground cover and erosion rates on different parts of the fire will take from less than a year to a year following the fire on low burn severity sites, from 3 to 4 years on moderate burn severity sites, and from 3 to 5 years on high burn severity sites (BAER burn severity ratings). Recovery refers to the standards and guidelines for effective ground cover in the Malheur National Forest Land and Resource Management Plan (1990). See the table below for the guidelines.

Table S-6: Minimum Percent Effective Ground Cover After Management Activities

Soil Erodibility	First Year %	Second Year %
Very High	60-75	75-90
High	50-60	65-75
Between Moderate & High	45	60
Moderate	38	50
Between Low & Moderate	30	40
Low	20	30

The rate of recovery would depend on the degree of the fire intensity, soil mantle stability, type of re-sprouting vegetation, availability of seed source and environmental factors affecting plant growth. The increase in surface-soil erosion would be realized more on steep-sloped areas where vegetation, litter, and duff have been burned/removed and soils exposed.

Soils with a high potential for surface-soil erosion that experienced high soil-fire intensities would produce the greatest contribution to surface soil erosion.

Following the establishment of vegetation, sediment yields would likely decline to near pre-fire levels in less than five years (Bitterroot 2001). However, hillslope and bank erosion can greatly increase turbidity during snowmelt and rain runoff after fires or especially after a severe storm event.

After a fire, forest sites recover quickly, as there is often a flush of new vegetation in the year following a fire. Elliot et al. (2001) noted that field observations and validation studies suggest that following fire the amount of exposed mineral soil is halved each year until the site is recovered. This usually takes about three or four years.

According to Elliot, Hall and Scheele (2000), forests generally have very low erosion rates unless they are disturbed. The impact of these operations, however, last only for a short time, perhaps one or two years. After that, the rapid regrowth of vegetation soon covers the surface with plant litter, and potential erosion is quickly reduced. In one study, erosion rates dropped from almost 17.8 tons/acre the first year after a fire to 1.0 ton/acre the second, and 0.4 ton/acre the third year (Elliot, Hall and Scheele 2000). The regrowth of vegetation and subsequent increase in canopy and ground cover overshadow any differences due to climate variation among the years.

Erosion on steep slopes would consist primarily of dry ravel and sheet erosion where little ground cover remains, and minor amounts of rill erosion. Low burn severity areas and portions of moderate burn areas would contribute less eroded material. This would occur due in part to the protective conifer needle cover that falls to the soil surface almost immediately following the fire. Soil erosion would be reduced as protective organic materials (live vegetation, needle and leaf fall, branches, and large woody debris) accumulate on the site.

The majority of slopes within the fire project area are stable to very stable. Minimal management activities, such as removal of dangerous trees along roads, would not significantly affect the slope stabilizing influence of naturally regenerating forests.

Steep ephemeral channels which have lost the protective litter/ground cover and woody debris can experience surface erosion and channel down cutting, until the ground cover and litter is reestablished. For comparison, in one unburned slope adjacent to an ephemeral draw, the litter layer was 1/4 to 3/8 inch thick. See the section on “Ephemeral Channels Tributary to Clear Creek (High burn severity area)” in the Fisheries and Water Quality section.

As stated earlier, the fire effects on the soils in the high burn severity areas were not as severe as the effects on the vegetation. The water repellency was mainly low or not present, with little strong repellency except at the surface. Some scattered points of medium or high repellency were found in burns and also found in unburned areas. The soils were generally moist at 2 inches with unburned, uncharred roots. There were usually common to many fine and very fine roots in the upper 1 to 2 inches. Where water repellent soils have formed, surface erosion would continue at accelerated rates. Fire-induced, water repellent soil areas generally persist for 2-3 years (Bitterroot 2001; Wondzell & King 2003).

In severely burned areas, fireweeds, lupines and bull thistles generally become established within the first year after a fire helping to stabilize the soils. Mosses and liverworts also help stabilize the ground after severe burns, the first several years after a fire (Johnson 1998).

On severely burned sites, mosses and lichens are often killed, but the remaining plant matter can help provide stabilization for the soil by protecting from raindrop and wind erosion.

Johnson (1998) found that by the first year following the most severe burn, mosses, liverworts, and pioneering forbs (fireweeds) generally become established. The response to fire by liverworts and mosses the year after the severe burns was dramatic (e.g., 50% liverwort cover in grand fir/bead Lilly plant communities; 0% liverwort cover by year five). With regard to shrubs, moderate and severe burns can also enhance grouse huckleberry coverage.

Other areas of the fire that contain elk sedge (Carex geyeri) and pine grass (Calmagrostis rubescens), are expected to recover quickly from the resprouting rhizomes (Post-Fire Grazing Guidelines 2003). These plants are often enhanced or stimulated in growth by moderate to severe burns, depending on the moisture regime.

For moderately burned sites, needle-fall can make up the principal coverage of bare ground immediately following a fire. The down woody debris and rock fragments would also serve to protect the soil. Mosses can also increase dramatically in the first year after a fire. By the fifth year, other herbaceous vegetation may overtake the mosses and lichens (Johnson 1998).

For low burn severity areas, the unburned duff and litter, plus rock and gravel fragments, remaining plant crowns, and down woody material serve to protect the soil.

Johnson (1998) found that the year following a fire, litter generally declined from pre-burn coverages. Then, by the fifth year, litter coverage was often nearly returned to pre-burn levels. In grand fir plant associations, the burn was usually severe. Shrubs, sedges, forbs, and grasses were totally consumed along with down woody material.

From the WEPP analysis, current upland erosion rates (fall 2004, two years after the fire) in areas having the highest amounts of moderate and high BAER severity ranged from 0.006 to 0.105 cubic yards per acre on gentle to moderate ground (8-40 percent slopes); and from 0.145 to 0.244 cubic yards per acre on steeper ground (40-70 percent slopes). These values are equivalent to 0.001 inch or less soil depth on tractor ground; and 0.001 to 0.002 inch soil depth for steep helicopter ground. The erosion rates on less severely burned ground and on gentler slopes would be less.

The average annual sediment rates are estimated at 0.007 to 0.101 cubic yards/acre on the tractor units, and 0.059 to 0.185 cubic yards/acre on the helicopter units. These values equate to 0.001 inch or less of soil depth per acre. Average values for ground that had less burn severity or gentler slopes would be less.

Plant Recovery

Tributaries to Clear Creek (High BAER burn severity area)

The following section on plant recovery discusses the processes occurring in the high burn severity areas in the tributaries of Clear Creek and in Easy Creek. These areas are of concern because of the lack of ground cover, the proximity to stream channels, and the surrounding steeper slopes.

Plant recovery had not yet started in the moderate to high burn severity timber stand areas where there was high crown closure (pre-fire) in the mixed forest. Most likely, high canopy cover had excluded the grasses to the point that seed sources were lacking. The remaining plant stubs from shrubs were not yet re-sprouting, with the underlying roots still present in the surface soil.

A smaller percentage of the moderate and high burn severity areas contained partially open areas (pre-fire) with ponderosa pine/Douglas-fir mixed, or around rock outcrops of shallow soils and open sunlight (in mid to upper slopes), where the grasses were re-growing well, from 4-5 inches in length in moderate to high burn severity sites.

Along intermittent stream channels that were moderately to severely burned, grasses, forbs, mosses and molds were re-establishing themselves in varying widths, from scattered pockets of ½ foot, up to 1-3 feet along the stream banks at the gentler gradient (<13%), lower (downstream) sections of Category 4 streams, and along Category 2 streams (especially along northwest aspects). The initial revegetation was mainly in the gentler bank slopes, and where there was accumulated material. In low burn severity or unburned areas, there was abundant litter cover, down wood and vegetation.

The steeper gradient stream sections (15-18%) were narrower width and more entrenched by the side slopes, with less vegetated widths (from none to about ½ to 2 foot width patches).

Ephemeral Channels Tributary to Clear Creek (High burn severity area)

The table below shows the ephemeral channels affected within the subwatershed area of Clear Creek where the predominant fire burn severity was high. Where low burn severity or scattered fire occurred in the ephemeral channels, there was little erosion, with the abundant down wood, litter and present vegetation.

Table S-7: Summary of Soil Burn Severity in Ephemeral Draws/ Conditions – Clear Creek Subwatershed (estimated lengths)

Ephemeral Draw	Length w/in Project Area (miles)	Soil (BAER) Burn Severity
A	0.5	Unburned to low
B	0.7	Low
C	0.4	Moderate to High
D	0.2	High
E	0.2	Unburned to moderate

However, ephemeral channel "C" which underwent moderate and high burn severity, showed movement of material from the first winter and spring precipitation and runoff. The removal of the ground cover allowed the water channel to erode the accumulated material (soil and remaining organic material). Material had moved from a rock outcrop/rock wall area and along the channel (15-30% gradient), and was deposited along the ephemeral channel and below the road culvert. The channel ended on a flattened slope adjacent to a Category 4 channel, about 200 feet downslope. The amount of channel material deposited within the channel and down through the lower road culvert was about 2 to 3 cubic yards along the 0.4 mile channel length. (A map of the ephemeral stream channels is included in the Soils Appendix C.)

Soil Productivity: Organic Matter, Litter, Soil Wood & Nutrient Status

Compared to historical conditions where fires were more frequent, fire suppression since the beginning of the 1800's had allowed increased accumulation of woody debris, organic matter and soil wood within the forested areas (Harvey et al. 1987). This increase in woody material resulted in increased levels of nitrogen, phosphorus, sulfur and other nutrients in the surface biomass, forest floor and surface soil. Fire reduces the amount of woody biomass, but releases stored nutrients (as gases or in ash), making a portion of the nutrients available to the plants for the first several years (National Wildfire Coordinating Group 2001).

Organic material in the form of coarse woody material is needed for long-term soil productivity (Harvey et al. 1987). Water retained in down woody material is not available for augmenting late-season stream flows. However, down wood provides moist micro-sites for conifers, shrubs, herbs, fungi, mycorrhizae, mosses, lichens, bacteria and small animals such as earthworms, snails and nematodes. If all dead trees were to remain on site, they would eventually fall to the forest floor, the majority falling over the next 10-30 years (Brown et al. 2003).

Total biomass contributions to soil/site productivity would be reduced until the forest returns to the vegetative diversity and maturity of pre-fire conditions. An indirect but significant beneficial effect would be the supply of large woody material to the site, over time, as dead trees fall to the forest floor. Large woody material on the ground would increase as branches and larger material from fire-killed trees fall to the ground. Ground-level biomass would increase over the next 10 years.

In about 20 years, ground-level biomass would be greater than pre-fire amounts and above-ground standing material would decline significantly. After approximately 30 years, total biomass would be approaching pre-fire conditions with a greater amount of material on the forest floor, but an increasing amount in the above-ground component as trees reestablish the site.

In the low burn severity and in some of the moderate burn severity areas of the Easy Fire, there is likely still more nutrients on site than at historic levels. In the high burn severity areas, where much of the forest floor and organic biomass were consumed, the nutrient levels may be at lower levels than existed historically. However, in many cases, fires burned often at varying intensities throughout the landscape, causing fluctuations in nutrient levels from one site to another.

In burned areas where the canopy is more open from the fire, the ground temperatures and soil moisture increases, which accelerates the decomposition rate of the remaining organic matter, humus and soil wood, depending on the available/remaining microorganisms, bacteria, and fungi (Harvey et al. 1987).

Also, with the loss of the tree canopy and underlying shrubs and grassy vegetation in the moderate to high burn severity areas (BAER soil burn severity), there could be an increase in soil moisture from reduced plant evapotranspiration. This increase in soil moisture would be counteracted by the regrowth of vegetation, increased temperatures during the growing season, and the eventual increased mineralization of the organic matter in the soil in the more opened areas. Helvey and Fowler (1998) found increased annual soil water content in harvested areas for about four years after the removal of the forest cover. The seasonal declines in soil moisture occurred at the same rate in forested versus harvested areas. However, the fall recharge appeared to be faster in the harvested units, indicating lower water use by plants. The study by Helvey and Fowler was conducted on the Umatilla National Forest, and most likely represents conditions found in the Easy Fire project area.

Regarding the effect on tree rooting depths, Johnson (1998) stated that as fire frequency is lengthened, a greater accumulation of duff occurs beneath the tree canopies. As a result, the deep-rooted trees develop fine roots that are oriented closer to the surface in the mineral soil. Now even some low-intensity burns can pose an increased risk of high tree mortality because the duff concentrates lethal heat for a longer duration and kills surface roots.

From the Bitterroot Fire, it was estimated that in high severity burn areas, the nutrient cycle would recover fully in 150-200 years, after trees have become established, matured, and died (Bitterroot 2001). In moderate severity burn areas, the nutrient cycle would recover fully in 15 to 80 years. Needles from dead trees not consumed in the fire would fall to the ground to begin building the litter and duff layers. Whole trees would begin to decay and fall. Coarse woody debris would continue to decay.

The fire burn severity definitions on the Bitterroot Fire differed slightly from those on the Easy Fire. In the high burn severity areas of the Easy Fire, hydrophobicity was predominantly in the “low” or “no water repellency” class, with little strong repellency except at the surface. The soils were generally moist at 2 inches with unburned, uncharred roots. Also, for the Easy Fire project area, fires historically occurred naturally every 25 to 100 years in the cool, moist, mixed conifer stands; every 20-40 years in the warm, dry, mixed conifer stands; and every 20 to 30 years in the lodge pole pine stands. See the Fuels report for more information.

Soil Biota and Food Web

Moisture retention in coarse woody material helps maintain the productivity of soil by providing moist micro-sites for conifers, other vegetation and soil microorganisms. Microbes and soil animals decompose forest litter components and contribute to maintenance of soil organic matter and to storage of nutrients, thus influencing site productivity (Cromack 1998; Harvey et al. 1987). Decaying material needed to support organisms and return nutrients to the soil would be formed as standing dead trees in the project area fall and come into contact with the ground.

Mycorrhizae form symbiotic communities with the roots of conifers and are important in aiding nutrient and water uptake and in warding off pathogenic fungi. Mycorrhizal fungal communities and other soil microbes are important because of their role in nutrient production and transfer (Li, C.Y. and Strzelczyk, E. 2000). They also contribute to soil formation and structure. Stability of soil aggregates is important for maintenance of soil pores that transmit air and water to plant roots.

Most mycorrhizal roots occur in surface soil horizons, particularly the organic soil layer, and in relation to decaying wood, such as decomposing logs (Graham et al. 1994; Harvey et al. 1987). If fire removes most of the organic matter on a forested site, productivity may be reduced for many years. If fire kills all species of plants that sustain mycorrhizal associations, spores of these fungi may die after several years. It may then be difficult for desired species of plants to reestablish, either by natural regeneration, planting, or direct seeding (National Wildfire Coordinating Group 2001).

Mycorrhizae populations are expected to decrease within the project area as result of the fire. Highest decreases in mycorrhizae populations would occur were burn severities were the highest. Many other organisms influence soil formation, fertility, and nutrient recycling. The soil horizons generally affected are the organic litter and duff layer, and the “A” horizon where carbon and nitrogen are stored and recycled. Organisms that influence soils include viruses, archaea, bacteria and blue-green algae, protozoa, mites fungi, molds and lichens, mosses and liverworts, all types of vascular plants (shrubs, trees, herbs); and various animals such as nematodes, millipedes, snails, earthworms, beetles and burrowing animals (Cromack 1998; James 2000). As discussed in sections “Recovery of Protective Ground Cover,” and “Plant Recovery,” mosses, lichens, liverworts and pioneering forbs can quickly re-vegetate burned areas.

Soil Conditions in Light of Past Management Activities

In the fire area, timber harvest has occurred over the past fifty years. Detrimental impacts, mainly compaction and some detrimental soil displacement, exist on tractor harvested units from past timber sales. The top 2 to 4 inches of compacted soil can be loosened in 3 to 6 years by weather processes such frost heave, and freeze thaw; by animals burrowing; and by plant roots. At deeper depths, however, compaction has been found to remain on sites that have been tractor harvested 20 years or more. This means that subsurface soil compaction takes much more time to recover. A large proportion of the skid trails have been subsoiled in the past harvest areas.

The fire caused small amounts of detrimentally burned soil, and small amounts of displacement and compaction were caused by the fire suppression (mainly in tractor fire lines).

Soil displacement is the movement of the forest floor (litter, duff and humus layers) and surface soil from one place to another by mechanical forces, such as during the yarding of logs. However, mixing of surface soil layers is not considered displacement (Forest Service Soil Management Handbook 2509.18; WO Amendment 91-1). Detrimental soil displacement is the removal of more than 50 percent of the A horizon from an area greater than 100 square feet, and is at least 5 feet in width (Forest Service Manual 2500, Region 6 Supplement 98-1).

Skyline units have a lower amount of detrimental impacts, with surface soil displacement being the main disturbance. Any compaction is generally within the top several inches along the yarding corridors, when partial log suspension is used (versus full log suspension). After the 1970 Entiat fire on the Wenatchee National Forest, Klock (1975) found that skyline and helicopter salvage logging produced 2.8 percent and 0.7 percent severe soil disturbance, respectively.

Quantifiable soil disturbance assessments (transect or walk-through field reconnaissance) were completed during the fall of 2002 throughout the analysis area, with the exception of a portion of the proposed tractor harvest units (170 acres - low to moderate burn severity). The soil surveys examined all impacts from past timber harvest activities, including landings and temporary roads within past harvest units, fire suppression, fuel treatments and past grazing.

Results from the field assessments conducted in the fall of 2002, which show that 51 of the 58 areas surveyed had less than 10% detrimental impacts and no areas had more than 15% detrimental impacts (Table S-8), were used to estimate the percent detrimental impacts for the non-inventoried areas. These estimates were based on representative field assessments from areas of similar soils, slopes, and previous land management activities (information from GIS data and photos). The portion of proposed tractor harvest units was estimated at 13% detrimental impacts.

Moderate and high soil disturbance classes were counted as detrimental impacts. (See Soils Appendix C for the procedure and disturbance class definitions.) The table below displays the number of areas in the different categories.

Table S-8: Detrimental Soil Impact Categories

Number of Surveyed Areas in Detrimental Soil Impact Categories (Not including roads)			
Not Harvested – No Disturbance	**Less than 10 % Impact**	**> 10 to 15 % Impact**	**Greater than 15 % Impact**
21	30	7	0

The majority of areas are within the "Less than 10%" impact category, and no areas had more than 15% detrimental soil impact. Seven areas had from 10 to 15% soil impact. The figures in Table S-8 do not include the areas in permanent roads. Permanent roads average 1.5 percent overall in the project area. Proposed tractor harvest areas have a road average of 1.2 percent; skyline harvest areas average 2.0 percent, and helicopter areas average 1.3 percent in roads. Table S-11 "Expected Soil Conditions after Management Activities" includes the percentage of affected areas from all activities for proposed units, including permanent roads. The existing soil conditions are listed under the column for Alternative 1 (No Action).

Environmental Consequences

Direct and Indirect Effects

Soil effects that are not described below would be small, or negligible. These negligible effects include effects on mass movement, detrimentally burned soil, soil temperature and soil microbes, and other effects. The processes discussed in the Existing Condition sections on plant recovery and protective ground cover would also occur for all alternatives.

Alternative 1, No Action Alternative

Under the No Action Alternative, no additional soil would be compacted, puddled, or displaced. No roads or landings would be constructed. No additional soil would be eroded by ground disturbing activities. No organic matter or nutrients would be removed. With time, organic matter would gradually accumulate from the coarse woody material, forbs, and grasses. Nutrients would gradually accumulate due to inputs (in precipitation, dry deposition, weathering of parent material, and nitrogen fixation) and retention. Changes in soil chemistry, such as an increase in soil pH from the release of available nutrients, are expected to be short-term, and would return to pre-fire levels in one or two years. According to Elliot et al. (2001), after a fire, forest sites recover quickly, as there is often a flush of new vegetation in the year following a fire. Field observations and validation studies suggest that following fire the amount of exposed mineral soil is halved each year until the site is recovered. This usually takes about three or four years. As discussed earlier, recovery of ground cover and erosion rates on different parts of the Easy Fire would take from less than a year to a year following the fire on low burn severity sites, from 3 to 4 years on moderate burn severity sites, and from 3 to 5 years on high burn severity sites (BAER burn severity ratings).

Alternative 1 would have no effect on ectomycorrhizae or other beneficial fungi or organisms. Ectomycorrhizae are most abundant in the organic soil components, including the litter, humus; soil wood, charcoal and organic-enriched mineral horizons. The post-fire population of mycorrhizae would be lower than pre-fire conditions, mainly in the high BAER burn severity areas from the reduced surface organic component (forest litter and humus; decomposing coarse wood). In the high burn severity areas, there are reduced habitat sites and chemical changes in the remaining organic matter. Prescribed fire has been observed to decrease ectomycorrhizae activity for up to four years. However, ectomycorrhizae are abundant in charcoal incorporated into the soil, and the habitat sites provided by burning may compensate for the initial population reductions.

Alternatives 2, 3 and 4

Roads and Landings

From 0.2 to 0.7 miles of temporary road construction would take place in Alternatives 2 thru 4. The temporary roads are not expected to have an effect on water quality due to their location on ridge tops or gentle slopes, away from streams. Also, most of the proposed temporary road segments consist of rehabilitated roads, or existing decommissioned roads. Thus, most of the temporary road routes are already on the landscape. Consequently, limited additional clearing and ground disturbance would be required for temporary road construction. Soil erosion from road construction would most likely travel less than 300 feet (McNeil 1999). All miles of temporary road would be decommissioned after harvest activities, through cross drains, subsoiling and seeding after harvest.

Alternative 2 would construct a total of 0.7 miles of temporary road to allow access to harvest. 0.2 miles is an existing rehabilitated road that would access unit 65, and 0.5 miles is a decommissioned road that would be re-opened as a temporary road to access unit 7.

Alternative 3 would re-open 0.5 miles of a decommissioned road to access unit 7. And Alternative 4 would re-open 0.2 mile of an existing rehabilitated road to access unit 65.

Productivity of a small percentage of land would be greatly decreased by displacement and compaction from landing construction. Subsoiling would restore part of the productivity lost to compaction in landings. However, soil displacement at landings can affect the soil productivity for years. Landings would be subsoiled to 18 inches depth with winged subsoilers. Alternatives 2, 3 and 4 would have 97, 66 and 63 tractor landings, respectively.

The burning of slash piles at landings can also affect soil productivity. The burning of slash piles generally occurs during late fall when fire season has ended and when a significant amount of moisture in the form of heavy rain or snow has occurred (1+” of moisture). Since pile burning would be done when the soil is wet, impacts to soil from burning piles are expected to be low. Pile burning would affect soil organisms in localized areas where soil is sterilized from high intensity heat.

Effects from Ground-Based Activities

Tractor skidding on steep slopes often causes soil compaction and displacement. Skidding also bares soil, decreases infiltration, and channels overland flow, and thus accelerates erosion. This acceleration occurs especially on steep slopes and on soil that has insufficient ground cover, including moderately and severely burned soil.

Except for areas that are harvested under winter conditions, much of the skid trails would be compacted, and some of the soil tracked only once or twice by tractor skidding would be compacted. Compaction deeper than the top 3 to 4 inches can last more than 20 years; some compaction lasts more than 50 years.

Subsoiling of skid trails and landings with winged subsoilers is planned for the majority of tractored units and for helicopter landings. Areas that have high amounts of cobbles and stones would not be subsoiled. Only a few areas in parts of proposed tractor units have been identified as unsuitable for subsoiling in terms of high rock content. Landings would be subsoiled to 18 inches depth.

Subsoiling only partially restores compacted soils. Subsoiling bares soil, forms channels, makes soil particles more easily detachable, and disrupts roots, thus raising the risk of erosion for a few years. However, subsoiling also increases infiltration, which decreases the risk of erosion. This increased infiltration, and the installation of cross drains, and seeding where specified, would likely reduce the amount of sediment production from subsoiling to negligible amounts. Subsoiling could also affect the soil organisms through mixing of the duff, litter and surface soil horizon. The detrimental effect, however, would not be significant, based on the amount of area that would be in skid trails and in subsoiled areas.

Some additional ground cover could be produced from the timber harvest. Harvest activities would produce small diameter materials on the ground, such as treetops, branches, and boles remaining on site. This material can help trap and retain sediment on the slope. However, this increase in ground cover would be a trade off for increased ground disturbance from log yarding, depending on the yarding method. In most tractor units the increased ground cover would be small, because trees tops and limbs would be taken to the landing and burned, or piled and burned, for fuel control.

Ground cover on skid trails would be decreased to 10 percent or less by tractor skidding. On skid trails that are seeded (the more erodible ones), ground cover would recover in one to two years with skid trails subsoiled. On the less erodible, un-seeded skid trails, ground cover would recover in about three to four years when the skid trails are subsoiled.

Erosion from skid trails and disturbed soil (landings, temporary roads and skyline corridors) would be controlled by cross drains, and seeding. Skid trails that would be seeded include those on low severity burns with slopes greater than 20%, those on moderate or high severity burns with slopes greater than 10%, those skid trails located on slopes steeper than 20%, and those within 100 feet of a stream.

The mitigation measures to minimize and control soil erosion in Alternatives 2, 3 and 4 include the following:

- Limiting ground skidding to 35 percent slopes or less, with pre-designated skid trails at spacing of 100-120 feet (80-100 feet for existing trails in appropriate locations)
- Cable winching of logs on short pitches of slopes steeper than 35 percent to designated skid trails
- Locating snag clumps on slopes steeper than 35% where feasible
- Avoiding skidding in draws
- Allowing operations on dry, frozen or snow-covered soil

- Subsoiling of skid trails and landings
- Installing cross drains;
- Seeding disturbed areas with a native or non-persistent, certified weed-free seed mixture. These areas include skid trails on slopes greater than 10% on moderate to high burn severity; all skid trails located on slopes greater than 20%; all disturbed areas within 100-200 feet of a stream; and all disturbed areas further than 200 feet that could erode into a stream. Temporary roads would also be seeded.

McNeil (1996) conducted soil monitoring on timber harvest on the Blue Mountain Ranger District. Timber harvest occurred on dry to slightly moist soils, with a feller buncher and tractor skidding. McNeil found that a total increase in compaction from the feller buncher was less than 2 percent of the harvest unit. The feller buncher was not restricted to the tractor skid trails, and tracked 11 percent of the unit. The feller buncher had low average ground pressure, 7.9 pounds per square inch (when unloaded, static and level). An additional 4 percent of the area was compacted from the skidding spaced 120 feet apart. The total percent compaction was less than 6 percent.

The Easy Fire Project would differ in the following ways. Skid trail spacing would be shorter (100-120 feet on new trails, 80-100 feet on existing trails). Also, the operable soil moisture content for ground based machinery would be dry to slightly moist, to minimize the amount of soil displacement on the ash soils. Lastly, the Easy Fire involves harvest on burned sites.

Given these differences, the expected percent of harvest units compacted by the feller buncher and tractor skidding is estimated to be 6 to 10 percent. Re-using the existing skid trails that are in appropriate locations would reduce the additional area of compaction. Subsoiling the majority of the skid trails would also reduce the compaction in units to about one-third to one-half, to 3 to 4 percent. (Any compaction by the feller buncher, about 2 percent on burned sites, would be off the skid trails, and would not be subsoiled.)

Listed below are the factors and assumptions for determining the expected ground impact.

- Ground activities would not start until December 2004 at the earliest. Some plant recovery would have taken place by then.
- Average skid trail width: 11 feet.
- Skid trail spacing: 100-120 feet. Existing skid trails can be used at 80-100 feet spacing, if they are in appropriate locations. This spacing would result in 9-11 percent of the area occupied by skid trails at the wider spacing, and 11-14 percent of the area in the closer spacing.
- Percent of skid trails compacted: 60-80% (average of 70%).
- Percent of ground compacted by skid trails & feller buncher: 6-10%.
- Subsoiling in ash soils: Reduced compaction in 60-80% of the skid trails.

Note: The compactibility of ash soils does not change as much with soil moisture as with non-ash soils (see Management Guidelines for Soils Derived from Volcanic Ash in the Blue Mountains of Oregon and Washington).

Given that the above study was not performed on burned ground, Davis et al. (2001) found acceptable ground impacts on machine logging on severely burned areas of the Summit Fire Recovery Project. The skid trail spacing ranged from 70-100 feet, to 100 feet, and 100-120 feet. The machinery used were harvesters and tractor skidders taking whole trees to the landing areas; feller buncher and tractor (on gentle ground), or FMC skidders (on 40% ground).

For the Easy Fire, on unburned or low burn severity sites, the expected ground impacts would match more closely the results from the study by McNeil (1996), where the total compaction was about 6 percent (with no subsoiling). Mitigations requiring heavy equipment use under specified soil moisture conditions or winter conditions, and the subsoiling of skid trails in the majority of tractor units, would reduce the resulting compaction.

On the moderate and high burn severity sites, cable winching logs would produce small areas of soil displacement. Subsoiling would not decrease the amount of detrimental soil displacement in the skid trails. After all activities, there would be some remaining compaction, and displacement; however, the amounts are expected to be within the Forest Plan Standards. Davis et al. (2001) examined several harvest units on Summit Fire, and didn't find any violations to standards. Puddling is associated with compaction, and statements about compaction also apply for puddling.

Skyline and Helicopter Harvest

Skyline logging causes much less displacement, erosion, and compaction than tractor logging - detrimentally affecting about one to three percent of the area. Logs that drag during skyline logging can displace soil and concentrate erosive runoff in furrows. Required cross drains would divert runoff from the furrows, so the amount of erosion would be negligible, and soil would be unlikely to leave the harvest units. For the proposed skyline units, the yarder equipment would rest on the current road surface, and logs would be pulled up the yarding corridor and then lowered onto the road surface. Essentially, there would be no additional ground taken for skyline landings. Accounting for the road area would include the skyline landing areas.

Detrimental impacts of helicopter logging would be negligible (about one percent), outside landings, because no heavy equipment would be used on soil. There would be minor soil disturbance from the falling of the trees and as the helicopter initially pulls up the logs, until the logs cleared the ground. The helicopter landings would be subsoiled at 18 inches depth with winged subsoilers. Alternatives 2 would have 7 helicopter landings, and Alternatives 3 and 4 would have 5 helicopter landings.

In skyline and helicopter units, treetops would be lopped and scattered in the units. So harvest in these units could generate some additional ground cover, which would reduce surface soil erosion.

Erosion and Sediment Risk

Even with water bars and seeding, skid trails can erode a small amount. For instance, some skid trail erosion may occur on slopes steeper than 30%. An intense summer thunderstorm would likely create isolated areas of erosion in disturbed soil sites and skid trails.

Concentrated runoff from roads, or draws can exacerbate skid trail erosion (McNeil 2001). Runoff from existing and new skid trails could interact similarly.

Usually erosion of skid trails decreases through one to three years. Decreased productivity due to severe displacement and erosion can last hundreds of years. However, mitigations would keep displacement and erosion to a minimum. The majority of ground-based acres are on slopes of less than 30%. Davis et al. (2001) found displacement and erosion after skidding on a severely burned 40% slope to be at an acceptable level on Summit fire on Blue Mountain Ranger District.

The mitigation measures for the soil resource include designated spaced skid trails; limiting tractor skidding to slopes of less than 35%; allowing operations on dry, frozen or snow-covered soil; subsoiling of skid trails; installing cross drains; and seeding disturbed areas with a native or non-persistent, certified weed-free seed mixture.

Under most weather conditions, skidding would cause negligible soil export from the units, despite soil movement within units as described in the preceding paragraph. Soil normally is deposited down slope as the water percolates into the soil. Two to three years after the Summit fire, skidding caused export of a total of 0.02 m3 of soil from units totaling 230 acres (McNeil 2001). This export was below average, since there were no heavy thunderstorms. It does indicate skidding usually causes negligible soil export from units, even after fire.

Similarly, Davis et al. (2001) saw no evidence of soil movement from logged, severely burned units on Summit Fire. McNeil (1999) found that the majority of eroded soil from roads in the Swamp Planning Area usually traveled less than 50 feet. In rare instances, it traveled 65 feet or more. The age and road design in the Swamp Planning Area are similar to those on the Easy Fire Project Area; most roads are more than 10 years old and well vegetated. Several differences between the two areas are that the Easy Fire area has steeper slopes (average of 30-35% versus 9%) and slightly more rainfall (32 inches versus 20-30 inches) than the Swamp Planning Area.

On the other hand, McIver & Starr (2000) reported on field studies in the West that indicated sediment can be produced by logging after wildfire. Of the five logging operations reviewed, two produced sediment (one of these had three studies), two did not produce sediment, and one had mixed results. Reasons for the varying results included variations in details of operations, study methods, ground cover, weather, and soils. Also, public information sources have stated that in some areas of the Summit Fire project, adverse effects from erosion and sediment was above projected levels from management activities.

Even though skidding likely would cause negligible soil export from units, there is a small risk of a small amount of soil export from units with moderately and severely burned soil. Weather and storm events are variable, and recovery of ground cover is difficult to predict.

WEPP Analysis

The WEPP model and Disturbed WEPP Interface were used to predict amounts of increased sediment produced from proposed management activities two years (2004) after the Easy Fire. Areas were selected which contained 85-100 percent of high to moderate BAER burn severity in the fall of 2002. Areas were also selected based on their proximity to stream channels. The results for these areas would show the higher amounts of sedimentation that could occur from harvest activities. For the tractor slope areas, the slope analyses continued to the edge of potential units. For helicopter slope areas, the slope analysis included the downslope portions beyond the potential unit, until a road or creek was reached.

The table of site conditions lists the analysis areas with the percent slopes and the BAER burn severities.

Table S-9a: Site Conditions for WEPP Analysis Areas

Logging System	Analysis Area	Water Flow Line	Percent Slopes	% BAER Burn Severity	
				High	Moderate
Tractor Harvest	A	1	20 – 40%	100	-
	A	2	5 – 30%	95	5
	B	1	8 – 20%	25	75
	B	2	8 – 20%	40	60
Helicopter Harvest	C	1	30 – 60%	81	6
	C	2	40 – 60%	52	41
	D	1	60 – 70%	40	60
	D	2	40 – 60%	63	32
	D	3	35 – 55%	51	42

Tractor areas A and B were among the potential tractor slope areas that had high amounts of high and moderate BAER burn severity. Helicopter areas C and D were also analyzed with WEPP since these units contain steep slopes that burned at high to moderate BAER burn severity above Clear Creek. These areas would show the higher amounts of sedimentation that could occur from harvest activities.

The figures in the table of Sediment Analysis show the potential sediment increase as annual averages.

Table S-9b: Table of Sediment Analysis

Proposed Activity	Analysis Area	Water Flow line	Before Activity Fall 2004 Sedimentation	Potential Sediment Increase From Harvest Activity (annual average)	
			Cubic yd/acre	Cubic yd/acre	Equivalent lbs/acre
Tractor Harvest	A	1	0.101	0.074	100
		2	0.030	0.043	58
	B	1	0.007	0.027	36
		2	0.022	0.027	36
Helicopter Harvest	C	1	0.178	0.016	22
		2	0.144	0.019	26
	D	1	0.185	0.009	12
		2	0.080	0.006	8
		3	0.059	0.001	2

Current average annual sediment rates are estimated at 0.007 to 0.101 cubic yards/acre on the tractor units, and 0.059 to 0.185 cubic yards/acre on the helicopter units. These values equate to 0.001 inch or less of soil depth per acre. Average values for ground that had less burn severity or gentler slopes would be less.

Harvest activities from tractor units could produce an increase of 0.027 to 0.074 cubic yards/acre, while helicopter units could produce 0.001 to 0.019 cubic yards/acre. The steeper slopes on the eastern, downslope end of area A accounts for the higher amounts of potential sediment along the end of flow line 1 (0.074 cubic yards/acre). These values are equivalent to 0.001 inch or less of additional sediment produced per acre. Again, values for ground that had less burn severity or gentler slopes would be less.

The following table lists the units in the final alternatives which have both high and moderate BAER burn areas, and that are close to stream courses. These units would have similar erosion and sedimentation rates as those analysis areas discussed above. Areas that had less severe BAER burn severity or gentler slopes would have less erosion and sedimentation.

Table S-9c: Units with High & Moderate BAER Severity Close to Stream Courses

Unit	Logging Method	High & Mod. BAER Acres	Adjacent Stream Course	In Alt. 2	In Alt. 3	In Alt. 4
12	Helicopter	29 ac.	Clear Creek, Cat. 1	Yes	No	No
22	Helicopter	65 ac.	Cat. 4 trib. to Clear Creek	Yes	No	Yes
30	Helicopter	70 ac.	Easy Creek (Cat. 4)	Yes	No	Yes
41	Tractor	20 ac.	Easy Creek (Cat. 4)	Yes	Yes	Yes
45	Tractor	56 ac.	Cat. 4 trib. to Easy Creek	Yes	Yes	Yes
65-S	Skyline	41 ac.	Cat. 2 & 4 trib. to Clear Creek	Yes	No	Yes
Total High & Moderate BAER Acres:				261	56	232

Alternative 2 contains all of the units listed in the table, for a total of 281 acres of high to moderate BAER burn severity near stream courses. Alternative 4 has 252 acres, and Alternative 3 has the least at 76 acres.

For the majority of the tractor slopes analyzed, in harvested areas, weather of 6-year return intervals or greater would produce sediment across the unit boundaries, except for the last 30 to 100 feet upslope from unit boundaries. Weather years of 3-year return intervals could produce sediment to the unit edge along the last 30 to 100 feet of unit boundaries. This is based on 30 years of climate.

The analysis based on 50 years of climate indicate that for most of the tractors slopes analyzed, in harvested areas, weather of 5-year return intervals or greater would produce sediment across the unit boundaries. The exception would be for the last 30 to 100 feet upslope from unit boundaries, where weather years of 2 ½-year return intervals could produce sediment to the unit edges. An average climate year (2.5 year return interval) would not produce sediment to unit edges.

For the helicopter units analyzed, in harvested areas, weather years of 5-year return intervals or greater could produce sediment beyond the unit boundaries from management activities, while an average climate year (2.5 year return interval) would not. This is based on 50 years of climate.

The annual sediment values from the tractor units assumes that all sediment in the upper slope segments would reach the lower segments, with no diverting of sediment by cross drains. In actual practice, the installation of cross drains would reduce the amount of sediment moving downslope by diverting overland flow and sediment out of the water's flow line down the slope. There would still be erosion from disturbed areas, however.

Also, the spacing of the cross drains is a key factor in controlling the resulting erosion and sedimentation in and from the tractor units. The spacing of the cross drains within the skid trails affects the length of the individual slope segments. This slope length influences the predicted amounts of potential runoff, erosion and sedimentation. Installing cross drains at closer spacing reduces the predicted erosion and sediment values, while wider spacing increases the resulting values. General guidelines for the spacing of cross drains were used in the WEPP analysis for tractor units.

For any one of the given years, however, the potential erosion depends on the climate. If the year is normal or dry, then it is unlikely for there to be any significant erosion. If the year has above average precipitation, however, then there could be more soil erosion.

Proximity of Tractor Units from Stream Network

Exported sediment from units are expected to be minimal from tractor-logged areas. The majority of ground-based acres are on slopes of less than 30%. Tractor units are located away from all perennial streams, and from the majority of the intermittent stream channel network, which reduces the likelihood of any sediment routing. The two units closest to intermittent streams (Units 41 and 45) are located on 0-30% ground slope. See the table in the previous section "WEPP Analysis." Maps showing the location of the tractor units along with the stream channels are included in Soils Appendix C.

Fuels Control - Grapple Piling

The discussion on effects of grapple piling is based on the following assumptions:

1. Grapple piling equipment is required to have a low ground pressure (<8 pounds per square inch), and will operate on skid trails where possible, and will operate on dry soil. Dry soil conditions are listed in Chapter 2 "Management Requirements, Constraints, and Mitigation Measures."
2. Grapple piling would occur before the skid trails are subsoiled. So the increased compaction from grapple piling would be in places where the grapple machine went off skid trails.

Grapple piling on dry soils can compact about 1% of each unit, in addition to the compaction from feller bunchers and skidders (McNeil 1996). If grapple piling occurs when the soils are moist, the amount of compaction could be higher. Note: The compactibility of ash soils does not change as much with soil moisture as with non-ash soils (Meurisse, 1985).

If grapple piling takes place after the subsoiling of the skid trails, then the amount of compaction by the grapple piling would be about 2 percent. The tables in Soils Appendix C display the proposed units in each alternative, with the logging system and their BAER burn severity acres. The tables also display the units proposed for grapple piling for Alternatives 2, 3, 4 and 5.

Direct and indirect effects from hand piling and burning would be negligible, because no heavy equipment is used. Burning of piles would produce small areas of detrimentally burned soil.

Soil Productivity – Nutrients

Logging and fuel control would remove nutrients and organic matter. This removal, especially removal of nitrogen, may decrease site productivity a few percent on some sites. Removing organic matter and nutrients by logging and fuel control would likely move many sites back toward their fertility status before European-Americans arrived (see Existing Condition Section).

In high and moderate burn severity areas, removing varying number of burned trees is not expected to have long term effects on the nutrient reservoir, since the minimum amounts of coarse woody debris for long-term site productivity would be left on site. Also, a relatively small percentage of nutrients would likely be removed, because wood has a lower concentration of nutrients compared to foliage, small branches, and the remaining forest floor. Also, non-merchantable trees would be left on site.

Within harvest units in Alternatives 2, 3 and 4, many dead and dying trees in smaller size classes within the harvest units would be retained to provide beneficial soil nutrients. Also, all live trees would be left to provide a future source of down wood (i.e. needle cast, limbs, and large logs). In addition, some organic materials and nutrients remain in the surface mineral soil. Even in the high severity burn areas, small plant roots were not charred in the upper 1-2 inches of soil (TenPas and McNeil 2002). See the Fuels section for estimates of the amount of fuels that would be left, compared to historical conditions.

Soil Biota & Food Web

Large down wood provides moist micro-sites for conifers, shrubs, herbs, fungi, mycorrhizae, mosses, lichens, bacteria and small animals such as earthworms, snails and nematodes. An important mechanism for reintroduction of mycorrhizal fungi on burned forest areas is dispersal by chipmunks. These animals eat fruiting bodies of mycorrhizal fungi in adjacent unburned areas, and spread spores in burned areas by their fecal material. Downed logs provide travel lanes and home sites for chipmunks. So the presence of residual logs enhances the reestablishment of mycorrhizal fungi, both by enhancing habitat for chipmunks, and by providing suitable microsites for mycorrhizal infection and growth (National Wildfire Coordinating Group 2001).

The proposed harvest areas that underwent high BAER burn severity would likely have reduced mycorrhizae populations in the near term, until young forest vegetation becomes re-established. Leaving well-dispersed snags would provide a more evenly distributed supply of near-future, large down wood for soil productivity and soil organisms, as the snags fall to the ground (Graham et al. 1994). Alternative 2 leaves an even distribution in the harvest units for retained snags in small clumps if possible. Alternative 4 would retain higher snag levels in small clumps in harvested areas, which would provide for larger amounts of near-future down wood. Outside harvest units, all snags would be retained, except for those felled along open roads to reduce safety hazards.

Alternative 3 leaves less snags (1-2 snags per acre for down wood recruitment) than the forest plan standard in harvest areas. However, in Alternative 3, harvest is avoided on the steeper, severely burned slopes in the Clear Creek tributaries and along Easy Creek, where significant snag patches would be retained. The actual acres of harvested high BAER burn areas with reduced snag levels (below the forest plan standard) would be about 183 acres. Outside harvest units, all snags would be retained, except for those felled along open roads to reduce safety hazards. Also, significant snag patches would be retained in the project area in Alternative 3.

All alternatives would leave at least the minimum amount of down wood or one to two snags per acre for down wood and long-term site productivity. Salvage prescriptions that leave all live trees and prescribed amounts of down woody material are expected to maintain current ectomycorrhizae populations over the project area. For the re-establishment of the coniferous vegetation, planted seedling survival has been comparable in both salvaged and unsalvaged areas on the forest. Planted seedling survival is expected to be at or slightly below average.

Leaving well-dispersed snags would also eventually help in slowing down surface runoff, and help trap sediments as the snags fall to the ground. The more immediate factor in reducing runoff and erosion would be the resprouting vegetation, litter fall, and the growth of mosses, lichens, forbs and other herbaceous vegetation, along with the current down wood. Elliot et al. (2001) noted that field observations and validation studies suggest that following fire the amount of exposed mineral soil is halved each year until the site is recovered. This usually takes about three or four years after a fire. Erosion rates generally decline significantly the third and fourth year after a fire.

Soil organisms are also influenced by photosynthates, which are exuded from the fine roots of living trees. Photosynthates serve as food for soil bacteria and fungi, which in turn are food sources for soil animals, such as arthropods and nematodes. Since Alternatives 2, 3 and 4 focus on the harvest of fire-killed trees or trees expected to die as a result of fire injury, there is not expected to be a significant effect from harvest activities on the roots of living trees and levels of photosynthates in the soil biotic system.

However, soil organisms and live plant roots would be reduced in areas where equipment is used for ground skidding, landing construction and operation, and subsoiling. Pile burning would also affect soil organisms in localized areas where soil is sterilized from high intensity heat.

Soil effects from other past, present and foreseeable actions would be negligible. These actions include road maintenance, hazard tree felling along roads (leaving felled trees on the slope), planting hardwoods, gathering mushrooms, and other activities.

Tables of Comparison for Alternatives 2, 3 and 4

<u>Proposed Ground Based Activity and BAER Burn Severity</u> - The estimates on ground impacts are based on the available monitoring data, expected conditions and events, and on professional judgment. Variables come to play that are harder to predict, such as weather, storm events, and plant recovery rates. Given this, the moderate and high BAER burn severity areas may have a higher level of uncertainty between expected impacts and actual impacts, than for unburned or low burn sites from ground based operations. The tables in the Soils Appendix C display the proposed units in each alternative, with the logging system and their BAER burn severity acres.

The tables also display the units proposed for grapple piling for Alternatives 2, 3 and 4. Alternatives 2 and 3 contain the same units to be grapple piled, for a total of 456 acres. Alternative 4 would grapple pile 335 acres. In tractor harvested units, grapple piling (with later subsoiling of skid trails) is expected to result in 1 to 2 percent of the units compacted.

The table below shows the summary of acres in each alternatives 2, 3 and 4 by logging system on the various BAER burn severities. Alternative 4 has the least acres in each category of logging system (helicopter, skyline and tractor). Alternative 3 has an intermediate amount of acres harvested by each type of logging system. And Alternative 2 has the most acres harvested by each logging system.

Table S-9d: Harvest Acres by Logging System and BAER Burn Severity

Alternative	BAER	Helicopter Acres	Skyline Acres	Tractor Acres
2	High	128	45	162
	Moderate	145	54	224
	Low - Unburned	272	154	593
	Total	**545**	**253**	**979**
3	High	24	8	151
	Moderate	66	41	218
	Low - Unburned	218	104	468
	Total	**308**	**153**	**837**
4	High	92	36	138
	Moderate	79	5	149
	Low -Unburned	94	17	346
	Total	**265**	**58**	**633**

Note: "Low – Unburned" acres include areas where the fire registered "unburned" on the BAER mapping, but the fire still burned the vegetation to some degree.

Also, slight differences in totals between different tables are due to rounding differences in the figures.

For ground-based yarding, Alternatives 2, 3 and 4 do not differ significantly in the high and moderate BAER severities that would be harvested. See the table below. The largest difference between alternatives is in the "low to unburned" acres that would be harvested by tractor (122 to 247 acres difference). Alternative 4 proposes the least acres in all BAER burn categories. Maps of the high and moderate severities in the tractor harvest units are included in Soils Appendix C.

Table S-10: Tractor Harvest Acres by BAER Burn Severity and Slope Category

BAER Burn Severity	Slope Range	Alt.2	Alt. 3	Alt. 4
High	0-30%	146	144	124
	31-60%*	16	7	14
	Subtotals	**162**	**151**	**138**
			Difference = 13 to 24 acres.	
Moderate	0-30%	194	193	134
	31-60%*	30	25	15
	Subtotals	**224**	**218**	**149**
			Difference = 69 to 75 acres.	
Low or unburned	0-30%	450	382	308
	31-60%*	143	86	38
	Subtotals	**593**	**468**	**346**
			Difference = 122 to 247 acres.	

*Tractor yarding would be avoided on slopes steeper than 35%

Alternative 5

Under Alternative 5, the direct and indirect effects to the soil resource would be very similar to those effects described for Alternative 1 (No Action). There would not be any significant effects on soil erosion, productivity or soil biota from Alternative 5.

The main difference would be the tree planting and the fuels treatment in Alternative 5. Alternative 5 would provide for tree planting in severely burned areas (vegetation burn severity). This tree planting would accelerate the establishment of young forest vegetation, and help maintain and increase the mycorrhizae populations in the severely burned areas (vegetation severity).

The fuels treatment in Alternative 5 involves hand felling, grapple piling, and burning of piles for the gentle ground; and hand felling, hand piling, and burning of piles on the steeper slopes. The fuels treatment would focus on the removal of small, dead and dying fuels (less than 7 inches in diameter). The large diameter down wood would be left on the ground. Grapple piling would treat 1,750 acres, and 1,902 acres would be hand piled with piles burned.

Grapple piling equipment would be required to have low ground pressure (<8 pounds per square inch), would operate on old skid trails where possible, and operate on dry soil. Grapple piling with burning of the piles would affect about 2 percent of the treated areas.

Direct and indirect effects from hand piling and burning of the steeper slopes would be negligible, because no heavy equipment would be used. Also, there would not be any fuels generated from any harvest activity. Burning of piles would produce small areas of detrimentally burned soil.

The burning of slash piles generally occurs during late fall when fire season has ended and when a significant amount of moisture in the form of heavy rain or snow has occurred (1+" of moisture). Since pile burning would be done when the soil is wet, impacts to soil from burning piles are expected to be low. Pile burning would affect soil organisms in localized areas where soil is sterilized from high intensity heat. The piling and burning for fuel control would remove some nutrients. A table showing the BAER burn severity in the grapple pile and hand-pile units in Alternative 5 is included in the Soils Appendix C.

Cumulative Effects

The processes discussed in the Existing Condition sections on plant recovery and protective ground cover would occur for all alternatives, in addition to those effects discussed below for each alternative.

Alternative 1, No Action Alternative

All of the past, ongoing, and reasonable foreseeable future activities identified in the beginning of Chapter 3 have been considered for their cumulative effects on soil resources for this alternative. The rehabilitation of the fire suppression activities in 2002, plus the likely return of ground cover to near pre-fire levels by fall of 2004, should be sufficient to reduce erosion from fire lines below the levels where cumulative effects could occur.

Alternative 1 would not cause significant short-term nor long-term impacts to soil from road maintenance activities, regulated mushroom collection, firewood sales or other foreseen activities.

Over time, ground cover would increase as forest conditions develop, and erosion levels would decrease. Root action, animals that burrow in the soil, and freezing water would gradually loosen compacted soil over the course of decades. Fire-killed trees would contribute large woody debris to the slopes and stream channels as they fall to the ground. Soil organic matter would gradually increase. Nutrients would gradually accumulate due to inputs by precipitation, dry deposition, weathering of parent material, and nitrogen fixation and retention.

Regarding future fire severity, Sessions et al. (2003) stated that for the Biscuit Fire, "fire risk would increase if fuels are not managed and insects further damage fire-injured timber. Primary tree-killing insects….can kill green timber, particularly weakened trees. Insect and disease buildup can follow fire by killing fire-stressed (weakened) trees, creating additional snags and accelerating the development of fine fuels that create high rates of fire spread. If the insect buildup is large, adjacent unburned forests can be threatened."

"Many fire-injured, but still live, trees are infested and killed by bark beetles and woodborers within 5 years of the burn… There is the risk that, as insect populations build in the fire-stressed trees, the insects will leave the stressed trees to attack healthy green trees both inside and outside the burned area, leading to even higher fuel loadings" (Sessions et al. 2003).

The Sessions report further states that "high numbers of snags will persist for several decades, and that down wood accumulations on the forest floor will grow as snags fall and/or deteriorate, reaching maximum levels in 40 years and remaining at those levels for several decades… Significant portions of dead and dying trees in Biscuit (fire) will leave the landscape prone to large, intense wildfires for at least 60 years into the future, further jeopardizing any potential for the forest to return to late successional conditions."

For the Easy Fire, Alternative 1 would have a higher risk (compared to alternatives 2, 3 and 4) of adverse soil impacts from a future fire in 10 to 30 years, and in 30 to 60 years. In the No Action Alternative, the dead standing trees and large down woody debris would be left on site. For the first 10 years after the fire, severe fire is unlikely on the moderate to high burn severity sites, since large woody debris would still be accumulating on the ground surface through the falling of the dead trees (Brown et al. 2003). The grass, forbs, shrubs and naturally established tree seedlings would contribute to the organic biomass and could burn at high fire intensity should a second wildland fire occur. However, the fire duration (fire residence time) and heat effects on the soil surface would be relatively short.

After 10 to 30 years, much of the dead trees would be falling to the ground, and large woody pieces would have some decay, which would support prolonged burning. In a second fire, high fire intensity for longer duration would likely occur where large woody material is lying on or near the ground surface. With the higher fuel loadings of large woody debris where greater tree mortality occurred, there would likely be greater amounts of detrimental burned soil conditions. After 30 years, the large woody debris would likely have considerable decay. Thus, more severe soil heating would be possible than during the earlier periods depending on the extent of soil coverage by the large woody debris (Brown et al. 2003).

Livestock grazing beginning as early as 2005 is foreseeable in the fire area if requirements of the Malheur Post-Fire Grazing Guidelines are met. Livestock grazing can result in the reduction of ground cover and increased soil displacement during dry and wet periods, and soil compaction during wet periods. Along streams, much of the effects to the soil would occur where livestock concentrated at water sources. Therefore, livestock grazing could delay the recovery of erosion rates to pre-fire levels.

Alternatives 2, 3 and 4

All of the past, ongoing, and reasonable foreseeable future activities identified in the beginning of Chapter 3 have been considered for their cumulative effects on soil resources for these alternatives. The rehabilitation of the fire suppression activities in 2002, plus the likely return of ground cover to near pre-fire levels by fall of 2004, should be sufficient to reduce erosion from fire lines below the levels where cumulative effects could occur. Tree planting would help increase ground cover after trees become established. The natural recovery processes discussed in Alternative 1 would also take place in Alternatives 2, 3 and 4.

Additional detrimental impacts to the soil resource would occur from Alternatives 2, 3 and 4. The table labeled “Expected Soil Conditions after Management Activities” displays the proposed ground based yarding units (feller buncher, tractor skidding and grapple piling), and the expected soil conditions after proposed activities. The figures include subsoiling the majority of skid trails and all tractor and helicopter landings. The survey information showed only a few areas of proposed tractor units as being unsuitable for subsoiling in terms of high rock content. Areas that have high amounts of cobbles and stones would not be subsoiled.

The figures in the table include the areas in landings, and permanent and temporary roads. The unit numbers in one alternative correspond to the same area in similar numbered units in the other alternatives, except for some units in Alternative 5, where those units are generally larger. Where the unit acres differ in Alternative 5, the acre sizes are listed in parentheses.

Alternative 5

All of the past, ongoing, and reasonable foreseeable future activities identified in the beginning of Chapter 3 have been considered for their cumulative effects on soil resources for this alternative. The rehabilitation of the fire suppression activities in 2002, plus the likely return of ground cover to near pre-fire levels by fall of 2004, should be sufficient to reduce erosion from fire lines below the levels where cumulative effects could occur.

The long-term effects for Alternative 5 would be similar to those effects described for Alternative 1 (No Action). Alternative 5 would not cause significant short-term nor long-term impacts to soil from road maintenance activities, regulated mushroom collection, firewood sales or other foreseen activities.

Tree planting in the severely burned areas (vegetation severity) would help increase ground cover after trees become established. The natural recovery processes discussed in Alternative 1 would also take place. Detrimental soil impacts from grapple piling and the burning of the piles would be about 2 percent over the treated areas. Direct and indirect effects from hand piling and burning of the steeper slopes would be negligible, 1 percent or less, since no fuels would be generated by harvest activity.

The risk from future fire severity would be similar to that of Alternative 1, since removal of the small diameter fuels would only minimally reduce the current fuel amounts on site.

Livestock grazing beginning as early as 2005 is foreseeable in the fire area if requirements of the Malheur Post-Fire Grazing Guidelines are met. Livestock grazing can result in the reduction of ground cover and increased soil displacement during dry and wet periods, and soil compaction during wet periods. Along streams, much of the effects to the soil would occur where livestock concentrated at water sources. Therefore, livestock grazing could delay the recovery of erosion rates to pre-fire levels.

The table labeled "Expected Soil Conditions after Management Activities" displays the expected cumulative effects in Alternative 5 for the grapple pile units. The existing soil conditions for the proposed harvest units are listed under Alternative 1 (No Action).

Table S-11: Expected Soil Conditions after Management Activities – Ground Based Activities

Unit Number	Acres	Average Percent Detrimental Soil Impact				
		Alternative 1 (No Action)	Alternative 2	Alternative 3	Alternative 4	Alternative 5
1	5	14	-	-	-	16
5	6 (9)	13	18	18	-	15
6	7	10	15	15	-	12
7	20 (32)	14	19	19	-	16
8	8 (9)	12	17	17	-	14
9	114 (158)	13	20	20	-	15
11	15	3	11	11	11	5
18	11	0	6	6	6	2
19	75	10	-	-	-	12
23	139	0	-	-	-	2
24	15	2	-	-	-	4
25	17	10	15	15	15	12
26	30 (31)	11	18	18	18	13
28	48 (134)	5	12	12	12	7
31	43 (90)	9	14	14	14	11
32	117 (116)	6	11	11	11	8
33	13	9	-	-	-	11
36	70 (78)	10	15	15	15	12
37	30	8	13	13	13	10
39	27	10	-	-	-	12
40	97	8	-	-	-	10
41	153	9	16	16	16	11
42	131	10	-	-	-	12
43	30	9	-	-	-	11
44	27	8	-	-	-	10

Table S-11: Expected Soil Conditions after Management Activities – Ground Based Activities - Continued

Unit Number	Acres	Average Percent Detrimental Soil Impact				
		Alternative 1 (No Action)	Alternative 2	Alternative 3	Alternative 4	Alternative 5
45	89 (99)	0	8	8	8	2
46 (NE 2/3)	64	11	16	-	-	13
46 (SW 1/3)	19	13	18	-	-	15
56	7 (8)	5	12	12	-	7
57	52	9	14	14	-	11
64	49	9	14	-	-	11
65	10	6	11	-	11	8

Note: – Indicates the unit is not included in the proposed alternative.
The existing soil conditions are listed under Alternative 1 (No Action).
Acres in ( ) are unit acres for Alternative 5.

The table below lists the proposed harvest units in Alternatives 2, 3 and 4 that would likely approach or reach the Regional and Malheur National Forest limit on detrimental soil impacts after management activities. Unit 5 is a relatively small unit along a road. Unit 7 contains a decommissioned road, which runs throughout the unit. This decommissioned road would be re-opened temporarily, then decommissioned after the end of harvest activities. The higher proportion of roads in these smaller units adds to the higher percent of resulting soil impacts. Grapple piling is proposed for unit 9, which adds to the total amount of expected soil disturbance.

Table S-12: Threshold Units in Alternatives 2, 3 and 4: Proposed Harvest Units that Approach or Reach the Limit on Percent of Detrimental Soil Impacts

Unit Number	Average Percent Detrimental Impact	Acres in Alternative 2	Acres in Alternative 3	Acres in Alternative 4
5	18 %	6	6	---
7	19 %	20	20	---
9	20 %	114	114	---
26	18 %	30	30	30
46 (SW 1/3)	18 %	19	---	---
	Total Acres	189	170	30

Forest Plan Standards are expected to be met with all alternatives. However, as stated earlier, there are variables that are harder to predict, such as weather and storm events, and plant recovery rates. Consequently, the moderate and high BAER burn severity areas may have a higher level of risk and uncertainty between expected impacts and actual impacts, than for unburned or low burn sites from ground based operations.

Alternative 4 would have the least acreage affected by ground based yarding on moderate and high burn severity areas (287 acres), while alternative 3 would have 369 acres, and alternative 2 would have 386 acres.

Livestock grazing beginning as early as 2005 is foreseeable in the fire area if requirements of the Malheur Post-Fire Grazing Guidelines are met. Livestock grazing can result in the reduction of ground cover and increased soil displacement during dry and wet periods, and soil compaction during wet periods. Along streams, much of the effects to the soil would occur where livestock concentrated at water sources.

Grazing could also potentially reduce ground cover and organic matter in upland areas where ground-disturbing activities are proposed. These activities include use and subsequent subsoiling of skid trails, construction of new landings, and the use and decommissioning of temporary roads. Therefore, livestock grazing could delay the recovery of erosion rates to pre-fire levels.

Over the intermediate to long term (in the period between 10 to 60 years), Alternatives 2, 3 and 4 would have lower risk than the No Action Alternative, for adverse soil conditions resulting from the intensity of future wildland fires. Alternatives 2, 3 and 4 would reduce the amount of dead standing trees and the large, down woody debris on burned sites. If a wildfire occurs, the proposed fuels treatments would decrease the intermediate and long-term soil fire severity (Vihnanek and Ottmar 1993). Large woody debris have little influence on spread and intensity of an initiating fire; however, they can contribute to the development of large fires and high fire severity, depending on the amount, size and decay state of the woody fuel (Brown et al. 2003). In the No Action Alternative and Alternative 5, with all fire-killed trees and large woody debris left on the moderate to high burn severity areas, there is more chance of incurring detrimental burned soils from the eventual higher fuel loading on the ground.

Rationale for Subsoiling Skid Trails and Landings

Although all treatment units are expected to meet Forest Plan Standards, the majority of skid trails and landings are proposed for subsoiling for the following reasons:

1. When the percent of landings and roads are included in the table of Expected Soil Conditions After Management Activities for the tractor harvest units, some of the units approach or reach the threshold of 20% detrimental soil damage. Thus, subsoiling is prescribed to ensure that soil standards would be met.

2. As discussed previously, the moderate and high BAER burn severity areas may have a higher level of risk and uncertainty between expected impacts and actual impacts, than for unburned or low burn sites from ground based operations. Again, subsoiling is prescribed to ensure that soil standards (for compaction) would be met.

3. Subsoiling skid trails is also prescribed to reduce the potential for the spread of Armillaria root rot in part of the project area. (See the Forest Vegetation and Structure section, Chapter 3)

Rationale for Extended RHCA Buffers in Alternatives 2, 4 and 5

Because of the condition of the burned RHCAs and the erosion taking place along the severely burned areas in the Clear Creek and Easy Creek drainages, the following mitigation measures are recommended to help minimize additional erosion and to provide for future recovery of the ground and channel conditions. See the sections on plant recovery, sedimentation and tributaries and ephemeral channels for the high burn severity area in Clear Creek, for the rationale for these measures.

Units 22, 30 and 65: The RHCA buffer along the burned intermittent channel should be extended to 150 feet slope distance from the water channel, to provide additional protection to help reduce the sideslope erosion and sedimentation, and to provide future down wood for ground cover and for trapping sediment. For Alternative 5, no fuels treatment, hand piling nor burning should occur in the RHCA buffer.

For Alternative 5, Unit 21: No fuels treatment, hand piling nor burning should occur within 15 to 20 feet of the ephemeral channel (channel "C"), to help minimize soil disturbance, and to retain the existing woody debris and organic material. Also, along the burned intermittent stream channel in the unit, the RHCA buffer should be extended to 150 feet slope distance from the water channel, to provide additional slope protection to minimize sideslope erosion and sedimentation. No fuels treatment, hand piling nor burning should occur in this RHCA as well.

Within unit 21, four small wet areas (seeps) and one small pond (6' by 9') are located adjacent to the lower burned section of the intermittent channel. These wet areas and seeps would be included in the RHCA buffer as well.

Foreseeable, Future Actions

The following foreseeable action would be covered under a Categorical Exclusion, to help the vegetative recovery of the burned Clear Creek tributaries and of Easy Creek.

Units 22, 30 and 65: Provide for riparian hardwood plantings along the intermittent channels (RHCAs) which underwent high BAER burn severity, to help the recovery of streamside vegetation and to provide for soil stabilization and future stream shading.

Other foreseeable or on-going actions include road maintenance activities, regulated mushroom collection, and firewood sales.

Consistency with Direction and Regulation

Forest Service Manual 2500, Region 6 Supplement 98-1 and the Malheur Forest Plan provide direction for the maintenance of soil quality and productivity within specified standards and guidelines for management activities. Alternative 1 (No Action) meets the protection of soil quality and productivity by not producing additional soil impacts within the fire project area.

All alternatives are expected to meet the Forest Service Manual and the Malheur Forest Plan within the allowable amounts of percent of total detrimental soil impacts within an activity area. However, as discussed in the cumulative effects section, Alternatives 2, 3 and 4 contain units that approach or reach the regional and forest wide limit for amount of detrimental soil impacts. There is also a difference in the total acres that would be affected by Alternatives 2, 3 and 4. With the greater amounts of proposed acres in the moderate to high burn severity areas, there is an inherent higher risk of incurring impacts. Alternatives 2 and 3 would have the most risk, Alternative 4 would have lower risk, and Alternative 1 would have no risk for incurring immediate impacts.

Over the intermediate to long term period (from 10 to 60 years), there would be a higher risk for incurring detrimental soil impacts from future wildland fires in Alternatives 1 (No Action) and 5, since there would be higher levels of large, dead and down fuels from the past fire. With the higher fuel levels, a future fire would likely have higher fire intensities and longer fire duration from the larger diameter, standing and down wood. The higher fire intensity with longer duration would produce more detrimental burned soil and impaired watershed conditions. For Alternatives 2, 3 and 4, there would be lower risk of incurring severely burned soil since some amount of dead and standing trees would be removed from the burned area.

Irreversible/Irretrievable Consequences

For alternatives 2, 3 and 4, there is a risk for small areas of increased soil erosion and detrimental soil displacement from skid trails. No other irreversible impacts are expected.