SOIL RESOURCES

ANALYSIS AREA

The overall analysis area for soil resources is the Basin-Butte watershed, (Hydrologic Unit Code number 170102010201, 6th field HUC). Watershed-level cumulative soil effects are described at this scale. In addition, local effects are described at an activity area or treatment unit level. Each treatment unit in this proposal is an activity area for these local effects. See the Alternatives Map for treatment unit locations and identification.

INTRODUCTION

The geomorphic processes, geology, and vegetation occurring on the Forest have been compiled in various GIS layers and coverages. These include regional 100k scale geology coverage; USGS 1x2° quads; Montana statewide compiled geology map; MSU's 'Geological Map of Montana'; various published and unpublished geology reports; Land Systems Inventories; Section, Subsection, Land Type Association, and Land Type maps; local soil survey that is in progress; and various vegetation layers including the most recent 'SILC' satellite imagery and interpretation. All of these are useful to this project to some degree, but the draft soil survey for the North Zone (Deerlodge) has been the most extensively used biophysical layer in this project for soils assessment. Table 3.61 lists the mapping units, composition, composition name, and soil taxonomic name of the soils known in the watershed containing the analysis area. This data does not necessarily represent existing soil conditions in this project area, but rather the potential generalized soil materials and conditions found within the soil mapping units comprising this area. Description of the series family, typical pedon, and range in characteristics for the soils in the area are in the project file.

Table 3.61: Basin Soil Map Units

Mapping Unit	Composition (%)	Composition Name	Soil Taxonomic Name
64GJ1	55	Cyrofluvents	Cryofluvents
	25	Finn	Loamy-skeletal, mixed, superactive Typic Cryaquolls
	10	Water	
71GD4	40	Blackleed	Loamy-skeletal, mixed, superactive Ustic Eutrocryepts
	25	Ovando	Sandy-skeletal, mixed Lamellic Cryorthents
	20	Tuckerville	Loamy-skeletal, mixed, superactive Ustic Glossocryalfs
	10	Comad	Sandy-skeletal, mixed Lamellic Cryorthents
75GA3	20	Caseypeak	Loamy-skeletal, mixed, superactive Lithic Eutrocryepts
	20	Como	Sandy-skeletal, mixed Typic Eutrocryepts
	20	Delmoe	Sandy-skeletal, mixed Ustic Eutrocryepts
	15	Hiore	Loamy-skeletal, mixed, superactive Ustic Eutrocryepts
	10	Opitz	Coarse-loamy, mixed, superactive Ustic Argicryolls
	5	Peeler	Fine-loamy, mixed, superactive Ustic Glossocryalfs
	5	Rubble land	
75GAF	50	Ambrant	Coarse-loamy, mixed, superactive, frigid Lamellic Haplustepts

Mapping Unit	Composition (%)	Composition Name	Soil Taxonomic Name
	35	Rochester	Sandy-skeletal, mixed, frigid Typic Ustorthents
	10	Rock outcrop	
	5	Rubble land	
75GB3	30	Delmoe	Sandy-skeletal, mixed Ustic Eutrocryepts
	20	Como	Sandy-skeletal, mixed Typic Eutrocryepts
	20	Hiore	Loamy-skeletal, mixed, superactive Ustic Eutrocryepts
	10	Rock outcrop	
	5	Caseypeak	Loamy-skeletal, mixed, superactive Lithic Eutrocryepts
	5	Opitz	Coarse-loamy, mixed, superactive Ustic Argicryolls
	5	Peeler	Fine-loamy, mixed, superactive Ustic Glossocryalfs
	3	Finn	Loamy-skeletal, mixed, superactive Typic Cryaquolls
	2	Lowder	Loamy-skeletal, mixed, superactive, nonacid Typic Cryaquepts
75GC3	30	Como	Sandy-skeletal, mixed Typic Eutrocryepts
	20	Delmoe	Sandy-skeletal, mixed Ustic Eutrocryepts
	15	Hiore	Loamy-skeletal, mixed, superactive Ustic Eutrocryepts
	10	Kurrie	Loamy-skeletal, mixed, superactive Ustic Glossocryalfs
	10	Peeler	Fine-loamy, mixed, superactive Ustic Glossocryalfs
	10	Rock Outcrop	
	5	Finn	Loamy-skeletal, mixed, superactive Typic Cryaquolls
75GD3	40	Tuckerville	Loamy-skeletal, mixed, superactive Ustic Glossocryalfs
	20	Goldflint	Sandy-skeletal, mixed Typic Cryorthents
	15	Warwood	
	10	Rock outcrop	
	5	Blackleed	Loamy-skeletal, mixed Typic Cryochrepts
	5	Ovando	Sandy-skeletal, mixed Lamellic Cryorthents
	3	Lowder	Loamy-skeletal, mixed, superactive, nonacid Typic Cryaquepts
	2	Finn	Loamy-skeletal, mixed, superactive Typic Cryaquolls
75GH2	45	Opitz	Coarse-loamy, mixed, superactive Ustic Argicryolls
	25	Bavdark	Fine-loamy, mixed, superactive Pachic Argicryolls
	15	Marcetta	Loamy-skeletal, mixed, superactive Pachic Haplocryolls
	5	Orofino	
	5	Sula	
	3	Shook	

DESCRIPTION OF BASIN SOIL COMPONENTS

In the above table, the soil names provide a classification at a coarse-scale for soil types. More than a name, the classifications are a way to describe complex materials and interactions. Below is a brief generic description of the soil taxonomic names in Table 3.61. There is a varying degree of detail in the classification names in the table. In map unit 64gj1, there are series names such as Finn. The series name is a place name where the soil was first documented and described. The reader can refer to "Soil Series of the United States", USDA (1990) for series locations by state and soil family names of the series. Field descriptions are in the project file. The descriptions here are for the mapping units and soils in the analysis area. For other soils in the watershed outside of the project analysis area, refer to the project file, "North-Zone Soil Survey".

Two taxonomic classes in map unit 64GJ1 are "Cryofluvents" and "Typic Cryaquolls, loamy-skeletal, mixed, superactive". The first, Cryofluvents, are soils that generally have little evidence of pedogenic development outside of the surface layer (epipedon). The Great Group Cryofluvents are soils formed in water deposited sediments such as on floodplains and alluvial fans. Their age ranges from relatively recent to several centuries but may be frequently flooded. The Cryofluvents are cold; they do not have permafrost or gelic materials but the growing season is short and cool. Typic Cryaquolls are Mollisols (dark colored, base rich) that are wet and cold (cryic temperature regime), have dominant low chroma and high contrast redox (reduction-oxidation) depletions in or below the surface soil (epipedon) due to oxygenated/anoxic cycles. The Typic Cryaquolls do not have an organic (histic) epipedon or an argillic (illuviated clay) layer. The base rich mollic surface soil is less than 50 cm thick. The "loamy-skeletal" refers to a particle-size class that has 35 percent or more rock fragments and less than 35 percent clay. "Mixed" means that the soil mineralogy does not meet any of the diagnostic criteria for any of the specific mineralogies, eg., "ferritic", "gibbsitic", "sesquic", etc. Finally, "superactive" is a cation exchange activity class indicating that the ratio of cation-exchange (by NH_4Oac) to clay (percent weight) is 0.60 or more. Therefore, this is a soil that is relatively reactive electrochemically, and nutrients or added amendments may not leach readily. Both the Cryofluvents and Cryaquolls are hydric soils and have obligate wetland plant species growing in them.

In map unit 75GA3, one of the predominant soils is "loamy-skeletal, mixed, superactive Ustic Eutrocryepts". These soils are moderately developed and have a cambic (pedogenic physical alterations, chemical transformations, removals or a combination of two or more of these processes) horizon and one of several kinds of surface horizons. The Eutrocryepts have a cryic temperature regime (mean annual temperature lower than 8° C at 50 cm) and free carbonates or greater than 60 percent base saturation in depths between 25 and 75 cm. This soil has an "ustic" moisture regime, indicating that the soil is generally dry but moisture is available during the growing season. The "loamy-skeletal" refers to a particle-size class that has 35 percent or more rock fragments and less than 35 percent clay. "Mixed" means that the soil mineralogy does not meet any of the diagnostic criteria for any of the specific mineralogies, eg., "ferritic", "gibbsitic", "sesquic", etc. Finally, "superactive" is a cation exchange activity class indicating that the ratio of cation-exchange (by NH_4Oac) to clay (percent weight) is 0.60 or more. Therefore, this is a soil that is relatively reactive electrochemically, and nutrients or added amendments may not leach readily.

Another dominant particle-size group (families) for this soil in this unit are "Sandy-skeletal". Sandy-skeletal has 35 percent or more (by volume) rock fragments and a fine-earth fraction with a texture of sand or loamy sand, including less than 50 percent (by weight) very fine sand.

Other subgroups of this soil include the "Lithic" and "Typic" Eutrocryepts. Lithic means that there is a contact (either Mohs hardness 3 and or materials that do not slake in water/sodium hexametaphosphate)

between the soil and underlying material. Typic means that the soil meets no other differentiating criteria for the subgroup.

In unit 75GB3 and 75GC3, the predominant soils are similar to most of those described in 75GA3, above.

In unit 75GD3, one of the predominant soils is “Loamy-skeletal, mixed, superactive Ustic Glossocryalfs”, which is a soil with thin, light-colored, low organic matter, and hard surface soil and a subsurface layer with a significantly higher percentage of phyllosilicate clay than the overlying soil (argillic horizon). This particular soil has a “glossic” subsurface horizon, which is the result of the degradation of the argillic from which clay and free iron oxides have been removed. This soil has a cryic temperature regime (mean annual temperature lower than 8° C at 50 cm) and free carbonates or greater than 60 percent base saturation in depths between 25 and 75 cm. This soil has an “ustic” moisture regime, indicating that the soil is generally dry but moisture is available during the growing season. The “loamy-skeletal” refers to a particle-size class that has 35 percent or more rock fragments and less than 35 percent clay. “Mixed” means that the soil mineralogy does not meet any of the diagnostic criteria for any of the specific mineralogies, eg., “ferritic”, “gibbsitic”, “sesquic”, etc. Finally, “superactive” is a cation exchange activity class indicating that the ratio of cation-exchange (by NH_4Oac) to clay (percent weight) is 0.60 or more. Therefore, this is a soil that is relatively reactive electrochemically, and nutrients or added amendments may not leach readily.

The other predominant soil in this unit is “Sandy-skeletal, Mixed Typic Cryorthents. These soils have little evidence of pedogenic development outside of a surface horizon that is relatively thin, dry, light colored, and low in organic carbon compared to some of the other surface layers (epipedon). This soil primarily occurs on relatively recent erosional surfaces. Any former soil that was on the landscape has been removed or truncated so that the other diagnostic horizons for all other kinds of soils do not occur. There is a cryic temperature regime (mean annual soil temperature at 50 cm is $< 8°$ C). “Sandy-skeletal” is a particle size class that has 35 percent or more (by volume) rock fragments and a fine-earth fraction with a texture of sand or loamy sand, including less than 50 percent (by weight) very fine sand. “Mixed” means that the soil mineralogy does not meet any of the diagnostic criteria for any of the specific mineralogies, eg., “ferritic”, “gibbsitic”, “sesquic”, etc. Typic means that the soil meets no other differentiating criteria for the subgroup.

In map unit 75GH2, the predominant soils are “Coarse-loamy, mixed, superactive Ustic Argicryolls”; and “Fine-loamy, mixed, superactive Pachic Argicryolls”. The Agricryolls are soils that are cold, dark colored (mollic epipedon, moderately high organic matter), and base rich that have an argillic horizon (illuvial accumulation of clays) close to the surface ($<$ 60 cm below the mineral surface). The “ustic” moisture regime indicates that the soil is generally dry but moisture is available during the growing season. The “Coarse-loamy particle-size class has 15 percent or more (by weight) particles with diameters of 0.1 to 75 mm (fine sand or coarser, including rock fragments up to 7.5cm) and, in the fine-earth fraction, less than 18 percent (by weight) clay. “Mixed” means that the soil mineralogy does not meet any of the diagnostic criteria for any of the specific mineralogies, eg., “ferritic”, “gibbsitic”, “sesquic”, etc. Finally, “superactive” is a cation exchange activity class indicating that the ratio of cation-exchange (by NH_4Oac) to clay (percent weight) is 0.60 or more. This indicates that the soil is quite reactive electrochemically. A reactive soil generally has a complex buffer system and can hold certain charged particles or ions and keep them out of the soil solution. The “Pachic Argicryoll” is similar to the Ustic Argicryoll except that the surface horizon (mollic) is $>$ 40 cm thick and has a texture finer than loamy fine sand.

PROCEDURES AND METHODS

In 1999 the Northern Region of the U.S. Forest Service, which includes the Beaverhead/Deerlodge National Forest, formally adopted its internal draft (1991) soil quality standards which were developed region by region across the National Forest System. The purpose of the standards is to maintain ecological stability, biological diversity, and integrity of the soil resource where multiple ecosystem processes occur. Soil quality standards on Forest Services lands require that 85 percent of an activity area must remain in an acceptable soil quality condition (FSM 2554). Soil quality standards typically cover compaction, puddling, displacement, burning, erosion, mass movement, and organic carbon (soil organic matter). The reason 85 percent was selected as a threshold for ground disturbance is because when more than 15 percent of the soil resources are in a low quality or non-functional condition, additional negative effects become difficult to mitigate or restore. At this threshold, degraded soil processes begin to severely constrain ecosystem productivity, and off-site effects generally become pervasive and severe (Daddow and Warrington, 1983; Maser, 1997; Harvey, et al., 1997; Everett, 1994).

When operations are planned in areas that do not meet soil quality standards due to prior activities, new activities should be designed and planned to meet standards. Damages due to prior activities should be restored, ameliorated, or mitigated as part of current activities, with the net result being an activity area that meets soil quality standards.

To determine how much soil disturbance exists and to determine a reference for effects of the proposed project, field investigations were conducted during the summer of 2002. Using the treatment units from the proposed action (July 2002) as the activity areas and the soil survey map layer as a stratification, field crews surveyed the units as well as the watershed areas between and adjacent to the proposed units. The field protocol used was Howe (2000) and a sampling transect set up by the Forest Soil Scientist. The Howe method determines the disturbance category and site class type on a belt transect. A woody debris count by diameter class was added to this transect to determine the existing amount of coarse woody debris on the plots. The proving ring data were evaluated based on the work by Costantini (1997); Reisinger, Simmons, and Pope (1988); Brady and Weil (2002); and Vaz, Bassoi, and Hopmans (2001). Soil resistance data by penetrometer varies by soil moisture content. Therefore, soil moisture data were collected on the same sites and depths as the soil resistance data. Whenever a different landscape/soil moisture situation was encountered, a new soil moisture reading was taken. The data were converted to constant soil moisture groups according to the method of Vaz, Bassoi, and Hopmans (2001).

A paper by Block, VanRees, and Pennock (2002) reviews the overall measurement of soil impacts from harvesting at a site and landscape scale. Although this paper came out in the fall after the field work for this project was finished, it corroborates the general approach used here. One can also review Bradford (1986) for a foundation reference on physical soil analysis techniques. Another paper by Page-Dumroese, Jurgensen, Elliot, Rice, Nesser, Collins, and Meurisse (2000) provides technical background on the Soil Quality Standards used by the Forest Service.

A proving ring penetrometer was the instrument chosen to collect the transect data since it is mobile, easy to use and maintain, and gives consistent results when stratified by observer. All raw data can be reviewed in the project file. A summary of the data follows. The disturbance classes are from Howe (2000) and are differentiated by “old” (O) or “new” (N) and are summarized here for the reader’s convenience:

WHAT THE NUMBERS MEAN

Soil resistance to any kind of deformation can be determined by a proving-ring penetrometer as used in this survey. Penetration resistance is correlated with, among other things, root growth. When penetration resistance exceeds 2.0 MPa (about 290 pounds), root growth is reduced by about 50 percent. Between 1.0 and 2.0 MPa, effects on root growth ability begin to occur; values greater than 3.0 MPa (435 pounds) often prevents root growth entirely. Land management practices utilizing tracked equipment can increase the critical stress value to > 3.5 Mpa depending on the nature of the pore system and soil structure (Skopp, 2000).

As interpreted from field data (available in the project file), the highest soil resistance values are around 1.0 MPa (149 lbs.). The resistance values average range is around 0.50 MPa to 0.92 MPa, and should not currently be approaching a root growth limiting condition. Those relatively few values that are approaching 1.0 MPa are possibly the remnant effects of the timberland clearing that occurred throughout this watershed after the turn of the 20th century. Evidence of old skid trails/primitive roads can still be observed when traversing these hills and some plots probably included some of these old disturbances as the transecting was relatively extensive.

The woody debris data are counts of logs by size class that are solid or mostly solid. If the piece was solid enough to be stepped on and kicked without showing collapse or breakage, it was counted. The objective is to determine how much wood would be available to the soil over the next several decades. The large wood component is the most important because it will provide soil carbon for the time between tree harvest to a mature stand. Fine woody debris and litter was not recorded but there is very little forest floor fine organic matter. The litter layer average ranges only from 1 to 4cm.

The large woody debris component is light across the project area watershed. Only on a few north slopes is there any appreciable woody debris. By unit, coarse woody debris averages from < 1 ac^{-1} across the analysis area, based on this data and cubic foot volume and weight relationships published by the Society of American Foresters (1961). This is far below Forest Plan standards of 10-15 tons ac^{-1} and below that recommended in the literature, which is in the range of 8-22 tons ac^{-1} for our habitat types (Graham, et al., 1994).

In summary, the existing soil resource condition in the project analysis area, including all proposed treatment units is: 1) Large woody debris is in short supply compared to what is known to be required to maintain soil productivity, soil quality, and the carbon cycle, and has probably been in this condition for many years as determined by woody debris surveys, observations of existing old stumps, and the observed composition of the surface soils; 2) Surface litter/duff layers are less extensive and generally thinner than what is normally encountered in other, similar landscapes, soil units, and habitat types on the Forest; 3) Soil density as determined by compaction data from proving-ring penetrometer surveys is not a problem for root growth within the proposed units or the watershed as a whole. If not a problem for root growth it is probably a safe conclusion that soil density/porosity is not a problem for other soil/watershed processes in the analysis area; 4) Erosion rates were not measured because transects across the project area did not discern current or recent evidence of accelerated soil erosion. No sheet erosion or other types of erosion action was observed. No accelerated soil depositional features were observed; 5) No evidence of recent (decades) burning was observed. Some charcoal can be observed in the surface soils.

ENVIRONMENTAL EFFECTS - SOILS

INTRODUCTION

All of the action alternatives in this project propose some level of temporary road construction and/or reconstruction, mechanical tree felling and removal (skidding or helicopter), slash piling and burning and/or broadcast slash burning. Although logging could occur in the winter over prescribed snow conditions, it would most likely occur during the summer and fall months (July-October). There are generally large differences in soil effects between ground-based operations that occur over snow versus those that occur over soil at various times of the year, with over-snow effects being much less, both in degree and area. The estimated effects in this section assume summer/fall operations both within and outside of roadless areas. Although helicopter operations could be used under Alternative 4 in inventoried roadless areas to haul out the logs, trees would still be machine felled, machine skidded or forwarded, and the slash would be machine (excavator) piled.

For this analysis it is assumed that the soil quality standards (described in the existing condition) will be met in all treatment units and at the watershed scale within each sub-watershed (see watershed boundary map). Traditional line-skidder logging often produces detrimental soil disturbance of from 20 to 60 percent. The added effects from slash piling and other site preparation following logging may push detrimental soil disturbance to 60 percent or greater (Idaho Forest Products Commission, 2002; WSU Cooperative Extension, 1985; CSU, 2002) at the treatment unit scale. At the watershed scale, the effects of road systems, logging units, dozer-slash piling and other disturbance including mining and grazing could produce detrimental soil conditions of 30 percent or more in a 6th code watershed. Detrimental soil disturbance levels as high as these cause degrees of soil productivity losses at the treatment and watershed scale depending on soil type and site conditions. At the watershed and landscape scales, soil function, including preferential flow and nitrogen and carbon cycling can be negatively altered (CSU, 2002; Arocena, 2000; Noguchi, et al, 1999; Wildenschild, et al, 2001).

The Forest Service developed the soil quality standards nationally and regionally based on local soil conditions to reduce the effects of logging and other land management activities on soil productivity and function. Total detrimental soil disturbance is limited to fifteen percent or less. Researchers suggest that when detrimental soil disturbance surpasses about fifteen percent, it becomes difficult to mitigate or restore soil function and quality, ecosystem productivity, and off-site effects (Daddow and Warington, 1983; Maser, 1997; Harvey, et al., 1997; Everett, 1994). If any areas are already at or over fifteen percent detrimental disturbance, then the Standards require that no additional increases be allowed, and that restoration be considered. Any area with soil effects predicted over fifteen percent due to this proposal will have modifications or restoration implemented. Modifications include altering the treatment, changing the treatment unit boundaries, deleting the treatment unit, changing the timing of operations, changing the type of operations, or other modifications. Restoration includes obliteration (re-contouring) of roads/trails, elimination of current active eroding sites, sub-soiling of compacted units or other restoration activities. The Deerlodge Forest Plan directs us to design projects to sustain site productivity and manage ground-disturbing activities to prevent detrimental effects on site productivity.

The soil and soil related parameters of most concern and their criteria for estimating effects (parameter: criteria) are:

1) Loss of soil organic carbon: the estimated reduction of soil organic matter from direct removal and oxidation loss due to soil disturbance;
2) Erosion and sedimentation: the estimated soil detachment and transport offsite;
3) Compaction: the estimated loss of porosity, especially macropores, which are the most affected from logging equipment traffic;
4) Displacement: the estimated amount of topsoil removed and relocated elsewhere on the site;
5) Severe burning, physical, chemical, and biological effects of severe burning (slash pile burning) including ignition loss of soil organic matter: the area affected by slash pile burning (severe burning).

Residual existing effects in the watershed are considered under cumulative effects.

ALTERNATIVE 1: NO ACTION

In this alternative, the existing condition will remain unchanged, allowing of course for existing processes above and below ground to continue.

There is a potential for “no-action” conditions to change drastically if a fire were to start somewhere in the project area. While research has been done on soil effects from wild and prescribed fires, much is unknown about how fire affects certain soil attributes, processes and functions. Additionally, a major difficulty in predicting both direct effects on soils and related effects that soil has on other resources comes from the variability of soils in particular ecological settings and variability of fire. Modeling in the project area has provided a set of possible conditions and fire scenarios that we have used to try and predict the effects of a fire at a point in time when fuel conditions may be worse than they are today (year 2003 vs. year 2028 (model criteria and data are in the project file).

The most pertinent results from these models from a soil effects standpoint are soil heating (temperature, depth) and the amount of bare ground exposed after surface organic matter consumption. These effects lead to potentially lowered soil productivity and increased erosion and sedimentation.

In the no-action fire in year 2003 scenario, a fire in lodgepole pine ("sawtimber") stands under "dry" conditions, consumes about 0.5 cm of the forest floor litter layer (a little less than exists currently) and about 15 percent of the soil surface is exposed. At no depth does soil heating reach 60° degrees C, slightly below the threshold temperature at which nitrogen is volatilized, and well below the threshold temperatures that would kill nitrifying bacteria and other organisms. Under the same scenario but in "very dry" conditions, the fire would consume about 3cm of litter (most of the layer) and expose about 82 percent of the surface soil.

In 2028, if a fire takes place under conditions predicted to occur at that time, there is a projected 234 percent increase in total fuels (38 t ac^{-1} to 89 t ac^{-1}). Under "dry" conditions, soil heating, litter consumption, and bare soil are the same as in the 2003 fire. Under "very dry" conditions, litter consumed and soil exposed is also the same as for the 2003 fire, but soil heating of 60° C reaches down to 9 cm and at 1 cm the temperature is 275° C. This is hot enough to volatilize all the nitrogen from the surface 1 cm; consume all soil organic matter; kill all bacteria and fungi; and begin to affect soil physical components including wettability and structure (DeBano, et al, 1998). Recovery from these heating effects can take from less than three years to seven years for minimum soil organism populations to more than a century for the soil

organic carbon (Dumeroese, Jurgensen, and Harvey, 2003; Tiedemann and Woodard, 2002; Neary, et al, 1999).

Post-burn large woody debris, needed for maintenance of soil organic matter, would be reduced in all fire scenarios, but is only a problem in the 2003 fires as woody debris is currently already very low for typical stands and below the amounts needed for soil organic matter maintenance (Graham, 1994).

Approximately 80 percent of the available productive capacity of soil resides in approximately the upper 25 cm. (Singer and Ewing, 2000). The modeled fire would exceed several threshold temperatures in the top 1 cm. Virtually everything biological would be eliminated, the nitrogen and much sulfur would be lost, and soil organic matter would all be oxidized. Below 1 cm, temperatures would be lower than 275°, but would still probably he high enough to kill bacteria and fungi down to perhaps 3 to 4 cm. Some organic carbon would likely be oxidized down to several centimeters as well. Physical effects leading from the modeled year 2028 fire include increased erosion rate, sediment delivery, and a potential reduction in soil quality and productivity.

Soil erosion and slope delivery sediment modeling (WEPP, 1995; 2003) for the existing condition, 2003 and 2028 model fires shows marked effects (see project file). For the existing condition, forty years and 3,829 storms do not produce a single upland erosion or sediment-leaving profile event. For the 2003 fire year, mean annual averages for 40 years of modeling shows one event producing just over one ton (1.05 t ac^{-1} $yr^{-1)}$) with 0.99 t ac^{-1} sediment leaving the profile (i.e. 20.23 kg m^{-1} width). Applying a slope coefficient applicable to these landtypes would produce a one-time sediment delivery ratio of approximately 0.10 percent of the erosion rate or about 0.09 t ac^{-1}. For the year 2028 fire, forty years of modeling produced two events. The predicted upland erosion rate is 3.00 tons per ac^{-1} with 2.71 tons per ac^{-1} leaving the profile. This would equate to approximately 0.30 t ac^{-1} rate as sediment delivered to a channel. The WEPP model cannot precisely mimic existing conditions in the Basin Creek project area or what is predicted with a fire now or in 2028, so these results are most appropriately used as a comparison between the different fire scenarios rather than absolute quantitative predictions. Thus, if the 2028 fire occurred under the worst-case scenario it would likely cause a measurable loss in soil quality and soil productivity. The delivered sediment would likely cause a measurable loss of channel stability and fish habitat (see "Aquatic Effects" section).

Cumulative Effects

The No-Action condition, plus effects of modeled fires is considered for cumulative effects. The area of existing detrimental disturbance for each existing development is compiled by watershed (see Map 27 for watershed boundaries). The types of disturbances considered are those noted in the 'Introduction' of this section and are defined as per Howe (2000) and Forest Service Soil Quality Standards (USDA, 1999), and Reference Guides for Administering Soil Quality Standards (USDA, 2000).

Under "No-Action" but with the modeled fire scenarios, the following are the expected cumulative effects See list of past, present and foreseeable actions, (Chapter 2, page 2.10) by predominant watershed. The letters (a, b, c, etc. correspond to that list: The watershed name after the description indicates that is the watershed(s) where the acres of detrimental effects occur.

Forest Service Timber harvest (after "Past, Present, and Reasonably Foreseeable Actions"):

a. About 5,000 acres logged cumulatively, remaining stumps circa 1940s over much of project area. Proving ring penetrometer data (project file) show few remaining effects from compaction. Estimated 1 percent residual compaction, or approximately 50 acres. Displacement and burning probably affected a lot more, judging by lack of O_{aei} horizon(s) and unusually thin litter layer, The original displacement also likely produced secondary erosion effects. All watersheds, most in Upper Basin.

b. Minimal ground disturbance; woody debris remaining. Upper Basin watershed.

c. Relatively poor logging job; occurred pre-soil quality standards. Observations suggest 25-50 percent soil disturbance. Estimate approximately 0.3 acres (of 2 acres) detrimental disturbance. Blacktail watershed.

d. Similar to above; estimate 15 acres (of 42 acres) detrimental disturbance. Little large woody debris. Blacktail watershed.

e. Assuming standards proposed for the Basin project, approximately 15 percent detrimental disturbance (55 acres of 366 acres). Blacktail watershed.

f. 500 acres of timber harvest in the Thompson Park/archery range areas. These would fall under the new Forest Service Categorical Exclusion review process. Assuming the same soil quality standards as per this proposal in Basin, 75 acres of detrimentally disturbed soil. Blacktail watershed.

Non-Forest Service Timber Harvest:

a. Assume as per "e" above. Estimate 8 acres detrimental disturbance. Herman Gulch watershed.

b. Passmore Canyon; Blacktail Canyon; Thompson; Terra Verde; Roosevelt with a minimum of 205 acres. Estimate 31 acres disturbance mostly in Upper Basin watershed.

Trail Construction/Reconstruction:

a. Along the divide between Blacktail and Basin watersheds. Approximately 2 acres based on tread width and length.

b. Will leave approximately 2 acres net mostly in the Upper Basin watershed.

Livestock:

Assuming this allotment becomes active again, estimate approximately 360 detrimentally affected acres in the Blacktail watershed and about 100 in the Upper Basin watershed due mostly to compaction and erosion.

Rural Homes:

Estimate approximately 160 acres permanently detrimentally affected because of lost soil productivity through houses and pavement mostly in Blacktail watershed.

Reservoirs:

The reservoirs cover approximately 30 acres of former riparian/wetland.

Special Uses:

Housing, roads, and powerlines detrimentally affect approximately 11 acres of soil productivity roughly equally over Basin, Herman, Blacktail watersheds.

Noxious weeds:

Noxious weeds directly affect soil productivity and biological diversity. Approximately 40 acres, largely in the Blacktail watershed.

Herman Gulch restoration:

Currently about 7 acres are affected. If this work were completed, about 1 acre would remain affected. Herman watershed.

Wright Mining Exploration:

Exploration by hand work with foot access would not cause measurable affects. Upper Basin watershed.

Small Tracts:

Approximately 1 acre affected by house and road in Herman Gulch.

- ***Transportation System***

Table 3.62 Existing acres consumed by roads and trails by watershed

Existing Road System	Existing Trail System
40.2 acres in Basin	3.4 acres in UpperBasin
10.5 acres in Lower Basin	1.6 acres in Lower Basin
97.84 acres in Blacktail	3.0 acres in Blacktail
0.0 acres in China Gulch	0.6 acres in China
10.23 acres in Herman	0.8 acres in Herman

The above compilation of existing effects from all known and foreseeable actions is summarized as follows:

Table 3.63 'No-Action' (existing) Detrimental Soil Disturbance

Watershed	% Disturbance	% Disturbance from Roads
Upper Basin	3.2	0.5
Blacktail	35.2*	5.2
China	<1.0	0.0
Herman	1.2	0.8
Lower Basin	1.0	0.6

* The total disturbance on FS land within the Blacktail watershed is approximately 0.1%

The 'No-Action' existing effects from above plus the effects as modeled for the 'Worst-Case Fire Scenario is summarized as follows (see earlier model discussion):

Table 3.64 'No-Action' Detrimental Soil Disturbance with Worst-case Scenario Fire

Watershed	% Disturbance	% Disturbance from Roads
Upper Basin	18.2	0.5
Blacktail	50.2*	5.2
China	~15.0	0.0
Herman	16.2	0.8
Lower Basin	16.0	0.6

* The total disturbance on FS land within Blacktail watershed would be approximately 17.0%

The 'No-Action' with the worst case fire disturbance was determined by using the soil erosion (WEPP) model and the fire behavior (FEFEM) model, discussed earlier, across the watersheds. The worst-case is the model results for the 'very dry' conditions run. As noted earlier, severe, lethal soil heating under these conditions would occur near the surface, and high but probably sub-lethal temperatures for soil organisms would occur at 9cm. Litter consumption would be virtually complete and up to 82 percent of the soil surface would be exposed. While these conditions are not good, they are not necessarily long-term, which is what the 40-year runs of the erosion model suggests.

Assuming these model effects, detrimental soil disturbance following the worst-case scenario fire is estimated to increase approximately fifteen percent compared to the no-action without fire condition. This estimate assumes that fires such as the 'worst-case scenario' modeled here would have similar burn severity (soil heating) as severe fires experienced around the area in similar fuel types in recent years. For example, the Foothills fire near Boise; the North Hills fire near Helena; and the Sandpoint fire near Niehart; had some of the higher soil-watershed effects compared to other, less severe fires around the region. Approximately 15 percent of the area actually burned in these fires had severely burned soils. The effects predicted from the erosion and fire models would be particularly detrimental on this proportion of burned area. Detrimental soil quality effects are expected to occur on the portion of the area with severe burning because here, the effects are expected to be long-term.

Table 3.65 'No-Action' Detrimental Soil Disturbance with Low to Moderate Scenario Fire

Watershed	% Disturbance	% Disturbance from Roads
Upper Basin	8.2	0.5
Blacktail	40.2*	5.2
China	~5	0.0
Herman	6.2	0.8
Lower Basin	6.0	0.6

* The total disturbance on FS land within the watershed would be approximately 7.0%

The 'No-Action' with the low to moderate scenario fire disturbance was determined by using the soil erosion (WEPP) model and the fire behavior (FEFEM) model, discussed earlier, across the watersheds. The low to moderate case is the model results from the 'dry' conditions run. As noted earlier, severe, lethal soil heating under these conditions would not occur near the surface or at depth, and high but probably sub-lethal temperatures for soil organisms would not occur. Litter consumption would be relatively low and 14.8 percent of the soil surface would be exposed. These results are not that bad and they are expected to be short-term, which is what the 40-year runs of the erosion model suggest.

Assuming these model effects are accurate, the amount of detrimental soil disturbance following the low to moderate case scenario fire is estimated to increase no more than about 5 percent compared to the no-action condition. This estimate assumes that fires such as the 'low to moderate scenario' modeled here would have similar burn severity (soil heating) as the low to moderately severe fires experienced around the region in similar fuel types in recent years. For example, the Purdy Creek fire near Bozeman and the Mussigbrod-Middle Fork fires near Wisdom and Philipsburg had low to moderate severity soil-watershed effects compared to other, less severe fires around the region. Approximately 2-5 percent of the area actually burned in these fires had severely burned-affected soils. The effects predicted from the erosion and fire models would be largely detrimental on this proportion of burned area. Detrimental soil quality effects would occur on the portion of the fire that is severely burned because the effects are would be expected to be long-term.

ALTERNATIVE 2

Direct and Indirect Effects

Chapter 2 describes what would happen under the Forest and private boundary "buffer" treatments as well as all the other proposed treatments across the project area. See Appendix B, Maps 2-5, for the specific treatment units (activity areas) that would be affected.

By design under this proposal, detrimental soil disturbance in all units would be at or below 15 percent, which is the maximum level allowed by the soil quality standards from all causes. The soil quality standards would be incorporated into the project contract(s). The operations would be administered progressively through a 'performance based end results contract'. See project file for copy of standards and methods. The standards guide also provides a short-list of literature references providing a basis for the upper limit. However, regardless of how the project would be carried out, the standards in this document would have to be met.

Fifteen percent detrimental disturbance of the soil resource is about the threshold where disturbance begins to become difficult to mitigate or restore. Degraded soil processes begin to severely constrain ecosystem productivity, and off-site effects become pervasive and severe (Daddow and Warington, 1983; Maser, 1997; Harvey, et al., 1997, Everett, 1994). If detrimental disturbance is low, long-term productivity, ecosystem health and watershed health can be maintained. At the watershed scale, the Blacktail watershed exceeds the level of allowable detrimental soil disturbance, due to disturbances on private land that the Forest Service cannot control. In these cases, the soil quality standards still apply. Where conditions are already not in standard, a new entry (project) can still occur but the net disturbance cannot be greater than it was before the new project. Therefore, either new disturbance from the proposed project or other pre-existing disturbance would be restored so that the area of detrimentally disturbed soil is not greater than the existing condition. In all other cases, the area of detrimental disturbance would not be greater than 15 percent.

The end-result soil-site conditions directed by the soil quality standards and the proposed treatments were simulated in the WEPP soil erosion model (eg., "lodgepole clear cut"). Projecting 40 years, the model found one event producing an erosion rate of 1.13 t $ac^{-1.}$ This rate under these site conditions (essentially a clear-cut with residual 16 percent canopy cover) produced 1.09 t ac^{-1} of sediment leaving the modeled profile. Again, these numbers should be considered comparative rather than absolute. If the event were to occur later in the forty-year modeling period, this rate would likely be much lower because some degree of recovery of ground surface vegetation and the surface soil structure would be expected.

The baseline erosion of land types and soils similar to the Basin Creek project area typically have soil formation rates of from about 0.1 mm y^{-1} in the recent historical climate (in Morgan, 1986). The worldwide range is from 0.01 mm y^{-1} to 7.7mm y^{-1}. In the continental United States the highest rate is 0.2mm y^{-1} in the loess region of the Great Plains and midwest to the lower end of 0.02mm y^{-1} in the southwest (in Morgan, 1986). A formation rate of 0.1 mm y^{-1} is equivalent to 0.1 kg m^{-2} y^{-1} with a bulk density of 1.0 Mg m^{-3}, which is approximately where soils mineralogically similar to Basin soils typically range (about 0.95 Mg m^{-3} to 1.2 Mg m^{-3}). Thus, the formation rate could be slightly exaggerated rather than underestimated. Soil loss tolerance is the measure commonly used to determine the amount of acceptable accelerated soil loss. Offsite effects such as sediment delivered to a valued stream reach are sometimes used in conjunction with soil loss tolerance and the combined effect is considered. Both erosion and sediment model results are noted above. Erosion loss and sediment for the temporary roads has also been modeled. Although the proposed temporary roads would be obliterated within about three years (completely re-contoured) some erosion would occur. A typical temporary road model run is the China Gulch "300 ft. segment" (see project file for WEPP information). Projected for forty years, the model predicted four erosion events causing 278 lb. road prism erosion and 60.15 lb. sediment leaving buffer. Thus, if during the three years that the temporary roads (maximum) exist, one or more of these events would cause these amounts per 300-foot section modeled. It is possible to get one or more of these events occurring during the three years design life of the temporary roads but very unlikely. From a worst-case standpoint, if all four events predicted over forty years occurred during the first year, about a half ton (1112.64 lb) of soil loss could occur with about 241 lbs. leaving the buffer. Again, due to the limitations of the model, these values are best used as relative values. In addition, a continuous, eroding 300-foot section is modeled as a worst case and is unlikely to occur on the ground. Other road segments were modeled with proportional results and can be reviewed in the project file and under some of the other alternative effects.

In a moderately deep to deep soil, or in a productive, high-quality, resilient soil, a one-time loss of 1.13 t ac^{-1} as modeled could be tolerated without measurable loss of productivity. However, soils in the Basin Creek project area (uplands) have relatively coarse particle size classes, low surface area and chemical reactivity,

and low moisture holding capacity (See project file for soil data and maps). The existing condition of Basin soils is already in relatively poor condition (chapter 3, Soil Resources). Adding 15 percent detrimental disturbance to these sites from the proposed project, as modeled, would be relatively safe as the model predicts a single erosion event over the next forty years. The worst effects would occur, of course, if the erosion event came shortly after treatments and before any recovery could take place. Soil processes and ecosystem function would still be maintained even with the erosion event as long as other disturbance eg., displacement were limited. Traditionally, common timber sale operations have typically added approximately 20 percent disturbance in the form of skid trails (Lee Harry, silviculturalist, pers.com.). Additional disturbance occurred from skidding logs to the trails and from site preparation, especially dozer piling the slash. Total detrimental disturbance from compaction, removal and oxidation of soil organic matter, and displacement could be in the range of 30-80 percent. Traditional or similar types of logging operations in the Basin Creek project area would cause proportionally more than 15 percent detrimental disturbance, causing proportionally more erosion, possibly an intolerable rate causing long-term reductions in productivity. Thus, the Soil Quality standards are critical to sites such as those in Basin to maintain productivity and prevent or limit off-site effects.

To maintain soil organic matter, detrimental disturbance is limited to 15 percent (including displacement) and a minimum of 12 tons ac^{-1} large woody debris (material no less than 3 inches diameter) remains distributed over each treatment area after all treatment is finished. This tonnage is required by the current Deerlodge Forest Plan, which still directs management in the Basin project area.

Cumulative Effects

As noted earlier, cumulative effects are those arising from this proposal, existing effects, and effects from any foreseeable future proposals (see list of past, present and foreseeable actions (Ch 2, pg. 2.10). A cumulative effect may be additive to direct/indirect effects, or an interaction with net effects more or less than direct effects. Effects from the treatment proposal in this alternative (15 percent detrimental disturbance) are considered with the analysis for the No-Action existing condition and effects from modeled fires. Existing disturbance in the treatment units is non-detectable to slight, as noted in Chapter 3, Existing Condition, Soil Resources. Proving-ring penetrometer data from each proposed unit showed a few values near 1MPa, the approximate threshold resistance where root elongation reduction begins. Root elongation is reduced by about 50 percent at 2MPa (Horn and Baumartl, 2000). No areas, including apparent former skid trails from past logging were at values approaching 2MPa (See chapter 3, Existing Condition, Soil Resources and project file). Only existing roads, and similar developments are compacted to the point of excluding root growth, and these have been included in the detrimentally disturbed category. Thus, the treatment unit soil effects remain at 15 percent and the treatment unit and other disturbance have been compiled at the watershed scale and are summarized in Table 3.65 below. For this table, the acres of treatment units were used (those with ground disturbing actions) by watershed, times unit disturbance (15 percent), and added temporary roads. This equals the net disturbance at the watershed scale.

Table 3.66: Alternative 2 Total Detrimental Soil Disturbance (treatment effects, existing, and future foreseeable actions)

Watershed	% Disturbance	% Disturbance from Roads
Upper Basin	3.5	0.5
Blacktail	35.9*	5.2
China	3.4	0.5
Herman	6.8	1.8
Lower Basin	3.7	1.0

***** THE TOTAL DISTURBANCE ON FS LAND IN THE WATERSHED WOULD BE APPROXIMATLEY 2.7%

ALTERNATIVE 3

Direct and Indirect Effects

Effects for this alternative are of a similar type as for alternative 2 and the reader is directed to review the discussion there. However, the acreage treated is about 231 percent more than in alternative 2 and is the major difference between alternatives. The net detrimental soil disturbance for any treatment unit would still be 15 percent, and the erosion model projections discussed in Alternative 2 apply to this alternative with the scope expanded proportionally. The proportions of treatment acres vary between watersheds compared to Alternative 2 and so the watershed scale effects vary by watershed (see cumulative effects). Thus, while the treatment unit-scale effects are the same rates as described for Alternative 2, the watershed-scale effects are considerably larger.

Cumulative Effects

The existing, proposed, and foreseeable future projects and effects are similar to those described under Alternative 2 but the percentage of detrimentally disturbed soil in each watershed would be increased due to the larger treatment acreage in this alternative as displayed in the following table:

Table 3.67: Alternative 3 Total Detrimental Soil Disturbance (treatment effects, existing, and future foreseeable actions)

Watershed	% Disturbance	% Disturbance

		from Roads
Upper Basin	4.3	0.7
Blacktail	35.9*	5.2
China	11.5	2.1
Herman	9.9	2.2
Lower Basin	4.0	0.8

THE TOTAL DISTURBANCE ON FS LAND IN THE WATERSHED WOULD BE APPROXIMATLEY 2.7%

ALTERNATIVE 4

Direct and Indirect Effects

Effects for this alternative are of a similar type as for Alternatives 2 and 3 and the reader is directed to review the discussion there. Like Alternatives 2 and 3, this alternative uses the same kinds of treatment (described in Chapter 2) and covers the same watersheds but in different proportions. However, the acreage treated is about 388 percent more than in alternative 2 and about 40 percent more than Alternative 3 and is the major difference between alternatives. The net detrimental soil disturbance for any treatment unit would still be 15 percent, and the erosion model projections discussed in Alternative 2 apply to this alternative with the scope expanded proportionally. The proportions of treatment acres vary between watersheds compared to Alternatives 2 and 3, and so the watershed scale effects vary by watershed (see cumulative effects). Thus, while the treatment unit-scale effects are the same rates as described for Alternative 2, the watershed-scale effects are considerably larger.

Cumulative Effects

The existing, proposed, and foreseeable future projects and effects are similar to those described under Alternatives 2 and 3 but the percentage of detrimentally disturbed soil in each watershed would increase due to the larger treatment acreage in this alternative as displayed in the following table:

Table 3.68: Alternative 4 Total Detrimental Soil Disturbance (treatment effects, existing, and future foreseeable actions)

Watershed	% Disturbance	% Disturbance from Roads
Upper Basin	6.8	0.7
Blacktail	37.1*	5.2
China	9.7	1.7
Herman	11.7	2.2
Lower Basin	7.8	0.8

* The total disturbance on FS land within the watershed would be approximately 7.1%

ALTERNATIVE 5

Direct and Indirect Effects

Effects for this alternative are of a similar type as for Alternatives 2, 3 and 4 and the reader is directed to review the discussion there. Like alternatives 2, 3 and 4, this alternative uses the same kinds of treatment (described in Chapter 2) and covers the same watersheds but in different proportions. However, the acreage treated is about 270 percent more than in Alternative 2; and about 16 percent more than Alternative 3; and about 30 percent less than Alternative 4 and is the major difference between alternatives. The net detrimental soil disturbance for any treatment unit would still be 15 percent, and the erosion model projections discussed in Alternative 2 apply to this alternative with the scope expanded proportionally. The proportions of treatment acres vary between watersheds compared to the other alternatives, so the watershed scale effects vary by watershed (see cumulative effects). Thus, while the treatment unit-scale effects are the same rates as described for Alternative 2, the watershed-scale effects are considerably larger except for Alternative 4.

Cumulative Effects

The existing, proposed, and foreseeable future projects and effects are similar to those described under Alternatives 2, 3, and 4, but the percentage of detrimentally disturbed soil in each watershed changes with the treatment acreage in this alternative as displayed in the following table:

Table 3.69: Alternative 5 Total Detrimental Soil Disturbance (treatment effects, existing, and future foreseeable actions)

Watershed	% Disturbance	% Disturbance from Roads
Upper Basin	5.2	0.7
Blacktail	37.9*	5.2
China	9.5	1.7
Herman	11.6	2.2
Lower Basin	4.3	0.8

* The total disturbance on FS land within the watershed would be approximately 7.1%

EFFECTS SUMMARY

At the treatment unit or "activity area" scale, no unit will have detrimental soil effects greater than 15 percent, the maximum allowable by Forest Service Soil Quality Standards (SQS). This is true for all alternatives. This proposal is for treatment of beetle killed or beetle infected and dying trees. Thinning, felling and removal, and burning would be the actions. Thinning and removal will involve heavy equipment to some degree, for example, feller, feller/buncher, forwarder, and excavator thus, all of the thinning/harvesting treatments were assumed to use heavy equipment in a potential "worst-case" assessment. Helicopter and winter logging are options that would have far less soil effects but the degree

that they could be used are unknown at this time so summer logging with mechanized equipment was assumed throughout the analysis.

Soil organic carbon is one area of major concern covered by the SQS. The proposal will follow existing Forest Plan direction regarding large woody debris. This direction generally is in accordance with research regarding the amount of organic carbon that should occur on sites of various habitat types (Graham, et.al., 1994). The other parameters in the SQS that are of concern in this proposal are displacement, compaction, erosion, sedimentation, and burning. Currently, soils are not compacted over threshold limits compared to undisturbed, similar areas and sites generally do not approach threshold values (see proving-ring penetrometer data in the project file). While the existing condition is poorer than most similar sites (soil/landform/habitat type/community type combination) in respect to woody debris and litter layer, the surface soil is stable. The soil contains charcoal but there are no indications that the sites have burned in recent years. Thus, within the proposed treatment units (activity areas) the new detrimentally disturbed soil because of this proposal would likely be 15 percent. Due to the nature and location of this proposal, the watershed scale effects are analyzed at the subwatershed level (6th code subwatershed). As can be seen from the watershed summary tables, all watersheds are still meeting soil quality standards in all alternatives except for the Blacktail watershed. The existing condition in the Blacktail watershed does not comply with soil quality standards because of disturbances on private land. In the case of the existing condition already out of compliance, the standards do not allow any further disturbance. For the proposed project to go forward, all new disturbance must be restored or an equivalent amount of existing disturbance must be restored, or a combination of thereof. This restoration would comply with both Forest Plan requirements to maintain site productivity and the Soil Quality Standards, which are designed to maintain site productivity.

Table 3.70: Amount of Restoration in the Blacktail Watershed to Meet Soil Quality Standards Following Alternative Implementation

Alternative	Percent	Acres
1	0.0	0.0
2	0.7	13.1
3	0.7	13.1
4	1.9	35.6
5	2.7	50.5