APPENDIX U: Effects on Soil Properties: Review of Proposed Herbicides

General characteristics for the proposed herbicides are displayed in Table 3-17 in Section 3.8 – Soil Productivity. Appendix prepared by John Dodd, Forest Soil Scientist, November 2005.

Chlorsulfuron

Studies on the effects of chlorsulfuron on soil biota include lab and field studies on nematodes; fungi; populations of actinomycetes, bacteria, and fungi; and soil microorganisms.

- Relatively little information is available on the toxicity of chlorsulfuron to soil invertebrates.
- No effects of chlorsulfuron were found for soil biota at recommended application rates, with the exception of transient decreases in soil nitrification (SERA, 2003a).
- The ‘no observable effects concentration’ for soil is 10 mg/kg, based on cellulose and protein degradation.
- Chlorsulfuron degrades in aerobic soil.
- Non-microbial hydrolysis plays an important role in chlorsulfuron breakdown, and hydrolysis rates increase as pH increases.
- Adsorption to soil particles, which affects the runoff potential of chlorsulfuron, is strongly related to the amount of organic material in the soil.
- Chlorsulfuron adsorption to clay is low.
- Chlorsulfuron is moderately mobile at high pH.
- **Leaching is reduced when pH is less than six.**
- Modeling results indicate that runoff would be negligible in relatively arid environments as well as sandy or loam soils.
- **In clay soils, off-site loss could be substantial** (up to about 55 percent of the applied amount) in regions with annual rainfall rates of 15 to 250 inches (SERA, 2003a; Herbicide Handbook, 2002).

Clopyralid

Studies of clopyralid effects on soil invertebrates have been conducted, including field studies on the effects to microorganisms.

- Soil concentrations from USDA Forest Service applications are expected to be 1,000 less than concentrations that would cause toxic effects. Therefore, no effects to soil invertebrates or microorganisms are expected from use of clopyralid (SERA, 1999a).

- Clopyralid is degraded by soil microbes, with an estimated half-life of 14 to 29 days, meaning that one-half of the amount applied remains in the soils after 90 days, one-fourth of the applied amount remains after 28 to 58 days, one –eight after 42 to 87 days, and so on.

- Increased soil moisture decreases degradation time.

- Clopyralid is weakly adsorbed and has moderate leaching potential.

- Modeling results indicate clopyralid **runoff is highest in clay soils** with peaks after rainfall events.

- Clopyralid ***percolation*** **is highest in sandy loam soils** (SERA, 1999a; Herbicide Handbook, 2002).

Glyphosate

Numerous soil bacteria, fungi, invertebrates, and other microorganisms have been studied for effects of glyphosate application.

- There is nothing to suggest glyphosate would adversely affect soil organisms.

- Glyphosate is readily metabolized by soil microorganisms and some species can use glyphosate as a sole source of carbon (SERA, 2003b).

- It is degraded by microbial action in both soil and water.

- Sylvia and Jarstfer (1997) found that after 3 years, pine trees in plots with grassy weeds had 75 percent fewer mycorrhizal root tips than plots that had been treated 3 times per year with a mixture of glyphosate and metsulfuron methyl to remove weeds.

- Glyphosate degrades in soil, with an estimated half-life of 30 days.

- Glyphosate is highly soluble, but adsorbs rapidly and tightly to soil.

- Glyphosate has low leaching potential because it binds so tightly to soil.
- Modeling results indicate glyphosate runoff is highest in loam soils with peaks after the first rainfall (SERA, 2003b; Herbicide Handbook, 2002).

Imazapic

Imazapic is a relatively new herbicide, and there are no studies on the effects of imazapic on either soil invertebrates or soil microorganisms.

- If imazapic was extremely toxic to soil microorganisms, it is reasonable to assume that secondary signs of injury to microbial populations would have been reported (SERA, 2001a).
- Imazapic degrades in soil, with a half-life of about 113 days.
- Half-life is decreased by the presence of microflora.
- Imazapic is primarily degraded by microbes and it does not degrade appreciably under anaerobic conditions.
- Imazapic is **weakly adsorbed in high soil pH, but adsorption increases with lower pH (acidic soils) and increasing clay and organic matter content.**
- Field studies indicate that imazapic remains in the top 12 to 18 inches of soil and do not indicate any potential for imazapic to move with surface water.
- Modeling results indicate imazapic runoff is highest in clay and loam soils with peaks after the first rainfall.
- Imazapic ***percolation*** **is highest in sandy soils** (SERA, 2001a; Herbicide Handbook, 2002).

Imazapyr

There are no studies on the effects of imazapyr on soil invertebrates, and incomplete information on the effects on soil microorganisms.

- One study indicates cellulose decomposition, a function of soil microorganisms, can be decreased by soil concentrations higher than concentrations expected from USDA Forest Service applications.
- There is no basis for asserting adverse effects to soil microorganisms (SERA, 1999b).

- Imazapyr degrades in soil, with a half-life of 25 to 180 days.
- Degradation rates are highly dependent on microbial action.
- Anaerobic conditions slow degradation.
- Imazapyr is weakly bound to soil, but **adsorption increases with lower pH and increasing clay and organic matter content.**
- Adsorption increases with time as soil dries and is reversible.
- Field studies indicate that imazapic remains in the top 20 inches of soil and do not indicate any potential for imazapic to move with surface water.
- In forest field studies, imazapyr did not run off and there was no evidence of lateral movement.
- Modeling results indicate imazapyr runoff is highest in clay and loam soils with peaks after the first rainfall.
- Imazapyr ***percolation*** **is highest in sandy soils** (SERA, 1999b; Herbicide Handbook, 2002).

Metsulfuron methyl

Studies on the effects of metsulfuron methyl on soil biota are limited to *Pseudomonas* species, though there are a few studies of insects that live in soil. The lowest observed effect concentration is 5 mg/kg, based on the *Pseudomonas* study. At recommended use rates, no effects are expected for insects.

- Effects to soil microorganisms appear to be transient (SERA, 2003c).
- Metsulfuron methyl degrades in soil, with a variable half-life up to 120 days.
- Half-life is decreased by the presence of organic matter though microbial degradation of metsulfuron methyl is slow.
- Non-microbial hydrolysis is slow at high pH but rapid at lower pH.
- Adsorption to soil particles, which affects the runoff potential of metsulfuron methyl, increased with increased pH and organic matter.
- Metsulfuron methyl has low adsorption to clay.

- Modeling results indicate that **off-site movement due to runoff could be significant in clay soils**.

- Metsulfuron methyl ***percolates*** **in sandy soils** (SERA, 2003c; Herbicide Handbook, 2002).

Picloram

The persistence of picloram increases with soil concentration, thus increasing the likelihood that it becomes toxic to soil microorganisms in the short-term.

- Since picloram is toxic to microorganisms at low levels, toxic effects can last for some time after application.

- Persistence in soils could affect soil microorganisms by decreasing nitrification.

- Long-term effects to soil microorganisms are unknown (SERA, 2003d).
- Picloram applied at a typical application rate is likely to change microbial metabolism, though detectable effects to soil productivity are not expected.

- Field studies (Brooks et. al., 1995; Nolte and Fulbright, 1997) have not noted substantial adverse effects associated with the normal application of picloram that might be expected if soil microbial activity were substantially damaged. (SERA, 2003d)
- Substantial effects to soil productivity from the use of picloram over the last 40 years have not been noted (SERA, 2003d).

- Picloram has been studied on a number of soil invertebrates.

- Metabolites may increase toxicity for some soil microorganisms.

- Picloram has a typical half-life of 90 days.

- However, picloram soil degradation rates vary in soil, depending on application rate and soil depth.

- Picloram is water soluble, poorly bound to soils that are low in clays or organics, has a high leaching potential, and is **most toxic in acidic soil.**

- Picloram should not be used on **coarse-textured soils** with a shallow water table, where groundwater contamination is most likely to occur (KSU, 2001; SERA, 2003d).

- Picloram ***percolation*** **is highest in loam and sandy soils** (SERA, 2003d; Herbicide Handbook, 2002). However, modeling results indicate picloram *runoff* (not percolation) is highest in clay soils.

Sethoxydim

Sethoxydim has not been studied on soil invertebrates.

- Assays of soil microorganisms noted transient shifts in species composition at soil concentration levels far exceeding concentrations expected from USDA Forest Service application.

- No adverse effects to soil organisms are expected (SERA, 2001c).

- Sethoxydim is degraded by soil microbes, with an estimated half-life of 1 to 60 days. Adsorption of sethoxydim varies with organic material content.

- Modeling results indicate sethoxydim **runoff is highest in clay and loam soils** with peaks after the first rainfall (SERA, 2001c; Herbicide Handbook, 2002).

Sulfometuron methyl

There are no studies on the effects of sulfometuron methyl on soil invertebrates. However, it is **toxic to soil microorganisms**. Microbial inhibition is likely to occur at typical application rates and could be substantial. Soil residues may alter composition of soil microorganisms. Sulfometuron methyl applied to vegetation at rates to control undesirable vegetation would probably be accompanied by secondary changes in the local environment that affect the soil microbial community more certainly than direct toxic action of sulfometuron methyl on microorganisms (SERA, 2003e).

- The typical half-life for sulfometuron methyl varies from 10 to 100 days, depending on soil texture. Half-life decreases as soil particle size decreases. Presence of soil microorganisms also decreases half-life, though microbial breakdown occurs slowly. Sulfometuron methyl degradation occurs most rapidly at lower pH soils where rates are dominated by hydrolysis.

- Sulfometuron methyl mobility is generally greater at higher soil pH and lower organic matter content.

- Modeling results indicate **sulfometuron methyl runoff is highest in clay and loam soils with peaks** after the first rainfall. Sulfometuron methyl ***percolation*** **is highest in sandy soils**. Monitoring results generally support modeling results (SERA, 2003e; Herbicide Handbook, 2002).

- Sulfometuron methyl applied to vegetation at typical application rates would probably be accompanied by secondary changes to vegetation that affect the soil microbial community more certainly than direct toxic action of sulfometuron methyl on soil microorganisms (SERA, 2003e). Arthur and Wang (1999) found that a formulation of sulfometuron methyl had a negative impact on the abundance of microorganisms and decreased soil nitrogen content on a Christmas tree farm.

Triclopyr

The five commercial formulations of triclopyr contain one of two forms of triclopyr, BEE (butoxyethyl ester) or TEA (triethylamine). Triclopyr BEE is much more toxic to aquatic organisms than triclopyr TEA. A breakdown product, TCP (3,5,6-trichloro-2-pyridinol), is more toxic than either form of triclopyr. Site-specific cumulative effects analysis buffer determinations need to consider the form of triclopyr used and the proximity of any aquatic triclopyr applications, as well as toxicity to aquatic organisms (SERA, 2003f).

- Triclopyr has not been studied on soil invertebrates.

- Soil fungi growth was inhibited at concentrations 2 to 5 times higher than concentrations expected from USDA Forest Service application rates.

- Triclopyr has an average half-life in soil of 46 days, while TCP has an average half-life in soil of 70 days. Warmer temperatures decrease the time to degrade triclopyr.

- **Soil adsorption is increased as organic material increases and decreased as pH increases.** Triclopyr is weakly adsorbed to soil, though adsorption varies with organic matter and clay content. Both light and microbes degrade triclopyr (SERA, 2003f; Herbicide Handbook, 2002).

Impurities

“Virtually no herbicide synthesis yields a totally pure product. Technical grade herbicides undoubtedly contain some impurities” (SERA, All risk assessments). Herbicide-specific risk assessments include the identity of impurities, if it is available. In some instances, toxicity and mobility of impurities is studied in conjunction with the technical grade of the herbicide. In other instances, risks of the impurities are assessed separately from the herbicide. Some impurities are more toxic than the associated herbicide, but the risks are minimized due to low concentrations of the impurity in the herbicide.

Hexachlorobenzene, classified as a human carcinogen, is an impurity in both clopyralid and picloram (SERA, 1999a and 2003d). Hexaclorobenzene is ubiquitous and persistent in the environment and volatizes from the soil surface. Because hexachlorobenzene binds tightly to soil, it is **not likely to percolate** through soil to contaminate groundwater.

Metabolites

Metabolites are substances created by the metabolism of herbicides. Most herbicides considered are not readily metabolized by aquatic animal species, and are passed through their bodies unchanged. Most herbicides are metabolized microbially. Herbicide-specific risk assessments include the identity of known metabolites. Some metabolites are more toxic or persistent than the associated herbicide, but the risks can be minimized by choosing herbicides appropriate to environmental factors such as soil type and climate.

Soil microbes are able to use **NPE surfactants** and breakdown products. Concern has been expressed about the potential for surfactant increasing the movement of other harmful materials, such as pesticides, into soils. A study shows that this is not a concern at soil concentrations resulting from typical USDA Forest Service application rates. In the presence of oxygen, NPE is biodegradable in soil or water, with a half-life of a few up to 90 days. Breakdown products biodegrade more slowly, but are ultimately biodegradable (Bakke, 2003a).