TOOLBOX FIRE RECOVERY PROJECT 7/29p/2003 Draft 2 by Desi Zamudio

This Toolbox Fire Recovery Project specialist report was prepared during March, April and May of 2003. It will be used, along with specialist reports from multiple resource areas, to prepare a Draft Environmental Impact Statement (DEIS) for the Toolbox Fire Recovery project. This specialist report will become a part of the planning record for the project, filed under:

"Toolbx/ Planning Record/ E_Specialists_reports_data_inventory_and_collection"

This report will be filed both in the 'hard-copy' planning record binders, on file at the Silver Lake Ranger District, and on the Fremont National Forest "K-Drive". In the interest of planning process efficiency, particularly in light of time and budget constraints, editing that occurs to the content of this report during the preparation of the DEIS will be reflected in the DEIS and will not necessarily be entered back into the content of this report. To insure the accuracy of such edits, I will review the content of both the DEIS and the (Final) FEIS and certify that their content is consistent with the analytical conclusions in this report. If during DEIS or FEIS editing, substantially different conclusions or interpretations are reached or substantial additional analysis is prepared from that displayed in this report, an addendum to this report will be prepared.

Specialist: /S/ Desi Zamudio Discipline: Soil Scientist Date: July 29, 2003

GEOLOGY, GEOMORPHOLOGY & SOILS RESOURCE REPORT

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Introduction

This Geology, Geomorphology, and Soils report discusses erosion and sediment, forest density and soil fertility, and compaction within the Toolbox Fire Recovery Project area and the potential effects of the proposed activities on soil productivity. Two themes pertinent to soil productivity are discussed: loss of topsoil and soil water functions relative to soil compaction.

Key Issue: Effects on Soils, Watersheds, and Aquatic Habitat

Issue Statement: The proposed salvage and connected actions, including temporary road construction, could potentially have adverse effects on watershed and riparian function and cumulatively contribute to adverse effects on soils.

Measurement Indicator: The following indicators will be evaluated for the effects on soil productivity for each of the alternatives:

- Fertility
- Sediment Risk (including the contribution of roads to sediment transport)
- Compaction

Gains and loss in soil productivity are now presented as soil quality gradients. Soil quality differs from the limited soil erosion or loss perspective. In soil quality there is attention to gains and recovery. Soil quality is an ecological awareness of soils as biological systems central to human environmental health. From the broader soil productivity or quality perspective, the interaction among forest composition, cover, and soil biology are considered. The Toolbox Complex burn patterns affect soil quality because they alter forest composition, stand density, and ground cover patterns that affect soil biology (DeBano et al., 1998, ecological report by Frederic Hall, 2003, West and Young, 2000).

In semiarid pine forest soil recovery is a function of forest gaps and it's floristic richness. Soil productivity gains are fostered by the Toolbox project purpose and need actions to a) develop a long-term sustainable forest that functions with fire rather than the current over dense forest (Friedrichsen, 2003) and its extensive fire mortality; b) reducing dense forest fuels loads to reduce adverse soil effects from long residence heating from heavy down fuel, which is to restore grass and shrub fuel load that correspond the soils dark soft "mollic" features; c) recover habitats lost with the fire and the dense forest which are gap associated semiarid forest soil biology: and d) to restore riparian areas damaged in the Toolbox Fire Complex.

Timely wildfire and forest practices are essential for maintaining healthy pine forests (Biswell, 1989). Re-establishment of historic forest structure in overly dense stands requires prudent actions that take into account the findings of broad scale analyses and at the same time answer several soil resource based questions. For this project, questions raised by both of the watershed analyses that have been completed for this area, need to be addressed. The Silver Creek Ecosystem Analysis (Forest Service, 1997) raised integration questions pertaining to soil compaction or disturbance and sedimentation. So compaction surveys and erosion estimated need to be better related to soil productivity. Fortunately, Water Erosion Prediction Project (WEPP, 2001) technology can help to better estimate soil hydrologic values and functions. Canopy closure well above historic values is identified in Silver Lake Watershed Assessment (Friedrichsen, 2003) sets the stage for soil productivity detritus nutrient topics. The manner in which conifer density corresponds to tree mortality raises questions about sustainable forest structure. The encroachment of ponderosa pine onto Hydric Soils in riparian areas raises wetland loss questions.

Purpose and Need

The purpose and need of this project includes six elements, two of which directly or indirectly relate to soil qualities:

- Reduce future surface fuel loading in order to influence subsequent fire behavior and effects. Reduce the risk of adverse effects on vegetation and soils that can result from long residence heat caused by heavy down fuels.
- Restore riparian areas damaged by the Toolbox Fire Complex.
- Develop a long-term sustainable forest that is maintainable by re-introduction of fire.

Regulatory Framework

Fremont Forest Plan

The Fremont National Forest Land and Resource Management Plan (often referred to as "the Forest Plan") sets a management goal, for all resource activity, of maintaining or improving soil productivity. Two related goals are to produce thrifty stands of timber and maintain or improve vegetative conditions of rangelands, which affect soil humus, biology, recovery, and productivity.

Long term research is the basis for a broader soil productivity or quality perspective among forest composition, soil fertility, and biology. The thrifty forest gains soil humus, biology, and productivity. Soil humus from a soil microbial point of view varies with carbon nitrogen ratios. Soils with carbon to nitrogen ratios approaching 5 to 1 have high fertility while carbon to nitrogen ratios approaching 100 to 1 have low fertility, and sites with higher total volume of carbon and nitrogen are more productive. Busse's et al. (1996) sandy eastside pine study areas have carbon nitrogen ratios of about 25 that improved 2 to 3 percent with understory ground cover. With ground cover vegetation there is 30 percent more nitrogen and increases in total volume of carbon and nitrogen. This "store house of nitrogen enriched soil humus" sustains vigorous forest growth. Pine trees with ground cover eclipsed the non ground cover pine site in 12 to 20 years. The time line in this 35-year study indicate likely nutrient re-supply periods that affect eastside pine forest growth. Similarly, statistical analysis of Riegel's Fremont data set (Riegel 2002) for wet and moist meadows shows promising correlation among carbon and nitrogen and ecological gradient. Soil humus and statue relationships in select riparian habitat may soon facilitate rangeland soil productivity monitoring. The long-term perspective supports the "thrift" semiarid forest goal, with well-developed grassy ground vegetation. For example, Hopkins (1979) ponderosa pine forest should have ample cover and composition of grass and grass-like plants such as Idaho fescue, Wheeler's bluegrass, and long-stolon sedge.

The second goal for soils: high quality water is understood with thinking similar to infiltration-based WEPP technology. The recognition of the importance of infiltration has a history dating back to the establishment of the National Forest System. Bernhard Fernow, chief of the US Division of Forestry in 1896 stressed infiltration for water regulation as he promoted the expansion of National Forest (Rowley, 1994). Fernow asserted, "If there were no other means by which a forest cover acted as a preserver of water supplies, the mere existence of the root systems, penetrating the soil in all directions and facilitating percolation of the water would be beneficial." Fernow's assertion has been born out by subsequent soil conservation and quality findings (Faulkner, 1943, Hillel, 1991, Lamarca, 1996). Similarly, Riegel's Fremont data set shows promising correlation among infiltration and ecological gradient in select riparian habitat, which will facilitate monitoring soil productivity and addressing rangeland fish and livestock issues.

Forest Service Manuals and Handbooks

Forest Service Manual 2500, Chapter 2520, Watershed Protection and Management, R-6 Supplement 2500-98-1, sets a criterion for detrimental soil condition to not exceed 20 percent, as follows:

<u>Standards and Guidelines</u>:

- For initial entries, plan and design new activities that do not exceed detrimental soil conditions on more than 20 percent of an activity area.
- In areas where less than 20 percent detrimental soil conditions exist from prior activities, the cumulative detrimental effect of the current activity following project implementation and restoration must not exceed 20 percent.
- In areas where more than 20 percent detrimental soil conditions exist from prior activities, the cumulative detrimental effects from project implementation and restoration must, at a minimum, not exceed the conditions prior to the planned activity and the goal is to move toward a net improvement in soil quality and to achieve less than 20 percent detrimental soil conditions in the long term.

A variety of indices have been used to estimating detrimental soil condition. In rangelands, litter cover is popular yet litter's relationship to soil productivity is complex. Still litter cover is useful when it has been correlated to specific plant community dynamics. Currently, litter cover correlation work has not been done for Hopkins' (1979) plant associations. The Forest Plan features erosion, compaction, mass movement, and displacement. Mass movement, displacement, and compaction are physical and geotechnical properties of the soils that vary with the geologic terrain. Mass movement is associated with steep deeply weathered terrains with ample moisture such the Klamath Mountains, where active nested slide complexes are common. Generally low mass movement potential is listed for soil capability areas in the Fremont National Forest. In the Toolbox tablelands weathered steep slope mass movement feature are uncommon. During construction activity, soil displacement is visually obvious, but in wildlands recognizing displacement has proved to be problematic. Displaced soils move around a slope more than they move off a slope and displaced soils are often deposited under adjacent shrubs or grass clumps. WEPP technology accounts for hill-slope displacement and deposition in wildland erosion estimates. In Great Basin terrain, displaced soils are practical issues at construction sites or along roadways. Detrimental soil compaction was emphasized in the Pacific Northwest Region workshop on the Fremont Winema National

Forest**.** Compaction features and interpretations are well studied in cropland, rangelands, and in forest the interpretations are supported by long tern soil productivity research in a variety of soil textures (Gomez et al. (2002).

The "Soil Productivity Guide for Ground Disturbing Activities" for the Fremont National Forest was developed to provide guidance in achieving Regional Soil Policy, FSM 2521.03. The Guide was developed with input from the Lake County Sustained Yield Group, Timber Sale Purchasers, Operators, Sale Administrators and Contracting Officer (Forest Service, 2000). Comments from Fremont National Forest Watershed Specialists, Region 6 Soil Scientists, and Fremont and Winema National Forests Line and Staff Officers were used to refine the Guide. The Guide is intended to be dynamic and refined as new technology becomes available to meet objectives and as monitoring results are obtained.

Legal Framework

The National Forest Management Act of 1976 (NFMA) requires serving the national interest with resource programs based on a) supply and demand, b) analysis of economic and environmental impacts, and c) knowledge derived by coordinated research that promotes sound technical and ecological basis for use and protection of the Nation's resources. Programs are required to provide for the diversity of plant and animal communities based on the suitability and capability of specific lands.

The Organic Administration Act of 1897 (OA) established National Forests with the purpose of improving and protecting the forest, or securing favorable conditions of water flows and continuous supply of timber, for the use and necessities of citizens of the United States.

Short and long term interactions and relationships among soil, plant, and animals are encapsulated in soil quality. An ecological awareness of soil biological systems is central to environmental health. For example, favorable conditions of water flow, as per the 1897 OA, vary with the nature of the soil fauna and microbial biology that sustains soil structures that allow favorable infiltration, instead of contributing to excess erosion or runoff.

Wetlands are protected under **Executive Order 11990,** which directs federal agencies to "minimize the destruction, loss or degradation of wetlands, and to preserve and enhance the natural and beneficial values of wetlands…."

Background Information

Soil Resource Inventory

Soil, geomorphic and geologic surveys on National Forest are shaped by the regulatory framework. For example the Forest Plan set a goal to maintain or improve soil productivity in all resource activity (Forest Service, 1989), which is a basis for surveys. Yet most of the knowledge we have on soil productivity is based on plant nutrients studied on agricultural lands. Productivity gains are associated with soil humus accumulation and plant community detritus nutrient webs. The types and conditions of plant communities and the minerals in the underlying geologic rock effects the rate of soil humus gains. Productivity losses are associated with erosion and sediment transport that vary with plant community, geomorphic topography, slope, mineral grain sizes, and especially climate. Prior to the Water Erosion Prediction Project technology (WEPP, 2001) erosion estimates on National Forest were statistical extrapolations of crop studies with limited forest studies. WEPP technology is a computer model bases on the Green-Amp infiltration equation that uses local climate data sets, soil texture, vegetation type, ground cover, and topography. Roadway and wildfires studied for WEPP model calibration by the Rocky Mountain Research Station scientist makes WEPP particularly well suited to National Forest assessments and Forest Plan goals.

With the advent of Forest Plans, soil surveys were adopted by the National Forests. Soil surveys have evolved over 300 hundred years for a wide range of land use assessments. A standard county soil survey contains plant production, nutrition, geographic, and geotechnical information for hundreds of land use interpretations. To meet Forest Plan timelines the National Forest produced simplified surveys called Soil Resource Inventories. Current National Forest work is underway to upgrade the vegetation information for types and conditions of plant communities to better estimate trends such as in range condition or forest health.

Watershed Analyses

Two Watershed Analyses were compiled for the Toolbox area: the Silver Creek Watershed/Ecosystem Analysis (Forest Service, 1997) and the Silver Lake Watershed Assessment (Friedrichsen, 2003). The analyses have complimentary and contrasting interpretations. The Silver Creek Ecosystem Analysis has multiple topics, so some key integration is lost. Geologic and geomorphic information is presented but geomorphic interpretation such as flows are not presented in a standard way. The flows are presented as "flashy" but the linear and low drainage density geomorphology is unlikely to produce "flashy" flows. In the watershed analysis, road densities are added to the steam densities (which are twice the value of the perennial and intermittent streams in the Forest data base); however, roads must be near the stream for hydrologic connection. With the Cross Drain portion of WEPP, hydrologic road effect can now be better estimated.

Erosion in the Silver Creek Ecosystem Analysis is presented in a way that emphasizes erosion, for example, of 419 tons over 24,001 acres in West Fork (Forest Service, 1997). However, when presented in the standard format of tons per acre, it indicates a very low erosion rate of 0.02 tons per acre. This erosion rate is well below 1 ton per acre of minor sheet erosion. In this sandy landscape however, the stream pools had high fines and high sediment levels for poor rating that are, in part, attributed to high erosion. An alternative cause is extensive soil impact of 31 to 45 percent. The 1997 detrimental soil impacts surveys only recorded ease of shovel penetration, which is an indirect measure of soil compaction that varies with site moisture and strength of the sampler. Shovel penetration is a first approximation that is affirmed or rejected with diagnostic soil structure, plant root patterns, and plant growth values. The 1997 sampling did not record features such as soil plates, root-bound plants, or limited shoot growth that is associated with detrimental compaction and soil impacts. The soil impact interpretations may be due to the lack of American Society for Testing and Materials (ASTM) and Association of State Highway and Transportation Officials (AASHTO) tables and testing in the Soil Resource Inventory. Using standard geotechnical ASTM and AASHTO tables and interpretations, sandy soils have slight compressibility and slight cohesion. Therefore, compaction is a challenge on these soil textures and the 31 to 45 percent values appear to be statistical anomalies.

Yet to better understand compaction risk in the Toolbox the areas sampled in 1997 were revisited in 2002 and they showed vigorous plant growth. For soil conditions four harvest areas with sandy and sandy loam textures were sampled for the Silver Creek Watershed Analysis (Forest Service, 1997). To obtain values to compare to regional standards transects were sampled at two areas in 2002 using the method in this analysis. Vegetation conditions were also noted along transects. For example, Ponderosa pine poles had 12 to 18 inch spacing between branch whorls and ground vegetation composed of grasses and sedges similar to historic plant communities. No detrimental soil features were found in 2002. Looking at the consistently wide whorls the areas have a 10 to 20 year vigorous growing tend of a favorable plant environs. So the 1997 soil impacts values seem in error relative to soil productivity. To our knowledge shovel penetration has not been correlated to plant growth, infiltration, or erosion aspect of soil productivity. As the revisited sites illustrate shovel penetration seems poorly related to soil-plant productivity.

The Silver Lake Watershed Assessment (Friedrichsen, 2003) is more focused. It better develops vegetation conditions and shows the amount of forested land that currently have canopy closure exceeding historic values. This assessment sets the stage for the complimentary loss in ground cover vegetation for nutrient decline in the semiarid forest. The assessment does not provide leaf area surface evaporation relationships that show exponential site drying with conifer density above historic norms. Still Friedrichsen's (2003) conifer density patterns in the assessment corresponded well to the fires tree mortality patterns found in forest vegetation surveys.

An alternative explanation for pool fine sediments comes to light given encroachment data from the on going riparian field guide survey. Gregg Riegel's Fremont data set indicates sod-binding sedge or willow root systems are being replaces by week-rooted pines, which may enhance steam bank erosion. So conifer density and encroachment may both dry wetland sites and they may facilitate erosion for two modes of wetland loss.

Burned Area Emergency Rehabilitation (BAER)

In wildfires, sandy soils with low surface areas often become water repellant, while clay soils with high surface areas tend not to become water repellant. Soils become water repellant as wildfires burn and coat soil surfaces with plant and fungus oils or waxes (DeBano et al., 1998). A shift from water absorbent to water-repellant soil conditions in catchments is a basis for a post fire emergency condition (DeBano et al., 1998). A catchment is a soil map unit scale areas of 20 to 100 acres. With extensive sandy soils in the Toolbox project area, a reduction in infiltration due to water repellant soil conditions was anticipated. However, the crown fire did not affect the soils as expected.

Burn severity is often confused with burn intensity. Burn severity describes the fire-caused damage to the soil, while burn intensity describes the nature of a fire in terms of its rate of energy release (DeBano, 1988). These are physical descriptions of the fires, rather than ecological effects. The severity ratings are based on the following standards (BAER Handbook, FSH 2509.13):

- High severity – More than 40 percent of the area exhibits soil features likely to significantly increase runoff and erosion (e.g., absence of duff layer, hydrophobic soils, soil discoloration).
- Moderate severity – Less than 40 percent of the area exhibits high severity indicators. Duff layers may be absent or mostly absent.
- Low severity – Duff layers are burned but intact. Unburned areas are intermingled with lightly burned areas.

Most burn soils sampled were water absorbent for a low burn severity in 74,673 acres and moderate severity in 11,311acres (Forest Service Staff, 2002). The 810-acre area in high severity with water-repellent soils was generally associated with lodgepole pine communities, especially where lodgepole pine encroached onto meadow. The BAER report for the Toolbox Complex lists a total burned area of 86,794 acres, with 51,284 acres on the Fremont NF, 8,015 acres in BLM Lakeview District and private holdings of 27,443 areas. (The acreage amounts differ slightly due to the inclusion of more portions of the Winter Fire in the BAER assessment. The actual acreage for the Toolbox project area is approximately 85,000 acres, including 48,000 acres of National Forest System lands). Overall, sandy soil water repellant response was less extensive than anticipated.

To assess post-fire risk, erosion was estimated with WEPP technology for landtypes grouped by capability areas (Forest Service Staff, 2002). The Water Erosion Prediction Project technology estimates dynamic erosion and runoff that incorporate fire effects, vegetation, soil, slope and local climate (WEPP, 2001). Background erosion rates were estimated at 0.01 to 0.05 ton per acre and runoff rates were estimated at 0.00 to 0.02 inches. These low values are similar to the values in the Silver Creek Ecosystem Analysis (Forest Service, 1997) when presented in the standard tons per acre format. Drainage scale post-fire erosion sediment transport was estimated at 0.09 ton per acre and runoff 0.04 inches in Duncan drainage overall. In the Silver drainage, the estimated post fire erosion is 0.06 ton per acre and runoff is 0.03 inches overall. Generally the erosion rates are below 1 ton per acre; however select water-repellant areas have an anticipated erosion rate of 1.72 tons per acre and runoff of 0.31 inches. Erosion and runoff risk are apt to be greatest directly after a fire.

As ground vegetation recovers, erosion risk and rates are likely to decline in a few years, where soils have low and moderate burn severity (Robichaud et al., 2000). Therefore, rapid native recovery is anticipated in the 74,673 acres with low severity and the 11,311acres with moderate severity. With erosion rates near background and rapid recovery likely, overall sediment risks are low. As with background sediment pulses, the fire effect sediment pulses are within the range that sustains native fluvial processes for gravel bar willow habitats, overbank meadow deposits, and basin forming processes.

On the other hand, tree mortality appeared more extensive than areas of water repellant soils during the burn area emergency assessment. Mortality was surveyed for recovery planning. In the Silver drainage, six times more area was found in the high class with 86 to 100 percent tree mortality than in the low class with 0 to 25 percent mortality. In the Duncan drainages, the high mortality class was three times more extensive than the low class. On the positive side, riparian habitats showed dramatic response with the mortality of pines that had encroached onto the wetlands. A flush of sedges and willows plants began recovering the wetlands. Thinned ponderosa pine forest sites or areas treated with prescribed fire that reestablishes forest gaps had ground fire characteristics. Low mortality was observed in areas with forest gaps and sagebrush grass vegetation patterns similar to historic eastside forest communities.

Emergency Treatments

Post-fire treatments on Toolbox Complex were developed following effectiveness and recovery guidelines (Forest Service Staff, 2002, Robichaud et al., 2000). Generally, sediment yields after fire decline as vegetation recovers in a year or two after a burn. A local recovery reference burn area exists in the 1996 Alder Ridge wildfire that occurred within the Silver fire boundary. The Silver and Alder burn patterns inter-fingered so the landscapes are composed of essentially the same soils, vegetation, and geomorphic elements. The 1996 Alder Ridge fire area shows extensive ground vegetation and grass recovery; therefore, this recovery is likely in the Silver Wildfire. With a timely grassy ground cover recovery likely, seeding was considered unnecessary with generally low burn severity on this low erosion tableland. On the other hand, on the extensive water repellant lodgepole pine communities in the adjacent Winter Fire, extensive areas were grass seeded.

The rocky riparian areas in the Soil Resource Inventory (SRI) land type 2 along streams and rim rock draws (Wenzel, 1979) presented a series of emergency treatment trade offs in light of effectiveness and recovery guidelines (Forest Service Staff, 2002, Robichaud et al., 2000). Encroaching conifers had displaced riparian plants and facilitated wildfire spread along rim rock draws. However, the extensive surface stones make most of the burned sites unsuitable for log terrace treatments and seeding is apt to compete with sedge and willow re-sprouting as the fire cooled. Sedge plants had begun to expand from their refuge along stream banks across floodplains to match the wet soil features. BAER team soil scientist and riparian specialist did not want to disrupt this overdue recovery process with post fire emergency stabilization treatments. So log terraces were limited to a few suitable areas and grass seeding was not applied. Yet follow-up treatments may be needed.

Long Term Treatment Considerations

Over the long term, topsoil recovery varies with the kind and the cover of plant species. The recovery plant succession drives the complementary soil detritus web for nutrient re-supply. On the other hand, ground cover loss in dense woodlands has yielded notable topsoil loss. To avert the soil loss in semiarid forest and rangelands West and Young, (2000) propose a soil productivity oriented early warning concept. West and Young (2000) identify the affects of conifer densities above historic norms as a "lignification," which identifies habitat shifts by changes in soil biochemical pathways. With a shift to lignin, and away from carbohydrates, native bacterial microbial populations in semiarid forest and rangelands are less suited to processing detritus into soil humus and available nutrient for plant growth—so the soils erode. Toolbox project area faces "lignification" with a semiarid climate, canopy closure exceeding historic values (Friedrichsen, 2003) and the associated extensive tree mortality. The forest vegetation survey found 15,074 acres with tree mortality above 50 percent, while the high burn severity area was only 810 acres. So by area there is greater risk of "lignification" soil losses than erosion losses from burnt soil effects. And treatment actions that recovery historic forest densities, gaps, and ground cover avert the soil losses.

The Forest Plan presents a goal, for all resource activity, of maintaining or improving soil productivity. Yet the areas proposed for treatment in the Toolbox project face West and Young's (2000) "lignification" affects with conifer densities above historic norms. Recall the shift to lignin, and away from carbohydrates in semiarid forest reduces the available of nutrient for plant growth—so soils are more apt to erode. On the other hand, long tern research support soil productivity gain due to accommodating ground cover in thrifty pine forest, which enhances nutrient detritus webs and tree growth (Busse et al. (1996).

Without a well-developed ground cover in the forest gaps the ponderosa pine trees are less apt to benefit from the frequent wildfires that are typical in the areas. A fire history study within the Toolbox Fire Complex showed wildfire occurred at 6 to 15 years for average 10-year intervals (Miller et al., 2001). Historic wildfires are characterized by low tree mortality. The extensive mortality in the Toolbox Fire Complex is a departure from historic wildfires conditions in eastside pine forest communities when wildfire were ground fires, and mature pine lived through wildfires with some scaring (Agee, 1993, Biswell, 1989, Miller et al., 2001). Historic (or native managed) Ponderosa pine forest had 60 to 70 percent "forest gaps" with ground vegetation of sagebrush grass and mixed shrub grass. Recommendations to (in the event of salvage) retain 50 percent of the standing dead trees (Beschta, R.L. et al, 1995) do not provide a historic or prior forest density context. Using historic vegetation context, Beschta et al's recommendation are apt to apply when the local forest have historic openings, rather than the current over-dense conditions. In any case recovering the ground cover limits "lignification" risk and recovers topsoil functions.

Analysis Area and Methods

The analysis area for soils encompasses all National Forest lands within the burned area of the Toolbox Fire Complex within:

<u>Silver Creek Watershed</u> –
(The following subwatersheds)

- Middle Silver Creek
- West Fork Silver Creek
- Upper Silver Creek
- Thompson Reservoir
- Benny Creek

<u>Silver Lake Watershed</u> –
(The following subwatersheds)

- Upper Duncan Creek
- East Duncan Creek
- Lower Duncan Creek

No portion of the Summer Lake Watershed, to the east of the area, is included in the analysis area. With minor exceptions, the adjacent 2002 Winter Fire occurred entirely within the Summer Lake Watershed, outside the analysis area.

Areas where salvage and fuels treatment recovery actions are proposed are grouped into seven cases studied based on recurring soil map units, eco-classes, and topographic slopes groups from the Forest resource surveys and databases. The cases are based on Alternative C, with 14,441 acres, which is the most extensive area proposed for actions. The cases are listed in Table 1 Toolbox Fire Recovery Project area geographic soil information is based on the Soil Resource Inventory (SRI) in combination with plant associations, riparian types, (Hopkins, 1979, Riegel et al., 2002, Wenzel, 1979) and field samples to approaches the utility of a modern soil survey (Soil Survey Division Staff, 1993). The Soil Resource Inventory's limitation is visible in the Silver Creek Ecosystem Analysis (Forest Service, 1997) so the soil characteristics are supplemented by the South Lake County survey (Kienzle, 1999) abutting the Toolbox Fire Recovery Project. With WEPP technology, soil, sediment, and hydrologic functions can be better estimated. The seven cases in Table 1 will also be used to present sample findings.

Table 1 - Case Studies Used to Assess Sediment Levels and Recovery Responses

Case Study	% of Proposed Salvage area*	Slope	Soil Characteristic	Ecoclasses	SRI Map Units
1	30%	0 to 15%	Loamy Texture	Ponderosa pine/fescue, with various sagebrush and bitterbrush shrub combinations in ecoclasses: CP-S2-11, CP-S3-11, CP-C2-11	35, 37A, and 64 Capability 4
2	16%	0 to 15%	Loamy Sand Texture	Ponderosa pine/fescue, with various sagebrush and bitterbrush shrub combinations in ecoclasses: CP-S2-11, CP-S3-11, CP-C2-11	88A, 85, 84, and 77A Capability 5
3	10%	0 to 15%	Stony Loamy Texture (rock content 50%)	Ponderosa pine/fescue, with various sagebrush and bitterbrush shrub combinations in ecoclasses: CP-S2-11, CP-S3-11, CP-C2-11	30A, 350, and 36 Capability 2, 13
4	5%	0 to 30%	Stony Loamy Texture (rock content 50%)	Ponderosa pine/fescue with various sagebrush and bitterbrush shrub combinations in ecoclasses: CP-S2-11, CP-S3-11, CP-C2-11	2 Capability 6
5	10%	0 to 30%	Loamy Texture	Ponderosa pine, white fir and aspen forest, with various ceanothus, manzanita and bitterbrush shrub combinations in ecoclasses: CP-S2-17, CW-H2-12, CP-S1-21	34B, 37B, and 41B Capability 6
6	7%	0 to 30%	Loamy Sand Texture	Ponderosa pine White fir and Aspen forest, with various ceanothus, manzanita and bitterbrush shrub combinations in ecoclasses: CP-S2-17, CW-H2-12, CP-S1-21	88B and 77B Capability 7
7	8%	0 to 15%	Loamy Texture	Lodgepole pine and ponderosa pine/fescue and sedge forest, ecoclass: CL-G3-15 (limited shrub component)	39 Capability 4

Two forest themes are pertinent for assessing soil productivity in the project area. The first is topsoil loss or loss in topsoil function due to canopy closure exceeding historic values (Friedrichsen, 2003) and the extensive tree mortality incurred in

the Toolbox Complex wildfire. The areas face West and Young's (2000) "lignification" affects with conifer densities above historic norms. Recall the shift to lignin, and away from carbohydrates in semiarid forest reduces the available of nutrient for plant growth—so soils are more apt to erode. On the other hand, nutrient detritus webs and tree growth are supported by ground cover. Long term research by Busse et al (1996) shows forest shrubs, grasses and forbs are key plant products needed to sustain humus "the store house for available nutrients, such as nitrogen." The study provides a time line of 12 to 20 years for nutrient re-supply that affects tree growth and soil productivity.

The second theme is soil water functions relative to soil compaction. A long-term study by Gomez et al. (2002) highlights the differences in cultivation effects. Compaction effects are not universal—said another way a one-size standard may not fit all soils or geologic terrains. In the long-tern study of Ponderosa pine seedlings and sapling growth in three contrasting textures: clayey, loamy, and sandy loam Gomez et al., (2002) found overall compaction effects on pine seedlings and sapling growth were detrimental in the clayey soil, insignificant or no effect in the loamy soil, and beneficial in the sandy loam soil. In the past most forest compaction studies have focused on clays soils but in this study soils are tested across a range of geotechnical soil conditions. So ASTM and AASHTO interpretations may be better compared to forest conditions. It helps to address questions about among site compaction values raised from the Silver Creek Ecosystem Analysis (Forest Service, 1997) for better integration among soil compaction, disturbance, and sediments.

Erosion and Sediment

The seven cases listed in Table 1 and shown in Figures 1 and 2 are used to estimate sediment rates using WEPP technology. The seven cases will also be used to identify salvage harvest unit issues.

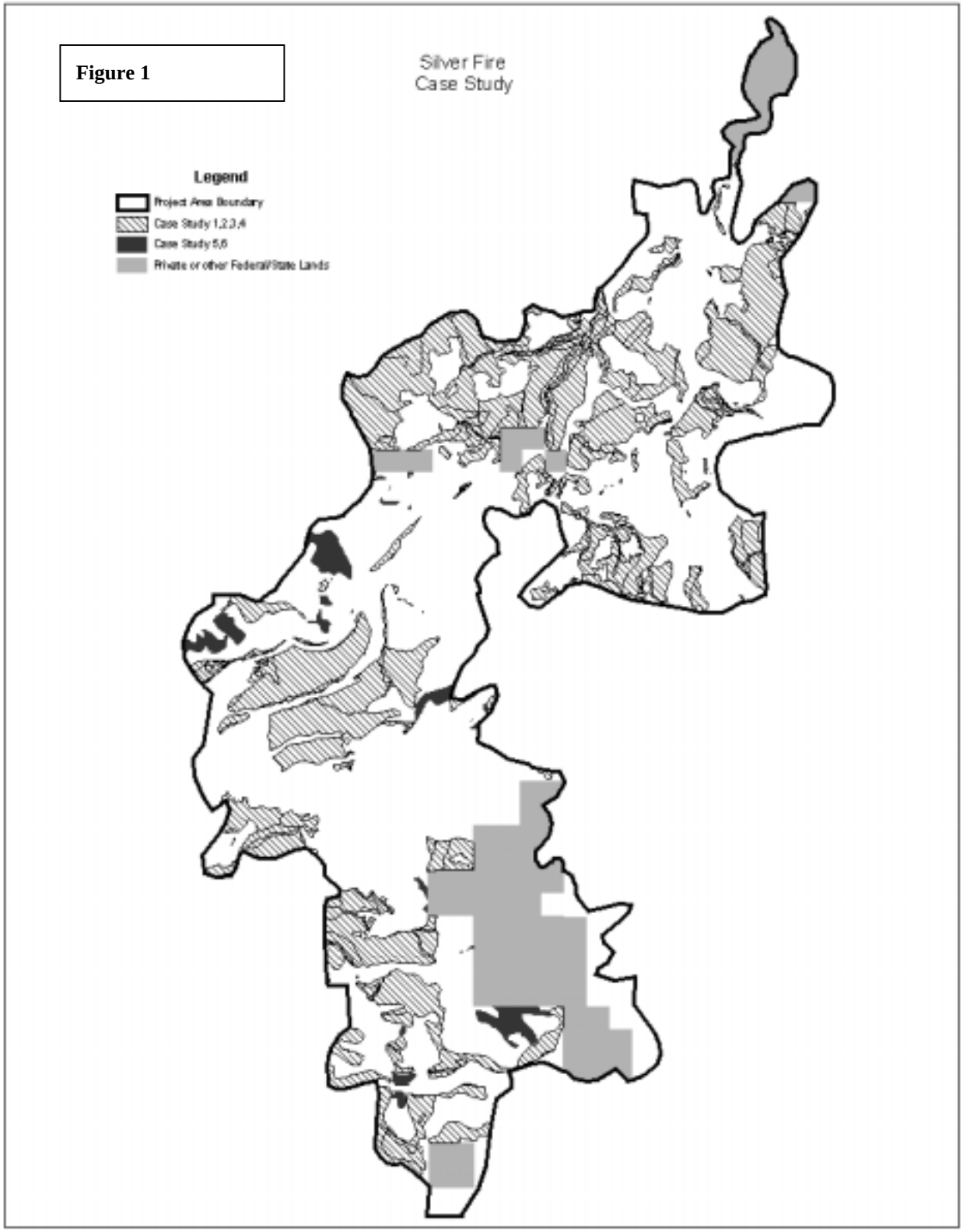


Figure 1
Silver Fire
Case Study
Legend
Project Area Boundary
Case Study 1,2,3,4
Case Study 5,6
Private or other Federal/State Lands

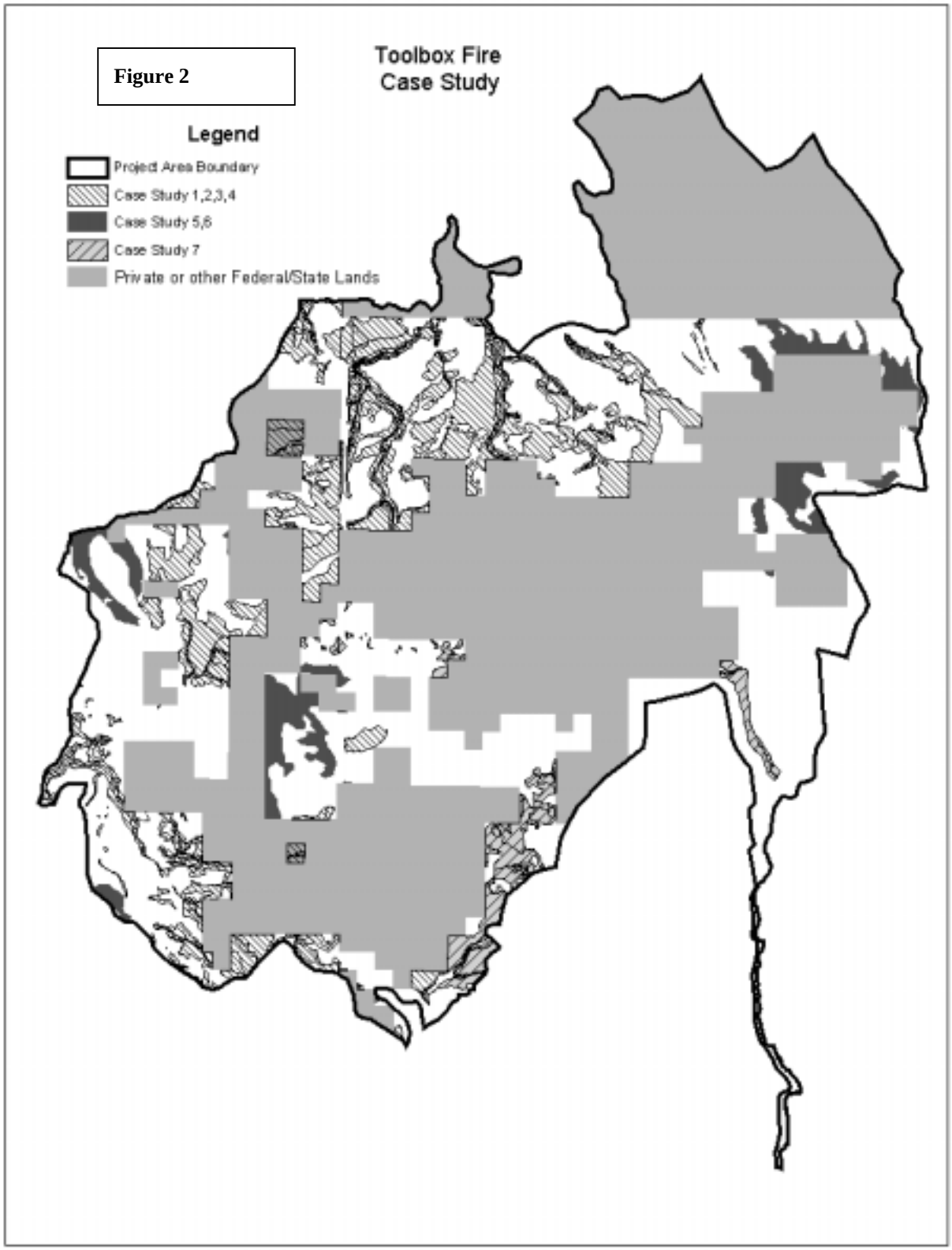


Figure 2
Toolbox Fire
Case Study
Legend
Project Area Boundary
Case Study 1,2,3,4
Case Study 5,6
Case Study 7
Private or other Federal/State Lands

Erosion by Case Study – Hill slope sediments were estimated with the Water Erosion Prediction Project technology (WEPP, 2001) for the cases in Table 1 (Forest Service, 1989, Hopkins, 1979, Wenzel, 1979). Proposed treatment areas in the action alternatives were grouped into seven case studies based on recurring eco-class, soil type, and slope patterns. Plausible scenarios for ground cover are used to generate values for initial recovery and ground based harvest.

Initial Recovery by Case Study—Sediment values were generated for each of the cases at two plausible checkpoints of recovery after fire. The first checkpoint scenario is a low severity burn in an overstocked forest, where the eco-class live ground cover is reduced to ½ of pre-fire potential. Low burn severity, in terms of soil water repellency, occurred on 85% of the fire. The second checkpoint occurs approximately 2 years after the wildfire, when live-ground-cover has recovered to ¾ of eco-class potential.

Erosion for Ground-Based Harvest by Case Study – Sediments begin with scenarios one and two, then introduce treatment scenarios three, four and five. The third checkpoint includes 15 percent of the area containing new skid trails, while ¾ of potential live ground cover is maintained over the remaining area. The fourth checkpoint represents full potential live ground cover recovery after logging, and the fifth checkpoint represents a reforested 5-year-old forest. The values are presented in Table 5 under "Existing Conditions" and Table 8 under "Direct and Indirect Effects."

To address long-term soil productivity the erosion estimates are compared to the T-factor of soil loss tolerances, which vary from 1 to 5 tons per acre (Soil Survey Division Staff. 1993). The T value of 1 ton per acre is a paper sheet thick layer of erosion that is tolerable for shallow soils, while a T of 5 tons is tolerable for deep soils.

Road Erosion – Given hydrologic connection roads convey water and sediment like channel networks. In the western Cascade Mountains roads may extend the stream network by 40 percent during a storm event (Wemple, 1994) for hydrologic and geomorphic effects similar to drainage density. Effectively, 40 percent of the road density can be added to the stream drainage density in estimating sediment transport. Caution is needed in applying Wemple's (1994) 40 percent finding in the western Cascades to the Toolbox Fire Recovery Project area, which is in the Great Basin. The 40 percent road to stream network may only occur during larger storm events in the Toolbox area.

The amount of road sediment was estimated using the Water Erosion Prediction Project (WEPP) Cross Drain Spacing and Sediment Yield Model (WEPP, 1999). Typically road characterize the Toolbox Fire Recovery Project area is a two percent grade native surface roads or graveled roads with 400 to 800 feet cross drain increments.

Forest Density and Soil Fertility

Indicators of favorable long-term soil productivity – In most of the project area the semiarid forest plant communities that sustained the soils are thrifty, single single-story LOS (Late/Old Structure) ponderosa pine stands, with well-developed grassy ground vegetation. Historic ponderosa pine forest had ample forest gaps, often 60 to 70 percent of the forest area. The ground vegetation in the forest gaps is essential for soil nutrient re-supply and sustaining forest growth (Busse et al. 1996). On the other hand, dense canopy limits competes with the soil humus re-supply conditions.

Soil productivity and recovery varies with the ground vegetation in the forest gaps. With ample gaps, historic fires in the ponderosa pine forest were generally ground fires, where mature pines lived through the fire with some scaring (Agee, 1993, Biswell, 1989, and Miller et al., 2001). Mortality would be low in the historic ponderosa pines architecture; a mortality class of 0 to 25 percent would be expected. Sites with 0-25% mortality have forest gaps and the ground vegetation for humus and nutrient re-supply within the historic fertility range.

Indicators of detrimental long-term soil productivity - Forest plant communities that depart from historic "forest gaps" limit soil humus re-supply conditions and contribute to extensive mortality during wildfires. Canopy closure exceeds historic values was identified as a problem in the Silver Lake Watershed Assessment (Friedrichsen, 2003). Assessment sets the stage for decline in soil productivity. Conifer mortality has been mapped in a forest vegetation survey (in GIS Layer in polygons "mort_f") for recovery planning. Generally mortality correspond the canopy density or lack of gaps as anticipated in Friedrichsen's (2003) Silver Lake Watershed Assessment.

A time line for "gap ground cover" formation and nutrient re-supply within the gaps can be estimated by comparing the Miller's et al., (2001) ten-year wildfire interval with Busse's et al. (1996) twenty-year nutrient humus enrichment intervals. A forest stand with 100 year old ponderosa pine in the "gap" has misses 10 gap clean outs cycles and it has displaces the ground vegetation for 5 nutrient re-supply cycles for chronic decline in humus.

Sites with 26 to 50 percent mortality have a decline in forest gaps, and ground vegetation that re-supplies soil humus. Alternately we could say a re-supply cycle has been missed. Sites with mortality of 51 to 85 percent or greater than 86 percent gave canopy densities that have excluded digestible ground vegetation detritus. In these sites several nutrient re-supply cycles or their effective has been limited for chronic a nutrient decline. These forest sites with 100-year dense pole within the historic "gap" may have missed up to 5 humus recovery cycles. Hot burn areas inclusions within the lower mortality classes may have high enough tree densities to indicate chronic detrimental soil conditions.

Table 2 - Post Fire Mortality as Indicator of Humus Re-Supply Conditions

Conditions		Definitions
Historic, 1_sl		0-25% and humus within historic fertility
Decline, 2_sl,		26-50% and humus decline from historic fertility
Chronic, 3_sl		51-85% and humus chronic decline from historic fertility--1
Chronic, 4_sl		86-100% and humus chronic decline from historic fertility--2

Compaction

The field protocol used to perform post-fire compaction surveys, accounts for two factors 1) evidence of equipment, and 2) evidence of soil compaction. A detailed protocol and field training is provided to the surveyors. Tables 3 and 4 display the factors identify by field crews and spot-checked by Forest soil scientist. The method is an adaptation of the Winema National Forest method (Forest Service, 2002a). Disturbance factors in are rated at six levels that vary from class 1, native cover and soil tilth condition; to class 6, traffic and compacted conditions. Tilth is a traditional word used to describe a soil structure and aroma associated with vigorous plant growth environs. Platy soil structure is traditionally associated with plow layers and foundation compaction.

As indicators of soil productivity the Winema method scale and features are consistent with 50 years of soil interpretations. Soil plates are a soil structures associated with root barriers and diminished plant growth environs (Veihmeyer and Hendrickson, 1948). The descriptions of platy layers in class 5 and 6 are similar to plow layers in crop fields; platy layers 5 to 10 cm (2 to 4 inches) thick have been shown to limit growth (Soil Survey Division Staff, 1993, Taylor, and Ashcroft, 1972, Veihmeyer, and Hendrickson, 1948). The description of plates at class 4 is too thin to be a plow layers in crop fields; platy layers less than 5 cm (2 inches) thick may or may not limit crop, range pasture, or forest growth.

Table 3 - Evidence of Equipment

Evidence of Equipment Factors	Class
• Well developed forest understory and overstory, no stumps or skid trails	1
• Faint impressions of wheel tracks or slight depressions in vegetated forest understory • (Local equipment feature: old skid trails or landing beyond 10 meters, decayed saw stumps)	2
• Visible indications of past equipment operation in forest openings • (Local equipment feature: skid trails, landing or saw cut stumps within 10 meters)	3
• Wheel or crawler depressions or tracks evident • (Local equipment feature: bare skid trail or landing and saw cut stumps within 10 meters)	4
• Fresh wheel or crawler tracks, and fresh removal of forest vegetation • (Local equipment feature: actively used two-track road or recent skid trail or landing)	5
• Active road surface, no understory vegetation in road way • (Local equipment feature: maintained or graded native road)	6

Table 4 - Evidence of Soil Compaction

Soil Compaction Factors	Class
• Well developed forest understory and overstory with granular surface soil structure • (Local soil feature: soft soil, garden like resistance to probing)	1
• Forest surface soil structure unaffected by past equipment operation • No evidence of platiness developing in surface soils • (Local soil feature: soft, slight resistance to probing)	2
• Soils show some signs of soil compression compaction • (Local soil feature: some resistance to probing; blocking structure with minor amounts or discontinuous plats, soil aggregates readily fall apart when shaken)	3
• Soils show evidence of compaction with firm footing and minimal duff or grass cover • (Local soil feature: moderate resistance to probing; moderate or strong platy structure continuous at about 30 cm (12 inches) depth thin plates that holds together when shaken)	4
• Soils provide firm to hard footing surface with limited plant cover • (Local soil feature: strong resistance to probing dry and some resistance moist; plate layers 5 to 10 cm (2 to 4 inches) thick about 30 cm depth, plates holds together when shaken)	5
• Soils provide a hard footing surface stunted or limited understory forest growth • (Local soil feature: Plates form at depth of less than 5cm)	6

Survey transects and samples were stratified by cases and capability areas map units with at leads five transects in common map areas. Transects are 400 meter long transects with 20 sample points, each 20 meters apart' were laid out on compass bearings. Disturbance factors were sampled at points along the survey transects. At each sample point a surveyor records a) evidence of equipment within a 10-meter radius of sample point, and b) evidence of soil compaction. A planting spade and ruler were used to determine underground soil structure tilth or platy layers, plate depth and thickness. The transect findings were then compiled to assess the relative rate of disturbance.

For the Toolbox analysis 1820 samples points on 91 transect locations on likely treatment areas are used to estimate soil conditions. Although, cases with loamy sand or the stony soils that resist compaction are common in the Toolbox area, textures in Table 1 alerted us to some possible compaction locations within proposed harvest units. Compaction surveys sampled all seven cases and ten capability areas for a wide range of conditions. Transects were distributed across recent logging, older logging and un-logged areas both inside and immediately outside the fire area.

Additional transects were sampled in the Alder Ridge fire (burned in 1996, partial salvage harvest in 1997) within the Toolbox Complex boundary; and in a 2002 revisit of samples initially taken for the 1997 watershed/ecosystem analysis.

Soil compaction census data in classes 5 and 6 are tallied for comparison to the detrimental soil condition limit of 20 percent in the Pacific Northwest Region (Forest Service, 1998).

Census data (hits) can be used to develop a probability distribution to present the finding in an objective way or for statistical test (Mendenhall and Scheaffer, 1973). The relative frequency of hits in high (5 & 6), moderate (3 & 4), and low (1 & 2) classes can be used to estimate recovery or potential problems. Changes in the proportions of hits in the moderate classes (3 & 4) aid in test Chi-Square estimates of recovery.

To assess project effects or recovery, hits in high (5 & 6), moderate (3 & 4), and low (1 & 2) classes may be compared over time or between evidence of equipment and soil compaction. The proportion of hits in the moderate effects: classes 3 and 4 are apt to aid estimating recovery or lingering problems. Few high value hits (5 and 6) indicate soil recovery or low treatment effect. Generally recovery is underway if soil compaction factors have lower value hits than evidence factors. In a recovering site the population distribution of compacted values of 5 and 6 are apt to shift to 3 and 4, with associated plant growth recovery.

Over time with plant root and humus recovery, compacted values are apt to shift to hits in classes 1 and 2 with garden like tilth. This recovery process is familiar to gardeners who have tended flowerbeds adjacent to new home foundations, where compaction occurred in home construction. Using 10 years of trend sampling the Forest soil scientist and riparian specialist has present workshops on the recovery processes with field examples from the Sierra Nevada and central Great Basin. Now trend studied that include soil quality are being implemented on the Fremont Winema National Forest.

Existing Condition

The Burn Area Emergency Report for the Toolbox Complex reports a total burned area of 86,794 acres, with 51,284 acres on the Fremont NF and 8,015 acres in BLM Lakeview District and private holdings of 27,443 areas (Forest Service Staff, 2002) (note: BAER took in slightly more of the Winter Fire, therefore the acreages are larger than considered in the EIS). The Toolbox BAER report found that most soils were water absorbent for a low burn severity rating on 74,673 acres and moderate severity rating on 11,311 acres. 810 acres were rated as high severity area, with water-repellent soils. These latter were generally associated with lodgepole pine communities, especially where lodgepole pine had encroached into meadows. Overall sandy soil water repellant response was less extensive than anticipated.

Conifer encroachment on to soils with wetland features were extensive in the Winter and Toolbox Complex, which is inconsistent with historic condition where conifers were limited to the well-drained margins of riparian ecosystems. Fifty to 70 year old conifers had encroached onto riparian soils, had displaced riparian specie and had resulted in fire-caused tree mortalities above 50 percent. Following the 2002 fires, sedge plants have began to expand along stream banks and across floodplains to match the wet soil features.

The Soil Resource Inventory survey information for the Toolbox project area shows sandy soils dominate the Silver Creek drainage in map unit 88A and in similar soils of Capability Area Five: Lava Tablelands with Ash and Pumice Mantles (Forest Service, 1989, Wenzel, 1979). The sandy soils are similar to the Mound soil series with a dry summer environ, ashy sandy loam deposits over stony clay loam subsoil of weathered basalt and andesite, and grass pine savanna (Forest Service, 1989, Kienzle, 1999, Wenzel, 1979). To the east in Duncan Creek drainages loamy soils dominate in map unit 37A and similar soils of Capability Area Four: Lava and Tuff Tablelands. The loamy soils are similar to Woodchopper and Roggers soil series with dry summer environs, loam over clay loam textures with shrink-swell clays weathered from basalt and andesite, and grass pine savanna. The relative soil fertility is moderate with a mix sandy ash and lava rock and grassy ground cover. Rocky soils in map unit 2 occur along fault trends rim rock draws and streams. The soils are similar to the Booth soil series with extensive surface stones.

Topsoil loss potential is listed the Soil Resource Inventories by static erosion classes yet erosion processes are dynamic processes that vary with the kind and cover of plant species. Considering the limitations of the Soil Resource Inventory, the Plant Associations of the Fremont National Forest (Hopkins, 1979) are essential for estimating changes in local plant condition. Hopkins' (1979) ground cover values provide reference condition for estimating effects that is trend down for topsoil loss or trend up for recovery. Similarly, Area Ecologist Gregg Riegel's (2002) on-going riparian field guide survey provides vital plant species and soil pattern for soil productivity estimates for wetlands. Riegel's Fremont data set has an odd yet common occurrence of ponderosa pine on Hydric Soil that had high water tabled features. Sites appear to be on a drying tend that corresponds to evaporation due to conifer density and encroachment for wetland loss.

With limited mining districts geologic surveys are limited, unlike most of the Basin and Range. Toolbox's catchments are Basin and Range terrain lava tablelands within the Great Basin (Orr and Orr, 1999). Yet sandy ash deposit from the adjacent Western Cascade terrain over the Basin and Range basement lava rocks effects soils water infiltration rates, nutrients, and sediment processes in Toolbox. The tablelands drained by Silver Creek have deposits of ash-fall tuff. Sediments from the Toolbox area drains into closed basins typical of Great Basin Physiographic Province. Tuffaceous deposits exposed within the West and North Forks of Silver Creek may be prone to post-fire slope in-stability. Foster Butte and Dead Indian Mountain in the center of Toolbox are cinder cones with several eruptive periods beginning in the Tertiary. Toolbox area has a fault fracture pattern in resistant volcanic bedrocks of Tertiary age basalts, andesite, and rhyolite, with minor quaternary alluvium and sedimentary rocks. Toolbox's tablelands dip to the northwest along north trending faults that dominating the catchment's geomorphology. For Basin and Range terrain the slope are gentile (Orr and Orr, 1999, Wenzel, 1979).

The fault line channel systems and linear subwatersheds in Toolbox are geomorphic indicators of a low geologic erosion rates. A linear basin has a geomorphic form that dissipates flood flows and yield low peak discharges (Strahler, 1964). Silver and Duncan Creek subwatersheds are linear with trellis main stems along faults. On the other hand, a typical stream basin is a pear shaped ovoid with treelike dendritic stream branches. As basins become round they concentrate flows for high peak flows. Toolbox's drainage patterns and density are controlled by the fault trends. The 86,794 acres (135.6 mi^2) burn area (BAER Report acreages) has 29 miles of perennial streams for drainage density of 0.2 mi/ mi^2 and including 121 miles of intermittent streams; the drainage density is approximately 1.1 mi/ mi^2. Drainage-densities, measured as a ratio of stream segment to basin area in mi/mi^2, is a topographic estimate of stream erosion forces balanced against basin resistance to erosion (Strahler, 1964). Ephemeral draws are generally not included in drainage patterns and density calculations

because they are difficult to estimate. And in this semiarid climate named intermittent streams such as Squaw and Benny Creeks are dry much of the summer, even after thunderstorm rain events. So some caution is needed in estimating geologic erosion.

Toolbox's drainage density of perennial and intermittent streams is 1.08 mi/ mi^2 using sub-shed areas in the recovery planning, which is very low compared to ratios over a wide range of geologic and climate types. Low values of 3 to 4 mi/mi^2 occur in resistant sandstone in Appalachia, mid values of 20 to 30 (mi/mi^2) occur in fractured weathered igneous rocks with dry summers in coastal southern California, and high values of 200 to 400 mi/mi^2 occur in badlands often barren of vegetation, as in South Dakota's Badlands National Park (Strahler, 1964). Toolbox's very low drainage-density is due in part to resistant bedrocks, permeable soils, and low relief.

Similarly, the Soil Resource Inventory erosion hazard rating is low for most of the Toolbox project area. The hazard rating applies to sites when all vegetation cover is removed as in road building (Wenzel in 1979). From the burn report the bare ground erosion hazard for the Toolbox and Sliver burn areas list 65,383 acres in low hazard, 14,003 acres in moderate, and 7,408 in high.

Erosion and Sediment

Post-fire erosion, sediment transport and rainfall runoff were estimated in the 2002 BAER Report using WEPP technology for landtypes grouped by capability areas (Forest Service Staff, 2002). Background erosion rates were estimated at 0.01 to 0.05 ton/acre and runoff rates were estimated at 0.00 to 0.02 inches. In the BAER report the default WEPP cover value of 85 percent was used for a low severity fire conditions. In most areas post-fire erosion rates are below 1 ton per acre that effect soil productivity (Soil Survey Division Staff. 1993). Drainage scale post fire erosion sediment transport was estimated at 0.09 ton/acre and runoff 0.04 inches in Duncan drainage overall (WEPP, 2001). In the Silver drainage the estimated post fire erosion is 0.06 ton/acre and runoff is 0.03 inches overall. The few water-repellant areas have an anticipated erosion rate of 1.72 ton/acre and runoff of 0.31 inches. Erosion rates and risk are apt to be greatest in runoff events directly after a fire.

With most soils in low and moderate burn severity, erosion risk and rates are apt to decline in a few years as ground vegetation recovers (Robichaud et al., 2000). Rapid native recovery is anticipated in the 74,673 acres with low severity and the 11,311acres with moderate severity. With a likely rapid recovery, overall sediment risks are low. Said another way, like background sediment pulses, the fire-effect sediment pulses are within the range that sustains native fluvial processes on hill slopes and along streams for gravel bar willow habitat deposits.

Toolbox project erosion and runoff estimates incorporate fire effects, vegetation, soil, slope and local climate for likely harvest area by cases and likely scenarios with the Water Erosion Prediction Project technology (WEPP, 2001). The ground cover values are based on Hopkins (1997) plant association ecoclasses. Water Erosion Prediction Project technology sediment values were generated for each of the cases at six plausible checkpoints of recovery using a local climate record for 50 years to reflect high intensity storm events. Average values for sediment production were calculated using Water Erosion Prediction Project (WEPP) technology, with the results presented in the table below.

In Table 5 the two checkpoint scenarios bracket current conditions. The first check point is the post fire condition. It is a low severity burn in an overstocked forest, where the eco-class live ground cover is reduced to ½ of pre-fire potential. The second checkpoint occurs approximately 2 years after the wildfire, where live ground cover has recovered to ¾ of eco-class potential. The long 2003 spring rainy season provided soil moisture conditions that contribute to seedbed response and rapid grass recovery. As current condition approach checkpoint 2 live ground vegetation recovery should be sufficient to limit the risk of a long-term decline in soil productivity with values well below soil loss tolerances of 1.00 to 5.00 tons per acre (Soil Survey Division Staff. 1993).

These two scenarios show soil erosion is a minor consideration in most of the likely harvest areas. Yet some erosion may occur in harvest units 130, 131, 133 and 134 associated with case study seven along Benny Creek drainage. Current or existing value is between 0.25 and 0.10 ton per acre. Granted the value is well below the lower tolerance limits of 1.00 tons per acre, yet it alerts us to areas that merit field checking.

Live Ground cover recovery and erosion scenarios presented in the following table are based on values in Hopkins (1979) Plant Association and likely recovery rates. Checkpoint 1 was the Existing Condition after the wildfire and the Current Condition is approaching Checkpoint 2. Erosion estimates are in tons per acre (t/ac) using WEPP Technology for Seven Case.

Table 5 - Live Ground Cover Recovery and Erosion Rates – Checkpoints 1 and 2

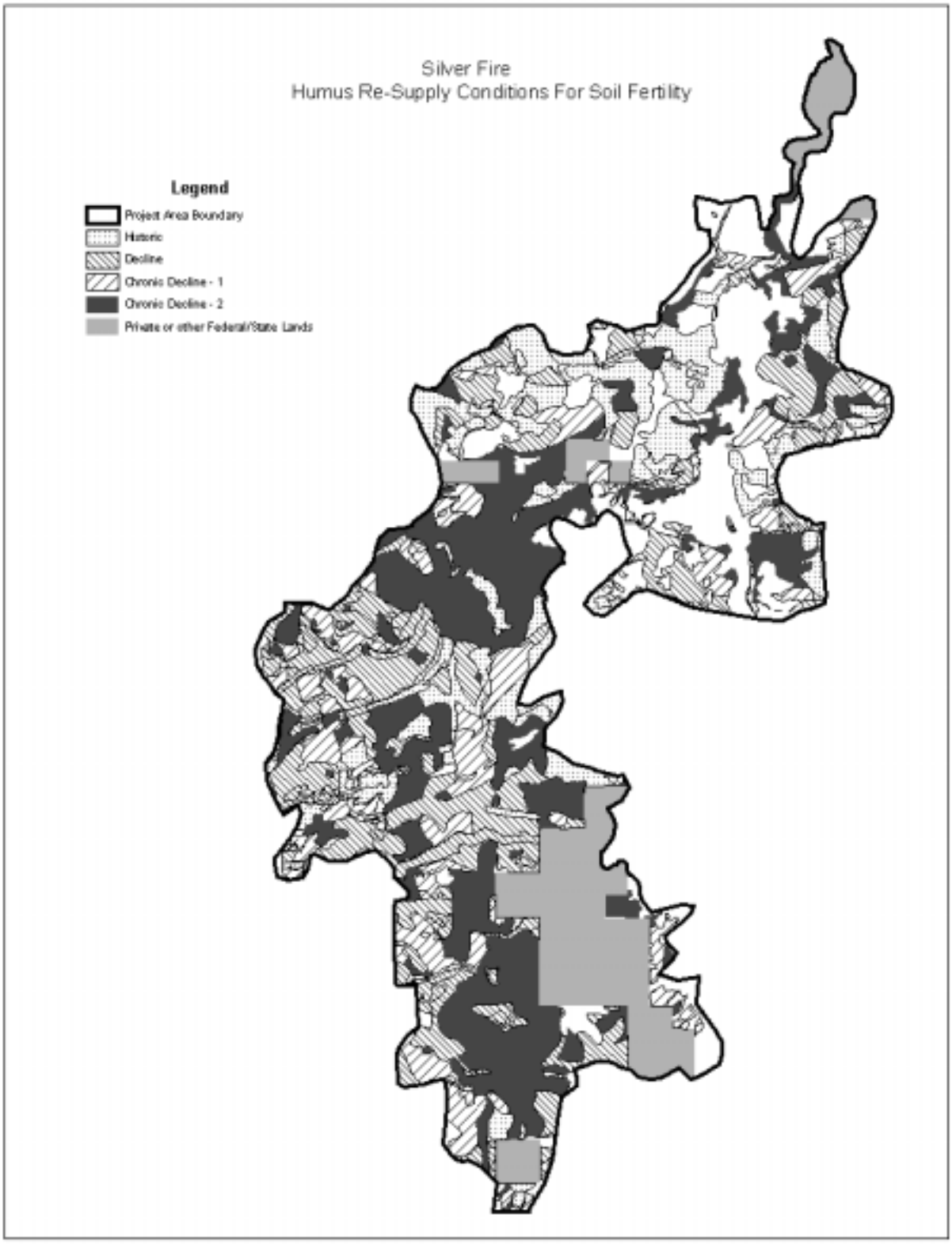
Case Study	Ecoclasses	Checkpoint 1, Cover Values	Checkpoint 1, Erosion Rates	Checkpoint 2, Cover Values	Checkpoint 2, Erosion Rates
1	Ponderosa pine/fescue, with sagebrush and bitterbrush shrub combinations in ecoclasses: CP-S2-11, CP-S3-11, CP-C2-11	40	0.09	63	0.00
2	Ponderosa pine/fescue, with sagebrush and bitterbrush shrub combinations in ecoclasses: CP-S2-11, CP-S3-11, CP-C2-11	40	0.06	63	0.00
3	Ponderosa pine/fescue, with sagebrush and bitterbrush shrub combinations in ecoclasses: CP-S2-11, CP-S3-11, CP-C2-11	40	0.19	63	0.00
4	Ponderosa pine/fescue, with sagebrush and bitterbrush shrub combinations in ecoclasses: CP-S2-11, CP-S3-11, CP-C2-11	40	0.37	63	0.00
5	Ponderosa pine, white fir and aspen forest, with ceanothus, manzanita and bitterbrush shrub combinations in ecoclasses: CP-S2-17, CW-H2-12, CP-S1-21	65	0.20	83	0.00
6	Ponderosa pine, white fir and aspen forest, with ceanothus, manzanita and bitterbrush shrub combinations in ecoclasses: CP-S2-17, CW-H2-12, CP-S1-21	65	0.08	83	0.00
7	Lodgepole pine and ponderosa pine/fescue and sedge forest, ecoclass: CL-G3-15 (limited shrub component)	35	0.25	45	0.10

Roads –Current road density on National Forest Lands within the project area is 3.68 miles of open road per square mile. A subset of these roads has a hydrologic connection that conveys water and sediment to the streams. In the wet west side 40 percent of the roads may deliver sediment to streams, yet in the dry east side the effect may be more limited. The amount of road sediment was estimated using the Water Erosion Prediction Project (WEPP) Cross Drain Model (WEPP, 1999). The typically road in the Toolbox Fire Recovery Project area is a two percent grade, native surface roads or graveled road with 400 to 800 feet cross drain increments. In a relatively dry east-side climate, native roads near streams (within 10 meters) yield an estimated 0.47 tons per mile to the stream and those with gravel surfaces yield an estimated 0.35 tons per mile. For comparison, with a wet west-side climate (North Bend, Oregon), which is closer to Wemple's (1994) conditions, the same road conditions would yield an estimated 17.5 tons per mile on graveled roads, a sediment value 50 times larger.

Forest Density and Soil Fertility

Forest vegetation mortality was surveyed for recovery planning. In the Silver Fire Portion, 6 times more area was found in the high mortality class of 86 to 100 percent tree mortality than on area in the low mortality class of 0 to 25 percent. In the Duncan drainage the high mortality class was 3 times more extensive than the low class. Low mortality was observed in areas within forest gaps in forest vegetation surveys and in the BAER assessment. The mortality classed found in the forest vegetation surveys correspondence to dense forest areas where canopy closure closes-out the nutrient re-supply process. Mortality classes above 25 percent indicate dense forest areas where Busse like nutrient re-supply has declined.

Estimates for humus re-supply condition in Tables 6 and 7 (from Toolbox Planning Record GIS Layer in polygons "mort_f") are based on the time line for "gap ground cover" formation and nutrient re-supply within the gaps estimated by comparing the Miller's et al., (2001) ten year wildfire interval with Busse's et al. (1996) twenty year nutrient humus enrichment intervals. Sites with 0-25% mortality had canopy gaps within the historic range so nutrient re-supply is also apt to be within the historic range. Above 25% mortality, forest density conditions closeout humus re-supply cycles. The estimated re-supply condition is presented in Tables 6 and 7 and Figures 3 and 4.


Silver Fire
Humus Re-Supply Conditions For Soil Fertility
Legend
Project Area Boundary
Historic
Decline
Chronic Decline - 1
Chronic Decline - 2
Private or other Federal/State Lands

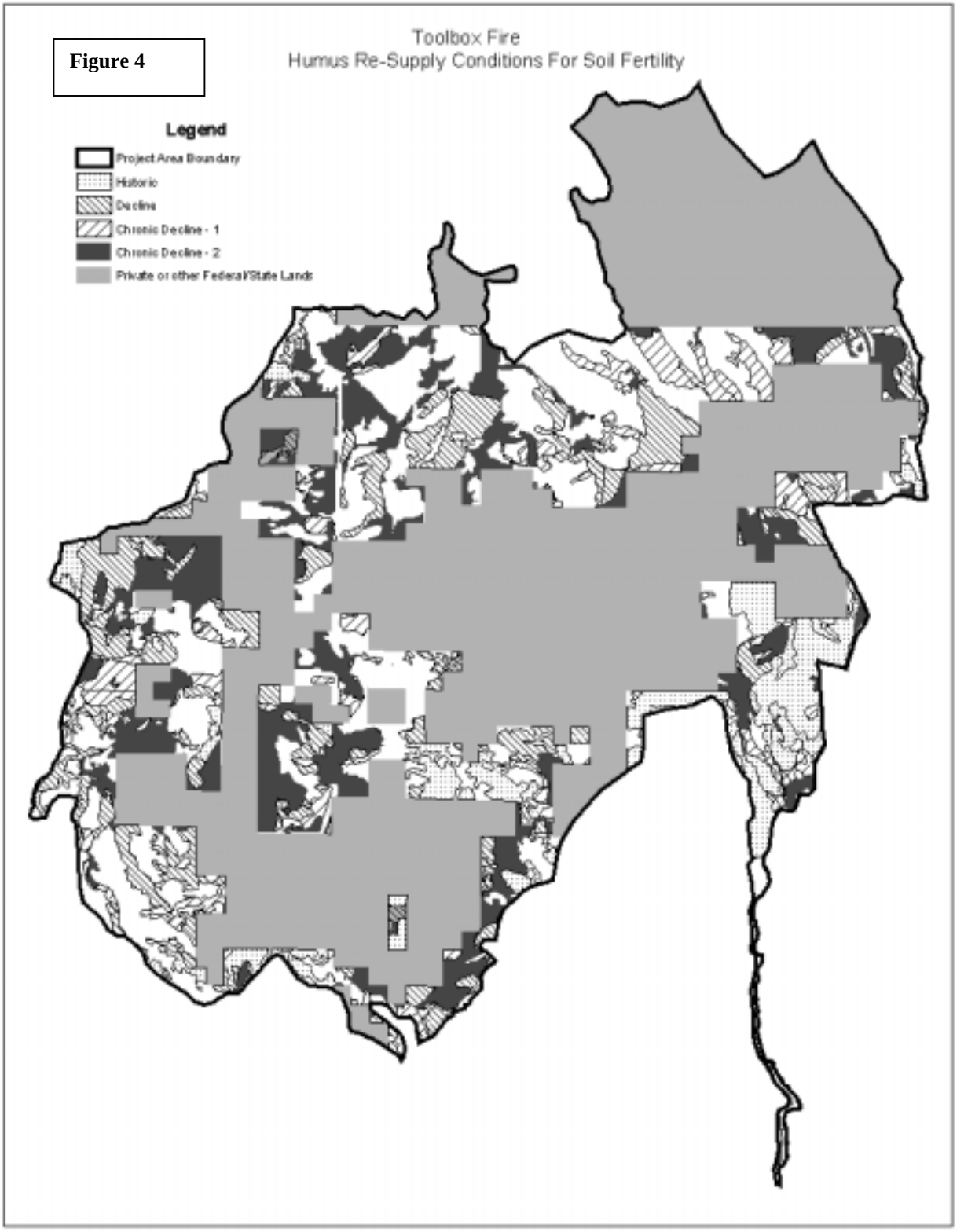


Figure 4
Toolbox Fire
Humus Re-Supply Conditions For Soil Fertility
Legend
Project Area Boundary
Historic
Decline
Chronic Decline - 1
Chronic Decline - 2
Private or other Federal/State Lands

A re-supply cycle may have been missed in sites with 26 to 50 percent mortality with a decline in forest gaps and ground vegetation. Several nutrient re-supply cycles may have been missed (or their effectiveness has been limited) for chronic nutrient decline in sites with mortality of 51 to 85 percent or greater than 86 percent mortality and dense canopies. For example forest sites with 100-year old dense pine poles within the "historic gap" may have missed 3 to 5 humus recovery cycles.

The extensive areas with high mortality and likely chronic humus decline shown in Tables 6 and 7 and Figures 3 and 4, illustrate a shift or shifting lands capability. Without gaps, low fertility is reinforced by the conifer's acid needle fall, their root structure, and biology. Hot burn and mortality areas included within the lower mortality classes may have high enough tree densities to indicate chronic detrimental soil conditions.

Table 6 -Silver Fire Portion Mortality as Indicator of Humus Re-Supply Conditions

Conditions by acres		Definitions
860 acres		0-25% and humus within historic fertility
2,776 acres		26-50% and humus decline from historic fertility
2,068 acres		51-85% and humus chronic decline from historic fertility--1
5,436 acres		86-100% and humus chronic decline from historic fertility--2

Table 7 -Toolbox Fire Portion Mortality as Indicator of Humus Re-Supply Conditions

Conditions by acres		Definitions
1,847 acres		0-25% and humus within historic fertility
2,658 acres		26-50% and humus decline from historic fertility
1,942 acres		51-85% and humus chronic decline from historic fertility
5,628 acres		86-100% and humus chronic decline from historic fertility

Compaction

Findings are based 1820 samples on 91 transects. Overall 1 percent of the samples had detrimental soil conditions with hits in classes 5 and 6. And 85 percent of the samples have tilth like soil classes of 3, 2 and 1. No transect or likely harvest area had detrimental soil compaction using the regional guidelines for detrimental soils (Forest Service. 1998). Chapter 2520, Pacific Northwest Supplement 2500-98-1 sets a soil disturbance criterion of 20 percent for detrimental soil condition in the Pacific Northwest Region (R6).

On site tours the clayey texture soil in the area was found to shrink about 10 percent, which is consistent with shrink swell clay. Similar landscapes in the adjacent South Lake County soil survey the clays have shrink-swell clays (Kienzle, 1999). Toolbox Fire Recovery Project area soils grade from a sandy volcanic ash deposit along Silver Creek to a loamy surface weathered from the basalt basement bedrock along Duncan Creek (Wenzel, 1979). Basalt rock often produces shrink-swell clays that recover with moisture recovery. So the less negative compaction findings may be due to shrink-swell soils as well as the sandy non-cohesive ash deposits.

The harvested areas used in the 1997 Watershed Analysis were recently found to have vigorous forest growth and favorable soil tilth—un-compacted by soil features or Pacific Northwest Region criteria. Similarly the recently burned and salvaged Alder Ridge area within the Toolbox project area has a grassy forest understory, like the historic forested rangeland for a mid or higher ecological status. Soil conditions are tilth-like with 95 percent of the samples in classes 1, 2, and 3.

The 2002 survey findings are consistent with ASTM and AASHTO tables and testing for sandy soils with slight compressibility and slight cohesion and shrink-swell cohesive soils. The findings are also consistent with the long-tern soil study by Gomez et al.'s (2002) of ponderosa pine seedlings and sapling growth in three contrasting textures. Gomez et al., (2002) found overall compaction effects on pine seedlings and sapling growth were detrimental in the clayey soil, insignificant or no effect in the loamy soil, and beneficial in the sandy loam soil. However, the Toolbox project area loam to clay loam soils had the ameliorating effects of shrink-swell clays.

To prepare for post treatment analysis such as Chi-Square transects were classified as moderate with samples along transects of > 40 percent hits of Class 3 and 4 soil compaction factors and low with transects of hits of Class 1 and 2 soil compaction factors with few hits of 3, 4, 5 or 5. Most transects were in low compaction conditions. The results from the

extensive 2002 post-fire compaction surveys also describe the cumulative effects of past activities and events that have occurred in the area.

Environmental Consequences

Direct and Indirect Effects

Erosion and Sediment

Following a fire, sediment yields decline in a year or two, as ground vegetation recovers. A local time line recovery reference is the 1996 Alder Ridge wildfire that occurred within the Silver Fire portion of the Toolbox Complex. The 1996 Alder Ridge and the 2002 Toolbox Complex fires inter-meshed with a land composed of essentially the same soils, vegetation, and geomorphic elements. The 1996 Alder Ridge Fire, which was partially salvaged logged in 1997, now has well developed ground vegetation and grass recovery. It is a ground cover recovery that is likely to occur in the Silver Fire, with salvage. This example helps to frame erosion recovery scenarios by case studies.

Ground Cover Recovery and Erosion with Ground-based Harvest by Case Studies – The effected area is based on the largest area of proposed harvest (Alternative C) with 14,441 acres of salvage out of the areas burned on the Fremont National Forest in the Toolbox Complex. Other action alternatives have harvest areas that range down to 6,367 acres (Alternative D). Alternative A has no active recovery treatments. Salvage units were grouped into seven case studies based on recurring eco-class, soil type, and slope patterns. Each of these case studies was examined in relation to vegetative recovery at six plausible "checkpoints." For each checkpoint, sediment values are estimated using Water Erosion Prediction Project (WEPP) technology.

Table 8 below, starts with the current or existing condition then presents likely treatment and recovery. The first checkpoint scenario is a low severity burn in an overstocked forest, where the eco-class live ground cover is reduced to ½ of pre-fire potential. The second checkpoint occurs approximately 2 years after the wildfire, where the live ground cover has recovered to ¾ of eco-class potential. The third checkpoint includes treatment of 15 percent of the area with skid trails, while maintaining ¾ of potential live ground cover over the remaining area. The fourth checkpoint represents full potential live ground cover after logging, and the fifth checkpoint represents a reforested 5-year-old forest.

Using the 1996 Alder Ridge wildfire as a model, most of the sequence of recovery checkpoints presented in the table below may occur within six years. The long 2003 spring rainy season and the extension of the snowfall into late May is encouraging since it provides soil moisture conditions that contribute to seedbed response and rapid grass recovery.

Table 8 - Live Ground Cover Recovery Sequence by Case Study

Case Study	Slope	Soil Characteristic	Ecoclasses	Live Ground Cover by Checkpoint (percent cover)				
				1	2	3	4	5
1	0 to 15%	Loamy Texture	Ponderosa pine/fescue, with various sagebrush and bitterbrush shrub combinations in ecoclasses: CP-S2-11, CP-S3-11, CP-C2-11	40	63	63; 10 on Skid Trails	80	100
2	0 to 15%	Loamy Sand Texture	Ponderosa pine/fescue, with various sagebrush and bitterbrush shrub combinations in ecoclasses: CP-S2-11, CP-S3-11, CP-C2-11	40	63	63; 10 on Skid Trails	80	100
3	0 to 15%	Stony Loamy Texture (rock content 50%)	Ponderosa pine/fescue, with various sagebrush and bitterbrush shrub combinations in ecoclasses: CP-S2-11, CP-S3-11, CP-C2-11	40	63	63; 10 on Skid Trail	80	100
4	0 to 30%	Stony Loamy Texture (rock content 50%)	Ponderosa pine/fescue with various sagebrush and bitterbrush shrub combinations in ecoclasses: CP-S2-11, CP-S3-11, CP-C2-11	40	63	63; 10 on Skid Trail	80	100

Table 8 - Live Ground Cover Recovery Sequence by Case Study (Continued)

Case Study	Slope	Soil Characteristic	Ecoclasses	Live Ground Cover by Checkpoint (percent cover)				
				1	2	3	4	5
5	0 to 30%	Loamy Texture	Ponderosa pine, white fir and aspen forest, with various ceanothus, manzanita and bitterbrush shrub combinations in ecoclasses: CP-S2-17, CW-H2-12, CP-S1-21	65	83	83; 10 on Skid Trail	100	
6	0 to 30%	Loamy Sand Texture	Ponderosa pine White fir and Aspen forest, with various ceanothus, manzanita and bitterbrush shrub combinations in ecoclasses: CP-S2-17, CW-H2-12, CP-S1-21	65	83	83; 10 on Skid Trail	100	100
7	0 to 15%	Loamy Texture	Lodgepole pine and ponderosa pine/fescue and sedge forest, ecoclass: CL-G3-15 (limited shrub component)	35	45	45; 10 on Skid Trail	55	100

Water Erosion Prediction Project technology sediment values were generated for each of the cases at six plausible checkpoints of recovery and treatment using a local climate record for 50 years to include high intensity storm events. Average values for sediment production were calculated using Water Erosion Prediction Project (WEPP) technology, with the results presented in the Table 3.104. The checkpoint live cover values in the above table are less than the default 85 percent cover in WEPP for a low severity fire. But checkpoint live cover values reflect current dense forest conditions and provide relative differences for estimating sediment transport. Live cover values are based on grass and shrub cover values from plant associations (Hopkins, 1979). The estimates also provide context for estimating the effect of skid trails that are developed and used two years into live ground cover recovery.

Overall soil erosion and sediment transport are expected to be minimal for most of the proposed harvest units among all alternatives. For 6 of the 7 cases by checkpoint 2 live ground vegetation recovery is sufficient to limit the risk of a long-term decline in soil productivity. Sediment estimates in Table 9 show that the effects from skid trails at checkpoint 3 are expected to be well below soil loss tolerances of 1.00 to 5.00 tons per acre (Soil Survey Division Staff. 1993). Since all activities are prescribed in accordance with practices in the Fremont National Forest Soil Productivity Guide and Best Management Practices for timber and road (See Appendix C) soil erosion and sediment transport should be minor with all action alternatives. With likely live ground vegetation recovery two years after the wildfire, direct effect and cumulative effects, proportionate to area treated, are expected to be minor.

Table 9 -Sediment Estimates in tons per acre (t/ac) using WEPP Technology for Seven Case Studies

Case	Checkpoint 1	Checkpoint 2	Checkpoint 3	Checkpoint 4	Checkpoint 5	Probability of Sediment Transport
	live cover of ½	live cover recovery to ¾	15 percent skid trail and ¾ live cover elsewhere	full live ground cover	reforested 5 year old forest	
Case 1, loam	0.09 t/ac	0.00 t/ac	0.00 t/ac	0.00 t/ac	0.00 t/ac	0 %
Case 2, loamy sand	0.06 t/ac	0.00 t/ac	0.00 t/ac	0.00 t/ac	0.00 t/ac	0 %
Case 3, stony loam	0.19 t/ac	0.00 t/ac	0.00 t/ac	0.00 t/ac	0.00 t/ac	0 %
Case 4, stony loam	0.37 t/ac	0.00 t/ac	0.00 t/ac	0.00 t/ac	0.00 t/ac	2 %
Case 5, loam	0.20 t/ac	0.00 t/ac	0.00 t/ac	0.00 t/ac	0.00 t/ac	2 %
Case 6, loamy sand	0.08 t/ac	0.00 t/ac	0.00 t/ac	0.00 t/ac	0.00 t/ac	0 %
Case 7, loam	0.25 t/ac	0.10 t/ac	0.05 t/ac	0.00 t/ac	0.00 t/ac	14 %

As in the Existing Condition some erosion risk is associated with case study seven. Case 7 lodgepole pine ecoclass: CL-G3-15 with loam texture, SRI map unit 39, produces a 14 percent probability of sediment transport. The proposed harvest areas in case 7 are units: 130, 131, 133 and 134 in the Toolbox Fire Portion by road 3012. All four units are ground-based units. They vary in size by alternative and by amount of temporary road developed for access. The sediment transport value at checkpoint 3 (0.05 tons/acre) is near a background erosion condition. Yet these units are of sufficient size to allow WEPP technology to discern a difference between alternatives, as displayed in the Table 10 of Sediment for Harvest Units 130, 131, 133 and 134 in tons per year (t/y) and for Temporary Roads.

Table 10 - Sediment for Harvest Units 130, 131, 133 and 134 in tons per year (t/y) and for Temporary Roads

Alternatives	D	H	C	E	G	A
Acres Harvested	31	741	781	781	781	0
Erosion t/y	1.5	37.1	39.1	39.1	39.1	0
Temporary road miles	0	0.9	0.9	0.9	0.9	0
Native road t/y	0	0.002	0.002	0.002	0.002	0

In the field the estimated soil erosion appears to be a minor consideration compared to wetland loss. Harvest units 130, 131, 133 and 134 are mostly lodgepole pine thickets with high mortality and spotty ground cover up from the moist silver sagebrush and wet tufted hairgrass meadows. The aerial photographs shows the meadows are large enough that they could be mapped in association with the adjacent lodgepole pine community in the soil map unit. In the burnt thickets no sign of sheet or rill erosion were evident in walks across the units from the mid July 2003 thunderstorms. The site infiltration accommodated the rainfall and on July 25 the soil recharge average 30 to 40 cm. The meadows are well vegetated, which limit sediment transport to the seasonally dry Benny Creek. Yet the encroachment of lodgepole pine is diminishing the meadows. Lodgepole pine is crowding out dry meadow and moist meadow habitats and is now extending into the wet meadow habitats. The wind thrown pine show the hydric soil feature under the lodgepole. The wetland has diminished by 40 to 50 percent for a notable wetland loss.

The four units along Benny Creek illustrate the trade off among the geology and soil topics. There is an erosion risk and a forest density risk. Yet on balance treating the units, particularly 131 in would aid wetland recovery.

Indirect Erosion Effects--The development of ground cover by the treatments limits long-term erosion. So over the long term the action alternatives would benefit the development of ground vegetation that limits soil erosion and sediment transport. And Aspen enhancement projects and riparian planting, included in Alternatives C, D, G, and H would contribute to the healthy riparian conditions to limit sediment to the streams. This contribution would not occur with Alternatives A or E.

Roads Densities– Alternatives vary by road amelioration for less erosion risks by treatments. The current high road densities represent a societal demand for transport, yet without a very high standard of design and maintenance, roads accelerate and concentrate erosive forces. From the soil quality perspective, the treatment of roads differentiates the alternatives.

In Alternative A the existing road density of 3.68 mi/mi^2 would be present both before and after treatment. In high storm events like Wemple's (1994) wet season model yields 40 percent of road density that may contribute to the stream drainage density. The Toolbox Fire Recovery Project area stream drainage density of 1.08 mi/mi^2 is added to the road-affected drainage density to produce an effective channel density by alternatives in Table 11. From a geomorphic perspective, including the road induced drainage-density values, the overall density values are within the low class 3 to 4 mi/mi^2 for modest sediment transport (Strahler, 1964), for all alternatives. However, Alternative A has twice the channel density, above the streams density of 1.08 mi/ mi^2 for perennial and intermittent streams, so there is a sustained road affect.

Table 11 - Channel Drainage Densities as affected by Roads Densities

Alternatives	A	C	D	E	G	H
Road density	3.68	1.76	1.68	2.57	2.57	1.72
Road affect (40% or 0.4)	1.47	0.70	0.67	1.03	1.03	0.69
Effective channel density	2.55	1.78	1.75	2.11	2.11	1.77

Alternative A, the no action alternative has more than double the native drainage density of 1.08 mi/mi^2, so it presents the greatest storm sediment density transport risk. Alternatives E and G with intermediate amounts of road closure and decommissioning, begin to reduce the current sediment risks identified in the Silver Creek Watershed Analysis (Forest Service, 1997). Alternative E has more miles of road closure than decommissioning, so it is likely to have a slower long-term sediment reduction than Alternative G. From a geomorphic perspective, Alternatives D, H, and C make the greatest investment in sediment transport risk reduction, with effective channel densities that range from 1.75 to 1.78 mi/mi$^{2.}$

Road Erosion—Sediment was estimated using the project areas typical 2 percent grade native surfaced or graveled roads, with 400 to 800 feet cross drain increments, for an eastside climate. Native surfaced roads away from steams yield 0.0025 tons per mile. Gravel surfaced roads yield 0.00 tons per mile. Native surfaced roads near (within 10 meters) of streams yield 0.47 tons per mile to a stream, and gravel surfaces yield 0.35 tons per mile. Decommissioned road segments should result in a reduction down to background rates as they re-vegetate. Over the long-term, closed roads, which may re-vegetate more slowly, would eventually provide similar sediment reductions.

On a per acre basis Table 12 shows the sediment reductions by Alternative due to road reduction. Alternatives D, H, and C reduce sediment by 0.48 ton per acre each year; or up to 0.47 tons per acre above the typical 0.01 to 0.05 ton per acre background conditions by the Toolbox Fire Recovery Project.

Table 12 - Sediment Reductions by Alternative Due to Road Decommissioning or Closure

Alternatives	A	C	D	E	G	H
Road miles decommissioned	0	69.0	71.6	14.6	71.6	71.6
Sediment reduction (tons/year)	0	0.4	0.4	0.2	0.4	0.4
Long-term sediment reduction – includes consideration for Road Closure (tons/year)	0	0.7	0.7	0.6	0.6	0.7

Indirect Soil Biology Effect-- Long-term recovery of soil biology habitats on former road surfaces is proportionate to road miles treated.

Forest Density and Soil Fertility

Conifer densities above historic norms negatively affect soil habitats and their functions (Biswell, 1989, West and Young, 2000). West and Young (2000) identify the shift in habitats as a "lignification," which identifies habitat shifts by changes in biochemical pathways to conditions are less suited to processing litter into humus and sustaining a rich forest soil life. Recovery is sustained by formation of gaps and ground cover vegetation within the forest.

From a soil site productivity and suitability perspective, the proposed alternatives can be compared by their gap ground cover recovery. There are 15,074 acres with tree mortality above 50 percent and 5,434 acres with tree mortality above 25 percent for 20,508 acres with a "lignification" risk or humus re-supply decline. Yet the alternatives treat a smaller area. The action alternatives range in size from Alternatives C (14,441 acres), Alternatives G (14,419 acres), H (13,031 acres), E (11,490 acres), to D (6,367 acres). Alternative A has no investment in recovering historic gaps, can be considered the maximum "lignifications" future course

Alternatives C and G treat approximately 28 percent of the National Forest in the burn and 70 percent of the area of "crown wildfire related mortality" in the Toolbox Complex. Preference for harvest has been skewed toward high density and high

mortality areas. In general, the harvest areas correlate to areas with forest soil "lignification" risk or humus re-supply fertility problems. The direct effect of action alternatives is reduced "lignification" and to restore gaps, which sustain live ground cover recovery and promote a shift toward appropriate biochemical pathways for humus re-supply. So by area treated this soil loss aspect is reduced.

Reforestation, which is planned at a low density, is with consideration for droughty semiarid soils and sites. It is expected to approach historic densities, after an initial thinning.

Indirect Effects on Soil Biology –Treatments effect on ground cover has an indirect effect of on soil biology and habitat recovery. Two recovery processes are associated with the changes in soil biology forest soil loosening and plant dynamics (Coleman and Crossley, 1996, Lutz and Chandler 1948, Young and Clements, 2002). For example burrowing voles, such as *Microtus montanus*, population correspond to grassy bacterial habitats of eastern Oregon (Verts and Carraway, 1998). With Ponderosa pine density and encroachment onto meadow there is a loss in burrowing vole habitats. The small mammal's food of *Arthropods*, such as mites, *Mollusk*, such as snails, and *Annelida*, such as earthworms also loosens the soil as it process forest detritus (Coleman and Crossley, 1996, Lutz and Chandler 1948). Mites are known for processing poorly digestible *Abies*, fir needles through various life stages. Example plant dynamics occurs in granivore relationships between deer mice, *Permyscus maniculatus*, and bitterbrush, *Purshia*, seeds that shape plant community composition and structure by seed predation, dispersal and seedling recruitment (Young and Clements, 2002). In turn mule deer habitat is supported by deer mice's practices. So restoring the forest's historic sagebrush grass and mixed forest shrub grass ground cover helps to recover soil fauna, soil biology and supported habitats.

Alternative A has the least habitat recovery with no action or investment in developing historic forest gaps and ground cover habitats. Investment in gap ground cover varies from Alternative C, which recovers habitats in 14,441 acres to Alternatives G, H, E and D at 6,367 acres. By accommodating soil fauna that loosens forest soils the harvest areas conform to the site protection provision in the 1897 Organic Act and recovery for Watershed Protection and Management. Harvest areas meet the 1976 NFMA that provides for the diversity of plant and animal communities based on the suitability and capability of specific lands.

Indirect Effect on Potential Adverse Soil Heating - The risk reduction from subsequent high intensity wildfire and its accompanying potential negative impacts on soil fauna is proportionate to the areas treated by the actions included in the alternatives, and their contribution to recovery of historic conditions. Harvest and fuel treatments are expected to limit the fuel loads, including those contributed by large wood with long resident burning time, so that burn severity, in the event of future fires, should still be primarily in the low severity category. This would contrast favorable with the contiguous moderate burn severity that was observed in Toolbox Complex on some adjacent private industrial forestlands, which were characterized by limited gaps among more contiguous down wood. Alternatives G and C, with the greatest number of acres with harvest and post-harvest fuel treatments, best address this potential for indirect adverse effects from excessive soil heating and the associated risk of loss of soil fauna habitat.

Compaction

The 2002 post-fire survey findings, presented in the "Existing Condition" section, revealed that past activities have yielded well under 20 percent detrimental soil conditions for the Pacific Northwest Region. Overall 1.04 percent of transect hits occur in soil compaction factor classes 5 and 6 that correspond to growth limiting detrimental soil conditions. None of the 91 transects or treatment areas sampled had detrimental soil conditions.

The survey data are skewed to tilth condition with evidence of past harvest. The burn extended into past harvest areas scattered though out the project area. In the 91 transect the most common value is evidence of equipment class 3 that indicates past harvest. In the Silver Fire Portion transects evidence of equipment factor 3 occurs at 59 percent of the hit and 63 percent of the hits in the Toolbox transects. The complementary compaction factor at class 3 occurs at a lower rate. In the Silver transects compaction class 3 occurs at 42 percent of hit and 51 percent of the hits in the Toolbox transects. The overall skewed distribution with 83 percent of hit in compaction classes 2 and 3 for tilth conditions, indicate that timely recovery has occurred, or that this landscape has minimal compaction risk from ground-based, skid-trail logging.

A third of the 312 proposed harvest units (maximum in Alternative C) were sampled by the 91 transects. Transects were broadly distributed to cover the range of harvest habitats. Adjacent harvest areas occur on similar soils and plant association as the transected harvest area. Often adjacent harvest areas had similar past harvest history, so the adjacent areas are apt to behave in a similar manner today and in the future.

The past treatment histories were evident in tours to spot checked compaction values. Potential harvest areas were visited on north south routes along Forest Roads 28, 29, 018 along the west face of Foster Butte and Rd 2901. For example past harvest has occurred near Road 28 in proposed harvest units 222, 223, 224 and 225 where transects were sampled. The sandy ash adds a grit feel to the loamy soil in this area. Past harvest also occurred near road 2901 in proposed harvest units 151 and 152 where transects were sampled. Along this rim area the shrink swell soil are evident and were a topic in the compaction training sessions. In these and other past harvest areas the soils did not have growth-limiting compaction of detrimental soil conditions.

Examples of the likely effects of the proposed salvage harvest and post-salvage activities in the Toolbox project were systematically recorded by post-Toolbox Fire sampling within the 1996 Alder Ridge Fire (salvaged in `1997) and sampling in the revisited 1997 watershed analysis sites. The burned and salvaged Alder Ridge by Forest Road 27 have a grassy forest under-story like the historic forest and tilth like soil conditions with most hits in classes 1, 2, and 3. Proposed Toolbox salvage units 255, 256 in this area have a similar environ to Alder Ridge so these units are apt to respond in a similar way. To the west, salvage unit 251 had transect soil values dominated by classes 1 and 2, as did the adjacent revisited harvested unit in the 1997 Watershed Analysis that has vigorous forest growth and favorable soil tilth. Similarly in the Toolbox Fire portion, proposed salvage units 83 to 89 are adjacent to the revisited harvested unit from in the 1997 Watershed Analysis with vigorous forest growth. These and other harvest units apt to have limited or short-lived compaction effects due to shrink swell soils and sandy non-cohesive ash deposits.

There may be short-lived effects that vary by area treated. With Alternative C, at 14,441 acres the largest area treated it is the most likely to have short-term effects. As borne out by compaction monitoring this is clearly a compaction resistive landscape. The primary factor in recovery relate to ground cover. The ground cover species by number are the major floristic components of a forest. The better tilth under a grass ground cover, as compared to one characterized by pine needle mats is a topic that is need of more complete sample statistics to better understand this ground cover relationship.

Indirect Effects on Soil Productivity-- An indirect treatment effect in loamy sand soils may be to enhance pine growth, like Gomez et al., (2002) findings for beneficial compaction effects in sandy soils.

With the application of practices in the Fremont National Forest Soil Productivity Guide and timber and road Best Management Practices (See Appendix C) there is an expectation that the new activities, proposed in all action alternatives, would not produce detrimental soil conditions in excess of the 20 percent standard. For all action alternatives direct and cumulative effects on soil compaction in areas with proposed activity are expected to be limited or short-lived.

Cumulative Effects

Hill-slope Erosion--Ground cover loss in dense forest and woodlands yields topsoil loss. To avert the soil loss in semiarid forest and rangelands West and Young, (2000) identify the ill affects of conifer densities above historic norms as a "lignification," which are less suited to processing detritus into soil humus and available nutrient for plant growth—so the soils erode. The Toolbox project area faces "lignification" with a semiarid climate, canopy closure exceeding historic values (Friedrichsen, 2003) and the associated extensive tree mortality. The reduced ground cover was used to estimate erosion. The first of six checkpoints is a low severity burn in an overstocked forest, where the eco-class live ground cover is reduced to ½ of pre-fire potential. The second checkpoint occurs approximately 2 years after the wildfire, where live ground cover has recovered to ¾ of eco-class potential.

Water Erosion Prediction Project technology sediment values were generated for each of the cases at six plausible checkpoints of recovery and treatment. As current condition approach checkpoint 2 live ground vegetation recovery is sufficient to limit erosion. The WEPP values are well below soil loss tolerances of 1.00 to 5.00 tons per acre (Soil Survey Division Staff. 1993). With most soils in low and moderate burn severity, erosion risk and rates are apt to decline in a few years as ground vegetation recovers (Robichaud et al., 2000). Rapid native recovery is anticipated in the 74,673 acres with low severity and the 11,311acres with moderate severity. Some erosion may occur in harvest units 130, 131, 133 and 134, yet the meadow systems are in a position to catch the sediment. Cumulatively the scenario shows soil erosion is a minor consideration in most of the likely harvest areas.

Cumulative Road Effects--The typically road in the Toolbox Fire Recovery Project area is a two percent grade, native surface roads or graveled road with 400 to 800 feet cross drain increments. In a relatively dry east-side climate, native roads near streams (within 10 meters) yield an estimated 0.47 tons per mile to the stream and those with gravel surfaces yield an estimated 0.35 tons per mile.

Alternative A sustains the road doubling of the streams density of 1.08 mi/ mi^2 for perennial and intermittent streams, so there is a sustained road affect. On the other hand there is a cumulative reduction in road effects and sediment with the action alternatives. The effects by action alternative vary proportionate to the miles of road closed and decommissioned. On a per acre basis Alternatives D, H, and C reduce sediment by 0.48 ton per acre each year for a hillslope saving up to 0.47 tons per acre above the 0.01 to 0.05 ton per acre background conditions. Cumulatively the action alternatives provide beneficial effect of road amelioration for less erosion.

Humus Re-Supply--The harvest areas with mortality classes above 25 percent correspondence to dense forest areas where Busse like nutrient re-supply has been limited for decline in soil productivity (Busse's et al.1996). High forest density conditions close out the humus re-supply cycle. Sites with 0-25% mortality typically had canopy gaps closer to the historic gap range, so nutrient re-supply is also apt to be within the historic range.

Nutrient re-supply cycle may have been missed in sites with 26 to 50 percent mortality with a decline in forest gaps and ground vegetation. The extensive areas with high mortality and likely chronic humus decline in Table 6 and 7 and Figures 3 and 4, illustrates a shift or shifting lands capability. Without gaps low fertility is reinforced by the conifers acid needle fall, their root structure, and biology. Cumulatively this dysfunction is alleviated by the wildfire and the proposed treatments that recover ground cover vegetation.

Soil Compaction—Current conditions are based on an extensive and intensive survey with 1820 samples on 91 transects. Overall 1 percent proposed harvest areas and transects sampled had detrimental soil conditions with hit in classes 5 and 6. Many prior harvest areas that burned were sampled, yet 85 percent of the samples have tilth-like soil classes of 3, 2 and 1. No transect or proposed harvest unit had detrimental soil compaction using the regional guidelines for detrimental soils (Forest Service. 1998). Chapter 2520, Pacific Northwest Supplement 2500-98-1 sets a soil disturbance criterion of 20 percent for detrimental soil condition in the Pacific Northwest Region (R6).

On site tours the clayey texture soil in the area was found to shrink about 10 percent, which is consistent with shrink swell clay. Similar landscapes in the adjacent South Lake County soil survey the clays have shrink-swell clays (Kienzle, 1999). Cumulatively less negative compaction findings may be due to shrink swell soils as well as the sandy non-cohesive ash deposits. Cumulatively new proposed harvest and fuels treatments are not apt to depart from the current conditions that have a harvest history. The Toolbox project area contains examples of recently burned (Alder Ridge Fire -1996), subsequently salvaged (Ridge Timber Sale -1997) that upon compaction testing (post-Toolbox Fire) exhibited acceptable conditions.

Since all activities would include the application of the practices detailed in the Fremont National Forest Soil Productivity Guide and timber and road Best Management Practices (See Appendix C), the expectation is that soil erosion and sediment transport would be minor with all action alternatives. With likely live ground vegetation recovery two years after the wildfire, direct effect and cumulative effects, proportionate to area treated, are expected to be minor.

Aspen enhancement projects and riparian planting, included in Alternatives C, D, G, and H would contribute to the healthy riparian conditions. This contribution would not occur with Alternatives A or E.

Reasonably foreseeable future actions that would occur in the specific areas that would experience direct or indirect effects on the soil resource are displayed in Appendix A, Tables A-14 through A-17. See also the Toolbox EIS Chapter 3 section (on Watershed and Fisheries), in which a subwatershed-by-subwatershed cumulative effects analysis is presented. This analysis includes consideration of specific past activities, indirect and direct effects of the Toolbox Fire Recovery Project, by alternative, and specific reasonably foreseeable future activities. The analysis synthesizes the expected cumulative effects on a number of elements, including soils, to determine whether a restoration, maintenance or degradation would be expected to occur.

Forest Plan Consistency

For all alternatives, protection of soil resources and maintenance of long-term soil productivity will be accomplished in accordance with the Fremont National Forest Soil Productivity Guide and timber and road Best Management Practices. The project is consistent with the Forest Plan, Forest Service Manual Guidelines, R6 Soil Quality Standards, and other legal frameworks. Soil technical support has been provided for all project alternatives through the assessment of existing condition and environmental consequences for soil resources included in this document, consistent with the Forest Plan and Forest Service Manual Guidelines. Harvest activities and other activities within RHCAs would be in accordance with

Fremont National Forest Land and Resource Management Plan (LRMP) Standards and Guidelines, as amended by the Inland Native Fish Strategy (INFISH). These specifically provide direction for: Category 1 – Fish Bearing Streams; Category 3 – Ponds, lakes, reservoirs, and wetlands greater than 1 acre; and Category 4 – Seasonally flowing or intermittent streams. There are no Category 2 streams in the project area. Judicious harvest and fuels within and adjacent to riparian habitat conservation areas RHCA is consistent with Executive Order 11990 for conservation of wetlands.

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