United States Department of Agriculture

Forest Service

Allegheny National Forest

March 2007

Allegheny National Forest

Final Environmental Impact Statement

Appendix G

To Accompany the

Land and Resource Management Plan

This document is available in large print.

Contact the Allegheny National Forest

Supervisor's Office

1-814-723-5150

TTY 1-814-726-2710

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Final Environmental Impact Statement

Appendix G

To Accompany the
Land and Resource Management Plan

Allegheny National Forest

March 2007

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Appendix G1

Human Health Risk Assessment for Glyphosate and Sulfometuron Methyl Treatment

Allegheny National Forest

March 2007

Prepared by

Jeffrey Jenkins PhD, Logan A. Norris PhD, and Kathleen Maas-Hebner MS

Cascade Environmental Consultants

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SUMMARY OF THE HUMAN HEALTH RISK ASSESSMENT

The purpose of this risk assessment is to document potential human health effects from using the herbicides glyphosate and sulfometuron methyl for vegetation management on the Allegheny National Forest (ANF). These herbicides are an important tool (herbicide treatment of interfering understory vegetation) that could be used to help sustain and improve the ability of the land to produce quality hardwood timber, to maintain wildlife habitat and plant diversity, and to reduce impacts from invasive plant species. The ANF Land and Resource Management Plan discusses herbicide use in detail.

Glyphosate: Trade Names: Glypro®, Rodeo®, Accord Concentrate®, Foresters'®

Glyphosate is commonly used in agriculture and as a home-use product. It controls a broad range of grasses, weeds and woody brush species. Certain formulations are registered for use on orchards and vineyards and in weed control prior to planting grains, soybeans, corn, and other food crops. They are also registered for forestry use and for controlling grass and weeds in recreation areas, around schools, in parking lots and on other public grounds. Glyphosate is applied on the ANF at a rate of one to four pounds of active ingredient per acre depending on the management objective and method of application (approximately one to four quarts of formulated product). It is mixed with water and in come cases with a small amount of a surfactant that helps the herbicide wet the leaves to increase its effectiveness.

SERA (1996) summarizes formation on the environmental behavior of glyphosate as it relates to the risk assessment process. Glyphosate is readily absorbed by foliage, is not metabolized in plants and primarily affects plants by disrupting amino acid synthesis. Glyphosate has practically no leaching tendency because it binds tightly to the soil. Complete and rapid degradation occurs in both soil and water by microbiological activity but not by chemical activity. In soil, it is degraded by microorganisms to aminomethylphosphonate (AMPA), and to an array of natural products such as carbon dioxide and water. Its half-life in soil (the time it takes for half of the active ingredient to break down) is about two months. Comprehensive studies of the movement, persistence and fate of glyphosate and AMPA in Oregon, Georgia and Michigan forests encompass a broad diversity of environments (cool moist winter, warm dry summer in Oregon; warm to hot and moist conditions in Georgia; and warm moist summer to cold dry winter in Michigan) making them particularly relevant to the ANF because it covers the full range of conditions encountered on the ANF.

The hazard analysis established the U.S. EPA Reference Dose (RfD) as the appropriate basis for the risk characterization. The RfD of 2 mg/kg/day is based on teratogenicity studies in rabbits, and is used for both acute and long-term exposure scenarios. SERA (2003a) has extensive discussion of this RfD and critical toxicity values. Glyphosate is neither carcinogenic nor mutagenic.

The exposure assessment established the levels and duration of exposure of workers and the general public under a series of scenarios. The results are in a series of tables in the text of the exposure assessment section. For proposed glyphosate applications in the ANF, central estimates of worker exposures span a factor of 28, from 0.0005 mg/kg/day to about 0.014 mg/kg/day. The upper range of exposures for the different application methods and management needs are about a factor of 15 higher, spanning a range from about 0.007 mg/kg/day to 0.21 mg/kg/day.

For the general public, the exposure analysis shows that all of the acute exposure scenarios are primarily accidental and are less than or similar to the general exposure scenarios in workers. The major exceptions are the accidental direct spray of an unclothed child and consumption of water from a pond following an accidental spill. Direct spray of an unclothed child associated with cut surface application results in estimates of exposure ranging from 0.5 to 5.1 mg/kg. An accidental spill of 200 gallons of a field solution into a small pond is assumed for dilute solutions (25 gal/acre) used for airblast and backpack applications. This results in modeled estimates of exposure from consumption of pond water in the range of 0.2 to about 0.6 mg/kg/day. A 5 gallon spill of undiluted produced is assumed for cut surface treatment. This is based on the maximum amount of product expected at a cut surface application site. Modeled estimates of exposure of this scenario are 0.5 to 2.3 mg/kg/day. These are extraordinarily extreme, highly unlikely, and conservative scenarios that are used in all U.S. Forest Service risk assessments.

The longer term or chronic exposure scenarios parallel the acute exposure scenarios for the consumption of contaminated fruit, water, and fish but are based on estimated levels of exposure for longer periods after application. The highest exposure for members of the general public for other scenarios is the longer-term consumption of contaminated fruit, resulting in time-weighted average estimated doses of 0.2 to 0.3 mg/kg/day for backpack applications for invasive species vegetation management.

The risk characterization for both workers and members of the general public are reasonably consistent and unambiguous. For workers, the highest hazard quotient, i.e., 0.1, results from the upper range of exposure for workers involved in backpack application for invasive species vegetation management, is below the level of concern (hazard quotient, HQ, of 1) by a factor of about 10. The highest hazard quotient (HQ) for any accidental exposure scenario for workers, i.e., 0.17 arises from the upper range of the exposure from cut surface application involving a spill over the lower legs for one hour, is lower than the level of concern by a factor of 6.

For the general public two scenarios associated with cut surface applications result in an HQ that is greater than one: accidental direct spray of an unclothed child resulting in an HQ of 2.5 and water consumption from a pond following an accidental spill of 5 gallons of undiluted product resulting in a HQ of 1.5. All other exposure scenarios for the general public result in HQ values that are less than one. The highest HQ from other exposure scenarios is 0.15, which is about 7 times less than the level of concern (HQ of 1). It is the result of the longer-term consumption of contaminated fruit by the general population.

Glyphosate Surfactants and Inerts

Prior to about 1996, some glyphosate formulations contained POEA surfactant at a level of up to about 20%. This surfactant is not in any of the formulations proposed for use by the ANF as covered in this risk assessment. Some formulations of glyphosate contain other surfactants or recommend the use of a surfactant to improve the efficacy of glyphosate. The EPA has several lists (classes) of inert ingredients in pesticides (USEPA 1994). Specifically:

List 1=Toxicological concern;
List 2=Potentially toxic with high priority for testing;
List 3=Unknown toxicity; for inerts where *"there was no basis for placing it on any of the other lists. The Agency will continue to evaluate these chemical substances, as additional information becomes available, to determine if reclassification to List 1, 2, or 4 is appropriate."*
List 4=minimum concern, further subdivided into List 4A=classified in U.S. EPA (1987) as List 4, and List 4B for inerts with "sufficient information to conclude that current use patterns in pesticide products will not adversely affect public health and the environment."

All of the surfactants included in this ANF program have inert ingredients that are on EPA's inert classification lists 3 or 4b.

Sulfometuron Methyl: Trade Names: Oust®, Oust XP®

Sulfometuron methyl is a broad spectrum, pre-emergent and post-emergent herbicide. That is, it affects plants both before and after they emerge from the ground. Its labeled uses include selective weed control in forestry, roadsides, turf grass and other non-cropland applications. On the ANF, it would be sprayed on foliage at the typical and maximum rates of 0.09 to 0.19 lbs a.i./acre mixed with 25 gallons of water.

Sulfometuron methyl is absorbed through plant leaves and by roots. In the plant, it suppresses and stops plant growth by interfering with an enzyme that participates in amino acid synthesis. Sulfometuron methyl does not absorb to soil particles as strongly as glyphosate, so it may move a small amount (up to several inches) in the root zone. In the soil environment, sulfometuron methyl is broken down by the addition of water under acid conditions (acid hydrolysis) and by soil microorganisms. Photolysis (breakdown in sunlight) also occurs.

Sulfometuron methyl's longevity in the soil is directly related to four soil characteristics: temperature, moisture, pH (acidity) and organic matter content. With the soil characteristics present on the ANF, its half-life would be less than two weeks. Principal breakdown products include saccharin, carbon dioxide and methyl 2-(aminosulfonyl) benzoate. There is still some growth regulating effect on emerging grass seedlings for up to two years, one of the benefits from using it for hardwood regeneration.

The hazard analysis established that the U.S. EPA Reference Dose (RfD) of 0.24 mg/kg/day for sulfometuron methyl could be used for the risk assessment, but it also found a more conservative provisional reference dose of 0.2 mg/kg/day had been used in previous Forest Service risk assessments on sulfometuron methyl (Durkin 1998). It is derived from the 2-year feeding study in rats by Mullin (1984), and is used in the current ANF risk assessment for characterizing risks associated with chronic exposure to sulfometuron methyl. The U.S. EPA has not derived an acute/single dose RfD for sulfometuron methyl, but a No Observed Adverse Effect Level (NOAEL) of 86.6 mg/kg/day was reported for decreased maternal and fetal body weights in rats following 10-day gestational exposure of dams (Lu 1981). Using a NOAEL 86.6 mg/kg/day and margin of exposure of 100, a provisional acute RfD is calculated as 0.87 mg/kg/day, and is used in this assessment for characterizing risks associated with acute exposure to sulfometuron methyl. Data reviewed in this assessment provide no evidence that exposure to sulfometuron methyl poses a carcinogenic or mutagenic risk to humans.

The risk analysis shows that typical exposures to sulfometuron methyl do not lead to estimated doses that exceed a level of concern. For workers, no exposure scenarios, acute or chronic, exceed the RfD at the upper bound of the estimated dose associated with the maximum application rate of 0.19 lb a.i./acre. At the typical application rate of 0.9 lb a.i./acre HQ values range from 0.02 to 0.04. These estimates are 50 to 25 times lower than the level of concern.

For the general public, exposure resulting from the consumption of contaminated water is closest to the level of concern. The exposure estimate for the consumption by a child of contaminated water from a small pond immediately after an accidental spill is 0.09, a factor of 11 below the HW. In addition, with the exception of longer-term consumption of contaminated fruit (HW of 0.28), all of the longer-term exposure scenarios result in HQs that are well below (>125 times) the level of concern.

The sulfometuron methyl risk characterization is relatively unambiguous: there is no route of exposure or exposure scenario suggesting that workers or the general public will be at risk from acute or longer-term exposure to sulfometuron methyl.

Sensitive Individuals

Within any population some individuals are hypersensitive. Individual susceptibility to the toxic effects of the herbicides cannot be specifically predicted. A factor of 10 has traditionally been used (NAS 1977) to account for inter-individual variation. The hazard quotient approach used in this risk assessment takes into account much of the variation in a human's response, incorporating a factor of 10 for interspecies variation and an additional factor of 10 for within-species variation, resulting in a combined factor of 100. In addition, the 1996 Food Quality Protection Act (FQPA) established a new standard of safety; EPA must conclude with "reasonable certainty" that "no harm" will come to infants and children or other sensitive individuals exposed to pesticides. In cases where evidence suggest that current margins of exposure are not protective of sensitive individuals, EPA is required to add an additional factor. Currently, as part of the re-registration process mandated by FQPA, EPA is evaluating each pesticide active ingredient (~450) to determine the need for an additional factor to protect sensitive individuals (particularly infants and children). EPA has completed more than 66% of these evaluations; prioritized based on potential human health risks. Glyphosate and sulfometuron methyl are considered low priority and have yet to be evaluated. (http: //www.epa.gov/pesticides/reregistration/reports.htm).

Aggregate Exposure And Cumulative Risk

In this assessment, potential health risks associated with pesticide exposure are evaluated for individual pathways of exposure for individual chemicals, and not on the potential for individuals to be exposed to multiple pesticides by all pathways concurrently. In 1996, FQPA imposed the requirement to consider potential human health risks from all pathways of dietary and nondietary exposures to more than one pesticide acting through a common mechanism of toxicity. Aggregate exposure considers exposure to a single chemical by multiple pathways (food, drinking water, drift, and work related exposures), and routes (ingestion, dermal, inhalation) of exposure. Additionally, in assessing cumulative risk, the combined effect of exposure to multiple chemicals with a common mechanism of toxicity is considered.

In the ANF, there are opportunities for workers and the general public to be exposed to multiple chemicals by multiple pathways and routes of exposure. For example, an individual consuming contaminated fish might also consume contaminated water and/or vegetation. For both glyphosate and sulfometuron methyl, these multiple sources of exposure are inconsequential. The only substantial exposure scenario for acute exposures is the consumption of contaminated water after a glyphosate spill into a small pond. All other plausible combinations of exposures, would not exceed the level of concern. Similarly for longer-term exposures the overriding route of exposure is the consumption of glyphosate-contaminated vegetation. Adding all other sources of exposure would have no substantial impact on the hazard quotient.

Individuals may also be exposed to glyphosate and sulfometuron methyl from other sources not related to ANF activities. For example, glyphosate has a number of approved uses on crops, and some exposure to glyphosate in crop residues is likely. The U.S. EPA/OPP (2002) has estimated that residues of glyphosate on crops could account for about 1% of the RfD. The ANF upper limit of glyphosate exposure is in the consumption of contaminated vegetation, which results in a hazard quotient of 0.14. Increasing this to include the possible contribution from residues on crops does not increase the HQ to the level of concern. The ANF contribution plus the dietary contribution is HQ = 0.14 + 0.01 = 0.15, which is more than 6 times less than the level of concern.

Lastly, there is no evidence to suggest that a common mechanism of toxicity exists for glyphosate, sulfometuron methyl, inerts, or surfactants used in the ANF.

Synergism And Mixtures Of Glyphosate And Sulfometuron Methyl Herbicides

The EPA guidelines for assessing the risk from exposures to chemical mixtures (EPA 1986b) recommend using additive models when little information exists on the toxicity of the mixture, and when components of the mixture appear to induce the same toxic effect by the same mode of action. They suggest that “There seems to be a consensus that for public health concerns regarding causative (toxic) agents, the additive model is more appropriate than any multiplicative model.”

On the basis of the maximum doses for workers (backpack application) in this risk assessment, the largest additive HQ is 0.81, which is less than the level of concern (HQ = 1.0). Based on this we conclude the likelihood is low of adverse toxicological effects from the combination of glyphosate and sulfometuron methyl.

SECTION 1. INTRODUCTION AND PURPOSE

The purpose of this risk assessment is to document probable effects on human health from using the herbicides glyphosate and sulfometuron methyl for vegetation management on the Allegheny National Forest (ANF).

The use of various types of chemicals plays an important role in maintaining the high living standards today's society expects. However, increased use of chemicals has created social concerns about human health effects relative to the benefits chemicals provide. Knowing the probable health effects of the herbicides glyphosate and sulfometuron methyl is very important to a number of readers. For this reason, detailed information about these herbicides that might otherwise be included in this analysis by reference will be covered in enough detail to maintain clarity.

This new ANF risk assessment contains information about how the risk analyses were performed, including a summary of exposure routes and amount of exposure, the associated inherent hazard posed by each herbicide, and an overall assessment of the resultant risk from using these chemicals for vegetation management on the ANF. It is developed as an appendix to the FEIS for the ANF Land and Resource Management Plan.

Relationship To Other Analyses

The overall management of the ANF is governed by the ANF Land and Resource Management Plan. The effects are disclosed in the Final Environmental Impact Statement (referred to as the Forest Plan; and Forest Plan FEIS). The Forest Plan allocates land to broad management prescriptions, defines management objectives for these areas, and provides standards and guidelines designed to mitigate potential adverse impacts. The Forest Plan FEIS evaluates a range of alternatives for managing the ANF to address the significant issues identified during the public involvement process.

Four risk analyses precede this document and are described below.

- The 1986 Forest Plan contains a brief analysis of the human health effects of glyphosate (1986 Forest Plan FEIS, p. 4-40; 1986 Forest Plan, p. D-15).
- In February 1989, the U.S. Department of Agriculture, Forest Service, Southern Region, issued a Final Environmental Impact Statement for Vegetation Management in the Coastal Plain/Piedmont (USDA FS 1989). It addressed broad vegetation management options for 4.6 million acres of National Forest Land, including the use of 11 herbicides and 3 additives. It contained a detailed Risk Assessment that documents the probable health effects from using these herbicides and additives.
- A more comprehensive ANF risk analysis completed in 1991 as part of an ANF Environmental Impact Statement for Understory Vegetation Management (USDA FS, 1991, Appendix A) provided additional and up to date information on glyphosate. It also included a detailed and comprehensive analysis of sulfometuron methyl, and it amended the 1986 Forest Plan to permit ANF personnel to consider using it in future projects. The “Human Health Risk Assessment” (USDA FS, 1991, Appendix A) and the “Wildlife and Aquatic Species Risk Assessment for Sulfometuron Methyl and Glyphosate Treatment” (USDA FS, 1991, Appendix C) incorporated a substantial amount of the Southern Region analysis by reference.
- Syracuse Environmental Research Associates (SERA) has completed 16 national herbicide risk assessments for the USDA Forest Service that are pertinent to this analysis. They are found at http: //www.fs.fed.us/foresthealth/pesticide/risk.shtm.l

This human health risk assessment for the ANF incorporates by reference (40 CFR 1502.21) a substantial portion of the analyses SERA has completed, as well as some information from the 1991 ANF Understory Vegetation Management EIS (USDA FS, 1991) and the 1989 Southern Region FEIS (USDA FS, 1989) mentioned above.

Source Of Information For This Risk Assessment

Earlier human health risk assessments for the ANF were prepared in 1991 and 1997 (USDA FS 1991, 1997a). They were based on Appendix A of the Southern Region FEIS (USDA FS 1989). They provide some information useful for this current assessment, but since then a more comprehensive risk assessment has been done by Syracuse Environmental Research Associates, Inc., (SERA) under contract to USDA Forest Service. The products of their work are available "on-line" at http: //www.fs.fed.us/foresthealt/pesticide. The SERA assessments for glyphosate (SERA 2003a, b) and sulfometuron methyl (SERA 2004a, b) are more comprehensive and use risk assessment procedures more consistent with the contemporary approaches used by EPA for this same purpose. Some of the information cited in this appendix is from the ANF 1991 and 1997 FEIS documents (USDA FS 1991, 1997a), but most of the information is from the SERA documents. Appropriate citations are used to clearly indicate the sources of the material.

The SERA analyses encompass a wide array of environmental conditions encountered on National Forests, and includes conditions found on the ANF. For this reason the SERA analyses are considered to be pertinent to ANF operations, and the risk assessments in this document are drawn from SERA (2003a, b; 2004a, b) documents. Pertinent information published since the completion of the SERA documents are included where appropriate. Specific information (and literature citations) on toxicity (hazard analysis) and exposure (exposure analysis) are in the SERA documents and are not necessarily repeated here in all cases. This risk assessment draws heavily on and from the SERA risk analyses but is not necessarily a verbatim reproduction of the SERA documents. This risk assessments adjusts the SERA analyses for ANF herbicide application rates, herbicide practices and environmental conditions to make the assessments specific to the ANF.

In addition to the SERA documents, we have made liberal use of a variety of major reviews that have been developed by or for the USDA Forest Service, the U.S. Environmental Protection Agency (U.S. EPA), the United States Department of Human and Health Services (USDHHS) Agency for Toxic Substances and Disease Registry, and the California Department of Pesticide Registration. Several thorough reviews have also been published in the open scientific literature. The reviews cited have been prepared with access to proprietary data not accessible to the public except under confidentiality agreements. All of the governmental reviews are publicly available on-line and in some libraries. Review series used for this assessment included:

- U.S. EPA Pesticide Tolerances. For any pesticide that may be used in crop agriculture, U.S. EPA examines and discusses the toxicology and environmental fate to determine acceptable limits for human exposure. As part of this exercise, the agency determines the No Observed Adverse Effect Level (NOAEL; defined as the maximum exposure level at which there is no statistically or biologically significant increase in the frequency or severity of adverse effects between the exposed test population and its appropriate untreated control population) and the reference dose (RfD; defined as the dose of a pesticide that the EPA considers safe for daily consumption by humans without adverse health effects), which are essential for systemic risk assessments. EPA documents on pesticide tolerances are found in the Federal Register (published by the Office of the Federal Register, National Archives and Records Administration), which may be accessed at www.epa.gov/fedrgstr.
- California Department of Pesticide Regulation reviews pesticide registrations and some other chemicals independently of the U.S. EPA. These are available on line at www.cdpr.ca.gov/docs/toxsums/toxsumlist.

This ANF risk assessment frequently cites and incorporates material from these two sources. In some cases, the material is attributed to these review documents and, as necessary in other cases, to the original literature cited in these other reports. Citation reflects acceptance of the literature as sound, except as noted.

In addition, to identify specific literature or other sources of information that may not have been included in these earlier reviews, electronic on-line searches of published scientific literature were conducted. Search engines used included Medline (maintained by the U.S. Library of Medicine and the National Institutes of Health); Agricola (maintained by USDA's National Agriculture Library and includes agricultural and forestry literature);

Cambridge Scientific Abstracts® including Toxline, Environmental Sciences and Pollution Management, and Aquatic Sciences and Fisheries Abstracts. In addition, searches were made in the Federal Register for rules, proposed rules and notices of federal agencies and organizations. Searches for commercial product information incorporated Google® and Google Scholar® (on-line search engines)and databases for Material Data Safety Sheets (contains important health, safety, and environmental information needed regarding the safe handling, transport and storage of pesticides and surfactant).

Organization Of This Risk Assessment

Section 1 presents the purpose, describes the structure, and outlines the methodology of the risk assessment.

Section 2 outlines vegetation management programs that use herbicides and the application methods used.

Section 3 describes the hazard assessment to include the mechanism of action, metabolism and toxic effects of glyphosate for humans.

Section 4 describes the behavior (i.e., movement, persistence and fate) of glyphosate in the environment because this information is important in the exposure analysis. It also describes the methods used to estimate levels of glyphosate human exposure and resultant acute and long-term doses to workers and the public.

Section 5 analyzes the glyphosate human risk by comparing the results of the exposure analysis with the toxic effect levels described in Section 3.

Section 6 describes the hazard assessment to include the mechanism of action, metabolism and toxic effects of sulfometuron methyl for humans.

Section 7 describes the behavior (i.e., movement, persistence and fate) of sulfometuron methyl in the environment because this information is important in the exposure analysis. It also describes the methods used to estimate levels of sulfometuron methyl human exposure and resultant acute and long-term doses to workers and the public.

Section 8 analyzes the sulfometuron methyl human risk by comparing the results of the exposure analysis with the toxic effect levels described in Section 6.

Overview Of The Human Health Risk Assessment Process

On a chemical by chemical basis, the pesticide human health risk assessment evaluates 1) hazard, i.e., toxicity, 2) potency, i.e. dose-response relationship, and 3) exposure potential. Risk is characterized by comparing an internal dose (estimated or calculated from an exposure assessment) to an acceptable intake level (based on hazard and potency assessments). Exposure pathways include ingestion, inhalation, and dermal. Expected patterns of exposure (magnitude, duration, and frequency) determine the need to assess acute and/or chronic risk. Assessment of pesticide hazard is divided into two categories; those chemicals which are considered carcinogens and those that are not.

For non-carcinogens it is assumed that there is a dose (threshold), below which there is no observable adverse effect (NOAEL). Acceptable intake is based on the NOAEL for the most sensitive toxicity endpoint and safety factors. As in almost all cases animal studies are used to evaluate human risk, safety factors are added to account for uncertainty in extrapolation from animals to humans, as well as variation in human susceptibility and other uncertainties associated with toxicity testing. Toxicity testing covers a broad range of adverse effects, to include effects on the nervous system, immune system, endocrine system, reproductive and teratogenic effects, irritation and sensitization of the skin and eyes. However a specific disease state need not be identified; often the most sensitive adverse effect is the lack of weight gain. The outcome of this process is the reference dose (RfD), the dose of a pesticide that EPA considers safe for daily consumption by humans without adverse heath effects.

For most carcinogens the assumption is that no threshold exists (i.e., exposure to a single molecule can cause cancer), and risk is determined based on probability. Carcinogenic potency is defined by the dose which results in an unacceptable probability of increased risk of cancer in a lifetime; the lower the dose the more potent the carcinogen. The upper bound of the 95% confidence limit is used to account for extrapolation from animals to humans, variation in human susceptibility, and other uncertainties. In addition to the pesticide active ingredient, all impurities and metabolites of toxicological concern should be evaluated, as well as the other ingredients in the formulated product (sometimes referred to as inerts) and spray adjuvants (see also pp. G1-36 to G1-38 and G1-101 and G1-102). Using this approach, the U.S. Environmental Protection Agency (U.S. EPA), the World Heath Organization (WHO) and regulatory agencies in most developed countries have developed pesticide human health standards for acceptable intake.

Variability and Uncertainty in Risk Assessment (SERA 2003a, b).

Risk assessments are usually expressed with numbers; however, the numbers are far from exact. Variability and uncertainty may be dominant factors in any risk assessment, and these factors should be expressed. Within the context of a risk assessment, the terms variability and uncertainty signify different conditions.

Variability reflects the knowledge of how things may change. Variability may take several forms. For this risk assessment, three types of variability are distinguished: statistical, situational, and arbitrary. Statistical variability reflects, at least, apparently random patterns in data. For example, various types of estimates used in this risk assessment involve relationships of certain physical properties to certain biological properties. In such cases, best or maximum likelihood estimates can be calculated as well as upper and lower confidence intervals that reflect the statistical variability in the relationships. Situational variability describes variations depending on known circumstances. For example, the application rate or the applied concentration of an herbicide will vary according to local conditions and goals. As discussed in the following section, the limits on this variability are known and there is some information to indicate what the variations are. In other words, situational variability is not random. Arbitrary variability, as the name implies, represents an attempt to describe changes that cannot be characterized statistically or by a given set of conditions that cannot be well defined. This type of variability dominates some spill scenarios involving either a spill of a chemical on to the surface of the skin or a spill of a chemical into water. In either case, exposure depends on the amount of chemical spilled and the area of skin or volume of water that is contaminated.

Variability reflects knowledge or at least an explicit assumption about how things may change, while uncertainty reflects a lack of knowledge. For example, the focus of the human health dose-response assessment is an estimation of an “acceptable” or “no adverse effect” dose that will not be associated with adverse human health effects. For glyphosate, sulfometuron-methyl, and for most other chemicals, however, this estimation regarding human health must be based on data from experimental animal studies, which cover only a limited number of effects. Generally, judgment is the basis for the methods used to make the assessment. Although the judgments may reflect a consensus (i.e., be used by many groups in a reasonably consistent manner), the resulting estimations of risk cannot be proven analytically. In other words, the estimates regarding risk involve uncertainty. The primary functional distinction between variability and uncertainty is that variability is expressed quantitatively, while uncertainty is generally expressed qualitatively.

In considering different forms of variability, almost no risk estimate presented in this document is given as a single number. Usually, risk is expressed as a central estimate and a range, which is sometimes very large. Because of the need to encompass many different types of exposure as well as the need to express the uncertainties in the assessment, this risk assessment involves numerous calculations.

Most of the calculations are relatively simple, and the very simple calculations are included in the body of the document. Some of the calculations, however, are cumbersome. For those calculations, see glyphosate worksheets in SERA (2003b) and sulfometuron methyl worksheets in SERA (2004b). The worksheets provide the detail for the estimates cited in the body of the document. The worksheets are divided into the following sections: general data and assumptions, chemical specific data and assumptions, exposure assessments for workers, exposure assessments for the general public, and exposure assessments for effects on non-target organisms. Two versions of the worksheets are available: one in a word processing format and one in a spreadsheet format. The worksheets that are in the spreadsheet format are used only as a check of the worksheets that are in the word processing format.

Presented here are human health risk assessments for products containing the active ingredients glyphosate and sulfometuron-methyl. Each risk assessment has four major sections, including an identification of human health hazards, an assessment of potential for exposure, an assessment of the dose-response relationships, and a characterization of the risks associated with plausible levels of exposure. These are the basic steps recommended by the National Research Council of the National Academy of Sciences (NRC 1983) for conducting and organizing risk assessments.

This is a technical support document, and it addresses some specialized technical areas. Nevertheless an effort was made to ensure that the document could be understood by individuals who do not have specialized training in the chemical and biological sciences. Certain technical concepts, methods, and terms common to all parts of the risk assessment are described in plain language in a separate document (SERA 2001). Some of the more complicated terms and concepts are defined, as necessary, in the text. In addition, in Appendix G3 we provide an acronym list, conversions between English and metric units, and a glossary of many of the terms used in Appendix G1 and G2 .

Glyphosate and sulfometuron methyl literature searches

In the preparation of the SERA reports (SERA 1998, 2003a, 2004a), literature searches of glyphosate and sulfometuron methyl were conducted in the open literature using PubMed, TOXLINE as well as the U.S. EPA files. Several reviews and risk assessments completed by the U.S. EPA were also consulted.

For glyphosate these include the science chapters for human health (U.S. EPA/OPP 1993a), the U.S. EPA Re-registration Eligibility Decision (RED) document (U.S. EPA/OPP 1993), pesticide tolerances for glyphosate (U.S. EPA/OPP 2002), the U.S. EPA Drinking Water Criteria Document on glyphosate (U.S. EPA/ODW 1992) and the IRIS entry for this compound (U.S. EPA/IRIS 1993). Additional reviews consulted in the preparation of this document include the EXTOXNET review of this compound (Extoxnet 1996), summaries prepared by the registrant of glyphosate (Monsanto The Agricultural Group 1995a, b, c, d), risk assessments conducted by the World Health Organization on glyphosate (WHO 1994) and AMPA, a metabolite of glyphosate (WHO 1998), public health goals for concentrations of glyphosate in drinking water prepared by CalEPA (CalEPA 1997; Howd et al. 2000), a reduced risk rationale for Roundup® ULTRA (Wratten 1998), a human health risk assessment on glyphosate and glyphosate formulations published by Williams et al. (2000), as well as a review of environmental concerns with the use of glyphosate (Cox 1998, 2002).

The search of U.S. EPA's Federal Insecticide, Fungicide, Rodentcide Act/Confidential Business Information (FIFRA/CBI) files indicated that there are 5829 submissions on glyphosate and glyphosate formulations. While many of these studies were conducted to support the initial registration and re-registration of glyphosate, a substantial number of studies (n=1288) were conducted and submitted to U.S. EPA after 1993, the date of the U.S. EPA Re-registration Eligibility Decision document on glyphosate (U.S. EPA/OPP 1993). Because of the extensive published literature on glyphosate, the re-registration document for glyphosate (U.S. EPA/OPP 1993) was used where possible to summarize information for the earlier CBI studies. Although full copies of some key studies (n=47) were obtained from the earlier CBI submissions, the acquisition of the CBI studies focused on the post-1993 period (n=138). Full text copies of the CBI studies [n=185] were kindly provided by the U.S. EPA Office of Pesticide Programs. The CBI studies were reviewed, and synopses of the information that can be disclosed from most relevant studies are included in the appendices to SERA (2003a).

Appendix G1

Human Health Risk Assessment for Glyphosate and Sulfometuron Methyl Treatment Allegheny National Forest

March 2007

Prepared by

Jeffrey Jenkins PhD, Logan A. Norris PhD, and Kathleen Maas-Hebner MS

Cascade Environmental Consultants

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SUMMARY OF THE HUMAN HEALTH RISK ASSESSMENT

The purpose of this risk assessment is to document potential human health effects from using the herbicides glyphosate and sulfometuron methyl for vegetation management on the Allegheny National Forest (ANF). These herbicides are an important tool (herbicide treatment of interfering understory vegetation) that could be used to help sustain and improve the ability of the land to produce quality hardwood timber, to maintain wildlife habitat and plant diversity, and to reduce impacts from invasive plant species. The ANF Land and Resource Management Plan discusses herbicide use in detail.

Glyphosate: Trade Names: Glypro®, Rodeo®, Accord Concentrate®, Foresters'®

Glyphosate is commonly used in agriculture and as a home-use product. It controls a broad range of grasses, weeds and woody brush species. Certain formulations are registered for use on orchards and vineyards and in weed control prior to planting grains, soybeans, corn, and other food crops. They are also registered for forestry use and for controlling grass and weeds in recreation areas, around schools, in parking lots and on other public grounds. Glyphosate is applied on the ANF at a rate of one to four pounds of active ingredient per acre depending on the management objective and method of application (approximately one to four quarts of formulated product). It is mixed with water and in come cases with a small amount of a surfactant that helps the herbicide wet the leaves to increase its effectiveness.

SERA (1996) summarizes formation on the environmental behavior of glyphosate as it relates to the risk assessment process. Glyphosate is readily absorbed by foliage, is not metabolized in plants and primarily affects plants by disrupting amino acid synthesis. Glyphosate has practically no leaching tendency because it binds tightly to the soil. Complete and rapid degradation occurs in both soil and water by microbiological activity but not by chemical activity. In soil, it is degraded by microorganisms to aminomethylphosphonate (AMPA), and to an array of natural products such as carbon dioxide and water. Its half-life in soil (the time it takes for half of the active ingredient to break down) is about two months. Comprehensive studies of the movement, persistence and fate of glyphosate and AMPA in Oregon, Georgia and Michigan forests encompass a broad diversity of environments (cool moist winter, warm dry summer in Oregon; warm to hot and moist conditions in Georgia; and warm moist summer to cold dry winter in Michigan) making them particularly relevant to the ANF because it covers the full range of conditions encountered on the ANF.

The hazard analysis established the U.S. EPA Reference Dose (RfD) as the appropriate basis for the risk characterization. The RfD of 2 mg/kg/day is based on teratogenicity studies in rabbits, and is used for both acute and long-term exposure scenarios. SERA (2003a) has extensive discussion of this RfD and critical toxicity values. Glyphosate is neither carcinogenic nor mutagenic.

The exposure assessment established the levels and duration of exposure of workers and the general public under a series of scenarios. The results are in a series of tables in the text of the exposure assessment section. For proposed glyphosate applications in the ANF, central estimates of worker exposures span a factor of 28, from 0.0005 mg/kg/day to about 0.014 mg/kg/day. The upper range of exposures for the different application methods and management needs are about a factor of 15 higher, spanning a range from about 0.007 mg/kg/day to 0.21 mg/kg/day.

For the general public, the exposure analysis shows that all of the acute exposure scenarios are primarily accidental and are less than or similar to the general exposure scenarios in workers. The major exceptions are the accidental direct spray of an unclothed child and consumption of water from a pond following an accidental spill. Direct spray of an unclothed child associated with cut surface application results in estimates of exposure ranging from 0.5 to 5.1 mg/kg. An accidental spill of 200 gallons of a field solution into a small pond is assumed for dilute solutions (25 gal/acre) used for airblast and backpack applications. This results in modeled estimates of exposure from consumption of pond water in the range of 0.2 to about 0.6 mg/kg/day. A 5 gallon spill of undiluted produced is assumed for cut surface treatment. This is based on the maximum amount of product expected at a cut surface application site. Modeled estimates of exposure of this scenario are 0.5 to 2.3 mg/kg/day. These are extraordinarily extreme, highly unlikely, and conservative scenarios that are used in all U.S. Forest Service risk assessments.

The longer term or chronic exposure scenarios parallel the acute exposure scenarios for the consumption of contaminated fruit, water, and fish but are based on estimated levels of exposure for longer periods after application. The highest exposure for members of the general public for other scenarios is the longer-term consumption of contaminated fruit, resulting in time-weighted average estimated doses of 0.2 to 0.3 mg/kg/day for backpack applications for invasive species vegetation management.

The risk characterization for both workers and members of the general public are reasonably consistent and unambiguous. For workers, the highest hazard quotient, i.e., 0.1, results from the upper range of exposure for workers involved in backpack application for invasive species vegetation management, is below the level of concern (hazard quotient, HQ, of 1) by a factor of about 10. The highest hazard quotient (HQ) for any accidental exposure scenario for workers, i.e., 0.17 arises from the upper range of the exposure from cut surface application involving a spill over the lower legs for one hour, is lower than the level of concern by a factor of 6.

For the general public two scenarios associated with cut surface applications result in an HQ that is greater than one: accidental direct spray of an unclothed child resulting in an HQ of 2.5 and water consumption from a pond following an accidental spill of 5 gallons of undiluted product resulting in a HQ of 1.5. All other exposure scenarios for the general public result in HQ values that are less than one. The highest HQ from other exposure scenarios is 0.15, which is about 7 times less than the level of concern (HQ of 1). It is the result of the longer-term consumption of contaminated fruit by the general population.

Glyphosate Surfactants and Inerts

Prior to about 1996, some glyphosate formulations contained POEA surfactant at a level of up to about 20%. This surfactant is not in any of the formulations proposed for use by the ANF as covered in this risk assessment. Some formulations of glyphosate contain other surfactants or recommend the use of a surfactant to improve the efficacy of glyphosate. The EPA has several lists (classes) of inert ingredients in pesticides (USEPA 1994). Specifically:

List 1=Toxicological concern;
List 2=Potentially toxic with high priority for testing;
List 3=Unknown toxicity; for inerts where *“there was no basis for placing it on any of the other lists. The Agency will continue to evaluate these chemical substances, as additional information becomes available, to determine if reclassification to List 1, 2, or 4 is appropriate.”*
List 4=minimum concern, further subdivided into List 4A=classified in U.S. EPA (1987) as List 4, and List 4B for inerts with “sufficient information to conclude that current use patterns in pesticide products will not adversely affect public health and the environment.”

All of the surfactants included in this ANF program have inert ingredients that are on EPA’s inert classification lists 3 or 4b.

Sulfometuron Methyl: Trade Names: Oust®, Oust XP®

Sulfometuron methyl is a broad spectrum, pre-emergent and post-emergent herbicide. That is, it affects plants both before and after they emerge from the ground. Its labeled uses include selective weed control in forestry, roadsides, turf grass and other non-cropland applications. On the ANF, it would be sprayed on foliage at the typical and maximum rates of 0.09 to 0.19 lbs a.i./acre mixed with 25 gallons of water.

Sulfometuron methyl is absorbed through plant leaves and by roots. In the plant, it suppresses and stops plant growth by interfering with an enzyme that participates in amino acid synthesis. Sulfometuron methyl does not absorb to soil particles as strongly as glyphosate, so it may move a small amount (up to several inches) in the root zone. In the soil environment, sulfometuron methyl is broken down by the addition of water under acid conditions (acid hydrolysis) and by soil microorganisms. Photolysis (breakdown in sunlight) also occurs.

Sulfometuron methyl's longevity in the soil is directly related to four soil characteristics: temperature, moisture, pH (acidity) and organic matter content. With the soil characteristics present on the ANF, its half-life would be less than two weeks. Principal breakdown products include saccharin, carbon dioxide and methyl 2-(aminosulfonyl) benzoate. There is still some growth regulating effect on emerging grass seedlings for up to two years, one of the benefits from using it for hardwood regeneration.

The hazard analysis established that the U.S. EPA Reference Dose (RfD) of 0.24 mg/kg/day for sulfometuron methyl could be used for the risk assessment, but it also found a more conservative provisional reference dose of 0.2 mg/kg/day had been used in previous Forest Service risk assessments on sulfometuron methyl (Durkin 1998). It is derived from the 2-year feeding study in rats by Mullin (1984), and is used in the current ANF risk assessment for characterizing risks associated with chronic exposure to sulfometuron methyl. The U.S. EPA has not derived an acute/single dose RfD for sulfometuron methyl, but a No Observed Adverse Effect Level (NOAEL) of 86.6 mg/kg/day was reported for decreased maternal and fetal body weights in rats following 10-day gestational exposure of dams (Lu 1981). Using a NOAEL 86.6 mg/kg/day and margin of exposure of 100, a provisional acute RfD is calculated as 0.87 mg/kg/day, and is used in this assessment for characterizing risks associated with acute exposure to sulfometuron methyl. Data reviewed in this assessment provide no evidence that exposure to sulfometuron methyl poses a carcinogenic or mutagenic risk to humans.

The risk analysis shows that typical exposures to sulfometuron methyl do not lead to estimated doses that exceed a level of concern. For workers, no exposure scenarios, acute or chronic, exceed the RfD at the upper bound of the estimated dose associated with the maximum application rate of 0.19 lb a.i./acre. At the typical application rate of 0.9 lb a.i./acre HQ values range from 0.02 to 0.04. These estimates are 50 to 25 times lower than the level of concern.

For the general public, exposure resulting from the consumption of contaminated water is closest to the level of concern. The exposure estimate for the consumption by a child of contaminated water from a small pond immediately after an accidental spill is 0.09, a factor of 11 below the HW. In addition, with the exception of longer-term consumption of contaminated fruit (HW of 0.28), all of the longer-term exposure scenarios result in HQs that are well below (>125 times) the level of concern.

The sulfometuron methyl risk characterization is relatively unambiguous: there is no route of exposure or exposure scenario suggesting that workers or the general public will be at risk from acute or longer-term exposure to sulfometuron methyl.

Sensitive Individuals

Within any population some individuals are hypersensitive. Individual susceptibility to the toxic effects of the herbicides cannot be specifically predicted. A factor of 10 has traditionally been used (NAS 1977) to account for inter-individual variation. The hazard quotient approach used in this risk assessment takes into account much of the variation in a human's response, incorporating a factor of 10 for interspecies variation and an additional factor of 10 for within-species variation, resulting in a combined factor of 100. In addition, the 1996 Food Quality Protection Act (FQPA) established a new standard of safety; EPA must conclude with "reasonable certainty" that "no harm" will come to infants and children or other sensitive individuals exposed to pesticides. In cases where evidence suggest that current margins of exposure are not protective of sensitive individuals, EPA is required to add an additional factor. Currently, as part of the re-registration process mandated by FQPA, EPA is evaluating each pesticide active ingredient (~450) to determine the need for an additional factor to protect sensitive individuals (particularly infants and children). EPA has completed more than 66% of these evaluations; prioritized based on potential human health risks. Glyphosate and sulfometuron methyl are considered low priority and have yet to be evaluated. (http: //www.epa.gov/pesticides/reregistration/reports.htm).

Aggregate Exposure And Cumulative Risk

In this assessment, potential health risks associated with pesticide exposure are evaluated for individual pathways of exposure for individual chemicals, and not on the potential for individuals to be exposed to multiple pesticides by all pathways concurrently. In 1996, FQPA imposed the requirement to consider potential human health risks from all pathways of dietary and nondietary exposures to more than one pesticide acting through a common mechanism of toxicity. Aggregate exposure considers exposure to a single chemical by multiple pathways (food, drinking water, drift, and work related exposures), and routes (ingestion, dermal, inhalation) of exposure. Additionally, in assessing cumulative risk, the combined effect of exposure to multiple chemicals with a common mechanism of toxicity is considered.

In the ANF, there are opportunities for workers and the general public to be exposed to multiple chemicals by multiple pathways and routes of exposure. For example, an individual consuming contaminated fish might also consume contaminated water and/or vegetation. For both glyphosate and sulfometuron methyl, these multiple sources of exposure are inconsequential. The only substantial exposure scenario for acute exposures is the consumption of contaminated water after a glyphosate spill into a small pond. All other plausible combinations of exposures, would not exceed the level of concern. Similarly for longer-term exposures the overriding route of exposure is the consumption of glyphosate-contaminated vegetation. Adding all other sources of exposure would have no substantial impact on the hazard quotient.

Individuals may also be exposed to glyphosate and sulfometuron methyl from other sources not related to ANF activities. For example, glyphosate has a number of approved uses on crops, and some exposure to glyphosate in crop residues is likely. The U.S. EPA/OPP (2002) has estimated that residues of glyphosate on crops could account for about 1% of the RfD. The ANF upper limit of glyphosate exposure is in the consumption of contaminated vegetation, which results in a hazard quotient of 0.14. Increasing this to include the possible contribution from residues on crops does not increase the HQ to the level of concern. The ANF contribution plus the dietary contribution is HQ = 0.14 + 0.01 = 0.15, which is more than 6 times less than the level of concern.

Lastly, there is no evidence to suggest that a common mechanism of toxicity exists for glyphosate, sulfometuron methyl, inerts, or surfactants used in the ANF.

Synergism And Mixtures Of Glyphosate And Sulfometuron Methyl Herbicides

The EPA guidelines for assessing the risk from exposures to chemical mixtures (EPA 1986b) recommend using additive models when little information exists on the toxicity of the mixture, and when components of the mixture appear to induce the same toxic effect by the same mode of action. They suggest that “There seems to be a consensus that for public health concerns regarding causative (toxic) agents, the additive model is more appropriate than any multiplicative model.”

On the basis of the maximum doses for workers (backpack application) in this risk assessment, the largest additive HQ is 0.81, which is less than the level of concern (HQ = 1.0). Based on this we conclude the likelihood is low of adverse toxicological effects from the combination of glyphosate and sulfometuron methyl.

SECTION 1. INTRODUCTION AND PURPOSE

The purpose of this risk assessment is to document probable effects on human health from using the herbicides glyphosate and sulfometuron methyl for vegetation management on the Allegheny National Forest (ANF).

The use of various types of chemicals plays an important role in maintaining the high living standards today's society expects. However, increased use of chemicals has created social concerns about human health effects relative to the benefits chemicals provide. Knowing the probable health effects of the herbicides glyphosate and sulfometuron methyl is very important to a number of readers. For this reason, detailed information about these herbicides that might otherwise be included in this analysis by reference will be covered in enough detail to maintain clarity.

This new ANF risk assessment contains information about how the risk analyses were performed, including a summary of exposure routes and amount of exposure, the associated inherent hazard posed by each herbicide, and an overall assessment of the resultant risk from using these chemicals for vegetation management on the ANF. It is developed as an appendix to the FEIS for the ANF Land and Resource Management Plan.

Relationship To Other Analyses

The overall management of the ANF is governed by the ANF Land and Resource Management Plan. The effects are disclosed in the Final Environmental Impact Statement (referred to as the Forest Plan; and Forest Plan FEIS). The Forest Plan allocates land to broad management prescriptions, defines management objectives for these areas, and provides standards and guidelines designed to mitigate potential adverse impacts. The Forest Plan FEIS evaluates a range of alternatives for managing the ANF to address the significant issues identified during the public involvement process.

Four risk analyses precede this document and are described below.

- The 1986 Forest Plan contains a brief analysis of the human health effects of glyphosate (1986 Forest Plan FEIS, p. 4-40; 1986 Forest Plan, p. D-15).
- In February 1989, the U.S. Department of Agriculture, Forest Service, Southern Region, issued a Final Environmental Impact Statement for Vegetation Management in the Coastal Plain/Piedmont (USDA FS 1989). It addressed broad vegetation management options for 4.6 million acres of National Forest Land, including the use of 11 herbicides and 3 additives. It contained a detailed Risk Assessment that documents the probable health effects from using these herbicides and additives.
- A more comprehensive ANF risk analysis completed in 1991 as part of an ANF Environmental Impact Statement for Understory Vegetation Management (USDA FS, 1991, Appendix A) provided additional and up to date information on glyphosate. It also included a detailed and comprehensive analysis of sulfometuron methyl, and it amended the 1986 Forest Plan to permit ANF personnel to consider using it in future projects. The "Human Health Risk Assessment" (USDA FS, 1991, Appendix A) and the "Wildlife and Aquatic Species Risk Assessment for Sulfometuron Methyl and Glyphosate Treatment" (USDA FS, 1991, Appendix C) incorporated a substantial amount of the Southern Region analysis by reference.
- Syracuse Environmental Research Associates (SERA) has completed 16 national herbicide risk assessments for the USDA Forest Service that are pertinent to this analysis. They are found at http: //www.fs.fed.us/foresthealth/pesticide/risk.shtm.l

This human health risk assessment for the ANF incorporates by reference (40 CFR 1502.21) a substantial portion of the analyses SERA has completed, as well as some information from the 1991 ANF Understory Vegetation Management EIS (USDA FS, 1991) and the 1989 Southern Region FEIS (USDA FS, 1989) mentioned above.

Source Of Information For This Risk Assessment

Earlier human health risk assessments for the ANF were prepared in 1991 and 1997 (USDA FS 1991, 1997a). They were based on Appendix A of the Southern Region FEIS (USDA FS 1989). They provide some information useful for this current assessment, but since then a more comprehensive risk assessment has been done by Syracuse Environmental Research Associates, Inc., (SERA) under contract to USDA Forest Service. The products of their work are available "on-line" at http: //www.fs.fed.us/foresthealt/pesticide. The SERA assessments for glyphosate (SERA 2003a, b) and sulfometuron methyl (SERA 2004a, b) are more comprehensive and use risk assessment procedures more consistent with the contemporary approaches used by EPA for this same purpose. Some of the information cited in this appendix is from the ANF 1991 and 1997 FEIS documents (USDA FS 1991, 1997a), but most of the information is from the SERA documents. Appropriate citations are used to clearly indicate the sources of the material.

The SERA analyses encompass a wide array of environmental conditions encountered on National Forests, and includes conditions found on the ANF. For this reason the SERA analyses are considered to be pertinent to ANF operations, and the risk assessments in this document are drawn from SERA (2003a, b; 2004a, b) documents. Pertinent information published since the completion of the SERA documents are included where appropriate. Specific information (and literature citations) on toxicity (hazard analysis) and exposure (exposure analysis) are in the SERA documents and are not necessarily repeated here in all cases. This risk assessment draws heavily on and from the SERA risk analyses but is not necessarily a verbatim reproduction of the SERA documents. This risk assessments adjusts the SERA analyses for ANF herbicide application rates, herbicide practices and environmental conditions to make the assessments specific to the ANF.

In addition to the SERA documents, we have made liberal use of a variety of major reviews that have been developed by or for the USDA Forest Service, the U.S. Environmental Protection Agency (U.S. EPA), the United States Department of Human and Health Services (USDHHS) Agency for Toxic Substances and Disease Registry, and the California Department of Pesticide Registration. Several thorough reviews have also been published in the open scientific literature. The reviews cited have been prepared with access to proprietary data not accessible to the public except under confidentiality agreements. All of the governmental reviews are publicly available on-line and in some libraries. Review series used for this assessment included:

- U.S. EPA Pesticide Tolerances. For any pesticide that may be used in crop agriculture, U.S. EPA examines and discusses the toxicology and environmental fate to determine acceptable limits for human exposure. As part of this exercise, the agency determines the No Observed Adverse Effect Level (NOAEL; defined as the maximum exposure level at which there is no statistically or biologically significant increase in the frequency or severity of adverse effects between the exposed test population and its appropriate untreated control population) and the reference dose (RfD; defined as the dose of a pesticide that the EPA considers safe for daily consumption by humans without adverse health effects), which are essential for systemic risk assessments. EPA documents on pesticide tolerances are found in the Federal Register (published by the Office of the Federal Register, National Archives and Records Administration), which may be accessed at www.epa.gov/fedrgstr.
- California Department of Pesticide Regulation reviews pesticide registrations and some other chemicals independently of the U.S. EPA. These are available on line at www.cdpr.ca.gov/docs/toxsums/toxsumlist.

This ANF risk assessment frequently cites and incorporates material from these two sources. In some cases, the material is attributed to these review documents and, as necessary in other cases, to the original literature cited in these other reports. Citation reflects acceptance of the literature as sound, except as noted.

In addition, to identify specific literature or other sources of information that may not have been included in these earlier reviews, electronic on-line searches of published scientific literature were conducted. Search engines used included Medline (maintained by the U.S. Library of Medicine and the National Institutes of Health); Agricola (maintained by USDA's National Agriculture Library and includes agricultural and forestry literature);

Cambridge Scientific Abstracts® including Toxline, Environmental Sciences and Pollution Management, and Aquatic Sciences and Fisheries Abstracts. In addition, searches were made in the Federal Register for rules, proposed rules and notices of federal agencies and organizations. Searches for commercial product information incorporated Google® and Google Scholar® (on-line search engines)and databases for Material Data Safety Sheets (contains important health, safety, and environmental information needed regarding the safe handling, transport and storage of pesticides and surfactant).

Organization Of This Risk Assessment

Section 1 presents the purpose, describes the structure, and outlines the methodology of the risk assessment.

Section 2 outlines vegetation management programs that use herbicides and the application methods used.

Section 3 describes the hazard assessment to include the mechanism of action, metabolism and toxic effects of glyphosate for humans.

Section 4 describes the behavior (i.e., movement, persistence and fate) of glyphosate in the environment because this information is important in the exposure analysis. It also describes the methods used to estimate levels of glyphosate human exposure and resultant acute and long-term doses to workers and the public.

Section 5 analyzes the glyphosate human risk by comparing the results of the exposure analysis with the toxic effect levels described in Section 3.

Section 6 describes the hazard assessment to include the mechanism of action, metabolism and toxic effects of sulfometuron methyl for humans.

Section 7 describes the behavior (i.e., movement, persistence and fate) of sulfometuron methyl in the environment because this information is important in the exposure analysis. It also describes the methods used to estimate levels of sulfometuron methyl human exposure and resultant acute and long-term doses to workers and the public.

Section 8 analyzes the sulfometuron methyl human risk by comparing the results of the exposure analysis with the toxic effect levels described in Section 6.

Overview Of The Human Health Risk Assessment Process

On a chemical by chemical basis, the pesticide human health risk assessment evaluates 1) hazard, i.e., toxicity, 2) potency, i.e. dose-response relationship, and 3) exposure potential. Risk is characterized by comparing an internal dose (estimated or calculated from an exposure assessment) to an acceptable intake level (based on hazard and potency assessments). Exposure pathways include ingestion, inhalation, and dermal. Expected patterns of exposure (magnitude, duration, and frequency) determine the need to assess acute and/or chronic risk. Assessment of pesticide hazard is divided into two categories; those chemicals which are considered carcinogens and those that are not.

For non-carcinogens it is assumed that there is a dose (threshold), below which there is no observable adverse effect (NOAEL). Acceptable intake is based on the NOAEL for the most sensitive toxicity endpoint and safety factors. As in almost all cases animal studies are used to evaluate human risk, safety factors are added to account for uncertainty in extrapolation from animals to humans, as well as variation in human susceptibility and other uncertainties associated with toxicity testing. Toxicity testing covers a broad range of adverse effects, to include effects on the nervous system, immune system, endocrine system, reproductive and teratogenic effects, irritation and sensitization of the skin and eyes. However a specific disease state need not be identified; often the most sensitive adverse effect is the lack of weight gain. The outcome of this process is the reference dose (RfD), the dose of a pesticide that EPA considers safe for daily consumption by humans without adverse heath effects.

For most carcinogens the assumption is that no threshold exists (i.e., exposure to a single molecule can cause cancer), and risk is determined based on probability. Carcinogenic potency is defined by the dose which results in an unacceptable probability of increased risk of cancer in a lifetime; the lower the dose the more potent the carcinogen. The upper bound of the 95% confidence limit is used to account for extrapolation from animals to humans, variation in human susceptibility, and other uncertainties. In addition to the pesticide active ingredient, all impurities and metabolites of toxicological concern should be evaluated, as well as the other ingredients in the formulated product (sometimes referred to as inerts) and spray adjuvants (see also pp. G1-36 to G1-38 and G1-101 and G1-102). Using this approach, the U.S. Environmental Protection Agency (U.S. EPA), the World Heath Organization (WHO) and regulatory agencies in most developed countries have developed pesticide human health standards for acceptable intake.

Variability and Uncertainty in Risk Assessment (SERA 2003a, b).

Risk assessments are usually expressed with numbers; however, the numbers are far from exact. Variability and uncertainty may be dominant factors in any risk assessment, and these factors should be expressed. Within the context of a risk assessment, the terms variability and uncertainty signify different conditions.

Variability reflects the knowledge of how things may change. Variability may take several forms. For this risk assessment, three types of variability are distinguished: statistical, situational, and arbitrary. Statistical variability reflects, at least, apparently random patterns in data. For example, various types of estimates used in this risk assessment involve relationships of certain physical properties to certain biological properties. In such cases, best or maximum likelihood estimates can be calculated as well as upper and lower confidence intervals that reflect the statistical variability in the relationships. Situational variability describes variations depending on known circumstances. For example, the application rate or the applied concentration of an herbicide will vary according to local conditions and goals. As discussed in the following section, the limits on this variability are known and there is some information to indicate what the variations are. In other words, situational variability is not random. Arbitrary variability, as the name implies, represents an attempt to describe changes that cannot be characterized statistically or by a given set of conditions that cannot be well defined. This type of variability dominates some spill scenarios involving either a spill of a chemical on to the surface of the skin or a spill of a chemical into water. In either case, exposure depends on the amount of chemical spilled and the area of skin or volume of water that is contaminated.

Variability reflects knowledge or at least an explicit assumption about how things may change, while uncertainty reflects a lack of knowledge. For example, the focus of the human health dose-response assessment is an estimation of an “acceptable” or “no adverse effect” dose that will not be associated with adverse human health effects. For glyphosate, sulfometuron-methyl, and for most other chemicals, however, this estimation regarding human health must be based on data from experimental animal studies, which cover only a limited number of effects. Generally, judgment is the basis for the methods used to make the assessment. Although the judgments may reflect a consensus (i.e., be used by many groups in a reasonably consistent manner), the resulting estimations of risk cannot be proven analytically. In other words, the estimates regarding risk involve uncertainty. The primary functional distinction between variability and uncertainty is that variability is expressed quantitatively, while uncertainty is generally expressed qualitatively.

In considering different forms of variability, almost no risk estimate presented in this document is given as a single number. Usually, risk is expressed as a central estimate and a range, which is sometimes very large. Because of the need to encompass many different types of exposure as well as the need to express the uncertainties in the assessment, this risk assessment involves numerous calculations.

Most of the calculations are relatively simple, and the very simple calculations are included in the body of the document. Some of the calculations, however, are cumbersome. For those calculations, see glyphosate worksheets in SERA (2003b) and sulfometuron methyl worksheets in SERA (2004b). The worksheets provide the detail for the estimates cited in the body of the document. The worksheets are divided into the following sections: general data and assumptions, chemical specific data and assumptions, exposure assessments for workers, exposure assessments for the general public, and exposure assessments for effects on non-target organisms. Two versions of the worksheets are available: one in a word processing format and one in a spreadsheet format. The worksheets that are in the spreadsheet format are used only as a check of the worksheets that are in the word processing format.

Presented here are human health risk assessments for products containing the active ingredients glyphosate and sulfometuron-methyl. Each risk assessment has four major sections, including an identification of human health hazards, an assessment of potential for exposure, an assessment of the dose-response relationships, and a characterization of the risks associated with plausible levels of exposure. These are the basic steps recommended by the National Research Council of the National Academy of Sciences (NRC 1983) for conducting and organizing risk assessments.

This is a technical support document, and it addresses some specialized technical areas. Nevertheless an effort was made to ensure that the document could be understood by individuals who do not have specialized training in the chemical and biological sciences. Certain technical concepts, methods, and terms common to all parts of the risk assessment are described in plain language in a separate document (SERA 2001). Some of the more complicated terms and concepts are defined, as necessary, in the text. In addition, in Appendix G3 we provide an acronym list, conversions between English and metric units, and a glossary of many of the terms used in Appendix G1 and G2 .

Glyphosate and sulfometuron methyl literature searches

In the preparation of the SERA reports (SERA 1998, 2003a, 2004a), literature searches of glyphosate and sulfometuron methyl were conducted in the open literature using PubMed, TOXLINE as well as the U.S. EPA files. Several reviews and risk assessments completed by the U.S. EPA were also consulted.

For glyphosate these include the science chapters for human health (U.S. EPA/OPP 1993a), the U.S. EPA Re-registration Eligibility Decision (RED) document (U.S. EPA/OPP 1993), pesticide tolerances for glyphosate (U.S. EPA/OPP 2002), the U.S. EPA Drinking Water Criteria Document on glyphosate (U.S. EPA/ODW 1992) and the IRIS entry for this compound (U.S. EPA/IRIS 1993). Additional reviews consulted in the preparation of this document include the EXTOXNET review of this compound (Extoxnet 1996), summaries prepared by the registrant of glyphosate (Monsanto The Agricultural Group 1995a, b, c, d), risk assessments conducted by the World Health Organization on glyphosate (WHO 1994) and AMPA, a metabolite of glyphosate (WHO 1998), public health goals for concentrations of glyphosate in drinking water prepared by CalEPA (CalEPA 1997; Howd et al. 2000), a reduced risk rationale for Roundup® ULTRA (Wratten 1998), a human health risk assessment on glyphosate and glyphosate formulations published by Williams et al. (2000), as well as a review of environmental concerns with the use of glyphosate (Cox 1998, 2002).

The search of U.S. EPA’s Federal Insecticide, Fungicide, Rodentcide Act/Confidential Business Information (FIFRA/CBI) files indicated that there are 5829 submissions on glyphosate and glyphosate formulations. While many of these studies were conducted to support the initial registration and re-registration of glyphosate, a substantial number of studies (n=1288) were conducted and submitted to U.S. EPA after 1993, the date of the U.S. EPA Re-registration Eligibility Decision document on glyphosate (U.S. EPA/OPP 1993). Because of the extensive published literature on glyphosate, the re-registration document for glyphosate (U.S. EPA/OPP 1993) was used where possible to summarize information for the earlier CBI studies. Although full copies of some key studies (n=47) were obtained from the earlier CBI submissions, the acquisition of the CBI studies focused on the post-1993 period (n=138). Full text copies of the CBI studies [n=185] were kindly provided by the U.S. EPA Office of Pesticide Programs. The CBI studies were reviewed, and synopses of the information that can be disclosed from most relevant studies are included in the appendices to SERA (2003a).

To update the literature on glyphosate for this appendix we searched current publications using PubMed®, TOXLINE®, Google® and Google Scholar®, and new information on glyphosate has been incorporated. The literature database searches focused on publications released from 2002 through July 2005.

For sulfometuron methyl some of the early literature is summarized in earlier risk assessments and environmental impact statements on this compound (USDA 1989a, b, c) as well as a Chemical Background Statement prepared by USDA (1989d). The literature also contains two brief reviews of the toxicology of sulfometuron methyl (Cox 1993, Extoxnet 1994); however there are no detailed reviews regarding the human health or ecological effects of Oust®. Moreover, almost all of the mammalian toxicology studies and most of the ecotoxicology studies are unpublished reports submitted to the U.S. EPA as part of the registration process for this compound.

Because of the lack of a detailed, recent review concerning Oust® and the preponderance of unpublished relevant data in U.S. EPA files, a complete search of the U.S. EPA files was conducted by SERA. Full text copies of all relevant studies were kindly provided by the U.S. EPA Office of Pesticide Programs. The studies were reviewed, and synopses of the most relevant studies are provided in the appendices of previous publications by SERA (1998, 2004a). The U.S. EPA Re-registration Eligibility Decision (RED) document on sulfometuron methyl is scheduled for release in September 2008.

To update the literature on sulfometuron methyl for this appendix we searched current publications using PubMed®, TOXLINE®, Google® and Google Scholar®. No new information on sulfometuron methyl relevant to this analysis was found. The literature database searches focused on publications released from 2003 through July 2005.

The human health risk assessments presented in this appendix are not, and are not intended to be, comprehensive summaries of all of the available information, and these risk assessments do not cite all of the available literature. The level of detail presented in the SERA (1998, 2003a, and 2004a) appendices and the discussions in this ANF risk assessment are intended to be sufficient to support a review of the risk analyses.

The ANF will update this and other similar risk assessments on a periodic basis and welcomes input from the general public on the selection of studies included in the risk assessment. This input is helpful, however, only if recommendations for including additional studies in the body of these risk assessments specify why and/or how the new or not previously included information would be likely to alter the conclusions reached in the risk assessments.

For the most part, the risk assessment methods used in this document are similar to those used in risk assessments previously conducted for the U.S. Forest Service as well as risk assessments conducted by other government agencies. Details regarding the specific methods used to prepare the human health risk assessment are provided in SERA (2001).

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For the most part, the risk assessment methods used in this document are similar to those used in risk assessments previously conducted for the U.S. Forest Service as well as risk assessments conducted by other government agencies. Details regarding the specific methods used to prepare the human health risk assessment are provided in SERA (2001).

SECTION 2. VEGETATION MANAGEMENT PROGRAMS

This section describes the annual herbicide vegetation management programs that the U.S. Forest Service conducts on the ANF. Application methods, equipment, surfactants, and herbicides used in those programs are identified. In addition, mitigation measures used to minimize the possible adverse effects of the herbicides on human health and the environment are referenced. Herbicide application rates for the different methods are also given. More detailed descriptions of the Forest Service vegetation management programs are in the ANF Land and Resource Management Plan (primarily Appendix A).

Program Descriptions

The ANF conducts vegetation management using herbicides to help achieve the following objectives:

- sustain forest cover over the long term,
- restore forest understories to more diverse vegetation conditions,
- maintain tree species diversity in young stands,
- maintain the integrity of improvements (such as electric fences),
- sustain and improve the production of forest products,
- assist in developing and maintaining certain types of wildlife habitat, visual enhancements (such as scenic overlooks), heritage resources, and
- treat/control native and non-native invasive plant species.

Occasionally, forested areas where the understory vegetation has been treated with herbicides may be prescribed burned during subsequent year(s) in order to further enhance oak seedling development. This is referred to as a “brown-and-burn” reforestation activity.

Sustaining Forest Cover, the Production of Forest Products and Maintaining Improvements

The understories of many stands on the ANF contain ground covers of ferns and grass or of understory trees (such as striped maple and thickets of small American beech) that interfere with the development of a wide variety of other species. Occasionally other species (such as birch and *Rubus* spp.) have demonstrated this same ability to interfere. These plants have the ability to completely dominate understory vegetation and to limit the development of a wide variety of desired tree seedlings, shrubs, and herbaceous plants. To control the interfering vegetation, understory vegetation on selected sites is sprayed between July and mid-September with glyphosate and/or sulfometuron methyl, often using a vehicle-mounted sprayer. Generally one pound of glyphosate and/or two ounces of sulfometuron methyl mixed with 25 gallons of water are applied per acre. Hand treatments using selective application techniques are desirable under certain situations. A portion of the overstory trees may be removed to let in more light in order to enhance new seedling and herbaceous plant development.

Glyphosate is a broad-spectrum herbicide that is effective on a wide variety of vegetation species. When ferns are present, the glyphosate sprayed on them is absorbed through the foliage and then translocated through the plant to the underground stem or rhizome. Any part of the rhizome into which the glyphosate does not translocate is capable of forming a new plant. As the spray vehicle passes through the area, its rubber tires or metal tracks sever the rhizome into small segments. Since these segments are no longer attached to the rest of the fern plant, the glyphosate will not reach them. They then can quickly grow to form new fern plants. If not controlled with a second application of glyphosate, the ferns can reinvade the stand within a few years.

In addition, when these areas are partially cut to provide light for new seedlings, the forest floor is disturbed by the logging equipment and the skidding of logs. In many areas, the forest floor contains many seeds of grasses and sedges. These seeds germinate on disturbed areas and sometimes these plants recapture the sites before new trees become established.

Local research and operational experience has shown that a small amount of sulfometuron methyl provides more effective control of ferns, sedges, and grasses (both mature plants and seed banks), thus eliminating the need for a second glyphosate treatment.

Depending on the type of interfering vegetation present, one of several herbicide mixtures will be used: sulfometuron methyl alone, glyphosate alone, or a mixture of the two. All of these will be mixed and applied with 25 gal water/acre. When glyphosate and sulfometuron methyl are applied as a mixture, the same amount of each herbicide is used as when they are applied separately. The spray mixture will not need to contain sulfometuron methyl if the understory does not include ferns, grasses, or sedges. The mixture often includes a spreader or surfactant that helps the herbicide wet the leaves better in order to increase its effectiveness.

In certain young established stands, herbicide treatments are an important tool that can be used to assist in maintaining tree species diversity. Desired tree seedlings or saplings sometimes grow more slowly than other competing vegetation in young, developing forest stands. In order to assure the desired seedlings/saplings survive, we release them by cutting down or treating the taller, competing vegetation. Release can be used to regulate tree species composition to species best suited for either even-aged or uneven-aged management or for site conditions. Release can also promote growth and survival of species not common on the site that are at risk of being killed by species that can outgrow them. Selective cut surface herbicide treatments can be an especially effective release tool when the trees to remove are known sprouters or when stem density is so high that felling the stems would unduly damage the favored residual trees.

Herbicides may also be used to control woody plants, ferns, and grasses to prevent them from contacting and short-circuiting electric fences. Hand treatment methods (such as cut surface, foliar treatment with a backpack applicator, etc.) would normally be most appropriate.

Developing and Maintaining Wildlife Habitat and Visual Enhancements

The same understory species (ferns, grasses, striped maple, beech thickets) that interfere with the establishment and growth of tree seedlings needed to help sustain forest cover can also interfere with the development and maintenance of desired wildlife habitat. Examples include the following:

- Backpack foliar or cut surface herbicide treatments can be used to prepare sites for wildlife shrub plantings or to help maintain them once they have been planted. Backpack foliar application would be used to reduce grass, fern, and weed competition around shrub plantings. Cut surface treatments may be most appropriate to remove encroaching woody vegetation, such as black locust, or to create snags.
- Mechanical foliar herbicide treatments can be used to remove competing vegetation prior to creating warm season grass openings that provide food and cover for a variety of game birds, small mammals, and songbirds. Once grassy openings are established, backpack foliar or cut-surface herbicide treatments can be used to selectively remove unwanted vegetation that is invading the site.

Backpack foliar or cut surface herbicide treatments can also be used to help create or maintain scenic vistas. This technique involves selectively treating small woody vegetation that can grow or has grown tall enough to block the view or by selectively treating cut stumps in order to prevent unwanted sprouting. The treatment would help maintain long-term scenic quality objectives.

Selective treatments can also be used to help protect heritage resource sites from unwanted damage caused by the roots of woody vegetation growing or spreading on the site.

Treat/Control Native and Non-native Invasive Plant Species

In February 1999, President Clinton issued Executive Order 13112, to “prevent the introduction of invasive species and provide for their control and to minimize the economic, ecological, and human impacts that invasive species cause.”

The order calls on Federal agencies to:

(i) prevent the introduction of invasive species,
(ii) detect and respond rapidly to and control populations of such species in a cost effective and environmentally sound matter,
(iii) monitor invasive species populations accurately and reliably,
(iv) provide for restoration of native species and habitat conditions in ecosystems that have been invaded,
(v) conduct research on invasive species and develop technologies to prevent introductions and provide for environmentally sound control of invasive species; and
(vi) promote public education on invasive species and the means to address them.

Executive Order 13112 (1999) defines alien (non-native) species as “with respect to a particular ecosystem, any species including its seeds, eggs, spores, or other biological material capable of propagating that species, that is not native to that ecosystem.” An invasive species is defined as “an alien species whose introduction does or is likely to cause, economic or environmental harm or harm to human health.”

Approximately 20 to 30 percent of the plants that occur in the northeastern U.S. are non-native species. A subset of these plants can alter natural ecosystems in several ways, including replacing native species with exotic species, inducing changes in water or fire regimes, causing changes in soil characteristics, adding a new or displacing an existing wildlife food source, and altering erosion and sedimentation processes. Of the approximately 1, 200 plant species listed for the ANF, over 250 are non-native species, and a subset of those are considered the most troublesome.

The most effective approach for invasive plant management is prevention, followed by the removal of new or scattered populations, and finally tackling the heavy infestations from the outside edges inward. It is also very important to assess the quality of the habitat being invaded, which species should be ‘restored’ to the site, estimating the resources needed to meet management goals, and knowing when not to undertake a treatment project. Successful invasive plant management is a long-term endeavor. Except in the earliest stages of invasion, complete eradication is unlikely.

Types Of Application Methods And Herbicide Usage

There are two basic methods of herbicide application used on the ANF:

1. Mechanical ground application, which requires using vehicle mounted equipment; and
2. Manual ground application, which requires hand-carried equipment, and includes the following treatment techniques:
   - Foliar spraying using backpack equipment and
   - Cut surface treatment (such as cut stump, frill or girdle, and tree injection) using various types of equipment (chainsaw and squirt bottle, hatchet/axe and squirt bottle, tubular tree injector, and injector hatchets).

Both glyphosate and sulfometuron methyl are applied as a foliar spray. Only glyphosate is applied as a cut surface treatment. The herbicide formulations containing glyphosate or sulfometuron methyl and the specific surfactants covered by this analysis are in Table 1.

Table 1. Commercial herbicide formulations and surfactants covered by this appendix

Commercial Product	Type of Product	Active Ingredient or Constituents
Accord Concentrate®	Herbicide	Glyphosate
Rodeo®	Herbicide	Glyphosate
Glypro®	Herbicide	Glyphosate
Foresters®	Herbicide	Glyphosate
Oust®	Herbicide	Sulfometuron Methyl
Oust XP®	Herbicide	Sulfometuron Methyl
Timberland 90®	Surfactant	*
Chemsurf 90®	Surfactant	*
Alenza 90®	Surfactant	*
Red River 90®	Surfactant	*
Red River Adherent 90®	Surfactant	*

* The active ingredients or constituents of the surfactants include one or more of the following: Alkylarylpolyoxyethylene ether, isopropanol, free fatty acids, Alkylphenol ethoxylate, Alkylarylpolyoxykane ether, Dimethylpolysiloxane, and Alkylarylpolyoxyethylene glycols.

Sustaining Forest Cover, the Production of Forest Products, and Maintaining Improvements

Mechanical Ground Application Method

Mechanical ground application equipment is used to prepare sites for regeneration or occasionally to prepare sites for wildlife habitat improvement planting. On the ANF the equipment consists of a rubber-tired or tracked skidder with an open cab and rear-mounted spray equipment. Mixtures of liquids and/or dry products diluted with water are used. These are applied using broadcast air blast spraying with the vehicle operator exercising control of the spraying (on/off, direction of application, timing, coordination with weather conditions, etc.).

The following example describes one type of equipment in use. The spray system is calibrated to apply 25 gallons per acre of herbicide mixture. There are two types of spray apparatus mounted on the rear of the vehicle: flat fan nozzles (median droplet diameter of 500 microns) that spray down and to the sides from the back of the vehicle and cover the area behind the vehicle and to the sides out to where the air blast hits the ground, and the air blast sprayer mounted on the rear of the vehicle which sprays out of both sides of the vehicle. The effective spray swath width is 40 feet out of each side. The normal operating pressure is 30 to 40 pounds per square inch (psi), and the fan produces a blast of air traveling at 110 MPH. This air blast flows around and past the nozzles and picks up the spray liquid as it leaves the nozzles. The nozzles are disc-core type cone spray nozzles, which produce a median droplet diameter (by volume) of 800 microns.

This air blast technique allows the spray mixture to penetrate dense ground cover, thus giving the droplet dispersal required to effectively treat most of the target vegetation. The vehicle carries a 500-gallon tank, the contents of which can generally be applied to 20 acres of under-story vegetation in 1 to 1.5 hours, depending on the terrain. The operator controls spraying with on/off switches in the cab for each side or the rear boom, and a Raven computer spray system. The Raven spray system monitors the sprayer ground speed and opens and closes a valve to increase or decrease the volume of spray being sent to the spray nozzles to maintain the calibrated application rate per acre. This system also shuts off the spray as the vehicle stops, or starts it again as the vehicle starts to move. The Raven computer system also records and displays the amount of acreage treated and the amount of spray mix applied.

Workers on the site usually include an equipment operator, a nurse truck driver, and a Forest Service inspector. The equipment operator and the nurse truck driver generally share the job of mixing and loading. Mixer/loaders can be accidentally exposed as a result of a splash or spill of herbicides or a ruptured or disconnected hose. The operator would be exposed to spray drift only during an exceptional situation since the high wind generated by the equipment carries the spray away from the cab.

The sprayer utilizes a global positioning system (GPS) guidance system that provides uniform swath widths and guides the operator to stay on the swath centerline while spraying. Before spraying begins, the Forest Service inspector provides the sprayer operator with a map of the spray area and discusses important features or concerns. The operator starts unit treatment by making a first pass around the outside boundary that is well-flagged. The Forest Service inspector walks through the area at a safe distance from the sprayer, maintaining radio contact with the sprayer operator in order to provide guidance or to respond to questions from the operator. After the first pass around the boundary, the GPS guidance system computes the swaths and guides the sprayer operator while following them through the treatment of the remainder of the unit. About 25 percent of the time the GPS system may not provide guidance due to atmospheric conditions, the density of the timber stand, or the slope of the unit, in which case the operator relies on observing his previous track in order to follow parallel swaths. The nurse truck driver does not enter the treatment unit unless the sprayer breaks down.

The spray mixture generally does not drift outside of the spray area, as has been confirmed through observation of Forest Service inspectors and through recent monitoring. There are several in-house reports that provide the specifics of the monitoring program (typically these are included in Monitoring and Evaluation Reports for specific fiscal years). These show no detectable herbicide in streams in 1987, 1988, 1989, and 2002 (Table 11). Chemical analysis of water was not conducted in other years. Visual monitoring for herbicide damage to vegetation was conducted in 2003 and 2004 and shows little or no damage to vegetation outside of the intended treatment area. Spraying on the ANF will generally be conducted below a closed forest canopy where winds rarely exceed four mph and droplets are intercepted by leaves, standing tree stems and vegetation, thus minimizing the potential for off-site drift.

Spraying is halted when winds exceed 10 mph in the open or four mph under the forest canopy. If the boundary of the unit is located next to private land, a seeded landing, a pipeline or power line, a buffer around water, or a road with a ditch where the existing vegetation is desired, the sprayer operator will follow the boundary as closely as possible, shutting off the outside sprayer and directing the spray only toward the inside of the unit. On additional passes, the operator sprays out of both sides of the machine. By then, the equipment is 80 feet away from the edge of the unit, and there is little opportunity for the spray to drift outside of the area.

To load the sprayer, the current contractor implements the following process. If another contractor were awarded the contract, the loading process may be slightly different. The sprayer pulls next to the nurse truck, which has a fold down walkway on one side of the truck. The sprayer tank lid is opened, and the amount of remaining tank mix is read from the 50 gal calibration tabs welded on a stainless steel rod inside of the tank. This measurement is used to calculate the amount of mix applied since the last fill-up as a means of checking the computer-calculated number to help ensure that the spray computer has not lost calibration. Then a calculated amount of water is pumped into the tank from the nurse truck’s 2,035 gallon tank through a 2 inch hose held in the tank opening. The water nozzle is placed in a “loading tube” that has a hole on one side and runs down to the bottom of the tank. This loading tube causes the added water to swirl, and therefore agitate the water and remaining mix in the tank. While the water is being added the chemicals are added: the Oust® by measuring the dry powder with the measuring tubes provided by the manufacturer and then pouring the powder into the tank; the Accord Concentrate® by pumping from the field pack, which has an electric pump and flow meter, into the top of the tank; and the surfactant by pouring out of the 2 1/2 gallon jugs into the top of the tank.

After the chemicals and water are added, the spray engine is started which starts the pump that continues to circulate and agitate the chemicals while the sprayer is driven back to the spray block. The return mix line from the pump has 2 jet nozzles in the tank, which cause violent agitation inside the tank. The chemicals are stored in a locked box on the rear of the nurse tank. The notebook for recording the chemical use and application is also kept handy in the locked storage box.

Mechanical airblast spraying on the ANF produces median droplet diameter of 800 to 1300 microns versus the 400 micron droplets used in SERA (2003 a) AgDRIFT modeling. The ANF droplets are dispersed by a strong blast of air rather than solely by a pressurized spray from a nozzle, but the larger median droplet diameter in ANF programs should mitigate and produce drift that is not greater than predicted by SERA. Therefore drift predicted by AgDRIFT and SERA are conservative for the circumstance on the ANF. Note that earlier versions of the Forest Service worksheets are the basis for the AgDRIFT estimates. Worksheet A06 is no longer available on the U.S. Forest Service website. For human health risk assessment, drift off site is not a factor since all analyses are based on deposition rates that occur on site. Thus, risk from off site drift will be less than direct deposit on site; so the risk analyses in the risk analysis section (Section 5) provide a conservative estimate of risk related to off site drift. Drift is an issue and is included in the wildlife risk analyses in Appendix G2.

Manual Ground Application Methods

Manual ground application would be used in areas where a larger mechanical power unit is not practical or where a very selective treatment is desirable.

Foliar spraying using backpack equipment

The number of workers involved in manual ground applications ranges from two to eight people according to the project size and type of activity. When treating scattered vegetation, a backpack spray applicator typically covers 0.5 to 1 acres/hour, depending on the terrain and the density of the vegetation. However, the vegetation treated usually consists of scattered patches on each acre, and only an average of ten percent of each acre is actually sprayed. Generally a backpack spray unit with a hand operated diaphragm pump, or small engine driven pump, and spray gun or wand is used to apply the herbicide. The same backpack equipment may be used for treating areas inaccessible to large equipment because of steep or rocky terrain. Selective foliar spraying can be used to effectively control competing vegetation around planted seedlings.

Both of these treatment methods spray coarse droplets onto the foliage of understory plants. Herbicides can be applied between the end of the July 4 weekend and the end of September when plants are fully leafed-out, green, and growing. Treated vegetation is generally low growing, and spray drift is negligible.

These techniques are similar to the directed foliar spray application technique described in SERA(2003a, p. 2-3). SERA notes that in directed foliar applications, the herbicide sprayer is carried by backpack and the herbicide is applied to selected target vegetation. Application crews may treat up to shoulder high brush, which means that chemical contact with the arms, hands, or face is plausible. To reduce the likelihood of significant exposure, application crews are directed not to walk through treated vegetation. However the vegetation treated on the ANF is generally shorter (generally below shoulder height). Personnel applying herbicides may be exposed to herbicides and additives during mixing, loading, application, or cleanup operations. Inadvertent exposure may occur by direct or indirect contact with spray, a spill, or as a result of failed equipment, such as a disconnected or ruptured hose, a leaky gasket or washer, or a leaky nozzle.

Cut Surface Treatment

Cut-surface treatments are used to selectively eliminate woody species that are competing with the desired vegetation. This method is appropriate where broadcast mechanical spraying is not appropriate, where the woody stems are too tall for broadcast mechanical or backpack foliar treatment, or where lower stem density or the need to protect nearby desired species makes selective treatment more desirable. Tree injection, frill or girdle, and cut-stump treatments are common types of cut-surface treatments. Only glyphosate, formulated as a liquid herbicide, would be considered for this type of treatment. Cut surface techniques evaluated for the ANF are similar to the cut surface techniques evaluated and described in SERA(2003a, p. 2-3). While available data regarding worker exposure from cut surface treatments suggest lower worker exposure rates than for backpack foliar treatment, SERA used the better documented backpack foliar exposure data as a surrogate for cut surface treatments (SERA 2001-01a, p 4-8). The same approach is taken for this ANF analysis.

These methods can be used throughout the year on virtually any sized tree, but on the ANF they will generally be used only during the growing season (June 1 to Oct 1) and primarily on trees less than eight inches diameter at breast height (DBH). Care would be taken to match the timing of the treatment with the most effective treatment window for individual species. Various types of equipment are commonly used to accomplish this method, including a hatchet and a squirt bottle, a chainsaw and a squirt bottle, a tubular tree injector, and injector-hatchets.

Tree injection (in which the cambium of the target tree is exposed using a blade mounted on the tree injector and an herbicide solution is deposited in the cut) is most efficient on sites with a lower density of stems to treat and for stems greater than 1.0 inch DBH. Incisions are generally spaced about 1.5 inches apart on the stem, and about 1.5 ml of herbicide solution is dispensed into each incision.

The frill or girdle method involves cutting through the bark of a tree into the sapwood with an ax or hatchet. Then the cut surface is completely wet with herbicide. Wood chips produced during the cutting are not removed, but are left to help hold the herbicide in the cut.

Effective control using tree injection or cut and frill techniques generally requires a 25 to 100% concentration of herbicide product mixed with water, depending on the species. A 50% solution would be the most common used on the ANF.

The cut stump method involves cutting off the stem near ground level, generally using a chainsaw. A pressurized backpack sprayer or a squirt bottle is then used to thoroughly wet the cambial area (generally the outer two inches) of the freshly cut stump with herbicide within one hour of cutting. Effective control usually requires a 50 to 100% concentration of herbicide mixed with water, with 50% the most common solution used.

Application Rates and Acres Treated Per Year

Table 2 shows the anticipated central, lower, and upper application rates of glyphosate and/or sulfometuron methyl when they are used to accomplish the objective of *Sustaining Forest Cover and the Production of Forest Products*. The central rate is a typical rate used in the ANF. The upper rate is the maximum anticipated rate, while lower is the minimum anticipated rate used in the ANF. Use of these designations is consistent with the terminology used in the SERA documents. The upper foliar rate is rarely used; when it is, it generally consists of a retreatment the following season in areas where vegetation has been inadequately controlled.

Table 2. Anticipated central, lower, and upper application rates in pounds per acre of active ingredient (a.i.) and acid equivalents (a.e.) for "Sustaining Forest Cover and the Production of Forest Products" in the ANF

Application Method	Tank Mixture gal/acre	Glyphosate[1]						Sulfometuron Methyl		
		a.i. (lb/acre)			a.e. (lb/acre)			a.i. (lb/acre)		
		lower	central	upper	lower	central	upper	lower	central	upper
Mechanical (broadcast foliar) Airblast	25	0.8	1.0	2.0	0.6	0.75	1.5	0.07	0.09	0.19
Manual (directed foliar) Backpack /hand sprayer	25	0.5	1.0	2.0	0.38	0.75	1.5	0.045	0.09	0.19
Cut surface[2]	0.25-0.75	1.0	2.0	3.0	0.75	1.5	2.25	0	0	0

[1] Assumes 4 lb a.i./gallon = 3 lb a.e./gallon
[2] Assumes 100% concentrate

Table 3 shows the typical and maximum anticipated number of acres treated in accomplishing the objective of *Sustaining Forest Cover and the Production of Forest Products*. Some of the acres shown for treatment in Table 3 are located in riparian areas. These riparian treatments are designed to help sustain forest cover and to restore forest understories to more diverse vegetation conditions. Sulfometuron methyl would be used in riparian areas to control invasive grasses.

Table 3. Typical and maximum anticipated number of acres treated per year for "Sustaining Forest Cover and the Production of Forest Products" in the ANF for 2006-2020

Application Method	Glyphosate	Sulfometuron Methyl
Mechanical (broadcast foliar) Airblast	1300 [3500]	2000 [3500]
Manual (directed foliar) Backpack/hand sprayer	180 [300]* *58[117] riparian areas*	180 [300]* *47[94] riparian areas*
Cut Surface	300 [450]* *12[24] riparian areas*	0 [0] *0[0] riparian areas*

[ ] Maximum acreage anticipated
* Includes acres in riparian areas; The numbers of acres that fall within riparian areas is in italics

Developing and Maintaining Wildlife Habitat, Heritage Resources, and Visual Enhancements

Mechanical Ground Application Methods

Application techniques would include the air blast treatment technique described above for maintaining forest cover and tree species diversity. In areas already open, other broadcast application techniques, such as tractor or all terrain vehicles (ATV) mounted sprayers, may also be appropriate. Broadcast mechanical ground application techniques generally are not appropriate for maintaining heritage resources and visual enhancements. Glyphosate would be appropriate for all three types of sites, whereas sulfometuron methyl generally would only be used to help develop or maintain wildlife habitat.

Manual Ground Application Methods

Backpack foliar spraying and cut surface treatments, described above for maintaining forest cover and tree species diversity, are appropriate application techniques for maintaining wildlife habitat, visual enhancements, and heritage resources. Glyphosate would be appropriate for all three types of sites, whereas sulfometuron methyl generally would only be used to help develop or maintain wildlife habitat.

Application Rates And Acres Treated Per Year

Table 4 shows the anticipated central, lower, and upper application rates of glyphosate and/or sulfometuron methyl when they are used to accomplish the objective of "Developing and Maintaining Wildlife Habitat, Heritage resources and Visual Enhancements.

Table 4. Anticipated central, lower, and upper application rates in pounds per acre of active ingredient (a.i.) and acid equivalents (a.e.) for "Developing and Maintaining Wildlife Habitat, Heritage resources and Visual Enhancements" in the ANF

Application Method	Tank Mixture gal/acre	Glyphosate[1]						Sulfometuron Methyl		
		a.i. (lb/acre)			a.e. (lb/acre)			a.i. (lb/acre)		
		lower	central	upper	lower	central	upper	lower	central	upper
Mechanical (broadcast foliar) Airblast	25	0.8	1.0	2.0	0.6	0.75	1.5	0.07	0.09	0.19
Manual (directed foliar) Backpack/hand sprayer	25	0.5	1.0	2.0	0.38	0.75	1.5	0.045	0.09	0.19
Cut surface[2]	0.25-0.75	1.0	2.0	3.0	0.75	1.5	2.25	0	0	0

[1] Assumes 4 lb a.i./gallon = 3 lb a.e./gallon
[2] Assumes 100% concentrate

Table 5 shows the typical and maximum anticipated number of acres treated in accomplishing the objective of *Developing and Maintaining Wildlife Habitat, Heritage Resources and Visual Enhancements.*

Table 5. Typical and maximum anticipated number of acres treated per year for "Developing and Maintaining Wildlife Habitat, Heritage Resources and Visual Enhancements" in the ANF for 2006-2020

Application Method	Glyphosate	Sulfometuron Methyl
Mechanical (broadcast foliar) Airblast	10 [20]	10 [20]
Manual (directed foliar) Backpack/hand sprayer	30 [60]* *3[6] riparian areas*	25 [50]* *2[4] riparian areas*
Cut Surface	10 [25]* *2[4] riparian areas*	0 [0] *0[0] riparian areas*

[ ] Maximum acreage anticipated
* Includes acres in riparian areas; The numbers of acres that fall within riparian areas is in italics

Treatment/Control of Native and Non-native Invasive Species

Herbicide treatment of invasive plants will occur in conjunction with other treatment methods including hand-pulling, cutting, and weed whacking and mowing sometimes followed by cultivation and seeding with desired native species. Judicious use of herbicides is key in conserving and restoring plant diversity. Site conditions to be considered before any herbicide application is proposed include assessing the target species (its life stage, amount of infestation, specific threats, etc.), seasonal timing of application for most effective treatment, the presence of desirable or rare species, accessibility, soil types, location of surface water, depth to groundwater, potential for off site drift, human safety and monitoring opportunities. The herbicide treatment window for invasive plants ranges from March to October, depending on growing conditions (site, temperature, precipitation, etc.) and the particular species itself. Depending on the site, i.e., presence of water, and the plant species, surfactants and/or dyes may be added for more effective treatment.

The majority of invasive plant species of concern are shade intolerant and occur along roads, right-of-ways and openings. Most areas of infestation are small and scattered. Infestations of some species adjacent to streams and rivers are long linear areas. Travel time between infestations is assumed to be greater than for reforestation treatments. Worker days and exposures are based on one, two-person crew.

Mechanical Ground Application Method

Mechanical ground application equipment may be used in areas with extensive invasive plant cover on upland or drier sites. Species such as Canada thistle (*Cirsium arvense*), buckthorns (*Rhamnus sp*.), Japanese and giant knotweed (*Polygonum cuspidatum* and *P. sachalinense*) often form dense monocultures where broadcast treatment would be more effective. Where knotweeds grow along stream and river corridors, the preferred treatment technique would be foliar spraying using backpack equipment. As mentioned previously mechanical ground equipment consists of a rubber-tired or tracked skidder with an open cab and rear-mounted spray equipment. In this case, mixtures of liquid products (glyphosate and surfactant) diluted with water are used. Sulfometuron methyl may be used to control seed/rhizome development for certain species. These are applied using broadcast air blast spraying with the vehicle operator exercising control of the spraying (on/off, direction of application, timing, coordination with weather conditions, etc.).

Manual Ground Application Methods

The primary method of herbicide application for invasive plant species includes both foliar spraying using backpack equipment and cut surface treatment. Glyphosate is the primary herbicide to be used for both foliar and cut stump treatment. Sulfometuron methyl may be used to control seed/rhizome development for certain species.

Foliar spraying using backpack equipment

Herbicides would be applied to invasive plant species using spot treatment. Spot treatment consists of various techniques for applying herbicides to target plants without impacting desirable vegetation and other non-target organisms. The potential for herbicide drift would be less with spot treatment. Spot treatment includes manual ground application, which requires hand-carried or ATV mounted equipment. ATV units consist of a tank with a hand-held wand for manual application. Hand cutting of some species throughout the growing season may be necessary prior to spraying foliage (to keep foliage at a treatable height) during their peak translocation time. Species such as Japanese knotweed (*Polygonum cuspidatum*) and Giant knotweed (*Polygonum sachalinense*) grow too tall for foliar treatment during late summer-early fall, during its peak translocation time. These species may also be treated with herbicide 2-3 times during the growing season when foliage is below waist level. Where abundant propagules exist (seeds, rhizomes, etc.) that are not susceptible to foliar treatment, new infestations and resprouting vegetation may also need to be retreated during subsequent growing seasons. Alternatively, sulfometuron methyl may be used to help prevent these abundant propagules from recapturing the site for species such as Japanese stiltgrass (*Microstegium vimineum*) and spotted knapweed (*Centaurea biebersteinii*). Typical foliar glyphosate application rates range from 1% (4 oz a.i./ 3 gal water) to 2% (8 oz a.i./ 3 gal water) solution of active ingredient. Where retreatment is necessary, the total amount applied per acre during the entire treatment period could be twice these amounts (Miller 2002; Tu et al. 2001).

Cut Surface Treatment

Cut-surface treatments are used to selectively eliminate invasive woody species that are competing with the desired vegetation. This method may be used on plants where the woody stems are too tall for broadcast mechanical or backpack foliar treatment, or where lower stem density or the need to protect nearby desired species makes this type of selective treatment more desirable. Injection, frill or girdle, and cut-stump treatments are common types of cut-surface treatments. Only glyphosate, formulated as a liquid herbicide, would be used for this type of treatment.

Typical cut stem glyphosate application rate is a 25% solution (32 oz a.i./1 gal water) with a maximum 50% solution for retreatment or hard to control species. Rates may vary by species and size of the plant (Miller 2002; Tu et al. 2001).

Application Rates and Acres Treated Per Year

Table 6 shows the anticipated central, lower, and upper application rates of glyphosate and/or sulfometuron methyl when they are used to accomplish the objective of *Controlling Non-native Invasive Species*.

Table 6. Anticipated central, lower, and upper application rates in pounds per acre of active ingredient (a.i.) and acid equivalents (a.e.) for "Controlling Native and Non-native Invasive Species" in the ANF

Application Method	Tank mixture gal/acre	Glyphosate[1]						Sulfometuron Methyl		
		a.i. (lb/acre)			a.e. (lb/acre)			a.i. (lb/acre)		
		lower	central	upper	lower	central	upper	lower	central	upper
Mechanical (broadcast foliar) Airblast	25	0.8	1.0	2.0	0.6	0.75	1.5	0.07	0.09	0.19
Manual (directed foliar) Backpack/hand sprayer	25	1.0	2.0	4.0	0.75	1.5	3.0	0.045	0.09	0.19
Cut surface[2]	0.13-0.50	0.5	1.0	2.0	0.38	0.75	1.5	0	0	0

[1] Assumes 4 lb a.i./gallon = 3 lb a.e./gallon
[2] Assumes 100% concentrate

Table 7 shows the typical and maximum anticipated number of acres treated in accomplishing the objective of "Controlling Native and Non-native Invasive Species."

Table 7. Typical and maximum anticipated number of acres treated per year for "Controlling Native and Non-native Invasive Species" in the ANF for 2006-2020

Application Method	Glyphosate	Sulfometuron Methyl
Mechanical (broadcast foliar) Airblast	5 [10]	2 [4]
Manual (directed foliar) Backpack/hand sprayer	30 [60]* *3[6] riparian areas*	3 [6]* *1[2] riparian areas*
Cut Surface	15 [30]* *2[4] riparian areas*	0 [0] *0[0] riparian areas*

[ ] Maximum acreage anticipated
* Includes acres in riparian areas; The numbers of acres that fall within riparian areas is in italics

Personal Protective Equipment

The type of clothing worn during herbicide application is an important determinant of the exposure of workers. On the ANF, all persons who might come into contact with the spray solution are required, under the terms of the Job Hazard Analysis or the contract, to wear eye protection, a long sleeved shirt, long pants, and a mask. The person conducting the mixing and loading must wear rubber gloves. Soap, water, and eyewash bottles are available at each worksite.

Mitigation Measures

Measures intended to ensure the proper and safe application of herbicides on lands managed by the U.S. Forest Service are required by federal and state laws and regulations and by U.S. Forest Service policy. Federal and state laws and regulations set the minimum standards followed during herbicide application on the ANF.

Additional guidelines are set in Section 2150 of the *Forest Service Manual* and the *Forest Service Pesticide Use Management and Coordination Handbook* (FSH 2109.14).

The ANF has developed additional restrictions, selection criteria and precautions, which are listed as follows in the revised ANF Land and Resource Management Plan:

- Forest-wide design criteria, subsection 2100 Environmental Management–Pesticide Use standards and guidelines.
- Appendix A "Rationale for Choice of Vegetation Management Practices," site selection and herbicide selection criteria.

SECTION 3. GLYPHOSATE HAZARD ANALYSIS

The glyphosate hazard analysis draws heavily, but not verbatim in all cases, on SERA (2003a). The purpose of the hazard analysis is to identify the most critical measures of toxicity. The most sensitive measure is expressed as the reference dose (RfD).

Overview and Summary

SERA (2003 a, b) conducted their risk analysis with formulations of glyphosate in one of two categories, more or less toxic. While SERA is not explicit in identification of formulations in specific categories, based on the toxicity classification used by EPA and cited by SERA formulations with LC_{50} values of 60 mg/L would include formulations in the slightly toxic category (10-100 mg/L) and 1000 mg/L is in the practically non toxic category (>100 mg/L). Using this guideline Accord Concentrate®, Rodeo® and Glypro® meet the arbitrary cut-off for toxicity of no more than slightly toxic and would be in the less toxic grouping of SERA. Foresters with a LC_{50} of 1000 mg/L is obviously in the less toxic group. Therefore in this risk analysis we treat all four herbicide formulations as being in the less toxic group from the analyses by SERA.

Sometimes it is helpful to see an array of toxicity values. While there are many such values in the text, following are a few that may provide some useful information (Table 8). Note that while these values are reported in the text of Appendix G1 and Appendix G2, none of these is the critical toxicity value used in the human health risk assessment. The critical toxicity value for the human health risk assessment is the EPA Reference Dose (RfD) of 2 mg/kg/day, as reported in the text. These values are for illustrative purposes only.

Table 8. Some toxicity values for glyphosate

Organism	Type of Toxicity	Measure of Toxicity	Form of Glyphosate
Mammal (rat, mouse)	Acute Oral LD_{50}	2,000 to 6,000 mg/kg	Technical Glyphosate
Mammal (rat)	Multi-Generation Reproduction LOAEL	30 mg/kg/day	Technical glyphosate
Mammal (rabbit, rat)	Acute Dermal LD_{50}	> 2000 mg/kg	All formulations tested
Mammal (rat)	4-hour inhalation LC_{50}	> 2.6 mg/L	Various formulations tested
Bird (bobwhite quail and mallard duck)	Acute LD_{50}	> 4640 mg/kg	Technical glyphosate
Fish	LC_{50}	> 1000 mg/L	Foresters®
Fish	LC_{50}	>1000 mg/L	Accord Concentrate®
Fish	LC_{50}	60 mg/L	Rodeo®
Fish	LC_{50}	60 mg/L	Glypro®

The herbicidal activity of glyphosate is due primarily to the inhibition of the synthesis of certain aromatic amino acids in plants and microorganisms. This metabolic pathway does not occur in humans or other animals and thus this mechanism of action is not relevant to the human health risk assessment. Two specific biochemical mechanisms of action have been identified or proposed for glyphosate: uncoupling of oxidative phosphorylation and inhibition of hepatic mixed function oxidases. Glyphosate will damage mucosal tissue, and many of the effects of acute oral exposure to high doses of glyphosate are consistent with corrosive effects on the mucosa.

Sorption

Glyphosate is not completely absorbed after oral administration and is poorly absorbed after dermal applications. Two dermal absorption studies have been published on glyphosate, and both of these studies indicate that glyphosate is very poorly absorbed across the skin.

Acute effects

Like all chemicals, glyphosate as well as commercial formulations of glyphosate may be toxic at sufficiently high exposure levels. In rats and mice, acute oral LD_{50} values of glyphosate range from approximately 2,000 to 6,000 mg/kg. Gastrointestinal effects (vomiting, abdominal pain, diarrhea), irritation, congestion, or other forms of damage to the respiratory tract, pulmonary edema, decreased urinary output sometimes accompanied by acute renal tubular necrosis, hypotension, metabolic acidosis, and electrolyte imbalances, probably secondary to the gastrointestinal and renal effects, are seen in human attempted suicide cases.

Subchronic or chronic effects

One of the more consistent signs of subchronic or chronic exposure to glyphosate is loss of body weight, as noted in mice, rats, dogs, and rabbits. This observation is consistent with experimental data indicating that glyphosate may be an uncoupler of oxidative phosphorylation. Other signs of toxicity seem general and non-specific. A few studies (authors note, presumably in one or more of the species cited above) report changes in liver weight, blood chemistry that would suggest mild liver toxicity, or liver pathology. Changes in pituitary weight have also been observed. Signs of kidney toxicity, which might be expected based on the acute toxicity of glyphosate, have not been reported consistently and are not severe. Various hematological changes have been observed that may be secondary to mild dehydration.

Neurotoxicity

Glyphosate has been tested for neurotoxicity in rats after both acute and subchronic exposures and has been tested for delayed neurotoxicity in hens. In both the animal data as well as the clinical literature involving suicide attempts, there is no clear pattern suggestive of a specific neurotoxic action for glyphosate or its commercial formulations. The weight of evidence suggests that any neurologic symptoms associated with glyphosate exposures are secondary to other toxic effects. No studies are reported that indicate morphologic abnormalities in lymphoid tissues, which could be suggestive of an effect on the immune system.

Endocrine system

The endocrine system is composed of a group of glands (pituitary, thyroid, parathyroid, adrenal, thymus, ovaries, testes and others) that maintain a stable internal environment by producing chemical regulatory substances called hormones. Chemicals that mimic hormones can disrupt the endocrine system. Only three specific tests on the potential effects of glyphosate on the endocrine system have been conducted, and all of these tests reported no effects. Nonetheless, glyphosate has not undergone an extensive evaluation for its potential to interact or interfere with the estrogen, androgen, or thyroid hormone systems; so caution in this assessment of the potential endocrine effects of glyphosate may be warranted.

Reproductive system effects

Glyphosate has been subject to multi-generation reproduction studies, which measure overall effects on reproductive capacity, as well as teratology studies, which assay for a compound's ability to cause birth defects. Signs of teratogenic activity have not been observed in standard assays in both rats and rabbits. In a multi-generation reproduction study in rats, effects on the kidney were observed in male offspring. This effect is consistent with the acute systemic toxicity of glyphosate, rather than a specific reproductive effect. Several other subchronic and chronic studies of glyphosate have been conducted with no mention of treatment-related effects on endocrine glands or reproductive organs.

A single study has reported substantial decreases in libido, ejaculate volume, sperm concentrations, semen initial fructose and semen osmolality as well as increases in abnormal and dead sperm in rabbits after acute oral exposures to glyphosate. This study is inconsistent with other studies reported on glyphosate and is poorly documented, i.e., specific doses administered to the animals are not specified. Numerous epidemiological studies have examined relationships between pesticide exposures or assumed pesticide exposures in agricultural workers and reproductive outcomes. Of those studies that have specifically addressed potential risks from glyphosate exposures, adverse reproductive effects have not been noted.

Carcinogenicity

Based on standard animal bioassays for carcinogenic activity in vivo, there is no basis for asserting that glyphosate is likely to pose a substantial cancer risk. The Re-registration Eligibility Decision document on glyphosate prepared by the U.S. EPA indicates that glyphosate is classified as Group E: Evidence of non-carcinogenicity for humans. This classification is also indicated in U.S. EPA's most recent publication of tolerances for glyphosate and is consistent with an assessment by WHO. This assessment has been challenged, and it may remain a cause of concern (at least in terms of risk perception), but there is no compelling basis for challenging the position taken by the U.S. EPA. No quantitative risk assessment for cancer is conducted as part of this ANF risk assessment. .

Eye and skin irritation

Glyphosate formulations used in the ANF are classified as either non-irritating or only slightly irritating to the skin and eyes in standard assays required for product registration. While there have been no known calls associated with ANF programs, based on a total of 1513 calls (nationwide) to a poison control center reporting ocular effects associated with the use of Roundup®, 21% were associated with no injury, 70% with transient minor injury, and 2% with some temporary injury. The most frequently noted symptoms included blurred vision, a stinging or burning sensation, and lacrimation. No cases of permanent damage were reported. ANF is not proposing the use of Roundup®.

Inert ingredients

Prior to about 1996 some glyphosate formulations contained POEA surfactant at a level of up to about 20%. This surfactant is not in any of the formulations proposed for use by the ANF as covered in this risk assessment. Some formulations of glyphosate contain other surfactants or recommend the use of a surfactant to improve the efficacy of glyphosate. While surfactants are typically classified as “inert” ingredients in herbicides, these compounds are not toxicologically inert and some surfactants may be more toxic than the herbicides with which they are used.

The EPA has several lists (classes) of inert ingredients in pesticides (USEPA 1994). Specifically:

List 1 = Toxicological concern;
List 2 = Potentially toxic with high priority for testing;
List 3 = Unknown toxicity; for inerts where “there was no basis for placing it on any of the other lists. The Agency will continue to evaluate these chemical substances, as additional information becomes available, to determine if reclassification to List 1, 2, or 4 is appropriate.”
List 4 = minimal concern, further subdivided into List 4A = classified in U.S. EPA, 1987 as List 4, and List 4B for inerts with “*sufficient information to conclude that current use patterns in pesticide products will not adversely affect public health and the environment.”*

All of the surfactants included in this ANF program have inert ingredients that are on EPA's inert classification lists 3 or 4b.

Detailed Information

Mechanisms of Action

While the mechanism of action of glyphosate in plants is well characterized, the mechanism by which glyphosate exerts toxic effects in humans or experimental mammals is not clear. Two specific biochemical mechanisms of action have been identified or proposed: uncoupling of oxidative phosphorylation and inhibition of hepatic mixed function oxidases. In addition glyphosate can damage mucosal tissue.

Oxidative phosphorylation is a metabolic process in which energy derived from the oxidation of nutrients is transferred to and stored in high-energy phosphate bonds. The uncoupling of this process results in energy loss in the organism and leads to death. Symptoms of uncouplers of oxidative phosphorylation include increased heart rate (tachycardia), increased respiratory rate, labored breathing, profuse sweating, fever, metabolic acidosis, and weight loss (ATSDR 2001).

Based on a series of experiments using rat liver mitochondria exposed to the isopropanolamine salt of glyphosate without any surfactant (summarized in detail by U.S. EPA 1992), glyphosate appears to be an uncoupler of oxidative phosphorylation. This effect has been noted after intraperitoneal doses as low as 15 mg/kg (Olorunsogo et al. 1979a).

The other specific mechanism of action that may account for some the effects of glyphosate involves the inhibition of hepatic mixed-function oxidases, a class of enzymes involved in the metabolism of both endogenous compounds and xenobiotics. Decreases in hepatic mixed function oxidase activity in rats has been noted after doses of glyphosate (as Roundup® 360 g/L) of 500 mg/kg/day for four days followed by doses of 300 mg/kg/day for 6 days (Hietanen et al. 1983).

Many of the effects of acute oral exposure to high doses of glyphosate or Roundup® are consistent with corrosive effects on the mucosa. Glyphosate, the POEA surfactant in Roundup®, as well as Roundup® itself all cause corrosive effects on the gastric mucosa as well as other tissue (Chang et al. 1999; Hung et al. 1997). Roundup® is not proposed for use by ANF.

Pharmacokinetics and Metabolism

Glyphosate is not completely absorbed after oral administration and is poorly absorbed after dermal applications. The early literature on the pharmacokinetics and metabolism of glyphosate is reviewed by WHO (1994) and Williams et al. (2000).

After oral exposure only about 30% of glyphosate is absorbed from the gastrointestinal tract (Davies 1996abcde). Most unabsorbed glyphosate remains in the gastrointestinal tract, but absorbed glyphosate is widely distributed in the body. Although glyphosate does not substantially concentrate and persist in any tissue, concentrations in the bone tend to be higher than in other tissue (WHO 1994; Davies 1996e). Most of the administered dose of glyphosate (>97%) is excreted unchanged (Williams et al. 2000). The toxicological response noted in studies with prolonged periods of exposure are consistent with the rapid elimination of and lack of toxic metabolites from glyphosate (Brewster et al. 1991 as cited in SERA 2003a; Monsanto Co. 1993a, b as cited in SERA 2003a; NTP 1992).

Two types of dermal exposure scenarios are considered: immersion and accidental spills. As detailed in SERA (2001), the calculation of absorbed dose for dermal exposure scenarios involving immersion or prolonged contact with chemical solutions use Fick's first law and require an estimate of the permeability coefficient, K_p, expressed in cm/hour. For exposure scenarios like direct sprays or accidental spills, which involve deposition of the compound on the skin's surface, dermal absorption rates (proportion of the deposited dose per unit time) rather than dermal permeability rates are used in the exposure assessment.

Webster et al (1991, 1996) indicate that glyphosate is very poorly absorbed across the skin. For skin from human cadavers they reported first-order dermal absorption rates for a 16-hour exposure period that ranged from 1.3×10^{-4} to 1.0×10^{-3} /hour (average of 4.1×10^{-4}/hour). 8-hour exposure test results ranged from 7.5×10^{-5} to 5.0×10^{-4} /hour. Results were similar for glyphosate concentrate or dilutions of 1: 20 or 1: 32. In *in-vivo* studies in monkeys about 1.5% of the glyphosate was absorbed in 12 hours, corresponding to a first-order dermal absorption rate of 1.3×10^{-3}/hour.

These experimental measurements of dermal absorption are very consistent with the standard methods used to estimate first-order dermal absorption rates (SERA 2001). The details of the method specified in SERA (2001) are given in SERA (2003b, Worksheet A07a). The application of this method to glyphosate is detailed in SERA (2003b, Worksheet B03) and yields a central estimate of 7.43×10^{-4}/hour with a range of 1.40×10^{-4} to 3.95×10^{-4}/hour.

Given the similarities between the estimated values of the first-order dermal absorption rates in SERA (2003b, Worksheet B03) and the experimental values calculated from the study by Wester et al. (1991), the use of either set in this risk assessment makes relatively little difference. Nonetheless, the experimental values for human skin preparations from Wester et al. (1991) are used in all exposure assessments requiring first-order dermal absorption rates as specified in SERA (2003b, Worksheet B05). U.S. EPA/ORD (1992) uses different types of models with or without lag times to estimate dermal permeability coefficients. The details of the U.S. EPA/ORD (1992) method for estimating K_p based on the molecular weight and octanol: water partition coefficient are given in SERA (2003b, Worksheet A07b). The application of this method to glyphosate is detailed in SERA (2003b, Worksheet B04).

For this risk assessment, the U.S. EPA/ORD (1992) method with no lag time is used. This is a more conservative approach than using the lag-time model because washing with soap and water will effectively remove about 90% of glyphosate applied to the skin (Wester et al. 1994). Under the standard spill scenarios used in this risk assessment, the pesticide is washed off the skin in less than the lag time noted by Wester et al. (1996) and hence exposure would be essentially zero, even though the Kp with lag-time reported by Wester et al. (1996) is substantially higher than the values estimated from the method of U.S. EPA/ORD (1992).

The only known metabolite of glyphosate is AMPA. While this is a common environmental metabolite formed in the degradation of glyphosate, only trace amounts of AMPA are formed in mammals (Macpherson 1996; U.S. EPA/ODW 1992; WHO 1994)

Acute Toxicity

Acute toxicity studies are used to determine the toxicity reference level known as the median lethal dose (LD_{50}), which is the dose that kills 50% of the test animals. The lower the LD_{50}, the greater the toxicity of the chemical. The LD_{50} ranges and toxicity categories used in this risk assessment are those of the EPA classification system using rat oral LD_{50} values, as shown in Table 9, adapted from Walstad and Dost (1984). Categories of toxicity using this classification system include: very slight (rat LD_{50} 5,000 to 50,000 mg/kg), slight (rat LD_{50} 500 to 5,000 mg/kg), moderate (rat LD_{50} 50 to 500 mg/kg), and severe (rat LD_{50} less that 50 mg/kg).

Table 9. Acute toxicity classification and acute toxicities of herbicides, additives, and formulations being evaluated for use in vegetation management in relation to other chemicals (adapted from Walstad and Dost, 1984).

Toxicity Category[1] (Label Signal Words)	Herbicide or Other Chemical Substance	Oral LD_{50} for Rats (mg/kg)	Equivalent Human Dose
IV Very slight		5,000-50,000 (range)	More than 1 pint
	Sugar	30,000	
	Ethyl alcohol	13,700	
	Accord Concentrate®	> 5,000	
	Rodeo®[2]	> 5,000	
	Red River Adherent 90®[3]	> 5,000	
	Red River 90®[4]	> 5,000	
	Timberland 90®[5]	> 5,000 (est.)	
	Chemsurf 90®[5]	> 5,000 (est.)	
	Alenza 90®[5]	> 5,000 (est.)	
III Slight (caution)		500-5,000 (range)	1 ounce to 1 pint
	Roundup®[6]	4,900	
	Glyphosate	4,320	
	Table salt	3,750	
	Bleach	2,000	
	Aspirin, Vitamin B3	1,700	
II Moderate (warning)		50-500 (range)	1 teaspoon to 1 ounce
	Caffeine	200	
I Severe (danger-poison)		0-50 (range)	1 teaspoon or less
	Nicotine	50	
	Strychnine	30	
	Botulinus Toxin	0.00001	

[1] Categories, signal words, and LD_{50} ranges are based on a classification system used by EPA for labeling pesticides.
[2] Monsanto MSDS, 1987
[3] Brewer International, 2005a
[4] Brewer International, 2005b
[5] Toxicology information was not available for these surfactants, however, inert ingredients were on EPA's inert lists 3 and 4b. The oral LD50 value for Red River 90 was adopted as the estimate of the oral LD50 values for Chemsurf 90, Timberland 90 and Alenza 90 based on the similar or identical composition of all four of these surfactants, as reported on their labels
[6] Monsanto MSDS, 1985

Like all chemicals, glyphosate as well as commercial formulations of glyphosate may be toxic at sufficiently high exposure levels. In rats and mice, acute oral LD_{50} values of glyphosate range from approximately 2,000 to 6,000 mg/kg (Williams et al. 2000) and intraperitoneal LD_{50} values are about 10 times lower, ranging from 134 to 234 mg/kg (Bababunmi et al. 1978). There appears to be no systematic differences in toxicity among species when doses of glyphosate are expressed in units of mg/kg body weight. In experimental mammals, signs of acute toxicity after oral or intraperitoneal dosing include increased respiratory rates, elevated rectal temperature, and in some instances asphyxia convulsion. The primary pathological lesion is lung hyperemia (Bababunmi et al. 1978; Olorunsogo et al. 1977; Olorunsogo and Bababunmi 1980).

In a recent analysis of suicides or attempted suicides in Taiwan (Lee et al. 2000), fatalities were associated with doses of glyphosate/surfactant formulations in the range of 330±42 mL and that survivors of poisonings were associated with doses of 122±12 mL. This is very similar to previous estimates of fatal and non-fatal doses

(Talbot et al. 1991; Tominack et al. 1991). Assuming a body weight of about 60 kg (about 132 lb), the lethal dose is about 5500 mg (about 11 fluid oz.) Roundup®/kg bw [330 mL × ca. 1000 mg/mL ÷ 60 kg], very similar to the acute LD_{50} of Roundup® in rats. The POEA surfactant used before 1990 in glyphosate formulations (e.g. some formulations of Roundup®) is probably the dominant factor, in some of the effects seen in humans in cases of the suicidal ingestion of glyphosate formulations. POEA is not in any of the glyphosate formulations proposed for use by the ANF.

General Subchronic or Chronic Systemic Toxicity

Systemic toxicity includes any effects that a chemical has after the chemical has been absorbed. Certain types of effects, however, are of particular concern and involve a specific subset of tests. Such special effects are considered below for the nervous system and immune system, development or reproduction, and carcinogenicity or mutagenicity. This section encompasses the remaining signs of general and non-specific toxicity.

One of the more consistent signs of subchronic or chronic exposure to glyphosate is loss of body weight. This effect has been noted in mice (U.S. EPA 1986a, NTP 1992), rats (Horner 1996b; Milburn 1996; NTP 1992; Stout and Ruecker 1990), dogs (Brammer 1996), and rabbits (Yousef et al. 1995) at exposure levels of 20,000 or more ppm in the diet. Dietary exposure at these levels will not occur from the use of glyphosate as proposed by the ANF.

Other signs of toxicity seem general and non-specific. A few studies report changes in liver weight, blood chemistry that would suggest mild liver toxicity, or liver pathology (U.S. EPA 1986; NTP 1992; Stout and Ruecker 1990). Changes in pituitary weight have also been observed (Monsanto Co. 1985). Signs of kidney toxicity, which might be expected based on the acute toxicity of glyphosate, have not been reported consistently and are not severe (Monsanto Co. 1987; NTP 1992; U.S. EPA 1986). As summarized by NTP (1992), various hematological changes have been observed but are not considered severe and are attributed to mild dehydration.

Effects on Nervous System

Glyphosate has been specifically tested for neurotoxicity in rats after both acute (Horner 1996a) and subchronic exposures (Horner 1996b) and has been tested for delayed neurotoxicity in hens (Johnson 1997). In all three assays, glyphosate was negative for signs of neurotoxicity.

In the acute study by Horner (1996a), 10 male and 10 female rats were given doses of 50, 100, or 200 mg glyphosate a.e./kg and observed for two weeks. Initially the animals exhibited decreased activity, subdued behavior, and hypothermia, but there were no effects on several other indicators of neurological impact, and there were no abnormal histologic changes in the central or peripheral nervous system tissue. In the subchronic study (Horner 1996b), groups of 12 male and 12 female rats were exposed to glyphosate in the diet at concentrations of 2000, 8000, or 20000 ppm for 13 weeks. Although effects were noted on growth and food utilization, there were no neurologic effects based on locomotor activity, no changes in brain weight or dimensions, and no evidence of damage to nerve tissue (peripheral or central). In hens (n=20) given a single dose (gavage) of glyphosate at 2000 mg/kg, a slight decrease in brain AChE activity was observed, but there were no signs of delayed locomotor ataxia and no signs of neuropathology (Johnson 1997).

Williams et al. (2000) also describe a study in which neurological examinations were conducted on dogs that received a single oral dose of 59 or 366 mg/kg of Roundup®. The information is attributed to an unpublished study by Monsanto (cited as Naylor 1988 in Williams et al. 2000). This study was not identified in a search of the U.S. EPA/CBI files and has not been reviewed in preparation of this ANF risk assessment. According to Williams et al. (2000):

> "A detailed examination consisting of 12 different measurements of spinal, postural, supporting, and consensual reflexes was performed before treatment, during the post administration observation period,

and again on the following day. Reflexes appeared normal, and there were no clinical signs indicative of neuromuscular abnormalities."

In subchronic studies in mice and rats, NTP (1992) did not report abnormal findings in neurological tissues, but histological changes were observed in salivary glands in both rats and mice. NTP (1992) concluded that glyphosate may have produced the salivary gland changes by acting through an adrenergic mechanism, but this is difficult to reconcile with the absence of $-adrenergic effects (e.g. on heart rate and blood pressure) when glyphosate was administered intravenously to dogs or rabbits (Williams et al. 2000). Milburn (1996) also reports increased incidence of mild focal basophilia of the acinar cells of parotid salivary gland in both sexes at 20000 ppm but not at 2000 ppm. No signs of neurotoxicity, however, were noted, and the mechanism of this effect is unclear.

Schiffman et al. (1995) noted that 1 or 10 mM glyphosate applied to the tongue of anesthetized gerbils decreased taste receptor response to table salt, sugars, and acids. The mechanism of this effect on the taste response has not been investigated. The effect could have been produced by a general biochemical alteration in the epithelial cells of the tongue, including the specialized cells that detect taste (glyphosate has been shown to produce injury to the oral cavity), by chemical injury to the tongue, or by a direct neurotoxic effect on the sensory nerve endings. Thus, effects reported in Schiffman et al. (1995) cannot be classified clearly as a glyphosate-induced neurologic effect.

As with the animal data, no clear pattern suggestive of neurotoxicity is apparent in an extensive and detailed literature review on health outcomes of accidental and intentional (e.g. suicide attempts) gross over-exposures to glyphosate or its commercial formulations (See numerous studies cited in SERA 2003a) In the hundreds of reported cases, neurological symptoms that are unrelated to respiratory tract distress and shock cannot be identified. The weight of evidence suggests that any neurologic symptoms associated with glyphosate exposures were secondary to other toxic effects.

Garry et al. (2002) has conducted a self-reporting survey of individuals exposed to herbicides and other pesticides, including glyphosate. This study reports that 14 children of parents who had used phosphonamino herbicides had parent-reported attention deficit disorder. While Garry et al. (2002) indicated that the odds ratio (OR) for this is statistically significant (OR=3.6; CI 1.35 to 9.65), the use of lay diagnosed disease and self-reported exposure histories diminishes the utility of this study for hazard identification.

Barbosa et al. (2001) reported a case of Parkinsonism in an adult male who was exposed to glyphosate. This study is essentially anecdotal and does not provide a clear or even credible causal relationship between glyphosate and neurotoxic effects. While the case reported by Barbosa et al. (2001) may have involved gross over-exposure to glyphosate, this over-exposure, in itself, is not dismissive of a possible neurologic risk, however, at this point, there is no evidence to conclude that glyphosate can produce or exacerbate Parkinsonism; indeed, the Barbosa et al. (2001) observation stands in contrast to the abundant case literature that suggests glyphosate is not a neurotoxicant in humans. No other cases of glyphosate-related Parkinsonism have been reported.

Effects on Immune System

Glyphosate has been tested specifically for effects on the immune system in both humans and experimental mammals. The only reported in vivo study (Blakley 1997) assayed for the effects of glyphosate on immune response to antigens in mice exposed for 26 days to Roundup® in drinking water (0, 0.35, 0.70, or 1.05 %). The response in exposed mice was the same as in unexposed mice and is consistent with in vitro assays using human immunocompetent cells (Flaherty et al. 1991). There is no evidence that glyphosate or glyphosate formulations produce sensitization in acute dermal sensitization tests performed in guinea pigs (Stebbins and Brooks 1999a, b; U.S. EPA/OPP 1993a,b, c; Williams et al. 2000). No studies are reported that indicate morphologic abnormalities in lymphoid tissues, which could be suggestive of an effect on the immune system (SERA 2003a).

In humans, experimental, clinical, and field studies have evaluated the ability of glyphosate formulations to induce allergic responses. Dermal exposure to Roundup® herbicide by Maibach (1986), Williams et al. (2000) and Shelanski (1973) did not produce allergic, photo allergic or sensitization. A study of five forest workers who participated in mixing and spraying operations did not observe changes in blood leukocyte counts or symptoms of allergy (e.g. skin rash, respiratory symptoms (Jauhiainen et al., 1991). Although cases of skin rashes following dermal exposures to glyphosate formulations have been reported (Barbosa et al., 2001), these are thought to derive primarily from irritation rather than allergy. Based on the study by Maibach (1986) using volunteers, there is no evidence that glyphosate itself causes photo irritation or photosensitization. El-Gendy et al. (1998) has reported that glyphosate caused immune suppression in a species of fish, but this study was deficient in several respects and does not provide a basis for impacting the hazard identification for effects on the immune system.

Effects on Endocrine Function

In terms of functional effects with important public health implications, endocrine function effects expressed as diminished or abnormal reproductive performance are important. This issue is addressed in the section on reproductive and teratogenic effects.

This section on effects on endocrine function is limited to direct and largely mechanistic assays that can be used to assess potential direct action on the endocrine system. Three specific tests on the potential effects of glyphosate on the endocrine system have been conducted, and all reported no effects. Glyphosate was inactive as an estrogen receptor agonist (estrogenic activity) in MCF-7 human breast cancer cells (Lin and Garry, 2000) as well as in yeast and trout hepatocyte assays (Petit et al., 1997). In a third assay, glyphosate did not inhibit steroid synthesis in MA-10 mouse Leydig tumor cells by disrupting expression of the steroidogenic acute regulatory (StAR) protein (Walsh et al., 2000). These studies do not indicate a basis for suggesting that glyphosate is an endocrine disruptor.

Note that the current RfD for glyphosate is based on reproductive effects. Glyphosate has not undergone an extensive evaluation for its impact on the estrogen, androgen, or thyroid hormone systems, thus, the assessment of a lack of potential endocrine effects of glyphosate has some uncertainty associated with it.

Reproductive and Teratogenic Effects

Glyphosate has been subject to multi-generation reproduction studies that measure overall effects on reproductive capacity as well as teratology studies that assay for a compounds ability to cause birth defects (SERA 2003a, Appendix 6).

Signs of teratogenic activity have not been observed in standard assays of rats (Moxon 1996a; Farmer et al. 2000; Rodwell et al. 1980a) or rabbits (Moxon 1996b; Rodwell et al. 1980b). No teratogenic effects in soft-tissue were observed in any study at doses of up to 3500 mg/kg/day. The only abnormal development was delayed bone development (ossification). This was seen in rats at 3500 mg/kg/day (Rodwell et al. 1980a; Farmer et al. 2000b) and in rabbits at 300 mg/kg/day (Moxon 1996b). Severe signs of maternal toxicity, including mortality, were observed in rats at 3500 mg/kg/day (Farmer et al. 2000b). Less severe signs of maternal toxicity (diarrhea, reduced fecal output, reduced food intake and body weight) were observed in rabbits at doses of 175 mg/kg/day and higher (Moxon 1996b).

In a multi-generation reproduction study in rats (Schroeder and Hogan 1981), unilateral focal tubular dilation of the kidney was observed in male F_{3b} pups at 30 mg/kg/day but not at 10 mg/kg/day. As discussed below in the section on Dose-Response Assessment, the U.S. EPA has classified 30 mg/kg/day as the LOAEL and has based the RfD for glyphosate on the 10 mg/kg/day NOAEL for this effect. This effect is consistent with the acute systemic toxicity of glyphosate, rather than a specific reproductive effect.

A 2-year dietary study, in which rats were exposed to 0, 2,000, 8,000 or 20,000 ppm glyphosate in diet, examined morphology of the reproductive organs, mammary glands, and all major endocrine glands, including the testis, ovary, pituitary, and thyroid (Stout and Ruecker, 1990). No treatment-related effects on reproductive organs or endocrine glands were observed at or below the maximally tolerated dose (20,000 ppm in diet). U.S. EPA (2001) summarized a study in which dogs were exposed to 0, 20, 100, and 500 mg/kg/day "glyphosate in gelatin capsules" for 1 year noting that a decrease in absolute and relative pituitary weight was observed at the 100 and 500 mg/kg/day dose levels.

Subchronic studies, in which mice and rats were exposed to 3,125; 6,250; 12,500; 25,000; or 50,000 ppm glyphosate in the diet, examined morphology of all reproductive organs; mammary glands; and major endocrine glands. The study also evaluated sperm counts and morphology and estrous cycle length (NTP 1992). NTP (1992) concluded that there was no evidence of adverse effects on the reproductive system of rats or mice. Several other subchronic and chronic studies of glyphosate are noted in Williams et al. (2000), with no mention of treatment-related effects on endocrine glands or reproductive organs; however, the specific tissues that were evaluated are not reported.

Yousef et al. (1995) has reported substantial decreases in libido, ejaculate volume, sperm concentrations, semen initial fructose and semen osmolality as well as increases in abnormal and dead sperm in rabbits after acute exposures to glyphosate. The authors report that all of the effects were statistically significant at $p<0.05$, but do not specify the actual doses. Using a reported rabbit LD_{50} of 3,800 mg/kg (SERA 1996), the doses would correspond to 38 and 380 mg/kg. A 3-generation study in rats found no treatment-related effects of glyphosate on mating, fertility, or reproductive parameters at doses of 3, 10, or 30 mg/kg body weight, although changes in kidney morphology were noted at the 30 mg/kg/day dose level (Schroeder and Hogan 1981). Very high dietary concentrations of glyphosate have not been associated with impaired reproductive performance or signs of damage in testicular tissue.

In a subsequent study, Yousef et al. (1996) demonstrated that glyphosate may reduce sperm motility in the range of 116 µM to about 300 µM in protein free media and 500 µM to about 740 µM in a media with protein. While this in vitro study cannot be applied directly to the risk assessment, it is worth noting that the lowest reported effect concentration, 116 µM, corresponds to a concentration of about 19.6 mg/L [116 µMoles/L × 169.07 µg/µMole = 19,612 µg/L], which is about a factor of 10 above the NOAEL used in the dose-response assessment.

Numerous epidemiological studies have examined relationships between pesticide exposures or assumed pesticide exposures in agricultural workers and reproductive outcomes. Very few studies, however, have attempted to characterize exposures, either qualitatively or quantitatively, to specific pesticides (Arbuckle and Sever 1998). Of those studies that have specifically addressed potential risks from glyphosate exposures, adverse reproductive effects have not been associated with glyphosate exposure.

In the Ontario Farm Health Study three retrospective studies (Arbuckle et al. 2001; Curtis et al. 1999; Savitz et al. 1997) examined relationships between exposures to glyphosate formulations and reproductive outcomes. Risk of miscarriage was unrelated to self-reported exposure to glyphosate formulations (Savitz et al. 1997). A second study of spontaneous abortions among 2,110 women and 3,936 pregnancies disaggregated the herbicide exposures into pre- and post conception and spontaneous abortions into early- (< 12 wk) and late-term (12-19 wk) abortions (Arbuckle et al. 2001). When maternal age was considered in a regression tree analysis, spontaneous abortions were found to be unrelated to glyphosate formulation use. Curtis et al. (1999) reported that fecundity was unrelated to glyphosate exposure.

Larsen et al. (1998a) examined relationships between use of pesticides (included Roundup®, 7% prevalence of use) and semen quality among farmers in Denmark. Semen quality and reproductive hormone levels were unrelated to pesticide use. Larsen et al. (1998b), reported fecundity was unrelated to pesticide use or participation in pesticide spraying operations.

Carcinogenicity and Mutagenicity

Information regarding the mutagenicity and carcinogenicity of glyphosate has been reviewed in detail by U.S. EPA (U.S. EPA/ODW 1992; U.S. EPA/OPP 1993a, b, c; WHO 1994) as well as in the open literature (Cox 1998; Williams et al. 2000).

EPA required testing for carcinogens relies on a number of *in vitro* and *in vivo* assays to assess carcinogenicity. Tests for genotoxicity include four core assays:

- Bacterial mutation assay (Ames test)
- Mammalian cell mutation assay (L5178Y TK assay; CHO HGPRT)
- *In vitro* cytogenetic assay (metaphase analysis; human peripheral lymphocytes; CHO; CHL)
- *In vivo* Bone-marrow cytogenetic assay (micronucleus assay; rat; mouse)

In most cases chronic studies in the rat and the mouse are also required to assess carcinogenicity. EPA uses a weight-of-the-evidence approach to assess cancer risk. In this scheme, short term bacterial assays, such as the Ames test or the SOS Chromtest, are no more than screening procedures; a positive finding suggests the possibility of genotoxicity that may lead to cancer in humans. However, many compounds test positive using these assays (see Ames and Gold, 2000, Mutation Research 447: 3-13), but upon evaluation of the entire body of evidence for carcinogenicity the data is equivocal.

As a part of EPA's re-registration process, glyphosate was screened for genotoxicity using bacterial and mammalian cell assays. The following assays all showed negative results (see Federal Register/Vol. 69, No. 159/Wednesday, August 18, 2004).

- Gene mutation assay in *S. typhimurium* strains, non-mutagenic[1] when tested up to 1,000 µg/plate, in presence and absence of activation, in *S. typhimurium* strains TA98, TA100, TA1535 and TA1537.
- Gene mutation assay in *E. coli* WP2hcrA and *S. typhimurium* strain for reverse gene mutation, both with and without S-9, up to 5,000 µg/plate (or cytotoxicity) with *E. coli* WP2hcrA and *S. typhimurium* TA98, TA100, TA1535, TA1537, and TA1538.
- Gene mutation assay in Chinese hamster ovary (CHO) cells/HGPRT, non-mutagenic at the HGPRT locus in Chinese hamster ovary cells tested up to cytotoxic concentrations or limit of solubility, in presence and absence of activation.
- *In vivo* bone marrow chromosomal aberration assay Negative, non-mutagenic in rat bone marrow chromosome assay up to 1,000 mg/kg in both sexes of Sprague Dawley rats.

Based on standard animal bioassays for carcinogenic activity in vivo (SERA 2003a, Appendix 5), there is no basis for asserting that glyphosate is likely to pose a substantial cancer risk. The Re-registration Eligibility Decision document on glyphosate (U.S. EPA/OPP 1993a) indicates that glyphosate is classified as Group E: Evidence of non-carcinogenicity for humans. This classification is also indicated in U.S. EPA's most recent publication of tolerances for glyphosate (U.S. EPA/OPP 2002). This is also consistent with the assessment by WHO (1994) and review by (Williams et al. 2000). Cox (1998) has challenged the interpretation of the cancer data but does not provide any reanalysis of the data. Tumors have been observed in some of the chronic toxicity studies (SERA 2003a, Appendix 3).

The U.S. EPA/ODW (1992) judged studies conducted before 1990 as insufficient for evaluating the potential carcinogenicity of glyphosate (observed responses were equivocal or the dose levels were inappropriate, i.e., the highest dose used was not the maximum tolerated dose). U.S. EPA requested the study by Stout and Ruecker (1990) and judged it to be adequate. Although the study indicated increases in some tumor types (pancreatic islet

[1] Genotoxic agents interact with genetic material which often results in mutations; hence genoxicity and mutagenicity are often used interchangeably.

cell adenomas in low dose male rats, hepatocellular adenomas in male rats, and C-cell adenomas of the thyroid males and females), the effects were not dose related. Gold et al. (1997) reports cancer potency estimates of 5.9×10^{-5} to 4.8×10^{-4} $(\text{mg/kg/day})^{-1}$ for glyphosate. The potency parameters provided by Gold et al. (1997), however, are based on experimental data in which there were no statistically significant increases in tumor rates at any dose level.

Roundup® has been shown to cause an increase in chromosomal aberrations in a plant (*Allium* spp.) associated with cell abnormalities in spindle fiber (Rank et al. 1993), DNA adduct formation in mice (Reluso et al. 1998 as cited in SERA 2003a) and single strand breaks in mice (Bolognesi et al. 1997). None of the in vivo studies using mammalian species or mammalian cell lines have reported mutagenic activity (i.e., NTP 1992; Rank et al. 1993). Two studies (Vyse and Vigfusson 1979; Vigfusson and Vyse 1980) report a significant increase in sister chromatid exchanges in human lymphocytes in vitro. The authors of these studies conclude from their results that glyphosate is, at most, slightly mutagenic. In addition, some positive assays in the fruit fly (Kale et al. 1995; Kaya et al., 2000) and in lymphocyte cultures (Lioi et al. 1998a; Lioi et al. 1998b) have been reported. Nonetheless, most of the other screening studies for mutagenicity are negative (SERA 2003, Appendix 7). Based on the weight of evidence of all available studies, U.S. EPA (U.S. EPA/ODW 1992; U.S. EPA/OPP 1993a; U.S. EPA/OPP 2002) concluded that glyphosate is not mutagenic.

The human data on the potential carcinogenic activity of glyphosate is sparse. Hardell and Erikson (1999a) reported an increased cancer risk of non-Hodgkin lymphoma (NHL) in individuals in Sweden who have a history of exposure to glyphosate, but the increased risk was not statistically significant. Acquavella et al. (1999) criticized the methodology used by Hardell and Erikson (1999a), but in response Hardell and Erikson (1999b) reported that an additional analysis of their data pooled with data from another study demonstrated a statistically significant increase in NHL associated with exposures to glyphosate. Details of the pooled analysis are not provided by Hardell and Erikson (1999b).

These results are of concern to the Forest Service, and the Forest Service requested that the U.S. EPA review these studies (Rubin 2000 as cited in SERA 2003a). The U.S. EPA (Tompkins 2000 as cited in SERA 2003a) replied that:

> The Office of Pesticides Programs Health Effects Division has reviewed the journal article entitled “A Case-Control Study of Non-Hodgkin Lymphoma and Exposure to Pesticides” and concluded that the study does not change EPA’s risk assessment for the currently registered uses of glyphosate.

This issue is also addressed in the most recent U.S. EPA/OPP (2002) assessment:

> This type of epidemiologic evaluation does not establish a definitive link to cancer. Furthermore, this information has limitations because it is based solely on unverified recollection of exposure to glyphosate-based herbicides.

Lee et al. (2004) evaluated the risk of the stomach and oesophageal adenocarcinomas associated with farming and agricultural pesticide use in a population based case-control study in eastern Nebraska and found no significant associations between specific agricultural pesticide (including glyphosate) exposures and the risk of stomach or oesophageal adenocarcinomas among Nebraska farmers. Through the Agricultural Health Study (AHS), a prospective study of pesticide applicators in Iowa and North Carolina, Flower et al. (2004) examined childhood cancer risk and associations with parental pesticide application. No association was detected between frequency of parental pesticide application and childhood cancer risk. An increased risk of cancer was detected among children whose fathers did not use chemically resistant gloves [odds ratio (OR) = 1.98; 95% CI, 1.05–3.76] compared with children whose fathers used gloves. The ORs were lower for glyphosate (maternal use OR = 0.61, paternal use OR=0.84). De Roos et al. (2005) suggest that although there has been little consistent evidence of genotoxicity or carcinogenicity from in vitro and animal studies, a few epidemiologic reports have indicated potential health effects of glyphosate. They evaluated associations between glyphosate exposure and cancer incidence in the AHS, a prospective cohort study of 57,311 licensed pesticide applicators in Iowa and North Carolina. Glyphosate exposure was not associated with cancer incidence overall or with most of the cancer subtypes studied.

Given the marginal mutagenic activity of glyphosate and the failure of several chronic feeding studies to demonstrate a dose-response relationship for carcinogenicity and the limitations in the available epidemiological study, the Group E classification given by the U.S. EPA/OPP (1993a, 2002) appears to be reasonable. As with any compound that has been studied for a long period of time and tested in a large number of different systems, some equivocal evidence of carcinogenic potential is apparent and may remain a cause of concern, at least in terms of risk perception (e.g. Cox 1998).

While these concerns are understandable, there is no compelling basis for challenging the position taken by the U.S. EPA, and no quantitative risk assessment for cancer is conducted as part of the current analysis.

Irritation and Sensitization

Glyphosate formulations used by the Forest Service are classified as either non-irritating or only slightly irritating to the skin and eyes in standard assays required for product registration. The U.S. EPA/OPP (1993c) classifies glyphosate as mildly irritating to the eyes (Category III) and slightly irritating to the skin (Category IV). Literature on the irritant effects of unformulated glyphosate is summarized by Williams et al. (2000). The IPA salt of glyphosate, the form proposed for use by the ANF, is nonirritating to the skin and eyes.

Systemic Toxic Effects from Dermal Exposures

Glyphosate is poorly absorbed from the skin, and thus systemic toxic effects from dermal exposure are likely to be less than those from oral exposure. In terms of acute exposures, however, there is relatively little apparent difference in the oral and dermal toxicity of glyphosate because glyphosate is relatively non-toxic by either route. U.S. EPA/OPP (1993c) classifies glyphosate as a Category III compound for both oral and dermal toxicity. SERA (2003a, Appendix 3) reports that all glyphosate formulations have dermal LD_{50} values in rats or rabbits that are >2000 mg/kg, and most are >5000 mg/kg.

A more meaningful assessment of the dermal toxicity of glyphosate can be made from repeated dose 21-day studies. U.S. EPA/OPP (1993c) cites a 1982 study in which glyphosate was applied to the intact or abraded skin of rabbits at doses of 10, 1000 or 5000 mg/kg/day, five days per week, for three weeks. The only treatment related effects included slight irritation of the abraded skin (a local and not a systemic effect), decreased food consumption, and decreased serum lactic dehydrogenase activity at 5000 mg/kg/day. In a more recent but similarly designed study in rats (Pinto 1996), dermal doses of 250, 500, 1000 mg/kg/day caused no effects on body weight, food consumption, hematology, clinical chemistry, or organ weights, and there were no signs of dermal irritation or pathologic changes in any tissue.

Inhalation Exposures

Some volatile pesticides may present practical risks in normal applications, but inhalation is not an important route of exposure for most low volatile herbicides (Dowling and Seiber 2002). Because of the low volatility rate for technical grade glyphosate (Tria 1994) and the available inhalation toxicity studies on a number of glyphosate formulations (SERA 2003a, Appendix 3), the U.S. EPA waived the requirement of an acute inhalation study for technical grade glyphosate (U.S. EPA 1993b, p. 10). The acute inhalation LC_{50} value of the isopropylamine salt glyphosate is >6.37 mg/L (no mortality in five rats of each sex exposed to this concentration for four hours) (Mcguirk 1999). As indicated in SERA (2003a, Appendix 3), the short-term (typically 4 hours) inhalation LC_{50} values for various glyphosate formulations range from >1.3 mg/L to >7.3 mg/L. The lowest LC_{50} value that is not designated with a greater than (>) symbol is 2.6 mg/L. This appears to reference the acute inhalation study by

Dudek and Cortner (1998) in which 20% mortality (1/5 rats of each sex) was observed after 4-hour inhalation exposures to MON 77063 at a concentration of 2.6 mg/L. MON 77063 appears to be an experimental formulation, and there is no information to link it to any formulation proposed for use on the ANF. Appendix 3a of SERA (2003a) provides inhalation LC50 values for ANF formulations as follows: Accord SP® > 5 mg/L, Foresters® >1.3 mg/L, Glypro® and Rodeo® > 6.7 mg/L. The greater than (>)sign indicates the highest concentration tested, and the effects were less than the LC_{50}.

A case of "Roundup Pneumonitis" has been reported by Pushnoy et al. (1998). This involved an individual with shortness of breath, respiratory irritation, and dizziness. Exposure to Roundup® resulted from disassembling sprayer equipment. As discussed by Goldstein et al. (1999), the plausibility of association between Roundup® exposure and the development of these symptoms is tenuous given that this individual may have been exposed to diesel fuel aerosols, chlorinated solvents, smoking, or welding fumes. Jamison et al. (1986) suggested a potential effect associated with glyphosate after inhalation exposures to flax dust, but the glyphosate treated flax dust contained about 25% more particles in the 0-1: range. Particles in this range typically penetrate to the alveolar sacs (Razman and Klassen 1996). Thus even though the distributions in the particle sizes for the two forms of flax may not be statistically significantly different, the higher concentration of respirable particles in the glyphosate treated flax may have contributed to the apparent difference in biological activity.

SERA (2003a) notes an area of uncertainty concerning operations where burning is done after herbicide application. Residues of glyphosate in air during brown-and-burn operations have not been measured, but SERA (2003a) concludes in their analysis that they are likely to be very low given that brown-and-burn operations take place about 30 to180 days after treatment with the herbicide and the foliar half-life is from 1.6 to 46 days. SERA (2003a) concludes that there is no evidence to suggest that toxic levels of glyphosate are likely to be encountered as the result of a brown and burn operation. SERA (2003a) also states that there is no basis for believing that the presence of low or even high levels of glyphosate residues will have a significant impact on this hazard (due to burning areas that have been treated). On ANF, burning is occasionally done in the oak type but not within 180 days of application, therefore the uncertainty about risk is further reduced.

Role of Surfactant

As summarized in SERA (2003a, Appendix 1), various glyphosate formulations contain a polyethoxylated tallow amine (POEA) surfactant at a level of up to about 20% (200 g/L) and Roundup Pro® contains a phosphate ester neutralized POEA surfactant at a level of 14.5% (145 g/L). Tallow contains a variety of fatty acids including oleic (37–43%), palmitic (24–32%), stearic (20 to 25%), myristic (3–6%), and linoleic (2–3%) acids as well as small amounts of cholesterol, arachidonic, elaidic, and vaccenic acids (Budavari 1989). The other formulations of glyphosate recommend the use of a surfactant to improve the efficacy of glyphosate. There is an extensive amount of literature on glyphosate indicating that the addition of surfactants can greatly enhance phytotoxicity of herbicides (De Ruiter et al.1996, De Ruiter and Meinen 1998; Denis and Delrot 1997; Laerke and Strebig 1995; Miller et al. 1998; O'Sullivan et al. 1981; Riechers et al. 1995; Sundaram 1990; Sundaram et al. 1996).

While surfactants are typically classified as "inert" ingredients in herbicides, these compounds are not toxicologically inert. It is beyond the scope of this risk assessment to specifically review all of the information available on surfactants. Much of the available information on the toxicity of surfactants used with glyphosate have been summarized in SERA (1997 as cited in SERA 2003a) and more recent studies (Chang et al. 1999; Garry et al. 1999; Lin and Garry 2000; Reluso et al. 1998 as cited in SERA 2003a) reinforce the conclusion reached in SERA (1997 as cited in SERA 2003a) that some surfactants may be more toxic than the herbicides with which they are used. Although surfactants may play a substantial role in the interpretation of a large number of suicides and attempted suicides involving the ingestion of glyphosate formulations, primarily Roundup®, the acute mammalian toxicity of different glyphosate formulations do not appear to differ substantially (Appendix 3a and 3b of SERA 2003a).

Only Glyphosate formulations without POEA are used on the ANF (Table 1). The surfactants proposed for use on the ANF (Table 1) include one or more of the following constituents: Alkylarylpolyoxyethylene ether, isopropanol, free fatty acids, Alkylarylpolyoxykane ether, and Alkylarylpolyoxyethylene glycols. These are all on EPA inerts lists 3 and 4b. List 3 indicates that there is unknown toxicity; for inerts where "there was no basis for placing it on any of the other lists. The Agency will continue to evaluate these chemical substances, as additional information becomes available, to determine if reclassification to List 1, 2, or 4 is appropriate." List 4B is for inerts with "*sufficient information to conclude that current use patterns in pesticide products will not adversely affect public health and the environment.*"

Inerts

Inert ingredients are chemicals used with the active ingredient in preparing herbicide formulations. They are used to provide a carrier for the active ingredient that facilitates the effective application of the herbicide. Inerts are not intended to supplement the herbicide's toxic properties.

EPA noted that concerns regarding the acute toxicity of inert ingredients are usually addressed through tests of the herbicides as formulated products. While the herbicides as formulated products have undergone acute toxicity testing, they generally have not undergone extensive chronic toxicity testing, or cancer, reproductive, developmental, or mutagenicity testing. The gap in the testing of the herbicides as formulated products, according to one view, gives rise to the inference that the environmental consequences, including hazards to human health, from using them are largely unknown.

The inerts in the formulations proposed for use on ANF are on EPA List 4b, a designation, which means EPA, has concluded that there is "sufficient information to conclude that current use patterns in pesticide products will not adversely affect public health and the environment."

Impurities and Metabolites

The primary metabolite of glyphosate in mammals and other organisms is aminomethylphosphonate (AMPA), which is formed together with glyoxylate (HCO-COOH).

In mammals, less than 1% of the absorbed dose of glyphosate is metabolized to AMPA (U.S. EPA/ODW 1992; Brewster et al. 1991). AMPA is formed in environmental media such as soil and water as a breakdown product of glyphosate. For example, Mao (1996) found that AMPA reached approximately 21.2% of applied dose of glyphosate by day 181 under anaerobic conditions in pond water. In addition, glyphosate is readily metabolized by soil bacteria with AMPA as a major metabolite (Dick and Quinn 1995a; Dick and Quinn 1995b).

These two differing sources of exposure, i.e., as an endogenous metabolite in mammals and as an environmental metabolite, are handled differently in this risk assessment. The approach of examining the potential importance of the metabolism of a chemical agent by a mammal is common in the risk assessment of xenobiotics, which generally involve the formation of one or more mammalian metabolites, some of which may be more toxic than the parent compound. Usually, the parent compound is selected as the agent of concern because the toxicology studies and monitoring studies provide information about the agent. Thus, the dose metameter for the risk assessment is most clearly expressed in terms of the parent compound. In cases where a toxic metabolite is known to be handled differently by humans, this simple approach may be modified. There is no indication that such a modification is necessary for glyphosate. Thus, in terms of assessing direct exposures to technical grade glyphosate, the inherent exposures to AMPA as a metabolite are encompassed by the existing toxicity data on glyphosate.

This approach does not, however, encompass concern for exposures to AMPA as an environmental metabolite. As noted above, about 20% of applied dose of glyphosate may be found in water as AMPA after about six months.

The toxicity and environmental fate of AMPA has been reviewed recently by WHO (1997 as cited in SERA 2003a), Cox (1998), and Williams et al. (2000). In addition, the U.S. EPA/OPP (2002) has reviewed this information and assessed the potential consequences of exposures to AMPA as an environmental degradate. Based on this review, the U.S. EPA/OPP (2002) concluded:

> The nature of the residue in plants and animals is adequately understood and consists of the parent, glyphosate. The Agency has decided that only glyphosate parent is to be regulated in plant and animal commodities and that the major metabolite, AMPA (aminomethylphosphonic acid) is not of toxicological concern regardless of its levels in food–U.S. EPA/OPP (2002, p. 17725).

While Cox (1998) has cited concerns for AMPA based on a limited subset of the literature on this compound, no formal dose-response and exposure assessment is presented that would argue against the position of U.S. EPA/OPP (2002). The position taken in U.S. EPA/OPP (2002) is supported by WHO (1997 as cited in SERA 2003a) and Williams et al. (2000). The position taken by U.S. EPA/OPP (2002) appears to be reasonable and is well supported. Consequently, in this risk assessment, AMPA is not quantitatively considered in the dose-response and exposure assessments.

Glyphosate also contains N-nitrosoglyphosate (NNG) as an impurity. Certain groups of nitrosoamines have served as model compounds in some of the classical studies on chemical carcinogenicity. While there is a general concern for the carcinogenic potential of nitroso compounds, the EPA re-registration document (RED) for glyphosate states:

> Technical grade glyphosate contains N-nitrosoglyphosate (NNG) as a contaminant. Carcinogenicity testing of nitroso contaminants is normally required only in those cases in which the level of nitroso compounds exceeds 1.0 ppm. Analyses showed that greater than 92% of the individual technical glyphosate samples contained less than 1.0 ppm NNG. The Agency concluded that the NNG content of glyphosate was not toxicologically significant.

As part of the conduct of the SERA (2003a) risk assessment, data available to U.S. EPA for RED as well as the more recent data on the levels of N-nitrosoglyphosate and related compounds has been reviewed (Bernard 2002; Hirsch and Augustin 1987). This information is classified as trade secret under FIFRA and cannot be detailed in this risk assessment. Nonetheless, no information has been encountered in the CBI files or in the open literature that contradicts the above assessment in the RED. In addition, none of the recent reviews on the toxicity of glyphosate cite contamination with N-nitrosoglyphosate (NNG) as a concern (Cox 1998; WHO 1994; Williams 2000). Consequently, as with AMPA, a detailed dose-response and exposure assessment for NNG does not appear to be justified within this risk assessment or as a separate assessment.

Dose Response Assessment

This section is the culmination of the hazard analysis and identifies the most critical toxicity value for use in the risk characterization section. Generally, the dose-response assessments used in U.S Forest Service risk assessments adopt the RfD proposed by the U.S. EPA as indices of 'acceptable' exposure. An RfD is the level of exposure that will not result in any adverse effects in any individual. The U.S. EPA RfDs are used because they generally provide a level of analysis, review, and resources that far exceed those that are or can be conducted in the support of most U.S. Forest Service risk assessments.

The most recent RfD on glyphosate is that proposed by the U.S. EPA/OPP. This RfD of 2 mg/kg/day was proposed originally in the RED for glyphosate and was also used in the recent glyphosate pesticide tolerances. This RfD is based on teratogenicity study in rabbits (Rodwell et al. 1980b) in which no effects were observed in offspring at any dose levels, and maternal toxicity was observed at 350 mg/kg/day with a NOAEL of 175 mg/kg/day. Using an uncertainty factor of 100, 10 for sensitive individuals and 10 for species-to-species extrapolation, U.S. EPA/OPP derived the RfD of 2 mg/kg/day, rounding the value of 1.75 mg/kg/day to one significant digit.

For this risk assessment, the RfD 2 mg/kg/day is used for both short and long-term exposure scenarios. This value was derived by U.S. EPA/OPP for long-term exposures and was also adopted by the U.S. EPA/ODW for shorter term exposures. SERA (2003a) has extensive discussion of this RfD and critical toxicity values.

SECTION 4. GLYPHOSATE EXPOSURE ASSESSMENT

Overview

Herbicides are commonly used in the U.S. to achieve forestry objectives; as a site preparation tool they help to control vegetation that may impede tree seedling establishment and growth by competing for soil nutrients, water, and light. This section provides the human exposure assessment to glyphosate for both workers and members of the general public. It provides the critical levels of exposure based on selected exposure scenarios for workers and the general public. The critical exposure values are used in the risk characterization section (Section 5) with the critical toxicity values to calculate the risk, expressed as the hazard quotient.

This section begins with a review of what is known of the movement, persistence and fate of glyphosate because these elements of the environmental behavior of the herbicide influence human exposure. This information is also relevant for the glyphosate exposure analysis for wildlife, aquatic and species federally listed or proposed as threatened, endangered or sensitive.

Detailed Information

Environmental Behavior of Glyphosate

SERA (1996b) summarizes information on the environmental behavior of glyphosate as it relates to the risk assessment process. Much of that information is summarized in this section with specific reference to its relevance to conditions on ANF.

In summary, glyphosate is relatively low in toxicity to animals and has a short persistence in soil and water. It is taken up by the plant primarily through the foliage and is then translocated through the plant to roots and other structures. Of the glyphosate in the soil, less than 1 percent is absorbed through the roots, primarily because glyphosate is quickly and tightly adsorbed to soil particles. Glyphosate is not metabolized in plants. Complete and rapid degradation occurs in both soil and water by microbiological activity but not by chemical activity (Rueppel et al. 1977; Ghassemi et al. 1981). We conclude that the proposed use of glyphosate will not adversely affect soil nutrient cycling or soil productivity.

Newton et al. (1994) summarized the results from comprehensive studies of the movement, persistence and fate of glyphosate and AMPA in three forests (Oregon, Georgia and Michigan). They reported eight-hectare residual stands of low-quality hardwoods were treated with 4.12 kg/ha (3.68 lb/acre, see Appendix G3 for English and metric conversion factors) glyphosate applied aerially in late summer. There was no streamside buffer. Residues were highest in upper crown foliage. The presence of the overstory reduced exposure of understory vegetation and streams. Residues in streams decreased to the detection limit or were undetectable in 3-14 days. Residues in soils were highest where cover was sparse and where litter was removed. No residues were detectable in soil 409 days after treatment; movement below 15 cm was negligible. AMPA appeared at low levels in all degrading matrices, including sediments, soon after deposition of glyphosate. In pond sediments, both glyphosate and AMPA remained bound and inactive. Residue concentrations in foliage, water, and soil were below levels known to be biologically active in non-target fauna. This study encompassed a broad diversity of environments (cool moist winter, warm dry summer in Oregon, warm to hot moist conditions in Georgia, and warm moist summer to cold dry winter in Michigan) making it particularly relevant to the ANF because it covers the full range of environmental conditions encountered on the ANF.

Behavior in Air

Glyphosate has a low vapor pressure so it does not volatilize into the atmosphere (Ghassemi et al. 1981; U.S. Department of Energy 1983). Rueppel et al. (1977) report that only a small amount of glyphosate should be expected to volatilize from either soil or water. This is what is expected to be the case for ANF as well.

Behavior in Plants

Glyphosate is taken up by the plant primarily through the foliage and is then translocated throughout the plant, including through underground structures such as roots and rhizomes where it inhibits further growth and sprouting. Depending upon soil type and conditions, some root uptake may occur, but typically of the glyphosate in the soil, less than 1 percent is absorbed through the roots, primarily because glyphosate is quickly and tightly adsorbed to soil particles (USDA FS 1991). Glyphosate is stable within the plant tissue and is not metabolized by plants. Residue levels of glyphosate and AMPA in fruits of wild blueberry and red raspberry were determined in field tests in Ontario, Canada, by Roy et al. (1989). Glyphosate was applied using a hand held spray boom to achieve glyphosate application rates, which were approximately 2 kg/ha close to the time when fruit would be approaching maturity and be ready for harvest. Ripe fruits were collected for chemical analysis at various times after application. Blueberry absorbed about 14 % of the glyphosate that fell on the fruits, while red raspberry absorbed about 9%. Washing the fruit with water removed the balance (Table 10).

Table 10. Residue levels of glyphosate and AMPA in blueberry and red raspberry fruits collected from boreal forests of Ontario, Canada

Plant	Days post-spray[a]	Glyphosate (mg/kg)	AMPA (mg/kg)
		Mean + SD	
Blueberry	0[a]	7.94+0.678	ND[1]
	1	6.60+0.708	ND
	2	5.66+1.210	0.055+0.017
	13	3.73+0.535	0.051+0.009
	20	2.50+0.524	0.031+0.010
	33	1.23+0.248	ND
	61	0.19+0.035	ND
Raspberry	0	19.49+2.110	ND
	1	18.25+2.570	ND
	2	17.12+0.990	0.102+0.024
	13	5.55+0.880	0.089+0.031
	20	3.39+0.420	0.033+0.0088
	33	1.22+0.122	0.024+0.004
	61	NA[2]	NA

Note: Adapted from Table 5, Roy et al. (1989). Data corrected for glyphosate and AMPA recovery efficiencies.
[a] Zero days post spray was August 8, 1985.
ND[1], not detectable; limits of detection for glyphosate and AMPA were 0.025 and 0.01 ppm, respectively.
NA[2], not available; no berries on the plantation.

As expected, highest residue levels occurred the day of application when glyphosate residue level in the washed fruit was approximately 8 mg/kg in blueberry, and 19.5 mg/kg in red raspberry. Residue levels declined with time. Residue levels of AMPA were small and transitory.

These data probably provide an estimate of the exposure of organisms that might consume fruits similar to these from treated plants, especially those treated by broadcast foliar methods. Low volume foliar applications would result in less exposure from fruit, and the basal and cut surface treatment methods should prevent such exposure. Lacking other specific data, we conclude these data reflect what should be expected on ANF.

In British Columbia, Canada where glyphosate was aerially applied for reforestation purposes, Feng and Thompson (1990) reported that the residue level of glyphosate on foliage of two species immediately after application was 261 and 448 ppm. Residue levels were not followed in the foliage over time, except as the foliage senesced and fell from the plant. The initial residue levels found in this material (i.e., in the first foliage to fall from the plants) was 12 to 20 ppm, declining to less than 1 ppm in 45 days. In an Oregon forest following aerial application of glyphosate, initial herbicide levels in foliage ranged from 80 to 489 ppm in the foliage most exposed to the spray material. In understory vegetation (that least likely to be directly sprayed on the right-of-way), the residue level immediately after treatments ranged from 20 to 1818 ppm. Levels of AMPA did not exceed 2 ppm at any time. The residue levels declined rapidly with time in the foliage, regardless of the initial herbicide residue levels. The half-life values were reported to range from 10 to 27 days in plants (Newton et al 1994). This is the pattern that should be expected from proposed applications on the ANF.

In summary, given the environmental conditions and treatments proposed for the ANF, we expect the half life of glyphosate in vegetation to be 13 days or less, and for there to be levels of AMPA that are less than 0.1 ppm at their highest, and are non-detectable in less than 30 days (nondetectable means less than 0.01 PPM).

Behavior in Soil and Groundwater

Soil. When glyphosate reaches the soil (the majority of the herbicide lands on vegetation and is absorbed by the plant tissue), it is completely and rapidly degraded by microbiological activity. Within the soil environment, it is resistant to chemical degradation, stable to sunlight, is relatively non-leachable, has no tendency to leach through the soil or to run off, is strongly adsorbed to soil particles, has negligible volatility, and has a minimal effect on soil microflora. (Rueppel et al. 1977; WSSA 1983). It does not accumulate in the soil (USDA FS 1989, Vol. II, pp. 4-25 through 4-27). Soil microflora degrade glyphosate to aminomethyl phosphonic acid, which is somewhat more stable than glyphosate. Principal decomposition end products are carbon dioxide, water, nitrogen and phosphate. Decomposition occurs under both aerobic and anaerobic conditions. Glyphosate has an average half-life of 60 days in the soil. The half-life is shorter than average in silt loam soils and longer than average in sandy soils.

Sacher (1978) compared $^{14}CO_2$ evolution over a period of seven days in sterile and non-sterile conditions with radio labeled glyphosate and with radio labeled sucrose (sugar) as a control. Minimal amounts of $^{14}CO_2$ evolved, along with lack of significant changes in composition of the radio labeled glyphosate compounds under sterile conditions, demonstrated that chemical degradation is not a major means of glyphosate degradation. The importance of biodegradation by soil microflora was indicated in the non-sterilized conditions, in which as much as 55 percent of the $^{14-}$C-labeled glyphosate was given off as $^{14}CO_2$ within 4 weeks using Lintonia Sandy Loam soil. Microbial degradation of glyphosate can occur under both aerobic and anaerobic conditions, and the same general distribution of glyphosate metabolites is found under both aerobic and anaerobic conditions (Rueppel et al. 1977).

The primary metabolite of glyphosate is aminomethyl phosphonic acid (AMPA). Studies with radio labeled AMPA in silt loam and silty clay loam soils resulted in 34.8 and 16.1 percent of the applied ^{14}C being given off as $^{14}CO_2$ within 63 days, respectively (Rueppel et al. 1977). Degradation of AMPA is generally slower than that of glyphosate, possibly because AMPA may adsorb onto soil particles more strongly than glyphosate and/or because it may have a lower permeability through the cell walls or membranes of soil microorganisms.

Glyphosate is relatively immobile in most soil environments as a result of its strong adsorption to soil particles. This tendency of glyphosate to adsorb to soil particles serves as the initial stage in the inactivation of glyphosate with respect to plant uptake--the adsorbed glyphosate is unavailable for uptake by plant roots.

Absorption of glyphosate to soil particles begins immediately after application, and binding occurs with particular rapidity to kaolinite, illite, and bentonite clays as well as to muck. Organic matter and clays saturated with Fe^{3+} and Al^{3+} tend to adsorb more glyphosate than do organic matter and clays saturated with Na^{+} or Ca^{2+}. The prime factor in determining the amount of glyphosate adsorbed to soil particles is the soil phosphate level, and it appears that glyphosate is bound to soil through the phosphonic acid portion of the molecule (Sprankle et al. 1975a).

The effect of both pH and phosphate on glyphosate adsorption was examined by Sprankle et al. (1975b) based on plant yield as an indicator of glyphosate unavailability due to adsorption. They found no significant difference in plant yield as an indicator of glyphosate unavailability due to adsorption. However, there was a decrease in glyphosate adsorption as the pH increased and the level of phosphate increased. Salazar and Appleby (1982), however, found that in some high-organic soils, glyphosate applied to soil at a rate of 3 lb/acre (3.4 kg/ha) reduced bentgrass seedling growth for seeds germinating as long as 5 days after glyphosate application. Brewster and Appleby (1972 as cited in Salazar and Appleby 1982) found similar reduction in wheat seedling growth with pre-emergence application of glyphosate that appeared to be related to increased levels of moisture in the soil.

In general, glyphosate dissipates relatively rapidly when applied to most soils. As a result of greenhouse soil dissipation studies with three different soil types, Rueppel et al. (1977) calculated half lives from 3 to 130 days, the former for a silty clay loam with 6 percent organic content and the latter for a sandy loam with 1 percent organic content. These data have been substantiated by field studies, in which glyphosate had an average half-life of 2 months in 11 soils and by other studies reporting half-lives of 17 to 19 weeks in sandy soil and 3 weeks in silt loam (USEPA data reported in Ghassemi et al. 1981).

In a field study in British Columbia, Feng and Thompson (1990) determined the persistence and movement of glyphosate in the soil after aerial application. They reported glyphosate and AMPA (a primary metabolite in the pathway of glyphosate decomposition) were retained primarily in the upper organic layers of the profile, with more than 90% of the total glyphosate residue in the 0 to 15 cm layer. They conclude there is a low propensity for the leaching probably as a result of the strong adsorption and the tendency for decomposition. Glyphosate soil residues dissipated as a function of time, with a half-life of 45 to 60 days. After 360 days, total soil residue levels were 6 to 18% of the initial levels. In an Oregon forest ecosystem, Newton et al. (1994) reported the half life of glyphosate ranged from 10 to 27 days in foliage and forest floor material, and roughly twice as long in the soil.

In a Canadian boreal forest, Roy et al. (1989a) studied the degradation, persistence and mobility of glyphosate under field conditions after application of herbicide (2 kg/ha, active ingredient) to areas with either a sand soil or a clay soil. The sand site was used to study leaching and persistence, and the clay site was used to assess lateral mobility due to runoff. Except on one sampling date, 100% of the herbicide was found in the upper organic layer throughout the 335 days in which detectable residues were found. On one date, 95% was in the organic layer, and 5% was in the next layer down. The herbicide level in the soil decreased 50% in 24 days and 90% in 78 days. There was no detectable lateral movement down the 8-degree slope at any time after application (762 day sampling period).

The behavior of glyphosate in soil has been tested in a wide range of environmental conditions, which bracket those found on ANF. Based on these studies we expect the soil half-life on the ANF to be less than 60 days with half-life in the litter of the forest floor to be less than 30 days. Glyphosate has not been found to leach in soil, and is not expected to do so on sites on the ANF.

Impact on Soil Productivity

Herbicides are commonly used in the U.S. to achieve forestry objectives; as a site preparation tool they help to control vegetation that may impede tree seedling establishment and growth by competing for soil nutrients, water, and light. The ANF proposes the use of herbicides to reduce dense ground vegetation that could out compete tree seedlings (see pp. 3-93 to 3-95 and 3-119 through 3-122 in ANF Final EIS). Abundant tree seedlings, native shrubs and herbaceous plants are able to develop during the first year after herbicide application, which indicates the treatment does not affect the viability of seed banks in the forest floor (see p. 3-121 ANF Final EIS). Recent research completed on the ANF found that herbicide application temporarily reduced the average number of species found, but 3 years after application the number of plant species returned to pre-treatment levels, and 5 years after application treated sites had higher species diversity and lower single species dominance in treated sites (see pp. 3-121 and 3-122 ANF Final EIS).

If previous use of the same herbicides on the ANF had caused disruption of soil fertility, it is logical that such effects would be manifested in inhibited plant establishment and growth. The ANF monitoring report of FY 2001 evaluated such effects on a series of areas that had been treated with herbicide (USDA-Forest Service, 2004, pp. 31-34). Based on tree seedling stocking surveys collected through 2001 (Table 12), 73% of all the areas treated between 1987 and 1999 are more than 50% stocked with tree seedlings. Before spraying, almost all areas had very few seedlings. These results indicate that herbicide use is not adversely affecting soil fertility.

Both herbicides are formulated to target plant growth (not soil microbes), and available studies do not indicate that either herbicide affects nutrient cycling in forest soils (e.g. nitrogen mineralization). Bromilow et al. (1996) noted no effects on soil fertility in repeated applications over 14 years, from 1980 to 1993, of glyphosate at 1.4 kg/ha based on assays for microbial biomass and crop productivity. From this and additional information in Appendix G2 pp. G2-33 and G2-42, we conclude that the proposed use of glyphosate and sulfometuron methyl will not adversely affect soil nutrient cycling.

Groundwater. The Monsanto Company (U.S. EPA data reported in Ghassemi et al. 1981) conducted soil column leaching studies in which glyphosate was aged for 30 days in soil columns and then eluted for 454 days with 1/2 acre-inch water. Leaching of parent compound was found to be insignificant.

Well water was monitored at three electrical substations in Newfoundland, Canada to determine the extent of glyphosate off-target movement after gravel platforms around substations were sprayed with 2% solution of glyphosate. Smith et al. (1996) reported that the levels of glyphosate at two substations were below the limits of detection throughout the duration of the study (32 weeks). Both substations had fragipan constricting layers below the surface, restricting water movement from the surface. The third substation was on a rapid to well-drained site and glyphosate levels were detected in well water. Levels peaked two weeks post-spray at 0.25 mg/l and at 37 weeks were at 0.13 mg/l. Albrechtsen et al. (2001) examined degradation of herbicides in shallow aquifers and reported that glyphosate showed little degradation under anaerobic conditions in water, but as a practical matter there is expected to be little or no glyphosate entering aquifers because of the tendency to bind to soil organic matter and its subsequent rapid microbial degradation.

Based on this information we conclude that there is no likelihood of groundwater contamination from the proposed applications on the ANF.

Behavior in Surface Water

In aquatic systems, glyphosate is strongly adsorbed to both organic and mineral matter and is degraded primarily by microorganisms. However, the rate of degradation of glyphosate in water is generally slower than it is in most soils because there are fewer microorganisms in water than in most soils (Ghassemi et al. 1981).

Stream samples of flowing canal water were taken by Comes et al. (1976) following metering of Roundup® at a rate of 150 ppb of glyphosate into the canals. Sampling 1 mile (1.6 km) downstream accounted for only 70 to 72 percent of the total glyphosate introduced into the stream. Subsequent downstream disappearance of glyphosate diminished and 5 to 9 miles (8 to 14.4 km) downstream, only 57 to 58 percent of the glyphosate remained in the water flow. These figures are for herbicide metered directly into flowing water. Sacher (1978) reports that when glyphosate is applied to ditch banks at 150 ppb concentration, maxima of only 10 and 3 ppb glyphosate could be expected in stream flow 1 and 5 miles (1.6 and 8 km) downstream, respectively. The level of glyphosate metered into the canal is far greater than the level that might occur from applications on the ANF, but the pattern of dissipation reported in this study is directly applicable to ANF programs.

In a pond at Fort Lauderdale, Florida, Sacher (1978) reported a half-life for glyphosate of approximately 12 days. Studies by Monsanto Company (U.S. EPA data reported in Ghassemi et al. 1981) on glyphosate persistence in natural water bodies found a half-life of 7 weeks in Sphagnum bogs at pH 4.23; of 9 weeks in cattail swamps at pH 6.25; and of 10 weeks in pond water at pH 7.33.

On the ANF, the majority of streams have pH values that fall within the range of 4.23 to 7.33. Headwater streams generally have the lowest pH values (4.5-7.5), while larger main streams generally have pH values that range from 6.0 to 7.5, with some values as high as 8.0. The pH values for ponds range from 4.5 to 7.0, with the pH for shallower ponds generally at the lower end of this range. Most broadcast treatment occurs within headwater watersheds. From this we conclude that the half-life in water on ANF would be from 7 to 10 weeks.

Leaching of residues from irrigation canal banks treated with glyphosate was investigated by Comes et al. (1976). Neither glyphosate nor its metabolite, aminomethyl phosphonic acid, were detected in the first flow of water through canals that had been dry for 23 weeks after glyphosate had been sprayed on the ditch banks at a rate of 5 lb/acre (5.6 kg/ha). Soil samples collected from the canal bed the day before the canals were filled indicated residual levels of both glyphosate and aminomethyl phosphonic acid (0.35 and 0.78 ppm, respectively) in the top 10 centimeters of the soil along the ditch banks. The authors concluded that glyphosate could be applied to ditch bank vegetation in the fall after draining canals, with little to no chance of glyphosate residues contaminating irrigation water the following spring.

Inclined beds of three different soils were used to evaluate the runoff potential of glyphosate (Rueppel et al. 1977). Radio labeled glyphosate was applied uniformly at a rate of 1.0 lb/acre (1.12 kg/ha) to the upper third of the soil bed and the surface then subjected to artificial rainfalls at days 1, 3, and 7 after treatment. The artificial rainfall was continued long enough for the collection of two consecutive 50 ml samples of runoff water and sediment. The ^{14}C activity of runoff water and sediment was measured. The results indicated a maximum runoff rate of less than 1.8×10^{-4} lb/acre (2×10^{-4}kg/ha), confirming that glyphosate binds tightly to soil particles.

Studies of the runoff of Roundup® applied to agricultural soils in Ohio were conducted by Edwards et al. (1980). Roundup® was applied as a pre-seeding treatment in early spring at rates of 1, 3, and 8 lb/acre (1.10, 3.36, and 8.96 kg/ha), and levels of glyphosate in the runoff water from natural rainfall were measured. The highest concentration of residual glyphosate, 5.2 ppm, was contained in runoff 1 day following treatment at the highest application rate. Glyphosate levels up to 2 ppb were detected in runoff from the highest application rate for up to 4 months following treatment. For watersheds treated at lower application rates, the highest level of glyphosate detected in runoff was 100 ppb for rainfall events 9 to 10 days after treatment. Two months following treatment, residual glyphosate levels in runoff had decreased to 2 ppb. Of the glyphosate applied to the soil, a maximum of 1.85 percent was removed by runoff transport and, of this amount, 99 percent was removed during the first rainfall event after herbicide application. Most of this loss is associated with soil erosion in agricultural watersheds. Because the forest floor and litter layer remain intact on herbicide-treated areas on the ANF, little or no soil erosion from herbicide treated areas is expected to occur.

In British Columbia, Canada in connection with a forestry application (aerial), the fate of glyphosate in a forested watershed was determined. In some cases streams in the area were intentionally over-sprayed (no buffers), in others a 10-meter buffer was used (although the investigators, Feng et al. (1990a) noted that the vegetation was dense around these streams and the buffers were indistinct from the air, suggesting some unintentional direct application to the stream also occurred). Buffered streams had very low residue levels (2 to 4 micrograms per liter [parts per billion, ppb]). Highest residues occurred in the stream directly and intentionally over-sprayed. The peak concentration measured was 162 micrograms per liter, which dissipated to less than 1 ppb in 96 hours. Water sampling conducted during the first storm after application (about 20 hours after application), showed peak herbicide concentration in the stream as less than 150 micrograms per liter, with residues declining to near 1 microgram per liter or less in less than 100 hours. Seven significant storm events were monitored subsequently; no quantifiable residues of glyphosate were detected in the next 150 days.

Newton et al. (1984) provided no buffer in an Oregon forest and aerially sprayed directly across a small stream. The peak herbicide residue level found in the stream was 270 micrograms per liter during the application, and declined rapidly thereafter. Residues were at or near the detection limit in less than 10 days, with this pattern continuing for the 55-day sampling period. Stream sediments adsorbed herbicide. The peak concentration in sediment was about 0.5 mg/liter, occurring about 14 days after application. While still measurable at 55 days, the residue level was decreasing. Adsorption on sediment and dilution with water movement likely produce the reduction in concentration in water observed with time in this study. There was no evidence of subsequent input to the stream due to leaching or surface runoff, despite the absence of a buffer.

Glyphosate dissipates rapidly from standing water, as in a pond. Goldsborough and Beck (1989) measured the concentration of glyphosate and AMPA in four small ponds in the boreal forest in Manitoba, Canada. They found a half-life of 1.5 to 3.5 days. In microcosms containing only water, glyphosate persisted for longer periods. Microcosms with sediment and water showed rapid dissipation of the herbicide, suggesting adsorption is a major route of dissipation from water, reflecting the behavior of glyphosate in soil, where adsorption is also a dominant factor in its dissipation. Goldsborough and Brown (1993) returned a second year to reapply glyphosate to two of the ponds, and to apply it to a third pond that had not been treated previously. They found that glyphosate dissipated rapidly from the surface waters of all ponds (dissipation half-lives of 3.5–11.2 days). AMPA residues were detected in water samples during the first 14 days after treatment, suggesting that herbicide degradation was occurring in the water column. However, not all applied herbicide was accountable in residues in the water. Glyphosate and AMPA increased in sediment samples to day 36, indicating that sediment adsorption was a major sink for the herbicide.

Buffers

Buffers are a strip of untreated vegetation adjacent to wetlands, water bodies and flowing water. The purpose of the buffer is to prevent the entry of unacceptable levels of herbicide to the water, thereby reducing water quality. The size of the buffer varies with the application technique and the characteristics of individual herbicides, such as the toxicity of the herbicide to animals and aquatic organisms that might use the water, and the movement, persistence and fate of the herbicide in the environment close to water. The critical element in protection of water quality with respect to glyphosate is protection of aquatic species. The following discussion focuses on protecting human health, but the buffer strategy outlined also protects aquatic species, as outlined in Appendix G2.

For broadcast foliar mechanical (airblast) application (1 and 2 lb/acre) the following buffers and application tactics will provide water quality protection for humans involving the use of glyphosate.

- No glyphosate shall be applied to surface waters.
- Buffers 25 ft wide along each side of perennial streams, impoundments, springs, intermittent streams and seeps with flowing water the day of spraying;
- 25 ft wide around wet areas (standing water) and vernal ponds with no defined outlet; and
- 10 ft wide along each side of dry intermittent streams, dry springs, and dry seeps.
- Airblast shall be directed away from the buffer when applications are made within 50 ft of the edge of the buffer, i.e., within 50 ft no airblast directed towards the edge of the buffer unless intervening vegetation 5 to 15 ft tall is sufficiently dense to intercept spray material.

For directed foliar backpack (up to 4 lb/acre) and for cut surface (up to 3 lb/acre) application methods the following buffers and tactics will provide water quality protection involving the use of glyphosate:

- No glyphosate shall be applied to surface waters.
- No glyphosate shall be applied within 10 ft of standing or flowing water.
- Within 10 ft of a dry intermittent stream course, dry spring , or dry seep, use only the cut surface herbicide treatment technique with glyphosate.
- No glyphosate shall be applied to cut stems in the stream channel.

This buffer strategy was developed incorporating the experience of ANF managers with the management of power line rights-of-way, and the results of ANF monitoring of silvicultural and power line management operations (results are in several ANF Monitoring and Evaluation Reports) and buffer-width research (Norris and Charlton, 1995). Details on the development of the buffer strategy for glyphosate are in Appendix G2, Section D.

ANF has conducted monitoring programs in connection with operational applications of herbicide on the ANF to verify protection of water quality and damage to vegetation outside of treatment areas. There are several in-house reports that provide the specifics of the monitoring program (typically these are included in Monitoring and Evaluation Reports for specific fiscal years). Table 11 shows the ANF water quality monitoring program activity. Visual monitoring for herbicide damage to vegetation was conducted in 2003 and 2004 and shows little or no damage to vegetation outside of the intended treatment area. Chemical water quality monitoring of silvicultural applications in 1987, 1988, and 2002 and of utility ROW applications in 1998-2000 has shown no detectable concentrations of glyphosate in water samples tested.

Table 11. Year and type of ANF monitoring for water quality

Year of Treatment and Survey Monitoring	Year of Monitoring and Evaluation Report	Vegetation Management Activity	Herbicide Monitored
1987	1988	Silviculture	glyphosate
1988	1989	Silviculture	glyphosate
1989	1990	Silviculture	sulfometuron methyl
1998	2000	Utility ROW[1]	glyphosate and imazapyr
1999	2001	Utility ROW	glyphosate and imazapyr
2000	2002	Utility ROW	glyphosate and imazapyr
2002	2002	Silviculture	glyphosate and sulfometuron methyl

* This table is also repeated as Table 64 in Section 7: Exposure Analysis for Sulfometuron Methyl in this appendix
[1] ROW= right-of-way.

Based on this experience, monitoring and research, and the analysis of drift done in this appendix, we conclude that the buffer strategy used previously by the ANF for silvicultural operations was unnecessarily restrictive. We believe the buffers proposed in this current ANF risk assessment will protect aquatic life and water users. However, continued monitoring is needed to increase the breadth of the experience base and to further verify the adequacy of this buffer strategy, and to provide documentation that water quality is protected.

The analysis done for this document shows that these buffers will protect water quality. When these buffer strips are used, glyphosate residues in water are expected to be less than 0.05 mg/L and to persist in measurable amounts for less than 1 week. During storms occurring within the first 30 days after application, the maximum concentration of glyphosate expected in stream water (perennial or intermittent) is less than 0.02 mg/L, with persistence of less than 1 week.

These values are much less than the 0.7 mg/L water quality protection criterion for glyphosate specified in the USDA FS (1997), and is considered to be currently valid. Consumption of water (2 L/day) contaminated at the level of the water quality protection criterion of 0.7 mg/L would result in an exposure value for a 70 kg human of 0.02 mg/kg/day. (The HQ for this exposure based on the RfD of 2 mg/kg/day is 0.01, which is 100 fold less than the level of concern, see Section 5.)

Residues in Animals and Fish

Glyphosate taken into the body does not accumulate in any tissues and is excreted rapidly, unchanged. Game or fish taken immediately after exposure may contain very low residues, but possible intake is orders of magnitude below levels of concern.

In bluegill fish exposed to 0.612 ppm radio labeled glyphosate for 28 days, there was an accumulation of residue in edible portions of the fish with a bioconcentration factor (BCF) of 1.6 (the BCF is the ratio of the concentration in the animal to the concentration in the water). Maximum residue levels in channel catfish of 0.55 ppm were found 7 days after exposure to 10 ppm glyphosate for 14 days. In the same study, largemouth bass and rainbow trout had maximum residue levels of 0.12 and 0.11 ppm, respectively. Rainbow trout exposed to varying concentrations of glyphosate for 12 hours had no detectable residues of glyphosate or its primary metabolite, aminomethyl phosphonic acid. However, trout exposed to Roundup® at 2.0 ppm for 12 hours were reported to have 80 ppb of glyphosate in fillets and 60 ppb of glyphosate in eggs (Folmar et al. 1979). Note: In the original publication the tissue concentration was reported as 80 ppm, which was a misprint, later corrected. There were no detectable residues of glyphosate in midge larvae exposed to 2.0 ppm. The bioconcentration factors are believed to be between 0.1 and 0.3 (USDA FS 1997).

BCFs for carp and tilapia fish were reported by Wang et al. (1994) using radioactively labeled and unlabeled glyphosate over a 14-day period. BCF factors for carp exposed to 0.5 and 0.05 ppm of glyphosate ranged from 11.3 (lowest on day 3) to 42.3 (peaked at day 7) and 10.0 (day 1) to 33.6 (peaked at day 7), respectively; for tilapia exposed to 0.5 and 0.05 ppm of glyphosate BFCs ranged from 12.9 (lowest on day 2) to 65.5 (peaked at day 5) and 12.0 (day 0.5) to 35.4 (peaked at day 3), respectively.

In an Oregon forest, the highest concentration (5 ppm) was found one day after application in the viscera of deer mice, an omnivore. The concentration fell rapidly with time, to 0.37 ppm at one week, 0.17 ppm at 2 weeks and not detectable at 4 and 7.8 weeks. No resides of glyphosate exceeded 0.5 ppm in the body (minus the viscera) of any animal in this study. Fish from the stream, which was directly over-sprayed in this study, did not contain detectable residues of glyphosate or AMPA, indicating it has little tendency to bioaccumulate despite its detectable presence in the water for 3 days, and a source of glyphosate and AMPA in the sediment for 55 days (USDA FS 1997).

We expect similar values for terrestrial animals to hold for the ANF, but values for aquatics will be lower because of the buffer strategy used on the ANF. There was no buffer in the Oregon study.

Glyphosate Human Exposure Analysis

The following tables (Tables 12–17) indicate the characteristics (magnitude, frequency and duration) of worker exposure on the ANF in connection with the application of glyphosate. Tables 12–17 were used to calculate the frequency and duration of applicator exposure.

Sustaining Forest Cover and the Production of Forest Products

Table 12. Anticipated acres treated daily by a worker for "Sustaining Forest Cover and the Production of Forest Products" in the ANF

Application Method	Acres treated daily with Glyphosate		
	lower	central	upper
Mechanical (broadcast foliar) Airblast	22	25	40
Manual (directed foliar) Backpack/hand sprayer	2.5	3	7
Cut surface	1.25	1.5	3.5

*Crew size = 2, so a crew treats double the acres shown above

Table 13. Anticipated worker exposure in hours per day and acres per hour for "Sustaining Forest Cover and the Production of Forest Products" in the ANF

Application Method	Hours per day			Acres per hour		
	lower	central	upper	lower	central	upper
Mechanical (broadcast foliar) Airblast	7	8	11	3.13	3.13	3.64
Manual (directed foliar) Backpack/hand sprayer	5	6	7	0.5	0.5	1.0
Cut surface	5	6	7	0.25	0.25	0.5

Developing and Maintaining Wildlife Habitat, Heritage Resources, and Visual Enhancements

Table 14. Anticipated number of acres treated daily by a worker for "Developing and Maintaining Wildlife Habitat, Heritage Resources, and Visual Enhancements" in the ANF

Application Method	Acres treated daily with Glyphosate		
	lower	central	upper
Mechanical (broadcast foliar) Airblast	22	25	40
Manual (directed foliar) Backpack/hand sprayer	2.5	3	7
Cut surface	1.25	1.5	3.5

*Crew size = 2, so a crew treats double the acres shown above

Table 15. Anticipated worker exposure in hours per day and acres per hour for "Developing and Maintaining Wildlife Habitat, Heritage Resources, and Visual Enhancements" in the ANF

Application Method	Hours per day			Acres per hour		
	lower	central	upper	lower	central	upper
Mechanical (broadcast foliar) Airblast	7	8	11	3.13	3.13	3.64
Manual (directed foliar) Backpack/hand sprayer	5	6	7	0.5	0.5	1.0
Cut surface	5	6	7	0.25	0.25	0.5

Treatment/Control of Native and Non-native Invasive Species

Table 16. Anticipated number of acres treated daily by a worker for "Treatment/Control of Native and Non-native Invasive Species" in the ANF

Application Method	Acres treated daily with Glyphosate		
	lower	central	upper
Mechanical (broadcast foliar) Airblast	2.3	3	5
Manual (directed foliar) Backpack/hand sprayer	2.3	3	7
Cut surface	1.1	1.5	3.5

*Crew size = 2, so a crew treats double the acres shown above

Table 17. Anticipated worker exposure in hours per day and acres per hour for "Treatment/Control of Native and Non-native Invasive Species" in the ANF

Application Method	Hours per day			Acres per hour		
	lower	central	upper	lower	central	upper
Mechanical (broadcast foliar) airblast	3	4	8	0.75	0.75	0.63
Manual (directed foliar) Backpack/hand sprayer	3	4	6	0.75	0.75	1.17
Cut surface	3	4	6	0.38	0.38	0.58

Human Exposure Assessment

Overview and Summary

Glyphosate worker and general public exposure assessments for the ANF are given in Tables 19–27 and Tables 31–39, respectively. These assessments correspond to the vegetation management activities outlined above, which include: sustaining forest cover and the production of forest products; developing and maintaining wildlife habitat, heritage resources, and visual enhancements; and treatment/control of non-native invasive species. Tables 19–27 and Tables 31–39 were developed using the USFS Worksheet Maker Version 4.02 created by SERA (http: //www.nvo.com/sera_inc/nss-folder/worksheets1v31/).

Two types of worker exposure assessments are considered: general and accidental/incidental. For general exposures, i.e., daily (chronic) exposures that might occur over the course of an application season, the general exposure assessment estimates the absorbed dose based on the handling of a specified amount of a chemical during specific types of applications. The accidental/incidental exposure scenarios estimate exposure from specific types of events that could occur during any type of application.

For general exposures in workers, exposure rates are expressed as milligrams (mg) of absorbed dose per kilogram (kg) of body weight per pound of chemical handled. Analysis of several worker exposure studies involving backpack applications indicate that the general exposure estimates used in many Forest Service risk assessments are extremely conservative. For this ANF risk assessment, we retain this conservative approach and use the standard worker exposure rates, recognizing that the upper range of exposures may overestimate risk. This conservative approach has little impact on the interpretation of risk because none of the worker exposures exceed a hazard quotient of one.

For proposed glyphosate applications in the ANF, central estimates of worker exposures span a factor of 28, from 0.0005 mg/kg/day to about 0.014 mg/kg/day. The upper range of exposures for the different application methods and management needs are about a factor of 15 higher, spanning a range from about 0.007 mg/kg/day to 0.21 mg/kg/day.

Under normal circumstances, members of the general public should not be exposed to substantial levels of glyphosate as a result of U.S. Forest Service activities. Nonetheless we developed several highly conservative scenarios for this risk assessment. The two types of exposure scenarios developed for the general public include acute exposure and longer-term or chronic exposure.

All of the acute exposure scenarios are primarily accidental. They assume that an individual is exposed to the compound during or shortly after its application. Specific scenarios are developed for direct spray, dermal contact with contaminated vegetation, as well as the consumption of contaminated fruit, water, and fish. Most of these scenarios should be regarded as extreme, some to the point of limited plausibility. The longer-term or chronic exposure scenarios parallel the acute exposure scenarios for the consumption of contaminated fruit, water, and fish but are based on estimated levels of exposure for longer periods after application.

Most acute accidental exposure scenarios for members of the general public are less than or similar to the general exposure scenarios in workers. The major exceptions are accidental direct spray of an unclothed child and consumption of water from a pond following an accidental spill. Direct spray of an unclothed child associated with cut surface application results in estimates of exposure ranging from 0.5 to 5.1 mg/kg. An accidental spill of 200 gallons of a field solution into a small pond is assumed for dilute solutions (25 gal/acre) used for airblast and backpack applications. This results in modeled estimates of exposure from consumption of pond water in the range of 0.2 to about 0.6 mg/kg/day. A 5 gallon spill of undiluted product is assumed for cut surface treatments. This is based on the maximum amount of product expected at a cut surface application site. Modeled estimates of exposure for this scenario are 0.5 to 2.3 mg/kg/day. These are extraordinarily extreme and conservative scenarios that are used in all Forest Service risk assessments.

The highest exposure for members of the general public for other scenarios is the longer-term consumption of contaminated fruit, resulting in time-weighted average estimated doses of 0.01 to 0.3 mg/kg/day for backpack applications for invasive species vegetation management.

Detailed Information

Workers

A summary of the exposure assessments for workers is presented in Tables 19–27. Two types of exposure assessments are considered: general and accidental/incidental. The term general exposure assessment is used to designate those exposures that involve estimates of absorbed dose based on the handling of a specified amount of a chemical during specific types of applications. The accidental/incidental exposure scenarios involve specific types of events that could occur during any type of application. Details regarding the exposure assessments are in the worksheets.

The following is a narrative description of the SERA (2001) analysis for workers with some comparisons, where appropriate, to ANF conditions or equipment. This is followed by Tables 19–27 that use the SERA protocol to quantify the exposure for ANF workers extrapolated (where possible) to ANF conditions.

General Exposures

General exposures are daily (chronic) exposures that might occur over the course of an application season. As described in SERA (2001), worker exposure rates are expressed in units of mg of absorbed dose per kilogram of body weight per pound of chemical handled. Based on analyses of several different pesticides using a variety of application methods, default exposure rates are estimated for three different types of applications: directed foliar (backpack); broadcast foliar (airblast spray); and cut surface treatment. The specific rates generally used for each of these application methods for various management scenarios are summarized in Tables 2, 4 and 6.

The ranges of estimated occupational exposure rates vary substantially among individuals and groups, (i.e., by a factor of 50 for backpack applicators) (SERA 2001), The Forest Service has not developed a worker exposure assessment for applicators using airblast spray equipment. Deposition-based worker exposure modeling described in the Pesticide Handlers Exposure Database (PHED; Leighton and Nielson 1995) was used to estimate the appropriate occupational exposure rate to be used to estimate applicator exposure for the airblast sprayer.

For minimal protective clothing (long pants, long shirt, and no gloves) the PHED uses a dermal unit exposure (mg/lb a.i.) of 0.014 for ground boom and 0.24 for airblast sprayer. This results in a dermal unit exposure for airblast that is about 17 times greater compared to ground boom. Assuming equal dermal adsorption, multiplying the adsorption-based exposure rates for ground boom used by the U.S. Forest Service by 17 gives exposure rates roughly equal to directed foliar applications, such as backpack. SERA (2001) also describes the rationale for grouping cut surface with direct foliar applications for estimating exposure rates used in risk assessments. In this ANF risk assessment, the SERA directed foliar exposure values, modified to reflect ANF application rates and the amount of herbicide applied per worker, were used to represent ANF worker exposure for cut surface application.

Note that the airblast equipment used by ANF is quite different than the agricultural airblast equipment (orchard airblast sprayer) on which the SERA analysis is based. The orchard airblast equipment typically sends the spray in a vertical 180 degree arc behind the equipment, with the operator riding ahead of the machine on a tractor. The ANF airblast equipment is much more directional and sends the spray material away from the operator, however there is no quantitative data on which to make an adjustment to the SERA and Forest Service analysis. Hence the SERA analysis is used, which should provide a conservative risk assessment for ANF programs.

The default rate derived in SERA (2001) for backpack application is 0.003 mg/kg bw per lb applied with a range of 0.0003 to 0.01 mg/kg bw per lb applied. For glyphosate, there are several worker exposure studies involving backpack applications that can be used to assess the quality of these values (Edmiston et al. 1995; Jauhiainen et al. 1991; Lavy et al. 1992; Machado-Neto et al. 2000; Middendorf 1993; and Schneider et al. 1999). Three of these studies (Edmiston et al. 1995; Machado-Neto et al. 2000; Schneider et al. 1999) provide only deposition data and cannot be used directly to assess the use of the standard exposure rates summarized in Table 18. The other three studies (Jauhiainen et al. 1991;Lavy et al. 1992; Middendorf 1993) involved backpack applications with both biomonitoring, i.e., urinary analysis, as well as deposition data as measures of exposure and are thus most relevant to the assessment of the general exposure values summarized in Table 18.

Table 18. Occupational exposure rates used in U.S. Forest Service risk assessments

Application Method	Rate (mg/kg bw per lb applied)		
	Central	Lower	Upper
Directed foliar[1]	0.003	0.0003	0.01
Cut Surface[1]	0.003	0.0003	0.01
Broadcast boom[1]	0.0002	0.00001	0.0009
Broadcast airblast[2]	0.003	0.0003	0.01

[*] This table is also repeated as Table 71 in Section 7, Sulfometuron methyl exposure analysis, this appendix.
[1] SERA (2001).
[2] EPA PHED: assuming minimal personal protective equipment (PPE), dermal unit exposure (mg/lb a/i.) is ~17 times greater for airblast compared to groundboom application.

In the study by Jauhiainen et al. (1991), biological monitoring was conducted on five workers applying Roundup®. Each worker handled an average of 9.8 L of an 8% solution of Roundup® (360 g a.i./L or 270 g a.e./L). Thus, the amount of glyphosate acid handled each day was approximately 0.211 kg [9.8 L × 0.08 × 0.270 kg/L] (Jauhiainen et al. 1991, p. 62, column one, top of page) or about 0.5 lbs. Urine samples [not total daily urine] were collected at the end of each work day for 1 week during the application period, and one sample was taken 3 weeks after the applications. The urine samples were assayed for glyphosate using gas chromatography/electron capture with a limit of detection of 0.1 ng/µL or 0.1 mg/mL. No glyphosate was detected in any of the urine samples using this method.

One urine sample was assayed for glyphosate by gas chromatography/mass spectroscopy (GC/MS), and glyphosate was detected at a level of 0.085 ng/µL, equivalent to 0.085 µg/mL. Assuming that this urine sample was representative and using the default body weight of 70 kg and urinary output of 2000 mL/day (SERA 2003b, Worksheet A-02), the absorbed dose would be 0.17 mg or 170 µg [0.085 µg/mL × 2,000 mL] or 0.0024 mg/kg bw [0.17 mg ÷ 70 kg]. The corresponding exposure rate would be 0.0048 mg/kg bw per lb a.e. applied [0.0024 mg/kg bw ÷ 0.5 lb a.e.]. This value is very similar to the central estimate of 0.003 mg/kg bw per lb applied that is generally used for directed foliar applications (SERA 2003a, Table 4-2).

As with the study by Jauhiainen et al. (1991), the Lavy et al. (1992) study involved applications of Roundup®. Nursery workers applied Roundup® to small weeds in a nursery bed by placing a 290 mL (2.5x3.5 cm) cylindrical metal shield surrounding the spray nozzle over the weed, to protect adjacent conifer seedlings, and then spraying the weeds with Roundup®. Biological monitoring consisted of 5-day complete urine collections. In a total of 355 urine samples, no glyphosate was detected (limit of detection = 0.01 µg/mL). Assuming that the concentration of glyphosate in the urine was just below the limit of detection and assuming a urinary output of 2,000 mL (SERA 2003b, Worksheet A-02), the total absorbed dose would be 20 µg or 0.02 mg. The most exposed individual in this study weighed 63.5 kg and handled, on average, 0.54 kg [1.18 lbs] of glyphosate per day. Thus, the maximum absorbed dose of 0.02 mg corresponds to 0.0003 mg/kg bw [0.02 mg ÷ 63.5 kg] and 0.00025 mg/kg bw per lb applied [0.0003 mg/kg ÷ 1.18 lbs]. This is modestly below the lower range of the value of 0.0003 mg/kg bw per lb applied that is generally used for directed foliar applications SERA (2003a, Table 4-2). Based on passive monitoring, estimated exposure rates were about 1.3×10^{-3} (2.6×10^{-4} to 1.27×10^{-2}) mg/kg bw per lb applied. This central estimate and range is virtually identical to the values for directed foliar applications given in SERA (2003a, Table 4-2).

The study by Middendorf (1993) also involved backpack (directed foliar) applications of Roundup® , albeit in a more dilute mixture (2.3%), which is similar to the concentration used on the ANF. Middendorf (1993) provides data (urinary excretion, lbs applied, body weight, and deposition) on 15 workers at three different application sites. The average exposure rate for all workers was approximately 0.00032 mg/kg bw per lb applied with a range of 0.00013 to 0.001 mg/kg bw per lb applied. The central estimate from the Middendorf (1993) study is virtually identical to the lower range of 0.0003 mg/kg bw per lb typically used for directed foliar applications, and the upper range noted in the Middendorf (1993) study is somewhat below the central estimate of 0.003 mg/kg bw given in SERA (2003a, Table 4-2).

The three worker studies (Jauhiainen et al. 1991; Lavy et al. 1992; Middendorf 1993) that provide biomonitoring data sufficient to estimate absorbed doses in workers support the use of the exposure rates described in SERA (2001). If anything, the upper range of exposure, i.e., 0.01 mg/kg bw per lb applied, likely overestimates exposure. None of the estimates based on biomonitoring approach this rate. Nonetheless, for this ANF risk assessment, the standard worker exposure rates are used, recognizing that the upper range of exposures may be extremely conservative. As discussed further in the section on risk characterization (Section 5), this conservative approach has little impact on the interpretation of risk because none of the worker exposures exceed a hazard quotient of one.

Estimates of the number of acres treated per hour is needed to apply these worker exposure rates. These values are given in Tables 13, 15 and 17. The range of acres treated per hour and hours worked per day is used to calculate a range for the number of acres treated per day. For this calculation as well as others in this section involving the multiplication of ranges, the lower end of the resulting range is the product of the lower end of one range and the lower end of the other range. Similarly, the upper end of the resulting range is the product of the upper end of one range and the upper end of the other range. This approach is taken to encompass as broadly as possible the range of potential exposures.

For the ANF, typical and maximum rates are reported. For purposes of human exposure assessment using USFS Worksheet Maker, the ANF typical rate was used for both the central and lower estimates.

The central estimate of the acres treated per day is taken as the arithmetic average of the range. Because of the relatively narrow limits of the ranges for backpack and ground airblast spray workers, the use of the arithmetic mean rather than some other measure of central tendency, like the geometric mean, has no marked effect on the risk assessment.

As detailed in SERA (2003b, Worksheets C01a (directed foliar) and C01b (broadcast foliar)), the central estimate of the amount handled per day is the product of the central estimates of the acres treated per day and the application rate. The ranges for the amounts handled per day are the product of the range of acres treated per day and the application rate. Similarly, the central estimate of the daily absorbed dose is the product of the central estimate of the exposure rate and the central estimate of the amount handled per day. The ranges of the daily absorbed dose are the range of exposure rates and the ranges for the amounts handled per day. The lower and upper limits are similarly calculated using the lower and upper ranges of the amount handled, acres treated per day, and worker exposure rate.

Accidental Exposures

Typical occupational exposures may involve multiple routes of exposure (i.e., oral, dermal, and inhalation); nonetheless, dermal exposure is generally the predominant route for herbicide applicators (Ecobichon 1998; van Hemmen 1992). Typical multi-route exposures are used for general exposures. Accidental exposures, on the other hand, are most likely to involve splashing a solution of herbicides into the eyes or to involve various dermal exposure scenarios.

Some glyphosate formulations can cause irritant effects in the skin and eyes (see above). The available literature does not include quantitative methods for characterizing exposure or responses associated with splashing a solution of a chemical into the eyes; furthermore, there appear to be no reasonable approaches to modeling this type of exposure scenario quantitatively. Consequently, accidental exposure scenarios of this type are considered qualitatively in the risk characterization.

There are various methods for estimating absorbed doses associated with accidental dermal exposure (U.S. EPA/ORD 1992; SERA 2001). Two general types of exposure are modeled: those involving direct contact with a solution of the herbicide (for instance immersing the hands in spray mixture) and those associated with accidental spills of the herbicide onto the surface of the skin. Any number of specific exposure scenarios could be developed for direct contact or accidental spills by varying the amount or concentration of the chemical on or in contact with the surface of the skin and by varying the surface area of the skin that is contaminated.

For this risk assessment, two exposure scenarios are developed for each of the two types of dermal exposure, and the estimated absorbed dose for each scenario is expressed in units of mg chemical/kg body weight.

Exposure scenarios involving direct contact with solutions of the chemical are characterized by immersion of the hands for 1 minute or wearing contaminated gloves for 1 hour. It is unlikely that the hands or any other part of a worker will be immersed in a solution of a herbicide for any period of time. On the other hand, contamination of gloves or other clothing is quite plausible, and these could be worn for a longer period of time. For these exposure scenarios, the key element is the assumption that wearing gloves grossly contaminated with a chemical solution is equivalent to immersing the hands in a solution. In either case, the concentration of the chemical in solution that is in contact with the surface of the skin and the resulting dermal absorption rate are essentially constant. For both scenarios (the hand immersion and wearing the contaminated glove), the assumption of zero-order absorption kinetics is appropriate. Following the general recommendations of U.S. EPA/ORD (1992), Fick's first law is used to estimate dermal exposure.

Exposure scenarios involving chemical spills include deposition on the lower legs and the hands. It is assumed that a solution of the chemical is spilled onto a given surface area of skin, and that a certain amount of the chemical adheres to the skin. The absorbed dose is then calculated as the product of the amount of the chemical on the surface of the skin (i.e., the amount of liquid per unit surface area multiplied by the surface area of the skin over which the spill occurs and the concentration of the chemical in the liquid) the first-order absorption rate, and the duration of exposure. The first-order dermal absorption rates (from the study by Wester et al. 1991) averages 4.1×10^{-4} /hour with a range of 1.3×10^{-4} to 1.0×10^{-3} /hour. For both scenarios, it is assumed that the contaminated skin is effectively cleaned after 1 hour. As with the exposure assessments based on Fick's first law, this product (mg of absorbed dose) is divided by body weight (kg) to yield an estimated dose in units of mg chemical/kg body weight. The specific equation used in these exposure assessments is taken from SERA (2000 as cited in SERA 2003a).

Table 19. Summary of glyphosate worker exposure assessments: Airblast applications for "Sustaining Forest Cover and the Production of Forest Products" in the ANF

Scenario	Receptor	mg/kg/day or mg/kg/event			SERA (2003b) Worksheet
		Central	Lower	Upper	
Accidental/Incidental Exposures (dose in mg/kg/event)					
Contaminated Gloves, 1 min.	Worker	0.0000011	0.0000002	0.0000091	C02a
Contaminated Gloves, 1 hour	Worker	0.0000648	0.0000129	0.0005443	C02b
Spill on Hands, 1 hour	Worker	0.0001417	0.0000362	0.0006909	C03a
Spill on lower legs, 1 hour	Worker	0.0003491	0.0000892	0.0017025	C03b
General (Chronic) Exposures (mg/kg/day)					
General (chronic) exposure	Airblast	0.0038	0.0001	0.0541	C01b

Note: Table 19 is derived from SERA worksheet E01.

Table 20. Summary of glyphosate worker exposure assessments: Backpack applications for "Sustaining Forest Cover and the Production of Forest Products" in the ANF

Scenario	Receptor	mg/kg/day or mg/kg/event			SERA (2003b) Worksheet
		Central	Lower	Upper	
Accidental/Incidental Exposures (dose in mg/kg/event)					
Contaminated Gloves, 1 min.	Worker	0.0000011	0.0000001	0.0000091	C02a
Contaminated Gloves, 1 hour	Worker	0.0000648	0.0000080	0.0005443	C02b
Spill on Hands, 1 hour	Worker	0.0001417	0.0000225	0.0006909	C03a
Spill on lower legs, 1 hour	Worker	0.0003491	0.0000554	0.0017025	C03b
General (Chronic) Exposures (mg/kg/day)					
General (chronic) exposure	Backpack	0.01350	0.00029	0.05250	C01a

Note: Table 20 is derived from SERA worksheet E01.

Table 21. Summary of glyphosate worker exposure assessments: Cut surface applications for "Sustaining Forest Cover and the Production of Forest Products" in the ANF

Scenario	Receptor	mg/kg/day or mg/kg/event			SERA (2003b) Worksheet
		Central	Lower	Upper	
Accidental/Incidental Exposures (dose in mg/kg/event)					
Contaminated Gloves, 1 min.	Worker	0.000108	0.000009	0.001386	C02a
Contaminated Gloves, 1 hour	Worker	0.006480	0.000533	0.083160	C02b
Spill on Hands, 1 hour	Worker	0.014167	0.001498	0.105547	C03a
Spill on lower legs, 1 hour	Worker	0.034911	0.003690	0.260099	C03b
General (Chronic) Exposures (mg/kg/day)					
General (chronic) exposure	Cut Surface	0.0068	0.0003	0.0788	C01a

Note: Table 21 is derived from SERA worksheet E01.

Table 22. Summary of Glyphosate Worker Exposure Assessments: Airblast Applications for "Developing and Maintaining Wildlife Habitat, Heritage Resources, and Visual Enhancements" in the ANF.

Scenario	Receptor	mg/kg/day or mg/kg/event			SERA (2003b) Worksheet
		Central	Lower	Upper	
Accidental/Incidental Exposures (dose in mg/kg/event)					
Contaminated Gloves, 1 min.	Worker	0.0000011	0.0000002	0.0000091	C02a
Contaminated Gloves, 1 hour	Worker	0.0000648	0.0000129	0.0005443	C02b
Spill on Hands, 1 hour	Worker	0.0001417	0.0000362	0.0006909	C03a
Spill on lower legs, 1 hour	Worker	0.0003491	0.0000892	0.0017025	C03b
General (Chronic) Exposures (mg/kg/day)					
General (chronic) exposure	Airblast	0.0038	0.0001	0.0541	C01b

Note: Table 22 is derived from SERA worksheet E01.

Table 23. Summary of glyphosate worker exposure assessments: Backpack applications for "Developing and Maintaining Wildlife Habitat, Heritage Resources, and Visual Enhancements" in the ANF.

Scenario	Receptor	mg/kg/day or mg/kg/event			SERA (2003b) Worksheet
		Central	Lower	Upper	
Accidental/Incidental Exposures (dose in mg/kg/event)					
Contaminated Gloves, 1 min.	Worker	0.0000011	0.0000001	0.0000091	C02a
Contaminated Gloves, 1 hour	Worker	0.0000648	0.0000080	0.0005443	C02b
Spill on Hands, 1 hour	Worker	0.0001417	0.0000225	0.0006909	C03a
Spill on lower legs, 1 hour	Worker	0.0003491	0.0000554	0.0017025	C03b
General (Chronic) Exposures (mg/kg/day)					
General (chronic) exposure	Backpack	0.01350	0.00029	0.05250	C01a

Note: Table 23 is derived from SERA worksheet E01.

Table 24. Summary of glyphosate worker exposure assessments: Cut surface applications for "Developing and Maintaining Wildlife Habitat, Heritage Resources, and Visual Enhancements" in the ANF.

Scenario	Receptor	mg/kg/day or mg/kg/event			SERA (2003b) Worksheet
		Central	Lower	Upper	
Accidental/Incidental Exposures (dose in mg/kg/event)					
Contaminated Gloves, 1 min.	Worker	0.000108	0.000009	0.001386	C02a
Contaminated Gloves, 1 hour	Worker	0.006480	0.000533	0.083160	C02b
Spill on Hands, 1 hour	Worker	0.014167	0.001498	0.105547	C03a
Spill on lower legs, 1 hour	Worker	0.034911	0.003690	0.260099	C03b
General (Chronic) Exposures (mg/kg/day)					
General (chronic) exposure	Cut Surface	0.0068	0.0003	0.0788	C01a

Note: Table 24 is derived from SERA worksheet E01.

Table 25. Summary of glyphosate worker exposure assessments: Airblast applications for "Treatment/Control of Native and Non-native Invasive Species" in the ANF

Scenario	Receptor	mg/kg/day or mg/kg/event			SERA (2003b) Worksheet
		Central	Lower	Upper	
Accidental/Incidental Exposures (dose in mg/kg/event)					
Contaminated Gloves, 1 min.	Worker	0.0000011	0.0000002	0.0000091	C02a
Contaminated Gloves, 1 hour	Worker	0.0000648	0.0000129	0.0005443	C02b
Spill on Hands, 1 hour	Worker	0.0001417	0.0000362	0.0006909	C03a
Spill on lower legs, 1 hour	Worker	0.0003491	0.0000892	0.0017025	C03b
General (Chronic) Exposures (mg/kg/day)					
General (chronic) exposure	Airblast	0.00045	0.00001	0.00680	C01b

Note: Table 25 is derived from SERA worksheet E01.

Table 26. Summary of glyphosate worker exposure assessments: Backpack applications for "Treatment/Control of Native and Non-native Invasive Species" in the ANF

Scenario	Receptor	mg/kg/day or mg/kg/event			SERA (2003b) Worksheet
		Central	Lower	Upper	
Accidental/Incidental Exposures (dose in mg/kg/event)					
Contaminated Gloves, 1 min.	Worker	0.0000022	0.0000003	0.0000176	C02a
Contaminated Gloves, 1 hour	Worker	0.0001296	0.0000160	0.0010584	C02b
Spill on Hands, 1 hour	Worker	0.0002833	0.0000449	0.0013433	C03a
Spill on lower legs, 1 hour	Worker	0.0006982	0.0001107	0.0033103	C03b
General (Chronic) Exposures (mg/kg/day)					
General (chronic) exposure	Backpack	0.0135	0.0005	0.2106	C01a

Note: Table 26 is derived from SERA worksheet E01.

Table 27. Summary of glyphosate worker exposure assessments: Cut surface applications for "Treatment/Control of Native and Non-native Invasive Species" in the ANF

Scenario	Receptor	mg/kg/day or mg/kg/event			SERA (2003b) Worksheet
		Central	Lower	Upper	
Accidental/Incidental Exposures (dose in mg/kg/event)					
Contaminated Gloves, 1 min.	Worker	0.000108	0.000007	0.001764	C02a
Contaminated Gloves, 1 hour	Worker	0.006480	0.000404	0.105840	C02b
Spill on Hands, 1 hour	Worker	0.014167	0.001136	0.134333	C03a
Spill on lower legs, 1 hour	Worker	0.034911	0.002798	0.331034	C03b
General (Chronic) Exposures (mg/kg/day)					
General (chronic) exposure	Cut Surface	0.00342	0.00013	0.05220	C01a

Note: Table 27 is derived from SERA worksheet E01.

General Public

General Considerations

Under normal circumstances, members of the general public should not be exposed to substantial levels of glyphosate as a result of ANF activities. Nonetheless, any number of exposure scenarios can be constructed for the general public, depending on various assumptions regarding application rates, dispersion, canopy interception, and human activity. Several highly conservative scenarios are developed for this risk assessment.

The two types of exposure scenarios developed for the general public include acute and chronic exposure. The acute exposure scenarios are primarily accidental, assuming that an individual is exposed to the compound either during or shortly after its application. Specific scenarios are developed for direct spray, dermal contact with contaminated vegetation, as well as the consumption of contaminated fruit, water, and fish. Most of these scenarios should be regarded as extreme, some to the point of limited plausibility. The longer-term or chronic exposure scenarios parallel the acute exposure scenarios for the consumption of contaminated fruit, water, and fish but are based on estimated levels of exposure for longer periods after application.

The following is a narrative description of the SERA (2003a) analysis for the general public. It includes narrative descriptions of ANF conditions that would likely lead to a more conservative estimate of exposure. This is followed by Tables 31–39 that use SERA protocol to quantify the ANF public exposure extrapolated, where possible, to ANF conditions.

Direct Spray

Direct sprays involving ground applications are modeled in a manner similar to accidental spills for workers. It is assumed that the individual is sprayed with a solution containing the compound and that an amount of the compound remains on the skin and is absorbed following first-order kinetics. The first-order absorption dermal absorption rates are taken from the study by Wester et al. (1991).

For direct spray scenarios, it is assumed that during a ground application, a naked child is sprayed directly with glyphosate. The scenario also assumes that the child is completely covered with glyphosate (that is, 100% of the surface area of the body is exposed). This an extremely conservative exposure scenario. An additional set of scenarios involve a woman accidentally sprayed over the feet and legs. For each of these scenarios, some assumptions are made regarding the surface area of the skin and body weight.

Dermal Exposure from Contaminated Vegetation

In this exposure scenario, it is assumed that the herbicide is sprayed at a given application rate and that an individual comes in contact with sprayed vegetation or other contaminated surfaces at some period after the spray operation. Lacking estimates of dislodgeable residue and the rate of transfer from the contaminated vegetation to the surface of the skin, we follow the estimation methods of Durkin et al. (1995) as defined in SERA (2003b, Worksheet D03). Other estimates in this exposure scenario involve body weight, skin surface area, and first-order dermal absorption rates as detailed in SERA (2003b, Worksheet A03), and the first-order absorption dermal absorption rates of Wester et al. (1991).

Contaminated Water

Water can be contaminated from runoff, as a result of leaching from contaminated soil, from a direct spill, or from unintentional contamination from airblast applications. For this risk assessment, the two types of estimates made for the concentration of glyphosate in ambient water are acute/accidental exposure from an accidental spill and longer-term exposure to glyphosate in ambient water that could be associated with the application of this compound to a 10 acre block that drains into a small stream or pond.

Acute Exposure

Two exposure scenarios are presented for the acute consumption of contaminated water: an accidental spill into a small pond (0.25 acres in surface area and 1 meter deep) and the contamination of a small stream by runoff.

The accidental spill scenario assumes that a young child consumes contaminated water shortly after an accidental spill into a small pond. The specifics of this scenario are given in SERA (2003b, Worksheet D05). No dissipation of glyphosate is considered, making this an extremely conservative scenario. The concentration of glyphosate in a small pond is estimated to range from 2.7 mg/L to 5.4 mg/L for dilute spray solutions (25 gal/acre) and range from 7 mg/L to 26 mg/L for concentrated spray solutions (undiluted product) used for cut surface application.

The other acute exposure scenario for the consumption of contaminated water involves runoff into a small stream. Several monitoring studies are useful for estimating exposure to glyphosate in streams. After an aerial application of Roundup® at a rate of 2 kg a.i./ha [about 1.8 lb a.i./acre] over a 10 km^2 area in Vancouver Island, British Columbia, maximum concentrations in streams that were intentionally oversprayed reached about 0.16 mg/L and rapidly dissipated to less than 0.04 mg/L after 10 minutes. After a storm event, peak concentrations in stream water were less than 0.15 mg/L, rapidly dissipating to less than 0.02 mg/L before the end of the storm event (Feng et al. 1990, Kreutzweiser et al. 1989). At the same application rate, another Canadian study noted maximum stream concentrations of 0.109–0.144 mg/L, occurring 7–28 hours after aerial application. Similar results were noted in a study conducted in Oregon (Newton et al. 1984). Maximum water levels in streams reached 0.27 mg/L. This concentration was associated with repeated helicopter applications, i.e., direct spray, no buffers) across a small stream at an application rate of 3.3 kg/ha (equivalent to 2.9 lbs/acre). In a more recent series of studies conducted in Oregon, Michigan, and Georgia, peak concentrations in streams shortly after application of glyphosate at 4.1 kg/ha (about 3.6 lbs/acre) ranged from less than 0.1 mg/L to about 1 mg/L (Newton et al. 1994, Figure 4, p. 1799). The upper range of 1 mg/L corresponds to 0.28 mg/L per lb applied. As reviewed by Neary and Michael (1996), some applications have resulted in much lower concentrations in streams, in the range of 0.003 to 0.007 mg/L per lb applied (Neary and Michael 1996, Table 11, p. 253).

While monitoring data provide practical and documented instances of water contamination, monitoring studies may not encompass a broad range of conditions which may occur during program applications, e.g. extremely heavy rainfall. Consequently, for this component of the exposure assessment, the monitored levels in ambient water are compared to modeled estimates based on Groundwater Loading Effects of Agricultural Management Systems (GLEAMS). GLEAMS is a root zone model that can be used to examine the fate of chemicals in various types of soils under different meteorological and hydrogeological conditions (Knisel et al. 1992). As with many environmental fate and transport models, the input and output files for GLEAMS can be complex. The general application of the GLEAMS model to estimating concentrations in ambient water is given in SERA (2003a, Attachment 2).

For the current ANF risk assessment, the application site was assumed to consist of a 10 acre square area that drained directly into a small pond or stream. The pond dimensions (1000 m^3 or about 0.25 acres with an average depth of 1 meter) are the same as those used in the acute spill scenario. The chemical specific values used in the GLEAMS modeling are summarized in Table 28. Glyphosate degrades in the environment to metabolites whose toxicity is the same or less than the toxicity of glyphosate. For this risk assessment, only glyphosate is modeled, and the half-life in water is set to 1000 days (This ignores microbial degradation and is therefore a highly conservative approach. In pond studies, Goldsborough and Brown (1993) found that glyphosate dissipated rapidly from the surface waters with a dissipation half-life of 3.5-11.2 days).

The GLEAMS modeling yielded estimates of glyphosate runoff and percolation that were used to estimate concentrations in the stream adjacent to a treated plot, as detailed in Section 5.5 of Attachment 2 in SERA

(2003a). The results of the GLEAMS modeling for the small stream are summarized in Table 30, and the corresponding values for the small pond are summarized in Table 29. These estimates are expressed as the water contamination rates (WCR), i.e., the concentration of the compound in water in units of mg/L normalized for an application rate of 1.0 lb a.i./acre.

Overall, the monitoring data are in relatively good agreement with the estimates from GLEAMS. The upper range of the estimates based on monitoring data, i.e., 0.28 mg/L per lb applied from Newton et al. 1994, is very close to peak rates of about 0.2 to 0.4 mg/L per lb applied from the GLEAMS stream modeling (SERA 2003a, Table 4-6). The lower range of values from the monitoring data of 0.003 to 0.007 mg/L per lb applied (Neary and Michael 1996) is reasonably close to maximum values of 0.001 to 0.007 mg/L per lb applied from GLEAMS with rainfall rates of 15 inches per year or about 0.4 inches per storm event.

Table 28. Glyphosate specific pesticide parameters used in GLEAMS modeling and estimation of concentrations in ambient water (Derived from Table 3-4 on page 3-55 of SERA 2003a.)

Parameter	Clay	Loam	Sand	Comment/Reference
Half-life (days)				
Sediment	203	203	203	Dix 1998
Foliar	10	10	10	Note 1
Soil	30	30	30	Note 2
Water	1000	1000	1000	Note 3
Others Parameters				
K_{oc} (ml/g)	2000	2000	2000	Note 4
K_d (ml/g)	2600	2100	500	Note 5
Water Solubility (mg/L)	12000	12000	12000	Note 6
Foliar wash-off fraction	0.5	0.5	0.5	Leung 1994

Note 1 Central value from Feng and Thompson 1990 and Newton et al. 1984.
Note 2 Typical value from Table 2-2 (SERA 2003a).
Note 3 Glyphosate is stable in water at neutral pH. Ignore microbial degradation for modeling.
Note 4 Highly variable. Used geometric mean from Gerritse et al. 1996. We assume the correct units are ml/g.
Note 5 Use ranges from USDA/ARS 1995. Central value for loam, lower value for sand, and upper value for clay. We assume the correct units are ml/g.
Note 6 Value for acid given by Tomlin (1994) and USDA/ARS (1995).

Given the close correspondence between the monitoring data and modeling estimates of peak concentrations in stream water, the selection of monitoring data or modeling estimates makes very little difference to the exposure assessment. For this risk assessment, the range of WCR will be taken as 0.001 to 0.4 mg/L per lb applied per acre. The lower range is somewhat arbitrarily set. The upper range of 0.4 mg/L per lb applied is based on the upper range of the modeled stream concentrations from GLEAMS based on sandy soil. The typical WCR is taken as 0.02 mg/L per lb applied per acre. This is the geometric mean of the range and the approximate value of maximum concentrations in stream water modeled for clay and loam soils at an annual rainfall rate of 50 inches per year, similar to the average annual rainfall of 46 in/yr for the ANF.

The majority (approximately 75%) of surface soil textures found on the ANF fall within the loam category (loam, silt-loam, etc.). Hazelton soils (approximately 25% of ANF soils) are a sandy loam, which would have properties somewhere in between the loam and sand category. About 50% of the ANF has soil map units with a high potential for a fragipan (clay layer) at a depth of 40 to 60 inches (though it sometimes occurs at 20 to 30 inches), at which point the soil would have the properties of the clay category.

Soil pH on the ANF typically ranges from 3.6 to 6.0, but it can be as high as 8.0 in riparian and floodplain soils or newly formed soils. These more basic soils make up less than 5% of the ANF and are typically in areas where herbicide use would be more limited. Most soils tested in the past few years at upland locations have had pH values in the 4.0 to 4.5 range. The rainfall on ANF is approximately 50 inches per year, which is the value used in the GLEAMS analysis.

Based on this specific information about ANF soils, the GLEAMS projections for the loam soil is most relevant for this risk assessment.

Longer Term Exposure

The scenario for chronic exposure to glyphosate from contaminated water is detailed in SERA (2003b, Worksheet D07). This scenario assumes that an adult (70 kg male) consumes contaminated ambient water (2 liters/day) for a lifetime. The estimated concentrations in pond water are based on modeled estimates from GLEAMS, which are supported by monitoring data. The specific methods used to calculate the concentration of glyphosate in a small pond based on the GLEAMS output are detailed in Section 5.4 of Attachment 2 (SERA 2003a).

The results of the GLEAMS modeling for the pond is summarized in Table 29 and the specific estimates of concentrations of glyphosate in ambient water that are used in this risk assessment are summarized in SERA (2003b, Worksheet D06). As with the corresponding values for a small stream (Table 30), these estimates are expressed as the water contamination rates (WCR) in units of mg/L per lb applied per acre.

Note that based on soil type and rainfall as it occurs on the ANF, the GLEAMS projections for loam soils are most relevant. It should be noted that GLEAMS does not provide for a no-spray buffer, but ANF does use buffers as standard procedure. Therefore the GLEAMS projections provide a conservative estimate for ANF conditions.

Table 29. Estimated concentrations of glyphosate in a small (0.25 acre, 1 meter deep) pond adjacent to a 10 acre plot based on GLEAMS modeling with different soil types and annual rainfall rates and using a normalized application rate of 1 lb/acre

Annual Rainfall (inches)	Clay		Loam		Sand	
	Concentrations in Ambient Water (µg/L per lb/acre)					
	Average	Maximum	Average	Maximum	Average	Maximum
5	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
10	0.00012	0.00030	0.09440	0.17565	1.10442	2.05992
15	0.13807	0.25089	0.34458	0.63596	3.18058	5.97802
20	0.29624	0.54061	0.73480	1.35134	5.60349	10.69358
25	0.47944	0.74475	1.14161	2.02281	8.10309	15.85858
50	0.75344	1.65665	1.39087	3.09125	4.34293	15.06299
100	0.97995	3.20707	1.53840	5.39600	3.30534	20.35153
150	1.03871	4.27997	1.49796	6.84364	2.73199	22.74196
200	1.03666	5.06852	1.41487	7.92040	2.33566	25.83345
250	1.01076	5.78976	1.32712	8.79284	2.04561	27.84026

Table 30. Estimated concentrations of glyphosate in a small stream (4,420 m^3/day) adjacent to a 10 acre plot based on GLEAMS modeling with different soil types and annual rainfall rates and using a normalized application rate of 1 lb/acre

Annual Rainfall (inches)	Clay		Loam		Sand	
	Concentrations in Ambient Water (µg/L per lb/acre)					
	Average	Maximum	Average	Maximum	Average	Maximum
5	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
10	0.00001	0.00492	0.00703	0.62660	0.02064	2.13822
15	0.01267	1.12481	0.02556	2.33913	0.05947	6.64604
20	0.02713	2.44600	0.05435	5.10484	0.10512	12.47003
25	0.05311	4.88123	0.08585	8.26234	0.15311	19.10679
50	0.18321	18.06811	0.26291	28.05858	0.37979	56.63863
100	0.45951	52.78010	0.59880	77.47465	0.73684	140.44210
150	0.69588	92.44662	0.86220	132.26409	0.98828	227.07054
200	0.88933	135.15046	1.06546	190.09709	1.17292	314.68937
250	1.04689	180.02965	1.22476	250.14160	1.31401	402.83056

The typical WCR is taken as 1 µg/L or 0.001 mg/L. This is about the average concentration that could be expected over a wide range of rainfall rates in clay or loam soil. The upper limit is taken as 0.008 mg/L, approximately the longer-term average concentration from sandy soil at rainfall rates of 25 inches per year or from loam at maximum concentrations modeled with 200 inches of rainfall per year. Conditions represented by this selection lead to a very conservative approach for the ANF since ANF soils are dominated by loam with little clay, and rainfall averages 50 inches per year. The lower limit of the WCR is taken as 0.0001 mg/L, about the average concentration from clay soil at an annual rainfall rate of 15 inches per year or from loam at an annual rainfall rate of 10 inches per year.

Monitoring data on glyphosate in pond water are reasonably consistent with these estimates. Over a period of 70 days after aerial application of 2.1 kg/ha (about 1.8 lbs/acre), Goldsborough and Brown (1993) reported concentrations of about 0.001–0.002 mg/L in the water of ponds that were less than 1 hectare (2.47 acres) in surface area and about 0.9 to 1.5 meters deep. Similarly, by 30 days after aerial applications of 3.7 lb/acre adjacent to small ponds (<1 m deep and 50 m^2 or 0.012 acres in surface area), monitored concentrations were in the range of 0.001 to 0.002 mg/L (Newton et al. 1994). Even in ponds that were directly sprayed with glyphosate at a rate of 0.89 kg a.i./ha (0.8 lbs a.i./acre), initial concentrations of between about 0.02 to 0.15 mg/L dissipated to about 0.001 mg/L by day 12 after application (Goldsborough and Beck 1989, Figure 1, p. 540).

Oral Exposure from Contaminated Fish

Chemicals may be concentrated from water or plants in the water into the tissues of animals. This process is referred to as bioconcentration. Glyphosate has a low potential for bioconcentration. Wang et al. 1994a reported BCF values ranging from 10 after 1 day to about 40 after 14 days of exposure. However these estimates are based on total radioactivity rather than the identification of glyphosate residues and are not consistent with other estimates. Based on the study by Forbis (1989), the U.S. EPA/OPP (1993c, p. 36) used maximum bioconcentration factors of 0.38 for edible tissues and 0.52 for whole fish. Calabrese and Baldwin (1993) reviewed a number of different methods for estimating BCF values in fish based on chemical and physical properties. Using a log K_{ow} of -4.85 at pH 6.86 (from Chamberlain et al. 1996), the estimated BCF values in fish would be well below unity, consistent with the study by Forbis (1989) and the BCF values used by U.S. EPA/OPP

(1993c). For the current risk assessment, the values reported by Forbis (1989) and used by EPA/OPP (1993c) will be used to estimate dietary exposure to fish.

These values are included in SERA (2003b, Worksheet B02) and used in all exposure assessments involving the consumption of contaminated fish. In the exposure assessment for humans, the assumption is made that the individual consumes only the edible portion of the fish.

For both the acute and longer-term exposure scenarios involving the consumption of contaminated fish, the water concentrations of glyphosate used are identical to the concentrations used in the contaminated water scenarios. The acute exposure scenario is based on the assumption that an adult consumes fish taken from contaminated water shortly after an accidental spill of 200 gallons of a field solution into a pond that has an average depth of 1 m and a surface area of 1000 m^2 or about one-quarter acre. No dissipation or degradation is considered. SERA (2003b, Worksheet D08) made separate exposure estimates for the general public and native American subsistence populations using data from U.S. EPA/ORD (1996). The chronic exposure scenario is constructed in a similar way, as detailed in SERA (2003b, Worksheet D09), except that estimates of glyphosate concentrations in ambient water are based on GLEAMS modeling.

Oral Exposure from Contaminated Vegetation

Under normal circumstances and in most types of applications, it is extremely unlikely that humans will consume vegetation contaminated with glyphosate. In most instances and particularly for longer-term scenarios, treated vegetation would probably show herbicide damage, thereby reducing the likelihood of consumption that would lead to significant levels of human exposure. However it is conceivable that individuals could consume contaminated vegetation such as berries collected shortly after application.

On the ANF there are a number of factors that significantly reduce the likelihood of such exposure. Specifically, ANF uses signs to indicate that an area has been treated with herbicide, providing members of the public the option of avoiding such areas and any vegetation (including berries) in or near treated areas. These signs are posted at logical areas of entry to treated areas Also, the abundance of berries in treated areas is expected to be quite low because the overstory vegetation significantly reduces the level of light on the forest floor where such plants normally grow. This makes the areas unattractive to berry pickers. In addition, most herbicide applications are made in August and September, which is after the period (July) when berries would normally be harvested

The most relevant publication for assessing exposure from such a scenario is that of Siltanen et al. (1981) who reported on levels of glyphosate on cowberries and bilberries after backpack sprays of Roundup® at an application rate of 0.25 and 0.75 kg a.i./ha [0.22 and 0.67 lb a.i./acre]. At 6 days after treatment with 0.67 lb/acre, residues on cowberries were 1.6 mg/kg. At 7 days after treatment, residues on bilberries were 2.1 mg/kg. The central estimate of residues immediately after application is approximately 1.6 ppm (mg/kg) with a 95% upper limit of 4 ppm. This corresponds to a residue rate of about 2.4 ppm per lb per acre [1.6 ppm ÷ 0.67 lb a.i./acre] with an upper limit of 5.9 ppm per lb per acre [4 ppm ÷ 0.67 lb a.i./acre]. As summarized in SERA (2003b, Worksheet A04), this is close to the estimate 1.5 ppm per lb per acre with an upper range of 7 ppm per lb per acre from the empirical relationships between application rate and concentration on fruit developed by Hoerger and Kenaga (1972) and somewhat lower than the estimated 7 ppm per lb per acre with an upper range of 15 ppm per lb per acre developed by Fletcher et al. (1994) which is in turn based on a re-analysis of data from Hoerger and Kenaga (1972). Because the study by Siltanen et al. (1981) uses glyphosate on two different types of fruit and because the results are reasonably consistent between the two types, there is no reason to use either the general relationships developed by Hoerger and Kenaga (1972) or Fletcher et al. (1994) for scenarios involving contaminated fruit. For other scenarios involving other types of vegetation, the estimates from Fletcher et al. (1994) are used since they are somewhat more conservative than the earlier estimates by Hoerger and Kenaga (1972).

The two accidental exposure scenarios developed for this exposure assessment include one scenario for acute exposure, as defined in SERA (2003b, Worksheet D03) and one scenario for longer-term exposure (SERA 2003b, Worksheet D04). In both scenarios, the concentration of glyphosate on contaminated vegetation is estimated using the empirical relationships between application rate and concentration on vegetation developed by Fletcher et al. (1994) which is in turn based on a re-analysis of data from Hoerger and Kenaga (1972). These relationships are defined in SERA (2003b, Worksheet A04). For the acute exposure scenario, the estimated residue level is taken as the product of the application rate and the residue rate (SERA 2003b, Worksheet D03).

For the longer-term exposure scenario (SERA 2003b, Worksheet D04), a duration of 90 days is used and the dissipation on the vegetation is estimated using the half-life of 46 days from Siltanen et al. (1981). As summarized in Table 2-2 of SERA (2003a), this is the most conservative value, i.e., the longest half-life, which leads to the highest time-weighted average residues. Although the duration of exposure of 90 days is intended to encompass the consumption of contaminated fruit that might be available over one season. Longer durations could be used for certain kinds of vegetation but would lower the estimated dose (i.e., would result in a less conservative exposure assessment).

For the longer-term exposure scenarios, the time-weighted average concentration on fruit is calculated from the equation for first-order dissipation. For the acute exposure scenario, it is assumed that a woman consumes 1 lb (0.4536 kg) of contaminated fruit. Based on statistics summarized in U.S. EPA/ORD (1996) and presented in SERA (2003b, Worksheet D04), this consumption rate is approximately the mid-range between the mean and upper 95% confidence interval for the total vegetable intake for a 64 kg woman. The range of exposures presented in Table 4-3 (SERA 2003a) is based on the range of concentrations on fruit and the typical application rate for glyphosate (In SERA 2003 a, b the typical application rate is 2 lb/acre). The longer-term exposure scenario is constructed in a similar way, except that the estimated exposures include the range of fruit consumption (SERA 2003b, Worksheet A03) as well as the range of concentrations on fruit. Note that on ANF the period when berries would likely be harvested is before most broadcast applications are made, minimizing the likelihood of such longer term exposure.

A separate scenario involving the consumption of vegetation contaminated by drift rather than direct spray is not developed in this risk assessment because the direct spray scenario leads to estimates of risk that are below a level of concern. Thus, considering spray drift and a buffer zone quantitatively would result in even a lower level of exposure and have no impact on the characterization of risk.

Table 31. Summary of glyphosate exposure assessments for the general public: Airblast applications for "Sustaining Forest Cover and the Production of Forest Products" in the ANF

Scenario	Receptor	mg/kg/day or mg/kg/event			SERA 2003b Worksheet
		Central	Lower	Upper	
Acute Exposures (dose in mg/kg/event)					
Direct Spray of Child, whole body	Child	0.00535	0.00137	0.02610	D01a
Direct Spray of Woman, feet and lower legs	Adult Female	0.00054	0.00014	0.00262	D01b
Vegetation Contact, shorts and T-shirt	Adult Female	0.00075	0.00019	0.00388	D02
Contaminated Fruit	Adult Female	0.00882	0.00706	0.27990	D03
Water consumption, accidental spill	Child	0.20490	0.10069	0.61471	D05
Water consumption, ambient	Child	0.00113	0.00003	0.06767	D06
Fish consumption, accidental spill	Adult Male	0.00234	0.00188	0.00467	D08a
Fish consumption, accidental spill	Subsistence Populations	0.01139	0.00918	0.02278	D08b
Chronic/Longer Term Exposures (dose in mg/kg/day)					
Contaminated Fruit	Adult Female	0.004828006	0.003862405	0.153215296	D04
Water consumption	Adult Male	0.000021429	0.000001200	0.000411429	D07
Fish consumption	Adult Male	0.000000041	0.000000003	0.000000651	D09a
Fish consumption	Subsistence Populations	0.000000330	0.000000026	0.000005277	D09b

Note: Table 31 is derived from SERA worksheet E03.

Table 32. Summary of glyphosate exposure assessments for the general public: Backpack applications for "Sustaining Forest Cover and the Production of Forest Products" in the ANF

Scenario	Receptor	mg/kg/day or mg/kg/event			SERA 2003b Worksheet
		Central	Lower	Upper	
Acute Exposures (dose in mg/kg/event)					
Direct Spray of Child, whole body	Child	0.00535	0.00085	0.02610	D01a
Direct Spray of Woman, feet and lower legs	Adult Female	0.00054	0.00009	0.00262	D01b
Vegetation Contact, shorts and T-shirt	Adult Female	0.00075	0.00011	0.00388	D02
Contaminated Fruit	Adult Female	0.00882	0.00447	0.27990	D03
Water consumption, accidental spill	Child	0.20490	0.06250	0.61471	D05
Water consumption, ambient	Child	0.00113	0.00002	0.06767	D06
Fish consumption, accidental spill	Adult Male	0.00234	0.00117	0.00467	D08a
Fish consumption, accidental spill	Subsistence Populations	0.01139	0.00570	0.02278	D08b
Chronic/Longer Term Exposures (dose in mg/kg/day)					
Contaminated Fruit	Adult Female	0.00482801	0.00244619	0.15321530	D04
Water consumption	Adult Male	0.00002143	0.00000076	0.00041143	D07
Fish consumption	Adult Male	0.00000004	0.00000000	0.00000065	D09a
Fish consumption	Subsistence Populations	0.00000033	0.00000002	0.00000528	D09b

Note: Table 32 is derived from SERA worksheet E03.

Table 33. Summary of glyphosate exposure assessments for the general public: Cut surface applications for "Sustaining Forest Cover and the Production of Forest Products" in the ANF

Scenario	Receptor	mg/kg/day or mg/kg/event			SERA (2003b) Worksheet
		Central	Lower	Upper	
Acute Exposures (dose in mg/kg/event)					
Direct Spray of Child, whole body	Child	0.53525	0.05658	3.98778	D01a
Direct Spray of Woman, feet and lower legs	Adult Female	0.05377	0.00568	0.40061	D01b
Vegetation Contact, shorts and T-shirt	Adult Female	0.00160	0.00024	0.00604	D02
Contaminated Fruit	Adult Female	0.01764	0.00882	0.41985	D03
Water consumption, accidental spill	Child	0.51226	0.10416	2.34784	D05
Water consumption, ambient	Child	0.00226	0.00003	0.10150	D06
Fish consumption, accidental spill	Adult Male	0.00584	0.00195	0.01786	D08a
Fish consumption, accidental spill	Subsistence Populations	0.02848	0.00949	0.08702	D08b
Chronic/Longer Term Exposures (dose in mg/kg/day)					
Contaminated Fruit	Adult Female	0.009656012	0.004828006	0.229822944	D04
Water consumption	Adult Male	0.000042857	0.000001500	0.000617143	D07
Fish consumption	Adult Male	0.000000081	0.000000004	0.000000977	D09a
Fish consumption	Subsistence Populations	0.000000660	0.000000033	0.000007915	D09b

Note: Table 33 is derived from SERA worksheet E03.

Table 34. Summary of glyphosate exposure assessments for the general public: Airblast applications for "Developing and Maintaining Wildlife Habitat, Heritage Resources, and Visual Enhancements" in the ANF

Scenario	Receptor	mg/kg/day or mg/kg/event			SERA (2003b) Worksheet
		Central	Lower	Upper	
Acute Exposures (dose in mg/kg/event)					
Direct Spray of Child, whole body	Child	0.00535	0.00137	0.02610	D01a
Direct Spray of Woman, feet and lower legs	Adult Female	0.00054	0.00014	0.00262	D01b
Vegetation Contact, shorts and T-shirt	Adult Female	0.00075	0.00019	0.00388	D02
Contaminated Fruit	Adult Female	0.00882	0.00706	0.27990	D03
Water consumption, accidental spill	Child	0.20490	0.10069	0.61471	D05
Water consumption, ambient	Child	0.00113	0.00003	0.06767	D06
Fish consumption, accidental spill	Adult Male	0.00234	0.00188	0.00467	D08a
Fish consumption, accidental spill	Subsistence Populations	0.01139	0.00918	0.02278	D08b
Chronic/Longer Term Exposures (dose in mg/kg/day)					
Contaminated Fruit	Adult Female	0.004828006	0.003862405	0.153215296	D04
Water consumption	Adult Male	0.000021429	0.000001200	0.000411429	D07
Fish consumption	Adult Male	0.000000041	0.000000003	0.000000651	D09a
Fish consumption	Subsistence Populations	0.000000330	0.000000026	0.000005277	D09b

Note: Table 34 is derived from SERA worksheet E03.

Table 35. Summary of glyphosate exposure assessments for the general public: Backpack applications for "Developing and Maintaining Wildlife Habitat, Heritage Resources, and Visual Enhancements" in the ANF

Scenario	Receptor	mg/kg/day or mg/kg/event			SERA (2003b) Worksheet
		Central	Lower	Upper	
Acute Exposures (dose in mg/kg/event)					
Direct Spray of Child, whole body	Child	0.00535	0.00085	0.02610	D01a
Direct Spray of Woman, feet and lower legs	Adult Female	0.00054	0.00009	0.00262	D01b
Vegetation Contact, shorts and T-shirt	Adult Female	0.00075	0.00011	0.00388	D02
Contaminated Fruit	Adult Female	0.00882	0.00447	0.27990	D03
Water consumption, accidental spill	Child	0.20490	0.06250	0.61471	D05
Water consumption, ambient	Child	0.00113	0.00002	0.06767	D06
Fish consumption, accidental spill	Adult Male	0.00234	0.00117	0.00467	D08a
Fish consumption, accidental spill	Subsistence Populations	0.01139	0.00570	0.02278	D08b
Chronic/Longer Term Exposures (dose in mg/kg/day)					
Contaminated Fruit	Adult Female	0.004828006	0.002446190	0.153215296	D04
Water consumption	Adult Male	0.000021429	0.000000760	0.000411429	D07
Fish consumption	Adult Male	0.000000041	0.000000002	0.000000651	D09a
Fish consumption	Subsistence Populations	0.000000330	0.000000017	0.000005277	D09b

Note: Table 35 is derived from SERA worksheet E03.

Table 36. Summary of glyphosate exposure assessments for the general public: Cut surface applications for "Developing and Maintaining Wildlife Habitat, Heritage Resources, and Visual Enhancements" in the ANF

Scenario	Receptor	mg/kg/day or mg/kg/event			SERA (2003b) Worksheet
		Central	Lower	Upper	
Acute Exposures (dose in mg/kg/event)					
Direct Spray of Child, whole body	Child	0.53525	0.05658	3.98778	D01a
Direct Spray of Woman, feet and lower legs	Adult Female	0.05377	0.00568	0.40061	D01b
Vegetation Contact, shorts and T-shirt	Adult Female	0.00160	0.00024	0.00604	D02
Contaminated Fruit	Adult Female	0.01764	0.00882	0.41985	D03
Water consumption, accidental spill	Child	0.51226	0.10416	2.34784	D05
Water consumption, ambient	Child	0.00226	0.00003	0.10150	D06
Fish consumption, accidental spill	Adult Male	0.00584	0.00195	0.01786	D08a
Fish consumption, accidental spill	Subsistence Populations	0.02848	0.00949	0.08702	D08b
Chronic/Longer Term Exposures (dose in mg/kg/day)					
Contaminated Fruit	Adult Female	0.009656012	0.004828006	0.229822944	D04
Water consumption	Adult Male	0.000042857	0.000001500	0.000617143	D07
Fish consumption	Adult Male	0.000000081	0.000000004	0.000000977	D09a
Fish consumption	Subsistence Populations	0.000000660	0.000000033	0.000007915	D09b

Note: Table 36 is derived from SERA worksheet E03.

Table 37. Summary of glyphosate exposure assessments for the general public: Airblast applications for "Treatment/Control of Native and Non-native Invasive Species" in the ANF

Scenario	Receptor	mg/kg/day or mg/kg/event			SERA (2003b) Worksheet
		Central	Lower	Upper	
Acute Exposures (dose in mg/kg/event)					
Direct Spray of Child, whole body	Child	0.00535	0.00137	0.02610	D01a
Direct Spray of Woman, feet and lower legs	Adult Female	0.00054	0.00014	0.00262	D01b
Vegetation Contact, shorts and T-shirt	Adult Female	0.00075	0.00019	0.00388	D02
Contaminated Fruit	Adult Female	0.00882	0.00706	0.27990	D03
Water consumption, accidental spill	Child	0.20490	0.10069	0.61471	D05
Water consumption, ambient	Child	0.00113	0.00003	0.06767	D06
Fish consumption, accidental spill	Adult Male	0.00234	0.00188	0.00467	D08a
Fish consumption, accidental spill	Subsistence Populations	0.01139	0.00918	0.02278	D08b
Chronic/Longer Term Exposures (dose in mg/kg/day)					
Contaminated Fruit	Adult Female	0.004828006	0.003862405	0.153215296	D04
Water consumption	Adult Male	0.000021429	0.000001200	0.000411429	D07
Fish consumption	Adult Male	0.000000041	0.000000003	0.000000651	D09a
Fish consumption	Subsistence Populations	0.000000330	0.000000026	0.000005277	D09b

Note: Table 37 is derived from SERA worksheet E03.

Table 38. Summary of glyphosate exposure assessments for the general public: Backpack applications for "Treatment/Control of Native and Non-native Invasive Species" in the ANF

Scenario	Receptor	mg/kg/day or mg/kg/event			SERA (2003b) Worksheet
		Central	Lower	Upper	
Acute Exposures (dose in mg/kg/event)					
Direct Spray of Child, whole body	Child	0.01070	0.00170	0.05075	D01a
Direct Spray of Woman, feet and lower legs	Adult Female	0.00108	0.00017	0.00510	D01b
Vegetation Contact, shorts and T-shirt	Adult Female	0.00160	0.00024	0.00826	D02
Contaminated Fruit	Adult Female	0.01764	0.00882	0.55980	D03
Water consumption, accidental spill	Child	0.40980	0.12499	1.19526	D05
Water consumption, ambient	Child	0.00226	0.00003	0.13534	D06
Fish consumption, accidental spill	Adult Male	0.00467	0.00234	0.00909	D08a
Fish consumption, accidental spill	Subsistence Populations	0.02278	0.01139	0.04430	D08b
Chronic/Longer Term Exposures (dose in mg/kg/day)					
Contaminated Fruit	Adult Female	0.009656012	0.004828006	0.306430592	D04
Water consumption	Adult Male	0.000042857	0.000001500	0.000822857	D07
Fish consumption	Adult Male	0.000000081	0.000000004	0.000001303	D09a
Fish consumption	Subsistence Populations	0.000000660	0.000000033	0.000010553	D09b

Note: Table 38 is derived from SERA worksheet E03.

Table 39. Summary of glyphosate exposure assessments for the general public: Cut surface applications for "Treatment/Control of Native and Non-native Invasive Species" in the ANF

Scenario	Receptor	mg/kg/day or mg/kg/event			SERA (2003b) Worksheet
		Central	Lower	Upper	
Acute Exposures (dose in mg/kg/event)					
Direct Spray of Child, whole body	Child	0.53525	0.04291	5.07536	D01a
Direct Spray of Woman, feet and lower legs	Adult Female	0.05377	0.00431	0.50987	D01b
Vegetation Contact, shorts and T-shirt	Adult Female	0.00075	0.00011	0.00388	D02
Contaminated Fruit	Adult Female	0.00882	0.00447	0.27990	D03
Water consumption, accidental spill	Child	0.51226	0.07899	2.98816	D05
Water consumption, ambient	Child	0.00113	0.00002	0.06767	D06
Fish consumption, accidental spill	Adult Male	0.00584	0.00148	0.02273	D08a
Fish consumption, accidental spill	Subsistence Populations	0.02848	0.00720	0.11075	D08b
Chronic/Longer Term Exposures (dose in mg/kg/day)					
Contaminated Fruit	Adult Female	0.004828006	0.002446190	0.153215296	D04
Water consumption	Adult Male	0.000021429	0.000000760	0.000411429	D07
Fish consumption	Adult Male	0.000000041	0.000000002	0.000000651	D09a
Fish consumption	Subsistence Populations	0.000000330	0.000000017	0.000005277	D09b

Note: Table 39 is derived from SERA worksheet E03.

SECTION 5. GLYPHOSATE RISK CHARACTERIZATION

Overview and Summary

Risk characterization is the process by which the critical toxicity value is compared to exposure values. The critical toxicity value is the Reference Dose (RfD), which is the result of the hazard analysis, and the exposure values come from the exposure analysis. Risk is expressed as the hazard quotient (HQ) and is the ratio of the exposure to the RfD. If the exposure is less than the RfD, then the HQ is less than one and the risk falls within an acceptable range.

The risk characterization for both workers and members of the general public are reasonably consistent and unambiguous. For both groups, there is very little indication of any potential risk at the typical application rates of 0.75 lbs a.e./acre (1.0 lbs a.i./acre) for ANF broadcast and backpack applications, and 1.5 lbs a.e./acre (2.0 lbs a.i./acre) for cut surface applications and backpack applications for invasive species vegetation management. Even at the upper range of plausible exposures in workers, most hazard quotients are below the level of concern (HQ of 1).

For workers, the highest hazard quotient, i.e., 0.1, results from the upper range of exposure for workers involved in backpack application for invasive species vegetation management, is below the level of concern (HQ of 1) by a factor of about 10. The highest hazard quotient for any accidental exposure scenario for workers, i.e., 0.17 arises from the upper range of the exposure from cut surface application involving a spill over the lower legs for one hour, is lower than the level of concern by a factor of 6. Confidence in these assessments is reasonably high because of the availability of dermal absorption data in human as well as worker exposure studies.

From a practical perspective, the most likely accidental exposure for workers that might require medical attention involves accidental contamination of the eyes. Glyphosate and glyphosate formulations are skin and eye irritants. Quantitative risk assessments for irritation are not normally derived, and, for glyphosate specifically, there is no indication that such a derivation is warranted. As with the handling of any chemical, including a variety of common household products, reasonable care should be taken to avoid contact of skin and eyes.

For the general public two scenarios associated with cut surface applications result in an HQ that is greater than one: direct spray of an unclothed child resulting in an HQ of 2.5 and water consumption from a pond following a spill of 5 gallons of undiluted product resulting in an HQ of 1.5. These exposure scenarios are highly unlikely and can be dealt with through mitigation. All other exposure scenarios for the general public result in HQ values that are less than one. The highest HQ from other exposure scenarios is 0.15, which is about 7 times less than the level of concern (HQ of 1). It is the result of the longer term consumption of contaminated fruit by the general population. The risk characterization for the general public is relatively unambiguous: based on the available information and under the foreseeable conditions of application and exposure, there is no route of exposure or exposure scenario suggesting that the general public will be at risk from longer-term exposure to glyphosate, or short-term acute exposure other than the case involving consumption of water following a spill into a pond.

SERA notes an area of uncertainty concerning operations where burning is done after herbicide application. Residues of glyphosate in air during brown-and-burn operations have not been measured, but SERA concludes in their analysis that they are likely to be very low given that brown-and-burn operations take place about 30 to180 days after treatment with the herbicide and the foliar half-life is from 1.6 to 46 days. SERA concludes that there is no evidence to suggest that toxic levels of glyphosate are likely to be encountered as the result of a brown and burn operation. SERA also states that there is no basis for believing that the presence of low or even high levels of glyphosate residues will have a significant impact on this hazard (due to burning areas that have been treated). On the ANF burning is not done within 180 days, therefore the uncertainty about risk is further reduced.

Detailed Information

Workers

A quantitative summary of the glyphosate risk characterization for workers is presented in Tables 40–48. The quantitative risk characterization is expressed as the hazard quotient. For both general and accidental exposures, the hazard quotient is calculated as the estimated exposure doses divided by the RfD of 2 mg/kg/day. For general exposures, i.e., daily (chronic) exposures that might occur over the course of an application season, there is no substantial dose-duration-effect relationship for glyphosate, and the acute and chronic RfDs are identical for the glyphosate application rates in a.e./acre given in Tables 2, 4, and 6.

Table 40. Glyphosate risk characterization for workers: Airblast applications for "Sustaining Forest Cover and the Production of Forest Products" in the ANF

SERA (2003b) Exposure Worksheet:		E01			
Scenario	Receptor	Hazard Quotient			Toxicity Value mg/kg/day
		Central	Lower	Upper	
Accidental/Incidental Exposures (dose in mg/kg/event)					
Contaminated Gloves, 1 min.	Worker	0.0000005	0.0000001	0.0000045	2
Contaminated Gloves, 1 hour	Worker	0.0000324	0.0000064	0.0002722	2
Spill on Hands, 1 hour	Worker	0.0000708	0.0000181	0.0003454	2
Spill on lower legs, 1 hour	Worker	0.0001746	0.0000446	0.0008512	2
General (Chronic) Exposures (mg/kg/day)					
General (chronic) exposure	Airblast	0.00188	0.00007	0.02703	2

Table 41. Glyphosate risk characterization for workers: Backpack spray applications for "Sustaining Forest Cover and the Production of Forest Products" in the ANF

SERA (2003b) Exposure Worksheet:		E01			
Scenario	Receptor	Hazard Quotient			Toxicity Value mg/kg/day
		Central	Lower	Upper	
Accidental/Incidental Exposures (dose in mg/kg/event)					
Contaminated Gloves, 1 min.	Worker	0.00000054	0.00000007	0.00000454	2
Contaminated Gloves, 1 hour	Worker	0.00003240	0.00000400	0.00027216	2
Spill on Hands, 1 hour	Worker	0.00007083	0.00001123	0.00034543	2
Spill on lower legs, 1 hour	Worker	0.00017455	0.00002768	0.00085123	2
General (Chronic) Exposures (mg/kg/day)					
General (chronic) exposure	Backpack	0.00675	0.00014	0.02625	2

Table 42. Glyphosate risk characterization for workers: Cut surface applications for "Sustaining Forest Cover and the Production of Forest Products" in the ANF

SERA (2003b) Exposure Worksheet:	E01				
Scenario	**Receptor**	**Hazard Quotient**			**Toxicity Value mg/kg/day**
		Central	**Lower**	**Upper**	
Accidental/Incidental Exposures (dose in mg/kg/event)					
Contaminated Gloves, 1 min.	Worker	0.000054	0.000004	0.000693	2
Contaminated Gloves, 1 hour	Worker	0.003240	0.000266	0.041580	2
Spill on Hands, 1 hour	Worker	0.007083	0.000749	0.052774	2
Spill on lower legs, 1 hour	Worker	0.017455	0.001845	0.130049	2
General (Chronic) Exposures (mg/kg/day)					
General (chronic) exposure	Cut Surface	0.00338	0.00014	0.03938	2

Table 43. Glyphosate risk characterization for workers: Airblast applications for "Developing and Maintaining Wildlife Habitat, Heritage Resources, and Visual Enhancements" in the ANF

SERA (2003b) Exposure Worksheet:	E01				
Scenario	**Receptor**	**Hazard Quotient**			**Toxicity Value mg/kg/day**
		Central	**Lower**	**Upper**	
Accidental/Incidental Exposures (dose in mg/kg/event)					
Contaminated Gloves, 1 min.	Worker	0.0000005	0.0000001	0.0000045	2
Contaminated Gloves, 1 hour	Worker	0.0000324	0.0000064	0.0002722	2
Spill on Hands, 1 hour	Worker	0.0000708	0.0000181	0.0003454	2
Spill on lower legs, 1 hour	Worker	0.0001746	0.0000446	0.0008512	2
General (Chronic) Exposures (mg/kg/day)					
General (chronic) exposure	Airblast	0.00188	0.00007	0.02703	2

Table 44. Glyphosate risk characterization for workers: Backpack applications for "Developing and Maintaining Wildlife Habitat, Heritage Resources, and Visual Enhancements" in the ANF

SERA (2003b) Exposure Worksheet:	E01				
Scenario	**Receptor**	**Hazard Quotient**			**Toxicity Value mg/kg/day**
		Central	**Lower**	**Upper**	
Accidental/Incidental Exposures (dose in mg/kg/event)					
Contaminated Gloves, 1 min.	Worker	0.00000054	0.00000007	0.00000454	2
Contaminated Gloves, 1 hour	Worker	0.00003240	0.00000400	0.00027216	2
Spill on Hands, 1 hour	Worker	0.00007083	0.00001123	0.00034543	2
Spill on lower legs, 1 hour	Worker	0.00017455	0.00002768	0.00085123	2
General (Chronic) Exposures (mg/kg/day)					
General (chronic) exposure	Backpack	0.00675	0.00014	0.02625	2

Table 45. Glyphosate risk characterization for workers: Cut surface applications for "Developing and Maintaining Wildlife Habitat, Heritage Resources, and Visual Enhancements" in the ANF

SERA (2003b) Exposure Worksheet:	E01				
Scenario	**Receptor**	**Hazard Quotient**			**Toxicity Value mg/kg/day**
		Central	**Lower**	**Upper**	
Accidental/Incidental Exposures (dose in mg/kg/event)					
Contaminated Gloves, 1 min.	Worker	0.000054	0.000004	0.000693	2
Contaminated Gloves, 1 hour	Worker	0.003240	0.000266	0.041580	2
Spill on Hands, 1 hour	Worker	0.007083	0.000749	0.052774	2
Spill on lower legs, 1 hour	Worker	0.017455	0.001845	0.130049	2
General (Chronic) Exposures (mg/kg/day)					
General (chronic) exposure	Cut Surface	0.00338	0.00014	0.03938	2

Table 46. Glyphosate risk characterization for workers: Airblast applications for "Treatment/Control of Native and Non-native Invasive Species" in the ANF

SERA (2003b) Exposure Worksheet:	E01				
Scenario	Receptor	Hazard Quotient			Toxicity Value mg/kg/day
		Central	Lower	Upper	
Accidental/Incidental Exposures (dose in mg/kg/event)					
Contaminated Gloves, 1 min.	Worker	0.0000005	0.0000001	0.0000045	2
Contaminated Gloves, 1 hour	Worker	0.0000324	0.0000064	0.0002722	2
Spill on Hands, 1 hour	Worker	0.0000708	0.0000181	0.0003454	2
Spill on lower legs, 1 hour	Worker	0.0001746	0.0000446	0.0008512	2
General (Chronic) Exposures (mg/kg/day)					
General (chronic) exposure	Airblast	0.000225	0.000007	0.003402	2

Table 47. Glyphosate risk characterization for workers: Backpack applications for "Treatment/Control of Native and Non-native Invasive Species" in the ANF

SERA (2003b) Exposure Worksheet:	E01				
Scenario	Receptor	Hazard Quotient			Toxicity Value mg/kg/day
		Central	Lower	Upper	
Accidental/Incidental Exposures (dose in mg/kg/event)					
Contaminated Gloves, 1 min.	Worker	0.0000011	0.0000001	0.0000088	2
Contaminated Gloves, 1 hour	Worker	0.0000648	0.0000080	0.0005292	2
Spill on Hands, 1 hour	Worker	0.0001417	0.0000225	0.0006717	2
Spill on lower legs, 1 hour	Worker	0.0003491	0.0000554	0.0016552	2
General (Chronic) Exposures (mg/kg/day)					
General (chronic) exposure	Backpack	0.00675	0.00025	0.10530	2

Table 48. Glyphosate risk characterization for workers: Cut surface applications for "Treatment/Control of Native and Non-native Invasive Species" in the ANF

SERA (2003b) Exposure Worksheet:	E01				
Scenario	**Receptor**	**Hazard Quotient**			**Toxicity Value mg/kg/day**
		Central	**Lower**	**Upper**	
Accidental/Incidental Exposures (dose in mg/kg/event)					
Contaminated Gloves, 1 min.	Worker	0.000054	0.000003	0.000882	2
Contaminated Gloves, 1 hour	Worker	0.003240	0.000202	0.052920	2
Spill on Hands, 1 hour	Worker	0.007083	0.000568	0.067166	2
Spill on lower legs, 1 hour	Worker	0.017455	0.001399	0.165517	2
General (Chronic) Exposures (mg/kg/day)					
General (chronic) exposure	Cut Surface	0.00171	0.00006	0.02610	2

Given the very low HQs for accidental exposure, the risk characterization is reasonably unambiguous. None of the accidental exposure scenarios approach a level of concern. While the accidental exposure scenarios are not the most severe one might imagine (e.g. complete immersion of the worker or contamination of the entire body surface for a prolonged period of time), they are representative of reasonable accidental exposures. The highest HQ for any accidental exposure scenario, i.e., 0.17 for the upper range of the hazard quotient for a cut surface application spill over the lower legs for one hour (Table 48), is a factor of 6 lower than the level of concern.

As summarized above, glyphosate and glyphosate formulations are skin and eye irritants. Quantitative risk assessments for irritation are not normally derived, and, for glyphosate specifically, there is no indication that such a derivation is warranted. As with the handling of any chemical, including a variety of common household products, reasonable care should be taken to avoid contact of skin and eyes.

General Public

The quantitative hazard characterization for the general public is summarized in Tables 49–57 for the glyphosate application rates in lb a.e./acre given in Tables 2, 4, and 6. Like the quantitative risk characterization for workers, the quantitative risk characterization for the general public is expressed as the HQ using the RfD of 2 mg/kg/day for both acute and longer-term exposures. Tables 49–57 are followed by discussion for basis and results of the analysis.

Table 49. Glyphosate risk characterization for general public: Airblast applications for "Sustaining Forest Cover and the Production of Forest Products" in the ANF

SERA (2003b) Exposure Worksheet:	E03				
Scenario	Receptor	Hazard Quotient			Toxicity Value mg/kg/day
		Central	Lower	Upper	
Acute Exposures (dose in mg/kg/event)					
Direct Spray of Child, whole body	Child	0.00268	0.00068	0.01305	2
Direct Spray of Woman, feet and lower legs	Adult Female	0.00027	0.00007	0.00131	2
Vegetation Contact, shorts and T-shirt	Adult Female	0.00038	0.00009	0.00194	2
Contaminated Fruit	Adult Female	0.00441	0.00353	0.13995	2
Water consumption, accidental spill	Child	0.10245	0.05034	0.30735	2
Water consumption, ambient	Child	0.00056	0.00001	0.03383	2
Fish consumption, accidental spill	Adult Male	0.00117	0.00094	0.00234	2
Fish consumption, accidental spill	Subsistence Populations	0.00570	0.00459	0.01139	2
Chronic/Longer Term Exposures (dose in mg/kg/day)					
Contaminated Fruit	Adult Female	0.002414003	0.001931202	0.076607648	2
Water consumption	Adult Male	0.000010714	0.000000600	0.000205714	2
Fish consumption	Adult Male	0.000000020	0.000000002	0.000000326	2
Fish consumption	Subsistence Populations	0.000000165	0.000000013	0.000002638	2

Table 50. Glyphosate risk characterization for general public: Backpack spray applications for "Sustaining Forest Cover and the Production of Forest Products" in the ANF

SERA (2003b) Exposure Worksheet:		E03			
Scenario	**Receptor**	**Hazard Quotient**			**Toxicity Value mg/kg/day**
		Central	**Lower**	**Upper**	
Acute Exposures (dose in mg/kg/event)					
Direct Spray of Child, whole body	Child	0.002676	0.000424	0.013051	2
Direct Spray of Woman, feet and lower legs	Adult Female	0.000269	0.000043	0.001311	2
Vegetation Contact, shorts and T-shirt	Adult Female	0.000377	0.000057	0.001941	2
Contaminated Fruit	Adult Female	0.004410	0.002234	0.139950	2
Water consumption, accidental spill	Child	0.102451	0.031248	0.307353	2
Water consumption, ambient	Child	0.000564	0.000009	0.033835	2
Fish consumption, accidental spill	Adult Male	0.001169	0.000584	0.002337	2
Fish consumption, accidental spill	Subsistence Populations	0.005696	0.002848	0.011391	2
Chronic/Longer Term Exposures (dose in mg/kg/day)					
Contaminated Fruit	Adult Female	0.002414003	0.001223095	0.076607648	2
Water consumption	Adult Male	0.000010714	0.000000380	0.000205714	2
Fish consumption	Adult Male	0.000000020	0.000000001	0.000000326	2
Fish consumption	Subsistence Populations	0.000000165	0.000000008	0.000002638	2

Table 51. Glyphosate risk characterization for general public: Cut surface applications for "Sustaining Forest Cover and the Production of Forest Products" in the ANF

SERA (2003b) Exposure Worksheet:		E03			
Scenario	**Receptor**	**Hazard Quotient**			**Toxicity Value mg/kg/day**
		Central	**Lower**	**Upper**	
Acute Exposures (dose in mg/kg/event)					
Direct Spray of Child, whole body	Child	0.26762	0.02829	**1.99389**	2
Direct Spray of Woman, feet and lower legs	Adult Female	0.02689	0.00284	0.20031	2
Vegetation Contact, shorts and T-shirt	Adult Female	0.00080	0.00012	0.00302	2
Contaminated Fruit	Adult Female	0.00882	0.00441	0.20993	2
Water consumption, accidental spill	Child	0.25613	0.05208	**1.17392**	2
Water consumption, ambient	Child	0.00113	0.00002	0.05075	2
Fish consumption, accidental spill	Adult Male	0.00292	0.00097	0.00893	2
Fish consumption, accidental spill	Subsistence Populations	0.01424	0.00475	0.04351	2
Chronic/Longer Term Exposures (dose in mg/kg/day)					
Contaminated Fruit	Adult Female	0.004828006	0.002414003	0.114911472	2
Water consumption	Adult Male	0.000021429	0.000000750	0.000308571	2
Fish consumption	Adult Male	0.000000041	0.000000002	0.000000489	2
Fish consumption	Subsistence Populations	0.000000330	0.000000016	0.000003957	2

Table 52. Glyphosate risk characterization for general public: Airblast applications for "Developing and Maintaining Wildlife Habitat, Heritage Resources, and Visual Enhancements" in the ANF

SERA (2003b) Exposure Worksheet:	E03				
Scenario	**Receptor**	**Hazard Quotient**			**Toxicity Value mg/kg/day**
		Central	**Lower**	**Upper**	
Acute Exposures (dose in mg/kg/event)					
Direct Spray of Child, whole body	Child	0.00268	0.00068	0.01305	2
Direct Spray of Woman, feet and lower legs	Adult Female	0.00027	0.00007	0.00131	2
Vegetation Contact, shorts and T-shirt	Adult Female	0.00038	0.00009	0.00194	2
Contaminated Fruit	Adult Female	0.00441	0.00353	0.13995	2
Water consumption, accidental spill	Child	0.10245	0.05034	0.30735	2
Water consumption, ambient	Child	0.00056	0.00001	0.03383	2
Fish consumption, accidental spill	Adult Male	0.00117	0.00094	0.00234	2
Fish consumption, accidental spill	Subsistence Populations	0.00570	0.00459	0.01139	2
Chronic/Longer Term Exposures (dose in mg/kg/day)					
Contaminated Fruit	Adult Female	0.002414003	0.001931202	0.076607648	2
Water consumption	Adult Male	0.000010714	0.000000600	0.000205714	2
Fish consumption	Adult Male	0.000000020	0.000000002	0.000000326	2
Fish consumption	Subsistence Populations	0.000000165	0.000000013	0.000002638	2

Table 53. Glyphosate risk characterization for general public: Backpack applications for "Developing and Maintaining Wildlife Habitat, Heritage Resources, and Visual Enhancements" in the ANF

SERA (2003b) Exposure Worksheet:		E03			
Scenario	Receptor	Hazard Quotient			Toxicity Value mg/kg/day
		Central	Lower	Upper	
Acute Exposures (dose in mg/kg/event)					
Direct Spray of Child, whole body	Child	0.002676	0.000424	0.013051	2
Direct Spray of Woman, feet and lower legs	Adult Female	0.000269	0.000043	0.001311	2
Vegetation Contact, shorts and T-shirt	Adult Female	0.000377	0.000057	0.001941	2
Contaminated Fruit	Adult Female	0.004410	0.002234	0.139950	2
Water consumption, accidental spill	Child	0.102451	0.031248	0.307353	2
Water consumption, ambient	Child	0.000564	0.000009	0.033835	2
Fish consumption, accidental spill	Adult Male	0.001169	0.000584	0.002337	2
Fish consumption, accidental spill	Subsistence Populations	0.005696	0.002848	0.011391	2
Chronic/Longer Term Exposures (dose in mg/kg/day)					
Contaminated Fruit	Adult Female	0.002414003	0.001223095	0.076607648	2
Water consumption	Adult Male	0.000010714	0.000000380	0.000205714	2
Fish consumption	Adult Male	0.000000020	0.000000001	0.000000326	2
Fish consumption	Subsistence Populations	0.000000165	0.000000008	0.000002638	2

Table 54. Glyphosate risk characterization for general public: Cut surface applications for "Developing and Maintaining Wildlife Habitat, Heritage Resources, and Visual Enhancements" in the ANF

SERA (2003b) Exposure Worksheet:	E03				
Scenario	**Receptor**	**Hazard Quotient**			**Toxicity Value mg/kg/day**
		Central	**Lower**	**Upper**	
Acute Exposures (dose in mg/kg/event)					
Direct Spray of Child, whole body	Child	0.26762	0.02829	**1.99389**	2
Direct Spray of Woman, feet and lower legs	Adult Female	0.02689	0.00284	0.20031	2
Vegetation Contact, shorts and T-shirt	Adult Female	0.00080	0.00012	0.00302	2
Contaminated Fruit	Adult Female	0.00882	0.00441	0.20993	2
Water consumption, accidental spill	Child	0.25613	0.05208	**1.17392**	2
Water consumption, ambient	Child	0.00113	0.00002	0.05075	2
Fish consumption, accidental spill	Adult Male	0.00292	0.00097	0.00893	2
Fish consumption, accidental spill	Subsistence Populations	0.01424	0.00475	0.04351	2
Chronic/Longer Term Exposures (dose in mg/kg/day)					
Contaminated Fruit	Adult Female	0.004828006	0.002414003	0.114911472	2
Water consumption	Adult Male	0.000021429	0.000000750	0.000308571	2
Fish consumption	Adult Male	0.000000041	0.000000002	0.000000489	2
Fish consumption	Subsistence Populations	0.000000330	0.000000016	0.000003957	2

Table 55. Glyphosate risk characterization for general public: Airblast applications for "Treatment/Control of Native and Non-native Invasive Species" in the ANF

SERA (2003b) Exposure Worksheet:		E03			
Scenario	**Receptor**	**Hazard Quotient**			**Toxicity Value mg/kg/day**
		Central	**Lower**	**Upper**	
Acute Exposures (dose in mg/kg/event)					
Direct Spray of Child, whole body	Child	0.00268	0.00068	0.01305	2
Direct Spray of Woman, feet and lower legs	Adult Female	0.00027	0.00007	0.00131	2
Vegetation Contact, shorts and T-shirt	Adult Female	0.00038	0.00009	0.00194	2
Contaminated Fruit	Adult Female	0.00441	0.00353	0.13995	2
Water consumption, accidental spill	Child	0.10245	0.05034	0.30735	2
Water consumption, ambient	Child	0.00056	0.00001	0.03383	2
Fish consumption, accidental spill	Adult Male	0.00117	0.00094	0.00234	2
Fish consumption, accidental spill	Subsistence Populations	0.00570	0.00459	0.01139	2
Chronic/Longer Term Exposures (dose in mg/kg/day)					
Contaminated Fruit	Adult Female	0.002414003	0.001931202	0.076607648	2
Water consumption	Adult Male	0.000010714	0.000000600	0.000205714	2
Fish consumption	Adult Male	0.000000020	0.000000002	0.000000326	2
Fish consumption	Subsistence Populations	0.000000165	0.000000013	0.000002638	2

Table 56. Glyphosate risk characterization for general public: Backpack applications for "Treatment/Control of Native and Non-native Invasive Species" in the ANF

SERA (2003b) Exposure Worksheet:		E03			
Scenario	**Receptor**	**Hazard Quotient**			**Toxicity Value mg/kg/day**
		Central	**Lower**	**Upper**	
Acute Exposures (dose in mg/kg/event)					
Direct Spray of Child, whole body	Child	0.00535	0.00085	0.02538	2
Direct Spray of Woman, feet and lower legs	Adult Female	0.00054	0.00009	0.00255	2
Vegetation Contact, shorts and T-shirt	Adult Female	0.00080	0.00012	0.00413	2
Contaminated Fruit	Adult Female	0.00882	0.00441	0.27990	2
Water consumption, accidental spill	Child	0.20490	0.06250	0.59763	2
Water consumption, ambient	Child	0.00113	0.00002	0.06767	2
Fish consumption, accidental spill	Adult Male	0.00234	0.00117	0.00455	2
Fish consumption, accidental spill	Subsistence Populations	0.01139	0.00570	0.02215	2
Chronic/Longer Term Exposures (dose in mg/kg/day)					
Contaminated Fruit	Adult Female	0.004828006	0.002414003	0.153215296	2
Water consumption	Adult Male	0.000021429	0.000000750	0.000411429	2
Fish consumption	Adult Male	0.000000041	0.000000002	0.000000651	2
Fish consumption	Subsistence Populations	0.000000330	0.000000016	0.000005277	2

Table 57. Glyphosate risk characterization for general public: Cut surface applications for "Treatment/Control of Native and Non-native Invasive Species" in the ANF

SERA (2003b) Exposure Worksheet:	E03				
Scenario	**Receptor**	**Hazard Quotient**			**Toxicity Value mg/kg/day**
		Central	**Lower**	**Upper**	
Acute Exposures (dose in mg/kg/event)					
Direct Spray of Child, whole body	Child	0.267623	0.021453	**2.537678**	2
Direct Spray of Woman, feet and lower legs	Adult Female	0.026885	0.002155	0.254935	2
Vegetation Contact, shorts and T-shirt	Adult Female	0.000377	0.000057	0.001941	2
Contaminated Fruit	Adult Female	0.004410	0.002234	0.139950	2
Water consumption, accidental spill	Child	0.256128	0.039493	**1.494079**	2
Water consumption, ambient	Child	0.000564	0.000009	0.033835	2
Fish consumption, accidental spill	Adult Male	0.002922	0.000739	0.011363	2
Fish consumption, accidental spill	Subsistence Populations	0.014239	0.003599	0.055375	2
Chronic/Longer Term Exposures (dose in mg/kg/day)					
Contaminated Fruit	Adult Female	0.002414003	0.001223095	0.076607648	2
Water consumption	Adult Male	0.000010714	0.000000380	0.000205714	2
Fish consumption	Adult Male	0.000000020	0.000000001	0.000000326	2
Fish consumption	Subsistence Populations	0.000000165	0.000000008	0.000002638	2

For members of the general public, none of the longer-term exposure scenarios approach a level of concern. Although there are several uncertainties in the longer-term exposure assessments for the general public, the upper limits for hazard indices are below a level of concern by factors of about 7 (longer term consumption of contaminated fruit) to 10 billion for longer-term consumption of fish by an adult male. The risk characterization is thus relatively unambiguous: based on the available information and under the foreseeable conditions of application and exposure, there is no route of exposure or exposure scenario suggesting that the general public will be at risk from longer-term exposure to glyphosate.

The exposure scenario (cut surface treatment) for the consumption of contaminated water after an accidental spill into a small pond results in a hazard quotient of 1.5. This exposure scenario is extreme to the point of limited plausibility, particularly with regard to the assumption of a 5 gallon spill, which is highly unlikely for cut surface treatments that will use 0.5 to 3.5 gallons of product per day for each worker.

Note that the ANF has not experienced an herbicide spill since the program began in 1987. However, this sort of scenario is routinely used in U.S. Forest Service risk assessments as an index of the measures that should be taken to limit exposure in the event of a relatively large spill into a relatively small body of water. For glyphosate, as well as for most other chemicals, in the event of a spill measures should be taken to ensure that members of the general public do not consume contaminated water. More unlikely is the direct spray of the undiluted product over the whole body of an unclothed child. This scenario results in a hazard quotient of 2.5.

Sensitive Individuals

Within any population some individuals are hypersensitive. Individual susceptibility to the toxic effects of the herbicides cannot be specifically predicted. A factor of 10 has traditionally been used (NAS 1977) to account for inter-individual variation. The hazard quotient approach used in this risk assessment takes into account much of the variation in human response, incorporating a factor of 10 for interspecies variation and an additional factor of 10 for within-species variation, resulting in a combined factor of 100. In addition, the 1996 Food Quality Protection Act (FQPA) established a new standard of safety; U.S. EPA must conclude with "reasonable certainty" that "no harm" will come to infants and children or other sensitive individuals exposed to pesticides. In cases where evidence suggests that current margins of exposure are not protective of sensitive individuals, U.S. EPA is required to add an additional factor. Currently, as a part of the re-registration process mandated by FQPA, U.S. EPA is evaluating each pesticide active ingredient (~450) to determine the need for an additional factor to protect sensitive individuals (particularly infants and children). U.S. EPA has completed more than 66% of these evaluations, prioritized based on potential human health risks. Glyphosate is considered low priority and has yet to be evaluated (http: //www.epa.gov/pesticides/reregistration/reports.htm).

Aggregate Exposure And Cumulative Risk

In this assessment, potential health risks associated with pesticide exposure are evaluated for individual pathways of exposure for individual chemicals, and not on the potential for individuals to be exposed to multiple pesticides by all pathways concurrently. In 1996, the FQPA imposed the requirement to consider potential human health risks from all pathways of dietary and nondietary exposures to more than one pesticide acting through a common mechanism of toxicity. Aggregate exposure considers exposure to a single chemical by multiple pathways (food, drinking water, drift, and work related exposures) and routes (ingestion, dermal, inhalation) of exposure. Additionally, in assessing cumulative risk the combined effect of exposure to multiple chemicals with a common mechanism of toxicity is considered.

In the ANF, there are opportunities for workers and the general public to be exposed to multiple chemicals by multiple pathways and routes of exposure. For example, an individual consuming contaminated fish might also consume contaminated water and/or vegetation. For glyphosate these multiple sources of exposure are inconsequential. The only substantial exposure scenario for acute exposures is the consumption of contaminated water after a glyphosate spill into a small pond. All other plausible combinations of exposures would not exceed a level of concern. Similarly, for longer term exposures, the over-riding route of exposure is the consumption of glyphosate contaminated vegetation. Adding all other sources of exposure would have no substantial impact on the hazard quotient.

Individuals may also be exposed to glyphosate from other sources not related to ANF activities. For example, glyphosate has a number of approved uses on crops and some exposure to glyphosate in crop residues is likely. The U.S. EPA/OPP (2002) has estimated that residues of glyphosate on crops could account for about 1% of the RfD. The ANF upper limit of glyphosate exposure is the consumption of contaminated vegetation, which results in a hazard quotient of 0.14. Increasing this to include the possible contribution from residues on crops does not increase the HQ to the level of concern. The ANF contribution plus the dietary contribution is HQ = 0.14 + 0.01 = 0.15, which is more than 6 times less than the level of concern. Lastly, there is no evidence to suggest that a common mechanism of toxicity exists for glyphosate, sulfometuron methyl, inerts, or surfactants used in the ANF.

Connected Actions

There is very little information available on the interaction of glyphosate with other compounds. As summarized above, there is some data suggesting that glyphosate may inhibit hepatic mixed-function oxidases. This is a very important system of enzymes in the metabolism of many xenobiotics. While the inhibition of hepatic mixed-function oxidases is a plausible mechanism of interaction, this does not lead to any definite conclusions regarding the potential influence of glyphosate on the toxicity of other chemicals. In any event, this mechanism of action would probably be relevant only at very high doses, substantially above exposures that can be anticipated in ANF programs.

Cumulative Effects

As noted above, this risk assessment specifically considers the effect of repeated exposures, and no adverse effects are anticipated. As discussed in the dose-response and dose-severity relationships, the daily dose rather than the duration of exposure determines the toxicological response. Consequently, repeated exposure to levels below the toxic threshold should not be associated with cumulative effects.

It is possible and even likely that some individuals will be exposed to multiple sources of glyphosate as a result of Forest Service and other programs. For example, an individual consuming contaminated fish might also consume contaminated water and/or vegetation. For glyphosate, these multiple sources of exposure are inconsequential. As detailed in Tables 51, 54 and 57, the only substantial exposure scenario for acute exposures is the consumption of contaminated water after a spill into a small pond. All other plausible combinations of exposures would not exceed a level of concern. Similarly, for longer term exposures, the over-riding route of exposure is the consumption of contaminated vegetation. Adding all other sources of exposure would have no substantial impact on the hazard quotient.

Lastly, individuals may be exposed to glyphosate from other sources not related to ANF activities. For example, glyphosate has a number of approved uses on crops and some exposure to glyphosate in crop residues is likely. The U.S. EPA/OPP (2002) has estimated that residues of glyphosate on crops could account for about 1% of the RfD for the U.S. population overall (U.S. EPA/OPP 2002, p. 17726). This amounts to a hazard quotient of 0.01, substantially higher than any of the central estimates of the hazard quotients for longer term exposure scenarios associated with ANF programs (Tables 49–51). Thus, except for the upper limit of exposure in the consumption of contaminated vegetation, the use of glyphosate by the ANF is not likely to substantially increase an individual’s potential exposure to glyphosate from other sources. For the consumption of contaminated vegetation, the upper limit of exposure combined with the U.S. EPA estimate of other dietary exposures would not exceed the RfD, i.e., 0.14 + 0.01 = 0.15.

SULFOMETURON METHYL HUMAN HEALTH RISK ASSESSMENT

The following sections draws heavily, but not verbatim in all cases, on SERA (2004a).

SECTION 6. SULFOMETURON Methyl HAZARD ANALYSIS

Overview and Summary

The purpose of the hazard analysis is to identify the most critical measures of toxicity. The most sensitive measure is expressed as the reference dose (RfD). There are several subchronic and chronic studies regarding exposure to sulfometuron methyl in the available literature. Although the mechanism of phytotoxic action of sulfonylurea herbicides including sulfometuron methyl is fairly well characterized, the mechanism of toxicity of sulfometuron methyl in mammals or other animal species is not well characterized.

Toxicity

In experimental mammals, the acute oral LD_{50} for sulfometuron methyl is greater than 17,000 mg/kg, which indicates a low order of toxicity. The lowest dose reported to cause any apparent effects after single gavage administration to rats is 5000 mg/kg. Acute exposure studies of sulfometuron methyl and the sulfometuron methyl formulation, Oust®, give similar results, indicating that formulations of sulfometuron methyl are not more toxic than sulfometuron methyl alone.

Sometimes it is helpful to see an array of toxicity values. While there are many such values in the text, Table 58 provides a few that may provide some useful information. Note that while these values are reported in the text of Appendix G1 or Appendix G2, none of these is the critical toxicity value used in this human health risk assessment. The critical toxicity value for the human health risk assessment is the EPA provisional RfD of 0.87 mg/kg/day, as reported in the text.

Table 58. Some Toxicity Values for Sulfometuron Methyl

Organism	Type of Toxicity	Measure of Toxicity	Form of Sulfometuron Methyl
Mammal (rat, mouse)	Acute Oral LD_{50}	> 17,000 mg/kg	Technical and formulated Sulfometuron Methyl
Mammal (rat)	2-Generation Reproduction LOAEL	300 mg/kg/day	Technical Sulfometuron Methyl
Mammal (rabbit)	Dermal LC_{50}	> 5000 mg/kg	Technical sulfometuron Methyl and Oust XP®
Mammal (rat)	4-hour inhalation, transient weight loss	5.3 mg/cubic meter	Oust XP®
Bird (mallard duck)	Acute LD_{50}	> 5000 mg/kg	Technical sulfometuron methyl
Fish	NOEC	> 7.3 mg/L	Technical sulfometuron Methyl

*These values are for illustrative purposes only. The critical toxicity value used is the EPA provisional (RfD) of 0.87 mg/kg/day.

The most common signs of toxicity involve changes in blood that are consistent with hemolytic anemia (i.e., a lysis or destruction of blood cells that results in a decreased number of red blood cells) and decreased body weight gain. It is plausible that the hemolytic anemia caused by sulfometuron methyl is attributable, at least partially, to sulfonamide and saccharin, which are metabolites of sulfometuron methyl. In one study, the investigators observed several effects, in addition to changes in the blood, in dogs exposed to dietary concentrations of sulfometuron methyl for 1 year. These effects, which included increased alkaline phosphatase activity, increased serum cholesterol (females only), decreased serum albumin and creatinine, as well as changes in liver and thymus weights, were not, however, clearly attributable to sulfometuron methyl exposure. In chronic feeding studies with rats, mice and dogs and in several in vitro assays, sulfometuron methyl did not display carcinogenic or mutagenic activity.

There is some concern regarding potential reproductive and teratogenic effects from exposure to sulfometuron methyl. Gavage studies in rabbits suggest that sulfometuron methyl exposure may increase the number of fetuses with anomalies as well as the proportion of fetal anomalies per litter. In addition to the two teratogenicity studies in rabbits, there are three reproduction studies involving dietary exposure of rats to sulfometuron methyl, in which effects were observed in dams (decreases in maternal body weight gain associated with decreased food consumption) and offspring (decreased fetal weight, decreased numbers of pups, and decreases in brain weights). As detailed in the dose-response assessment, these effects were not consistently dose-related and do not appear to be the most sensitive effect for sulfometuron methyl.

Both sulfometuron methyl and the commercial formulations Oust® and Oust XP®, can cause skin and eye irritation. Although a direct comparison between the irritant effects of sulfometuron methyl and the irritant effects of Oust® is precluded by the use of different exposure levels in the available studies, there appears to be no remarkable difference. Neither sulfometuron methyl nor Oust® caused sensitization following repeated dermal exposure. The inhalation toxicity of sulfometuron methyl is not well documented in the literature. Sulfometuron methyl and Oust® can induce irritant effects and possibly systemic toxic effects at very high exposure levels. The potential inhalation toxicity of sulfometuron methyl, however, is not of substantial concern to this risk assessment because of the implausibility of inhalation exposure involving high concentrations of this compound.

Toxicokinetcs

Limited information is available on the toxicokinetics of sulfometuron methyl. The kinetics of absorption of sulfometuron methyl following dermal, oral or inhalation exposure are not documented in the available literature. In both mammals and bacteria, sulfometuron methyl is degraded by cleavage of the sulfonyl urea bridge to form sulfonamide and a dimethyl pyrimidine urea or pyrimidine amine. Sulfonamide may be further degraded by demethylation to the free benzoic acid, which, in turn, may undergo a condensation reaction to form saccharin. Sulfometuron methyl does not appear to concentrate in tissues and is eliminated fairly rapidly, with a half-life in goats ranging from 28 to 40 hours. In goats, nearly all of the administered sulfometuron methyl dose was excreted in urine. Studies on the toxicity of sulfometuron methyl metabolites have not been conducted, however, the toxicity of the metabolites of sulfometuron methyl is likely to be encompassed by the available mammalian toxicity studies.

As discussed in the exposure assessment, skin absorption is the primary route of exposure for workers. Data regarding the dermal absorption kinetics of sulfometuron methyl are not available in the published or unpublished literature. For this risk assessment, estimates of dermal absorption rates, both zero order and first order, are based on quantitative structure-activity relationships. These estimates of dermal absorption rates are used in turn to estimate the amounts of sulfometuron methyl that might be absorbed by workers, which then are used with the available dose-response data to characterize risk. The lack of experimental data regarding dermal absorption of sulfometuron methyl adds substantial uncertainties to this risk assessment. Uncertainties in the rates of dermal absorption, although they are substantial, can be estimated quantitatively and are incorporated in the human health exposure assessment.

Mechanism of Action

Although the mechanism of phytotoxic action of sulfonylurea herbicides including sulfometuron methyl is characterized in some detail, the mechanism of toxic action in mammals or other animal species is not well characterized.

As noted in the recent review on sulfometuron methyl by Cox (1993) and described in detail by Melander et al. (1989), several of the sulfonylureas are biologically active in humans and are used or were considered for use in the treatment of non-insulin-dependent diabetes mellitus (NIDDM or type 2 diabetes). A variety of sulfonylureas reduce blood glucose stimulating the release of insulin from pancreatic B cells, and some sulfonylureas may reduce the hepatic extraction of insulin. Secondarily, some sulfonylureas may affect levels of blood cholesterol and serum triglycerides. Sulfometuron methyl was not tested specifically for effects on glucose metabolism or cholesterol. With the exception of an increased level of serum cholesterol in female dogs (Wood and O'Neal 1983), there is no information indicating a relationship between this spectrum of effects and exposure to sulfometuron methyl.

It is plausible that some and perhaps most of the toxic effects observed in the studies on sulfometuron methyl are attributable to its metabolites. Hemolytic anemia is the most consistent systemic effect of exposure to sulfometuron methyl. As discussed further in the section on dose-response assessment, this effect is also the most sensitive (i.e., the adverse effect that occurs at the lowest dose). There is no information in the available literature suggesting that anemia is associated with the pyrimidine metabolites of sulfometuron methyl. Recently, however, exposure to sulfonamides, was associated (p=0.004) with the development of hemolytic anemia in humans (Issaragrisil et al. 1997). This finding is supported by an earlier, more qualitative association of sulfonamide with anemia in humans (Dickerman 1981). Moreover, saccharin was shown to cause hematological effects in mice (Prasad and Rai 1987) that were similar to the hematological effects of sulfometuron methyl in rats. The doses of saccharin associated with the effects in mice, 500, 1000, and 1500 mg/kg/day, are much higher than the doses of sulfometuron methyl that caused similar effects in rats and dogs (i.e., 20-30 mg/kg/day). However, no mechanism of action for this effect has been identified.

Kinetics and Metabolism

Limited information is available on the toxicokinetics of sulfometuron methyl. The kinetics of absorption of sulfometuron methyl following dermal, oral or inhalation exposure are not documented in the available literature. The lack of experimental data regarding the dermal absorption of sulfometuron methyl adds substantial uncertainties to this risk assessment. Nonetheless, the available laboratory data in rabbits and guinea pigs, albeit relatively sparse, do not suggest that sulfometuron methyl is likely to be absorbed through the skin in amounts that may cause systemic toxic effects (SERA 2004a Appendix 1, Dermal Administration Studies). Uncertainties in the rates of dermal absorption, although they are substantial, can be estimated quantitatively and are incorporated in the human health exposure assessment.

Dermal exposure scenarios involving immersion or prolonged contact with chemical solutions use Fick's first law and require an estimate of the permeability coefficient, K p , expressed in cm/hour. Using the method recommended by U.S. EPA (1992), the estimated dermal permeability coefficient for sulfometuron methyl is 0.0000005 cm/hour with a 95% confidence interval of 0.0000001-0.000002 cm/hour. These estimates are used in all exposure assessments that are based on Fick’s first law. The calculations for these estimates are presented in SERA (2004b, Worksheet B05).

For exposure scenarios like direct sprays or accidental spills, which involve deposition of the compound on the skin’s surface, dermal absorption rates (proportion of the deposited dose per unit time) rather than dermal permeability rates are used in the exposure assessment. The estimated first-order dermal absorption coefficient is 0.000087 $hour^{-1}$ with 95% confidence intervals of 0.000012-0.00063 $hour^{-1}$. The calculations for these estimates are presented in SERA (2004b, Worksheet B04).

In both mammals and bacteria, sulfometuron methyl is degraded by cleavage of the sulfonyl urea bridge to form sulfonamide and a dimethyl pyrimidine urea or pyrimidine amine. Sulfonamide may be further degraded by demethylation to the free benzoic acid, which, in turn, may undergo a condensation reaction to form saccharin. At least in bacteria, the pyrimidine metabolites may be degraded further to hydroxypyrimidine amine and pyrimidine-ol. Although data regarding mammalian metabolism of sulfometuron methyl are limited, there is an apparent qualitative difference between mammalian and microbial metabolism that involves changes to sulfometuron methyl prior to cleavage of the sulfonyl urea bridge. In mammals, the major metabolic route seems to involve hydroxylation of a methyl group on the pyrimidine ring (Koeppe and Mucha 1991); in bacteria, the major metabolic pathway seems to involve demethylation of the methyl ester group on the benzoate ring (Monson and Hoffman 1990).

There is only one detailed study regarding the metabolism of sulfometuron methyl by mammals. Koeppe and Mucha (1991) examined the metabolism of sulfometuron methyl in two lactating goats. The sulfometuron methyl used in the study was double labeled: pyrimidine-2-^{14}C- and uniformly labeled phenyl ring. It was administered as capsules, 0.575 or 0.625 mg/kg, twice a day for 7 days. The authors give 'dietary' equivalents, apparently based on differences in food consumption, as 25 and 60 ppm; however, the actual dosing appears to have been by gavage. The animals were sacrificed 20 hours after the last dose. About 94-99% of dose was recovered in the urine, 60% in the form of hydroxyl- sulfometuron methyl (i.e., no cleavage of the sulfonyl urea bridge). Most of the metabolites resulting from cleavage of the sulfonyl urea bridge were recovered in the liver and kidney and were tightly bound to protein. The only other information available on mammalian metabolism of sulfometuron methyl comes from an unpublished DuPont study, which reports half-lifes of 28 and 40 hours in rats after gavage doses of 16 and 3000 mg/kg, respectively (DuPont 1989). Thus, sulfometuron methyl is eliminated fairly rapidly and does not appear to accumulate in tissues.

Detailed Information

Acute Oral Toxicity

Acute toxicity studies are used to determine the toxicity reference level known as the median lethal dose (LD_{50}), which is the dose that kills 50 percent of the test animals. The lower the LD_{50}, the greater the toxicity of the chemical. The LD_{50} ranges and toxicity categories used in this risk assessment are those of the U.S. EPA classification system using rat oral LD_{50} values, as shown in Table 59, adapted from Walstad and Dost (1984). Categories of toxicity using this classification system include: very slight (rat LD_{50} 5,000 to 50,000 mg/kg), slight (rat LD_{50} 500 to 5,000 mg/kg), moderate (rat LD_{50} 50-500 mg/kg), and severe (rat LD_{50} less that 50 mg/kg).

Table 59. Acute Toxicity Classification and Acute Toxicities of Herbicides, Additives, and Formulations Being Evaluated for Use in Vegetation Management in Relation to Other Chemicals (adapted from Walstad and Dost, 1984)

Toxicity Category[1] (Label Signal Words)	Herbicide or Other Chemical Substance	Oral LD_{50} for Rats (mg/kg)	Equivalent Human Dose
IV Very slight		5,000-50,000 (range)	More than 1 pint
	Sugar	30,000	
	Ethyl alcohol	13,700	
	Sulfometuron Methyl	> 5,000	
	Oust®	> 5,000	
	Oust XP®	> 5,000	
	Red River Adherent 90®[2]	> 5,000	
	Red River 90®[3]	> 5,000 (est.)	
	Timberland 90®[4]	> 5,000 (est.)	
	Chemsurf 90®[4]	> 5,000 (est.)	
III Slight (caution)		500-5,000 (range)	1 ounce to 1 pint
	Roundup®[6]	4,900	
	Glyphosate	4,320	
	Table salt	3,750	
	Bleach	2,000	
	Aspirin, Vitamin B3	1,700	
II Moderate (warning)		50-500 (range)	1 teaspoon to 1 ounce
	Caffeine	200	
I Severe (danger-poison)		0-50 (range)	1 teaspoon or less
	Nicotine	50	
	Strychnine	30	
	Botulinus Toxin	0.00001	

[1]Categories, signal words, and LD_{50} ranges are based on a classification system used by EPA for labeling pesticides
[2]Brewer International, 2005a
[3]Brewer International, 2005b
[4] Toxicology information was not available for these surfactants, however, inert ingredients were on EPA's inert lists 3 and 4b. The oral LD50 value for Red River 90 was adopted as the estimate of the oral LD50 values for Chemsurf 90, Timberland 90 and Alenza 90 based on the similar or identical composition of all four of these surfactants, as reported on their labels
[5] Monsanto MSDS, 1985

As summarized in SERA (2004a, Appendix 1), there are three acute oral studies in rats involving exposure to technical grade sulfometuron methyl (Dashiell and Hall 1980; Dashiell and Hinckle 1980c; Trivits 1979) and one acute oral study in rats involving exposure to the 75% sulfometuron methyl formulations Oust® (Filliben 1995a) and Oust XP® (Finlay 1999a). Sulfometuron methyl doses in these studies ranged from 5,000 to 17,000 mg/kg. Results show that acute oral exposure to sulfometuron methyl has a low order of toxicity. As summarized in SERA (2004a, Appendix 1), neither mortality nor overt signs of toxicity were observed in rats given single oral doses of up to 17,000 mg/kg (Dashiell and Hall 1980; Dashiell and Hinckle 1980c; Trivits 1979). Thus, the LD_{50} value for sulfometuron methyl is > 17,000 mg/kg (Trivits 1979).

Qualitative assessments of toxicity were also made in all acute toxicity studies. The only effects commonly noted in the treated animals were weight loss and stained or wet perineal (genital) areas. Dashiell and Hall (1980) observed alopecia (hair loss) in male rats but not female rats, and the study by Dashiell and Hinckle (1980) reports an unspecified increase in lung weight in both male and female rats and 'pink thymus' in four of five female rats after a single gavage dose of 5000 mg/kg. It is not clear whether the changes in lung weight were relative to body weight or were absolute.

Comparison of acute toxicity studies of technical grade sulfometuron methyl and the formulations Oust® and Oust XP® show similar results. Oral administration of up to 5000 mg/kg Oust® (3750 mg a.i./kg) to rats did not result in a single mortality (Filliben 1995a). The only clinical sign of toxicity observed in this study was alopecia in one female rat. Acute oral administration of 5000 mg/kg Oust XP® (3750 mg a.i./kg) did not result in any mortalities, clinical signs of toxicity or gross lesions in any animal (Finlay 1999a). Thus, like technical grade sulfometuron methyl, acute exposure to the 75% formulations Oust® and Oust XP® does not appear to result in any significant toxicity.

Subchronic and Chronic Systemic Toxic Effects

Systemic toxicity encompasses virtually any effects that a chemical has after the chemical has been absorbed. Certain types of effects, however, are of particular concern and involve a specific subset of tests. Such special effects are considered in the following subsections and include effects on the nervous system, immune system, endocrine function, development or reproduction, and carcinogenicity or mutagenicity. This section encompasses the remaining signs of general and non-specific toxicity. The subchronic or chronic toxicity of sulfometuron methyl to humans or mammals is not documented in the published literature, and all of the available toxicological data comes from unpublished studies that were conducted to support the registration of sulfometuron methyl as an herbicide. As summarized in SERA 2004, Appendix 1, there are two subchronic exposure studies in rats (Hinckle 1979; Wood et al. 1980), and chronic exposure studies in rats (Mullin 1984), mice (Summers 1990), and dogs (Wood and O’Neal 1983). Subchronic and chronic exposure studies involving reproductive performance assays were also conducted in rats (Lu 1981; Mullin 1984) and rabbits (Hoberman et al. 1981; Serota et al. 1981).

The most common signs of toxicity involve changes in blood (Wood and O'Neal 1983, Summers 1990; Wood et al. 1980; Mullin 1984) and decreased body weight gain (Hoberman et al. 1981). The changes in the blood appear to be consistent with hemolytic anemia (i.e., a lysis or destruction of blood cells that results in a decreased number of red blood cells). Details of these studies are provided in SERA (2004a, Appendix 1). In rats, changes in red blood cell parameters were observed following subchronic dietary exposure to 1000 ppm sulfometuron methyl for male rats (NOAEL = 100 ppm) (Wood et al. 1980). In a 2-year feeding study, a NOAEL of 50 ppm for decreased erythrocyte count and hematocrit was observed in male rats (Mullin 1984). A NOAEL of 100 ppm was reported for anemia in female mice exposed to dietary sulfometuron methyl for 18 months (Summers 1990), and a NOAEL of 200 ppm was reported for hemolytic anemia in dogs exposed to dietary sulfometuron methyl for 1 year (Wood and O’Neal 1983).

No other specific signs of toxicity were noted consistently among the different subchronic or chronic bioassays summarized in SERA (2004a, Appendix 1). Following exposure of six rats to 3,400 mg/kg bw/day sulfometuron methyl for 14 days, the investigators observed reduced testicular size in one rat and mild testicular lesions in another (Hinckle 1979). No such effects were observed in any of the six control rats. In a 1 year long dog feeding study, several effects in addition to those on the blood were observed in various dose groups; however, the effects were not considered by the authors to be clearly dose-related (Wood and O'Neal 1983). The potentially significant effects reported in this study include increased alkaline phosphatase activity, increased serum cholesterol (females only), and decreased serum albumin and creatinine. At dietary concentrations of 5,000 ppm, the observed effects include increased absolute liver weights in females and increased relative liver weight in males and females, as well as increased absolute and relative thymus weights in females. Thymus weights were also increased in males at 200 and 1,000 ppm but not at 5,000 ppm. No pathological changes in the thymus were noted in either sex at any dose level.

Effects on Nervous System

As discussed in Durkin and Diamond (2002), a neurotoxicant is a chemical that disrupts the function of nerves, either by interacting with nerves directly or by interacting with supporting cells in the nervous system. This definition of neurotoxicant is critical because it distinguishes agents that act directly on the nervous system (direct neurotoxicants) from those agents that might produce neurologic effects that are secondary to other forms of toxicity (indirect neurotoxicants). Virtually any chemical will cause signs of neurotoxicity in severely poisoned animals and thus can be classified as an indirect neurotoxicant. This is the case for sulfometuron methyl in that sulfometuron methyl was reported to cause signs of depression in rabbits exposed to up to 1,000 mg/kg by gavage for 13 days (Hoberman et al. 1981).

Effects on Immune System

There is very little direct information on which to assess the immunotoxic potential of sulfometuron methyl. Dermal studies in rabbits show that sulfometuron methyl does not produce sensitization. Results of subchronic and chronic exposure studies show that sulfometuron methyl may produce changes to immune system function at high doses. In male rats exposed to 5,000 ppm sulfometuron methyl in the diet for 90 days, elevated mean leukocyte and lymphocyte counts and decreased neutrophil count were reported (Wood et al. 1980). No effect on these parameters was observed at dietary concentrations of sulfometuron methyl of 100 and 1,000 ppm. Increased thymus weights were observed in female dogs exposed to 5,000 ppm and in male dogs exposed to 200 and 1,000 ppm, but not 5,000 ppm, dietary sulfometuron methyl for 1 year (Wood and O'Neal 1983). However, no pathological changes were observed in the thymus at any dose. While results of these studies suggest that exposure to sulfometuron methyl may produce changes in immune system parameters, the observations in these studies do not provide conclusive evidence supporting the immunotoxic potential of sulfometuron methyl.

Effects on Endocrine System

A variety of sulfonylureas reduce blood glucose by stimulating the release of insulin from pancreatic B cells, and some sulfonylureas reduce the hepatic extraction of insulin. No studies investigating the effects of sulfometuron methyl on insulin release or metabolism were identified. As noted in SERA (2004a, Appendix 1 and Appendix 2), weight loss and decreased weight gain are observed in animals treated with sulfometuron methyl, implying a change in metabolic status. However, there is no evidence to suggest that changes in weight are due to effects of sulfometuron methyl on the endocrine system. Following exposure of six rats to 3400 mg/kg/day sulfometuron methyl for 14 days, reduced testicular size in one rat and mild testicular lesions in another were reported (Hinckle 1979). In a 2-generation reproductive study, a decrease in reproductive performance was observed in rat's 5000 ppm dietary sulfometuron methyl for 90 days, but not at dietary concentrations of 50 and 500 ppm (Mullin 1984). While results of these studies suggest that exposure to sulfometuron methyl may produce changes in the function of the reproductive endocrine system, the observations in these studies do not provide conclusive evidence.

The administration of 2000 mg/kg sulfonamide over a 15-day period caused dose-related changes to the thyroid gland and changes in circulating levels of T3 and T4 in rats (Nishikawa 1983a,b). Elevated serum thyroxine levels have been observed in female rats exposed to 100 and 1000 ppm, but not 5000 ppm, dietary sulfometuron methyl for 90 days (Wood et al. 1980). A decrease in tail resorption rates, a morphological biomarker of thyroid disruption, was observed in African clawed frogs to 0.001 and 0.01 mg/L sulfometuron methyl for 14 days (Fort 1998). Effects were partially reversed by the administration of thyroxine. Based on results of these studies, it appears that sulfometuron methyl has the potential to produce changes in thyroid gland function. No mechanism has been identified for effects of sulfonamides on thyroid gland function.

Reproductive and Teratogenic Effects

Studies investigating the reproductive effects of sulfometuron methyl in humans or mammals are not documented in the published literature, and all of the available toxicological data comes from unpublished studies that were conducted to support the registration of sulfometuron methyl as an herbicide. As detailed in SERA (2004a, Appendix 1), studies assessing the reproductive and teratogenic effects of sulfometuron methyl have been conducted in rats (Lu 1981; Mullin 1984; Wood et al.1980) and rabbits (Hoberman et al. 1981; Serota et al. 1981).

In the two teratogenicity studies in rabbits, sulfometuron methyl was administered by gavage, as shown in SERA (2004a, Appendix 1). The study by Hoberman et al. (1981) was a range finding study with daily doses of 100-1000 mg/kg, while the study by Serota et al. (1981) involved lower dose levels of 30-300 mg/kg. In the Hoberman et al. (1981) study, signs of maternal toxicity, including death in some dams, were apparent at all dose levels. In the study by Serota et al. (1981), there were no signs of toxicity in the dams or offspring at any exposure level. At the 30 and 100 mg/kg dose levels, an increase in the incidences of fetal anomalies was observed; however, at the 300 mg/kg dose level, there were actually fewer incidences of fetal anomalies than were observed at 100 mg/kg dose level. The author’s state that statistical evaluation of all parameters, including fetal anomalies, revealed no statistical differences between the control and sulfometuron methyl treated groups. Given the clear lack of dose-response relationship, the NOAEL for this study for both maternal and fetal toxicity is 300 mg/kg/day.

The three studies in rats involve dietary exposure to sulfometuron methyl (Wood et al.1980; Lu 1981; Mullin 1984). As SERA (2004a, Appendix 1) shows, decreases in maternal body weight gain associated with decreased food consumption (Lu 1981; Mullin 1984) and hematological changes (Mullin 1984; Wood et al. 1980) were the common effects observed in these studies. Gestational exposure of rats to 5000 ppm dietary sulfometuron methyl resulted in decreased maternal weight gain and decreased fetal weights, with NOAEL for the dams and fetuses of 1000 ppm (Lu 1981). Exposure of rats for 90 days to dietary levels of 5000 ppm was associated with a decreased number of pups in the F1 and F2 generations (Mullin 1984). In addition to these effects, mean absolute brain weights were significantly decreased in male rats, with an NOAEL of 500 ppm (Mullin 1984). No adverse effects on reproductive parameters were observed in rats exposed to dietary sulfometuron methyl at dietary concentrations up to 5000 ppm (Wood et al. 1980).

Carcinogenicity and Mutagenicity

Sulfometuron methyl has been tested for mutagenicity in a number of different test systems and has been assayed for carcinogenic activity in rats, mice and dogs. Studies are summarized in SERA (2004a, Appendix 1). Rats were exposed to dietary sulfometuron methyl at concentrations up to 5000 ppm for one year (Mullin 1984), mice to concentrations up to 1000 ppm for 18 months (Summers 1990), and dogs to concentrations up to 5000 ppm for 1 year.

No evidence of carcinogenic activity was found in any sulfometuron methyl chronic exposure study. In all three studies, toxicity was indicated by hematological changes in the high dose groups (SERA 2004a, Appendix 1). Also, the study by Mullin (1984) reports bile duct hyperplasia and fibrosis in female rats exposed to the two higher dose levels and a significant decrease in mean absolute brain weight in male rats exposed to the highest dose level. Each of these studies can be viewed as involving doses that approximate the maximum tolerated dose based on alterations in body weight and clinical blood indices.

Sulfometuron methyl did not show mutagenic activity in assays in Salmonella typhimurium strains TA 1535, TA 1537, TA 98, and TA 100 (Taylor 1979; Taylor and Krahn 1990) and Chinese hamster ovary cells (Krahn and Fitzpatrick 1981). Moreover, sulfometuron methyl did not induce chromosomal damage in Chinese hamster ovary cells (Galloway 1981) or unscheduled DNA synthesis in rat hepatocytes (Ford 1982). These data provide no evidence that exposure to sulfometuron methyl poses a carcinogenic risk to humans.

Irritation and Sensitization (Effects on Skin and Eyes)

Both sulfometuron methyl and the commercial formulations, Oust® and Oust XP®, were tested for irritant effects on the skin and eyes as well as for sensitization resulting from dermal exposure. Details of all studies are summarized in SERA (2004a, Appendix 1).

Results of studies in rabbits and rats show that single and repeated dermal application of sulfometuron methyl (Dashiell and Henry 1980a; Dashiell and Hinckle 1983; Dashiell and Silber 1980c, 1981; Sarver 1990b) and single dermal applications of Oust® (Filliben 1995b,c) and Oust XP® (Finlay 1999b,c) induced skin irritation characterized by mild erythema and mild edema. A direct comparison between the irritant effects of sulfometuron methyl and those of Oust® is difficult to make because of dissimilarities in study protocols. Nonetheless, there appears to be no remarkable difference between the irritant effects of sulfometuron methyl and the commercial formulations. Mild skin irritation was observed in guinea pigs exposed to 50% sulfometuron methyl in dimethyl phthalate (Dashiell and Silber 1980b; Edwards 1979a). Neither sulfometuron methyl nor Oust® caused sensitization in guinea pigs (Edwards 1979a; Dashiell and Silber 1980a,b; Moore 1995).

Applications of technical grade sulfometuron methyl to the eyes of rabbits produced transient, mild irritant effects to the cornea and conjunctiva, including redness, transient corneal cloudiness, discharge, and chemosis. (Dashiell and Henry 1980a; Edwards 1979b; Malek 1990). Although sulfometuron methyl, Oust® and Oust XP® all cause mild eye irritation (SERA 2004a, Appendix 1), sulfometuron methyl caused transient corneal opacity in rabbits after ocular instillation of 61.8 mg a.i. (Dashiell and Henry 1980b), an effect not observed in rabbits exposed similarly to Oust® at a dose of 46 mg or approximately 34.5 mg a.i. (Filliben 1995d) or Oust XP® at a dose of 32 mg or approximately 24 mg a.i.(Finlay 1999b). In all studies, effects were resolved within 72 hours.

Systemic Toxic Effects from Dermal Exposure

Most of the occupational exposure scenarios and many of the exposure scenarios for the general public involve the dermal route of exposure. For these exposure scenarios, dermal absorption is estimated and compared to an estimated acceptable level of oral exposure based on subchronic or chronic toxicity studies. Thus, it is necessary to assess the consequences of dermal exposure relative to oral exposure and the extent to which sulfometuron methyl is likely to be absorbed from the surface of the skin.

Studies on the systemic toxicity of sulfometuron methyl following dermal exposure have been conducted in rabbits and rats (summarized in SERA 2004a, Appendix 1). Dermal exposure to doses up to 8000 mg/kg technical grade sulfometuron methyl were not associated with any signs of significant systemic toxicity in rabbits (Dashiell and Henry 1980a; Dashiell and Silber 1980c, 1981). Only 1 death, which was not considered to be treatment related, was reported (Dashiell and Silber 1980c). Thus, the LD_{50} for dermal exposure of sulfometuron methyl in rabbits is >8000 mg/kg (Dashiell and Silber 1980c). Dermal exposure to 2000 mg/kg sulfometuron methyl (Dashiell and Silber 1980c; Dashiell and Silber 1981) caused weight loss similar to that observed in rats after acute oral exposure to 5000 mg/kg sulfometuron methyl (Trivits 1979). This effect, however, was not reported in a subchronic dermal study in which doses of up to 2000 mg/kg/day were applied to the intact skin of rabbits for 21 days (Dashiell and Hinckle 1983). Furthermore, none of the dermal studies that examined hematological changes noted any effects.

Hematological effects are the most common effects observed after oral exposure to sulfometuron methyl. The results of the dermal studies with Oust® in rabbits (Filliben 1995b,c) and Oust XP® in rats (Finlay 1999c) suggest that there is no substantial difference between the dermal toxicity of the 75% sulfometuron formulations and technical grade sulfometuron methyl. The LC_{50} value for dermal applications for both sulfometuron methyl formulations was greater than 5000 mg/kg (equivalent to 3750 mg a.i./kg).

Effects from Inhalation Exposure

As summarized in SERA (2004a, Appendix 3), there is only one inhalation toxicity study on sulfometuron methyl (Kinney 1982), one inhalation toxicity study on Oust® (Sarver 1995), and one on Oust XP® (Bamberger 1999). All three studies involve acute (4-hour) exposure to relatively high concentration levels (>5 mg/L or >5000 mg/m^3). Although no toxic effects were observed in rats after head-only exposure to 6.4 or 11 mg/L sulfometuron methyl (Kinney 1982), irritant effects (nasal and ocular discharge) were observed in male rats after head only exposure to 5.1 mg/L Oust® (Sarver 1995). Transient weight loss and wet perineum were also observed in the Oust® study, which is consistent with the signs of sulfometuron methyl toxicity after oral exposure. Similar transient effects were observed following 4-hour exposure to Oust XP® at a concentration of 5.3 mg/L formulation or about 4 mg a.i./L (Bamberger 1999).

The extremely limited data suggest only that sulfometuron methyl can induce irritant effects as well as systemic toxic effects at very high exposure levels. This finding is not directly relevant to this risk assessment because of the implausibility of exposure to such high concentrations of the compound.

Inerts and Adjuvants

The formulations of sulfometuron methyl used by the U.S. Forest Service contains materials other than sulfometuron methyl that are included as adjuvants to improve either efficacy or ease of handling and storage. The identity of these inert materials in Oust XP® is confidential. The inerts were disclosed to the U.S. EPA (DuPont Agricultural Products 1999) and were reviewed in the preparation of the SERA (2004a) risk assessment. All that can be disclosed explicitly is that none of the additives in Oust XP® are classified by the U.S. EPA as toxic. However, the identity of inert ingredients for the sulfometuron methyl formulation Oust® has been disclosed. The Northwest Coalition for Alternatives to Pesticides (NCAP) has obtained information on the identity of the inerts in Oust® from U.S. EPA under the Freedom of Information Act and has listed this information on the NCAP web site (http: //www.pesticide.org/inertspage.html). The inerts listed in this web site are sucrose, sodium salt of naphthalene-sulfonic acid formaldehyde condensate, polyvinyl pyrrolidone, sodium salt of sulfated alkyl carboxylated and sulfated alkyl naphthalene, and hydroxypropyl methylcellulose. Sucrose (CAS No. 57-50-1) is classified by the U.S. EPA as a List 4 inert and therefore, is generally recognized as a safe compound and is approved as a food additive (U.S. EPA/OPP 2003). Hydroxypropyl methylcellulose (CAS. No. 009004-65-3) is classified as a List 4a inert, which is generally recognized as safe (U.S. EPA/OPP 2003). There is no evidence to assert that either sucrose or hyrdoxypropyl methylcellulose will materially impact the risks associated with the use of sulfometuron methyl. Polyvinyl pyrrolidone (CAS No. 88-12-0) is classified as a List 3 inert (U.S. EPA/OPP 2003). In other words, there is insufficient information to categorize this compound as either hazardous (Lists 1 or 2) or non-toxic (List 4). Sodium naphthalene sulfonate-formaldehyde condensate and the mixture of a sulfate of alkyl carboxylate and sulfonated alkyl naphthalene (sodium salt) were not identified in the EPA Inert List (U.S. EPA/OPP 2003). Other naphthalene derivatives identified on the EPA Inert List are classified as List 3 or List 4; no naphthalene derivatives are classified as List 1 or List 2 inerts (U.S. EPA/OPP 2003). Thus, there is insufficient information available to assess the impact of either polyvinyl pyrrolidone or the naphthalene derivatives on the risks associated with the use of sulfometuron methyl. However, as noted above, the toxicity of Oust® and Oust XP® appears to be comparable to that of technical grade sulfometuron methyl. Therefore, there is no plausible basis for asserting that these inerts are present in Oust® or Oust XP® in toxicological amounts.

The manufacturers recommend that sulfometuron methyl formulations be mixed with a non-ionic surfactant. However, there is no published literature or information in the FIFRA files that would permit an assessment of toxicological effects of sulfometuron methyl mixed with surfactant. However, all of the surfactants proposed for use by ANF have inert ingredients that are in U.S. EPA's inert classification lists 3 and 4b. List 3 indicates that there is unknown toxicity; for inerts where "there was no basis for placing it on any of the other lists. The Agency will continue to evaluate these chemical substances, as additional information becomes available, to determine if reclassification to List 1, 2, or 4 is appropriate." List 4B is for inerts with "*sufficient information to conclude that current use patterns in pesticide products will not adversely affect public health and the environment."*

Impurities and Metabolites

Virtually no chemical synthesis yields a totally pure product. Technical grade sulfometuron methyl, as with other technical grade products, undoubtedly contains some impurities. To some extent, concern for impurities in technical grade sulfometuron methyl is reduced by the fact that the existing toxicity studies on sulfometuron methyl were conducted with the technical grade product. Thus, if toxic impurities are present in the technical grade product, they are likely to be encompassed by the available toxicity studies on the technical grade product. In addition, acute toxicity studies with technical sulfometuron methyl and Oust® show quite similar LD_{50} values, indicating little impact from impurities.

No studies investigating the toxicity of the sulfometuron methyl metabolites produced by mammals were identified in the published literature or unpublished studies. The toxicity of the metabolites of sulfometuron methyl is likely to be encompassed by the available mammalian toxicity studies. As discussed in the section on kinetics and metabolism, metabolites of sulfometuron methyl are rapidly excreted and do not appear to concentrate in any tissue.

Dose Response Assessment

This section is the culmination of the hazard analysis and identifies the most critical toxicity value for use in the risk characterization section. Generally, the dose-response assessments used in U.S. Forest Service risk assessments adopt the RfD proposed by the U.S. EPA as indices of 'acceptable' exposure. An RfD is the level of exposure that will not result in any adverse effects in any individual. The U.S. EPA RfDs are used because they generally provide a level of analysis, review, and resources that far exceed those that are or can be conducted in the support of most Forest Service risk assessments.

The U.S. EPA has derived an RfD of 0.24 mg/kg/day for sulfometuron methyl. This RfD is based on a NOAEL for bladder toxicity of 500 ppm dietary sulfometuron methyl (equivalent to 24.4 mg/kg/day) and a 100-fold safety factor. A more conservative provisional reference dose of 0.02 mg/kg/day was used in the previous Forest Service risk assessment on sulfometuron methyl (Durkin 1998 as cited in SERA 200a). It is derived from the 2-year feeding study in rats by Mullin (1984). The provisional reference dose is based on the 2 mg/kg/day (50 ppm) NOAEL for hematological effects in male rats and an uncertainty factor of 100: a factor of 10 for species-to-species extrapolation and a factor of 10 for sensitive subgroups in the human population. The provisional RfD of 0.02 mg/kg/day is used in this ANF risk assessment for characterizing risks associated with chronic exposure to sulfometuron methyl.

With regard to species sensitivity for hematological effects, rats appear to be most sensitive with reported NOAELs of 2-3 mg/kg/day and an AEL of 20-26 mg/kg/day (SERA 2004, Appendix 1). Dogs appear to have a sensitivity similar to that of rats, with a reported NOAEL of 5 mg/kg/day and a LOAEL of 28 mg/kg/day (Wood and O'Neal 1983). Mice appear to be much less sensitive than either rats or dogs to the hematological effects of sulfometuron methyl with a NOAEL of about 18 mg/kg/day and a LOAEL of 180 mg/kg/day (Summers 1990; dose conversions provided in SERA 2004a, Appendix 1). Although these data are not amenable to formal statistical analysis, they lend qualitative support to the use of an uncertainty factor for species-to-species extrapolation for the human health risk assessment (i.e., the larger animals appear to be more sensitive than smaller animals to sulfometuron methyl).

The U.S. EPA has not derived an acute/single dose RfD for sulfometuron methyl. However, a provisional acute RfD can be calculated based on the short-term exposure NOAEL for decreased body weight of 86.6 mg/kg/day reported in the teratology study in rats by Lu (1981). Exposure of rats to 5000 ppm dietary for 10 days during gestation resulted in decreased maternal body weight, with a NOAEL of 1000 ppm. As reported by the author, the dietary concentration of 5000 ppm is equivalent to a daily dose of 433 mg/kg/day and was determined using mean daily food consumption and body weight. Thus, assuming that food consumption and body weights were similar between the 1000 and 5000 ppm exposure groups, the concentration of 1000 ppm is estimated as equivalent to 86.6 mg/kg/day [433 mg/kg/day ÷ 5]. Using a margin of exposure of 100, a provisional acute RfD can be calculated as 0.87 mg/kg/day [86.6 mg/kg/day ÷ 100]. For this ANF risk assessment, the provisional RfD of 0.87 mg/kg/day is used for characterizing risks associated with acute exposure to sulfometuron methyl.

SECTION 7. SULFOMETURON METHYL EXPOSURE ASSESSMENT

Overview

This section provides the human exposure assessment to sulfometuron methyl for both workers and members of the general public. It provides the critical levels of exposure based on selected exposure scenarios for workers and the general public for the typical application rate of sulfometuron methyl used by the ANF of 0.09 lb a.i./acre. The critical exposure values are used in the risk characterization section with the critical toxicity values to calculate the risk, expressed as the hazard quotient. The consequences of using the maximum application rate that might be used by the ANF, 0.19 lb a.i./acre, are discussed in the risk characterization.

This section begins with a review of what is known of the movement, persistence and fate of sulfometuron methyl because these elements of the environmental behavior of the herbicide influence human exposure. This information is also relevant for the sulfometuron methyl exposure analysis for wildlife and aquatic species, for species federally listed or proposed as threatened or endangered, and for species listed as sensitive by the Regional Forester.

Detailed Information

Environmental Behavior of Sulfometuron Methyl

Behavior in Air

Sulfometuron methyl has a vapor pressure that is extremely low. There should be no significant vaporization from droplets or environmental surfaces, meaning that residues in air will be restricted to the distribution of droplets during the application.

Behavior in Plants

Sulfometuron methyl is readily absorbed into foliage and (from treated soil) roots. SERA (1998a) reports plant uptake as 10% in 72 hours. It translocates in both xylem and phloem, accumulating in the meristematic plant tissues. Growth of treated plants is inhibited shortly (a few hours) after application although injury symptoms typically do not become apparent for a few weeks. Symptoms typically include chlorosis of meristematic areas, foliar chlorosis and necrosis. It acts by inhibiting a key enzyme in the biosynthesis of branch-chained amino acids, and plant death results from the events related to this inhibition, although the precise mechanisms are not known.

Little is known of its persistence in plant tissue, except for a study done by Michael (2003) in connection with reforestation in Mississippi. Sulfometuron methyl residue levels in loblolly pine foliage and foliage from competing understory plants were measured for 27 days after foliar application of Oust® at 0.42 kg/ha (6 oz. a.i./acre). The data show a rapid dissipation of sulfometuron methyl in foliage, with a half-life of less than 7 days in each case (Table 60). Note that the typical planned rates of application on the ANF of 0.09 lb/acre (0.1 kg/ha) is 4.2 times lower, and the maximum rate of 0.19 lb/acre (0.21 kg/ha) is about ½ the rate used in the Michael (2003) study.

Table 60. Sulfometuron methyl residues (mg/kg) in forest vegetation in Mississippi after application of 0.42 kg/ha (0.375 lb/acre) sulfometuron methyl as Oust®

Vegetation	Days After Treatment					
	0	1	3	7	14	27
	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
Loblolly Pine	6.14	4.07	1.49	0.42	0.19	0.19
Grass	6.89	5.83	5.38	1.46	1.63	ND
Pokeweed	33.60	24.16	14.06	10.55	4.55	0.82
Blackberry	40.77	24.86	11.33	2.23	0.39	ND

From Table 6, Michael (2003)
ND is not detectable

Michael and Neary (1988) reported that residues of sulfometuron methyl dissipated from vegetation, litter, and soil rapidly after being applied aerially (April 1985) to a 445 ha Mississippi forested watershed and by ground application to a 4 ha watershed area (June 1985) in Florida at a rate of 0.42 kg a.i./ha. Residues in vegetation were not detectable after 90 days. It has a foliar half-life of 10 days based on a report by Knisel et al (1992 as cited in SERA 1998a). The apparent half-lives from the Michael (2003) study are shorter, ranging from less than 3 days to about one week. Based on this limited amount of data it appears likely that vegetation half-life on the ANF would not be greater than 10 days.

Behavior in Soil and Groundwater

According to WSSA (1994), the typical field half-life is 20–28 days at pH 6-7, but persistence is increased by cool temperatures, low soil moisture and higher pH. Microbial degradation does occur, but slowly. Non-microbial hydrolysis appears to be an important mechanism in sulfometuron methyl dissipation. It is moderately rapid at pH 6, but quite slow at pH 8. Sulfometuron methyl degradation in soil occurs most rapidly at lower pH values where it is dominated by hydrolysis causing cleavage of the sulfonylurea bridge. Mobility in soil is greater at higher pH values and lower levels of organic matter. Volatilization from soil is insignificant. Neary and Michael (1989) reported half-lives for sulfometuron methyl of 5 and 33 days on forested sites in Mississippi and Florida.

Cambon et al. (1992) reported that the mechanism for soil degradation of sulfometuron methyl is most likely chemical, based on finding the Arrhenius relationship [rate of chemical reactions in relation to temperature] was followed for temperatures up to 70 ºC in lab tests.

Soil half-lives determined for sulfometuron methyl are shown in Table 61.

Table 61. Sulfometuron methyl field dissipation study half-life in weeks determinations (modified from Table 1 in Trubey et al. 1998)

Location	Field Type	Treatment Date	Half-life in Weeks	Reference
Newark, DE	bare ground	July 3, 1980	2-3	Anderson and Dulka (1985)
Raleigh, NC	bare ground	July 18, 1980	2-3	Anderson and Dulka (1985)
Rosetown, SK	bare ground	July 29, 1980	5	Anderson and Dulka (1985)
Pendleton, OR	bare ground	Sept. 8, 1980	13	Anderson and Dulka (1985)
Ft Collins, CO*	bare ground	Nov. 14, 1980	21	Anderson and Dulka (1985)
Gainesville, FL	pine forest	June 13, 1985	0.7	Michael and Neary (1993)
Wahalak, MS	pine forest	April 9, 1985	4.7	Michael and Neary (1993)
Greenville, MS	bare ground	May 13, 1991	14	Trubey et al. (1998)
Rochelle, IL	bare ground	May 15, 1991	12	Trubey et al. (1998)
Uvalde, TX	bare ground	May 15, 1991	15	Trubey et al. (1998)
Madera, CA	bare ground	April 3, 1991	25	Trubey et al. (1998)

A series of field studies reviewed by SERA (1998a) reported on the persistence of sulfometuron at several sites (Table 62).

Table 62. Soil persistence of sulfometuron methyl at field sites

Location	Rate of Application	Time after application	Proportion remaining
Delaware	1.1 kg/ha	1 year	1%
North Carolina	0.91 kg/ha	1 year	1%
Oregon	0.44 kg/ha	2 years	3%
Colorado	0.15 kg/ha	78 weeks	9%
Saskatchewan	0.11 kg/ha	2 years	5%

From SERA 1998a.
Note: 1 kg/ha = 0.892 lb/acre

In a laboratory study (as reported by SERA 1998a) sulfometuron applied at 120 g/ha showed a half-life of about 1 month. There was no degradation in a sterile soil, suggesting the decomposition was microbially mediated. In a separate study, SERA (1998a) reported complete decomposition of sulfometuron after 1 year in both a sterile and non-sterile soil systems. In these systems, the half-life was 17 and 96 days in the non-sterile system, and 53 days in the sterile system.

Michael and Neary (1988) reported that residues of sulfometuron methyl dissipated from litter and soil rapidly after aerial application to a 445 ha Mississippi forested watershed and by ground application to a 4 ha watershed in Florida (application rate was 0.42 kg a.i./ha). In the soil profiles sulfometuron methyl was not detected below 30 cm and was not detected after 60 days (detection limit for soil was 0.020 ppm).

Harvey et al. (1985) reported that C_{14}-labeled sulfometuron methyl was mobile on soils when tested using thin-layer plates and soil columns. Hubbard et al. (1989) reported that during simulated rainfall tests, sulfometuron methyl was primarily lost due to percolation on two sandy Coastal Plain soils (Red Bay loamy sand and Bonifay sand) whereas the primary route of lost herbicides from a clayey soil, Greenville sandy clay loam, was from surface runoff (Table 63).

Table 63. Percent of sulfometuron methyl lost during 2 hour simulated rainfall trials on three Coastal Plain soils Modified from Hubbard et al. (1989). Sulfometuron methyl was applied at a rate of 0.6 kg/ha (0.54 lb/acre)

Soil	Low Intensity (43 mm/hr)		Medium Intensity (75 mm/hr)		High Intensity (125 mm/hr)	
	Surface runoff	Percolation	Surface runoff	Percolation	Surface runoff	Percolation
Greenville sandy clay loam	4.2%	0.2%	24.5%	>0.1%	34.7%	1.0%
Red Bay loamy sand	0.0%	71.3%	1.0%	82.2%	15.9%	81.3%
Bonifay sand	0.2%	56.1%	2.5%	53.9%	24.3%	11.8%

According to a study by Stone et al. (1993) reviewed by SERA (1998a) sulfometuron methyl and its metabolites from the phenyl portion of molecule are mobile in most soils; more so in sandy vs. loamy soils and less so in high organic matter soils and less so in soils at pH 6 and below. In field lysimeters with intact soil columns of bare sandy soils from the northern lake state forests and sulfometuron methyl applied at 42.5 g a.i./ha, the mean concentration in soil water was 0.5 µg/L at 10 cm and 0.4 µg/L at 20 cm and none was detected in soil water below 20 cm. By 80 days post-treatment most of the compound had been degraded or irreversibly absorbed into the upper soil layers. Mean concentrations detected from 80 to 130 days post-treatment were 0.5 µg/L at 10 cm, 0.4 µg/L, and 0.0 µg/L at 40 and 150 cm.

Based on this information, we conclude that sulfometuron methyl will be neither very persistent nor mobile in the types of soils found on the ANF because of the generally higher level of organic matter and the lower pH. The layer of vegetation and litter present on the ground promotes infiltration into the soil. This decreases the likelihood of surface run off of water which might contain chemical residues and increases the likelihood of the movement of this water and any chemical residue it contains into the upper most portions of the soil. The high levels of organic matter in ANF soils will limit the movement (leaching) of sulfometuron methyl and accelerate its rate of decomposition. Half-life in ANF soil is expected to be less than 3 weeks. Applications should not be made to bare and/or compacted soils because runoff of this herbicide could possibly damage adjacent vegetation.

Impact on Soil Productivity

Herbicides are commonly used in the U. S. to achieve forestry objectives. One of the concerns about herbicide use is the possibility it might impact soil nutrient cycling and soil productivity. This topic is addressed in detail on pp. G1-40, G1-42 to G1-44, G1-104 to G1-106, and also in Appendix G2 pp. G2-33 and G2-42. Based on the information in these sections, we conclude that the proposed use of sulfometuron methyl will not adversely affect soil nutrient cycling.

Behavior in Surface Waters

There is little data on sulfometuron methyl residues in surface water. The most relevant data are from Neary and Michael (1989) who followed an application of 0.36 lbs sulfometuron methyl a.i./acre to forests in the southeastern U.S. Monitored levels of sulfometuron methyl in ambient water ranged from 0.005 mg/L to 0.044 mg/L at a 445 ha treated site in Mississippi and at a 4 ha watershed in Florida. Herbicide was detected only briefly after application, with detectable residues in only 10 out of 85 samples collected. Herbicide residues did not persist beyond 7 days at the Florida site or 63 days in Mississippi.

In a simulated runoff study, Wauchope et al. (1990) report that 1 to 2% of sulfometuron methyl applied at a 0.4 kg/ha rate was lost in runoff (simulated rainfall event equaled 69 mm/h until 2 mm of runoff occurred) from a loamy sand soil one day after application on plots with bare ground or with grass cover. Losses were similar for both suspension and emulsifiable concentrate formulations. Authors reported that total losses were sensitive to the length of time between rainfall initiation and runoff initiation.

Harvey et al. (1985) reported that C_{14}-labeled sulfometuron methyl was stable in water at pH 7 and 9, but hydrolyzed readily at pH 5.0 with a reported half-life of 2 weeks. Products of hydrolysis were [^{14}C]methyl 2-(aminosulfonyl) benzoate and [^{14}C] 1,2-benzisothialzol-3-one, 2,3-dihydro 1,1-dioxide (saccharin). C_{14}-labeled sulfometuron methyl was completely photolyzed to $^{14}CO_2$ under aquatic photolysis conditions.

On the ANF, the majority of streams have pH values that fall within the range of 4.23-7.33. Headwater streams generally have the lowest pH values (4.5-7.5), while larger main streams generally have pH values that range from 6.0 to 7.5, with some values as high as 8.0. The pH values for ponds range from 4.5 to 7.0, with the pH for shallower ponds generally at the lower end of this range. Most broadcast treatment occurs within headwater watersheds. Given the slightly acidic nature of surface water on ANF, we believe the half-life in water will be about 2 weeks.

SERA (1998a) estimated an ambient sulfometuron methyl concentration from forestry activities over prolonged periods of 0.0002 (0.00005-0.0005) mg/L. In an accidental spill, they estimate ambient levels are likely to be about 0.33 mg/L with a range of 0.053-2.29 mg/L. They note that sulfometuron methyl is stable in water at pH 7 to 10, but it decomposes appreciably in water at pH 5. It is important to put the SERA (1998a) analysis in perspective. They are projecting the larger aerial scale of usage that might occur in traditional forest management operations, but aerial application is not part of the proposed ANF program.

Despite the limited amount of direct data on sulfometuron methyl residues in water, we believe residue levels will be similar to that for other herbicides (adjusted for rates of application), since the dominant route of entry is drift or direct application. These processes are largely independent of the herbicide. For this analysis we adopt the SERA value of 0.0002 mg/L.

Buffers

Buffers are a strip of untreated vegetation adjacent to wetlands, water bodies and flowing water. The purpose of the buffer is to prevent the entry of unacceptable levels of herbicide to the water, thereby reducing water quality. The size of the buffer varies with the application technique and the characteristics of individual herbicides, such as the toxicity of the herbicide to animals and aquatic organisms that might use the water, and the movement, persistence and fate of the herbicide in the environment close to water. The critical element in protection of water quality with respect to glyphosate is protection of aquatic species. The following discussion focuses on protecting human health, but the buffer strategy outlined also protects aquatic species, as outlined in Appendix G2.

For broadcast foliar (airblast) mechanical application (0.09 or 0.19 lb/acre application rate), the following buffers and application tactics will provide water quality protection involving the use of sulfometuron methyl (note the width varies with the rate of application):

- No sulfometuron methyl shall be applied to surface waters**.**
- Buffers 25 feet (0.09 lb/acre) or 50 feet (0.19 lb/acre) wide along each side of perennial streams, impoundments, springs, intermittent streams and seeps with flowing water the day of spraying;
- Buffers 25 feet (0.09 lb/acre) or 50 feet (0.19 lb/acre) wide around wet areas (standing water) and vernal pools with no defined outlet.
- Buffers 10 feet (0.09 lb/acre) or 25 feet (0.19 lb/acre) wide along each side of dry intermittent streams, dry springs, and dry seeps
- Airblast shall be directed away from the buffer when applications are made within 50 feet (0.09 lb/acre) or 100 feet (0.19 lb/acre) of the edge of the buffer, i.e., within 50 or 100 feet no airblast directed towards the edge of the buffer unless intervening vegetation 5 to 15 feet tall is sufficiently dense to intercept spray materials.

For the directed foliar backpack (0.09 or 0.19 lb/acre) application method, the following buffers and tactics will provide water quality protection involving the use of sulfometuron methyl:

- No sulfometuron methyl shall be applied to surface waters.
- No sulfometuron methyl shall be applied within 10 ft (0.09 lb/acre) or 25 ft (0.19 lb/acre) of standing or flowing water.
- No sulfometuron methyl shall be applied within 10 feet (0.09 lb/acre) or 25 feet (0.19 lb/acre) of dry intermittent stream courses, dry springs, or dry seeps.

This buffer strategy was developed based on the experience of ANF managers, the results of ANF monitoring (results are in several ANF Monitoring and Evaluation Reports) and buffer-width research (Norris and Charlton, 1995). The basis is explained in detail in Appendix G2, Section D.

ANF has conducted monitoring programs in connection with operational applications of herbicide on the ANF to verify protection of water quality and damage to vegetation outside of treatment areas. There are several in-house reports that provide the specifics of the monitoring program (typically these are included in Monitoring and Evaluation Reports for specific fiscal years). Table 64 shows the ANF water quality monitoring program activity. Visual monitoring for herbicide damage to vegetation was conducted in 2003 and 2004 and shows little or no damage to vegetation outside of the intended treatment area. Chemical water quality monitoring of silvicultural applications in 1990 and 2002 has shown no detectable concentrations of sulfometuron methyl in water samples tested.

Table 64. Date and type of ANF Monitoring for Water Quality

Year of Treatment and Survey Monitoring	Year of Monitoring and Evaluation Report	Vegetation Management Activity	Herbicide Monitored
1987	1988	Silviculture	glyphosate
1988	1989	Silviculture	glyphosate
1989	1990	Silviculture	Sulfometuron methyl
1998	2000	Utility ROW[1]	glyphosate and imazapyr
1999	2001	Utility ROW	glyphosate and imazapyr
2000	2002	Utility ROW	glyphosate and imazapyr
2002	2002	Silviculture	glyphosate and sulfometuron methyl

* Same as Table 11 in Section 4, Glyphosate Exposure Assessment, this appendix
[1] ROW= right-of-way

Based on this experience, monitoring and research, and the analysis of drift done in this appendix, we conclude that the buffer strategy used previously by ANF silvicultural operations was unnecessarily restrictive. We believe the buffers proposed in this current ANF risk assessment will protect aquatic life and water users. However, continued monitoring is needed to increase the breadth of the experience base and to further verify the adequacy of this buffer strategy, and to provide documentation that water quality is protected.

We believe these buffers will protect water quality. When these buffer strips are used, sulfometuron methyl residues in water are expected to be less than 0.0002 mg/L and 0.00019 mg/L for application rates of 0.19 and 0.09 lb/acre respectively. These values are similar to the 0.00021 mg/L water quality protection criterion for sulfometuron methyl.

Consumption of water (2 L per day) contaminated at the level of the water quality protection criterion of 0.00021 mg/L would result in an exposure value for a 70 kg human of 0.0000061 mg/kg/day. The Hazard Quotient for this exposure based on the RfD of 0.87 mg/kg/day is 0.0000068, which is far less than the level of concern (HQ = 1) for human health.

Residues in Animals

Sulfometuron methyl does not accumulate in game animals or fish, which is consistent with its low octanol-water partition coefficient (K_{ow}). One study in bluegill sunfish found no bioconcentration after exposure to sulfometuron methyl. In addition, no bioconcentration occurred in channel catfish exposed to aged sediments containing sulfometuron methyl. Sulfometuron methyl does not accumulate in game animals or fish. Harvey et al. (1985) reported that C_{14}-labeled sulfometuron methyl has a low partition ratio (0.31) and did not accumulate in fish tissue when bluegill sunfish were exposed to 0.01 ppm or 1.0 ppm C_{14}-labeled sulfometuron methyl. This lack of bioconcentration is consistent with its low octanol-water partition coefficient (K_{ow}), a situation we expect will hold on the ANF as well.

Human Exposure Analysis

There are no occupational exposure studies in the available literature that are associated with the application of sulfometuron methyl. Consequently, worker exposure rates are estimated from an empirical relationship between absorbed dose per kilogram of body weight and the amount of chemical handled in worker exposure studies on nine different pesticides. For workers, two types of application methods are modeled for ANF risk assessments: directed ground (backpack), broadcast ground (mechanical airblast).

Tables 65–70 indicate the characteristics (magnitude, frequency and duration) of worker exposure on ANF in connection with the application of sulfometuron methyl. These provide the quantitative exposure data used in the risk analysis.

Sustaining Forest Cover and the Production of Forest Products

Table 65. Anticipated number of acres treated daily by a worker for "Sustaining Forest Cover and the Production of Forest Products" in the ANF

Application Method	Acres treated daily with Sulfometuron Methyl		
	lower	central	upper
Mechanical (broadcast foliar) Airblast *	22	25	40
Manual (directed foliar) Backpack/hand sprayer	2.5	3	7

*Crew size = 2, so a crew treats double the acres shown above

Table 66. Anticipated worker exposure in hours per day and acres per hour for "Sustaining Forest Cover and the Production of Forest Products" in the ANF

Application Method	Hours per day			Acres per hour		
	lower	central	upper	lower	central	upper
Mechanical (broadcast foliar) Airblast	7	8	11	3.13	3.13	3.64
Manual (directed foliar) Backpack/hand sprayer	5	6	7	0.5	0.5	1.0

Developing and Maintaining Wildlife Habitat, Heritage Resources, and Visual Enhancements

Table 67. Anticipated number of acres treated daily by a worker for "Developing and Maintaining Wildlife Habitat, Heritage Resources, and Visual Enhancements" in the ANF

Application Method	Acres treated daily with Sulfometuron Methyl		
	lower	central	upper
Mechanical (broadcast foliar) Airblast	22	25	40
Manual (directed foliar) Backpack/hand sprayer	2.5	3	7

*Crew size = 2, so a crew treats double the acres shown above

Table 68. Anticipated worker exposure in hours per day and acres per hour for "Developing and Maintaining Wildlife Habitat, Heritage Resources, and Visual Enhancements" in the ANF

Application Method	Hours per day			Acres per hour		
	lower	central	upper	lower	central	upper
Mechanical (broadcast foliar) Airblast	7	8	11	3.13	3.13	3.64
Manual (directed foliar) Backpack/hand sprayer	5	6	7	0.5	0.5	1.0

Treatment/Control of Native and Non-native Invasive Species

Table 69. Anticipated number of acres treated daily by a worker for "Treatment/ Control of Native and Non-native Invasive Species" in the ANF

Application Method	Acres treated daily with Sulfometuron Methyl		
	lower	central	upper
Mechanical (broadcast foliar) Airblast *	2.3	3	5
Manual (directed foliar) Backpack/hand sprayer	2.3	3	7

*Crew size = 2, so a crew treats double the acres shown above

Table 70. Anticipated worker exposure in hours per day and acres per hour for "Treatment/Control of Native and Non-native Invasive Species" in the ANF

Application Method	Hours per day			Acres per hour		
	lower	central	upper	lower	central	upper
Mechanical (broadcast foliar) Airblast	3	4	8	0.75	0.75	0.63
Manual (directed foliar) Backpack/hand sprayer	3	4	6	0.75	0.75	1.17

Human Exposure Assessment

Overview and Summary

Sulfometuron methyl worker and general public exposure assessments for the ANF are given in Tables 72–79. These assessments correspond to the vegetation management activities outlined above, which include: sustaining forest cover and the production of forest products; developing and maintaining wildlife habitat, heritage resources, and visual enhancements; and treatment/control of native and non-native invasive species. Tables were developed using the USFS Worksheet Maker Version 4.02 created by SERA (http: //www.nvo.com/sera_inc/nss-folder/worksheets1v31/).

Workers

Two types of worker exposure assessments are considered: general and accidental/incidental. The term general exposure assessment is used to designate those exposures that involve estimates of absorbed dose based on the handling of a specified amount of a chemical during specific types of applications. General exposures are daily (chronic) exposures that might occur over the course of an application season. The accidental/incidental exposure scenarios involve specific types of events that could occur during any type of application. For general exposures in workers, exposure rates are expressed in units of mg of absorbed dose per kilogram of body weight per pound of chemical handled. For proposed sulfometuron methyl applications in the ANF, central estimates of worker exposures are within a narrow range, from 0.0005 mg/kg/day to about 0.002 mg/kg/day. The upper range of exposures for the different application methods and management needs are about a factor of 15 higher, spanning a range from about 0.007 mg/kg/day to 0.03 mg/kg/day.

General Public

Under normal circumstances, members of the general public should not be exposed to substantial levels of sulfometuron methyl as a result of ANF activities. Nonetheless we have developed acute exposure and longer-term exposure scenarios for the general public.

All of the acute exposure scenarios are primarily accidental. They assume that an individual is exposed to the compound either during or shortly after its application. Specific scenarios are developed for direct spray, dermal contact with contaminated vegetation, as well as the consumption of contaminated fruit, water, and fish. Most of these scenarios should be regarded as extreme, some to the point of limited plausibility. Most acute accidental exposure scenarios for members of the general public are less than or similar to the general exposure scenarios in workers. The major exception is the scenario for an accidental spill of 200 gallons of a field solution into a small pond. For dilute solutions (25 gallon per acre) this leads to modeled estimates of exposure in the range of 0.02 to about 0.08 mg/kg/day. This is an extraordinarily extreme and conservative scenario that is used in all Forest Service risk assessments. Note the ANF has never had such a spill occur.

The longer-term or chronic exposure scenarios parallel the acute exposure scenarios for the consumption of contaminated fruit, water, and fish but are based on estimated levels of exposure for longer periods after application. Most longer-term estimates of exposure for members of the general public are much lower than exposure estimates for workers. The one exception involves the longer-term consumption of contaminated fruit, which leads to time-weighted average estimated doses of 0.0002 to 0.006 mg/kg/day for backpack applications.

Detailed Information

Workers

The following is a narrative description of the SERA (2001) analysis for workers with some comparisons, where appropriate, to ANF conditions or equipment. This is followed by Tables 72–77 that use the SERA protocol to quantify the exposure for ANF workers. Two types of exposure assessments are considered: general and accidental/incidental. The term general (chronic) exposure assessment is used to designate those exposures that involve estimates of absorbed dose based on the handling of a specified amount of a chemical during specific types of applications. The accidental/incidental exposure scenarios involve specific types of events that could occur during any type of application.

General Exposures

General exposures are daily (chronic) exposures that might occur over the course of an application season. As described in SERA (2001), worker exposure rates are expressed in units of mg of absorbed dose per kilogram of body weight per pound of chemical handled. Based on analyses of several different pesticides using a variety of application methods, default exposure rates are estimated for two different types of applications: directed foliar (backpack) and broadcast foliar-airblast spray.

As described in SERA (2001), the ranges of estimated occupational exposure rates vary substantially among individuals and groups, (i.e., by a factor of 50 for backpack applicators). The Forest Service has not developed a worker exposure assessment for applicators using airblast spray equipment. Deposition-based worker exposure modeling described in the Pesticide Handlers Exposure Database (PHED; Leighton and Nielson 1995) was used to estimate the appropriate occupational exposure rate to be used to estimate applicator exposure for the airblast sprayer. For minimal protective clothing (long pants, long shirt, and no gloves) the PHED uses a dermal unit exposure (mg/lb a.i) of 0.014 for ground boom and 0.24 for airblast sprayer. This results in ~17 times greater dermal unit exposure for airblast compared to ground boom. Assuming equal dermal adsorption, multiplying the adsorption-based exposure rates for ground boom used in the SERA (2001) analysis by 17 gives exposure rates roughly equal to directed foliar applications, such as backpack and airblast applications, as shown in Table 71. which is repeated here for convenience.

Table 71. Occupational Exposure Rates used in U.S. Forest Service risk assessments

Application Method	Rate (mg/kg bw per lb applied)		
	Central	Lower	Upper
Directed foliar[1]	0.003	0.0003	0.01
Cut Surface[1]	0.003	0.0003	0.01
Broadcast boom[1]	0.0002	0.00001	0.0009
Broadcast airblast[2]	0.003	0.0003	0.01

[*] Also shown earlier as Table 18 in Section 4 of this appendix
[1] ERA (2001).
[2] U.S. EPA PHED: assuming minimal personal protective equipment (PPE), dermal unit exposure (mg/lb a/i.) is ~17 times greater for airblast compared to groundboom application.

Note however that the airblast equipment used by the ANF is quite different than the agricultural airblast equipment (orchard airblast sprayer) on which the SERA analysis is based. The orchard airblast equipment typically sends the spray in a vertical 180 degree arc behind the equipment, with the operator riding ahead of the machine on a tractor. The ANF airblast equipment is much more directional and sends the spray material away from the operator, however there is no quantitative data on which to make an adjustment to the SERA and Forest Service analysis. Hence the SERA analysis is used, which should provide a conservative risk assessment for ANF programs.

No worker exposure studies with sulfometuron methyl were found in the literature. As described in SERA (2001), worker exposure rates are expressed in units of mg of absorbed dose per kilogram of body weight per pound of chemical handled. These exposure rates are based on worker exposure studies on nine different pesticides with molecular weights ranging from 221 to 416 and log K_{ow} values at pH 7 ranging from -0.75 to 6.50. The estimated exposure rates are based on estimated absorbed doses in workers as well as the amounts of the chemical handled by the workers. The molecular weight of sulfometuron methyl is 364.38 and the log K_{ow} at pH 7 is approximately -0.46, with both parameters falling within the range defined above (SERA 2001). As described in SERA (2001), the ranges of estimated occupational exposure rates vary substantially among individuals and groups, (i.e., by a factor of 50 for backpack applicators). Much of the variability can probably be attributed to the hygienic measures taken by individual workers (i.e., how careful the workers are to avoid unnecessary exposure); however, pharmacokinetic differences among individuals (i.e., how individuals absorb and excrete the compound) also may be important.

Estimates of the number of acres treated per hour is needed to apply these worker exposure rates. These values are given in tables 65–70.

The range of acres treated per hour and hours worked per day is used to calculate a range for the number of acres treated per day. For this calculation as well as others in this section involving the multiplication of ranges, the lower end of the resulting range is the product of the lower end of one range and the lower end of the other range. Similarly, the upper end of the resulting range is the product of the upper end of one range and the upper end of the other range. This approach is taken to encompass as broadly as possible the range of potential exposures. For the ANF typical and maximum rates are reported. For purposes of human exposure assessment using USFS Worksheet Maker, the ANF typical rate was used for both the central and lower estimates.

The central estimate of the acres treated per day is taken as the arithmetic average of the range. Because of the relatively narrow limits of the ranges for backpack and airblast spray workers, the use of the arithmetic mean rather than some other measure of central tendency, like the geometric mean, has no marked effect on the risk assessment.

As detailed in SERA (2003b, Worksheets C01a (directed foliar) and C01b (broadcast foliar)), the central estimate of the amount handled per day is calculated as the product of the central estimates of the acres treated per day and the application rate. The ranges for the amounts handled per day are calculated as the product of the range of acres treated per day and the application rate. Similarly, the central estimate of the daily absorbed dose is calculated as the product of the central estimate of the exposure rate and the central estimate of the amount handled per day. The ranges of the daily absorbed dose are calculated as the range of exposure rates and the ranges for the amounts handled per day. The lower and upper limits are similarly calculated using the lower and upper ranges of the amount handled, acres treated per day, and worker exposure rate.

Accidental Exposures

Typical occupational exposures may involve multiple routes of exposure (i.e., oral, dermal, and inhalation); nonetheless, dermal exposure is generally the predominant route for herbicide applicators (Ecobichon 1998; van Hemmen 1992). Typical multi-route exposures are encompassed by the methods used in the section on general exposures. Accidental exposures, on the other hand, are most likely to involve splashing a solution of herbicides into the eyes or to involve various dermal exposure scenarios.

Sulfometuron methyl can cause irritant effects to the skin and eyes. The available literature does not include quantitative methods for characterizing exposure or responses associated with splashing a solution of a chemical into the eyes; furthermore, there appear to be no reasonable approaches to modeling this type of exposure scenario quantitatively. Consequently, accidental exposure scenarios of this type are considered qualitatively in the risk characterization.

There are various methods for estimating absorbed doses associated with accidental dermal exposure (U.S. EPA/ORD 1992; SERA 2001). Two general types of exposure are modeled: those involving direct contact with a solution of the herbicide (i.e., immersion of the hand in the spray solution) or the accidental spills of the herbicide onto the surface of the skin. Any number of specific exposure scenarios could be developed for direct contact or accidental spills by varying the amount or concentration of the chemical on or in contact with the surface of the skin and by varying the surface area of the skin that is contaminated.

For this ANF risk assessment, two exposure scenarios are developed for each of the two types of dermal exposure, and the estimated absorbed dose for each scenario is expressed in units of mg chemical/kg body weight. Both sets of exposure scenarios are summarized in SERA (2004b, Worksheet E01), which references other worksheets in which the specific calculations are detailed.

Exposure scenarios involving direct contact with solutions of the chemical are characterized by immersion of the hands for 1 minute or wearing contaminated gloves for 1 hour. Generally, it is not reasonable to assume or postulate that the hands or any other part of a worker will be immersed in a solution of a herbicide for any period of time. On the other hand, contamination of gloves or other clothing is quite plausible. For these exposure scenarios, the key element is the assumption that wearing gloves grossly contaminated with a chemical solution is equivalent to immersing the hands in a solution. In either case, the concentration of the chemical in solution that is in contact with the surface of the skin and the resulting dermal absorption rate are essentially constant.

For both scenarios (the hand immersion and the contaminated glove), the assumption of zero-order absorption kinetics is appropriate. Following the general recommendations of U.S. EPA/ORD (1992), Fick's first law is used to estimate dermal exposure. As an experimental dermal permeability coefficient (Kp) for sulfometuron methyl is not available, the Kp for sulfometuron methyl is estimated using the algorithm from U.S. EPA/ORD (1992), which is detailed in SERA (2004b, Worksheet A07b). The application of this algorithm to sulfometuron methyl, based on molecular weight and the $k_{o/w}$, is given in SERA (2004b, Worksheet B04).

Exposure scenarios involving chemical spills onto the skin are characterized by a spill on to the lower legs and the hands. In these scenarios, it is assumed that a solution of the chemical is spilled on to a given surface area of skin and that a certain amount of the chemical adheres to the skin. The absorbed dose is then calculated as the product of the amount of the chemical on the surface of the skin (i.e., the amount of liquid per unit surface area multiplied by the surface area of the skin over which the spill occurs and the concentration of the chemical in the liquid), the first-order absorption rate, and the duration of exposure.

For both scenarios, it is assumed that the contaminated skin is effectively cleaned after 1 hour. As with the exposure assessments based on Fick's first law, this product (mg of absorbed dose) is divided by body weight (kg) to yield an estimated dose in units of mg chemical/kg body weight. The specific equation used in these exposure assessments is specified in SERA (2004b, Worksheet B03).

Confidence in these exposure assessments is diminished by the lack of experimental data on the dermal absorption of sulfometuron methyl. Nonetheless, as summarized in SERA (2004b, Worksheet E01), there is a noteworthy similarity between the exposure scenario in which contaminated gloves are worn for 1 hour (SERA 2004b, Worksheet C02b) and the exposure scenario in which a chemical solution is spilled on to the skin surface of the hands and cleaned after 1 hour (SERA 2004b, Worksheet C03a). Confidence in these assessments is enhanced somewhat by the fact that two similar scenarios based on different empirical relationships yield similar estimates of exposure.

Table 72. Summary of sulfometuron methyl worker exposure assessments: Airblast applications for "Sustaining Forest Cover and the Production of Forest Products" in the ANF

Scenario	Receptor	mg/kg/day or mg/kg/event			SERA (2004b) Worksheet
		Central	Lower	Upper	
Accidental/Incidental Exposures (dose in mg/kg/event)					
Contaminated Gloves, 1 min.	Worker	0.0000004	0.0000001	0.0000024	C02a
Contaminated Gloves, 1 hour	Worker	0.0000263	0.0000082	0.0001420	C02b
Spill on Hands, 1 hour	Worker	0.0000091	0.0000016	0.0000856	C03a
Spill on lower legs, 1 hour	Worker	0.0000224	0.0000039	0.0002109	C03b
General (Chronic) Exposures (mg/kg/day)					
General (chronic) exposure	Airblast	0.00045	0.00002	0.00685	C01b

Note: Table 72 is derived from SERA worksheet E01.

Table 73. Summary of sulfometuron methyl worker exposure assessments: Backpack applications for "Sustaining Forest Cover and the Production of Forest Products" in the ANF

Scenario	Receptor	mg/kg/day or mg/kg/event			SERA (2004b) Worksheet
		Central	Lower	Upper	
Accidental/Incidental Exposures (dose in mg/kg/event)					
Contaminated Gloves, 1 min.	Worker	0.0000004	0.0000001	0.0000024	C02a
Contaminated Gloves, 1 hour	Worker	0.0000263	0.0000053	0.0001420	C02b
Spill on Hands, 1 hour	Worker	0.0000091	0.0000010	0.0000856	C03a
Spill on lower legs, 1 hour	Worker	0.0000224	0.0000025	0.0002109	C03b
General (Chronic) Exposures (mg/kg/day)					
General (chronic) exposure	Backpack	0.00081	0.00003	0.01330	C01a

Note: Tables 73 is derived from SERA worksheet E01.

Table 74. Summary of sulfometuron methyl worker exposure assessments: Airblast applications for "Developing and Maintaining Wildlife Habitat, Heritage Resources, and Visual Enhancements" in the ANF

Scenario	Receptor	mg/kg/day or mg/kg/event			SERA (2004b) Worksheet
		Central	Lower	Upper	
Accidental/Incidental Exposures (dose in mg/kg/event)					
Contaminated Gloves, 1 min.	Worker	0.0000004	0.0000001	0.0000024	C02a
Contaminated Gloves, 1 hour	Worker	0.0000263	0.0000082	0.0001420	C02b
Spill on Hands, 1 hour	Worker	0.0000091	0.0000016	0.0000856	C03a
Spill on lower legs, 1 hour	Worker	0.0000224	0.0000039	0.0002109	C03b
General (Chronic) Exposures (mg/kg/day)					
General (chronic) exposure	Airblast	0.00045	0.00002	0.00685	C01b

Note: Tables 74 is derived from SERA worksheet E01.

Table 75. Summary of sulfometuron methyl worker exposure assessments: Backpack applications for "Developing and Maintaining Wildlife Habitat, Heritage Resources, and Visual Enhancements" in the ANF

Scenario	Receptor	mg/kg/day or mg/kg/event			SERA (2004b) Worksheet
		Central	Lower	Upper	
Accidental/Incidental Exposures (dose in mg/kg/event)					
Contaminated Gloves, 1 min.	Worker	0.0000004	0.0000001	0.0000024	C02a
Contaminated Gloves, 1 hour	Worker	0.0000263	0.0000053	0.0001420	C02b
Spill on Hands, 1 hour	Worker	0.0000091	0.0000010	0.0000856	C03a
Spill on lower legs, 1 hour	Worker	0.0000224	0.0000025	0.0002109	C03b
General (Chronic) Exposures (mg/kg/day)					
General (chronic) exposure	Backpack	0.00081	0.00003	0.01330	C01a

Note: Tables 75 is derived from SERA worksheet E01.

Table 76. Summary of sulfometuron methyl worker exposure assessments: Airblast applications for "Treatment/Control of Native and Non-native Invasive Species" in the ANF

Scenario	Receptor	mg/kg/day or mg/kg/event			SERA (2004b) Worksheet
		Central	Lower	Upper	
Accidental/Incidental Exposures (dose in mg/kg/event)					
Contaminated Gloves, 1 min.	Worker	0.0000004	0.0000001	0.0000024	C02a
Contaminated Gloves, 1 hour	Worker	0.0000263	0.0000053	0.0001420	C02b
Spill on Hands, 1 hour	Worker	0.0000091	0.0000010	0.0000856	C03a
Spill on lower legs, 1 hour	Worker	0.0000224	0.0000025	0.0002109	C03b
General (Chronic) Exposures (mg/kg/day)					
General (chronic) exposure	Airblast	0.00202	0.00003	0.02873	C01b

Note: Tables 76 is derived from SERA worksheet E01.

Table 77. Summary of sulfometuron methyl worker exposure assessments: Backpack applications for "Treatment/Control of Native and Non-native Invasive Species" in the ANF

Scenario	Receptor	mg/kg/day or mg/kg/event			SERA (2004b) Worksheet
		Central	Lower	Upper	
Accidental/Incidental Exposures (dose in mg/kg/event)					
Contaminated Gloves, 1 min.	Worker	0.0000022	0.0000003	0.0000176	C02a
Contaminated Gloves, 1 hour	Worker	0.0001296	0.0000160	0.0010584	C02b
Spill on Hands, 1 hour	Worker	0.0002833	0.0000449	0.0013433	C03a
Spill on lower legs, 1 hour	Worker	0.0006982	0.0001107	0.0033103	C03b
General (Chronic) Exposures (mg/kg/day)					
General (chronic) exposure	Backpack	0.0135	0.0005	0.2106	C01a

Note: Tables 77 is derived from SERA worksheet E01.

General Public

Under normal conditions, members of the general public should not be exposed to substantial levels of sulfometuron methyl. Nonetheless we evaluated several exposure scenarios that tend to over-estimate exposures in general. The two types of exposure scenarios developed for the general public include acute exposure and longer-term or chronic exposure.

The following is a narrative description of the SERA (2004a) analysis for the general public. It includes narrative descriptions of ANF conditions that would likely lead to a more conservative estimate of exposure than is actually portrayed by the values shown in the tables. Tables 81–86 use SERA protocol to quantify the ANF public exposure, extrapolated where possible to ANF conditions.

All of the acute exposure scenarios are primarily accidental. They assume that an individual is exposed to the compound either during or shortly after its application. Specific scenarios are developed for direct spray, dermal contact with contaminated vegetation, as well as the consumption of contaminated fruit, water, and fish. Most of these scenarios should be regarded as extreme, some to the point of limited plausibility. The longer-term or chronic exposure scenarios parallel the acute exposure scenarios for the consumption of contaminated fruit, water, and fish but are based on estimated levels of exposure for longer periods after application.

As with the worker exposure scenarios, details of the assumptions and calculations are in SERA (2004b) Worksheets D01–D09. The remainder of this section focuses on a qualitative description of the rationale for and quality of the data supporting each of the assessments.

Direct Spray

Direct sprays involving ground applications are modeled in a manner similar to accidental spills for workers. In other words, it is assumed that the individual is sprayed with a solution containing the compound, and that an amount of the compound remains on the skin and is absorbed by first-order kinetics. For these exposure scenarios, it is assumed that during a ground application, a naked child is sprayed directly with sulfometuron methyl. These scenarios assume that 100% of the surface area of the body is exposed, likely representing the upper limits of plausible exposure. An additional set of scenarios are included involving a woman who is accidentally sprayed over the feet and legs. For each of these scenarios, some assumptions are made regarding the surface area of the skin and body weight, as detailed in SERA (2004b, Worksheet A03).

Dermal Exposure from Contaminated Vegetation

In this exposure scenario, it is assumed that the herbicide is sprayed at a given application rate, and that an individual comes in contact with sprayed vegetation or other contaminated surfaces at some period after the spray operation. Data relating to dislodgeable residue and the rate of transfer from the contaminated vegetation to the surface of the skin are not available; so the estimation methods of Durkin et al. (1995) are used as defined in SERA (2004b, Worksheet D02). The exposure scenario assumes a contact period of one hour and assumes that the chemical is not effectively removed by washing for 24 hours. Other estimates used in this exposure scenario involve estimates of body weight, skin surface area, and first-order dermal absorption rates, as discussed in the previous section.

Contaminated Water

Water can be contaminated from runoff, as a result of leaching from contaminated soil, from a direct spill, or from unintentional contamination from airblast applications. For this risk assessment, the two types of estimates made for the concentration of sulfometuron methyl in ambient water are acute/accidental exposure from an accidental spill and longer-term exposure to sulfometuron methyl in ambient water that could be associated with the application of this compound to a 10 acre block that is adjacent to and drains into a small stream or pond.

Acute Exposure

Two exposure scenarios are presented for the acute consumption of contaminated water: an accidental spill into a small pond (0.25 acres in surface area and 1 meter deep) and the contamination of a small stream by runoff or percolation.

The accidental spill scenario assumes that a young child consumes contaminated water shortly after an accidental spill into a small pond. The specifics of this scenarios are given in SERA (2004b, Worksheet D05). Because exposure occurs shortly after the spill, no dissipation or degradation of sulfometuron methyl is considered. Based on the spill scenario used in this risk assessment, the concentration of sulfometuron methyl in a small pond is estimated to range from about 0.33 mg/L to 0.69 mg/L).

The other acute exposure scenario for the consumption of contaminated water involves runoff into a small stream. Monitoring data on sulfometuron methyl are available from Battaglin et al. (1999), Neary and Michael (1989 and 1996), and Michael and Neary (1993). A single random sampling study reports monitoring data on sulfometuron methyl concentrations obtained from Midwestern streams, rivers, and ground-water in 1998 (Battaglin et al. 1999). Of the 130 samples collected from streams and rivers, sulfometuron methyl was detected in only two samples, with a maximum concentration of 0.018 µg/L, just slightly above the method reporting limit of 0.01 µg/L. In ground-water, sulfometuron methyl was below the method reporting limit in the 25 samples tested. Unfortunately, these monitoring data are of limited use in the exposure assessment because sampling was random and not associated with a specific application of sulfometuron methyl.

Monitoring data associated with a known application rate of sulfometuron methyl are available from the study by Neary and Michael (1989). Additional details are taken from Michael and Neary (1993) and Neary and Michael (1996). In the Neary and Michael (1989) study at a site in Florida, sulfometuron methyl was applied at a rate of 0.4 kg a.i./ha, equivalent to 0.3568 lbs/acre, as either dispersible granules (DG) or an experimental pellet formulation (P). Application was made by broadcast ground applications with predominantly sandy soil. A five meter buffer was used along streams. Sulfometuron methyl was monitored at maximum concentrations of 5 µg/L(P) and 7 µg/L (DG). Sulfometuron methyl was detected in only 10 of 185 stream samples and only from day 3 to day 7 after treatment. Monitoring was conducted up to 203 days after treatment.

In most instances, the sulfometuron methyl was detected in the surface water after storm events. In each of these applications, rainfall began 24 hours after treatment, and a total of 54 mm of rain fell over the first 3 days after treatment. Monitoring data are also available from broadcast aerial applications in an area of Mississippi with predominantly clay soil (Michael and Neary 1993; Neary and Michael 1996); fewer details are available from this application site, and streamside buffer widths are not specified. Aerial application was made at a rate of 0.4 kg a.i./ha (equivalent to 0.3568 lbs/acre). At this site, the maximum reported levels of sulfometuron methyl in surface water were 23 µg/L(P) and 44 µg/L (DG).

As described in the SERA (2004a) risk assessment, the maximum concentration reported by Michael and Neary (1989), 7 µg/L, is used as the basis for the upper estimate of sulfometuron methyl in surface water. Normalized for an application rate of 1 lb a.i./acre, this value is converted to approximately 20 µg/L per lbs/acre [7 µg/L ÷ 0.3568 lbs/acre = 19.57]. This approach may be viewed as extremely conservative. The higher concentrations from Michael and Neary (1993) are both associated with aerial application and are approximately 3 to 9-fold higher than the concentrations based on ground applications. The ANF will not use aerial applications for sulfometuron methyl, so a case could be made for using only the lower values for estimating potential human exposure from ground applications, but monitoring data from only two locations (Florida and Mississippi) are not likely to reflect the diversity of meteorological or hydrogeological conditions under which sulfometuron methyl may be applied on the ANF. Since data obtained following aerial applications may not be representative of ground applications, they are not used in this ANF risk assessment. We adopt the SERA analysis and their basis for risk calculation as a conservative approach for the ANF.

Although these values are used for the longer-term exposure scenario for humans, it is implausible to suggest that these concentrations would be maintained for prolonged periods of time. For the characterization of potential human health effects, this extremely conservative approach makes no difference because the exposure levels are far below those of toxicological concern. A fuller use of these monitoring studies, however, is required for the assessment of toxicological effects on aquatic vegetation.

While monitoring data provide practical and documented instances of water contamination, monitoring studies may not encompass a broad range of conditions that may occur during program applications, e.g. extremely heavy rainfall, or they may reflect atypical applications that do not reflect program practices. Consequently, for this component of the exposure assessment, modeled estimates are made based on GLEAMS (Groundwater Loading Effects of Agricultural Management Systems).

GLEAMS is a root zone model that can be used to examine the fate of chemicals in various types of soils under different meteorological and hydrogeological conditions (Knisel and Davis 2000). As with many environmental fate and transport models, the input and output files for GLEAMS can be complex. The general application of the GLEAMS model and the use of the output from this model to estimate concentrations in ambient water are detailed in SERA (2003a).

For the current ANF risk assessment, the application site was assumed to consist of a 10 acre square area that drained directly into a small pond or stream. The chemical specific values as well as the details of the pond and stream scenarios used in the GLEAMS modeling are summarized in Table 78. The GLEAMS model yields estimated runoff, sediment loss and percolation that were used to estimate concentrations in the stream adjacent to a treated plot, as detailed in Section 6.4 of SERA (2003a).

The results of the GLEAMS modeling for the small stream are summarized in Table 79, and the corresponding values for the small pond are summarized in Table 80. Note that GLEAMS modeling does not include the use of a buffer. The ANF does use a buffer, so the results from GLEAMS will overestimate the situation as it is expected to develop on the ANF. However there is no quantitative way to adjust GLEAMS, so the output is used in the risk assessment, providing a conservative risk analysis.

These estimates are expressed as both average and maximum water contamination rates (WCR), i.e., the concentration of the compound in water in units of mg/L normalized for an application rate of 1 lb a.i./acre. This rate is roughly 5-10 greater than the rates used in the ANF. Note that ANF soils are predominantly loam; so the most relevant GLEAMS prediction is for loam soils and a precipitation of 50 inches per year.

As noted in SERA, the modeled maximum concentrations in the stream range from about 0.08 µg/L (less in loam or sand) to somewhat over 2 µg/L (clay) at annual rainfall rates from 15 to 250 inches per year, with the highest concentrations associated with clay at annual rainfall rates of 150 inches or more. While not detailed in Table 79, the losses from clay and loam are associated primarily with runoff (about 86 to 90%), with the remaining amount due to sediment loss. For sand, the pesticide loss is associated almost exclusively with percolation. For both clay and loam, the maximum losses occur with the first rainfall after application. For sand, time to maximum loss is delayed due to the time required to percolate through the soil column.

Modeled peak concentrations in ponds (Table 80) are generally similar to those in streams, ranging from about 0.06 to 1.6 µg/L in clay soil with much lower concentrations for other soil types, i.e., up to about 0.4 µg/L in sand and 0.03 µg/L in loam. Modeled average concentrations in ponds, however, are substantially higher than those in streams. The highest average concentration is estimated at about 0.07 µg/L, i.e., clay or sandy soil at a rainfall rates of 50 to 200 inches per year. Over all soil types, typical concentrations are in the range of 0.02 to 0.07 µg/L.

Comparisons of the modeled maximum concentrations in streams to the maximum concentration of 19.57 µg/L reported by Neary and Michael (1989) show that modeled maximum concentrations are approximately 10-fold less than the observed maximum concentration of 2.1 in clay associated with 150 inches of rainfall (Table 79). While the reasons for this discrepancy cannot be determined, it is possible that the concentrations noted in the Neary and Michael (1989) study could have been due to drift during application rather than offsite transfer of sulfometuron methyl after deposition on to soil.

The GLEAMS scenarios do not specifically consider the effects of accidental direct spray. For example, the stream modeled using GLEAMS is about 6 feet wide, and it is assumed that the herbicide is applied along a 660 foot length of the stream with a flow rate of 4,420,000 L/day. At an application rate of 1 lb/acre, accidental direct spray onto the surface of the stream would deposit about 41,252,800 µg [1 lb/acre = 112,100 µg/m^2, 6'x660' = 3960 ft^2 = 368 m^2, 112,100 µg/m^2 × 368 m^2 = 41,252,800 µg]. This would result in a downstream concentration of about 10 µg/L [41,252,800 µg/day ÷ 4,420,000 L/day], similar to the concentrations reported by Neary and Michael (1989). As indicated in Table 79, the expected peak concentrations from runoff or percolation are below this value by a factor of about 5 or more.

Note that GLEAMS does not include a buffer as is used on the ANF, and the ANF application rate is 5 to 10 times less than modeled by GLEAMS, hence the predictions from GLEAMS are quite conservative relative to ANF conditions.

Table 78. Chemical and site parameters used in GLEAMS modeling for sulfometuron methyl Note that loam is the dominant soil on the ANF. (Derived from Table 3-1 on p. Tables-4 of SERA 2004a.)

Parameter	Clay	Loam	Sand	Comment/ Reference
Half-life (days)				
Aquatic Sediment		60		
Foliar		10		Note 1
Soil	10	30	100	Note 2
Water		113		Note 3
Other Parameters				
K_{oc} (ml/g)		78		Note 4
K_d (ml/g)	0.15	0.6	1	Note 5
Water Solubility (mg/L)		300		Budavari 1989 (pH 7, 25°C)
Foliar wash-off fraction		0.65		Knisel and Davis (2000)

Note 1 Upper limit of range (3 weeks to 2 months) reported by (Dulka 1980b) and (Anderson 1990) in fresh anaerobic aquatic system and flooded soil.

Note 2 Value for loam is the approximate value for silt-loam soil reported by Anderson (1990) and Anderson and Dulka (1985). Longer half-lifes of about 50 to 170 days are reported in sterile soil (Monson and Hoffman 1990; Anderson and Dulka 1985). The shorter soil half-life of 20 days recommended by Knisel and Davis (2000) may reflect a more active or abundant soil microorganisms. The wider range of field dissipation half-lifes of 10 to 120 days (USDA/ARS 1995) probably reflects combination of arid conditions with low microbial populations (100 to 120 days) and moist field conditions with richer microbial populations (10 to 20 days). For GLEAMS models, the upper range of 100 is used for sand and lower range of 10 is used for clay. These may vary substantially with site conditions.

Note 3 Based on pH 7 hydrolysis half-life reported by Schneiders (1993). A somewhat shorter pH 7 hydrolysis rate of 43.6 days has been reported by Naidu (1990). For acidic waters (pH of about 5), half-lifes of about 14 days are more representative (Brattsten 1987; Harvey 1990b; Naidu 1990; Schneiders 1993).

Note 4 Value recommended by Knisel and Davis (2000). A wide range of Ko/c values have been reported, i.e, 61-122 in USDA/ARS (1995) and 16-50 Oliviera et al.(2001 as cited in SERA 2003b). Differences in humic acid content of various soils may account for some of this variability (Strek et al. 1990) and could need to be considered in site-specific assessments.

Note 5 Value for clay taken as average of 0.12 and 0.17 reported by Wehtje et al. (1987). Value of 1.0 for sand taken from Cadwgan (1990b). Value for loam taken as approximate average of values used for sand and clay.

Site Parameters (see SERA 2003a, SERA AT 2003b-02d dated for details)
Pond: 1 acre pond, 2 meters deep, with a 0.01 sediment fraction. 10 acre square field (660' by 660') with a root zone of 60 inches and four soil layers.
Stream: Base flow rate of 4,420,000 L/day with a flow velocity of 0.08 m/second or 6912 meters/day. Stream width of 2 meters (about 6.6 feet) and depth of about 1 foot. 10 acre square field (660' by 660') with a root zone of 60 inches and four soil layers.

Table 79. Summary of GLEAMS modeled concentrations of sulfometuron methyl in streams (all units are µg/L or ppb per lb/acre applied)

Annual Rainfall (inches)	Clay		Loam		Sand	
	Average	Maximum	Average	Maximum	Average	Maximum
5	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
10	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
15	0.00044	0.07473	0.00000	0.00000	0.00000	0.00004
20	0.00093	0.16841	0.00000	0.00000	0.00056	0.01324
25	0.00144	0.27655	0.00000	0.00000	0.00174	0.02907
50	0.00358	0.81902	**0.00000**	**0.00102**	0.00677	0.12316
100	0.00576	1.63619	0.00030	0.04322	0.00962	0.26951
150	0.00639	2.10070	0.00049	0.04651	0.00913	0.34413
200	0.00605	1.98950	0.00060	0.03894	0.00822	0.37910
250	0.00563	1.85116	0.00065	0.03135	0.00736	0.39285

Note: The most relevant conditions for the ANF (50 inches annual rainfall in loam soil) are highlighted in bold print.

Table 80. Summary of modeled concentrations of Sulfometuron methyl in ponds (all units are µg/L or ppb per lb/acre applied)

Annual Rainfall (inches)	Clay		Loam		Sand	
	Average	Maximum	Average	Maximum	Average	Maximum
5	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
10	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
15	0.02102	0.06455	0.00000	0.00000	0.00001	0.00009
20	0.02916	0.13608	0.00000	0.00000	0.01022	0.01795
25	0.03589	0.21133	0.00000	0.00000	0.02576	0.04038
50	0.05446	0.56238	**0.00006**	**0.00066**	0.06528	0.16301
100	0.06556	1.15455	0.00246	0.02971	0.06851	0.29436
150	0.06629	1.61771	0.00310	0.03412	0.06113	0.34969
200	0.05952	1.63274	0.00322	0.03024	0.05427	0.37395
250	0.05370	1.59417	0.00317	0.02556	0.04859	0.38694

Note: The most relevant conditions for the ANF (50 inches annual rainfall in loam soil) are highlighted in bold print.

For the current risk assessment, the upper bound for the short-term water contamination rate will be taken as 20 µg/L per lb/acre (0.02 mg/L per lb/acre), the maximum value observed in the monitoring study by Neary and Michael (1989). The central estimate will be taken as 1 µg/L (0.001 mg/L), about the concentration for clay at an annual rainfall rate of 100 inches. The lower range will be taken as 0.06 µg/L (0.00006 mg/L), concentrations that might be expected in relatively arid regions with clay soil, i.e., annual rainfall of 15 inches. Note that GLEAMS predicts much lower concentrations for loam soils with the fifty inch annual precipitation found on the ANF (average <0.00003 µg/L per lb/acre and a maximum of 0.00102 µg/L per lb/acre). However, given the conservative approach we have taken in this ANF risk assessment, we adopt the higher concentrations and exposure levels used by SERA.

Longer-term Exposure

The scenario for chronic exposure from contaminated water is detailed in Worksheet D07 of SERA (2004b). This scenario assumes that an adult (70 kg male) consumes contaminated ambient water from a contaminated pond for a lifetime. The estimated concentrations in pond water are based on the modeled estimates from GLEAMS, discussed in the previous section. Note the application rates on the ANF are lower than modeled in GLEAMS, and the ANF uses buffers, both factors that will reduce the amount of sulfometuron methyl in water. The GLEAMS modeling results in a conservative risk analysis for ANF conditions and practices.

For this risk assessment, the typical longer term WCR is taken as 0.04 µg/L or 0.00004 mg/L per lb/acre. This is about the average concentration modeled in a pond using GLEAMS at a rainfall rate of 20 to about 50 inches per year in clay soil (Table 80). The upper bound of the WCR is taken as 0.07 µg/L or 0.00007 mg/L per lb/acre. This is the highest average concentration modeled from sandy soil at rainfall rates of 100 inches per year or clay soil at annual rainfall rates of 150 inches per year. The lower bound is taken as 0.01 µg/L or 0.00001 mg/L per lb/acre. This selection is somewhat arbitrary but would encompass the array of soil conditions found on the ANF. Although the ANF rainfall rate is less, averaging about fifty inches/year, adopting the basis of the SERA analysis for this ANF risk assessment continues the conservative risk evaluation strategy we use for the ANF.

The WCR values discussed in this section are summarized in Worksheet B06 (SERA 2004b) and used for all longer term exposure assessments involving contaminated water. As with the corresponding values for a small stream, these estimates are expressed as the water contamination rates (WCR) in units of mg/L per lb/acre.

Oral Exposure from Contaminated Fish

Many chemicals may be concentrated or partitioned from water into the tissues of animals or plants in the water. This process is referred to as bioconcentration. The potential for accumulation of sulfometuron methyl in fish was studied in bluegill fish exposed to 0.01 and 1.0 mg/L and in channel catfish exposed to 0.01-0.02 mg/L ^{14}C-sulfometuron methyl (Harvey 1981a) . The bioconcentration of ^{14}C-sulfometuron methyl in muscle (edible tissue), liver and viscera was examined during a 28-day exposure period. Details of these studies are provided in SERA (2004a, Appendix 2).

For this ANF risk assessment, concentrations in viscera are considered to reflect the concentration in whole fish. No bioaccumulation of sulfometuron methyl in either muscle or viscera occurred in bluegill sunfish. In catfish, bioaccumulation occurred in both muscle and viscera. Following 1 day of exposure, the bioconcentration factor (BCF) in muscle was 3, which is used for acute exposure to edible tissue, and the BCF observed in viscera was 3.5, which is used for acute exposure to whole fish. Over the 28-day exposure period, the highest BCF in edible tissue was 7, which was observed following 21 days of exposure, and the highest BCF in viscera was 6, observed after 28 days of exposure. For this ANF risk assessment, a bioconcentration factor for edible tissue for chronic exposure in fish for edible tissue will be taken as 7 and for whole fish will be taken as 6.

For both the acute and longer-term exposure scenarios involving the consumption of contaminated fish, the water concentrations of sulfometuron methyl used are identical to the concentrations used in the contaminated water scenarios. The acute exposure scenario is based on the assumption that an adult consumes fish taken from contaminated water shortly after an accidental spill of 200 gallons of a field solution into a pond that has an average depth of 1 m and a surface area of 1000 m or about one-quarter acre. No dissipation or degradation is considered. Well-documented information is available on the amount of caught fish consumed by the general public and native American subsistence populations. Separate exposure estimates are made for these two groups, as illustrated in Worksheet D08 (SERA 2004b). The chronic exposure scenario is constructed in a similar way, as detailed in Worksheet D09 (SERA 2004b), except that estimates of sulfometuron methyl concentrations in ambient water are based on GLEAMS modeling.

Oral Exposure from Contaminated Vegetation

The consumption by humans of vegetation contaminated with sulfometuron methyl is unlikely, in part because treated vegetation would probably show signs of damage from exposure to sulfometuron methyl, thereby reducing the likelihood of consumption. However, it is conceivable that individuals could consume contaminated vegetation (such as berries) from treated areas. In most instances, and particularly for longer-term scenarios, that would lead to significant levels of human exposure.

On the ANF there are a number of factors that significantly reduce the likelihood of such exposure. Specifically, ANF uses signs to indicate that an area has been treated with herbicide, providing members of the public the option of avoiding such areas and any vegetation (including berries) in or near treated areas. These signs are posted at logical areas of entry to treated areas. Also, the abundance of berries in treated areas is expected to be quite low because overstory vegetation significantly reduces the level of light on the forest floor where such plants normally grow. In addition, most herbicide applications are made in August and September, which is after the period (July) when berries would normally be harvested.

The two accidental exposure scenarios developed for this exposure assessment include one scenario for acute exposure, as defined in Worksheet D03 (SERA 2004b) and one scenario for longer-term exposure, as defined in Worksheet D04 (SERA 2004b). In both scenarios, the concentration of sulfometuron methyl on contaminated vegetation is estimated using the empirical relationships between application rate and concentration on vegetation developed by Fletcher et al. (1994) (based on a re-analysis of data from Hoerger and Kenaga, 1972). These relationships are defined in SERA (2004, Worksheet A04). For the acute exposure scenario, the estimated residue level is taken as the product of the application rate and the residue rate (SERA 2004b, Worksheet D03).

For the longer-term exposure scenario (SERA 2004b, Worksheet D04), a duration of 90 days is used. The rate of decrease in the residues over time is taken from the vegetation half-life of 10 days reported by Knisel and Davis (2000). Although the duration of exposure of 90 days is somewhat arbitrarily chosen, this duration is intended to represent the consumption of contaminated fruit that might be available over one season. Longer durations could be used for certain kinds of vegetation but would lower the estimated dose (i.e., would reduce the estimate of risk). For the longer-term exposure scenarios, the time-weighted average concentration on fruit is calculated from the equation for first-order dissipation.

A separate scenario involving the consumption of contaminated vegetation by drift rather than direct spray is not developed in this risk assessment because exposure from drift and/or the use of a buffer zone quantitatively would result in lower levels of exposure and have no impact on the characterization of risk.

The results of the exposure analysis are in Tables 81–86.

Table 81. Summary of Sulfometuron methyl exposure assessments for the general public: Airblast applications for "Sustaining Forest Cover and the Production of Forest Products" in the ANF

Scenario	Receptor	mg/kg/day or mg/kg/event			SERA (2004b) Worksheet
		Central	Lower	Upper	
Acute Exposures (dose in mg/kg/event)					
Direct Spray of Child, whole body	Child	0.0003431	0.0000592	0.0032330	D01a
Direct Spray of Woman, feet and lower legs	Adult Female	0.0000345	0.0000059	0.0003248	D01b
Vegetation Contact, shorts and T-shirt	Adult Female	0.0000402	0.0000067	0.0004003	D02
Contaminated Fruit	Adult Female	0.0010584	0.0008232	0.0354540	D03
Water consumption, accidental spill	Child	0.0244744	0.0118046	0.0776921	D05
Water consumption, ambient	Child	0.0000068	0.0000002	0.0004286	D06
Fish consumption, accidental spill	Adult Male	0.0022042	0.0017428	0.0046646	D08a
Fish consumption, accidental spill	Subsistence Populations	0.0107418	0.0084935	0.0227327	D08b
Chronic/Longer Term Exposures (dose in mg/kg/day)					
Contaminated Fruit	Adult Female	0.0001693296	0.0001317008	0.0056721566	D04
Water consumption	Adult Male	0.0000001029	0.0000000140	0.0000004560	D07
Fish consumption	Adult Male	0.0000000018	0.0000000004	0.0000000067	D09a
Fish consumption	Subsistence Populations	0.0000000146	0.0000000028	0.0000000539	D09b

Note: Tables 81 is derived from SERA worksheet E03.

Table 82. Summary of sulfometuron methyl exposure assessments for the general public: Backpack applications for "Sustaining Forest Cover and the Production of Forest Products" in the ANF

Scenario	Receptor	mg/kg/day or mg/kg/event			SERA (2004b) Worksheet
		Central	Lower	Upper	
Acute Exposures (dose in mg/kg/event)					
Direct Spray of Child, whole body	Child	0.0003431	0.0000383	0.0032330	D01a
Direct Spray of Woman, feet and lower legs	Adult Female	0.0000345	0.0000038	0.0003248	D01b
Vegetation Contact, shorts and T-shirt	Adult Female	0.0000402	0.0000041	0.0004003	D02
Contaminated Fruit	Adult Female	0.0010584	0.0005292	0.0354540	D03
Water consumption, accidental spill	Child	0.0244744	0.0076383	0.0776921	D05
Water consumption, ambient	Child	0.0000068	0.0000001	0.0004286	D06
Fish consumption, accidental spill	Adult Male	0.0022042	0.0011277	0.0046646	D08a
Fish consumption, accidental spill	Subsistence Populations	0.0107418	0.0054958	0.0227327	D08b
Chronic/Longer Term Exposures (dose in mg/kg/day)					
Contaminated Fruit	Adult Female	0.0001693296	0.0000846648	0.0056721566	D04
Water consumption	Adult Male	0.0000001029	0.0000000090	0.0000004560	D07
Fish consumption	Adult Male	0.0000000018	0.0000000002	0.0000000067	D09a
Fish consumption	Subsistence Populations	0.0000000146	0.0000000018	0.0000000539	D09b

Note: Tables 82 is derived from SERA worksheet E03.

Table 83. Summary of sulfometuron methyl exposure assessments for the general public: Airblast applications for "Developing and Maintaining Wildlife Habitat, Heritage Resources, and Visual Enhancements" in the ANF

Scenario	Receptor	mg/kg/day or mg/kg/event			SERA (2004b) Worksheet
		Central	Lower	Upper	
Acute Exposures (dose in mg/kg/event)					
Direct Spray of Child, whole body	Child	0.0003431	0.0000592	0.0032330	D01a
Direct Spray of Woman, feet and lower legs	Adult Female	0.0000345	0.0000059	0.0003248	D01b
Vegetation Contact, shorts and T-shirt	Adult Female	0.0000402	0.0000067	0.0004003	D02
Contaminated Fruit	Adult Female	0.0010584	0.0008232	0.0354540	D03
Water consumption, accidental spill	Child	0.0244744	0.0118046	0.0776921	D05
Water consumption, ambient	Child	0.0000068	0.0000002	0.0004286	D06
Fish consumption, accidental spill	Adult Male	0.0022042	0.0017428	0.0046646	D08a
Fish consumption, accidental spill	Subsistence Populations	0.0107418	0.0084935	0.0227327	D08b
Chronic/Longer Term Exposures (dose in mg/kg/day)					
Contaminated Fruit	Adult Female	0.0001693296	0.0001317008	0.0056721566	D04
Water consumption	Adult Male	0.0000001029	0.0000000140	0.0000004560	D07
Fish consumption	Adult Male	0.0000000018	0.0000000004	0.0000000067	D09a
Fish consumption	Subsistence Populations	0.0000000146	0.0000000028	0.0000000539	D09b

Note: Tables 83 is derived from SERA worksheet E03.

Table 84. Summary of sulfometuron methyl exposure assessments for the general public: Backpack applications for "Developing and Maintaining Wildlife Habitat, Heritage Resources, and Visual Enhancements" on the ANF

Scenario	Receptor	mg/kg/day or mg/kg/event			SERA (2004b) Worksheet
		Central	Lower	Upper	
Acute Exposures (dose in mg/kg/event)					
Direct Spray of Child, whole body	Child	0.0003431	0.0000383	0.0032330	D01a
Direct Spray of Woman, feet and lower legs	Adult Female	0.0000345	0.0000038	0.0003248	D01b
Vegetation Contact, shorts and T-shirt	Adult Female	0.0000402	0.0000041	0.0004003	D02
Contaminated Fruit	Adult Female	0.0010584	0.0005292	0.0354540	D03
Water consumption, accidental spill	Child	0.0244744	0.0076383	0.0776921	D05
Water consumption, ambient	Child	0.0000068	0.0000001	0.0004286	D06
Fish consumption, accidental spill	Adult Male	0.0022042	0.0011277	0.0046646	D08a
Fish consumption, accidental spill	Subsistence Populations	0.0107418	0.0054958	0.0227327	D08b
Chronic/Longer Term Exposures (dose in mg/kg/day)					
Contaminated Fruit	Adult Female	0.0001693296	0.0000846648	0.0056721566	D04
Water consumption	Adult Male	0.0000001029	0.0000000090	0.0000004560	D07
Fish consumption	Adult Male	0.0000000018	0.0000000002	0.0000000067	D09a
Fish consumption	Subsistence Populations	0.0000000146	0.0000000018	0.0000000539	D09b

Note: Tables 84 is derived from SERA worksheet E03.

Table 85. Summary of sulfometuron methyl exposure assessments for the general public: Airblast applications for “Treatment/Control of Native and Non-native Invasive Species” on the ANF

Scenario	Receptor	mg/kg/day or mg/kg/event			SERA (2004b) Worksheet
		Central	Lower	Upper	
Acute Exposures (dose in mg/kg/event)					
Direct Spray of Child, whole body	Child	0.0003431	0.0000383	0.0032330	D01a
Direct Spray of Woman, feet and lower legs	Adult Female	0.0000345	0.0000038	0.0003248	D01b
Vegetation Contact, shorts and T-shirt	Adult Female	0.0000402	0.0000041	0.0004003	D02
Contaminated Fruit	Adult Female	0.0010584	0.0005292	0.0354540	D03
Water consumption, accidental spill	Child	0.0244744	0.0076383	0.0776921	D05
Water consumption, ambient	Child	0.0000068	0.0000001	0.0004286	D06
Fish consumption, accidental spill	Adult Male	0.0022042	0.0011277	0.0046646	D08a
Fish consumption, accidental spill	Subsistence Populations	0.0107418	0.0054958	0.0227327	D08b
Chronic/Longer Term Exposures (dose in mg/kg/day)					
Contaminated Fruit	Adult Female	0.0001693296	0.0000846648	0.0056721566	D04
Water consumption	Adult Male	0.0000001029	0.0000000090	0.0000004560	D07
Fish consumption	Adult Male	0.0000000018	0.0000000002	0.0000000067	D09a
Fish consumption	Subsistence Populations	0.0000000146	0.0000000018	0.0000000539	D09b

Note: Tables 85 is derived from SERA worksheet E03.

Table 86. Summary of sulfometuron methyl exposure assessments for the general public: Backpack applications for "Treatment/Control of Native and Non-native Invasive Species" in the ANF

Scenario	Receptor	mg/kg/day or mg/kg/event			SERA (2004b) Worksheet
		Central	Lower	Upper	
Acute Exposures (dose in mg/kg/event)					
Direct Spray of Child, whole body	Child	0.01070	0.00170	0.05075	D01a
Direct Spray of Woman, feet and lower legs	Adult Female	0.00108	0.00017	0.00510	D01b
Vegetation Contact, shorts and T-shirt	Adult Female	0.00160	0.00024	0.00826	D02
Contaminated Fruit	Adult Female	0.01764	0.00882	0.55980	D03
Water consumption, accidental spill	Child	0.40980	0.12499	1.19526	D05
Water consumption, ambient	Child	0.00226	0.00003	0.13534	D06
Fish consumption, accidental spill	Adult Male	0.00467	0.00234	0.00909	D08a
Fish consumption, accidental spill	Subsistence Populations	0.02278	0.01139	0.04430	D08b
Chronic/Longer Term Exposures (dose in mg/kg/day)					
Contaminated Fruit	Adult Female	0.009656012	0.004828006	0.306430592	D04
Water consumption	Adult Male	0.000042857	0.000001500	0.000822857	D07
Fish consumption	Adult Male	0.000000081	0.000000004	0.000001303	D09a
Fish consumption	Subsistence Populations	0.000000660	0.000000033	0.000010553	D09b

Note: Tables 86 is derived from SERA worksheet E03.

SECTION 8. SULFOMETURON METHYL RISK CHARACTERIZATION

Overview and Summary

Typical exposures to sulfometuron methyl do not lead to estimated doses that exceed a level of concern (HQ of 1). For workers, no exposure scenarios, acute or chronic, exceed the RfD at the upper bound of the estimated dose associated with the typical application rate of 0.09 lb a.i./acre. Hazard quotients for the maximum application rate of 0.19 lb a.i./acre for directed foliar spray (backpack) and broadcast foliar (airblast) spray are 0.7 and 0.3, respectively. These upper limits of exposure are constructed using the highest anticipated application rate, the highest anticipated number of acres treated per day, and the upper limit of the occupational exposure rate. At the typical application rate of .09 lb a.i./acre, HQ values range from 0.02 to 0.04. These estimates are 50 to 25 times lower than the level of concern. Given the conservative nature of the RfD itself, it is unlikely that there would be any signs of toxicity in workers applying sulfometuron methyl.

Irritation and damage to the skin and eyes can result from exposure to relatively high levels of sulfometuron methyl. From a practical perspective, eye or skin irritation is likely to be the only overt effect as a consequence of mishandling sulfometuron methyl. These effects can be minimized or avoided by prudent industrial hygiene practices during the handling of sulfometuron methyl.

For members of the general public, all upper limits for hazard quotients are below a level of concern for the typical (central) application rate. The upper end of the range of exposure resulting from the consumption by a child of contaminated water from a small pond immediately after an accidental spill is a factor of 11 below the level of concern (HQ of 1) for the maximum application rate of 0.19 lbs/acre, i.e., a hazard quotient of 0.09. For chronic exposure, all upper limits are well below the level of concern for the maximum application rate. Thus, based on the available information and under the foreseeable conditions of application, there is no route of exposure or scenario suggesting that workers or members of the general public will be at risk from acute or longer term exposures to sulfometuron methyl.

Irritation to the skin and eyes can result from exposure to relatively high levels of sulfometuron methyl. From a practical perspective, eye or skin irritation is likely to be the only overt effect as a consequence of mishandling sulfometuron methyl. These effects can be minimized or avoided by prudent industrial hygiene practices during the handling of the compound.

Detailed Information

Workers

A quantitative summary of the risk characterization for workers associated with exposure to sulfometuron methyl is presented in SERA (2004b, Worksheet E02). The quantitative risk characterization is expressed as the hazard quotient, the ratio of the estimated doses from Worksheet E01 (SERA 2004b) to the RfD. For acute exposures, i.e., accidental or incidental exposures, a provisional acute RfD of 0.87 mg/kg/day is used. For general exposures, i.e., daily exposures that might occur over the course of an application season, a provisional chronic RfD of 0.02 mg/kg/day is used. The results of risk characterization for workers are in Tables 87-92, and are followed by discussion of the basis and results of the analysis.

Table 87. Sulfometuron methyl risk characterization for workers: Airblast applications for "Sustaining Forest Cover and the Production of Forest Products" in the ANF

SERA (2004b) Exposure Worksheet:	E01				
Scenario	Receptor	Hazard Quotient			Toxicity Value mg/kg/day
		Central	Lower	Upper	
Accidental/Incidental Exposures (dose in mg/kg/event)					
Contaminated Gloves, 1 min.	Worker	0.0000005	0.0000002	0.0000027	0.87
Contaminated Gloves, 1 hour	Worker	0.0000302	0.0000094	0.0001632	0.87
Spill on Hands, 1 hour	Worker	0.0000104	0.0000018	0.0000984	0.87
Spill on lower legs, 1 hour	Worker	0.0000257	0.0000044	0.0002424	0.87
General (Chronic) Exposures (mg/kg/day)					
General (chronic) exposure	Airblast	0.0225	0.0008	0.3423	0.02

Table 88. Sulfometuron methyl risk characterization for workers: Backpack applications for "Sustaining Forest Cover and the Production of Forest Products" in the ANF

SERA (2004b) Exposure Worksheet:	E01				
Scenario	Receptor	Hazard Quotient			Toxicity Value mg/kg/day
		Central	Lower	Upper	
Accidental/Incidental Exposures (dose in mg/kg/event)					
Contaminated Gloves, 1 min.	Worker	0.0000005	0.0000001	0.0000027	0.87
Contaminated Gloves, 1 hour	Worker	0.0000302	0.0000061	0.0001632	0.87
Spill on Hands, 1 hour	Worker	0.0000104	0.0000012	0.0000984	0.87
Spill on lower legs, 1 hour	Worker	0.0000257	0.0000029	0.0002424	0.87
General (Chronic) Exposures (mg/kg/day)					
General (chronic) exposure	Backpack	0.0405	0.0017	0.6650	0.02

Table 89. Sulfometuron methyl risk characterization for workers: Airblast applications for "Developing and Maintaining Wildlife Habitat, Heritage Resources, and Visual Enhancements" in the ANF

SERA (2004b) Exposure Worksheet:	E01				
Scenario	Receptor	Hazard Quotient			Toxicity Value mg/kg/day
		Central	Lower	Upper	
Accidental/Incidental Exposures (dose in mg/kg/event)					
Contaminated Gloves, 1 min.	Worker	0.0000005	0.0000002	0.0000027	0.87
Contaminated Gloves, 1 hour	Worker	0.0000302	0.0000094	0.0001632	0.87
Spill on Hands, 1 hour	Worker	0.0000104	0.0000018	0.0000984	0.87
Spill on lower legs, 1 hour	Worker	0.0000257	0.0000044	0.0002424	0.87
General (Chronic) Exposures (mg/kg/day)					
General (chronic) exposure	Airblast	0.0225	0.0008	0.3423	0.02

Table 90. Sulfometuron methyl risk characterization for workers: Backpack applications for "Developing and Maintaining Wildlife Habitat, Heritage Resources, and Visual Enhancements" in the ANF

SERA (2004b) Exposure Worksheet: E01

Scenario	Receptor	Hazard Quotient			Toxicity Value mg/kg/day
		Central	Lower	Upper	
Accidental/Incidental Exposures (dose in mg/kg/event)					
Contaminated Gloves, 1 min.	Worker	0.0000005	0.0000001	0.0000027	0.87
Contaminated Gloves, 1 hour	Worker	0.0000302	0.0000061	0.0001632	0.87
Spill on Hands, 1 hour	Worker	0.0000104	0.0000012	0.0000984	0.87
Spill on lower legs, 1 hour	Worker	0.0000257	0.0000029	0.0002424	0.87
General (Chronic) Exposures (mg/kg/day)					
General (chronic) exposure	Backpack	0.0405	0.0017	0.6650	0.02

Table 91. Sulfometuron methyl risk characterization for workers: Airblast applications for "Treatment/Control of Native and Non-native Invasive Species" in the ANF

SERA (2004b) Exposure Worksheet: E01

Scenario	Receptor	Hazard Quotient			Toxicity Value mg/kg/day
		Central	Lower	Upper	
Accidental/Incidental Exposures (dose in mg/kg/event)					
Contaminated Gloves, 1 min.	Worker	0.0000005	0.0000001	0.0000045	0.87
Contaminated Gloves, 1 hour	Worker	0.0000324	0.0000064	0.0002722	0.87
Spill on Hands, 1 hour	Worker	0.0000708	0.0000181	0.0003454	0.87
Spill on lower legs, 1 hour	Worker	0.0001746	0.0000446	0.0008512	0.87
General (Chronic) Exposures (mg/kg/day)					
General (chronic) exposure	Ground spray	0.000225	0.000007	0.003402	0.02

Table 92. Sulfometuron methyl risk characterization for workers: Backpack applications for "Treatment/Control of Native and Non-native Invasive Species" in the ANF

SERA (2004b) Exposure Worksheet: E01

Scenario	Receptor	Hazard Quotient			Toxicity Value mg/kg/day
		Central	Lower	Upper	
Accidental/Incidental Exposures (dose in mg/kg/event)					
Contaminated Gloves, 1 min.	Worker	0.0000005	0.0000001	0.0000027	0.87
Contaminated Gloves, 1 hour	Worker	0.0000302	0.0000061	0.0001632	0.87
Spill on Hands, 1 hour	Worker	0.0000104	0.0000012	0.0000984	0.87
Spill on lower legs, 1 hour	Worker	0.0000257	0.0000029	0.0002424	0.87
General (Chronic) Exposures (mg/kg/day)					
General (chronic) exposure	Backpack	0.0405	0.0015	0.6669	0.02

The exposures are based on the application rates given in Tables 2, 4, and 6. All HQs are below the level of concern for the typical application rate of 0.09 lb a.i./acre. It should be noted that confidence in these assessments is diminished by the lack of a worker exposure study and the lack of experimental data on the dermal absorption kinetics of sulfometuron methyl. Nonetheless, the statistical uncertainties in the estimated dermal absorption rates, both zero-order and first-order, are incorporated into the exposure assessment and risk characterization. HQs for the upper end of the ranges for directed foliar (backpack) spray (0.7), and broadcast foliar (airblast) spray (0.3) are below the level of concern for maximum application rate of 0.19 lb a.i./acre. These upper limits of exposure are constructed using the highest anticipated application rate, the highest anticipated number of acres treated per day, and the upper limit of the occupational exposure rate. If any of these conservative assumptions are modified (e.g. the compound is applied at a rate less than the maximum application rate), the hazard indices are reduced significantly.

While the accidental exposure scenarios are not the most severe one could imagine (e.g. complete immersion of the worker or contamination of the entire body surface for a prolonged period of time), they are representative of reasonable accidental exposures. The highest HQ was 0.0002 for a spill to the lower leg for 1 hour associated with the maximum application rate of 0.19 lbs a.i./acre. The simple verbal interpretation of this quantitative characterization of risk is that under the most protective set of exposure assumptions, workers would not be exposed to levels of sulfometuron methyl that are regarded as unacceptable so long as reasonable and prudent handling practices are followed.

As discussed previously, sulfometuron methyl can cause irritation to eyes and skin. Quantitative risk assessments for irritation are not derived; however, from a practical perspective, effects on the eyes or skin are likely to be the only overt effects as a consequence of mishandling sulfometuron methyl. These effects can be minimized or avoided by prudent industrial hygiene practices during the handling of sulfometuron methyl.

General Public

The quantitative hazard characterization for the general public associated with exposure to sulfometuron methyl is summarized Tables 93–98. Like the quantitative risk characterization for workers, the quantitative risk characterization for the general public is expressed as the hazard quotient using the acute RfD of 0.87 mg/kg/day for acute/short term exposure scenarios and the provisional chronic RfD of 0.02 mg/kg/day chronic or longer term exposures. Tables 93–98 are followed by discussion of the basis and results of the analysis.

Table 93. Sulfometuron methyl risk characterization for general public: Airblast applications for "Sustaining Forest Cover and the Production of Forest Products" in the ANF

SERA (2004b) Exposure Worksheet:	E03				
Scenario	**Receptor**	**Hazard Quotient**			**Toxicity Value mg/kg/day**
		Central	**Lower**	**Upper**	
Acute Exposures (dose in mg/kg/event)					
Direct Spray of Child, whole body	Child	0.0003943	0.0000680	0.0037161	0.87
Direct Spray of Woman, feet and lower legs	Adult Female	0.0000396	0.0000068	0.0003733	0.87
Vegetation Contact, shorts and T-shirt	Adult Female	0.0000462	0.0000077	0.0004601	0.87
Contaminated Fruit	Adult Female	0.0012166	0.0009462	0.0407517	0.87
Water consumption, accidental spill	Child	0.0281315	0.0135686	0.0893013	0.87
Water consumption, ambient	Child	0.0000078	0.0000002	0.0004926	0.87
Fish consumption, accidental spill	Adult Male	0.0025335	0.0020033	0.0053616	0.87
Fish consumption, accidental spill	Subsistence Populations	0.0123469	0.0097627	0.0261296	0.87
Chronic/Longer Term Exposures (dose in mg/kg/day)					
Contaminated Fruit	Adult Female	0.00846648	0.00658504	0.28360783	0.02
Water consumption	Adult Male	0.00000514	0.00000070	0.00002280	0.02
Fish consumption	Adult Male	0.00000009	0.00000002	0.00000033	0.02
Fish consumption	Subsistence Populations	0.00000073	0.00000014	0.00000269	0.02

Table 94. Sulfometuron methyl risk characterization for general public: Backpack applications for "Sustaining Forest Cover and the Production of Forest Products" in the ANF

Scenario	Receptor	Hazard Quotient			Toxicity Value mg/kg/day
SERA (2004b) Exposure Worksheet: E03					
		Central	Lower	Upper	
Acute Exposures (dose in mg/kg/event)					
Direct Spray of Child, whole body	Child	0.0003943	0.0000440	0.0037161	0.87
Direct Spray of Woman, feet and lower legs	Adult Female	0.0000396	0.0000044	0.0003733	0.87
Vegetation Contact, shorts and T-shirt	Adult Female	0.0000462	0.0000047	0.0004601	0.87
Contaminated Fruit	Adult Female	0.0012166	0.0006083	0.0407517	0.87
Water consumption, accidental spill	Child	0.0281315	0.0087797	0.0893013	0.87
Water consumption, ambient	Child	0.0000078	0.0000001	0.0004926	0.87
Fish consumption, accidental spill	Adult Male	0.0025335	0.0012962	0.0053616	0.87
Fish consumption, accidental spill	Subsistence Populations	0.0123469	0.0063170	0.0261296	0.87
Chronic/Longer Term Exposures (dose in mg/kg/day)					
Contaminated Fruit	Adult Female	0.00846648	0.00423324	0.28360783	0.02
Water consumption	Adult Male	0.00000514	0.00000045	0.00002280	0.02
Fish consumption	Adult Male	0.00000009	0.00000001	0.00000033	0.02
Fish consumption	Subsistence Populations	0.00000073	0.00000009	0.00000269	0.02

Table 95. Sulfometuron methyl risk characterization for general public: Airblast applications for "Developing and Maintaining Wildlife Habitat, Heritage Resources, and Visual Enhancements" in the ANF

SERA (2004b) Exposure Worksheet: E03

Scenario	Receptor	Hazard Quotient Central	Hazard Quotient Lower	Hazard Quotient Upper	Toxicity Value mg/kg/day
Acute Exposures (dose in mg/kg/event)					
Direct Spray of Child, whole body	Child	0.0003943	0.0000680	0.0037161	0.87
Direct Spray of Woman, feet and lower legs	Adult Female	0.0000396	0.0000068	0.0003733	0.87
Vegetation Contact, shorts and T-shirt	Adult Female	0.0000462	0.0000077	0.0004601	0.87
Contaminated Fruit	Adult Female	0.0012166	0.0009462	0.0407517	0.87
Water consumption, accidental spill	Child	0.0281315	0.0135686	0.0893013	0.87
Water consumption, ambient	Child	0.0000078	0.0000002	0.0004926	0.87
Fish consumption, accidental spill	Adult Male	0.0025335	0.0020033	0.0053616	0.87
Fish consumption, accidental spill	Subsistence Populations	0.0123469	0.0097627	0.0261296	0.87
Chronic/Longer Term Exposures (dose in mg/kg/day)					
Contaminated Fruit	Adult Female	0.00846648	0.00658504	0.28360783	0.02
Water consumption	Adult Male	0.00000514	0.00000070	0.00002280	0.02
Fish consumption	Adult Male	0.00000009	0.00000002	0.00000033	0.02
Fish consumption	Subsistence Populations	0.00000073	0.00000014	0.00000269	0.02

Table 96. Sulfometuron methyl risk characterization for general public: Backpack applications for "Developing and Maintaining Wildlife Habitat, Heritage Resources, and Visual Enhancements" in the ANF

SERA (2004b)	Exposure Worksheet:	E03			
Scenario	**Receptor**	**Hazard Quotient**			**Toxicity Value mg/kg/day**
		Central	**Lower**	**Upper**	
Acute Exposures (dose in mg/kg/event)					
Direct Spray of Child, whole body	Child	0.0003943	0.0000440	0.0037161	0.87
Direct Spray of Woman, feet and lower legs	Adult Female	0.0000396	0.0000044	0.0003733	0.87
Vegetation Contact, shorts and T-shirt	Adult Female	0.0000462	0.0000047	0.0004601	0.87
Contaminated Fruit	Adult Female	0.0012166	0.0006083	0.0407517	0.87
Water consumption, accidental spill	Child	0.0281315	0.0087797	0.0893013	0.87
Water consumption, ambient	Child	0.0000078	0.0000001	0.0004926	0.87
Fish consumption, accidental spill	Adult Male	0.0025335	0.0012962	0.0053616	0.87
Fish consumption, accidental spill	Subsistence Populations	0.0123469	0.0063170	0.0261296	0.87
Chronic/Longer Term Exposures (dose in mg/kg/day)					
Contaminated Fruit	Adult Female	0.00846648	0.00423324	0.28360783	0.02
Water consumption	Adult Male	0.00000514	0.00000045	0.00002280	0.02
Fish consumption	Adult Male	0.00000009	0.00000001	0.00000033	0.02
Fish consumption	Subsistence Populations	0.00000073	0.00000009	0.00000269	0.02

Table 97. Sulfometuron methyl risk characterization for general public: Airblast applications for "Treatment/Control of Native and Non-native Invasive Species" in the ANF

SERA (2004b) Exposure Worksheet: E03

Scenario	Receptor	Hazard Quotient			Toxicity Value mg/kg/day
		Central	Lower	Upper	
Acute Exposures (dose in mg/kg/event)					
Direct Spray of Child, whole body	Child	0.00268	0.00068	0.01305	2
Direct Spray of Woman, feet and lower legs	Adult Female	0.00027	0.00007	0.00131	2
Vegetation Contact, shorts and T-shirt	Adult Female	0.00038	0.00009	0.00194	2
Contaminated Fruit	Adult Female	0.00441	0.00353	0.13995	2
Water consumption, accidental spill	Child	0.10245	0.05034	0.30735	2
Water consumption, ambient	Child	0.00056	0.00001	0.03383	2
Fish consumption, accidental spill	Adult Male	0.00117	0.00094	0.00234	2
Fish consumption, accidental spill	Subsistence Populations	0.00570	0.00459	0.01139	2
Chronic/Longer Term Exposures (dose in mg/kg/day)					
Contaminated Fruit	Adult Female	0.002414003	0.001931202	0.076607648	2
Water consumption	Adult Male	0.000010714	0.000000600	0.000205714	2
Fish consumption	Adult Male	0.000000020	0.000000002	0.000000326	2
Fish consumption	Subsistence Populations	0.000000165	0.000000013	0.000002638	2

Table 98. Sulfometuron methyl risk characterization for general public: Backpack applications for "Treatment/Control of Native and Non-native Invasive Species" in the ANF

SERA (2004b) Exposure Worksheet: E03					
Scenario	**Receptor**	**Hazard Quotient**			**Toxicity Value mg/kg/day**
		Central	**Lower**	**Upper**	
Acute Exposures (dose in mg/kg/event)					
Direct Spray of Child, whole body	Child	0.0003943	0.0000440	0.0037161	0.87
Direct Spray of Woman, feet and lower legs	Adult Female	0.0000396	0.0000044	0.0003733	0.87
Vegetation Contact, shorts and T-shirt	Adult Female	0.0000462	0.0000047	0.0004601	0.87
Contaminated Fruit	Adult Female	0.0012166	0.0006083	0.0407517	0.87
Water consumption, accidental spill	Child	0.0281315	0.0087797	0.0893013	0.87
Water consumption, ambient	Child	0.0000078	0.0000001	0.0004926	0.87
Fish consumption, accidental spill	Adult Male	0.0025335	0.0012962	0.0053616	0.87
Fish consumption, accidental spill	Subsistence Populations	0.0123469	0.0063170	0.0261296	0.87
Chronic/Longer Term Exposures (dose in mg/kg/day)					
Contaminated Fruit	Adult Female	0.00846648	0.00423324	0.28360783	0.02
Water consumption	Adult Male	0.00000514	0.00000045	0.00002280	0.02
Fish consumption	Adult Male	0.00000009	0.00000001	0.00000033	0.02
Fish consumption	Subsistence Populations	0.00000073	0.00000009	0.00000269	0.02

Although there are several uncertainties in the longer-term exposure assessments for the general public, the upper limits for hazard quotients associated with the longer-term exposures at an application rate of 0.09 lbs/acre are below a level of concern (HQ of 1). Thus, the risk characterization is relatively unambiguous: there is no route of exposure or scenario suggesting that the general public will be at risk from longer-term exposure to sulfometuron methyl.

For the acute/accidental scenarios, none of the HQs exceed the level of concern. Exposure resulting from the consumption of contaminated water associated with an application at the maximum rate of 0.19 lb a.i./acre is closest to the level of concern. The exposure estimate for the consumption by a child of contaminated water from a small pond immediately after an accidental spill results in the highest HQ with a value of 0.09 (Table 98). An HQ of 0.09 is a factor of 11 below the level of concern (HQ of 1).

For members of the general public, with the exception of longer term consumption of contaminated fruit (HQ of 0.28), none of the longer-term exposure scenarios even approach a level of concern. Although there are several uncertainties in the longer-term exposure assessments for the general public, the upper limits for hazard indices are below a level of concern by a factor of 125 to 10 million for longer-term consumption of fish by the general population. The risk characterization is thus relatively unambiguous: there is no route of exposure or exposure scenario suggesting that the general public will be at risk from longer-term exposure to sulfometuron methyl.

Sensitive Individuals

Within any population some individuals are hypersensitive. Individual susceptibility to the toxic effects of the herbicides cannot be specifically predicted. A factor of 10 has traditionally been used (NAS 1977) to account for inter-individual variation. The hazard quotient approach used in this risk assessment takes into account much of the variation in human response, incorporating a factor of 10 for interspecies variation and an additional factor of 10 for within-species variation, resulting in a combined factor of 100. In addition, the 1996 Food Quality Protection Act (FQPA) established a new standard of safety; U.S. EPA must conclude with "reasonable certainty" that "no harm" will come to infants and children or other sensitive individuals exposed to pesticides. In cases where evidence suggests that current margins of exposure are not protective of sensitive individuals, U.S. EPA is required to add an additional factor. Currently, as a part of the re-registration process mandated by FQPA, U.S. EPA is evaluating each pesticide active ingredient (~450) to determine the need for an additional factor to protect sensitive individuals (particularly infants and children). U.S. EPA has completed more than 66% of these evaluations; prioritized based on potential human health risks. Sulfometuron methyl is considered low priority and has yet to be evaluated (http: //www.epa.gov/pesticides/reregistration/reports.htm).

Aggregate Exposure And Cumulative Risk

In this assessment potential health risks associated with pesticide exposure are evaluated for individual pathways of exposure for individual chemicals, and not on the potential for individuals to be exposed to multiple pesticides by all pathways concurrently. In 1996, the FQPA imposed the requirement to consider potential human health risks from all pathways of dietary and nondietary exposures to more than one pesticide acting through a common mechanism of toxicity. Aggregate exposure considers exposure to a single chemical by multiple pathways (food, drinking water, drift, and work related exposures) and routes (ingestion, dermal, inhalation) of exposure. Additionally, in assessing cumulative risk the combined effect of exposure to multiple chemicals with a common mechanism of toxicity is considered.

In the ANF there are opportunities for workers and the general public to be exposed to multiple chemicals by multiple pathways and routes of exposure. For example, an individual consuming contaminated fish might also consume contaminated water and/or vegetation. For sulfometuron methyl these multiple sources of exposure are inconsequential. Adding all sources of exposure would have no substantial impact on the HQ.

Individuals may also be exposed to sulfometuron methyl from other sources not related to ANF activities. For example, sulfometuron methyl has a number of approved uses on crops and some exposure to sulfometuron methyl in crop residues is likely.

The U.S. EPA/OPP (1997) has estimated that residues of sulfometuron methyl on crops could account for about 0.02% of the RfD. Considering this route of dietary exposure in addition to exposures in the ANF would increase the HQ by 0.0002.

Lastly, there is no evidence to suggest that a common mechanism of toxicity exists for glyphosate, sulfometuron methyl, inerts, or surfactants used in the ANF.

Cumulative Effects

As noted above, this risk assessment specifically considers the effect of both single and repeated exposures. Based on the hazard quotients summarized in SERA (2004b, Worksheet E04), as discussed above, there is no indication that repeated exposures will exceed the threshold for toxicity.

There are instances when it could be argued that cumulative doses would occur. If an area is re-sprayed with an herbicide before herbicide from the previous spraying has been totally degraded, then it is possible for larger herbicide doses to occur than from a single application. However, re-spraying is rare on the Allegheny.

Cumulative exposure could also occur in individuals who use one of the herbicides in their lawn or garden work or are exposed to an herbicide from nearby agricultural areas and are then exposed to the same herbicide as a result of the Forest Service application program.

Although herbicide doses from the other types of sources mentioned were not evaluated in the risk assessment, adverse health effects from cumulative doses in this program were analyzed. The total dose from various exposure routes estimated in this analysis should be greater than what a person would normally contact. This is because the assumptions in the risk assessment overestimate exposures from eating, drinking, and coming in contact with vegetation. To the extent that these estimates are large enough to cover exposure from other unknown sources, the risks from the hypothetical cumulative exposures should be no greater than the risks already discussed in this assessment.

Synergistic Effects of Glyphosate and Sulfometuron Methyl

Synergistic effects of chemicals are those that occur from exposure to two chemicals either simultaneously or within a relatively short period of time. Synergism occurs when the combined effects of two chemicals is greater than the sum of the effects of each agent given alone (simple additive effect). Synergistic toxic effects of herbicide combinations other than EPA-registered commercial mixtures are not normally explicitly studied. Time and money normally limit toxicity testing to the effects of the herbicides individually, and the number of combinations that could be tested are too numerous to make that testing feasible.

The combination of interest in this risk assessment is the glyphosate and sulfometuron methyl mixture. Based on the limited amount of data available on pesticide combinations, it is possible, but quite unlikely, that synergistic effects could occur as a result of exposure to these two herbicides (Southern Region FEIS, Volume II, p. 5-46). EPA has approved this mixture for use.

The EPA guidelines for assessing the risk from exposures to chemical mixtures (EPA 1986e) recommend using additivity models when little information exists on the toxicity of the mixture and when components of the mixture appear to induce the same toxic effect by the same mode of action. They suggest that "There seems to be a consensus that for public health concerns regarding causative (toxic) agents, the additive model is more appropriate than any multiplicative model."

The EPA suggests using the model of additivity of the hazard quotient (HQ) based on the dose and RfD for each chemical as follows:

$$HQ = D_1/RfD_1 + D_2/RfD_2$$

where: D1and D2 are the respective doses of each chemical and

RfD 1 and RfD2 are the respective reference doses for each chemical.

On the basis of the maximum doses for workers (backpack application) in this risk assessment, the largest additive HQ results from general exposure and is 0.81, which is less than the standard of one. Based on this we conclude the likelihood is low of adverse toxicological effects from the combination of glyphosate and sulfometuron methyl.

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Appendix G2

Wildlife, Terrestrial Plant, and Aquatic Species Risk Assessment for Glyphosate and Sulfometuron Methyl Treatment

Allegheny National Forest

March 2007

Prepared by

Logan A. Norris, PhD and Kathleen Maas-Hebner, MS

Cascade Environmental Consultants

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SUMMARY

Glyphosate and Sulfometuron Methyl Hazard Analysis

The hazard analysis identifies critical toxicity values for use in the risk analysis. The critical toxicity value is typically the no-observed-adverse-effects level (NOAEL, for terrestrial species) or the no-observed-effects concentration (NOEC, for aquatic species) as reported for the most sensitive species tested. In a few cases the LC_{50} value is used when other toxic responses are not available.

Following are the critical toxicity values identified in the hazard assessment.

Critical toxicity values for glyphosate risk analysis

Type of Organism	Critical Toxicity Value	Type of Value
Mammal		
acute exposure	175 mg/kg	Acute NOAEL
chronic exposure	175 mg/kg/day	Chronic NOAEL
Bird		
acute exposure	562 mg/kg	NOAEL
chronic exposure	100 mg/kg/day	NOAEL
Honey Bee		
acute exposure	540 mg/kg	NOEC
Terrestrial Plants (one-time application)		
Tolerant	0.56 lb/acre	NOEC
Sensitive	0.035 lb/acre	NOEC
Fish, Typical Species		
acute exposure	97 mg/L	LC_{50}
chronic exposure	25.7 mg/L	NOEC
Fish, Sensitive Species		
acute exposure	10 mg/L	LC_{50}
chronic exposure	2.57 mg/L	NOEC
Aquatic Invertebrates		
acute exposure	780 mg/L	LC_{50}
chronic exposure	50 mg/L	NOEC
Aquatic Plants		
acute and chronic exposure	3 mg/L	NOEC

These values for glyphosate were derived from SERA (2003a). The SERA analysis considered two broad groups of glyphosate formulations, labeling them as less toxic or more toxic. The four formulations (Accord Concentrate®, Rodeo®, Glypro®, and Foresters®) proposed for use by ANF are in the less toxic group in the SERA (2003a) analysis. The surfactants (Timberland 90®, Chemsurf 90®, Alenza 90®, Red River 90®, and Red River Adherent 90®) proposed for use by Allegheny National Forest (ANF) have inert ingredients that are in the U.S. EPA inert classifications on Lists 3 and 4b. List 3 indicates that there is unknown toxicity; for inerts where "there was no basis for placing it on any of the other lists. The Agency will continue to evaluate these chemical substances, as additional information becomes available, to determine if reclassification to List 1, 2, or 4 is appropriate." List 4 indicates minimal concern, further subdivided with List 4B for inerts with "*sufficient information to conclude that current use patterns in pesticide products will not adversely affect public health and the environment.*" All of the surfactants are listed for terrestrial and aquatic use. Values for sulfometuron methyl were derived from SERA (2004a, b).

Critical toxicity values for sulfometuron methyl risk analysis

Type of Organism	Critical Toxicity Value	Type of Value
Mammal		
acute exposure	87 mg/kg	Acute NOAEL
chronic exposure	2 mg/kg/day	Chronic NOAEL
Bird		
acute exposure	312 mg/kg	Acute NOAEL
chronic exposure	2 mg/kg/day	Chronic NOAEL
Honey Bee		
acute exposure	1075 mg/kg	NOEC
Terrestrial Plants (one-time application)		
Sensitive (corn)	0.000024 lb/acre	NOEC
Tolerant (pea)	0.00078 lb/acre	NOEC
Fish, Tolerant Species		
acute exposure	150 mg/L	NOEC
chronic exposure	1.17 mg/L	NOEC
Fish, Sensitive Species		
acute exposure	7.3 mg/L	NOEC
chronic exposure	1.17 mg/L	NOEC
Amphibians		
acute exposure	0.38 mg/L	NOEC
chronic exposure	0.00075 mg/L	NOEC
Aquatic Invertebrates, Tolerant Species		
acute exposure	1800 mg/L	NOEC
chronic exposure	75 mg/L	LOEC
Aquatic Invertebrates, Sensitive Species		
acute exposure	6.1 mg/L	NOEC
chronic exposure	0.19 mg/L	NOEC
Aquatic Plants, Algae (acute and chronic exposure)		
Tolerant Species	0.37 mg/L	NOEC
Sensitive Species	0.0025 mg/L	NOEC
Aquatic Plants, Macrophytes (acute and chronic exposure)		
Tolerant and Sensitive Species	0.00021 mg/L	NOEC

Glyphosate and Sulfometuron Methyl Exposure Analysis

The exposure analysis identifies the dose that specific organisms are likely to receive in the field from the proposed ANF management program. This is determined from the amount or concentration of a specific chemical expected to occur in the field. The terms central, lower and upper appear in several table column headings. These are meant to cover the variation in values that might result due to environmental variation and uncertainty. The central value is the "most likely," but the lower and upper are at the upper and lower ends of the range within which the actual value might occur.

Following are the exposure values (dose) determined in the glyphosate exposure analysis.

Summary of exposures for various glyphosate application rates and exposure scenarios for terrestrial animals in the ANF

Scenario	Central				Lower				Upper			
	ANF Application Rates (lbs a.i./acre)											
	1.0	**2.0**	**3.0**	**4.0**	**1.0**	**2.0**	**3.0**	**4.0**	**1.0**	**2.0**	**3.0**	**4.0**
Acute/Accidental Exposures (mg/kg)												
Direct Spray												
small mammal, first-order absorption	0.18	0.3	0.6	0.71	0.06	0.09	0.19	0.23	0.43	0.72	1.44	1.72
small animal, 100% absorption	18.19	30.31	60.62	72.75	18.19	30.31	60.62	72.75	18.19	30.31	60.62	72.75
bee, 100% absorption	120.38	200.62	401.25	481.5	120.38	200.62	401.25	481.5	120.38	200.62	401.25	481.5
Contaminated vegetation												
small mammal	0.32	0.54	1.07	1.28	0.32	0.54	1.07	1.28	0.79	1.32	2.64	3.16
large mammal	12.9	21.5	43	51.6	12.9	21.5	43	51.6	36.41	60.69	121.38	145.65
large bird	20.18	33.62	67.25	80.7	20.18	33.62	67.25	80.7	57	95	190	228
Contaminated Water												
small mammal, spill	1	1.66	3.32	3.99	0.4	0.66	1.32	1.59	2	3.32	6.65	7.98
small mammal, stream	0.002	0.004	0.007	0.009	0.0001	0.0002	0.0004	0.0004	0.04	0.07	0.15	0.18
Contaminated Insects												
small bird	28.12	46.88	93.75	112.5	28.12	46.88	93.75	112.5	84.38	140.62	281.25	337.5
Contaminated Fish												
predatory bird, spill	0.35	0.59	1.18	1.42	0.07	0.12	0.24	0.28	1.06	1.77	3.54	4.24
Longer-term Exposures (mg/kg/day)												
Contaminated Vegetation												
small mammal, on-site	0.018	0.03	0.06	0.07	0.009	0.01	0.03	0.04	0.09	0.14	0.29	0.35
small mammal, off-site	0.0002	0.0003	0.0006	0.0007	0.00005	0.00008	0.0002	0.0002	0.002	0.003	0.005	0.006
large mammal, on-site	2.12	3.53	7.06	8.48	0.7	1.18	2.35	2.82	19.95	33.25	66.5	79.8
large mammal, off-site	0.071	0.12	0.24	0.28	0.04	0.07	0.14	0.16	0.37	0.62	1.24	1.49
large bird, on-site	3.32	5.5	11.05	13.26	1.11	1.84	3.69	4.42	31.2	52	104	124.8
large bird, off-site	0.11	0.19	0.37	0.45	0.06	0.11	0.21	0.26	0.58	0.98	1.95	2.34
Contaminated Water												
small mammal	0.0001	0.0002	0.0004	0.0004	0.00001	0.00002	0.00004	0.00004	0.0009	0.001	0.003	0.004
Contaminated Fish												
predatory bird	0.00004	0.00006	0.0001	0.0002	0.000002	0.000003	0.000006	0.000008	0.0005	0.0008	0.002	0.002

The glyphosate exposure values for terrestrial species cover direct contact as a result of dermal absorption of glyphosate due to deposition on the body from application or contact with contaminated surfaces. It also includes acute and chronic exposure due to ingestion of contaminated food or water. Except for direct spray on a bee, the highest acute exposure values are associated with consumption of contaminated insects by a small bird. The highest chronic (long-term) exposure values result from consumption of contaminated vegetation within a treated area by a large bird.

The glyphosate exposure values for aquatic species are based on estimated concentrations of glyphosate in water used in the human health risk assessment (Appendix G1, Section 4). For a stream where contamination might occur due to drift or runoff, the values for each pound per acre applied range from 0.001 mg/L at the lower range of estimation to 0.02 mg/L as the most likely central value to 0.4 mg/L at the upper end of estimation (SERA 2003b, Worksheet B). For an accidental spill of 200 gallons in a pond, the central estimate for the concentration of glyphosate in a small pond is estimated at about 18.2 mg/L, with a range from 7.3 mg/L to 36.3 mg/L (SERA 2003b, Worksheet D05). For longer-term exposure scenarios, the expected concentrations of glyphosate in ambient water range from 0.0001 to 0.008 mg/L with a central value of 0.001 mg/L per pound per acre applied (SERA 2003b, Worksheet B).

The following table shows the exposure values (dose) determined in the sulfometuron methyl exposure analysis.

The sulfometuron methyl exposure values for terrestrial species cover direct contact as a result of dermal absorption due to deposition on the body from application or contact with contaminated surfaces. It also includes acute and chronic exposure due to ingestion of contaminated food or water. Except for direct spray on a bee, the highest acute exposure values are associated with consumption of contaminated insects by a small bird. The highest chronic (long-term) exposure values result from consumption of contaminated vegetation within a treated area by a large bird.

The potential for effects on aquatic species are based on estimated concentrations of sulfometuron methyl in water that are identical to those used in the human health risk assessment. The peak estimated rate of sulfometuron methyl contamination of ambient water is estimated be 0.00009 and 0.00019 mg/L for rates of application of 0.09 and 0.19 lb/acre respectively. For longer-term exposures are estimated to be 0.000004 and 0.000008 mg/L.

Summary of sulfometuron methyl exposures for various application rates and exposure scenarios for terrestrial animals in the ANF

Scenario	Central		Lower		Upper	
	ANF Application Rates (lbs a.i./acre)					
	0.09	0.19	0.09	0.19	0.09	0.19
Acute/Accidental Exposure (mg/kg)						
Direct Spray						
small mammal, first-order absorption	0.01	0.02	0.002	0.005	0.05	0.11
small animal, 100% absorption	2.18	4.58	2.18	4.58	2.18	4.58
honey bee, 100% absorption	14.42	30.28	14.42	30.28	14.42	30.28
Contaminated Vegetation						
small mammal	0.11	0.24	0.11	0.24	0.24	0.51
large mammal	1.55	3.25	1.55	3.25	4.38	9.2
large bird	2.42	5.08	2.42	5.08	6.84	14.36
Contaminated Water						
small mammal, spill	0.09	0.19	0.03	0.06	0.24	0.51
small mammal, stream	0.00001	0.00003	0.0000008	0.000002	0.0003	0.0006
Contaminated Insects						
small mammal	2.08	4.37	2.08	4.37	6.24	13.1
small bird	3.38	7.1	3.38	7.1	10.16	21.34
Contaminated Fish						
predatory bird, spill	0.42	0.89	0.07	0.14	1.75	3.67
Contaminated Small Mammal						
carnivorous mammal	0.19	0.4	0.19	0.4	0.19	0.4
carnivorous bird	0.29	0.61	0.29	0.61	0.29	0.61
Longer-term Exposures (mg/kg/day)						
Contaminated Vegetation						
small mammal, on-site	0.002	0.004	0.0009	0.002	0.008	0.02
small mammal, off-site	0.00002	0.00004	0.000005	0.00001	0.0001	0.0003
large mammal, on-site	0.07	0.16	0.02	0.05	0.7	1.47
large mammal, off-site	0.002	0.005	0.001	0.003	0.01	0.03
large bird, on-site	0.12	0.24	0.04	0.08	1.09	2.3
large bird, off-site	0.004	0.008	0.002	0.005	0.02	0.04
Contaminated Water						
small mammal	0.0000005	0.000001	0.0000001	0.0000003	0.0000009	0.000002
Contaminated Fish						
predatory bird	0.000002	0.000004	0.0000003	0.0000006	0.000006	0.00001

Glyphosate and Sulfometuron Methyl Risk Analysis

The risk analysis compares the exposure value to the critical toxicity value. Risk is expressed as the hazard quotient (HQ) which is the ratio of exposure to toxicity. If the exposure is less than the critical toxicity value then the HQ is less than one and the risk falls within an acceptable range. Following is the summary of risk for terrestrial animals to glyphosate on the ANF.

Summary of quantitative risk characterization for terrestrial animals for glyphosate applied at various rates on the ANF
Risk is expressed as the hazard quotient (HQ)

Scenario	Central				Lower				Upper			
	ANF Application Rates (lbs a.i./acre)											
	1.0	2.0	3.0	4.0	1.0	2.0	3.0	4.0	1.0	2.0	3.0	4.0
Acute/Accidental Exposure												
Direct Spray												
small mammal, first-order absorption	0.001	0.002	0.004	0.004	0.0003	0.0006	0.001	0.001	0.003	0.004	0.009	0.01
small animal, 100% absorption	0.1	0.2	0.4	0.4	0.1	0.2	0.4	0.4	0.1	0.2	0.4	0.4
bee, 100% absorption	0.2	0.4	0.8	0.9	0.2	0.4	0.8	0.9	0.2	0.4	0.8	0.9
Contaminated Vegetation												
small mammal	0.002	0.003	0.006	0.008	0.002	0.003	0.006	0.008	0.004	0.006	0.01	0.02
large mammal	0.08	0.1	0.2	0.3	0.08	0.1	0.2	0.3	0.2	0.4	0.8	0.9
large bird	0.04	0.06	0.1	0.2	0.04	0.06	0.1	0.2	0.1	0.2	0.4	0.4
Contaminated Water												
small mammal, spill	0.008	0.01	0.02	0.03	0.002	0.004	0.008	0.009	0.01	0.02	0.04	0.04
small mammal, stream	0.00001	0.00002	0.00004	0.00004	0.0000008	0.000001	0.000002	0.000003	0.0003	0.0004	0.0009	0.001
Contaminated Insects												
small bird	0.04	0.06	0.1	0.15	0.04	0.06	0.1	0.2	0.2	0.2	0.5	0.6
Contaminated Fish												
predatory bird, spill	0.0008	0.001	0.002	0.003	0.0001	0.0002	0.0004	0.0004	0.002	0.003	0.006	0.008
Longer-term Exposures												
Contaminated Vegetation												
small mammal, on-site	0.0001	0.0002	0.0004	0.0004	0.00004	0.00006	0.0001	0.0002	0.0004	0.0006	0.001	0.002
small mammal, off-site	0.000001	0.000002	0.000004	0.000004	0.0000003	0.0000005	0.000001	0.000001	0.000008	0.00001	0.00002	0.00003
large mammal, on-site	0.01	0.02	0.04	0.04	0.004	0.006	0.01	0.02	0.1	0.2	0.4	0.4
large mammal, off-site	0.0004	0.0006	0.001	0.002	0.0002	0.0004	0.0008	0.0009	0.002	0.004	0.008	0.009
large bird, on-site	0.03	0.06	0.1	0.1	0.01	0.02	0.04	0.04	0.3	0.5	1	1.2
large bird, off-site	0.001	0.002	0.004	0.004	0.0008	0.001	0.002	0.003	0.008	0.01	0.02	0.03
Contaminated Water												
small mammal	0.0000008	0.000001	0.000002	0.000003	0.00000008	0.0000001	0.0000002	0.0000003	0.000004	0.000006	0.00001	0.00002
Contaminated Fish												
predatory bird	0.0000004	0.0000006	0.000001	0.000002	0.00000002	0.00000003	0.00000006	0.00000008	0.000004	0.000006	0.00001	0.00002

The results of the risk analysis show that HQ exceeds one only in the case of long-term consumption of vegetation by a large bird in an area treated at 3 or 4 lb/acre. Note that the 3 lb/acre rate is only used with cut surface application and the 4 lb/acre rate is only used in directed foliar, backpack applications. The proportion of the ANF program that includes 3 and 4 lb/acre rates is very small, thereby reducing the likelihood of this risk occurring to insignificant levels.

The quantitative risk characterization for ANF aquatic species is as follows:

Summary of quantitative risk characterization for aquatic species for glyphosate applied at various rates in the ANF
Risk is expressed as the hazard quotient (HQ)

Scenario	Central				Lower				Upper			
	ANF Application Rates (lbs a.i./acre)											
	1.0	2.0	3.0	4.0	1.0	2.0	3.0	4.0	1.0	2.0	3.0	4.0
Fish, Acute Exposure												
Typical Species	0.0002	0.0003	0.0005	0.0006	0.000008	0.00001	0.00003	0.00003	0.003	0.005	0.01	0.01
Sensitive Species	0.002	0.002	0.005	0.006	0.00008	0.0001	0.0002	0.0003	0.03	0.05	0.1	0.1
Fish, Chronic Exposure												
Typical Species	0.00003	0.00005	0.0001	0.0001	0.000003	0.000005	0.00001	0.00001	0.0002	0.0004	0.0008	0.0009
Sensitive Species	0.0003	0.0005	0.001	0.001	0.00003	0.00005	0.0001	0.0001	0.002	0.004	0.008	0.009
Aquatic Invertebrates												
Acute Exposure	0.00002	0.00003	0.00006	0.00008	0.000001	0.000002	0.000003	0.000004	0.0004	0.0006	0.001	0.002
Chronic Exposure	0.00002	0.00002	0.00005	0.00006	0.000002	0.000002	0.000005	0.000006	0.0001	0.0002	0.0004	0.0005
Aquatic Plants												
Acute Exposure	0.005	0.008	0.02	0.02	0.0002	0.0004	0.0008	0.001	0.1	0.2	0.3	0.4
Chronic Exposure	0.0002	0.0004	0.0008	0.001	0.00002	0.00004	0.00008	0.0001	0.002	0.003	0.007	0.008

The risk analysis shows that the use of less toxic formulations of glyphosate (Accord Concentrate®, Glypro®, Foresters® and Rodeo®) results in HQs that are less than one in every case, and therefore do not approach a level of concern for any species. Based on this risk analysis we conclude that the likelihood of the proposed ANF programs resulting in direct toxic effects on aquatic invertebrates, fish or aquatic plants is extremely remote.

The results of the risk analyses for terrestrial species to sulfometuron methyl are as follows:

Summary of sulfometuron methyl quantitative risk characterization for terrestrial animals in the ANF at various application rates
Risk is expressed as the hazard quotient (HQ)

Scenario	Central		Lower		Upper	
	ANF Application Rates (lbs a.i./acre)					
	0.09	**0.19**	**0.09**	**0.19**	**0.09**	**0.19**
Acute/Accidental Exposure						
Direct Spray						
small mammal, first-order absorption	0.0001	0.000252	0.00002	0.000042	0.0006	0.00126
small animal, 100% absorption	0.02	0.042	0.02	0.042	0.02	0.042
honey bee, 100% absorption	0.01	0.0294	0.014	0.0294	0.014	0.0294
Contaminated Vegetation						
small mammal	0.001	0.002	0.001	0.002	0.002	0.004
large mammal	0.02	0.04	0.02	0.04	0.06	0.1
large bird	0.008	0.02	0.008	0.02	0.02	0.04
Contaminated Water						
small mammal, spill	0.001	0.002	0.0004	0.00084	0.002	0.004
small mammal, stream	0.0000002	0.0000003	0.00000001	0.00000002	0.000004	0.000008
Contaminated Insects						
small mammal	0.02	0.04	0.02	0.04	0.08	0.12
small bird	0.01	0.02	0.01	0.02	0.04	0.08
Contaminated Fish						
predatory bird, spill	0.001	0.003	0.0002	0.0004	0.006	0.01
Contaminated Small Mammal						
carnivorous mammal	0.002	0.004	0.002	0.004	0.002	0.004
carnivorous bird	0.001	0.002	0.001	0.002	0.001	0.002
Longer-term Exposures						
Contaminated Vegetation						
small mammal, on-site	0.001	0.002	0.0004	0.0008	0.004	0.008
small mammal, off-site	0.00001	0.00002	0.000002	0.000004	0.00008	0.0002
large mammal, on-site	0.04	0.08	0.01	0.02	0.4	0.84
large mammal, off-site	0.001	0.002	0.0008	0.002	0.006	0.01
large bird, on-site	0.06	0.13	0.02	0.04	0.6	1.26
large bird, off-site	0.002	0.004	0.001	0.002	0.01	0.021
Contaminated Water						
small mammal	0.0000002	0.0000004	0.00000006	0.0000001	0.0000004	0.0000008
Contaminated Fish						
predatory bird	0.000001	0.000002	0.0000001	0.0000003	0.000002	0.000004

The highest HQ for vertebrate and invertebrate terrestrial species is 1.26 for chronic exposure of a large bird consuming treated vegetation on site. All other HQ values are less than one. With this one exception the analysis shows there is no basis for asserting that adverse effects on terrestrial vertebrates and invertebrates are likely from the application of sulfometuron methyl in ANF programs. For this exception, an HQ of 1.26 is only slightly higher than the acceptable value of 1.0. Given the highly conservative assumptions used in this risk assessment, it is highly likely that this overestimates the actual risk. In addition, the HQ only exceeds 1.0 at the highest rate of application, which is rarely used.

A quantitative summary of the risk characterization for terrestrial plants is more complicated. Sulfometuron methyl is a very effective herbicide, and adverse effects on some plant species due to drift are likely under certain application conditions and circumstances. The analysis in this risk assessment shows that with an on-site application rate of 0.09 lb/acre, tolerant plants will not be harmed at 25 feet, and sensitive plants will not be harmed at 500 feet. The HQ value for sensitive plants at 300 feet is 0.00003/0.000024 = 1.25, which is very close to the level of concern of one.

This analysis shows that with an on-site application rate of 0.19 lb/acre, tolerant plants will not be harmed at 50 feet, and sensitive plants will not be harmed at 500 feet. The HQ value for sensitive plants at 300 feet is 0.00007/0.000024 = 2.92, which is fairly close to the level of concern of one.

Whether or not damage due to drift would actually be observed after the application of sulfometuron methyl would depend on a several site-specific conditions, including wind speed and foliar interception by the target vegetation. We believe the risk analysis is extremely conservative, and significantly overestimates the HQ for risk due to drift. The key factors contributing to this overestimate are low wind speed under the canopy and the density of vegetation providing significant surfaces for interception of spray droplets close to the point of release. Significantly, monitoring for vegetation damage by ANF personnel shows little or no off site vegetation damage.

The results of the sulfometuron methyl risk assessment for aquatic species are shown in the following table:

All HQ values for aquatic animals are less than one, indicating sulfometuron methyl has low potential to cause any adverse effects in aquatic animals. Aquatic plants are more sensitive than aquatic animals. For algae, the only HQ value greater than one is for a sensitive species (HQ = 1.7). Aquatic macrophytes appear to be more sensitive, exhibiting an HQ value of 8 and 16.8 for acute exposure following application of 0.09 and 0.19 lb/acre respectively. For chronic exposure all HQ values are less than one. The buffer strategy for sulfometuron methyl will adequately mitigate for protection of macrophytes.

Summary of sulfometuron methyl quantitative risk characterization for aquatic species in the ANF at various application rates
Risk is expressed as the hazard quotient (HQ)

Scenario	Central		Lower		Upper	
	ANF Application Rates (lbs a.i./acre)					
	0.09	0.19	0.09	0.19	0.09	0.19
Fish, Acute Exposure						
Tolerant Species	0.0000006	0.000001	0.00000004	0.00000008	0.00001	0.00002
Sensitive Species	0.00001	0.00002	0.0000008	0.000002	0.0002	0.0004
Fish, Chronic Exposure						
Tolerant Species	0.000004	0.000008	0.0000008	0.000002	0.000006	0.00001
Sensitive Species	0.000004	0.000008	0.0000008	0.000002	0.000006	0.00001
Amphibians						
Acute Exposure	0.0002	0.0004	0.00001	0.00003	0.004	0.008
Chronic Exposure	0.004	0.008	0.001	0.002	0.008	0.02
Aquatic invertebrates, Acute Exposure						
Tolerant Species	0.00000006	0.0000001	0.000000004	0.000000008	0.000001	0.000002
Sensitive Species	0.000001	0.000002	0.00000008	0.0000002	0.00002	0.00004
Aquatic Invertebrates, Chronic Exposure						
Tolerant Species	0.0000006	0.000001	0.0000001	0.0000003	0.000001	0.000002
Sensitive Species	0.00002	0.00004	0.000004	0.000008	0.00004	0.00008
Aquatic Plants, Algae, Acute Exposure						
Tolerant Species	0.0002	0.0004	0.00001	0.00003	0.004	0.008
Sensitive Species	0.04	0.08	0.002	0.004	0.8	1.68
Aquatic Plants, Algae, Chronic Exposure						
Tolerant Species	0.00001	0.00002	0.000002	0.000004	0.00002	0.00004
Sensitive Species	0.001	0.003	0.0004	0.0008	0.002	0.004
Aquatic Plants, Macrophytes						
Acute Exposure	0.4	0.84	0.02	0.04	8	16.8
Chronic Exposure	0.02	0.04	0.004	0.008	0.04	0.08

Buffers

Buffers are a strip of untreated vegetation adjacent to wetlands, water bodies and flowing water. The purpose of the buffer is to prevent the entry of unacceptable levels of herbicide to the water, thereby reducing water quality. The size of the buffer varies with the application technique and the characteristics of individual herbicides, such as the toxicity of the herbicide to animals and aquatic organisms that might use the water, and the movement, persistence and fate of the herbicide in the environment close to water. The critical element in protection of water quality with respect to glyphosate is protection of aquatic species, but the buffers that will protect aquatic organisms will also protect humans. The following buffer strategies should be used for glyphosate.

For broadcast foliar mechanical (airblast) application (1 and 2 lb/acre), the following buffers and application tactics will provide water quality protection for wildlife and aquatic species involving the use of glyphosate:

- No glyphosate shall be applied to surface waters.
- Buffers 25 feet wide along each side of perennial streams, springs, impoundments, intermittent streams and seeps with flowing water the day of spraying.
- 25 feet wide around wet areas (standing water) and vernal ponds with no defined outlet.
- 10 feet wide along each side of dry intermittent streams, dry springs, and dry seeps.

- Airblast shall be directed away from the buffer when applications are made within 50 feet of the edge of the buffer, i.e., within 50 feet no airblast directed towards the edge of the buffer unless intervening vegetation 5 to 15 feet tall is sufficiently dense to intercept spray material.

For directed foliar backpack (up to 4 lb/acre) and for cut surface (up to 3 lb/acre) application methods the following buffers and tactics will provide water quality protection involving the use of glyphosate:

- No glyphosate shall be applied to surface waters.
- No glyphosate shall be applied within 10 feet of standing or flowing water.
- Within 10 feet of an intermittent stream course, use only the cut surface herbicide treatment technique with glyphosate.
- No glyphosate shall be applied to cut stems in the stream channel.

When using sulfometuron methyl for broadcast foliar mechanical (airblast) application, the following buffers and application tactics will provide water quality protection

For an application rate of 0.09 lb/acre

- No sulfometuron methyl shall be applied to surface waters.
- Buffers 25 feet wide along each side of perennial streams, springs, impoundments, or intermittent streams with flowing water the day of spraying;
- 25 feet wide around wet areas (standing water) and vernal ponds with no defined outlet.
- 10 feet wide along each side of dry intermittent streams, dry springs, and dry seeps
- Airblast shall be directed away from the buffer when applications are made within 50 feet of the edge of the buffer, i.e., within 50 feet no airblast directed towards the edge of the buffer.

For an application rate of 0.19 lb/acre

- No sulfometuron methyl shall be applied to surface waters.
- Buffers 50 feet wide along each side of perennial streams, springs, impoundments, or intermittent streams with flowing water the day of spraying;
- 50 feet wide around wet areas (standing water) and vernal ponds with no defined outlet.
- 25 feet wide along each side of dry intermittent streams, dry springs, and dry seeps
- Airblast shall be directed away from the buffer when applications are made within 100 feet of the edge of the buffer, i.e., within 100 feet no airblast directed towards the edge of the buffer.

For directed foliar backpack (0.09 or 0.19 lb/acre) application method, the following buffers and tactics will provide water quality protection involving the use of sulfometuron methyl:

- No sulfometuron methyl shall be applied to surface waters.
- No sulfometuron methyl shall be applied within 10 feet (when using 0.09 lb/acre) or 25 ft (when using 0.19 lb/acre) of standing or flowing water.
- No sulfometuron methyl shall be applied within 10 feet (0.09 lb/acre) or 25 feet (0.19 lb/acre) of dry intermittent streams, dry springs, or dry seeps.

This buffer strategy was developed incorporating the experience of ANF managers with the management of power line rights-of-way, and the results of ANF monitoring of silvicultural and power line management operations (results are in several ANF Monitoring and Evaluation Reports) and buffer-width research (Norris and Charlton, 1995). Chemical water quality monitoring has shown no detectable concentrations of sulfometuron methyl or glyphosate in water samples tested.

Glyphosate and Sulfometuron Methyl Risk Assessment for Federally Listed or Proposed, Threatened, Endangered, and Sensitive Species

The wildlife and aquatic species risk analysis is based on the dose response data for each herbicide as reported in SERA (2003a, b and 2004a, b). Because there are no studies that use Federal listed or proposed species as the test organisms, it is assumed that Federal listed or proposed, threatened, endangered and sensitive species would respond similarly to the most sensitive species of similar type that is included in toxicity testing. The critical toxicity values are shown below. Note there are no values for reptiles or mollusks, reflecting the limited degree to which such organisms are included in toxicity testing. For purposes of this risk assessment we assume reptiles are reflected by amphibians, and mollusks are represented by aquatic invertebrates.

Critical toxicity values for ANF terrestrial and aquatic wildlife
Values derived from SERA (2003a,b and 2004a,b)

Type of Species	Glyphosate Critical Toxicity Value	Sulfometuron Methyl Critical Toxicity Value
Mammals	175 mg/kg (NOAEL*)	2 mg/kg (NOAEL)
Birds	100 mg/kg (NOAEL)	2 mg/kg (NOAEL)
Fish (sensitive)	2.57 mg/l (NOEC§)	1.17 mg/l (NOEC)
Aquatic Invertebrates	50 mg/l (chronic NOEC)	0.19 mg/L (chronic NOEC, calculated)

*NOAEL–No Observed Adverse Effect Level
§ NOEC–No Observed Effect Concentration

Hazard quotients (HQ) for animal species federally listed or proposed as threatened, endangered, or sensitive species are summarized below. They are taken from the risk analyses for various wildlife species in this appendix. The highest HQ value reported for a particular type organism is used here in order to provide an increased margin of certainty for Federal listed or proposed threatened, endangered, or sensitive species.

Quantitative risk characterization for ANF terrestrial and aquatic species selected as a surrogate for Federal listed or proposed threatened, endangered, and sensitive species

Organism type/ Exposure Scenario	Glyphosate, Upper Hazard Quotient				Sulfometuron Methyl, Upper Hazard Quotient	
	ANF Application Rates (lbs a.i./acre)					
	1.0	2.0	3.0	4.0	0.09	0.19
Large Mammal						
acute exposure	0.22	0.38	0.75	0.90	0.06	0.10
chronic exposure	0.112	0.188	0.375	0.45	0.40	0.84
Bird						
acute exposure	0.15	0.25	0.50	0.60	0.04	0.08
chronic exposure	0.30	0.50	1.00	1.20	0.60	1.26
Fish, sensitive species						
acute exposure	0.03	0.05	0.10	0.12	***0.0002***	***0.0004***
chronic exposure	0.002	0.004	0.008	0.009	***0.000006***	***0.000001***
Aquatic invertebrates						
acute exposure	0.0004	0.0006	0.001	0.002	***0.00002 (sensitive species)***	***0.00004 (sensitive species)***
chronic exposure	0.0001	0.0002	0.0004	0.0005	***0.00004 (sensitive species)***	***0.00008 (sensitive species)***

The analysis shows nearly all HQs are less than 1, meaning there is no plausible basis for asserting that adverse effects are likely to occur (SERA 2003a) in these specific cases. No HQ values exceed 1 for acute exposure from use of either glyphosate or sulfometuron methyl. It is only the highest rates of application of glyphosate and of sulfometuron methyl that produce an HQ value greater than 1. In each case this is for a large bird consuming vegetation, and the HQ value is 1.2 and 1.26 for glyphosate and sulfometuron methyl respectively. However, none of the bird species on the ANF federally listed or proposed as threatened, endangered and sensitive list are herbivores. There are no HQ values greater than 1 for aquatic species.

From this we conclude that Federal listed or proposed threatened, endangered and sensitive animal species will not be toxicologically adversely affected by the use of glyphosate or sulfometuron methyl as proposed by the ANF.

Federally listed or proposed threatened, endangered, or sensitive plant species are likely to be impacted if either glyphosate or sulfometuron methyl are directly applied to them or if substantial drift reaches them. To use herbicides with safety to these species, a pretreatment survey to locate and mark such plants so they will not be sprayed will be required. It may be necessary to establish a no-spray buffer around sites that contain Federal listed or proposed threatened, endangered and sensitive plant species or to physically cover the plants to prevent injury due to spray drift.

For glyphosate, the analysis of drift for ANF application rates with non-forested conditions over relatively bare ground and no adjacent intercepting vegetation and the use of airblast application equipment indicates the hazard quotient is less than 1 at 25 feet for rates of applications of 4 lb/acre and less. Note the ANF uses the 4 lb/acre application rate only for directed backpack foliar invasive species control and the 3 lb/acre only for cut surface treatments, where virtually no drift is expected to occur.

For sulfometuron methyl this same analysis, again for non-forest conditions, indicates that a buffer between 300 and 500 feet may be required for sensitive plants at application rates of 0.09 lb/acre and 0.19 lb/acre. However, AgDRIFT testing and modeling with an orchard airblast application (trees 14 feet tall) shows a marked reduction in deposition beyond the first two layers of intercepting vegetation, and downwind spray deposition was essentially zero at 100 feet (Teske et al. 2001).

We consider this analysis extremely conservative because it does not take into account the lower wind speeds that occur in the forest interior or the interception of spray particles by the dense intervening vegetation. The monitoring history on ANF indicates little off-site vegetation damage, suggesting smaller buffers will likely provide protection for sensitive plants, but rigorous monitoring may be required for verification.

Except for plants, no adverse toxicological impacts on Federal listed or proposed species are expected to occur. For plants, it will be necessary to survey for their presence, and when found to implement mitigation measures to protect them.

SECTION A. INTRODUCTION

The purpose of this risk assessment is to document probable effects on wildlife, terrestrial plant, and aquatic species from using the herbicides glyphosate and sulfometuron methyl for vegetation management on the Allegheny National Forest (ANF). This risk assessment provides information related to the herbicides glyphosate (trade names Rodeo®, Accord Concentrate®, Glypro®, and Foresters®) and sulfometuron methyl (trade name Oust XP® and Oust®). Wildlife species refers to mammals, birds, reptiles, amphibians, and insects. Aquatic species include fish, aquatic invertebrates, aquatic life-stages of amphibians, and aquatic plants.

The use of various types of chemicals plays an important role in maintaining the high living standards today's society expects. However, increased use of chemicals has created social concerns about environmental health effects relative to the benefits chemicals provide. Knowing the probable environmental effects of the herbicides glyphosate and sulfometuron methyl is very important to a number of readers. For this reason, detailed information about these herbicides that might otherwise be included in this analysis by reference will be covered in enough detail to maintain clarity.

This new ANF risk assessment contains information about how the risk analyses were performed, including a summary of exposure routes and amount of exposure, the associated inherent hazard posed by each herbicide, and an overall assessment of the resultant risk from using these chemicals for vegetation management on the ANF. It is developed as an appendix to the FEIS for the ANF Land and Resource Management Plan.

Organization of This Risk Assessment

Section A presents the purpose and describes the organization of the documents.

Section B describes the relations of this assessment to other analyses and identifies the chemicals covered by the assessment and the sources of information used in its preparation.

Section C is the hazard analysis with separate subsections for glyphosate and sulfometuron methyl.

Section D is the exposure analysis with separate subsections for glyphosate and sulfometuron methyl.

Section E is the risk analysis with separate subsections for glyphosate and sulfometuron methyl.

Section F is the hazard analysis, exposure analysis and risk analysis for Federal listed or proposed threatened, endangered, or sensitive species.

SECTION B. RELATIONSHIP TO OTHER ANALYSES

The overall management of the ANF is governed by the ANF Land and Resource Management Plan. The effects are disclosed in the Final Environmental Impact Statement (referred to as the Forest Plan and Forest Plan FEIS). The Forest Plan allocates land to broad management prescriptions, defines management objectives for these areas, and provides standards and guidelines designed to mitigate potential adverse impacts. The Forest Plan EIS evaluates a range of alternatives for managing the ANF to address the significant issues identified during the public involvement process.

Four risk analyses precede this document and are described below.

The 1986 Forest Plan contains a brief analysis of the human health effects of glyphosate (1986 Forest Plan FEIS, p. 4-40; 1986 Forest Plan, p. D-15).

In February 1989, the USDA Forest Service, Southern Region, issued a Final Environmental Impact Statement for Vegetation Management in the Coastal Plain/Piedmont (USDA FS, 1989). It addressed broad vegetation management options for 4.6 million acres of National Forest Land, including the use of 11 herbicides and 3 additives. It contained a detailed Risk Assessment that documents the probable health effects from using these herbicides and additives.

A more comprehensive ANF risk analysis completed in 1991 as part of an ANF Environmental Impact Statement for Understory Vegetation Management (USDA FS 1991, Appendix C) provided additional and up to date information on glyphosate. It also included a detailed and comprehensive analysis of sulfometuron methyl, and it amended the 1986 Forest Plan to permit ANF personnel to consider using it in future projects. The "Human Health Risk Assessment" (USDA FS 1991, Appendix C) and Appendix B, the "Wildlife and Aquatic Species Risk Assessment for Sulfometuron Methyl and Glyphosate Treatment" (USDA FS 1991, Appendix B) incorporated a substantial amount of the Southern Region analysis by reference.

Syracuse Environmental Research Associates (SERA) has completed 16 national herbicide risk assessments for the USDA Forest Service that are pertinent to this analysis. They are found at http: //www.fs.fed.us/foresthealth/pesticide/risk.shtml

This wildlife, terrestrial plant, and aquatic species risk assessment for the ANF incorporates by reference (40 CFR 1502.21) a substantial portion of the analyses SERA has completed, as well as some information from the 1991 ANF Understory Vegetation Management EIS (USDA FS 1991) and the 1989 Southern Region FEIS (USDA FS 1989) mentioned above.

Chemicals Covered By This Appendix

Table 1. Commercial herbicide formulations and surfactants covered by this appendix

Commercial Product	Type of Product	Active Ingredient or Constituents
Accord Concentrate®	Herbicide	Glyphosate
Rodeo®	Herbicide	Glyphosate
Glypro®	Herbicide	Glyphosate
Foresters®	Herbicide	Glyphosate
Oust®	Herbicide	Sulfometuron methyl
Oust XP®	Herbicide	Sulfometuron methyl
Timberland 90®	Surfactant	*
Alenza 90®	Surfactant	*
Chemsurf 90®	Surfactant	*
Red River 90®	Surfactant	*
Red River Adherent 90®	Surfactant	*

* The active ingredients or constituents of the surfactants include one or more of the following: Alkylarylpolyoxyethylene ether, Alkylphenol ethoxylate, isopropanol, free fatty acids, Alkylarylpolyoxykane ether, Dimethylpolysiloxane, and Alkylarylpolyoxyethylene glycols.

Sources of Information Used in this Appendix

The wildlife risk assessments in the Final Environmental Impact Statement (FEIS) on Understory Vegetation Management (USDA FS 1991) and the 1997 FEIS on Vegetation Management on Electric Utility Rights-of-way (USDA FS 1997) were based on the wildlife risk assessment done for the Southern Region (USDA FS 1989). Since then a comprehensive and recent risk assessment has been done by SERA under contract to USDA Forest Service. The products of their work are available “online” at http: //www.fs.fed.us/foresthealth/pesticide. The SERA assessments for glyphosate (SERA 2003a, b) and sulfometuron methyl (SERA 2004a,b) are more comprehensive than either the 1991 or 1997 FEIS and use risk assessment procedures more consistent with the contemporary approaches used by U.S. EPA for this same purpose. Some of the information cited in this appendix is from the 1991 and 1997 FEIS, but most is from the SERA documents. Appropriate citations are used to clearly indicate the source of the material. The SERA assessments and other review documents contain the citations of the original literature.

The SERA analyses encompass a wide array of environmental conditions, including those relevant to the ANF. For this reason, the SERA analysis is considered pertinent to the ANF. The wildlife, terrestrial plant, and aquatic species assessments in this document are drawn from the SERA documents cited above, with updates as needed to include literature appearing after the completion of the SERA documents.

Electronic online searches for scientific literature published since the completion of the SERA documents used several databases including Agricola (maintained by USDA’s National Agriculture Library and includes agricultural and forestry literature); Cambridge Scientific Abstracts® including Aquatic Sciences and Fisheries Abstracts, Toxline, Wildlife and Ecology Studies Worldwide, and Fish and Fisheries Worldwide; and Medline (maintained by the U.S. Library of Medicine and the National Institutes of Health). The literature database searches focused on publications released from 2002 through July 2005 for glyphosate and from 2003 through July 2005 for sulfometuron methyl. Specific information (and literature citations) on toxicity (hazard analysis) and exposure (exposure analysis) are in the SERA documents and are not repeated here. This assessment relies heavily on SERA (2003a, b; 2004a, b), and some portions of the SERA risk analyses are included verbatim. These are followed by risk assessments adjusted for ANF herbicide application rates to make the assessments specific to the ANF.

This assessment compliments Appendix G1, the Human Health Risk Assessment for the use of herbicides on the ANF. Many of the items relevant to the wildlife risk assessment are covered in Appendix G1 and are not repeated here. Examples include information on the environmental behavior of glyphosate and sulfometuron methyl, and much of the mammalian toxicity data. Acronyms, conversion factors between English and metric units, and a glossary covering both Appendix G1 and G2 can be found in Appendix G3.

SECTION C. HAZARD ANALAYSIS (Toxicity)

A hazard analysis identifies the toxicity characteristics of the particular chemical under consideration. The basic process is described in detail in the Hazard Assessment section of Appendix G1 (this document), and also in Section 4.1.1 in the glyphosate risk assessment documents (SERA 2003a). The goal of hazard analysis is to identify the most sensitive known toxicity values for a variety of responses, which are detailed in the specific sections dealing with each type of toxicity for each chemical.

This hazard analysis summarizes the findings of laboratory and field studies that indicate the toxicity of glyphosate and sulfometuron methyl and surfactants proposed for use on the ANF. In many cases, laboratory studies of domestic animals have been used because of a lack of studies specifically on wildlife, and the results are considered to be representative of the effects that would occur in similar species in the wild. Note that there are many formulations of herbicide containing the active ingredient glyphosate or sulfometuron methyl. In the hazard analysis that follows, some formulations not proposed for use on the ANF are included as a matter of completeness in identifying the critical toxicity values that are relevant for the proposed ANF program. Only the critical toxicity values relevant for the formulations and mixtures in the proposed ANF program are used in the actual risk analysis. These are listed in Table 3 for glyphosate and Table 5 for sulfometuron methyl.

The first section addresses glyphosate followed by sulfometuron methyl. Within each section empirical studies for mammals, birds, reptiles/amphibians (terrestrial life-stages), terrestrial invertebrates (mainly insects), and aquatic species (including fish, aquatic invertebrates, aquatic life-stages of amphibians, and aquatic plants) are discussed. Rodent toxicity studies as well as carcinogenicity and mutagenicity results are summarized in the Human Health Risk Assessment (Appendix G1, Section 3) for the ANF and will not be repeated in detail here.

Variability

Variability reflects the knowledge of how things may change. For example, various estimates involve relationships in which a most likely (central) estimate can be calculated. Where appropriate the upper and lower limits of the estimate are used in considering variability. In this document we use the terms *central*, *upper*, and *lower* where needed in considering variability.

Glyphosate Toxicity

A significant portion of the mammalian hazard assessment in Appendix G1 applies equally to mammalian species of wildlife. Refer to Appendix G1 for this discussion. What follows emphasizes toxicity characteristics derived primarily for non-mammalian wildlife species, although there is some information included about mammals reflecting studies of toxicity not covered or referenced in Appendix G1.

Terrestrial Wildlife Species

Glyphosate is generally recognized to be of low toxicity in the environment (USDA 1984 Syracuse 1996b). Acute oral LD_{50}s are >5,000 mg/kg for rats and 3,800 mg/kg for rabbits (EPA 1984b; USDA 1984; Monsanto 1993).

Oral LD_{50} values for Roundup® and Rodeo® formulations in rats are 5,400 mg/kg and greater than 5,000 mg/kg, respectively (Monsanto 1983, 1985). Oral LD_{50} value for Accord Concentrate® is also >5,000. Additionally, LD_{50} values for Roundup® in goats is 4,860 mg/kg (Monsanto 1983, 1985). Glyphosate, Roundup®, and Rodeo® are reported to be nonirritating or slightly irritating to the eyes and skin of rabbits (Monsanto 1983, 1985). The NOELs derived from chronic feeding studies in rats are 362 mg/kg/day for males and 457 mg/kg/day for females (USDA FS 1997). In a one-year oral study with dogs, a NOEL of 500 mg/kg/day was determined (U.S. EPA/OPTS 1987). Glyphosate has caused no reproductive or teratogenic effects in rats or rabbits (U.S. EPA/OPTS 1984).

Studies conducted on black-tailed deer in captivity in the Pacific Northwest showed no gross adverse health effects caused by the use of glyphosate for vegetation management (Sullivan 1985). The food preference of deer was the same for glyphosate-treated browse and untreated commercial chow. Likewise, weed and shrub control with glyphosate did not adversely affect deer use of treated habitat areas for at least the first year after treatment. Moose were found to browse preferentially in untreated areas of clearcuts treated with glyphosate (Santillio 1994). This would likely minimize their exposure to glyphosate.

In a study to evaluate the direct effects of glyphosate on small mammals, no adverse effects on reproduction, growth, or survival were observed in populations of deer mice during the year following treatment (Sullivan 1985). In forest areas that had been clearcut and then sprayed with glyphosate for reforestation, the body weights and the number of placental scars and foeti of deer mice were the same as in adjacent unsprayed forest areas, although the total number of animals was reduced in sprayed as opposed to unsprayed clearcut areas. The authors conclude that this is likely the result of habitat changes induced by the herbicide rather than direct toxic effects (Ritchie et al. 1987).

The following is largely derived (not verbatim) from SERA (2003a). SERA (2003a) specifically addresses the Accord Concentrate® and Rodeo® commercial products used on the ANF. For purposes of this hazard and risk analysis, the Glypro® formulation is essentially the same as Accord Concentrate® and Rodeo®. All three have only water as the inert ingredient. Foresters® has a lower toxicity to aquatic species; so conclusions based on SERA (2003a) are conservative for this formulation. SERA (2003a) and the following discussion in this document include formulations that are not used on ANF. They are included where appropriate to ensure identification of the most sensitive indicators of toxicity.

The World Health Organization (WHO, 1994) criteria document summarizes a study in heifers that is cited on several Material Safety Data Sheets (MSDS's in C and P Press, 2002) for glyphosate formulations. According to WHO (1994), this study involved dosing of Brahman-cross heifers with Roundup® at 400, 500, 630 or 790 mg/kg body weight per day by nasogastric intubation. At 790 mg/kg, some animals died with labored breathing and pneumonia from the aspiration of rumen contents. This is consistent with lung damage seen in experimental mammals (SERA 2003a, Section 3.1.4). Additional signs of toxicity at 500, 630 and 790 mg/kg body weight (bw) included diarrhea and decreased food intake. No adverse effects were observed at 400 mg Roundup®/kg bw (equivalent to 215 mg a.i./kg bw or about 160 mg acid equivalent (a.e.)/kg bw). In herbicide concentrates, the acid equivalent (a.e.) is the content of active ingredient expressed as a free acid. Although this report is attributed to Monsanto Inc, this study was not found in a search of the U.S. EPA studies submitted for registration. The MSDS for Glyphosate Original® (C and P Press, 2002) is consistent with this summary but the MSDS's for Aqua Neat®, Debit TMF®, Eagre®, Forester's Non-Selective® Herbicide, and Glyphosate contain a different summary:

> *This product was administered to Brahman-cross heifers by gavage at daily doses of 0, 540, 830, 1290, or 2000 mg/kg for 7 consecutive days. Clinical signs of toxicity, including loss of appetite, diarrhea, and death (1290 and 2000 mg/kg) were observed at 830 mg/kg or above. The no-effect level was considered to be 540 mg/kg/day.*

The reason for differences between these summaries is unclear (SERA 2003a).

A reported incident of fatal poisoning of a horse by drift from glyphosate was investigated by the Texas Department of Agriculture (1992), which made the determination that glyphosate was not the cause of death and that the horse died of natural causes.

Because toxicity data in mammals are available in few species of experimental mammals, the use of these data to assess the potential hazards to large number of diverse mammalian wildlife species is an uncertain process. One approach to this process involves identifying patterns of toxicity in mammals of various sizes (i.e., allometric relationships as discussed in SERA 2003a, Section 3.2.). As detailed in Section 4.3.2 (SERA 2003a), there do not appear to be any systematic differences among mammalian species, including humans, when comparable toxicity values are expressed in units of mg/kg/day. While the available data are limited, this apparent consistency among species diminishes concern with the use of data based on a limited subset of species to characterize risk for terrestrial mammals in general.

Glyphosate is slightly toxic to birds based on the acute oral LD_{50} of greater than 4,640 mg/kg in bobwhite quail and mallard duck (Monsanto 1993). The eight-day dietary LC_{50} is more than 4,000 ppm (4000 mg/kg) for both mallard ducks and bobwhite quail (U.S. EPA/OPP 1986). Avian reproductive studies yielded no reproductive effects at dietary exposure levels of up to 1,000 ppm (U.S. EPA/OPP 1986). Toxicity in birds and findings in available studies was discussed in detail by SERA (2003a, pp. 4-4 to 4-5):

The most relevant data for this risk assessment are the standard dietary and bird reproduction studies required for registration as well as the acute oral LD_{50} studies. The toxicity of glyphosate on acute gavage administration to birds is >2000 mg/kg (Fink et al. 1978), comparable to that seen in experimental mammals. No effects on reproduction have been seen in bobwhite quail (Fink 1975) and mallard ducks (Fink and Beavers 1978 as cited in SERA (2003a)) at concentrations of up to 1000 ppm. While the available toxicity studies do not suggest any specific or unique toxicity in birds, the study in zebra finches by Evan and Batty (1986) noted pronounced weight loss in animals after dietary exposures to 5000 ppm (5000 mg/kg) glyphosate for 3 to 7 days accompanied by a 20-30% decrease in food consumption but a 30-60% decrease in body weight. This is consistent with observations in experimental mammals suggesting that glyphosate may inhibit oxidative phosphorylation and consequently reduce food conversion efficiency.

Also consistent with the data in experimental mammals is the apparent lack of teratogenic activity in birds. There is no indication that glyphosate or Roundup® causes birth defects in birds (Batt et al. 1980; Hoffman and Albers 1984).

Residue and metabolism studies have indicated that glyphosate is incompletely absorbed across the gastrointestinal membranes and that in the vertebrates tested, there is minimal metabolism or retention by tissues and rapid elimination of residues (Monsanto 1982).

The U.S. Fish and Wildlife Service tested 19 pesticides on the adult stage of the bullfrog. No tests were done on reptiles. There was a good correlation ($r = 0.67$) between the LD_{50}'s for the bullfrog and the LD_{50}'s for the mallard for the tested chemicals when 17 of the 19 chemicals were used in a prediction equation. Suitable data are lacking for terrestrial stages of amphibians and for reptiles. Because there is a reasonable correlation between avian and amphibian toxicity as indicated in the mallard versus bullfrog analysis and reason to suspect the same for avian and reptile toxicity, available avian toxicity data were used as surrogates for both amphibians and reptiles.

In an Oregon study, Cole et al. (1997) report no effect on populations of six species of amphibians (based on capture rates) among clear-cut sites with and without glyphosate applications. Species included rough-skin newt, ensatina, Pacific giant salamander, Dunn’s salamander, western redback salamander, and red-legged frog. Removal of red alder from the habitat reduced amphibian populations regardless of the method used to remove the alder.

Terrestrial Invertebrates

SERA (2003b, pp. 4-5 to 4-7) presented a detailed discussion of available studies on terrestrial invertebrates including honey bees (the standard test organism for assessing the effects of pesticides on terrestrial invertebrates), earthworms, isopods, snails, spiders, butterflies, and terrestrial arthropods.

The LD_{50} values for bees is more than 100 µg/bee as summarized in U.S. EPA/OPP (1993b) and substantiated by later studies reported by Palmer and Beavers (1997) and Palmer and Krueger (2001a) who found no effect at 100 µg/bee. In an acute dietary study (Palmer and Krueger 2001b), the 48 h oral LD_{50} is reported as >100 µg/bee, and the NOEC is reported as 50 µg/bee.

Glyphosate has been tested as an insecticide for spider mites and on an important predator of spider mites (Weppleman 1998a,b). Glyphosate isopropylamine (IPA) formulation at 0.593 to 4.74 mg a.i. per leaf (kidney bean plants) had no effect on the spider mite based on mortality in eggs, larva, nymphs or adults (Ahn et al. 1997) and was essentially ineffective as an insecticide. Applications equivalent to 10 L/ha Round Up ULTRA® (glyphosate isopropylamine salt at 360 g/L or an application rate of 3.6 kg a.i./ha) applied to glass slides caused 100% mortality in spider mites after 24 hours of contact and was classified as "harmful" (Weppleman 1998a). In a similar assay using *Aphidius rhopalosiphi* (a beneficial wasp that is a parasite of the cereal aphid), the same contact exposure also resulted in 100% mortality after 24 hours. The relevance of the studies by Weppleman (1998a, b) to the assessment of potential effects under normal use is unclear. As noted in Weppleman (1998a),

> *the 5% v/v (volume/volume) test solution of Roundup ULTRA® produced a wet sticky layer on the treated glass plates that resulted in alterations of the moving behavior of the wasps to the point of sticking.*

In other words, it appears the application of the glyphosate formulation to the glass slides causes the test organism to stick to the slides, and this may have contributed to the observed mortality.

Haughton et al. (1999, 2001a, b) have conducted a series of laboratory and field studies on the effects of glyphosate on the spider, *Lepthyphantes tenuis*. Direct spray laboratory bioassays at rates equivalent to 180, 360, 720, 1080, 1440, and 2160 g/ha resulted in low rates of mortality that were not dose related (Haughton et al. 2001a). In the field, application rates of 360, 720, and 1440 g a.e./ha resulted in decreased spider populations that were attributed to secondary effects from changes in the vegetation (Haughton et al. 2001b). No substantial effects were observed in spider populations at application rates of 90 or 180 g a.e./ha (Haughton et al. 1999).

Data on other arthropods are less detailed but also indicate a low potential for a direct toxic effect from glyphosate. In a laboratory study in which isopods were exposed to leaf litter at levels equivalent to application rates of 2.1 kg/ha, the effect on litter degradation depended on the tree species. Direct toxic effects, evidenced by increased mortality, could not be ruled out but were not statistically significant (Eijsackers 1992 as cited in SERA (2003a)). Samsoe-Petersen (1995) report no measurable effect on rove beetles (mortality and egg production) after spray of substrate with 1% Roundup® (3.6 g/L) at 6 $\mu L/cm^2$. Bramble et al. (1997) conducted a series of studies in Pennsylvania on effects of using herbicides (including glyphosate) in rights-of-way maintenance compared to using mechanical maintenance and noted no significant or substantial differences in butterfly populations.

Three studies are available relating to the potential effects of glyphosate on earthworms. In a laboratory study, effects on earthworm cultures treated at levels equivalent to application rates of 0.7 to 2.8 g glyphosate/ha included decreased growth rates and early mortality (Springett and Gray 1992). The direct relevance of this study is limited, however, because the exposure conditions (spraying twice weekly on culture dishes) do not closely approximate field conditions. Dalby et al. (1995) report no effects on earthworms in applications designed to mimic agricultural use. This study, however, does not report exposures either as g/ha or ppm soil and thus cannot be used directly in this risk assessment. The soil LC_{50} for glyphosate to *Aporrectodea caliginosa*, a worm common in Libya, has been reported to be 246 to 177 mg glyphosate/kg soil dry weight over exposure periods of 8 to 37 days (Mohamed et al. 1995).

One study is available on the toxicity of glyphosate to a terrestrial snail, *Helix aspersa*, Brown garden snail, in which diets containing 4994 ppm glyphosate resulted in no mortality over a 14 day exposure period. Assuming a 30% food consumption factor for this species (APHIS 1993), this corresponds to a dose of about 1,500 mg/kg (4994 ppm × 0.3 mg/kg bw = 1498.2 mg/kg bw).

Terrestrial Plants

The 1991 ANF FEIS for vegetation management did not include terrestrial plants, however terrestrial plants support wildlife populations by providing food, shelter, and nesting materials. SERA (2003a, section 4.1.2.5, pp. 4-8 to 4-10) did include all categories of terrestrial plants as part of their analyses and summarized several studies related to toxicity to agricultural crops, non-target plants, and target weed species from which we draw heavily for the following discussion:

Glyphosate is absorbed primarily through the foliage, and the absorption is rapid. Approximately 33% of the applied glyphosate is absorbed within a few hours after application. Glyphosate absorption by plants may be enhanced by high humidity (Schonherr 2002). Because glyphosate is strongly adsorbed to soil, relatively little if any absorption occurs through the roots (Smith and Oehme 1992). In actively growing plants, translocation involves cell to cell transport through the cuticle followed by long distance transport via vascular tissue. The retention of glyphosate on foliage is affected by the use of adjuvants, with a wash off of about 50% with adjuvants and 64% without adjuvants (Leung 1994).

In dormant plants, transport is much slower and may be negligible. Glyphosate is not extensively metabolized or detoxified in plants.

Studies on the mechanism of action of glyphosate on plants are numerous and are cited in SERA (2003a). Glyphosate inhibition of the shikimic acid pathway in plants effectively blocks the synthesis of certain phenolic compounds and the synthesis of aromatic amino acids. This, in turn, leads to a variety of toxic effects in plants, including the inhibition of photosynthesis, respiration, and nucleic acid synthesis. At the level of the whole plant, inhibition of the shikimic acid pathway leads to an inhibition or cessation of growth, cellular disruption, and, at sufficiently high levels of exposure, plant death. The time course for these effects can be relatively slow, depending on the plant species, growth rate, climate, and application rate. Gross signs of toxicity, which may not be apparent for 2 to 4 days in annuals or for more than 7 days in perennials, include wilting and yellowing of the vegetation, followed by browning, breakdown of plant tissue, and, ultimately, root decomposition.

As noted in the U.S. EPA/OPP (1993b) re-registration eligibility decision (RED) for glyphosate, data submitted up to 1993 did not include bioassays for vegetative vigor (i.e., direct application to foliage after plants have emerged) or sufficient studies on the effects of drift on non-target species. The only data on toxicity to terrestrial plants summarized in the RED involved seedling emergence assays using a 50% solution of glyphosate IPA. In this assay (Bohn 1987), glyphosate applications of up to 10 lb a.i./acre resulted in <25 % effect on the monocots and dicots tested.

Since the publication of the RED, additional studies have been submitted to the U.S. EPA or published in the open literature on seedling emergence (Willard 1996; Everett et al. 1996a; Shuma et al. 1995) and vegetative vigor (Chetram and Lucash 1994; Everett et al. 1996b). In addition, several studies have been conducted on the effects of drift on nontarget plant species (Al-Khatib and Peterson 1999; Bhatti et al. 1997; De Jong and de Haes 2001; Fletcher et al. 1996; Marrs and Frost 1997; Newmaster et al. 1999).

The studies on seedling emergence submitted to the U.S. EPA involve a water dispersible granule formulation (Willard 1996) and a wettable powder formulation (Everett et al. 1996a). Both studies were consistent with earlier reports indicating no adverse effects in monocots and dicots at application rates of about 4.5 lb a.e./acre. In an open literature publication by Shuma et al. (1995), a Roundup® formulation (356 g a.i./L) was associated with complete inhibition of seed viability when applied to oats 15 days after anthesis (flowering or seed formation) at an application rate of 1.76 kg/ha (about 1.6 a.i. lb/acre), and applications as low as 0.44 kg/ha partially inhibited seed germination. This study is not inconsistent with the studies by Everett et al. (1996a) or Willard (1996). These latter studies involved standard test protocols in which seeds were exposed directly rather than harvested from plants after anthesis.

From this we conclude glyphosate as used on the ANF will have no effect on germination or development of seed if it is treated after being shed by the plant and prior to emergence.

The two vegetative vigor studies (Chetram and Lucash 1994; Everett et al. 1996b) assess the consequences of direct spray and drift. In the study by Everett et al. (1996b) (glyphosate applied as a wettable powder) the most sensitive species was oilseed rape (*Brassica napus*), with an EC_{25} of 0.083 kg a.e./ha (0.07 lb a.e./acre) and EC_5 of 0.042 kg a.e./ha (0.037 lb a.e./acre; note that the EC xx value is the value that affects xx percent of the test population). The least sensitive species was the monocot, purple nutsedge (*Cyperus rotundus*), with an EC_{25} of 0.891 kg a.e./ha (0.79 lb a.e./acre) and EC_5 of 0.58 kg a.e./ha (0.52 lb a.e./acre). The EC_5 values are essentially NOECs. In the study by Chetram and Lucash (1992), the most sensitive species based on reduced growth were tomato and radish, with a NOEC of 0.035 lb a.e./acre and the least sensitive species were ryegrass, corn, and onions with a NOEC of 0.56 lb a.e./acre.

Unintended drift is one of the more plausible exposure scenarios for nontarget terrestrial plant species (SERA 2003a, Section 4.2). The lowest reported effect level in drift studies is reported by Al-Khatib and Peterson (1999) at 0.034 kg/ha or about 0.03 lb/acre, resulting in transient damage but no net decrease in soybean production by the end of the season. Grapes were less sensitive. A grass (*Poa annua*) and a dicot (*Brassica napus*) both exhibited substantial damage at deposition rates of over 1.8 lbs/acre. Fletcher et al. (1996) found that simulated drift in the range of 0.4 to 0.8% of an application rate of 0.43 kg/ha had no marked effect on canola, smartweed, soybean or sunflower plants.

The study by Newmaster et al. (1999) suggests that some bryophytes and fungi may be sensitive to long term effects after glyphosate exposure. The EC_{50} for a decrease in relative abundance two years after application is about 0.8 kg/ha or 0.7 lbs/acre (Newmaster et al. 1999, Figure 3, p. 1105). In addition, changes in relative abundance were apparent at six weeks after application (Newmaster et al. 1999, Figure 7, p. 1108). While the statistical methods of analysis may be less appropriate for risk assessment (discussed further in SERA 2003a, Section 4.3), the study does appear to present a plausible basis for concern that exposure to substantial glyphosate drift may have long term impacts on bryophyte and lichen communities.

Note that monitoring has shown little evidence of drift in ANF operations, therefore we conclude that except for bryophytes in spray areas, little affect on these plants should be expected.

Aquatic Species

Presently there are several different commercial formulations that contain glyphosate including: Roundup®, Rodeo®, Accord Concentrate®, Glypro®, and Foresters®. The 1991 FEIS for the ANF determined that because of the content of its surfactant, the earlier formulation of Roundup® was more toxic than Rodeo® or Accord Concentrate® (no surfactant) to aquatic species. The acute toxicity was greater at pH 7.5 than at 6.5, and toxicity also increased with increases in temperature (Folmar et al. 1979). Rainbow trout did not exhibit avoidance behavior at concentrations up to 10 ppm, but mayfly nymphs did (Folmar et al. 1979). No effects on rainbow trout fecundity or gonad maturation have been observed. At concentrations of 2.0 ppm, significant midge larvae drift occurred (Folmar et al. 1979). In the 1991 FEIS, Rodeo® and Accord Concentrate® were considered to be practically nontoxic to aquatic organisms (Monsanto 1983) since the inert ingredient in these formulations is water. Glypro® is similar to Rodeo® and Accord Concentrate® in toxicity to aquatics, and Foresters® is less toxic.

As discussed in the human health risk assessment (Appendix G1, Section 3), the formulation of glyphosate with surfactants, especially the POEA (polyethoxylated tallow amine) surfactant commonly used in some formulations, has a pronounced effect on the acute lethal potency of glyphosate. Most toxicity studies of specific surfactants have focused on Roundup® formulations and the POEA surfactant (see SERA 2003a, section 4.1.3.1.3). In the SERA (2003a) risk assessment, the toxicity of glyphosate was characterized based on the use of a surfactant, either in formulation or added as an adjuvant in a tank mixture.

None of the glyphosate formulations proposed for use on the ANF (Table 1; Rodeo®, Glypro®, Accord Concentrate®, and Foresters®) contain POEA. Although POEA-containing formulations are not used on ANF, we include such formulations in this review to ensure completeness in searching for the most sensitive critical toxicity values. All of the surfactants proposed for use on ANF (Table 1) have inert ingredients categorized on the EPA inerts lists 3 and 4b. List 3 indicates that there is unknown toxicity; for inerts where "there was no basis for placing it on any of the other lists. The Agency will continue to evaluate these chemical substances, as additional information becomes available, to determine if reclassification to List 1, 2, or 4 is appropriate." List 4 indicates minimal concern, further subdivided and List 4B for inerts with "*sufficient information to conclude that current use patterns in pesticide products will not adversely affect public health and the environment.*"

SERA (2003, pp. 4-12 to 4-13) reviews standard toxicity studies available after the 1991 ANF FEIS was prepared (note that most toxicity tests with fish and other aquatics involve a constant level of toxicant, which greatly exaggerates exposure compared to the typical pattern of rapidly falling concentrations in water in the field). The purpose of this review is to identify the most critical toxicity value for use in this risk assessment.

Fish

Glyphosate and glyphosate formulations have been tested in a large number of fish species, and this information is summarized in Appendix 9 (SERA 2003a). As summarized by U.S. EPA/OPP (1993b, p. 40), the 96-hour LC_{50} values in freshwater fish range from 86 (70-106) mg/L in rainbow trout for an 83% pure sample of technical grade glyphosate to 140 (120-170) mg/L in rainbow trout for a 97.6% pure sample of technical grade glyphosate (U.S. EPA/OPP 1993b, p. 40). Based on these bioassays, U.S. EPA/OPP (1993b) classified technical grade glyphosate as non-toxic to practically non-toxic in freshwater fish. Some bioassays of technical grade glyphosate resulted in much lower LC_{50} values, i.e., 10 mg/L for trout in softwater (Wan et al. 1989) and about 3 mg/L for unfed flagfish (Holdway and Dixon 1988).

Some formulations of glyphosate can be much more toxic to fish than technical grade glyphosate. As also summarized by U.S. EPA/OPP (1993b) and detailed in Appendix 9 (SERA 2003a), the 96 hour LC_{50} values for formulated glyphosate in freshwater fish range from 1.3 (1.1-16) mg/L in rainbow trout for a 41% glyphosate formulation to >1000 mg/L in rainbow trout and bluegill sunfish for a 62.4% glyphosate formulation (U.S. EPA/OPP 1993b, pp. 42-43). Based on these LC_{50} values, U.S. EPA/OPP (1993b) classified glyphosate formulations as moderately toxic to practically non-toxic in freshwater fish. The less toxic surfactants appearing in literature are identified only as "AA surfactant," "W" surfactant, and "x-77" surfactant. The "x-77" surfactant appears to be X-77®, a non-ionic alkylphenol ethoxylate-based surfactant supplied by Loveland Industries. As detailed in Appendix 9 (SERA 2003a), this surfactant modestly increases the toxicity of Rodeo®, e.g. decreases the LC_{50} value by about 30% (Mitchell and Chapman 1985). The identity of the other surfactants in these formulations is not specified in U.S. EPA/OPP (1993b). Abdelghani et al. (1997) have noted that Syndets surfactant, a surfactant used with glyphosate and other herbicides, is much more toxic to fish (as well as crawfish) than Roundup®.

In terms of the dose-response assessment for longer term exposures to glyphosate, the most relevant study remains the life cycle toxicity studies done in fathead minnow. As summarized in the U.S. EPA/OPP (1993b), no effect on mortality or reproduction was observed at a concentration of 25.7 mg/L using 87.3% pure technical grade glyphosate. No other chronic toxicity studies have been encountered in fish either in the published literature or the more recent studies submitted to U.S. EPA.

SERA (2003a) noted that sub-lethal effects of glyphosate have not been as well characterized as its acute lethal potency. SERA (2003a, section 4.1.3.1.4) presented this detailed discussion on six studies on sub-lethal effects:

Five studies have reported and focused on acute effects other than mortality in fish (El-Gendy et al. 1998; Janz et al. 1991 (as cited in SERA (2003a); Morgan et al. 1991; Neskovic et al. 1996b; Szarek et al. 2000). The studies by

Szarek et al. (2000) involve observations of non-lethal endpoints that do not substantially impact the hazard identification for fish. Janz et al. (1991) noted that short-term exposures at 5 to 85% of the 96 hour LC_{50} values of several glyphosate formulations do not induce indicators of physiological stress assayed as changes in biochemical parameters in blood. Morgan et al. (1991) noted that trout do not exhibit avoidance responses to glyphosate formulations at concentrations less than the 96 hour LC_{50}. Behavioral changes, i.e., changes in coughing and ventilation rates, changes in swimming, loss of equilibrium, and changes in coloration, were observed at 25% of the LC_{50} values over exposure periods of up to 96 hours. The study by Szarek et al. (2000) involved very brief exposures of carp to Roundup® concentrations that are far greater than the LC_{50} values, i.e., 1 hour exposures to 205 mg a.e./L and one-half hour exposures to and 410 mg a.e./L. All fish died during these exposures. Changes were observed in the mitochondria of carp hepatocytes. The observed effects may be due to the uncoupling oxidative phosphorylation (SERA 2003a, Section 3.1.2). Conversely, given that all fish died during exposure, these effects may represent normal post-mortem pathology. In either event, this is not suggestive of a sub-lethal effect that is relevant to the assessment of population level effects.

The studies by Neskovic et al. (1996b) and El-Gendy et al. (1998) report effects that could be viewed as true sub-lethal toxicity. The study by Neskovic et al. (1996b) noted histologic changes in the gills, kidneys, and liver of carp, *Cyprinus carpio*. In this study, carp were exposed to *technical grade* glyphosate but the purity was only 62%, much lower than that used in current commercial formulations. Nonetheless, the 96 hour LC_{50} value for the technical grade glyphosate in carp is reported as 620 (607-638) mg/L, which is higher than values for more highly purified forms of glyphosate (SERA 2003a, Section 4.1.3.1.2) in trout and bluegill sunfish. The sub-lethal studies were conducted over 14 days of exposure to concentrations of 2.5, 5, 10 mg a.e./L. At 10 mg/L abnormal histopathologic changes were noted in the gills and liver. At 5 mg/L abnormal histopathologic changes were noted only in the gills. These changes were accompanied by increased alkaline phosphatase activity. While these effects cannot be directly associated with potential longer term effects on fish populations, the histologic changes in the gills and liver would be classified as adverse.

Relative to the SERA (2003a) risk assessment, it should be noted that a full life-cycle toxicity study has been conducted in fathead minnow, as was the standard chronic toxicity test required by and accepted by the U.S. EPA/OPP (1993a). In this study, the NOEC was 25.7 mg/L (U.S. EPA/OPP 1993a, p. 41). It is important to note that the NOEC from this full life-cycle toxicity study also indicates that the fish were able to reproduce normally. It is conceivable, based on the work of Neskovic et al. (1996b) that some transient histopathologic effects could occur at the NOEC of 25.7 mg/L, but, in terms of the risk assessment, the life cycle NOEC of 25.7 mg/L remains the most appropriate basis for risk characterization.

El-Gendy et al. (1998) published a study on potential effects of glyphosate on immune function in fish. This is the only study that has reported any effect on immune function in any species. However there appear to be several problems with this study, and SERA (2003a) concludes that in terms of the ecological risk assessment, the study by El-Gendy et al. (1998) has no substantial impact. SERA (2003a) also notes that El-Gendy et al. (1998) is inconsistent with a full life-cycle toxicity study conducted in fathead minnow (U.S. EPA/OPP 1993a, p. 41).

SERA (2003a) also included several studies on the effects of glyphosate toxicity on amphibians, aquatic invertebrates, and aquatic plants not available at the time the 1991 ANF FEIS was completed. These are included here verbatim (SERA 2003a, pp. 4-20 through 4-23):

Amphibians (aquatic life-stages)

The observation of hind limb deformities in free-living amphibians has substantially increased concern for the effects of xenobiotics on populations of amphibians (e.g. Quellet et al. 1997). Glyphosate IPA, Roundup®, and the POEA surfactant used in Roundup® have been specifically tested for malformations in the frog embryo teratogenesis assay (Perkins et al. 2000). In this assay, frog (*Xenopus laevis*) embryos are exposed to the test solution in petri dishes for 96 hours. As in the bioassay in fish, the least toxic agent was glyphosate IPA with an

LC_{50} of 5407 mg a.e./L and an LC_5 of 3779 mg a.e./L, indicating that glyphosate IPA is less toxic to frog embryos than to fish. Also as with fish, the most toxic agent was the POEA surfactant with LC_{50} of 2.7 mg/L and an LC_5 of 2.2 mg/L. The Roundup® formulation has an intermediate toxicity with an LC_{50} of 9.4 mg a.e./L and an LC_5 of 6.4 mg a.e./L. The LC_{50} values are comparable to those of fish. No reported hind limb abnormalities were noted. The only abnormalities specified in the publication include uncoiling of the gut, edema, blistering, abnormal pigmentation, and axial twisting in control embryos. No statistically significant increase in abnormalities were seen in any groups exposed to glyphosate IPA, Roundup®, and the POEA surfactant at levels that were not lethal. The precise number and nature of abnormalities in the groups exposed to lethal concentrations of glyphosate IPA, Roundup®, and the POEA surfactant are, however, not specified.

Smith (2001) assayed another formulation of glyphosate, Kleeraway ®Grass and Weed Killer RTU (Monsanto) that contains glyphosate IPA at 0.75% as well as an ethoxylated tallowamine surfactant. Bioassays were conducted on tadpoles (1 week post-hatching) of the western chorus frog, *Pseudacris triseriata*, and the plains leopard frog (*Rana blairi*). The concentrations used in the bioassays are specified in the publication as 0.0001, 0.001, 0.01, 0.1 dilutions of the formulated product. A 0.75% formulation contains 7.5 g/L. Thus, the concentrations used in this study correspond to 0.75 mg IPA/L, 7.5 mg IPA/L, 75 mg IPA/L, and 750 mg IPA/L or 0.56 mg a.e./L, 5.6 mg a.e/L, 56 mg a.e./L, and 560 mg a.e./L. The test protocol involved a 24 hour exposure period followed by a two week observation period to detect sub-lethal toxicity. In *Pseudacris triseriata,* 100% mortality was observed at all concentrations above 0.56 mg a.e./L, and 55% mortality was observed at this concentration. During the post-exposure observation period, 4/9 animals died in first 2 days. In an initial experiment with *Rana blairi*, all tadpoles died at all concentrations. In a repeat experiment using older tadpoles (not otherwise specified), all animals survived at 0.56 mg a.e./L. In both species, normal growth and development was observed over the two week observation period in all survivors.

This very high sensitivity of tadpoles reported by Smith (2001) is not consistent with the study by Bidwell and Gorrie (1995), who assayed the toxicity of glyphosate and "Roundup 360" in four species of frogs from western Australia. For juvenile frogs, 48 hour LC_{50} values were 51.8 mg a.e./L for Roundup® 360 and 83.6 mg/L for technical grade glyphosate. For tadpoles, 48 hour LC_{50} values were 11.6 mg a.e./L for Roundup® 360 and 121 mg/L for technical grade glyphosate. Thus, while the tadpoles were somewhat more sensitive than juveniles, the reported LC_{50} values are in the range of those seen in fish.

Since the completion of the SERA (2003a, b) analyses for glyphosate, several studies have been published on the toxicity of glyphosate formulations on amphibians. Most of these are centered around formulations with the surfactant POEA. These published studies include Roundup® (Mann et al 2003; Relyea 2004, 2005a,b,c; Howe et al 2004; Relyea et al. 2005), Glyphos® (Lajmanovich et al. 2003) and Vision® (Chen et al. 2004; Edington et al. 2004; Thompson et al. 2004; Wojtacszek et al. 2004). As discussed in detail in SERA (2003, Section 3.1.14), the POEA surfactant has been found to be more toxic to aquatic biota than glyphosate alone. Most of the studies cited above did not separate the toxicity of the POEA surfactant from glyphosate. Few of these studies (Relyea 2005c; Connors and Black 2004; Edington et al. 2004) reported toxicity values for the formulations containing the POEA surfactant which are summarized below:

Relyea (2005c) examined Roundup® toxicity to six species of amphibian larvae (*Rana sylvatica, R. pipens, R. clamitans, R. catesbeiana, Bufo americanus,* and *Lyla versicolor*) and estimated the 16 day LC_{50} values for five species which ranged from 1.3 to 2.5 mg a.i./L (which was calculated across species and predator treatments where chemical cues from adult predators, caged red-spotted newts, were emitted). In contrast, for *R. sylvatica* the LC_{50} was 1.32 mg a.i./L estimated without predator cues and the LC_{50} was 0.55 mg a.i./L with predator cues.

For the Vision® formulation, Edington et al. (2004) reported 96 hour LC_{10} and LC_{50} values ranging from 0.83 to 3.5 mg a.e/L for early larval stages of *Rana clamitans* and *R. pipiens*; ranging from 0.85 to 15.6 mg a.e./l for *Xenopus laevis*; and ranging from 1.2 to 2.9 for *Bufo americanus*. Additionally, Edington et al. (2004) found Vision® to be more toxic to amphibian larvae at pH 7.5 than at pH 6.0. Wojtaszek et al. (2004) also examined acute toxicity of Vision® to *R. clamitans* and *R. pipiens* under field conditions by using forested wetlands in Canada. Wojtaszek et al. (2004) reported 96 hour LC_{50} values ranging from 2.70 to 11.5 mg a.e./L (8.71–37.1 mg Vision®/L) depending on species and site. Wojtaszek et al. (2004) concluded that experimental site and the abiotic/biotic factors present, such as pH and suspended sediments, substantially affected the expression of Vision® toxicity in the amphibian larvae tested, and when used in accordance with the product label and Canadian (where the experiments took place) regulations it should have negligible adverse effects on sensitive native amphibian larval life stages. In addition, Thompson et al. (2004) studied Vision® toxicity to larval amphibian in wetlands and found that vegetated buffers used in the study (width ranged from 30 to 60 m) significantly mitigated against exposure to the herbicide and its potential acute effects.

Although the studies mentioned above did not address the differences in toxicity to amphibians of glyphosate and the surfactant POEA, Howe et al. (2004) did look at several glyphosate formulations and POEA. They compared the acute toxicity of Roundup Original® to four amphibian species (*Rana clamitans*, *R. pipiens*, *R. sylvatica*, and *Bufo americanus*) and the toxicity of technical glyphosate, POEA surfactant, and 5 newer formulations to *R. clamitans*. Comparisons between the four amphibian species showed that Roundup Original® toxicity varied with species and developmental stages. Exposure to POEA alone showed toxicity similar to that of Roundup Original® when the toxicity data were compared on the basis of formulation glyphosate acid equivalents (FAE). For *R. clamitans*, acute toxicity values in order of decreasing toxicity were POEA (24 hour LC_{50}= 2.4 mg FAE/L) > Roundup Original® (2.0 mg FAE/L) > Roundup Transorb® (2.3 mg FAE/L) > Glyphos AU® (9.0 mg FAE/L). No significant acute toxicity was observed with technical glyphosate (>17.9 mg FAE/L), Roundup Biactive® (>1709 mg FAE/L), Touchdown® (>17.9 mg FAE/L), or Glyphos BIO® (>17.9 mg FAE/L).

Trumbo (2005) reported LC_{50} values for Rodeo® and the non-ionic surfactant R-11® with an active ingredient nonyphenol polyethoxylate for larval amphibian stage of *Rana pipiens*. The 96-hour LC_{50} for a tank mixture of Rodeo®/R-11® was 6.5 mg/L for Rodeo® and 1.7 mg/L for R-11®.

Aquatic Invertebrates

As with the toxicity data on fish, the U.S. EPA/OPP (1993b) summarizes a standard set of bioassays of toxicity to aquatic invertebrates. For aquatic invertebrates, however, the LC_{50} values are typically given based on a 48 hour rather than 96 hour exposure period. The 48 hour LC_{50} of technical grade glyphosate (83%) to *Daphnia magna* is listed as 780 mg/L, substantially higher than the 96 hour LC_{50} values in freshwater fish. For the common midge, *Chironomus plumosus*, the 48 hour LC_{50} of 96.7% technical grade glyphosate is listed as 55 (31-97) mg/L (U.S. EPA/OPP 1993c, p. 44). As with fish, the toxicity of some formulated glyphosate products to aquatic invertebrates is much greater, with LC_{50} values as low as 3 mg/L (U.S. EPA/OPP 1993b, p. 46). These and other more recent studies submitted to U.S. EPA (e.g. Long et al. 1996a; Long et al. 1996b; Drottar and Swigert 1998a) on the toxicity of glyphosate and glyphosate formulations are summarized in SERA (2003a, Appendix 3; comparison of formulations in toxicity to aquatic organisms). Selected values are shown in Table 2.

Table 2. Aquatic toxicity values for selected formulations of glyphosate Values are from Appendix 3 in SERA (2003a). Note that not all formulations listed are proposed for use on the ANF.

Formulation	Organism Type	Toxicity Value LC_{50} or EC_{50}
Aquamaster®	Fish, Rainbow Trout	>1000 mg/L (96 hr)
	Algae *Scenedesmus subspicatus*	72.9 mg/L (72 hr)
	Daphnia	930 mg/L (48 hr)
Foresters'®	Fish, Rainbow Trout	>1000 mg/L (96 hr)
	Daphnia	930 mg/L (48 hr)
Glyphos®	Fish, Rainbow Trout	22 mg/L (96 hr) (static)
	Daphnia	37 mg/L (48 hr)
	S. capricornutum	2.1 mg/L (72 hr)
Roundup Original®	Fish, Rainbow Trout	8.2 mg/L (96 hr) (flowthrough)
	Daphnia	12.9 mg/L (48 hr) (static)
	S. capricornutum	2.6 mg/L (96 hr) (static)
Roundup Pro Concentrate®	Fish, Rainbow Trout	5.4 mg/L (96 hr) (static)
	Daphnia	11 mg/L (48 hr) (static)
Glypro®	Fish, Rainbow Trout	60 mg/L (acute)
Rodeo®	Fish, Rainbow Trout	60 mg/L (acute)

In addition to registrant submitted studies, Alberdi et al. (1996) has published a comparative study on the toxicity of a glyphosate formulation to two species of daphnids, *Daphnia magna* and *Daphnia spinulata*. The formulation of glyphosate tested in this study contained glyphosate IPA 48% and a different surfactant, characterized as an oxide-coco-amide-propyl dimethyl-amine (15%). The 48 hour EC_{50}s at IPA are reported as 66.18 mg/L in *D. spinulata* and 61.72 (58.8-64.2) mg/L in *D. magna*. These are comparable to the LC_{50} of 72 mg/L for a glyphosate formulation containing the "W" surfactant (U.S. EPA/OPP 1993b).

One chronic life cycle toxicity study with *Daphnia magna* is reported in U.S. EPA/OPP (1993b) with a maximum allowable toxicant concentration (MATC) of between 50 and 96 mg/L. This is comparable to the NOEC of 25.7 mg/L in the life-cycle study in fish (Section 4.1.3.1.2). As with the fish study, this is the most relevant bioassay in aquatic invertebrates for assessing the longer term effects of glyphosate in ambient water.

The effects of glyphosate have also been determined in an aquatic snail, *Pseudosuccinea columella*, an intermediate host of the sheep liver fluke. Tate et al. (1997) assayed glyphosate acid for sub-lethal effects on egg production at concentrations of 0.1, 1, and 10 mg a.e./L for 3 generations. No marked effects were noted on the first or second generations. In the third generation, snail embryos exposed to 1 mg/L developed much faster than those exposed at 0.1 or 10 mg/L and faster than control snails. Hatching, however, was inhibited at 10 mg/L and inhibited slightly at 0.1 mg/L, but egg-laying capacity increased at both of these concentrations. In a follow up study, Tate et al. (2000) noted effects on concentrations of amino acids in snails (specifically alanine, glycine, glutamic acid and threonine) at the same concentrations. Effects on concentrations of some proteins have also been noted by Christian et al. (1993) for this species of snail. The mechanism for the effect of glyphosate on amino acid and protein metabolism is not known. In terms of reproductive effects that might be significant, the

Tate et al. (1997) study suggests that some changes could be observed at concentrations as low as 0.1 mg/L, but that the mixed effects of glyphosate on egg-laying capacity and hatching could be off-setting in terms of total reproductive capacity.

Various field studies have not noted any remarkable effects on aquatic invertebrates. At application rates of 1 L Rodeo®/ha for the control of purple loosestrife, Gardner and Grue (1996) noted no adverse effects on aquatic invertebrates. At application rates of 0.94 or 1.48 kg a.i./ha as glyphosate IPA (Rodeo®), Haag (1986) found no indication of lethality in two water hyacinth weevils, *Neochetin eichhorniae* and *N. bruchi*. In a forest pond mesocosm, Hildebrand et al. (1980) found no differences in invertebrate survival over an 8 day period after sprays of 2.2 kg/ha, 22 kg/ha and 220 kg/ha. Lastly, no indication of short or long term (119 days) effects were noted after the application of a Rodeo® and X-77® mixture in control of smooth cordgrass in a marine estuary. In this study, Rodeo was applied at a rate of 4.7 L/ha and X-77® was applied at a rate of 1 L/ha (Simenstad et al. 1996).

Connors and Black (2004) studied Roundup® toxicity to freshwater mussel glochidia (Bilvalvia: Unionidae *Utterbackia imbecillis*) and reported an LC_{50} value of 18.3 mg/L and for genotoxicity reported an NOEC of 10.04 mg/L.

Tsui and Chu (2003) examined the acute toxicity of technical grade glyphosate acid, isopropylamine (IPA) salt of glyphosate, Roundup®, and POEA surfactant to several aquatic organisms including Microtox® bacterium (*Vibrio fischeri*), microalgae (*Selenastrum capricornutum* and *Skeletonema costatum*), protozoa (*Tetrahymena pyriformis* and *Euplotes vannus*) and crustaceans (*Ceriopdaphuia dubia* and *Acartia tonsa*). The relative toxicity order of the chemicals was POEA > Roundup® > glyphosate acid > IPA salt of glyphosate; however, the toxicity of glyphosate acid was primarily due to its high acidity. Tsui and Chu (2003) concluded that except for photosynthetic microalgae, POEA accounted for more than 86% of Roundup® toxicity, and the toxicity contribution of POEA was species specific.

In 2004, Tsui and Chu compared acute toxicity of three glyphosate formulations (Rodeo®, Roundup®, and Roundup Biactive®) using a water-column organism (Cladoceran: *Ceriodaphnia dubia*) and a benthic organism (Amphipod: *Hyalella azteca*). Tsui and Chu (2004) reported 48 hour LC_{50} values in the water-only tests for Roundup® (1.5–5.7 mg a/L) > Roundup Biactive® (82–120 mg/L) > Rodeo® (225–415 mg/L); *H. azteca* was more sensitive than *C. dubia* to the herbicides. They concluded that the toxicity differences between formulations were due to the different surfactants in the formulations.

One other study (Xi and Feng 2004) reported acute toxicity of glyphosate to freshwater planktonic rotifers (*Brachionus calyciflorus*) as 24 hour LC_{50} at 28.0 mg/L, however the authors only identified the herbicide as a USA commercial grade product containing 41% glyphosate so it is not known if it was a formulation containing a surfactant. Benetsson et al. (2004) also published a study concerning glyphosate toxicity to *Daphnia pulex*, but did not specify the formulation so it is not known if it had a surfactant such as POEA.

Aquatic Plants

The toxicity of glyphosate to aquatic plants has been evaluated by U.S. EPA/OPP (1993b) based on studies submitted for the registration of glyphosate. In addition, several studies are available from the open literature as well as more recent studies submitted to U.S. EPA. These studies are detailed in Appendix 11 for both algae and aquatic macrophytes. As would be expected from an herbicide, glyphosate is much more toxic to aquatic plants than animals. EC_{50} values for technical grade glyphosate in algae reported by U.S. EPA/OPP (1993b, p. 51) are as low as 0.85 mg/L for *Skeletonema costatum* (a marine species). The lower value of 0.85 mg/L for *Skeletonema costatum* appears to be the most sensitive bioassay reported. In a more recent study on this species, Smyth et al. (1996b) report an EC_{50} of 12 (7.6-19) mg/L (and in what we believe was a 5-day acute toxicity exposure test) with an NOEC of 1.8 mg/L and a LOEC of 3.2 mg/L.

Some species appear to be much more tolerant than *Skeletonema costatum*. Smyth et al. (1996c) report EC_{50} of 17 (13-24) mg/L for a freshwater diatom *Navicula pelliculosa*, with growth enhancement observed at 1.8 mg/L and no inhibition observed at concentrations below 32 mg/L, i.e., the EC_{50} was estimated by extrapolation. The EC_{50} value reported for this species in EPA/OPP (1993c, p. 51) is 39.9 mg/L. Stimulation of chlorophyll-a synthesis has also been reported by Wong (2000) in *Scenedesmus quadricauda* at low (0.02 mg/L) concentrations. The most tolerant species of algae appears to be *Chlorella fusca*, with an EC_{50} of 377 mg/L for growth inhibition (Faust et al. 1994).

Freshwater aquatic macrophytes appear to be as sensitive to glyphosate as algae. The U.S. EPA/OPP (1993b) report a 7 day EC_{50} of 21.5 mg/L in duckweed for technical grade glyphosate, very similar to the EC_{50} reported for the freshwater diatom, *Navicula pelliculosa*. More recently, Smyth et al. (1996a) reported an EC_{50} in duckweed for frond numbers to be 12 (11-14) mg/L, with a NOEC of 3 mg/L and a LOEC of 6 mg/L.

Austin et al. (1991) studied the effects of glyphosate on periphyton in artificial streams and noted an increase in periphyton concentrations at concentrations of 0.0019-0.2874 mg/L. The authors suggest that algae are using glyphosate as a phosphorous source, that glyphosate could contribute to eutrophication of coastal oligotrophic (nutrient poor and oxygen rich) waterways, and this could effect salmonid populations. No specific data supporting this supposition, however, is reported. In a pond study, Perschbacher et al. (1997) report no adverse effect on plankton after an application of glyphosate at a rate of 0.43 kg/ha or about 0.4 lbs/acre.

Dose Response Assessment for Glyphosate

This represents the culmination of the hazard analysis and identifies the critical toxicity values used in the risk characterization section. The dose response assessment used by SERA (2003a, b) is used for this assessment as well. The basis of the SERA dose response assessment is as follows:

Glyphosate Toxicity to Terrestrial Wildlife

Mammals

As summarized in the dose-response assessment for the acute and chronic human health risk assessment (Appendix G1, Section 3), the NOAEL in experimental mammals is taken as 175 mg/kg with an associated LOAEL of 350 mg/kg.

The application of these NOAEL and LOAEL values to small rodents is clearly appropriate, since the NOAEL and LOAEL come from a study in rabbits (Rodwell et al. 1980). Ecological risk assessments, however, are intended to encompass a wide range of mammalian species, from very small animals such as mice and voles to large mammals such as deer. For many chemicals, systematic differences in species sensitivity are apparent and generally indicate that small animals are less sensitive (i.e., have higher toxicity values) than large animals. This is not the case for glyphosate. Toxicity values for rats are very similar to the toxicity estimates in humans. For example, as discussed in Section 3.3.3 (SERA 2003a), the threshold for toxicity based on an analysis of lethality data is about 445 mg/kg, virtually identical to the LOAEL of 350 mg/kg in rabbits from the study by Rodwell et al. (1980). The estimated LD_{50} in humans is approximately 3,000 mg/kg, which is consistent with oral LD_{50} values of glyphosate in mammals, which range from approximately 2,000 to 6,000 mg/kg (Williams et al. 2000). Thus, for the SERA (2003a) ecological risk assessment, NOAEL of 175 mg/kg is used directly for both small and large mammals.

The 175 mg/kg NOAEL and 350 mg/kg LOAEL values are used for both the acute and chronic risk assessments. This approach is taken because of the lack of a substantial dose-duration or dose-severity relationship for glyphosate. It may be argued that this approach is somewhat conservative in that the 175 mg/kg/day NOAEL is based on a teratology study in rabbits involving a 21 day exposure period, i.e., days 6-27 of gestation, in which the compound was administered by gavage. Most acute exposure scenarios considered in this risk assessment will involve peak exposures that will occur over a much shorter period, i.e., a 1 day maximum concentration in water or on vegetation. Shorter-term toxicity values that might be used, however, would have very little impact on the risk characterization. As summarized above, the threshold for acute lethality is about 445 mg/kg, virtually identical to the LOAEL of 350 mg/kg in rabbits from the study by Rodwell et al. (1980). Because of concern for non-lethal adverse effects, the estimated NOAEL for lethality would not be an appropriate basis for risk characterization.

Birds

As noted in Section 4.1.2.2 (SERA 2003a), glyphosate has been classified by the U.S. EPA/OPP (1993b) as no more than slightly toxic to birds. As an index of potential toxicity from acute exposure, the U.S. EPA/OPP 1993c uses the gavage study by Fink et al. (1978 as cited in SERA (2003a)) in which the LD_{50} was >2000 mg/kg in bobwhite quail. The more recent studies by Palmer and Beavers (1997a, b) indicate five day dietary LC_{50} values of greater than 5620 ppm in both bobwhite quail and mallard ducks. These dietary values are actually an NOEC in that no mortality or signs of toxicity were observed in any test animals.

For longer-term effects, U.S. EPA/OPP (1993b) uses the dietary NOAELs of 1000 ppm in bobwhite quail (Fink 1975) and mallard ducks (Fink and Beavers 1978). Both of these studies were assays for reproductive toxicity, a relevant and sensitive endpoint for the ecological risk assessment. In the SERA (2003a) risk assessment, the acute dietary studies by Palmer and Beavers (1997a, b) will be used to assess the effects from acute exposures. For longer term exposures, the reproductive NOAEL of 1000 ppm (Fink 1975; Fink and Beavers 1978) was used in the SERA (2003b) risk characterization.

The dietary concentrations will be converted to doses expressed as mg/kg body weight. This approach is taken because the direct use of dietary concentrations from laboratory studies may be under-protective. Laboratory diets generally involve the use of dry food. Dry laboratory chow usually has a higher caloric content than food consumed in the wild, if only because most food consumed in the wild has a high water content. In addition, most reported concentrations of a pesticide in environmental samples are given on a wet (natural) weight rather than a dry (dedicated) weight basis. Consequently, animals tend to eat greater amounts of food in the wild than they do under laboratory conditions (U.S. EPA/ORD 1993b), and thus ingested doses expressed as mg/kg bw/day will be higher in free living animals than in laboratory animals for a fixed concentration in food.

Because of these relationships, U.S. Forest Service risk assessments use doses expressed as mg/kg body weight for both the exposure and dose-response assessments. As detailed in the worksheets, information on caloric requirements and caloric values of different foods is used to estimate the amount of a particular food that an animal will use.

Based on average measured food consumption and body weight from other laboratory toxicity studies on mallard ducks and pheasant, the daily food consumption rates of the birds are approximately 10 to 20% of the body weight. Taking a conservative value of 10% (i.e., a value that leads to the lowest estimate of dose), the 1000 ppm benchmark dietary concentration cited by U.S. EPA corresponds to a daily dose of 100 mg/kg bw.

For the SERA (2003a) risk assessment, the dose of 100 mg/kg bw was used as a NOAEL for characterizing chronic risks for birds. It should be noted that this dose is very close to the NOAEL of 175 mg/kg used for mammals and is consistent with the apparent lack of variability in the toxicity of glyphosate among species. As in the assessment for mammals, this NOAEL is based on a repeated dose study for reproductive effects but will be applied to both acute and longer-term exposures. The acute NOAEL will be taken as 562 mg/kg bw from the acute dietary studies by Palmer and Beavers (1997a, b).

Terrestrial Invertebrate

A standard set of studies are available on the toxicity of glyphosate to honey bees (Palmer and Beavers 1997c; Palmer and Krueger 2001a; Palmer and Krueger 2001b). Palmer and Krueger (2001a) report an NOEC of 100 µg/bee, and the U.S. EPA/OPP (1993b) classifies glyphosate as practically non-toxic based on an LD_{50} of >100 µg/bee. The NOEC used in the SERA (2003a) risk assessment, however, will be taken as 50µg/bee. The dose of 100 µg/bee from the study by Palmer and Krueger (2001a) was associated with 5% mortality (3/60), and this response was statistically significant when untreated and solvent controls are pooled.

Taking the NOEC of 50 µg/bee and using a body weight of 0.093 g for the honey bee (USDA/APHIS 1993), the 50 µg/bee dose corresponds to about 540 mg/kg bw [0.050 mg/0.000093 kg = 537.6 mg/kg]. This value will be used in the risk characterization for assessing effects of direct contact on terrestrial invertebrates.

Given the large number of species of terrestrial invertebrates, the use of data from a single species for the risk characterization obviously leads to uncertainty in the risk assessment. As noted in the hazard section, several additional studies are available on other terrestrial invertebrates. These studies, however, cannot be used quantitatively in the dose-response assessment either because of the way in which exposures were conducted or characterized. Nonetheless, they provide information that can be used in the risk characterization.

Impact on Soil Nutrient Cycling

As reported by SERA (2003a, section 4.1.2.4), soil concentrations of 100 ppm of glyphosate or AMPA had no significant effect on soil denitrification (Pell et al. 1998). Bromilow et al. (1996) noted no effects on soil fertility in repeated applications over 14 years–1980 to 1993–of glyphosate at 1.4 kg/ha based on assays for microbial biomass and crop productivity. From this we conclude the proposed use of glyphosate will not adversely affect soil nutrient cycling (see additional discussion on this topic in Appendix G1 on p G1-43 and G1-44).

Terrestrial Plants (Vascular)

Standard toxicity studies required for pesticide registration are available on pre-emergence and post-emergence exposures. In seedling emergence assays, very high concentrations, i.e., 10 lb a.i./acre or about 7.5 lbs a.e./acre, will modestly inhibit seed germination in both monocots and dicots (Bohn1987). The NOEC for seed germination is 4.5 lb a.e./acre in both monocots and dicots (Everett et al. 1996a; Willard 1996). This value is used in Worksheet G04 (SERA 2003b) to assess the consequences of off-site movement of glyphosate in runoff. However, note that the maximum application rate on ANF is 4 lb/acre, which is less than the NOEC, hence we conclude there will be no impact on vascular plants from runoff.

Glyphosate appears to be more toxic in vegetative vigor assays, i.e., direct application to the foliage of growing plants. The lowest reported NOEC for growth in standard bioassays required for registration is 0.035 lb a.e./acre, reported for tomato and radish in the study by Chetram and Lucash (1992). The highest reported NOEC for growth is 0.56 lb a.e./acre for ryegrass, corn, and onions, also from the study by Chetram and Lucash (1992). This range of values for sensitive and relatively insensitive species is very similar to the range of LC_5 values reported in the vegetative vigor assay of Everett et al. (1996b).

The report by Al-Khatib and Peterson (1999) that transient visual injury occurs in soybeans at an application rate of about 0.03 lb a.e./acre is not consistent with the study by Chetram and Lucash (1992), in which no visual damage to soybeans was evident at 0.07 lb a.e./acre. Nonetheless, variations among studies is not uncommon and the study by Al-Khatib and Peterson (1999) appears to have been well-conducted.

In the SERA (2003a) risk assessment, growth is used in preference to transient visual damage for the quantitative characterization of risk. Thus, as indicated in Worksheet G05 (SERA 2003b), the NOEC values for sensitive and tolerant species are taken from the study by Chetram and Lucash (1992).

As also noted in SERA (2003a, Section 4.1.2.5), exposures substantially above the NOEC of 0.07 lb/acre, i.e., in the range of 0.7 lb/acre, may have long term impacts on bryophyte and lichen communities (Newmaster et al. 1999). This is not a highly sensitive endpoint compared to the much lower NOEC values used above for the quantitative dose-response assessment.

Glyphosate Toxicity to Aquatic Organisms

Fish

As detailed in the hazard section, U.S. EPA/OPP (1993b) classified technical grade glyphosate as non-toxic to practically non-toxic in freshwater fish, and LC_{50} values for glyphosate are in the range of 70 to 170 mg/L. In addition, the U.S. EPA/OPP (1993b) used the NOEC of 25.7 mg/L from life cycle toxicity study on technical grade glyphosate using fathead minnow and concluded that:

> *"technical glyphosate should not cause acute or chronic adverse effects to aquatic environments. Therefore, minimal risk is expected to aquatic organisms from the technical glyphosate."*

The selection of the toxicity values by U.S. EPA/OPP (1993b), however, does not explicitly address the higher toxicity of some glyphosate formulations containing surfactants, nor does it address the higher sensitivity of some species of fish to technical grade glyphosate. We note that much of the following discussion includes glyphosate formulations with surfactants that contribute significantly to toxicity, especially in aquatic species. Accord Concentrate® and Rodeo® do not contain these surfactants. All of the surfactants proposed for use by the ANF in this program are in U.S. EPA Class 4b, meaning their use is not expected to have adverse effects on human health or the environment. We include the discussion of toxicity that encompasses more toxic surfactants for completeness.

As discussed in SERA (2003a, Section 4.1.3.1.3), some formulations of glyphosate contain surfactants that are highly toxic to fish, and the 96 hour LC_{50} values for these formulations can be in the range of 1 mg/L, substantially below the NOEC for glyphosate in the fathead minnow life cycle toxicity study. In terms of sensitive species, trout and other salmonids have much lower LC_{50} than those cited by U.S. EPA/OPP (1993b), with the lowest LC_{50} value for salmonids of 10 mg glyphosate/L, for trout (SERA 2003a, Table 4-2).

The data necessary to address these issues directly are not available. Given the apparently high sensitivity of some salmonids to some glyphosate formulations, it would be desirable to have a life cycle toxicity study or at least an egg-and-fry study available on salmonids. In addition, given the apparently high toxicity of surfactant formulations compared to technical grade glyphosate, a life cycle toxicity study on at least one formulation containing a toxic surfactant would be desirable.

In the absence of these types of studies, the relative potency method is the only remaining approach to assessing the potential consequences of longer-term exposures of more toxic formulations to more sensitive species. As discussed in U.S. EPA/ORD (2000), the relative potency method involves the assumption that the ratios of toxicity values are equal among differing bioassays. As applied to the current problem, the relative potency method involves the assumption that the ratios of the available data on acute LC_{50} values for glyphosate and glyphosate formulations can be used to assess the chronic NOEC for a glyphosate formulation.

Specifically, the LC_{50} value of a glyphosate formulation containing a more toxic type of surfactant to the fathead minnow is 2.3 (1.9-2.8) mg/L (U.S. EPA/OPP 1993b, p. 42). The LC_{50} value of technical grade glyphosate (96.7%) to the fathead minnow is 97 (79-120) mg/L (U.S. EPA/OPP 1993b, p. 40). Using the central estimates, the formulated product is more toxic than technical grade glyphosate by a factor of about 40 [97 mg/L ÷ 2.3 mg/L = 42.2]. Taking the life cycle NOEC of 25.7 mg/L for technical grade glyphosate in the fathead minnow and using the relative potency method, the life cycle NOEC for the formulation is estimated at 0.64 mg/L [25.7 mg/L ÷ 40].

The issue of species sensitivity may be addressed in a similar manner. As noted above, the lowest LC_{50} value for technical grade glyphosate in salmonids is 10 mg/L for rainbow trout in soft-water (Wan et al. 1989 as summarized in SERA (2003a, Table 4-2). Thus, salmonids may be more sensitive than fathead minnows to technical grade glyphosate by a factor of about 10 [97 mg/L ÷ 10 mg/L]. Taking the life cycle NOEC of 25.7 mg/L for technical grade glyphosate in the fathead minnow and using the relative potency method for species sensitivity, the life cycle NOEC for technical grade glyphosate in rainbow trout is estimated at about 2.57 mg/L [25.7 mg/L ÷ 10].

A similar approach may be taken to estimate the life cycle NOEC for trout. As discussed above, the life cycle NOEC for the surfactant formulation (surfactant identity unknown, but it seems logical it would be the more toxic forms, which are not used on ANF) in fathead minnow is estimated at 0.64 mg/L. The lowest LC_{50} value in the fathead minnow is 2.3 mg/L. In salmonids, the lowest reported LC_{50} value for a surfactant formulation is 1.3 mg/L (U.S. EPA/OPP 1993b, rainbow trout, p. 42). This is lower than any of the LC_{50} values for surfactant formulations of glyphosate published in the open literature. Thus, for surfactant containing formulations, the sensitivity of salmonids relative to minnows is a factor of about 1.8 [2.3 mg/L ÷ 1.3 mg/L= 1.77]. Thus, the NOEC for the surfactant formulation in salmonids is estimated at 0.36 mg/L [0.64 mg/L ÷ 1.8 = 0.355]. SERA (2003a, Appendix 3c) reports rainbow trout LC_{50} toxicity values for Accord SP®, Rodeo®, Foresters® and Glypro®, which are the same or similar to the formulations proposed for use by the ANF. Specifically the LC_{50} values are as follows: Accord SP® 60 mg/L, Foresters® >1000 mg/L, Glypro® 60 mg/L and Rodeo® 60 mg/L. These values are much higher than the value for the less sensitive fat head minnow, and therefore provide assurance that the aquatic risk assessment based on the critical toxicity values we use is conservative.

Thus, the following chronic NOEC values are used in Worksheet G03 (SERA 2003b) to characterize risk to fish: Note that the surfactant referred to in this portion of SERA (2003a) is believed to be the POEA type surfactant, which is not in any of the formulations used by the ANF. Therefore we adopt the values either for technical glyphosate, or the low toxicity commercial formulations for use in this risk assessment.

typical fish, technical grade glyphosate:	25.7 mg/L [observed]
sensitive fish, technical grade glyphosate:	2.57 mg/L [estimated]

For acute toxicity, the data on sub-lethal effects, summarized in SERA (2003a, Section 4.1.3.1.4), could be considered, but reported concentrations are generally above the LC_{50} values.

As an alternative, the LC_{50} values will be used to characterize the risk of observing mortality in fish associated with peak concentrations of glyphosate. While the use of LD_{50} and LC_{50} values is generally avoided, the use of 96 hour LC_{50} values to assess the risks of peak exposure is inherently conservative in that most peak exposures will occur for a period of time much shorter than 96 hours (Authors note: 96 hours is the standard period of exposure in toxicity tests). Thus, the following 96 hour LC_{50} values are used for characterizing the risks of short-term exposures in Worksheet G03 (SERA 2003b): Note that the surfactant referred to in this portion of SERA (2003a) is believed to be the POEA type surfactant, which is not in any of the formulations used by the ANF. Therefore we adopt the values either for technical glyphosate or the low toxicity commercial formulations for use in this risk assessment.

typical fish, technical grade glyphosate:	97 mg/L
sensitive fish, technical grade glyphosate:	10 mg/L

Amphibians

No separate dose-response assessment is conducted in this risk assessment for amphibians. As detailed in the hazard section, glyphosate and glyphosate formulations have been tested in a number of different bioassays with amphibians, and there is no indication that glyphosate or glyphosate formulations induce deformities in amphibians. Most of the available toxicity data suggest that amphibians are no more sensitive to glyphosate than fish. The report by Smith (2001) does suggest a greater sensitivity of tadpoles to a specific formulation. However, this study is not supported by the other available amphibian studies on glyphosate and glyphosate formulations. In addition, this study involves a formulation that is not used in ANF programs.

Aquatic Invertebrates

The issues in the dose-response assessment for aquatic invertebrates are very similar to those encountered in the dose-response assessment for fish (SERA 2003a, Section 4.3.3.1). There is sufficient data to assert that some glyphosate formulations that contain toxic surfactants may be much more toxic to aquatic invertebrates than technical grade glyphosate. There is only one chronic study on technical grade glyphosate and no chronic studies on glyphosate formulations.

One quantitative difference, however, involves the apparent magnitude of the differences in toxicity among technical grade glyphosate and various glyphosate formulations. The 48 hour LC_{50} value for technical grade glyphosate to *Daphnia magna* is listed in U.S. EPA (1993b, p. 45) as 780 mg/L. The 48 hour LC_{50} values for *Daphnia magna* of various glyphosate formulations, however, range from 3 mg/L (surfactant not specified) to >1000 mg/L (glyphosate with X-77 surfactant, note X-77 is labeled for use in aquatic systems). The one chronic life cycle toxicity study with *Daphnia magna* using technical grade glyphosate reports an MATC of between 50 and 96 mg/L, similar to the NOEC of 25.7 mg/L in the life-cycle study in fish.

As summarized in Appendix 3c (SERA 2003a), the formulations of glyphosate that are registered for forestry uses have a wide but narrower range of toxicity than the range reported in U.S. EPA (1993b). Based on the data presented in Appendix 3c (SERA 2003a), the acute toxicity of glyphosate formulations to *Daphnia magna* ranges from 11 mg/L (e.g. Roundup Pro®, Roundup Pro Concentrate®, Roundup UltraMax®) to 930 mg/L (e.g. Aqua Neat®, Aquamaster®).

The 48 hour LC_{50} value for technical grade glyphosate to *Daphnia magna* will be taken as 780 mg/L. Recognizing that some surfactant formulations may be at least somewhat less toxic than technical grade glyphosate, it will be assumed that formulations summarized in Appendix 3c (SERA 2003a) that have a low toxicity, i.e., 930 mg/L, are either technical grade glyphosate or glyphosate with a surfactant of low toxicity. It will be assumed that the formulations with a substantially lower LC_{50} contain a toxic surfactant. The extremely toxic product reported in U.S. EPA/OPP (1993b) that has an LC_{50} value of 3 mg/L will not impact the dose-response assessment because none of the products that might be used in U.S. Forest Service programs, including the ANF, (Appendix 3c, SERA 2003a) have an LC_{50} value that is this low.

The four formulations of glyphosate proposed for use on the ANF are believed to be what SERA (2003a) calls less toxic formulations. The values used to characterize risk to aquatic invertebrates in SERA (2003b, Worksheet G03) and are used in this ANF risk assessment are:

Acute LC_{50}, less toxic formulation:	780	mg/L
Chronic NOEC, less toxic formulation:	50	mg/L

Note that among the four formulations of glyphosate proposed for the ANF, SERA (2003a) contains data for aquatic invertebrates only for Foresters® (LC_{50} 930 mg/L). However for all formulations in which there is toxicity data for both trout and an aquatic invertebrate, the magnitude of the trout LC_{50} is very similar to the LC_{50} for the aquatic invertebrate. Therefore we conclude that the invertebrate LC_{50} for Glypro®, Accord Concentrate® and Rodeo® should be less than 100 mg/L. Therefore, as with the fish, the use of these critical toxicity values provides a conservative estimate of risk.

Aquatic Plants

As discussed in Section 3.1.3.4 and detailed in Appendix 11 (SERA 2003a), glyphosate appears to be about equally toxic to both algae and macrophytes. A greater complication in the characterization of ecological effects may involve the enhancement of algal populations at low concentrations of glyphosate. It is unclear whether this is a hormetic effect or simply a stimulation of algal growth due to the utilization of glyphosate as a nutrient source by algae.

In terms of growth inhibition, the NOEC of 3 mg/L in duckweed (Smyth et al. 1996a) will be used to characterize risk due to inhibition. At lower concentrations, i.e., in the range of 0.002 mg/L to 0.3 mg/L or higher, stimulation of algal growth may be a more common response and has been noted in several studies (Austin et al. 1991; Smyth et al. 1996c; Wong 2000.

Based on this hazard analysis we conclude the toxicity values in Table 3 are most relevant and appropriate for this risk analysis. Typically these values are the NOAEL for the most sensitive species of a given type and for formulations of glyphosate of the type to be used on the ANF.

Table 3. Critical Toxicity Values for Glyphosate Risk Analysis

Type of Organism	*Critical Toxicity Value*	*Type of Value*
Mammal		
acute exposure	*175 mg/kg*	*Acute NOAEL*
chronic exposure	*175 mg/kg/day*	*Chronic NOAEL*
Bird		
acute exposure	*562 mg/kg*	*Acute NOAEL*
chronic exposure	*100 mg/kg/day*	*Chronic NOAEL*
Honey Bee		
acute exposure	*540 mg/kg*	*NOEC*
Fish, typical species		
acute exposure	*97 mg/L*	LC_{50}
chronic exposure	*25.7 mg/L*	*NOEC*
Fish, sensitive species		
acute exposure	*10 mg/L*	LC_{50}
chronic exposure	*2.57 mg/L*	*NOEC*
Aquatic Invertebrates		
acute exposure	*780mg/L*	LC_{50}
chronic exposure	*50 mg/L*	*NOEC*
Aquatic Plants		
acute and chronic exposure	*3 mg/L*	*NOEC*

Table 4 shows the results of limited specific toxicity testing with the formulations or similar formulations of glyphosate proposed for use on the ANF.

Table 4. Toxicity values for domestic animals and terrestrial wildlife (including invertebrates) for a few glyphosate formulations, some of which are proposed for use on the ANF Values are from SERA (2003b; Appendix 3)*

Formulation	**Rat Oral LD_{50}**	**Rabbit Dermal LD_{50}**	**Domestic goat (non target toxicity) LD_{50}**	**Bobwhite quail (*Colinus virginianus*) LD_{50}**	**Earthworm (*Eisnia foetida*) LC_{50}**
Glyphosate acid	>5000 mg/kg	>5000 mg/kg	*not available*	*not available*	*not available*
Glyphosate IPA	*not available*	*not available*	*not available*	*not available*	*not available*
Accord SP®	>5000 mg/kg	>5000 mg/kg	*not available*	>2000 mg/kg	>1000 mg/kg
Foresters' Non-selective herbicide®	>5000 mg/kg	>5000 mg/kg	5700 mg/kg	*not available*	*not available*
Glypro ®	>5000 mg/kg	>5000 mg/kg	*not available*	>2000 mg/kg	>1000mg/kg
Rodeo®	>5000 mg/kg	>5000 mg/kg	*not available*	>2000 mg/kg	>1000mg/kg

*Accord SP® is similar to Accord Concentrate® except that Accord Concentrate® is slightly more concentrated.

Sulfometuron Methyl Toxicity

Terrestrial Wildlife Species

Sulfometuron methyl is slightly toxic to birds and mammals based on acute oral LD_{50}s of greater than 5,000 mg/kg in the rat and mallard duck (U.S. EPA 1984a; DuPont 1983b). No data from studies conducted under field conditions (i.e., not in the laboratory) are available that assess the impact of sulfometuron methyl applications on mammalian wildlife species. Toxicity experiments have been conducted on laboratory animals (rats, rabbits, and dogs) and are discussed in greater detail in Appendix G1, Section 6. It is slightly irritating to rabbit eyes and skin but is nonsensitizing to guinea pigs (U.S. EPA 1984a). No teratogenic effects have been observed in rats and rabbits exposed to sulfometuron methyl (U.S. EPA 1984a), however, lower maternal body weights and decreased numbers of offspring were observed at 250 mg/kg/day in a reproductive study in rats (DuPont 1986).

SERA (2004a, pp. 4-2 to 4-3) discussed four available studies on birds:

In one of these studies, Dudeck and Bristol (1981b), considerably high and unexplained mortality was observed in the control group (5 of 10 animals died). Consequently, the study is not used in this risk assessment. Apparently, the other three studies, one single dose gavage study in mallard ducks (Dudeck and Bristol 1981a), one 9 day dietary study in mallard ducks (Dudeck and Twigg 1980), and one 5 day dietary study in young bobwhite quail (Fink et al. 1981) assayed only for relatively gross effects (i.e., overt signs of toxicity, changes in body weight and food consumption). No longer-term or chronic exposure studies or standard bioassays on reproductive effects in birds were identified in the available literature. No studies investigating the acute or chronic toxicity of formulations of sulfometuron methyl to birds were identified in the available literature.

In adult mallard ducks administered single doses of technical grade sulfometuron methyl ranging from 312 to 5000 mg/kg, no mortality was observed, placing the LD50 value > 5000 mg a.i./kg (Dudeck and Bristol 1981a). Compared to control birds, males, but not females had decreased weight gain at doses of 625 mg/kg and higher. Although the decrease in weight gain did not exhibit dose-dependence with respect to the magnitude of effect, the NOAEL for changes in body weight is 312 mg/kg. In the dietary exposure studies with technical grade sulfometuron methyl, no mortality or signs of toxicity were reported at concentrations up to 5000 ppm in ducks (equivalent to 332.5 mg/kg/day) (Dudeck and Twigg 1980) or up to 5620 ppm in quail (equivalent to 1068 mg/kg/day) (Fink et al. 1981). All dose-conversions are described in Appendix 4 (SERA 2004a). Thus, the NOAEL for short-term dietary exposure in mallard ducks is 5000 ppm (332.5 mg/kg/day) and in bobwhite quail is 5620 ppm (1068 mg/kg/day).

Terrestrial Invertebrate Species

Only two studies have been reported for terrestrial invertebrates, in this case domesticated bees. No studies on the terrestrial life-stages of some insects with early aquatic life-stages have been reported. SERA (2004a, p. 4-4) summarized the bee toxicity studies:

No mortality was noted in bees exposed to up to100 µg/bee (Hoxter and Smith 1990). In this study, nominal doses of 13, 22, 36, 60, or 100 µg a.i./bee in an ethanol vehicle were applied to 1 to 4 day post-emergence bees, with two replicates per dose level and 25 bees per replicate. The bees were observed twice a day on days 1 and 2. Similar results were reported by Du Pont de Nemours (1983), with no mortality or signs of toxicity at doses of 6.25 and 12.5 µg a.i./bee. Using a body weight of 0.093 g for the honey bee (USDA/APHIS 1993), these values correspond to doses ranging from about 65 mg/kg [0.00625 mg/0.000093 kg] to 1075 mg/kg [0.1 mg/0.000093 kg] , with an LD_{50} value >1075 mg/kg and the NOAEL for mortality and toxicity of 1075 mg/kg. No longer-term exposure studies for terrestrial invertebrate were identified in the available literature. No studies investigating the acute or chronic toxicity of formulations of sulfometuron methyl to terrestrial invertebrates were identified in the available literature.

Terrestrial Plants

The 1991 ANF FEIS for vegetation management did not include terrestrial plants, however terrestrial plants support wildlife populations by providing food, shelter, and nesting materials. SERA (2004a, Section 4.1.2.4 on pp. 4-4 to 4-5) did include terrestrial plants as part of their analyses and summarized several studies related to toxicity to agricultural crops, non-target plants, and target weed species.

The toxicity of sulfometuron methyl to terrestrial plants was studied extensively and is well characterized (e.g. Aulgur 1996, Gaeddert et al. 1997, Landstein et al. 1995, Schloss et al. 1988, Shaner et al. 1990, Stidham 1991). Sulfometuron methyl inhibits acetolactate synthase (ALS), an enzyme that catalyzes the biosynthesis of three branched-chain amino acids (valine, leucine, and isoleucine), all of which are essential for plant growth. This target enzyme (ALS) is also referred to as acetohydroxy acid synthase or AHAS (e.g. Epelbaum et al. 1996). Other ALS inhibiting herbicides include other sulfonylureas as well as imidazolinones, triazolopyrimidines, and pyrimidinylthiobenzoates.

The most relevant laboratory bioassay regarding the toxicity of sulfometuron methyl to terrestrial plants is summarized in Appendix 5 (SERA 2004a). The quantitative use of these studies for this risk assessment is discussed in Section 4.3 (SERA 2004a). In a recent study submitted to the U.S. EPA (McKelvey 1995), bioassays were conducted on pre-emergence and post-emergence toxicity to corn, cucumber, onion, pea, rape, sugar beet, sorghum, soybean, tomato, and wheat. In the pre-emergence assay, the most sensitive species based on the NOEC were rape, tomato, sorghum, wheat, and corn with an NOEC of 0.0000086 lb a.i./acre. The most tolerant species based on the NOEC were onion, pea, cucumber, and soybean with an NOEC of 0.00026 lb/acre. In the post-emergence assay, most sensitive species based on the NOEC is corn with an NOEC of 0.000024 lb a.i./acre. The most tolerant species in the post-emergence assay was pea with an NOEC of 0.00078 lb a.i./acre.

In terms of a hazard identification, however, it is noteworthy that some target species, like the leafy spurge (Beck et al. 1993) and certain species of pine (Barnes et al. 1990) are much less sensitive than a number of non-target dicots and monocots (Drake 1990) to the effects of sulfometuron methyl. Adverse effects were observed in most plants tested at application rates of 0.001 kg/ha [0.000892 lbs a.i./acre]. This application rate is about 100 to 200 times lower than the application rate of 0.09 and 0.19 lb/acre proposed for use by ANF. In the experience of ANF personnel, early fall applications (first two weeks of September) of Oust XP® effectively controls herbaceous species without having an adverse effect on tree seedlings.

Only two new terrestrial studies using sulfometuron methyl were published since the completion of the SERA (2004 a, b) analyses (Michael 2003 and Keyser et al. 2003). Keyser et al. (2003) examined how vegetation controlled with Oust® (used three different rates; 0, 2, and 4 oz/acre) compared to physical site preparation vegetation control techniques in terms of their affect on wildlife habitat quality in Virginia pine plantations but did not look at toxicity of the herbicide to terrestrial organisms.

Michael (2003) examined the environmental fate and impacts of Oust® on watersheds from aerial applications (helicopter) made to loblolly pine (*Pinus taeda*) plantations in Mississippi. The target application rate in the treated watershed was 0.42 kg a.i./ha. Fifteen meter (15 m) untreated steamside management zones were maintained on each side of the streams throughout their length where water was visible at the time the zones were established. Twenty-four hours after application the average sulfometuron methyl concentrations in surface waters ranged from non-detectable to a maximum of 49.3 µg/L; sulfometuron methyl was not detected at quantifiable levels (1 µg/L) downstream from the treated areas. Sulfometuron methyl dissipated from the watersheds with half-lives ranging from 4 days in plant tissues to 33 days in soil. The 15-meter buffer in this study is similar to the 50-foot buffer proposed for the ANF when using an application rate of 0.19 lb/acre. In contrast however, the Michael study involved aerial application, which is not used on ANF.

Aquatic Species

The 1991 FEIS for the ANF determined that sulfometuron methyl was only slightly toxic to aquatic organisms based on toxicity tests using bluegill, rainbow trout, crayfish, and water fleas. No effects were observed on embryo hatch or larval survival at concentrations up to 1.2 mg/l using fathead minnows (DuPont 1983). Since then more studies have been reported and more detail on earlier studies was made available to SERA. Note that toxicity testing and the description of environmental levels are all done in concentrations typically expressed as mg/liter a.i. While formulations as they are applied in the field and described in this document often express concentration as percent in solution, these values do not translate to concentrations in the environment or toxicity tests.

This information was summarized by SERA (2004a, pp. 4-6 through 4-9):

Fish

Acute toxicity studies have been conducted in fathead minnow (Muska and Driscoll 1982), rainbow trout (Brown 1994b, Muska and Trivits 1980b) and bluegill sunfish (Brown 1994a, Muska and Hall 1980) and chronic exposure was studied in fathead minnow (Muska and Driscoll 1982). No field studies on the effect of sulfometuron methyl in fish were identified in the published literature or the U.S. EPA files. Due to the poor solubility of sulfometuron methyl, the maximum concentration tested was 150 mg/L in the studies by Brown (1994 a, b); the maximum concentrations tested in all other studies were lower than 150 mg/L. In some studies dimethyl formamide (DMF) was added (Muska and Driscoll 1982, Muska and Hall 1980, Muska and Trivits 1980b) or the pH of the water was adjusted (Brown 1994a, b) to increase solubility. In each case, appropriate control groups were included. No studies investigating the acute or chronic toxicity of formulations of sulfometuron methyl in fish were identified in the available literature.

Investigations of the acute LC_{50} have been hampered by the limited water solubility of sulfometuron methyl. For acute toxicity studies, the LC_{50} values range from >7.3 mg/L in fathead minnow (Muska and Driscoll 1982) to > 150 mg/L in bluegill sunfish (Brown 1994a) and rainbow trout (Brown 1994b). The lowest concentration at which any mortality was observed in any species of fish is 1.25 mg/L. At this level, mortality was observed in 1/10 bluegill sunfish. No mortality, however, was observed in 10 bluegills exposed to 12.5 mg/L (Muska and Hall 1980). Thus, mortality does not appear to be treatment related. Since no signs of toxicity were observed in any study, NOEC values are placed at the highest concentration of sulfometuron methyl tested in each study–7.3 mg/L for fathead minnows (Muska and Driscoll 1982), 12.5 mg/L (Muska and Hall 1980) and 150 mg/L (Brown 1994a) in bluegill sunfish, and 12.5 mg/L (Muska and Trivits 1980b) and 150 mg/L (Brown 1994b) in rainbow trout.

Muska and Driscoll (1982) is the only study available regarding the toxicity of sulfometuron methyl to fish eggs or fry. These investigators observed no effects on fathead minnow embryo hatch, larval survival, or larval growth over 30 day exposure periods in which the measured average concentrations were 0.06, 0.14, 0.32, 0.65, and 1.17 mg a.i./L.

Amphibians (Aquatic Life-stages)

The toxicity of sulfometuron methyl to amphibians has been evaluated in a single study in African clawed frogs (*Xenopus laevis*, Fort 1998 as cited in SERA (2004a)). Results show that short-term (96 hours) and longer-term (14 and 30 days) exposure to the sulfometuron methyl resulted in alterations in limb development, organogensis, and metamorphosis. The most sensitive endpoint examined in this study was metamorphosis. To enhance solubility of the test material, DMSO (1% v/v) was added; the authors state that this concentration of DMSO did not adversely alter normal larval development. The author did not state whether data were reported in terms of mg sulfometuron methyl/L or mg Oust®/L. Taking the most conservative approach, the authors of SERA (2004a) assumed that the values are to be expressed in terms of mg Oust®/L to avoid any complications from the use of the DMSO in the test done with sulfometuron methyl. Due to the higher water solubility of Oust®, acute toxicity studies could test much higher concentrations than those evaluated in studies on technical grade sulfometuron methyl. Unfortunately, since the full dose-response relationship could not be defined in studies with technical grade sulfometuron methyl, comparisons of LC_{50} values of Oust® and technical grade sulfometuron methyl are of limited value.

The effects of short-term exposures to sulfometuron methyl on lethality and organogensis were studied in blastulae stage embryos of the African clawed frog (*Xenopus laevis*, Fort 1998 as cited in SERA (2004a)). The embryos were exposed to concentrations of sulfometuron methyl ranging from 0.001 to 10 mg Oust®/L (the limit of solubility) for 4 days. No mortality was observed at concentrations up to 0.1 Oust® mg/L (0.00075 to7.5 mg a.i./L). Although 2.5% morality was observed at the 0.38 mg a.i./L mg/L concentration, this was not statistically different from the control group. Malformations observed in this study include miscoiling of the gut, incomplete lens formation of the eye, and abnormal craniofacial development. The severity of these malformations was graded as moderate. At the highest concentration tested, malformations were observed in 100% of animals. NOAEL [0.38 mg a.i./L] and LOAEL [0.75 mg a.i./L] values are the same for both mortality and malformations.

The effects of longer-term exposure on organogensis was studied by exposing blastula stage embryos to concentrations of sulfometuron methyl ranging from 0.001 to 10 mg Oust®/L for 30 days. Malformations were observed in 100% of animals at concentrations of 1.0 mg/L and 10.0 mg/L (0.75 and 7.5 mg a.i./L). A decrease in tail resorption rates, a morphological indicator of thyroid disruption, was observed in blastula stage embryos exposed to sulfometuron methyl for 14 days. In animals exposed for 14 days to concentration ranging from 0.0001 to 1 mg/L (0.000075 to 0.75 mg a.i./L), resorption rates were increased in the 0.001 and 0.01 mg/L (0.00075 and 0.0075 mg/L) treatment groups. Effects were partially reversed by the addition of thyroxin. Results indicate that exposure to sulfometuron methyl adversely affects metamorphosis in frogs at concentrations of 0.00075 mg a.i./L, but this is greater than the ANF water quality protection criterion of 0.00021 mg/L.

Aquatic Invertebrates

Acute toxicity studies on technical grade sulfometuron methyl have been conducted in *Daphnia magna* (Brown 1994b, Muska and Trivits 1980a), and on Oust® have been conducted in *Daphnia magna* (Wetzel 1984), crayfish (Naqvi et al. 1987), and four other species of fresh water aquatic invertebrates (Naqvi and Hawkins 1989). Chronic exposure to technical grade sulfometuron methyl was studied in *Daphnia magna* (Baer 1990). No field studies on the effect of sulfometuron methyl in aquatic invertebrates were identified in the published literature or the U.S. EPA files.

Acute exposure to sulfometuron methyl appears to be relatively non-toxic to aquatic invertebrates, based on acute bioassays in *Daphnia* (Muska and Trivits 1980a, Brown 1994b, Wetzel 1984), crayfish (Naqvi et al. 1987), and field-collected species of *Diaptomus*, *Eucyclops*, *Alonella*, and *Cypria* (Naqvi and Hawkins 1989). For studies on technical grade sulfometuron methyl in *Daphnia*, 48 hour LC_{50} values range from > 12.5 mg/L (Muska and Trivits 1980a) to >150 mg/L (Brown 1994b), the maximum concentrations tested. In the Muska and Trivits (1980a) study, mortality was observed in 1 of 10 daphnids in the lowest exposure group (0.125 ppm) (Muska and Trivits 1980a) and in the DMF control group, but not in groups exposed to 1.25 and 12.5 ppm. Thus, mortality does not appear to be related to sulfometuron methyl exposure.

The LC_{50} value reported in *Daphnia* for Oust® is considerably higher than for technical grade sulfometuron methyl (8500 mg Oust/L or 6375 mg a.i./L), with a NOEC of 2400 mg Oust®/L (1800 mg a.i./L) and an LOEC of 3200 mg Oust®/L (2400 mg a.i./L) (Wetzel 1984). High LC_{50} values ranging from 802 mg Oust®/L (602 mg a.i./L) in *Alonella* sp. to 2241 mg Oust®/L (1681 mg a.i./L) in *Cypria* sp. were reported by Naqvi and Hawkins 1989, with LOEC values for both species of 100 mg Oust®/L (75 mg a.i./L), the lowest dose tested. The highest LC_{50} value of 12,174 mg/L was reported in crayfish (Naqvi et al. 1987). Neither of the Naqvi studies specifically state whether data are reported in terms, of mg Oust®/L or mg a.i./L, although it is implied that data are reported in terms of the formulation; taking the most conservative approach, the authors of SERA (2004a) inferred that data are reported in terms of mg Oust®/L. However, regardless of how these data are expressed, crayfish appear to be far more tolerant to the effects of sulfometuron methyl than other aquatic invertebrate species tested based on LC_{50} values. Due to the higher water solubility of Oust®, acute toxicity studies could test much higher concentrations than those evaluated in studies on technical grade sulfometuron methyl. Unfortunately, since the full dose-response relationship could not be defined in studies with technical grade sulfometuron methyl, comparisons of LC_{50} values of Oust® and technical grade sulfometuron methyl are of limited value.

One daphnid reproduction study on technical grade sulfometuron methyl was conducted (Baer 1990). As indicated in Appendix 6 (SERA 2004a), the number of neonates per surviving adult was significantly reduced at 24 mg/L but not at 97 mg/L or any of the lower concentrations. The authors report the NOEC as 6.1 mg a.i./L. Although the effect observed at 24 mg/L may have been a random variation, it is treated as an LOEC for the purpose of this risk assessment. While this approach may be regarded as conservative, in the absence of additional studies regarding reproductive effects in aquatic invertebrates, the approach seems prudent. Studies investigating effects of chronic exposure to sulfometuron methyl formulations were not identified in the available literature.

Impact on Soil Nutrient Cycling and Soil Productivity

SERA (2004a, section 4.1.2.5) reports that sulfometuron methyl, at concentrations as low as 0.2 μM [73 μg/L] in a liquid glucose medium, caused significant growth inhibition in *Salmonella typhimurium* after exposure periods of less than 3 hours (Epelbaum et al. 1996). In plate cultures using solid growth media, Burnet and Hodgson (1991) found that sulfometuron methyl also inhibited the growth of several soil microorganisms. However, at concentrations up to 1000 μg/g soil, no effects were observed on the microbial populations and at soil concentrations ranging from 0.098 to 0.98 ppm no significant effects were observed on nitrate production, or cellulose, protein or starch metabolism (Anderson and Berg 1980). From this we conclude the proposed use of sulfometuron methyl will not adversely affect soil nutrient cycling or soil productivity. (see additional discussion of this topic in Appendix G-1 p. G1-106).

Aquatic Plants

The toxicity of sulfometuron methyl has been examined in both algae and aquatic macrophytes. Study results are summarized in Appendix 6 (SERA 2004a). Studies on the mechanism of action of sulfometuron methyl in aquatic plants were not identified. However, sulfometuron methyl is assumed to have the same mechanism in aquatic plants as in terrestrial plants (i.e., the inhibition of ALS). As might be expected for an herbicide, aquatic plants are far more sensitive than aquatic animals to the effects of sulfometuron methyl.

Little information is available on the effects of sulfometuron methyl on aquatic macrophytes, one 7day exposure study in *Hydrilla verticillata* (Byl et al. 1994), an aquatic angiosperm commonly called Hydrilla or water thyme, and one 14 day exposure study in *Lemna gibba*, a species of duckweed (Kannuck and Sloman 1995). For the Byl et al. (1994) study, the authors did not state whether data were reported in terms of mg sulfometuron methyl/L or mg Oust®/L. Taking the most conservative approach, values are assumed to be expressed in terms of mg Oust®/L (note previous comments about use of DMSO and limited water solubility of sulfometuron methyl). In *Hydrilla,* the 7 day EC_{50} value for growth inhibition was reported as 10 μg Oust®/L (7.5μg a.i./L), with an NOEC value for growth inhibition of 1 g Oust®/L (0.75 μg a.i./L). In duckweed exposed to technical grade sulfometuron methyl for 14 days, the most sensitive effect was on frond count, with an EC_{50} value of 0.462 μg a.i./L and an NOEC of 0.207 μg a.i./L. No field studies on the effects of sulfometuron methyl in aquatic macrophytes were identified in the available literature.

Three studies have investigated the effects of sulfometuron methyl on algae (Hoberg 1990, Landstein et al. 1993, Thompson 1994), with dose-response data available in *Selenastrum capricornutum* (Hoberg 1990) and *Anabaen flosaquae* (Thompson 1994). Based on growth inhibition as measured by cell density, *Selenastrum capricornutum*, with a 120 hour EC_{50} value of 4.6 μg/L (Hoberg 1990), appears to be more sensitive to the effects of sulfometuron methyl than *Anabaen flosaquae*, with a 120 hour EC_{50} value of 65 μg/L (Thompson 1994). In the

Hoberg study, growth stimulation was observed at concentrations up to 2.5 µg/L following 72 hours of exposure; thus, the NOEC could be taken as 2.5 µg/L. In *Navicula pelliculosa* exposed to 370 µg/L, no growth inhibition was observed (Thompson 1994); thus, the NOEC for *Navicula pelliculosa* is 370 µg/L. No field studies on the effects of sulfometuron methyl in aquatic macrophytes were identified in the available literature.

Dose Response Assessment for Sulfometuron Methyl

The dose response assessment used by SERA (2004a, b) is used for this assessment as well. Critical toxicity values for sulfometuron methyl are summarized in Table 3. The basis of the SERA dose response assessment is as follows:

Toxicity to Terrestrial Wildlife

Mammals

As summarized in the dose-response assessment for the human health risk assessment (Appendix G1, Section 6)), according to a Federal Registry Notice, the U.S. EPA has derived a chronic RfD of 0.24 mg/kg/day based on a NOAEL for bladder toxicity of 500 ppm dietary sulfometuron methyl (equivalent to 24.4 mg/kg/day) and a 100-fold safety factor (U.S. EPA 1997). Although an RfD has been derived by U.S. EPA, a more conservative provisional reference dose of 0.02 mg/kg/day was derived from data reported in the 2 year feeding study in rats by Mullin (1984). The provisional reference dose is based on the 2 mg/kg/day (50 ppm, dose conversions described in SERA (2004a, Appendix 1) NOAEL for hematological effects in male rats and an uncertainty factor of 100: 10 for species-to-species extrapolation and 10 for sensitive subgroups in the human population. All of the potential longer-term exposures of terrestrial mammals to sulfometuron methyl are substantially below the NOAEL of 2 mg/kg/day (see SERA 2004b, Worksheet G01); thus, it is not necessary to elaborate much more on the dose-response assessment for longer-term exposures. A dose of 2 mg/kg/day is used to assess the consequences of all longer-term exposures.

As discussed in Section 3.3.3 (SERA 2004a), since the U.S. EPA has not derived an acute/single dose RfD for sulfometuron methyl, a provisional acute RfD is calculated as 0.87 mg/kg/day. The provisional acute RfD is based on a NOAEL for dietary exposure of 86.6 mg/kg/day (1000 ppm, dose conversions described in SERA (2004a, Appendix 1) reported for decreased maternal and fetal body weights in rats following 10 day gestational exposure of dams (Lu 1981) and margin of exposure of 100. All of the potential acute exposures of terrestrial mammals to sulfometuron methyl are substantially below the NOAEL of 87 mg/kg/day (see SERA 2004b, Worksheet G01); thus, it is not necessary to elaborate much more on the dose-response assessment for acute exposures. A dose of 87 mg/kg/day is used to assess the consequences of all acute exposures.

Birds

As discussed in the hazard section, results of all acute exposure studies in birds show that sulfometuron methyl has very low toxicity, with LD_{50} values exceeding 5000 mg/kg by gavage (Dudeck and Bristol 1981a) and exceeding 5620 ppm in the diet (equivalent to 1068 mg/kg/day, dose conversions described in SERA (2004a, Appendix 4) (Fink et al. 1981). Only one study reported signs of toxicity following acute sulfometuron methyl exposure, a gavage study in mallard ducks using single doses of technical grade sulfometuron methyl ranging from 312 to 5000 mg/kg (Dudeck and Bristol 1981a). Results show that compared to control birds, male birds, but not females, had decreased weight gain at doses of 625 mg/kg and higher. Although the decrease in weight gain did not exhibit dose-dependence with respect to the magnitude of effect, the NOAEL for changes in body weight is 312 mg/kg. For this risk assessment, the NOAEL for acute exposure to birds is taken as 312 mg/kg/day. No chronic exposure studies in birds were identified in the available literature.

However, LD_{50} values obtained from acute exposure studies in both mammals and birds are of similar magnitude and show that both birds and mammals appear to have a very low order of toxicity to sulfometuron methyl. In the absence of chronic exposure data in birds, the NOAEL of 2 mg/kg/day obtained in rats is used for chronic exposure of birds to sulfometuron methyl.

Terrestrial Invertebrates

Two standard bioassays were conducted on the toxicity of sulfometuron methyl to bees, as detailed in Section 4.1.2.3 (SERA 2004a). Results of these studies yield LD_{50} values of sulfometuron methyl greater than the highest dose tested in each study–12.5 µg/bee (Du Pont de Nemours 1983) and 100 µg/bee (Hoxter and Smith 1990,). Using a body weight of 0.093 g for the honey bee (USDA/APHIS 1993), these values correspond to doses of about 134 to 1075 mg/kg [0.0125 mg/0.000093 kg to 0.1 mg/0.000093 kg]. For the purposes of this risk assessment, the NOAEL 1075 mg/kg will be used for risk characterization.

Terrestrial Plants (Vascular)

Sulfometuron methyl is an herbicide and causes adverse effects in a variety of non-target plant species (Section 3.1.2.4 and Appendix 4 in SERA 2004a). The most relevant studies for assessing the effects of direct spray or drift are the series of bioassays conducted by Drake (1990) and McKelvey (1995). The more recent study by McKelvey (1995) clearly defines NOEC's for growth inhibition, whereas the earlier study by Drake (1990) did not.

For assessing the potential consequences of exposure to nontarget plants via runoff, results of pre-emergence studies are used from the study by McKelvey (1995). In this assay, the most sensitive species based on the NOEC are rape, tomato, sorghum, wheat, and corn with an NOEC of 0.0000086 lb a.i./acre. Onion, pea, cucumber, and soybean are most tolerant species based on the NOEC, 0.00026 lb/acre. These values are used in Worksheet G04 to assess the risks to nontarget plant species from soil contamination associated with the runoff of sulfometuron methyl from the application site.

For assessing the impact of drift, bioassays on vegetative vigor from the study by McKelvey (1995) will be used. In this assay, the most sensitive species based on the NOEC is corn with an NOEC of 0.000024 lb a.i./acre. The most tolerant species based on the NOEC is pea with an NOEC of 0.00078 lb a.i./acre. These NOEC values are used in Worksheets G05a and G05b for characterizing risks associated with off-site drift.

Monitoring done on the ANF indicates little off-site drift, which may be a better representation of conditions on the ANF than those predicted by drift models. See later discussion of buffers.

Aquatic Organisms

The toxicity values used in this risk assessment are summarized in Worksheet G03 (SERA 2004b) based on the information presented in the hazard section.

Fish

Fish do not appear to be highly sensitive to sulfometuron toxicity, although investigations of the acute LC_{50} have been hampered by the limited water solubility of sulfometuron methyl. Results of all acute exposure studies yield LC_{50} values at the highest concentration tested in each study, a range of >7.3 mg/L in fathead minnow (Muska and Driscoll 1982) to >150 mg/L in bluegill sunfish (Brown 1994a) and rainbow trout (Brown 1994b). For this risk assessment, the NOEC of 7.3 mg/L in fathead minnow is used for the most sensitive species and the NOEC of 150 mg/L in bluegill sunfish and rainbow trout is used for the most tolerant species. Due to the limited water solubility of sulfometuron methyl, the most sensitive and tolerant species cannot truly be identified, and it is quite possible that no species would respond at concentrations of 150 mg/L or substantially higher. However, for this risk assessment, fathead minnows are considered to be approximately 20 times more sensitive to sulfometuron methyl toxicity than bluegill sunfish and rainbow trout.

Toxicity values for chronic toxicity may be based on the available egg-and-fry/early life stage studies; only one study of chronic exposure in fish, a 90 day exposure of fathead minnow, was identified in the available literature (Muska and Driscoll 1982). No effects on fathead minnow embryo hatch, larval survival, or larval growth were observed over 30 day exposure periods at measured average concentrations up to 1.17 mg a.i./L. As discussed above for acute exposure studies in fish, it is not possible to identify with certainty the most sensitive and tolerant species based on the available data. Thus, for this risk assessment, the NOEC of 1.17 mg/L is used for both the most sensitive and tolerant species for chronic exposure.

Amphibians

As discussed in the hazard section and summarized in SERA (2004a, Appendix 7), the toxicity of acute and chronic exposure to sulfometuron methyl to amphibians has been evaluated in a single study in African clawed frogs (*Xenopus laevis*, Fort 1998 as cited in SERA (2004b)). In this report, the author did not state whether data were reported in terms of mg sulfometuron methyl/L or mg Oust®/L. Taking the most conservative approach, SERA (2004a) authors assumed the values are to be expressed in terms of mg Oust®/L (note see earlier discussion about difficulty of testing sulfometuron methyl due to limited solubility in water). For this risk assessment, the acute NOEC of 0.38 mg a.i./L for both lethality and malformations and the chronic NOEC of 0.00075 mg a.i./L for decreased tail resorption rate will be used. Since no studies on other amphibian species were identified in the available literature, it is not possible to identify a most tolerant and most sensitive amphibian species.

Aquatic Invertebrates

Studies assessing the toxicity of sulfometuron methyl have been conducted in several species of aquatic invertebrates, as detailed in the hazard section and SERA (2004a, Appendix 6). As reported for studies in fish, studies on the toxicity of technical grade sulfometuron methyl have been somewhat hampered by the limited water solubility of sulfometuron methyl. Although studies have been conducted using both technical grade sulfometuron methyl and Oust®, studies using Oust are considered to be most relevant to this risk assessment. Based on the results of acute exposure studies, the most sensitive aquatic invertebrates appear to be *Alonella* sp. and *Cypria* sp., with LOAEC values of 100 mg Oust®/ L (75 mg a.i./L) (Naqvi and Hawkins 1989). Since 100 mg Oust®/L was the lowest concentration tested, NOEC values could not be determined. Although Naqvi and Hawkins (1989) do not specifically state whether data are reported as mg a.i./L or mg Oust®/L, it is implied that data are reported in terms of the formulation; taking the most conservative approach, SERA (2004a) authors assumed the values are to be expressed as mg Oust®/L (see comments above about using this approach due to limited water solubility of sulfometuron methyl).

Based on reported NOAEC values, *Daphnia* appear to be the most tolerant species, with an LC_{50} of 6375 mg a.i./L, an NOAEC of 1800 mg a.i./L and an LOAEC of 2400 mg a.i./L (Wetzel 1984). A higher LC_{50} value of 12,175 mg/L was reported in crayfish, however an NOAEC and LOAEC values were not reported (Naqvi et al. 1987). For this risk assessment for acute exposure of aquatic invertebrates, the LOAEC of 75 mg a.i./L in *Alonella* sp. and *Cypria* sp. will be used for the most sensitive species, and the NOAEC of 2400 mg a.i./L will be used for the most tolerant species. Comparison of LOAEC values for *Daphnia* (2400 mg a.i./L) and *Alonella* and *Cypria* (75 mg a.i./L) show that *Daphnia* have a relative potency factor of 32 (i.e., *Daphnia* are 32 times more tolerant than *Alonella* and *Cypria* to acute exposure of sulfometuron methyl).

Data regarding chronic exposure to aquatic invertebrates are only available from a single reproductive study with technical grade sulfometuron methyl in *Daphnia* (Baer 1990). As discussed in Section 4.1.3.3 (SERA 2004a), the number of neonates per surviving adult was significantly reduced at 24 mg a.i./L but not at 97 mg a.i./L or any of the lower concentrations. The authors report the NOEC as 6.1 mg a.i./L. Although the effect observed at 24 mg/L may have been a random variation, it is treated as an LOEC for the purpose of this risk assessment. While this approach may be regarded as conservative, in the absence of additional studies regarding reproductive effects in aquatic invertebrates, the approach seems prudent.

Thus, the NOEC of 6.1 mg a.i./L will be used to assess the risk of chronic exposure to the most tolerant species. Although no data are available to determine the most sensitive species for chronic exposures, parallels can be drawn to the acute exposure studies. As discussed above, the relative potency factor comparing *Daphnia* to *Alonella* and *Cypria* based on acute LOAEC values is 32, (i.e., *Daphnia* are 32 times more tolerant to sulfometuron methyl toxicity than *Alonella* and *Cypria* in acute exposures). Using the relative potency factor for acute exposures of 32 and the chronic NOEC in *Daphnia* of 6.1 mg/L, an NOEC for *Alonella* and *Cypria* is estimated to be 0.19 mg/L [6.1 mg/L ÷ 32 = 0.19 mg/L]. This surrogate NOEC for chronic exposure in *Alonella* and *Cypria* will be used to estimate the chronic NOEC for the most sensitive species.

Aquatic Plants

The relevant data on the toxicity of sulfometuron methyl to aquatic plants is summarized in SERA (2004a, Appendix 6). The most sensitive algal species appears to be *Selenastrum capricornutum*, with a72 hour NOAEC value for growth inhibition based on cell density of 2.5 µg/L (0.0025 mg/L) (Hoberg 1990). The 120 hour NOAEC in *Navicula pelliculosa* for growth inhibition is reported as 370 µg/L (0.37 mg/L) and is the value used for the most tolerant species (Thompson 1994). The maximum exposure period in all studies was 120 hours; no long-term exposure studies were identified in the available literature. Therefore, for risk characterization for both acute and chronic exposure, the NOAEC 0.0025 mg/L will be used as the most sensitive species and the NOAEC of 0.37 for the most tolerant species.

Only two studies in aquatic plants were identified in the available literature, a 7 day exposure study in *Hydrilla* using Oust® (Byl et al. 1994) and a 14 day exposure study in *Lemna* (duckweed) using technical grade sulfometuron methyl (Kannuck and Sloman 1995). For the Byl et al. (1994) study, the authors did not state whether data were reported in terms of mg sulfometuron methyl/L or mg Oust®/L. Taking the most conservative approach, SERA (2004a) assumed that the values are to be expressed in terms of mg Oust®/L (see comments above about using this approach due to limited water solubility of sulfometuron methyl).

In *Hydrilla*, the 7 day EC_{50} value for growth inhibition was reported as 10 µg Oust®/L (7.5 µg a.i./L), with an NOAEC of 1 µg Oust®/L (0.75 µg a.i./L). In duckweed exposed to technical grade sulfometuron methyl for 14 days, the most sensitive effect was on frond count, with an EC_{50} of 0.46 µg a.i./L (0.00046 mg a.i./L) and an NOAEC of 0.21 µg a.i./L (0.00021 mg/L). Comparison of NOAEC values for the two species are similar, although the duckweed appears to be slightly more sensitive than *Hydrilla*. However, due to differences in the exposure period in these two studies, it is not possible to determine which, if either, of these two species is more sensitive to sulfometuron toxicity. Taking the most conservative approach, the lower NOAEC value of 0.00021 mg a.i./L in duckweed will be used for both the sensitive and tolerant species. Since data are only available for 14 days, this value will also be used for both acute and chronic exposures.

Based on this hazard analysis, we conclude the toxicity values in Table 5 are most relevant and appropriate for the risk analysis. Typically these values are the NOAEL for the most sensitive species of a given type.

Table 5. Critical toxicity values for sulfometuron methyl risk analysis

Type of Organism	*Critical Toxicity Value*	*Type of Value*
Mammal		
acute exposure	87 mg/kg	Acute NOAEL
chronic exposure	2 mg/kg/day	Chronic NOAEL
Bird		
acute exposure	312 mg/kg	Acute NOAEL
chronic exposure	2 mg/kg/day	Chronic NOAEL
Honey Bee		
acute exposure	1075 mg/kg	NOEC
Fish, Tolerant Species		
acute exposure	150 mg/L	NOEC
chronic exposure	1.17 mg/L	NOEC
Fish, Sensitive Species		
acute exposure	7.3 mg/L	NOEC
chronic exposure	1.17 mg/L	NOEC
Amphibians		
acute exposure	0.38 mg/L	NOEC
chronic exposure	0.00075 mg/L	NOEC
Aquatic Invertebrates (acute exposure)		
Tolerant Species	1800 mg/L	NOEC
Sensitive Species	75 mg/L	LOEC
Aquatic Invertebrates (chronic exposure)		
Tolerant Species	6.1 mg/L	NOEC
Sensitive Species	0.19 mg/L	NOEC
Aquatic Plants, Algae (acute and chronic exposure)		
Tolerant Species	0.37 mg/L	NOEC
Sensitive Species	0.0025 mg/L	NOEC
Aquatic Plants, Macrophytes (acute and chronic exposure)		
Tolerant and Sensitive Species	0.00021 mg/L	NOEC

SECTION D. EXPOSURE ASSESSEMENT

Both typical and maximum exposure estimates were made for representatives of each group based on the three major exposure routes: inhalation, dermal, and ingestion. Contact may occur as direct spray, indirect contact with contaminated vegetation, grooming activities, and ingestion of contaminated food, water, or prey species. The highest exposures for terrestrial vertebrates will occur after the consumption of contaminated vegetation or contaminated insects (SERA 2003a). Sulfometuron methyl and glyphosate degrade relatively rapidly, and sites are normally treated once or in the case of the management goal of sustaining forest cover, occasionally twice per 80 year rotation. Maintaining openings for wildlife and treatment of invasive species may require more frequent application, but these sites tend to be small and are scattered, so no analysis of chronic wildlife dosing was done. Since neither herbicide bioaccumulates, long-term persistence in food chains and subsequent toxic effects were not considered a problem and were not analyzed.

Typical application methods to be used on the ANF include mechanical ground application and manual ground application. The application methods are discussed in detail in Appendix G1, Section 2. Mechanical ground applications in forested areas will be done with vehicle mounted air blast sprayers. In areas already open (i.e., with little forest cover), tractor or ATV mounted sprayers may be used. Manual ground application of herbicides will include foliar spraying using backpack equipment, or cut surface treatment.

This exposure assessment first addresses glyphosate, and then it addresses sulfometuron methyl. The assessment relies on the assumptions and methods used by SERA for glyphosate (SERA 2003a, b) and sulfometuron methyl (SERA 2004a, b). The behavior and fate of glyphosate in the air, plants, soil, groundwater, and surface waters is addressed in Appendix G1, Section 4. The behavior and fate of sulfometuron methyl in air, plants, soil, groundwater, and surface waters is addressed in Appendix G1, Section 7.

Variability

Variability reflects the knowledge of how things may change. For example, various estimates involve relationships in which a most likely (central) estimate can be calculated. Where appropriate the upper and lower limits of the estimate are used in considering variability. In this document we use the terms *central*, *upper*, and *lower* where needed in considering variability.

Terrestrial and Aquatic Species Exposure Assessment for Glyphosate

The typical and maximum rates of application on the ANF are shown in Table 6. The typical and maximum rates on the ANF range from 1-4 lbs/acre. Differences in rates of application used on ANF are accounted for in the results of the risk analyses. The typical and maximum anticipated acres treated are in Table 7.

Table 6. Typical and maximum application rates on the ANF for glyphosate

Application Method	Sustaining forest cover/forest products and Improvements	Developing/maintaining wildlife habitat/visual enhancements	Control/treat invasive species
	Typical [maximum] (lbs a.i./acre)		
Mechanical (broadcast foliar) Air blast	1.0 [2.0]	1.0 [2.0]	1.0 [2.0]
Manual (directed foliar) Backpack/hand sprayer	1.0 [2.0]	1.0 [2.0]	2.0 [4.0]
Cut surface	2.0 [3.0]	2.0 [3.0]	1.0 [2.0]

The data in Table 6 was used in estimating the exposure values in Table 8.

Table 7. Typical and maximum anticipated number of acres treated per year with glyphosate on the ANF for 2006 to 2020

Application Mtechod	Sustaining forest cover/forest products and Improvements	Developing/maintaining wildlife habitat/visual enhancements	Control/treat invasive species
	Typical [maximum] (acre/year)		
Mechanical (broadcast foliar) Air blast	1300 [3500]	10 [20]	5 [10]
Manual (directed foliar) Backpack/hand sprayer	180 [300]* *58 [117] riparian areas*	30 [60]* *3 [6] riparian areas*	30 [60]* *7 [14] riparian areas*
Cut surface	300 [450]* *12 [24] riparian areas*	10 [25]* *2 [4] riparian areas*	15 [30]* *4 [8] riparian areas*

Total acres all application methods and vegetation management objectives: Typical: 1,880 acres, Maximum: 4,455 acres
The number of acres that fall within riparian areas is in italics
*Includes acres in riparian areas

Riparian areas are listed on a separate line in this table to show that glyphosate treatments would be needed there because they have similar interference problems as the rest of the ANF. These acres listed for riparian areas are included in the total acres proposed for treatment in each column for a particular application method; they are not additional acres to be treated. The same water buffer strips and mitigation measures would apply to riparian areas as to the rest of the ANF. The data in Table 7 are not used explicitly in the exposure analysis but are presented to provide perspective on the extent of such operations.

The following is the basis for SERA's (2003a, b; 2004a, b) method for exposure assessments:

Terrestrial Wildlife

Terrestrial animals might be exposed to any applied herbicide from direct spray, the ingestion of contaminated media (vegetation, prey species, or water), grooming activities, or indirect contact with contaminated vegetation.

In this exposure assessment, estimates of oral exposure are expressed in the same units as the available toxicity data (i.e., oral LD_{50} and similar values). As in the human health risk assessment, these units are usually expressed as mg of agent per kg of body weight and abbreviated as mg/kg body weight. For dermal exposure, the units of measure usually are expressed in mg of agent per cm^2 of surface area of the organism and abbreviated as mg/cm^2. In estimating dose, however, a distinction is made between the exposure dose and the absorbed dose. The *exposure dose* is the amount of material on the organism (i.e., the product of the residue level in mg/cm^2 and the amount of surface area exposed), which can be expressed either as mg/organism or mg/kg body weight. The *absorbed dose* is the proportion of the exposure dose that is actually taken in or absorbed by the animal.

For the exposure assessments discussed below, general allometric relationships are used to model exposure.

Estimates of exposure are given for both a small and a large mammal as well as a small and a large bird. For many compounds, allometric relationships for interspecies sensitivity to toxicants indicate that for exposure levels expressed as mg toxicant per kg body weight (mg/kg body weight), large animals, compared with small animals, are more sensitive.

As discussed in (Appendix G1, Section 3), the limited data on glyphosate suggest that larger mammals (specifically the dog), appear to be more sensitive to glyphosate than smaller mammals (i.e., rats and mice) but the data are not adequate to support the development of quantitative allometric relationships for toxicity. There are no data to assess species sensitivity in small and large birds.

The exposure assessments for terrestrial animals are summarized in (SERA 2003a, Table 4-3). As with the human health exposure assessment, the computational details for each exposure assessment presented in this section are provided in Worksheets F01 through F14 (SERA 2003b). This table (Table 8) is derived from (SERA 2003a, Table 4-3), with the values adjusted proportionally to reflect the rates of application used on the ANF. The ANF applications rates of 1, 2, 3 and 4 lb/acre are included in this table. The 1 lb/acre rate is the most widely used rate on the ANF, although rates of 2 lb/acre are also used in airblast, backpack and cut surface treatments for all forest management objectives. The 3 lb/acre rate is only used in the cut surface method of application to sustain forest cover and for wildlife habitat management objectives. The 4 lb/acre rate is only used for control of invasive species in back pack applications.

In the SERA risk assessment, they calculate exposure and risk values for three ranges of condition called lower, central, and upper, to take into account variability in environmental conditions and uncertainties with respect to exposure. Lower estimates are meant to encompass the range of environmental conditions and uncertainties expected to produce the lowest levels of exposure. The central values are meant to encompass the range of environmental conditions and uncertainties expected to produce the most likely levels of exposure. The upper values are meant to encompass the range of environmental conditions and uncertainties expected to produce the highest levels of exposure.

The central value is the “most likely” value. For perspective, the lower value is 10 times less than the upper value, thus the table provides for a 10-fold level of uncertainty, and provides a conservative approach to this assessment. Also, note that the section on environmental behavior of glyphosate in Appendix G1, Section 4 and the discussion in SERA (2003a) provide the basis for deriving the values reported in Table 8.)

Table 8. Summary of exposure scenarios for terrestrial animals for ANF glyphosate application rates of 1, 2, 3 and 4 lbs a.i./acre (equivalent to 0.75, 1.25, 2.25, and 3.0 lbs a.e./acre, respectively)

Scenario	Central				Lower				Upper			
	ANF Application Rates (lbs a.i./acre)											
	1.0	2.0	3.0	4.0	1.0	2.0	3.0	4.0	1.0	2.0	3.0	4.0
Acute/Accidental Exposures (mg/kg)												
Direct Spray												
small mammal, first-order absorption	0.18	0.3	0.6	0.71	0.06	0.09	0.19	0.23	0.43	0.72	1.44	1.72
small animal, 100% absorption	18.19	30.31	60.62	72.75	18.19	30.31	60.62	72.75	18.19	30.31	60.62	72.75
bee, 100% absorption	120.38	200.62	401.25	481.5	120.38	200.62	401.25	481.5	120.38	200.62	401.25	481.5
Contaminated Vegetation												
small mammal	0.32	0.54	1.07	1.28	0.32	0.54	1.07	1.28	0.79	1.32	2.64	3.16
large mammal	12.9	21.5	43	51.6	12.9	21.5	43	51.6	36.41	60.69	121.38	145.65
large bird	20.18	33.62	67.25	80.7	20.18	33.62	67.25	80.7	57	95	190	228
Contaminated Water												
small mammal, spill	1	1.66	3.32	3.99	0.4	0.66	1.32	1.59	2	3.32	6.65	7.98
small mammal, stream	0.002	0.004	0.007	0.009	0.0001	0.0002	0.0004	0.0004	0.04	0.07	0.15	0.18
Contaminated Insects												
small bird	28.12	46.88	93.75	112.5	28.12	46.88	93.75	112.5	84.38	140.62	281.25	337.5
Contaminated Fish												
predatory bird, spill	0.35	0.59	1.18	1.42	0.07	0.12	0.24	0.28	1.06	1.77	3.54	4.24
Longer-term Exposures (mg/kg/day)												
Contaminated Vegetation												
small mammal, on-site	0.018	0.03	0.06	0.07	0.009	0.01	0.03	0.04	0.09	0.14	0.29	0.35
small mammal, off-site	0.0002	0.0003	0.0006	0.0007	0.00005	0.00008	0.0002	0.0002	0.002	0.003	0.005	0.006
large mammal, on-site	2.12	3.53	7.06	8.48	0.7	1.18	2.35	2.82	19.95	33.25	66.5	79.8
large mammal, off-site	0.071	0.12	0.24	0.28	0.04	0.07	0.14	0.16	0.37	0.62	1.24	1.49
large bird, on-site	3.32	5.5	11.05	13.26	1.11	1.84	3.69	4.42	31.2	52	104	124.8
large bird, off-site	0.11	0.19	0.37	0.45	0.06	0.11	0.21	0.26	0.58	0.98	1.95	2.34
Contaminated Water												
small mammal	0.0001	0.0002	0.0004	0.0004	0.00001	0.00002	0.00004	0.00004	0.0009	0.001	0.003	0.004
Contaminated Fish												
predatory bird	0.00004	0.00006	0.0001	0.0002	0.000002	0.000003	0.000006	0.000008	0.0005	0.0008	0.002	0.002

Direct Spray

In the broadcast application of any herbicide, wildlife species may be sprayed directly. Direct spray of wildlife is not expected to be widespread because in airblast the noise is likely to cause animals to leave the area before application occurs. In the case of the backpack and cut surface methods of application, wildlife are also likely to leave the area to avoid contact with humans, and in addition the operator can avoid direct application on wildlife that remain.

This scenario is similar to the accidental exposure scenarios for the general public discussed in Appendix G1, Section 5. In a scenario involving exposure to direct spray, the extent of dermal contact depends on the application rate, the surface area of the organism, and the rate of absorption. Note that the 1 lb/acre rate is the most widely used rate on ANF, although rates of 2 lb/acre are also used in airblast, backpack and cut surface treatments. The 3 lb/acre rate is only used in the cut surface method of application to sustain forest cover and for wildlife habitat management objectives. The 4 lb/acre rate is only used for control of invasive species in back pack applications.

For this risk assessment, three groups of direct spray exposure assessments are conducted (small mammal, first-order absorption, small animal, 100% absorption, and bee, 100% absorption)

Small Mammal, First-order Absorption

This analysis is defined in Worksheet F01 (SERA 2003b). It involves a 20 g mammal that is sprayed directly over one half of the body surface as the chemical is being applied. The range of application rates as well as the typical application rate is used to define the amount deposited on the organism. The absorbed dose over the first day (i.e., a 24 hour period) is estimated using the assumption of first-order dermal absorption. In the absence of any data regarding dermal absorption in a small mammal, the estimated absorption rate for humans is used (Appendix G1, Section 4). An empirical relationship between body weight and surface area (Boxenbaum and D'Souza 1990) is used to estimate the surface area of the animal. The estimates of absorbed doses in this scenario may bracket plausible levels of exposure for small mammals based on uncertainties in the dermal absorption rate of glyphosate.

Other, perhaps more substantial, uncertainties affect the estimates for absorbed dose. For example, the estimate based on first-order dermal absorption does not consider fugitive losses [loss of the chemical in the form of gas, fumes, vapor, dust, liquid after contact) from the surface of the animal and may overestimate the absorbed dose. Conversely, some animals, particularly birds and mammals, groom frequently, and grooming may contribute to the total absorbed dose by direct ingestion of the compound residing on fur or feathers. Furthermore, other vertebrates, particularly amphibians, may have skin that is far more permeable than the skin of most mammals (Moore 1964). Quantitative methods for considering the effects of grooming or increased dermal permeability are not available.

Small Animal, 100% and Absorption

As a conservative upper limit, the second exposure scenario, detailed in SERA (2003b, Worksheet F02a), assumes complete absorption (100% absorption) over day 1 of exposure.

Bee, 100% Absorption

Because of the relationship of body size to surface area, very small organisms, like bees and other terrestrial insects, might be exposed to much greater amounts of glyphosate per unit body weight, compared with small mammals. Consequently, a third exposure assessment is developed using a body weight of 0.093 g for the honey bee (USDA/APHIS 1993). Because there is no information regarding the dermal absorption rate of glyphosate by bees or other invertebrates, this exposure scenario, detailed in Worksheet F02b (SERA 2003b), also assumes complete absorption over the first day of exposure.

Large Mammals

Direct spray scenarios are not given for large mammals. As noted above, allometric relationships dictate that large mammals will be exposed to lesser amounts of a compound in any direct spray scenario than smaller mammals. The direct spray scenarios for the small mammal are substantially below a level of concern. Consequently, elaborating direct spray scenarios for a large mammal would have no impact on the characterization of risk.

On the ANF, large mammals typically leave the areas to escape the noise from mechanized equipment or hand treatment crews and would most likely not come in contact with directly sprayed herbicides.

Indirect Contact

As in the human health risk assessment (Appendix G1, Section 5), the only approach for estimating the potential significance of indirect dermal contact is to assume a relationship between the application rate and dislodgeable foliar residue. The study by Harris and Solomon (1992) is used to estimate that the dislodgeable residue will be approximately 10 times less than the nominal application rate.

Unlike the human health risk assessment in which transfer rates for humans are available, there are no transfer rates available for wildlife species. As discussed in Durkin et al. (1995), the transfer rates for humans are based on brief (e.g. 0.5 to 1 hour) exposures that measure the transfer from contaminated soil to uncontaminated skin. Species of wildlife are likely to spend longer periods of time, compared to humans, in contact with contaminated vegetation.

It is reasonable to assume that for prolonged exposures a steady-state may be reached between levels on the skin, rates of absorption, and levels on contaminated vegetation, although there are no data regarding the kinetics of such a process. The bioconcentration data on glyphosate (Appendix G1, Section 5) as well as its high water solubility and low octanol/water partition coefficient suggest that glyphosate is not likely to partition from the surface of contaminated vegetation to the surface of skin, feathers, or fur. Thus, a plausible but conservative partition coefficient is unity (i.e., the concentration of the chemical on the surface of the animal will be equal to the dislodgeable residue on the vegetation).

Under these assumptions, the absorbed dose resulting from contact with contaminated vegetation will be one-tenth that associated with comparable direct spray scenarios. As discussed in the risk characterization for ecological effects, the direct spray scenarios result in exposure levels far below those of toxicological concern. Consequently, details of the indirect exposure scenarios for contaminated vegetation are not further elaborated in this document.

Ingestion of Contaminated Vegetation or Prey

Since glyphosate will be applied to vegetation, the consumption of contaminated vegetation is an obvious concern, and separate exposure scenarios are developed for acute and chronic exposure scenarios for a small mammal (SERA 2003b, Worksheets F04a and F04b) and large mammal (SERA 2003b, Worksheets F10, F11a, and F11b) as well as large birds (SERA 2003b, Worksheets F12, F13a, and F13b).

A small mammal is used because allometric relationships indicate that small mammals will ingest greater amounts of food per unit body weight, compared with large mammals. The amount of food consumed per day by a small mammal (i.e., an animal weighing approximately 20 g) is equal to about 15% of the mammal's total body weight (U.S. EPA/ORD 1989). When applied generally, this value may overestimate or underestimate exposure in some circumstances. For example, a 20 g herbivore has a caloric requirement of about 13.5 kcal/day. If the diet of the herbivore consists largely of seeds (4.92 kcal/g), the animal would have to consume a daily amount of food equivalent to approximately 14% of its body weight [(13.5 kcal/day ÷ 4.92 kcal/g)÷20g = 0.137]. Conversely, if the diet of the herbivore consists largely of vegetation (2.46 kcal/g), the animal would have to consume a daily amount of food equivalent to approximately 27% of its body weight [(13.5 kcal/day ÷ 2.46 kcal/g)÷20g = 0.274]

(U.S. EPA/ORD 1993, pp.3-5 to 3-6). For the SERA exposure assessment, the amount of food consumed per day by a small mammal weighing 20 g is estimated at about 3.6 g/day from the general allometric relationship for food consumption in rodents (U.S. EPA/ORD 1993, p. 3-6).

Contaminated vegetation

A large herbivorous mammal is included because empirical relationships of concentrations of pesticides in vegetation, discussed below, indicate that grasses may have substantially higher pesticide residues than other types of vegetation such as forage crops or fruits (Worksheet A04, SERA 2003b). Grasses are an important part of the diet for some large herbivores, but most small mammals do not consume grasses as a substantial proportion of their diet. Thus, even though using residues from grass to model exposure for a small mammal is the most conservative approach, it is not generally applicable to the assessment of potential adverse effects. Hence, in the exposure scenarios for large mammals, the consumption of contaminated range grass is modeled for a 70 kg herbivore, such as a deer. Caloric requirements for herbivores and the caloric content of vegetation are used to estimate food consumption based on data from U.S. EPA/ORD (1993). Details of these exposure scenarios are given in Worksheet F10 (SERA 2003b) for acute exposures as well as Worksheets F11a and F11b (SERA 2003b) for longer-term exposures.

For the acute exposures, the assumption is made that the vegetation is sprayed directly, i.e., the animal grazes on site and assumes that 100% of the animals' diet is contaminated. While appropriately conservative for acute exposures, neither of these assumptions are plausible for longer-term exposures. Thus, for the longer-term exposure scenarios for the large mammal, two sub-scenarios are given. The first is an on-site scenario that assumes that a 70 kg herbivore consumes short grass for a 90 day period after application of the chemical. The contaminated vegetation accounts for 10 to 100% of the diet assuming that the animal would spend 10 to 100% of the grazing time at the application site. Because the animal is assumed to be feeding at the application site, drift is set to unity, i.e., direct spray. This scenario is detailed in Worksheet 12a (SERA 2003b). The second sub-scenario is similar except the assumption is made that the animal is grazing at distances of 25 to 100 feet from the application site (lowering risk), but that the animal consumes 100% of the diet from the contaminated area (increasing risk). For this scenario, detailed in Worksheet F12b (SERA 2003b), AgDRIFT is used to estimate deposition on the off-site vegetation. Drift estimates from AgDRIFT are summarized in Worksheet A06, and this model is discussed further in the section on off-site drift.

The consumption of contaminated vegetation is also modeled for a large bird. For these exposure scenarios, the consumption of range grass by a 4 kg herbivorous bird, like a Canada goose, is modeled for both acute (SERA 2003b; Worksheet F12) and chronic exposures (SERA 2003b; Worksheets F13a and F13b). As with the large mammal, the two chronic exposure scenarios involve sub-scenarios for on-site as well as off-site exposure.

For this component of the exposure assessment, the estimated amounts of pesticide residue in vegetation are based on the relationship between application rate and residue rates on different types of vegetation. As summarized in Worksheet A04 (SERA 2003b), these residue rates are based on estimated residue rates from Fletcher et al. (1994).

As indicated in Section 3.2.3.6 (SERA 2003a), the empirical relationships recommended by Fletcher et al. (1994) for fruit may somewhat overestimate concentrations on fruit based on the study by Siltanen et al. (1981). As indicated in Worksheet A04 (SERA 2003b), Fletcher et al. (1994) estimate residue rates on leaves at 45 to 135 ppm per lb applied and on short grasses as 85 to 240 ppm per lb applied. Newton et al. (1994) found that initial residues on "herbaceous vegetation" were typically in the range of 360 to 1273 ppm after the application of glyphosate at a rate of 4.12 kg/ha or about 3.7 lb/acre (Newton et al. 1994, p. 1798, Table 3). This corresponds to residue rates of about 97 to 344 ppm per lb applied per acre [360ppm to 1273 ppm ÷ 3.7 lb/acre]. This suggests that the estimates of glyphosate on grasses could be somewhat underestimated using the residue rates from Fletcher et al. (1994). The potential impact of this underestimate is discussed further in the risk characterization.

Contaminated insects

Similarly, the consumption of contaminated insects is modeled for a small (10g) bird. No monitoring data have been encountered on the concentrations of glyphosate in insects after applications of glyphosate. The empirical relationships recommended by Fletcher et al. (1994) are used as surrogates as detailed in Worksheet F14 (SERA 2003b). To be conservative, the residue rates from small insects are used, i.e., 45 to 135 ppm per lb/ac, rather than the residue rates from large insects, i.e., 7 to 15 ppm per lb/ac. As detailed in Worksheet F14 (SERA 2003b), this approach yields dose estimates of about 20 to 800 mg/kg bw for a small bird. This is higher than any monitored residues in terrestrial animals by factors or about 10 to 400 and is likely to be grossly conservative (Newton et al. 1984, p. 1148, Table II).

Contaminated fish

In addition to the consumption of contaminated vegetation and insects, glyphosate may reach ambient water and bioconcentrate in fish. Thus, a separate exposure scenario is developed for the consumption of contaminated fish by a predatory bird in both acute (SERA 2003b, Worksheet F08) and chronic (SERA 2003b, Worksheet F09) exposures. Because predatory birds usually consume more food per unit body weight than do predatory mammals (U.S. EPA 1993, pp. 3-4 to 3-6), separate exposure scenarios for the consumption of contaminated fish by predatory mammals are not developed.

Terrestrial Plants

In general, the primary hazard to non-target terrestrial plants associated with the application of most herbicides is unintended direct deposition or spray drift. In addition, herbicides may be transported off-site by percolation or runoff or by wind erosion of soil.

Direct Spray

Unintended direct spray will result in an exposure level equivalent to the application rate. For many types of herbicide applications, e.g. sustaining forest cover or controlling invasive plant species, it is plausible that some non-target plants immediately adjacent to the application site could be sprayed directly. This type of scenario is modeled in the human health risk assessment for the consumption of contaminated vegetation (Appendix G1, Section 5).

Off-site Drift and Buffers

Off-site drift is a physical process that depends primarily on droplet size and meteorological conditions rather than the specific properties of the herbicide. Estimates of off-site drift can be modeled using AgDRIFT (Teske et al. 2001). AgDRIFT is a model developed as a joint effort by the EPA Office of Research and Development and the Spray Drift Task Force, a coalition of pesticide registrants. Further details of AgDRIFT are available at http: //www.AgDRIFT.com/. AgDRIFT is based on the algorithms in Forest Service Aerial Spray Computer Model (FSCBG; Teske and Curbishley. 1990), a drift model previously used by USDA. This model was developed for aerial application, which is not used on ANF, but it has subsequently been adapted to provide analysis for ground applications.

For ground applications, AgDRIFT provides estimates of drift based solely on distance downwind and the application method: low boom ground spray, high boom ground spray, and orchard airblast. SERA used drift data for the low boom ground sprayer in all of their risk assessments, and this is the approach used in this ANF risk assessment, except in the analysis of risk for terrestrial and aquatic plants and of buffers where the AgDRIFT data for the orchard airblast is used to represent airblast on the ANF. Note that AgDRIFT modeling for the low boom ground sprayer is done for essentially bare ground, and includes no intercepting vegetation. In contrast, applications on ANF are typically in dense forest cover, with an abundance of vegetative surfaces for spray interception. For this reason, we believe SERA estimates of drift based on the low boom ground sprayer for ANF conditions result in a conservative risk estimate.

Buffers

Buffers are a strip of untreated vegetation adjacent to wetlands, water bodies and flowing water. The purpose of the buffer is to prevent the entry of unacceptable levels of herbicide to the water, thereby reducing water quality. The size of the buffer varies with the application technique and the characteristics of individual herbicides, such as the toxicity of the herbicide to animals and aquatic organisms that might use the water, and the movement, persistence and fate of the herbicide in the environment close to water. The critical element in protection of water quality with respect to glyphosate is protection of aquatic species, but the buffers that will protect aquatic organisms will also protect humans. The following buffer strategies should be used for glyphosate.

For broadcast foliar mechanical (airblast) application (1 and 2 lb/acre) the following buffers and application tactics will provide water quality protection for wildlife and aquatic species involving the use of glyphosate.

- No glyphosate shall be applied to surface waters.
- Buffers 25 feet wide along each side of perennial streams, impoundments, intermittent streams and seeps with flowing water the day of spraying;
- 25 feet wide around wet areas (standing water) and vernal ponds with no defined outlet.
- 10 feet wide along each side of dry intermittent streams, dry springs, and dry seeps.
- Airblast shall be directed away from the buffer when applications are made within 50 feet of the edge of the buffer, i.e., within 50 feet no airblast directed towards the edge of the buffer unless intervening vegetation 5 to 15 feet tall is sufficiently dense to intercept spray material.

For directed foliar backpack (up to 4 lb/acre) and for cut surface (up to 3 lb/acre) application methods the following buffers and tactics will provide water quality protection involving the use of glyphosate:

- No glyphosate shall be applied to surface waters.
- No glyphosate shall be applied within 10 feet of standing or flowing water.
- Within 10 feet of an intermittent stream course, use only the cut surface herbicide treatment technique with glyphosate.
- No glyphosate shall be applied to cut stems in the stream channel.

This buffer strategy was developed incorporating the experience of ANF managers with the management of power line rights-of-way, and the results of ANF monitoring of silvicultural and power line management operations (results are in several ANF Monitoring and Evaluation Reports) and buffer-width research (Norris and Charlton 1995).

ANF has conducted monitoring programs in connection with operational applications of herbicide on the ANF to verify protection of water quality and damage to vegetation outside of treatment areas. There are several in-house reports that provide the specifics of the monitoring program (typically these are included in Monitoring and Evaluation Reports for specific fiscal years). Table 9 shows the ANF water quality monitoring program activity. Visual monitoring for herbicide damage to vegetation was conducted in 2003 and 2004 and shows little or no damage to vegetation outside of the intended treatment area. Chemical water quality monitoring of silvicultural applications in 1987, 1988, and 2002 and of utility rights-of-way applications in 1998 to 2000 has shown no detectable concentrations of glyphosate in water samples tested.

Table 9. Date and type of ANF water quality monitoring

Year of Treatment and Survey Monitoring	Year of Monitoring and Evaluation Report	Vegetation Management Activity	Herbicide Monitored
1987	1988	Silviculture	glyphosate
1988	1989	Silviculture	glyphosate
1989	1990	Silviculture	sulfometuron methyl
1998	2000	Utility ROW[1]	glyphosate and imazapyr
1999	2001	Utility ROW	glyphosate and imazapyr
2000	2002	Utility ROW	glyphosate and imazapyr
2002	2002	Silviculture	glyphosate and sulfometuron methyl

[1] ROW=right-of-way

The buffer strategy was developed by using the most sensitive measure of toxicity (critical toxicity value) established in the hazard analysis. For the formulations of glyphosate used on the ANF, the chronic exposure of sensitive fish species results in the lowest NOEC, which is 2.57 mg/L (SERA 2003b, Worksheet G03). Values shown in Table 10 were used to identify the off-site deposition as a proportion of the rate of application. These values were used to calculate the concentration of glyphosate that might occur in a body of water one foot deep for rates of application of 1, 2, 3 and 4 lb/acre and buffer widths of 25, 50 and 100 ft. SERA (2003a) discusses the effect of different methods of application and reports that off-site drift will be lower for back pack applications compared to airblast (airblast conclusion is based on data from orchard airblast equipment). There should be little or no drift from the cut-surface application technique.

Table 10. Central estimates of off-site drift expressed as a fraction of the application rate, for airblast applications

Distance Down Wind (Feet)	Low Boom	Airblast
25	0.0187	0.0057
50	0.0101	0.0029
100	0.0058	0.0007
500	0.0015	< 0.0001
900	0.0008	< 0.0001

(Adapted from SERA 2003b, Worksheet A06); Version 1.16, From Teske et al. (2001.)

The concentration of glyphosate in water 1 foot deep was calculated for varying distances from the point of application (Table 11).

Table 11. Concentration of glyphosate in water one foot deep at various distances from the point of airblast application*

Distance (Feet)	Proportion of Application Rate that is Deposited (Airblast)	Glyphosate concentration in water 1 foot deep** (mg/L) and Rate of Application			
		1(lb/acre)	2 (lb/acre)	3 (lb/acre)**	4 (lb/acre)***
25	0.0056	0.002	0.004	0.006	0.008
50	0.0029	0.001	0.002	0.003	0.004
100	0.0007	0.0003	0.0005	0.0008	0.001

*Based on airblast deposition as per Table 10.
**Calculated as proportion of application deposited X 0.37 mg/L X application rate
***Note that the 3 and 4 lb/acre application rate is not used with airblast, but the 3 lb/acre rate is used for cut surface and the 4 lb/acre rate is used for backpack applications. These rates are

included in this table to provide perspective for drift deposition from back pack and cut surface methods of application, which will produce less deposition than the values shown here under the analysis for airblast.

Using these concentrations the HQ was calculated (Table 12).

Table 12. Hazard quotient (HQ) for sensitive aquatic species with airblast application of glyphosate*

Distance (Feet)	ANF Formulations and Rate of Application			
	1 (lb/acre)	2 (lb/acre)	3 (lb/acre)** (cut surface only)	4 (lb/acre)** (backpack only)
25	0.0008	0.0016	0.0023	0.0031
50	0.0004	0.0008	0.0012	0.0016
100	0.0001	0.0002	0.0003	0.0004

The lowest NOEC for aquatic species is 2.57 mg/L for formulations used on ANF
*HQ = concentration in water/NOEC
** Note that the 3 and 4 lb/acre application rate is not used with airblast, but the 3 lb/acre rate is used for cut surface and the 4 lb/acre rate is used for backpack applications. These rates are included in this table to provide perspective for drift deposition from back pack and cut surface methods of application, which will produce less deposition than the values shown here under the analysis for airblast

The highest HQ value was 0.0031 for a 25 foot buffer and a 4 lb/acre backpack application. The most common rate of application on the ANF is1 lb/acre (primarily for airblast and backpack treatments) which results in an HQ of 0.0008 at 25 feet. This analysis shows that buffers of 25 feet provide abundant protection for sensitive aquatic species.

The analysis done for this document shows that these buffers will protect water quality. When these buffer strips are used, glyphosate residues in water are expected to be less than 0.05 mg/L and to persist in measurable amounts for less than 1 week. During storms occurring within the first 30 days after application, the maximum concentration of glyphosate expected in stream water (perennial or intermittent) is less than 0.02 mg/L, with persistence of less than 1 week.

These values are much less than the 0.7 mg/L water quality protection criterion for glyphosate specified in the 1997 ANF FEIS (USDA FS 1997) that is considered to be currently valid. Consumption of water (2 L per day) contaminated at the level of the water quality protection criterion of 0.7 mg/L would result in an exposure value for a 70 kg human of 0.02 mg/kg/day. The hazard quotient for this exposure based on the RfD of 2 mg/kg/day is 0.01, which is 100 fold less than the level of concern.

According to SERA (2003a), drift associated with backpack (directed foliar applications) are likely to be much less. This is discussed further in the risk characterization. Drift distance can be estimated using Stoke's law, which describes the viscous drag on a moving sphere. In typical backpack ground sprays, droplet sizes are greater than 100µ, and the distance from the spray nozzle to the ground is 3 feet or less. In mechanical sprays, raindrop nozzles might be used. These nozzles generate droplets that are usually greater than 400µ, and the maximum distance above the ground is about 6 feet. In both cases, the sprays are directed downward. Thus, the amount of time required for a 100 µ droplet to fall 3 feet (91.4 cm) is approximately 3.2 seconds,

$$91.4 \div (2.87 \text{ @ } 10^5(0.01)^2).$$

The comparable time for a 400 µ droplet to fall 6 feet (182.8 cm) is approximately 0.4 seconds,

$$182.8 \div (2.87 \text{ @ } 10^5(0.04)^2).$$

For most applications, the wind velocity will be no more than 5 miles/hour, which is equivalent to approximately 7.5 feet/second (1 mile/hour = 1.467 feet/second). Assuming a wind direction perpendicular to the line of application, 100μ particles falling from 3 feet above the surface could drift as far as 23 feet (3 seconds @ 7.5 feet/second). A raindrop or 400μ particle applied at 6 feet above the surface could drift about 3 feet (0.4 seconds @ 7.5 feet/second). (Authors note: The overstory vegetation on ANF will moderate wind speeds, thus the exposure estimates based on this section are conservative. For backpack applications, wind speeds of up to 10 miles/hour are allowed in ANF, which would cause a 100μ droplet to drift as far as 45 feet (3 seconds @ 10 @ 1.5 feet/second), if it does not impact intervening vegetation. Smaller droplets will of course drift further, and the proportion of these particles in the spray as well as the wind speed will affect the proportion of the applied herbicide that drifts off-site.

There are several factors in ANF operations that substantially reduce the potential for drift predicted by AgDRIFT for low boom ground applications. First, mechanical airblast spraying on the ANF produces median droplet diameters of 800 to 1300 microns, two to three times larger than those those used in SERA (2003a) AgDRIFT modeling. Second, AgDRIFT evaluates open conditions over relatively bare ground with no adjacent intercepting vegetation. The heavily vegetated sites proposed for treatment on ANF will significantly reduce spray drift due to interception of spray droplets by intervening vegetation. Finally, ANF personnel measure wind speed in the open and terminate applications in winds above 10 mph. AgDRIFT also uses 10 mph wind speed, but ANF experience shows the wind speed is greatly moderated in the heavily forested canopy of the ANF, hence terminating ANF spray operations when the wind rises to 10 mph in the open, results in termination at a much lower wind speed (~ 4 mph) where applications are actually being made under the canopy.

AgDRIFT testing and modeling with an orchard airblast application shows a marked reduction in deposition beyond the first two layers of intercepting vegetation. In testing conducted in an apple orchard (trees 14 feet tall) with foliage fully developed, downwind spray deposition immediately beyond the second row of trees was more than 90% less than the deposition beyond the first row, and downwind spray deposition was essentially zero at 100 feet (Teske et al. 2001).

Based on this experience, monitoring and research, and the analysis of drift done in this appendix, we conclude that the buffer strategy used previously by ANF for silvicultural operations was unnecessarily restrictive. We believe the buffers proposed in this current ANF risk assessment will protect aquatic life and water users. However, continued monitoring is needed to increase the breadth of the experience base and to further verify the adequacy of this buffer strategy, and to provide documentation that water quality is protected.

Runoff

Glyphosate or any other herbicide may be transported to off-site soil by runoff or percolation. Both runoff and percolation are considered in estimating contamination of ambient water. For assessing off-site soil contamination, however, only runoff is considered. This is similar to the approach used by U.S. EPA (1995) in their exposure assessment for terrestrial plants. The approach is reasonable because off-site runoff will contaminate the off-site soil surface and could impact non-target plants. Percolation, on the other hand, represents the amount of the herbicide that is transported below the root zone and thus may impact water quality but should not affect off-site vegetation.

Based on the results of the GLEAMS modeling conducted by SERA (2003a), the proportion of the applied glyphosate lost by runoff was estimated for clay, loam, and sand at rainfall rates ranging from 5 inches to 250 inches per year.

The majority (approximately 75%) of surface soil textures found on the ANF fall within the loam category (loam, silt-loam, etc.). Hazelton soils (approximately 25% of ANF soils) are a sandy loam, which would have properties somewhere in between the loam and sand category. About 50% of the ANF has soil map units with a high potential for a fragipan (clay layer) at a depth of 40 to 60 inches (though it sometimes occurs at 20 to 30 inches), at which point the soil would have the properties of the clay category.

Soil pH on the ANF typically ranges from 3.6 to 6.0, but it can be as high as 8.0 in riparian and floodplain soils or newly formed soils. These more basic soils make up less than 5% of the ANF and are typically in areas where herbicide use would be more limited. Most soils tested in the past few years at upland locations have had pH values in the 4.0 to 4.5 range. The rainfall on ANF is approximately 50 inches per year, which is the value used in a portion of the GLEAMS analysis. Based on this specific information about ANF soils, the GLEAMS projections for the loam soil is most relevant for this risk assessment. However, GLEAMS is based on agricultural soils and does not include consideration of the litter and duff layer common on the forest floor of the ANF. The litter and duff layer as well as the predominance of loam soils on the ANF result in relatively rapid percolation of rainfall into the soil profile, significantly reducing the potential for runoff.

Wind Erosion

Wind erosion is a major transport mechanism for soil (e.g. Winegardner 1996) and is associated with the environmental transport of herbicides (Buser 1990), although this is characteristically in agricultural settings, often involving tillage and bare soils. The ANF forest condition is markedly different. For instance the soil surface is almost never exposed as it is in an agricultural setting, because of the litter and forest floor layers found under the canopies where ANF vegetation management is done. For these reasons we believe wind transport of sulfometuron methyl would be neither substantial nor significant on the ANF, and it is not considered further in this risk assessment.

Aquatic Organisms

The potential for effects on aquatic species are based on estimated concentrations of glyphosate in water that are identical to those used in the human health risk assessment (Appendix G1, Section 4). Thus, for an accidental spill, the central estimate for the concentration of glyphosate in a small pond is estimated at about 18.2 mg/L (SERA 2003b, Worksheet D05). For longer term exposure scenarios, the expected concentrations of glyphosate in ambient water range from 0.0001 to 0.008 mg/L with a central value of 0.001 mg/L (SERA 2003b, Worksheet B06).

Terrestrial and Aquatic Species Exposure Assessment for Sulfometuron Methyl

The typical and maximum rates of application on the ANF are shown in Table 13. The application rates included in SERA (2004a, b) are lower than most rates proposed for use on the ANF. A common rate of application used in SERA (2004a, b) risk analysis is 0.045 pounds per acre, whereas the typical and maximum rates proposed for ANF are 0.09 and 0.19 pounds per acre. The ANF risk analyses for sulfometuron methyl are adjusted for these differences in rates of application. The data in Table 13 is used in estimating exposure and calculating the dose. The typical and maximum anticipated acres treated are shown in Table 14 and are included here to show the extent of the operations included in the analysis.

Table 13. Typical and maximum application rates on the ANF for sulfometuron methyl

Application	Sustaining forest cover/forest products and Improvements	Developing/maintaining wildlife habitat/visual enhancements	Treat/Control invasive species
	Typical [maximum] (lbs a.i./acre)		
Mechanical-foliar (air blast sprayer)	0.09 [0.19]	0.09 [0.19]	0.09 [0.19]
Manual-ground (backpack)	0.09 [0.19]	0.09 [0.19]	0.09 [0.19]
Cut surface	0 [0]	0 [0]	0 [0]

Table 14. Typical and maximum anticipated number of acres treated per year with sulfometuron methyl on the ANF for 2006–2020*

Application	Sustaining forest cover/forest products and improvements	Developing/maintaining wildlife habitat/visual enhancements	Treat/Control invasive species
	Typical [maximum] (acre/year)		
Mechanical-foliar (air blast sprayer)	2000 [3500]	10 [20]	2 [4]
Manual-ground (backpack)	180 [300] *47 [94] in riparian areas*	25 [50] 2[4] in riparian	3 [6] 1[2] in riparian
Cut surface	0 [0]	0 [0]	0 [0]

Total acres all application methods and vegetation management objectives: Typical–2220 acres, Maximum–3880 acres
*The Number Of Acres That Fall Within In Riparian Areas Is In Italics.
**Includes riparian acres

Riparian areas are listed on a separate line in this table to show that glyphosate treatments would be needed there because they have similar interference problems as the rest of the ANF. These acres listed for riparian areas are included in the total acres proposed for treatment in each column for a particular application method; they are not additional acres to be treated. The same water buffer strips and mitigation measures would apply to riparian areas as to the rest of the ANF. Data in Table 14 is not used in the risk analysis but is included to show the spatial extent of the proposed ANF program.

The following is the basis for SERA's (2004a, b) method for exposure assessments:

Terrestrial Wildlife

Terrestrial animals might be exposed to any applied herbicide from direct spray, the ingestion of contaminated media (vegetation, prey species, or water), grooming activities, or indirect contact with contaminated vegetation.

In the SERA (2004a, b) exposure assessment, estimates of oral exposure are expressed in the same units as the available toxicity data. As in the human health risk assessment, these units are usually expressed as mg of agent per kg of body weight and abbreviated as mg/kg. For dermal exposure, the units of measure usually are expressed in mg of agent per cm of surface area of the organism and abbreviated as mg/cm^2. In estimating dose, however, a distinction is made between the exposure dose and the absorbed dose. The *exposure dose* is the amount of material on the organism (i.e., the product of the residue level in mg/cm and the amount of surface area exposed), which can be expressed either as mg/organism or mg/kg body weight. The *absorbed dose* is the proportion of the exposure dose that is actually taken in or absorbed by the animal.

The exposure assessments for terrestrial animals are summarized in Worksheet G01 (SERA 2004b). As with the human health exposure assessment, the computational details for each exposure assessment presented in this section are provided in scenario specific worksheets (SERA 2004b; Worksheets F01 through F16b). Given the large number of species that could be exposed to herbicides and the varied diets in each of these species, a very large number of different exposure scenarios could be generated. For this risk assessment, animals on the ANF are (adequately) represented by the types included in the SERA analysis.

Because of the relationship of body weight to surface area as well as the consumption of food and water, small animals will generally receive a higher dose, in terms of mg/kg body weight, than large animals will receive for a given type of exposure. Consequently, most general exposure scenarios for mammals and birds are based on a small mammal or bird. For small mammals, the body weight is taken as 20 grams, typical of mice, and exposure assessments are conducted for direct spray (SERA 2004b; Worksheets F01 and F02a), consumption of contaminated fruit (SERA 2004b; Worksheets F03, F04a, F04b), and the consumption of contaminated water (SERA 2004b; Worksheets F05, F06, F07). Grasses will generally have higher concentrations of herbicides than fruits and other types of vegetation (Fletcher et al. 1994; Hoerger and Kenaga 1972). Because small mammals do not generally consume large amounts of grass, the scenario for the assessment of contaminated grass is based on a large mammal–a deer (SERA 2004b; Worksheets F10, F11a, and F11b). Other exposure scenarios for mammals involve the consumption of contaminated insects by a small mammal (SERA 2004b; Worksheet F14a) and the consumption of small mammals by a large mammalian carnivore (SERA 2004b; Worksheet F16a). Exposure scenarios for birds involve the consumption of contaminated insects by a small bird (SERA 2004b; Worksheet F14b), the consumption of contaminated fish by a predatory bird (SERA 2004b; Worksheets F08 and F09), the consumption of small mammals by a predatory bird (SERA 2004b; Worksheet F16b), and the consumption of contaminated grasses by a large bird (SERA 2004b; Worksheets F12, F13a, and F13b).

In the SERA risk assessment, they calculate exposure and risk values for three ranges of condition called lower, central, and upper, to take into account variability in environmental conditions and uncertainties with respect to exposure. Lower estimates are meant to encompass the range of environmental conditions and uncertainties expected to produce the lowest levels of exposure. The central values are meant to encompass the range of environmental conditions and uncertainties expected to produce the most likely levels of exposure. The upper values are meant to encompass the range of environmental conditions and uncertainties expected to produce the highest levels of exposure.

The central value is the “most likely” value. For perspective, the lower value is 10 times less than the upper value, thus the table provides for a 10-fold level of uncertainty, and provides a conservative approach to this assessment. Also, note that the section on environmental behavior of sulfometuron methyl in Appendix G1, Section 7 and the discussion in SERA (2003a) provide the basis for deriving the values reported in Table 15.)

After this review of data and analyses related to exposure, we summarize critical ANF exposure values for wildlife in Table 15. These values are used in the risk assessment.

Table 15. Summary of exposure scenarios for terrestrial animals for ANF sulfometuron methyl application rates of 0.09 and 0.19 lbs a.i./acre*

Scenario	Central		Lower		Upper	
	ANF Application Rates (lbs a.i./acre)					
	0.09	0.19	0.09	0.19	0.09	0.19
Acute/Accidental Exposure(mg/kg)						
Direct Spray						
small mammal, first-order absorption	0.01	0.02	0.002	0.005	0.05	0.11
small animal, 100% absorption	2.18	4.58	2.18	4.58	2.18	4.58
honey bee, 100% absorption	14.42	30.28	14.42	30.28	14.42	30.28
Contaminated Vegetation						
small mammal	0.11	0.24	0.11	0.24	0.24	0.51
large mammal	1.55	3.25	1.55	3.25	4.38	9.2
large bird	2.42	5.08	2.42	5.08	6.84	14.36
Contaminated Water						
small mammal, spill	0.09	0.19	0.03	0.06	0.24	0.51
small mammal, stream	0.00001	0.00003	0.0000008	0.000002	0.0003	0.0006
Contaminated Insects						
small mammal	2.08	4.37	2.08	4.37	6.24	13.1
small bird	3.38	7.1	3.38	7.1	10.16	21.34
Contaminated Fish						
predatory bird, spill	0.42	0.89	0.07	0.14	1.75	3.67
Contaminated Small Mammal						
carnivorous mammal	0.19	0.4	0.19	0.4	0.19	0.4
carnivorous bird	0.29	0.61	0.29	0.61	0.29	0.61
Longer-term Exposures(mg/kg/day)						
Contaminated Vegetation						
small mammal, on-site	0.002	0.004	0.0009	0.002	0.008	0.02
small mammal, off-site	0.00002	0.00004	0.000005	0.00001	0.0001	0.0003
large mammal, on-site	0.07	0.16	0.02	0.05	0.7	1.47
large mammal, off-site	0.002	0.005	0.001	0.003	0.01	0.03
large bird, on-site	0.12	0.24	0.04	0.08	1.09	2.3
large bird, off-site	0.004	0.008	0.002	0.005	0.02	0.04
Contaminated Water						
small mammal	0.0000005	0.000001	0.0000001	0.0000003	0.0000009	0.000002
Contaminated Wish						
predatory bird	0.000002	0.000004	0.0000003	0.0000006	0.000006	0.00001

* Values Are Based On SERA (2004b) Worksheet G01.

The following is a discussion of SERA's basis and analysis for the exposure values reported in Table 15. The process used by SERA applies to the ANF except where noted.

Direct Spray

In a scenario involving exposure to direct spray, the extent of dermal contact depends on the application rate, the surface area of the organism, and the rate of absorption. Note that the 0.09 lb/acre rate is the most widely used rate on the ANF. Occasionally the aggregate rate is 0.19 lb/acre if retreatment is necessary. Direct spray of wildlife is not expected to be widespread because in airblast the noise is likely to cause animals to leave the area before application occurs. In the case of the backpack method of application wildlife are also likely to leave the area to avoid contact with humans, and in addition the operator can avoid direct application on wildlife that remain. Cut surface applications are not made with sulfometuron methyl.

This scenario is similar to the accidental exposure scenarios for the general public discussed in Appendix G1, Section 7. For this risk assessment, three groups of direct spray exposure assessments are conducted (small mammal, first-order absorption, small animal, 100% absorption, and bee, 100% absorption)

Small Mammal, First-order Absorption

This scenario is defined in Worksheet F01 (SERA 2004b) and involves a 20g mammal that is sprayed directly over one half of the body surface as the chemical is being applied. The absorbed dose over the first day (i.e., a 24 hour period) is estimated using the assumption of first-order dermal absorption. In the absence of any data regarding dermal absorption in a small mammal, the estimated absorption rate for humans is used (Appendix G1, Section 7). An empirical relationship between body weight and surface area (Boxenbaum and D'Souza 1990) is used to estimate the surface area of the animal. The estimates of absorbed doses in this scenario may bracket plausible levels of exposure for small mammals based on uncertainties in the dermal absorption rate of sulfometuron methyl.

Small Animal, 100% Absorption

Other, perhaps more substantial, uncertainties affect the estimates for absorbed dose. For example, the estimate based on first-order dermal absorption does not consider fugitive losses from the surface of the animal and may overestimate the absorbed dose. Conversely, some animals, particularly birds and mammals, groom frequently, and grooming may contribute to the total absorbed dose by direct ingestion of the compound residing on fur or feathers. Furthermore, other vertebrates, particularly amphibians, may have skin that is far more permeable than the skin of most mammals. Quantitative methods for considering the effects of grooming or increased dermal permeability are not available. As a conservative upper limit, the second exposure scenario, detailed in SERA (2004b, Worksheet F02), is developed in which complete absorption over day 1 of exposure is assumed.

Bee, 100% Absorption

Because of the relationship of body size to surface area, very small organisms, like bees and other terrestrial insects, might be exposed to much greater amounts of sulfometuron methyl per unit body weight, compared with small mammals. Consequently, a third exposure assessment is developed using a body weight of 0.093 g for the honey bee (USDA/APHIS 1993) and the equation above for body surface area proposed by Boxenbaum and D'Souza (1990). Because there is no information regarding the dermal absorption rate of sulfometuron methyl by bees or other invertebrates, this exposure scenario, detailed in Worksheet F02b (SERA 2004b), also assumes complete absorption over the first day of exposure.

Large Mammals

Direct spray scenarios are not given for large mammals. As noted above, allometric relationships dictate that large mammals will be exposed to lesser amounts of a compound in any direct spray scenario than smaller mammals. As detailed further in Section 4.4 (SERA 2004a), the direct spray scenarios for the small mammal are substantially below a level of concern. Consequently, elaborating direct spray scenarios for a large mammal would have no impact on the characterization of risk. In addition it is expected that large animals would leave the area in which spray operations are being conducted.

Indirect Contact

As in the human health risk assessment (Appendix G1, Section 7), the only approach for estimating the potential significance of indirect dermal contact is to assume a relationship between the application rate and dislodgeable foliar residue. The study by Harris and Solomon (1992) (SERA 2004b, Worksheet A04) is used to estimate that the dislodgeable residue will be approximately 10 times less than the nominal application rate.

Unlike the human health risk assessment in which transfer rates for humans are available, there are no transfer rates available for wildlife species. As discussed in Durkin et al. (1995), the transfer rates for humans are based on brief (e.g. 0.5 to 1 hour) exposures that measure the transfer from contaminated soil to uncontaminated skin.

Wildlife, compared with humans, are likely to spend longer periods of time in contact with contaminated vegetation.

It is reasonable to assume that for prolonged exposures, an equilibrium may be reached between levels on the skin, rates of absorption, and levels on contaminated vegetation, although there are no data regarding the kinetics of such a process. The bioconcentration data on sulfometuron methyl suggest that sulfometuron methyl may accumulate to a small degree in muscle and viscera of fish (Appendix G1, Section 7). However, the high water solubility and low octanol/water partition coefficient for sulfometuron methyl suggest that sulfometuron methyl is not likely to partition from the surface of contaminated vegetation to the surface of skin, feathers, or fur. Thus, a plausible partition coefficient is unity (i.e., the concentration of the chemical on the surface of the animal will be equal to the dislodgeable residue on the vegetation).

Under these assumptions, the absorbed dose resulting from contact with contaminated vegetation will be one-tenth that associated with comparable direct spray scenarios. As discussed later in the risk characterization for ecological effects, the direct spray scenarios result in exposure levels below the estimated NOAEL (i.e., hazard quotients below one). Consequently, details of the indirect exposure scenarios for contaminated vegetation are not further elaborated in this document.

Ingestion of Contaminated Vegetation or Prey

Since sulfometuron methyl will be applied to vegetation, the consumption of contaminated vegetation is an obvious concern, and separate exposure scenarios are developed for acute and chronic exposure scenarios for a small mammal (SERA 2004b, Worksheets F04a and F04b) and large mammal (SERA 2004b, Worksheets F10, F11a, and F11b) as well as large birds (SERA 2004b, Worksheets F12, F13a, and F13b).

For the consumption of contaminated vegetation, a small mammal is used because allometric relationships indicate that small mammals will ingest greater amounts of food per unit body weight, compared with large mammals. The amount of food consumed per day by a small mammal (i.e., an animal weighing approximately 20 g) is equal to about 15% of the mammal's total body weight (U.S. EPA/ORD 1989). When applied generally, this value may overestimate or underestimate exposure in some circumstances. For example, a 20 g herbivore has a caloric requirement of about 13.5 kcal/day. If the diet of the herbivore consists largely of seeds (4.92 kcal/g), the animal would have to consume a daily amount of food equivalent to approximately 14% of its body weight [(13.5 kcal/day ÷ 4.92 kcal/g)÷20g = 0.137]. Conversely, if the diet of the herbivore consists largely of vegetation (2.46 kcal/g), the animal would have to consume a daily amount of food equivalent to approximately 27% of its body weight [(13.5 kcal/day ÷ 2.46 kcal/g)÷20g = 0.274] (U.S. EPA/ORD 1993, pp.3-5 to 3-6). For the SERA (2004a, b) exposure assessment (SERA 2004b, Worksheet F03), the amount of food consumed per day by a small mammal weighing 20 g is estimated at about 3.6 g/day or about 18% of body weight per day from the general allometric relationship for food consumption in rodents (U.S. EPA/ORD 1993, p. 3-6).

A large herbivorous mammal is included because empirical relationships of concentrations of pesticides in vegetation, discussed below, indicate that grasses may have substantially higher pesticide residues than other types of vegetation such as forage crops or fruits (SERA 2004b, Worksheet A04). Grasses are an important part of the diet for some large herbivores, but most small mammals do not consume grasses as a substantial proportion of their diet. Thus, even though using residues from grass to model exposure for a small mammal is the most conservative approach, it is not generally applicable to the assessment of potential adverse effects. Hence, in the exposure scenarios for large mammals, the consumption of contaminated range grass is modeled for a 70 kg herbivore, such as a deer. Caloric requirements for herbivores and the caloric content of vegetation are used to estimate food consumption based on data from U.S. EPA/ORD (1993). Details of these exposure scenarios are given in worksheets F10 for acute exposures as well as Worksheets F11a and F11b (SERA 2004b) for longer-term exposures.

For the acute exposures, the assumption is made that the vegetation is sprayed directly, i.e., the animal grazes on site, and that100% of the animal's diet is contaminated. While appropriately conservative for acute exposures, neither of these assumptions is plausible for longer-term exposures. Thus, for the longer-term exposure scenarios for the large mammal, two sub-scenarios are given. The first is an on-site scenario that assumes that a 70 kg herbivore consumes short grass for a 90 day period after application of the chemical. In the worksheets, the contaminated vegetation is assumed to account for 30% of the diet with a range of 10 to 100% of the diet. These are essentially arbitrary assumptions reflecting grazing time at the application site by the animal. Because the animal is assumed to be feeding at the application site, drift is set to unity, i.e., direct spray. This scenario is detailed in Worksheet 11a (SERA 2004b). The second sub-scenario is similar except the assumption is made that the animal is grazing at distances of 25 to 100 feet from the application site (lowering risk), but that the animal consumes 100% of the diet from the contaminated area (increasing risk). For this scenario, detailed in Worksheet F12b (SERA 2004b), AgDRIFT is used to estimate deposition on the off-site vegetation. Drift estimates from AgDRIFT are summarized in Worksheet A06 (SERA 2004b), but AgDRIFT is believed to overestimate the extent of drift on ANF operations. See additional comments below.

The consumption of contaminated vegetation is also modeled for a large bird. For these exposure scenarios, the consumption of range grass by a 4 kg herbivorous bird, like a Canada Goose, is modeled for both acute (SERA 2004b, Worksheet F12) and chronic exposures (SERA 2004b, Worksheets F13a and F13b). As with the large mammal, the two chronic exposure scenarios involve sub-scenarios for on-site as well as off-site exposure.

For this component of the exposure assessment, the estimated amounts of pesticide residue in vegetation are based on the relationship between application rate and residue rates on different types of vegetation. As summarized in Worksheet A04 (SERA 2004b), these residue rates are based on estimated residue rates from Fletcher et al. (1994).

Similarly, the consumption of contaminated insects is modeled for a small (10g) bird and a small (20g) mammal. No monitoring data have been encountered on the concentrations of sulfometuron methyl in insects after applications of sulfometuron methyl. The empirical relationships recommended by Fletcher et al. (1994) are used as surrogates as detailed in Worksheets F14a and F14b (SERA 2004b). To be conservative, the residue rates from small insects are used, i.e., 45 to 135 ppm per lb/ac, rather than the residue rates from large insects, i.e., 7 to 15 ppm per lb/ac.

A similar set of scenarios are provided for the consumption of small mammals by either a predatory mammal (SERA 2004b, Worksheet 16a) or a predatory bird (SERA 2004b, Worksheet 16a). Each of these scenarios assume that the small mammal is directly sprayed at the specified application rate, and the concentration of the compound in the small mammal is taken from the worksheet for direct spray of a small mammal under the assumption of 100% absorption (SERA 2004b, Worksheet F02a).

In addition to the consumption of contaminated vegetation and insects, sulfometuron methyl may reach ambient water and fish. Thus, a separate exposure scenario is developed for the consumption of contaminated fish by a predatory bird in both acute (SERA 2004b, Worksheet F08) and chronic (SERA 2004b, Worksheet F09) exposures. Because predatory birds usually consume more food per unit body weight than do predatory mammals (U.S. EPA 1993, pp. 3-4 to 3-6), separate exposure scenarios for the consumption of contaminated fish by predatory mammals are not developed.

Ingestion of Contaminated Water

Estimated concentrations of sulfometuron methyl in water are identical to those used in the human health risk assessment (SERA 2004b, Worksheet B06) and Appendix G1, Section 7. The only major differences involve the weight of the animal and the amount of water consumed. There are well-established relationships between body weight and water consumption across a wide range of mammalian species (e.g. U.S. EPA 1989). Mice, weighing about 0.02 kg, consume approximately 0.005 L of water/day (i.e., 0.25 L/kg body weight/day). These values are used in the exposure assessment for the small (20 g) mammal. Unlike the human health risk assessment, estimates of the variability of water consumption are not available. Thus, for the acute scenario, the only factors affecting the variability of the ingested dose estimates include the field dilution rates (i.e., the concentration of the chemical in the solution that is spilled) and the amount of solution that is spilled. As in the acute exposure scenario for the human health risk assessment, the amount of the spilled solution is taken as 200 gallons. In the exposure scenario involving contaminated ponds or streams due to contamination by runoff or percolation, the factors that affect the variability are the water contamination rate and the application rate. Details regarding these calculations for both acute and chronic exposure scenarios are summarized in Worksheets F06 and Worksheet F07 (SERA 2004b) and in Appendix G1, Section 7.

Terrestrial Plants

In general, the primary hazard to non-target terrestrial plants associated with the application of most herbicides is unintended direct deposition or spray drift. In addition, herbicides may be transported off-site by percolation or runoff or by wind erosion of soil.

Direct Spray

Unintended direct spray will result in an exposure level equivalent to the application rate. For many types of herbicide applications, e.g. sustaining forest cover or controlling invasive plant species, it is plausible that some non-target plants immediately adjacent to the application site could be sprayed directly. This type of scenario is modeled in the human health risk assessment for the consumption of contaminated vegetation (Appendix G1, Section 7).

Off-site Drift and Buffers

Off-site drift is a physical process that depends primarily on droplet size and meteorological conditions rather than the specific properties of the herbicide, and estimates of off-site drift can be modeled using AgDRIFT (Teske et al. 2001). AgDRIFT is a model developed as a joint effort by the EPA Office of Research and Development and the Spray Drift Task Force, a coalition of pesticide registrants. Further details of AgDRIFT are available at http: //www.AgDRIFT.com/. AgDRIFT is based on the algorithms in FSCBG (Teske and Curbishley. 1990), a drift model previously used by USDA. This model was developed for aerial application, which is not used on the ANF, but it has subsequently been adapted to provide analysis for ground applications.

For ground applications, AgDRIFT provides estimates of drift based solely on distance downwind and the application method: low boom ground spray, high boom ground spray, and orchard airblast. SERA used drift data for the low boom ground sprayer in all of their risk assessments, and this is the approach used in this ANF risk assessment, except in the analysis of risk for terrestrial and aquatic plants and of buffers where AgDRIFT data for the orchard airblast is used to represent airblast for the ANF. Note that AgDRIFT modeling for the low boom ground sprayer is done for essentially bare ground, and includes no intercepting vegetation. In contrast, applications on ANF are typically in dense forest cover, with an abundance of vegetative surfaces for spray interception. For this reason we believe SERA estimates of drift based on the low boom ground sprayer for ANF conditions results in a conservative risk estimate.

Buffers

Buffers are a strip of untreated vegetation adjacent to wetlands, water bodies and flowing water. The purpose of the buffer is to prevent the entry of unacceptable levels of herbicide to the water, thereby reducing water quality. The size of the buffer varies with the application technique and the characteristics of individual herbicides, such as the toxicity of the herbicide to animals and aquatic organisms that might use the water, and the movement, persistence and fate of the herbicide in the environment close to water.

For broadcast foliar mechanical (airblast) application, the following buffers and application tactics will provide water quality protection involving the use of sulfometuron methyl.

For an application rate of 0.09 lb/acre

- No sulfometuron methyl shall be applied to surface waters.
- Buffers 25 ft wide along each side of perennial streams, springs, impoundments, or intermittent streams with flowing water the day of spraying;
- 25 ft wide around wet areas (standing water) and vernal ponds with no defined outlet.
- 10 ft wide along each side of dry intermittent streams, dry springs, and dry seeps.
- Airblast shall be directed away from the buffer when applications are made within 50 ft of the edge of the buffer, i.e., within 50 ft no airblast directed towards the edge of the buffer.

For an application rate of 0.19 lb/acre

- No sulfometuron methyl shall be applied to surface waters.
- Buffers 50 ft wide along each side of perennial streams, springs, impoundments, or intermittent streams with flowing water the day of spraying;
- 50 ft wide around wet areas (standing water) and vernal ponds with no defined outlet.
- 25 ft wide along each side of dry intermittent streams and spring seeps.
- Airblast shall be directed away from the buffer when applications are made within 100 ft of the edge of the buffer, i.e., within 100 ft no airblast directed towards the edge of the buffer.

For directed foliar backpack (0.09 or 0.19 lb/acre) application method, the following buffers and tactics will provide water quality protection involving the use of sulfometuron methyl:

- No sulfometuron methyl shall be applied to surface waters.
- No sulfometuron methyl shall be applied within 10 ft (when using 0.09 lb/acre) or 25 ft (when using 0.19 lb/acre) of standing or flowing water.
- No sulfometuron methyl shall be applied within 10 feet (0.09 lb/acre) or 25 feet (0.19 lb/acre) of dry intermittent streams, dry springs, or dry seeps.

This buffer strategy was developed based on the experience of ANF managers, the results of ANF monitoring (results are in several ANF Monitoring and Evaluation Reports) and analysis of off-site deposition outlined in SERA (2003a, 2004a). The approach used is as follows:

Macrophytes with a NOEC of 0.00021 mg/L are the most sensitive aquatic species identified in SERA. The NOEC of 0.00021 mg/L for macrophytes is designated as the water quality protection criterion for sulfometuron methyl.

The water quality protection criterion is the NOEC for aquatic plant macrophytes, the most sensitive aquatic organisms identified in the hazard analysis. This criterion is more than 10,000 times lower than the value that would be used for human health protection, about 3-fold lower than the value to protect amphibians in a chronic exposure scenario, 1000 times lower then the criterion that would be used for sensitive aquatic invertebrates, and about 10,000 times lower than would be used as the criterion for fish.

Protection of aquatic macrophytes requires a water concentration less than 0.00021 mg/L. Direct application at a rate of 1 lb/acre to surface water 1 foot deep will result in a concentration of 0.37 mg/L. A deposition rate of 0.00057 lb/acre will meet this criterion (0.0021mg/L / 0.37 mg/L per pound per acre).

Table 10 gives the proportion of the application rate that is off-site deposition as a function of distance from the airblast application equipment. Based on the deposition fraction from Table 10, the buffer widths needed to achieve a deposition < 0.00057 lb/acre can be calculated. The critical buffer widths are 25 feet for an application rate of 0.09 lb/acre, and 50 feet for an application rate of 0.19 lb/acre.

We believe these buffers will protect water quality. When these buffer widths are used, sulfometuron methyl residues in water are expected to be less than 0.0002 mg/L at 50 feet and 0.00019 mg/L at 25 feet for application rates of 0.19 and 0.00009 mg/L for application rates of 0.09 lb/acre. These values are slightly less than the 0.00021 mg/L water quality protection criterion for sulfometuron methyl. Note that on the ANF, aquatic macrophytes are rare in headwater streams since they are cold and tend to scour frequently enough to prevent macrophyte establishment. Headwater streams constitute the majority of streams on the ANF; most herbicide treatment would occur in areas of the ANF dominated by them, providing an increased level of certainty of protection.

The ANF has conducted monitoring programs in connection with operational applications of herbicide on the ANF to verify protection of water quality and damage to vegetation outside of treatment areas. There are several in-house reports that provide the specifics of the monitoring program (typically these are included in Monitoring and Evaluation Reports for specific fiscal years). Table 16 shows the ANF water quality monitoring program activity. Visual monitoring for herbicide damage to vegetation was conducted in 2003 and 2004 and shows little or no damage to vegetation outside of the intended treatment area. Chemical water quality monitoring of silvicultural applications in 1990 and 2002 has shown no detectable concentrations of sulfometuron methyl in water samples tested.

Table 16. Date and type of ANF water quality monitoring

Year of Treatment and Survey Monitoring	Year of Monitoring and Evaluation Report	Vegetation Management Activity	Herbicide Monitored
1987	1988	Silviculture	glyphosate
1988	1989	Silviculture	glyphosate
1989	1990	Silviculture	sulfometuron methyl
1998	2000	Utility ROW[1]	glyphosate and imazapyr
1999	2001	Utility ROW	glyphosate and imazapyr
2000	2002	Utility ROW	glyphosate and imazapyr
2002	2002	Silviculture	glyphosate and sulfometuron methyl

[1] ROW=right-of-way

According to SERA, drift associated with backpack (directed foliar) applications are likely to be much less. This is discussed further in the risk characterization. Drift distance can be estimated using Stoke's law, which describes the viscous drag on a moving sphere. In typical backpack ground sprays, droplet sizes are greater than 100µ, and the distance from the spray nozzle to the ground is 3 feet or less. In mechanical sprays, raindrop nozzles might be used. These nozzles generate droplets that are usually greater than 400µ, and the maximum distance above the ground is about 6 feet. In both cases, the sprays are directed downward. Thus, the amount of time required for a 100 µ droplet to fall 3 feet (91.4 cm) is approximately 3.2 seconds,

$$91.4 \div (2.87 \ @ \ 10^5(0.01)^2).$$

The comparable time for a 400 µ droplet to fall 6 feet (182.8 cm) is approximately 0.4 seconds,

$$182.8 \div (2.87 \ @ \ 10^5(0.04)^2).$$

For most applications, the wind velocity will be no more than 5 miles/hour, which is equivalent to approximately 7.5 feet/second (1 mile/hour = 1.467 feet/second). Assuming a wind direction perpendicular to the line of application, 100µ particles falling from 3 feet above the surface could drift as far as 23 feet (3 seconds @ 7.5 feet/second). A raindrop or 400µ particle applied at 6 feet above the surface could drift about 3 feet (0.4 seconds

@ 7.5 feet/second). (Authors note: The overstory vegetation on ANF will moderate wind speeds, thus the exposure estimates based on this section are conservative. For backpack applications, wind speeds of up to 10 miles/hour are allowed in the ANF, which would cause a 100µ droplet to drift as far as 45 feet (3 seconds @ 10 @ 1.5 feet/second), if it does not impact intervening vegetation. Smaller droplets will of course drift further, and the proportion of these particles in the spray as well as the wind speed will affect the proportion of the applied herbicide that drifts off-site.

There are several factors in ANF operations that substantially reduce the potential for drift predicted by AgDRIFT for low boom ground applications. First, mechanical airblast spraying on the ANF produces median droplet diameters of 800 to 1300 microns, two to three times larger than those used in SERA (2003a) AgDRIFT modeling. Second, AgDRIFT evaluates open conditions over relatively bare ground with no adjacent intercepting vegetation. The heavily vegetated sites proposed for treatment on the ANF will significantly reduce spray drift due to interception of spray droplets by intervening vegetation. Finally, ANF personnel measure wind speed in the open and terminate applications in winds above 10 mph. AgDRIFT also uses 10 mph wind speed, but ANF experience shows the wind speed is greatly moderated in the heavily forested canopy of the ANF, hence terminating ANF spray operations when the wind rises to 10 mph in the open results in termination at a much lower wind speed (~ 4 mph) where applications are actually being made under the canopy.

AgDRIFT testing and modeling with an orchard airblast application shows a marked reduction in deposition beyond the first two layers of intercepting vegetation. In testing conducted in an apple orchard (trees 14 feet tall) with foliage fully developed, downwind spray deposition immediately beyond the second row of trees was more than 90% less than the deposition beyond the first row, and downwind spray deposition was essentially zero at 100 feet (Teske et al. 2001).

Based on this experience, monitoring and research, and the analysis of drift done in this appendix, we conclude that the buffer strategy used previously by ANF for silvicultural operations was unnecessarily restrictive. We believe the buffers proposed in this current ANF risk assessment will protect aquatic life and water users. However, continued monitoring is needed to increase the breadth of the experience base and to further verify the adequacy of this buffer strategy, and to provide documentation that water quality is protected

Runoff

Sulfometuron methyl or any other herbicide may be transported to off-site soil by runoff or percolation. Both runoff and percolation are considered in estimating contamination of ambient water. For assessing off-site soil contamination, however, only runoff is considered. This approach is reasonable because off-site runoff will contaminate the off-site soil surface and could impact non-target plants. Percolation, on the other hand, represents the amount of the herbicide that is transported below the root zone and thus may impact water quality but should not affect off-site vegetation.

Based on the results of the GLEAMS modeling conducted by SERA (2004a), the proportion of the applied sulfometuron methyl lost by runoff was estimated for clay, loam, and sand at rainfall rates ranging from 5 inches to 250 inches per year. These results are summarized in Worksheet G04 and indicate that runoff will be negligible in relatively arid environments as well as sandy or loam soils. The majority (approximately 75%) of surface soil textures found on the ANF fall within the loam category (loam, silt-loam, etc.). Hazelton soils (approximately 25% of ANF soils) are a sandy loam, which would have properties somewhere in between the loam and sand category. About 50% of the ANF has soil map units with a high potential for a fragipan (clay layer) at a depth of 40 to 60 inches (though it sometimes occurs at 20 to 30 inches), at which point the soil would have the properties of the clay category.

Soil pH on the ANF typically ranges from 3.6 to 6.0, but it can be as high as 8.0 in riparian and floodplain soils or newly formed soils. These more basic soils make up less than 5% of the ANF and are typically in areas where herbicide use would be more limited. Most soils tested in the past few years at upland locations have had pH values in the 4.0 to 4.5 range. The rainfall on ANF is approximately 50 inches per year, which is the value used in a portion of the GLEAMS analysis. Based on this specific information about ANF soils, the GLEAMS projections for the loam soil is most relevant for this risk assessment.

Two detailed studies (Hubbard et al. 1989, Wauchope et al. 1990) that investigate the fate and transport of sulfometuron methyl in soil are useful for assessing the potential for off-site vegetation to be exposed to sulfometuron methyl.

In the Hubbard et al. (1989) study, 0.6-4.48 kg/ha sulfometuron methyl was applied to three types of soil: sandy clay loam, loamy sand, and sand. The soil surfaces were free of vegetation, and the soil slope was 2%. One day before application, the soils were saturated with water by backflushing, which maximized the potential for runoff. Rainfall rates of 125, 75, and 43 mm/hour were then simulated for 2 hours, and runoff and percolation were measured. Concentrations of sulfometuron methyl in runoff were less than 2.4 mg/L (2.4 ppm), and the concentrations in percolate were less than 0.1 mg/L (0.1 ppm). Under low rainfall conditions (43 mm/hour), relatively little sulfometuron methyl was removed by runoff: 0 to 4.2% of the applied amount with the greatest proportion found in sandy clay loam. Under moderate or high levels of rainfall, however, up to 34.7% of the applied amount was lost by runoff. Again, the greatest losses were noted in the sandy clay loam soil, and losses were not as great in loamy sand or sand. As would be expected, percolation was generally greater in the sandier soils. As part of the study, Hubbard et al. (1989) compared the results of GLEAMS modeling with the monitoring runoff. In all instances, GLEAMS under-predicted runoff, in some cases by a factor of more than 30, with the greatest discrepancies apparent under heavy rainfall. According to the investigators, these discrepancies are probably attributable to the 1 day time step used by GLEAMS, which fails to account for rapid water and herbicide movement during short-term but intense rainfall events.

In the Wauchope et al. (1990), study, sulfometuron methyl was applied at a rate of 0.4 kg/ha to a sandy loam soil with an average slope of 2.5%. Bare soil as well as soil covered with Bermudagrass and Bahiagrass were used. Beginning 5 days before application, simulated rainfall was applied until runoff occurred. Thus, although the soil was moist at the time of application, like it was in the Hubbard et al. (1989) study, the soil was probably not as moist because of the longer period of time between effective soil saturation and herbicide application. After application, simulated rainfall was applied until 10 to12 500 mL runoff samples were collected. Although rainfall rates are not specified, total rainfall ranged from about 12 to 30 mm at each site. Thus, the amount of rainfall in this study was substantially less than that in the Hubbard et al. (1989) study, in which the lowest rate used was 43 mm/hour for 2 hours. In all cases, the fractional loss in runoff ranged from 0.7 to1.4% of the applied sulfometuron methyl and did not differ substantially on bare and covered plots. For this study, unlike the study by Hubbard et al. (1989), the GLEAMS model did a good job of predicting the amount of sulfometuron methyl runoff. The difference may be due to the lesser amounts of rainfall in the Wauchope et al. (1990), which would tend to diminish the importance of brief intense rainfall events.

These studies by Hubbard et al. (1989) and Wauchope et al. (1990) are fairly consistent with one another. The runoff losses of 0.7 to 1.4% from sandy loam soil after 12-30 mm of rain, observed by Wauchope et al. (1990), are comparable to the 0 to 4.2% runoff losses after a total rainfall of 84 mm (43 mm/hour for 2 hours), reported by Hubbard et al. (1989).

We note however that GLEAMS is based on agricultural soils and does not include consideration of the litter and duff layer common on the forest floor of ANF. The litter and duff layer, and the predominance of loam soils results in relatively rapid percolation of rainfall into the soil profile, significantly reducing the potential for runoff. It is highly unlikely that the runoff projected by Hubbard et al. and by Wauchope et al. would result in ANF operations.

Wind Erosion

Wind erosion is a major transport mechanism for soil (e.g. Winegardner 1996). Although no specific incidents of nontarget damage from wind erosion have been encountered in the literature for sulfometuron methyl, this mechanism has been associated with the environmental transport of other herbicides (Buser 1990), but the studies are in agricultural settings, often involving tillage. The ANF forest condition is markedly different. For instance the soil surface is almost never exposed as it is in an agricultural setting, because of the litter and forest floor layers found under the canopies where ANF vegetation management is done. For these reasons we believe wind transport of sulfometuron methyl would be neither substantial nor significant, and it is not considered further in this risk assessment.

Aquatic Organisms

The potential for effects on aquatic species are based on estimated concentrations of sulfometuron methyl in water that are identical to those used in the human health risk assessment (SERA 2003b, Worksheet B06). As summarized in Worksheet B06, the peak estimated rate of contamination of ambient water associated with the normal application of sulfometuron methyl is 0.001 (0.00006 to 0.02) mg a.e./L at an application rate of 1 lb a.e./acre. When adjusted for ANF rates of application of 0.09 and 0.19 lb/acre, the concentration in water is calculated to be 0.00009 and 0.00019 mg/L, respectively. For longer-term exposures related to ANF application rates of 0.09 and 0.19 lb/acre, the average estimated rate of contamination of ambient water 0.000004 and 0.000008 mg/L, respectively.

SECTION E. WILDLIFE RISK ANALYSIS

Wildlife risk from vegetation management with glyphosate and sulfometuron methyl is a function of the inherent toxicity (hazard) of each herbicide to different species and of the amount of each chemical (exposure) those species may take in as a result of a vegetation management operation.

Glyphosate Risk Analysis

This risk analysis for wildlife and aquatic organisms is based on and largely drawn from the Forest Service-wide glyphosate risk analysis by SERA (2003 a, b). The SERA (2003a) risk analysis is based on a rate of application of 2 pounds per acre. The most widely used rate of application on ANF is 1 lb/acre, although 2 pounds per acre is also used. A rate of 3 lb/acre is used in some cut surface applications, and in some cases 4 pounds per acre is used in control of invasive species by backpack sprayer. The hazard quotient (HQ) values were adjusted from the values in SERA (2003a, Table 4-4) by proportion to the ANF rate of application. For instance if the ANF rate of application is half of the rate SERA used in Table 4-4 (SERA 2003a), the HQ value is halved in Tables 17 and 18 of this ANF risk assessment. If the ANF rate is twice the rate SERA used in Table 4-4 (SERA 2003a), the HQ value is doubled in Tables 17 and 18.

Terrestrial Wildlife

The risk analysis for terrestrial vertebrates and invertebrates (the bee) is in Table 17. The risk in this analysis is expressed as the HQ, which is defined as the ratio of the exposure (from Table 8) to the critical toxicity value (from Table 3). SERA (2003a) states that an HQ value of less than 1.0 indicates that no adverse effects are likely to occur. Based on the application rates of 1, 2, 3 and 4 lbs/acre, all HQs are less than the level of concern (HQ = 1). At an HQ of 1.0 or less, there is no plausible basis for asserting that adverse effects are likely to occur.

Terrestrial Plants

The quantitative risk characterizations for terrestrial plants are summarized in Worksheet G04 (SERA 2003b) for the offsite movement of glyphosate in runoff and Worksheet G05 (SERA 2003b) for offsite movement of glyphosate by drift and wind erosion. Using the maximum ANF application rate of 4 lb/acre, the HQ value is less than 1 for runoff, based on SERA (2003b, Worksheet G04). Logically it would also be less than 1 for ANF rates of application of 1, 2 and 3 lb/acre. Based on this index of toxicity, plant species are not likely to be affected by runoff of glyphosate under any conditions.

SERA (2003b) calculated hazard quotients for offsite drift in Worksheet G05. Note that all of the SERA HQ values are based on drift estimates for the low-boom ground sprayer using the AgDRIFT model. Airblast modeling done by AgDRIFT indicates less off site drift than occurs with the low-boom sprayer. In instances where directed foliar applications are made by backpack or the cut surface method of application is used, little if any damage due to drift would occur.

In this ANF risk assessment we used SERA's NOEC value of 0.035 lb/acre for sensitive plant species and the NOAEL of 0.56 lb/acre for tolerant plant species in calculating HQ values. We used airblast off-site deposition data (Table 10) for all rates and methods of application (note: this will overestimate drift deposition for back pack and cut surface methods of application but will result in conservative estimates of HQ for these conditions). The HQ values are less than 1 in every instance. This indicates that at any proposed ANF rate of application, glyphosate is not likely to damage tolerant or sensitive plant species at distances as close as 25 feet from the application site.

Table 17. Summary of quantitative risk characterization for terrestrial animals at ANF glyphosate application rates of 1, 2, 3 and 4 lbs a.i/acre (0.75, 1.25, 2.25, and 3.0 lbs a.e./acre, respectively)
Values were derived from Table 4-4 in SERA (2003a). Risk is expressed in the table as HQ, the hazard quotient.

Scenario	Central				Lower				Upper			
	ANF Application Rates (lbs a.i./acre)											
	1.0	2.0	3.0	4.0	1.0	2.0	3.0	4.0	1.0	2.0	3.0	4.0
Acute/Accidental Exposures												
Direct Spray												
small mammal, first-order absorption	0.001	0.002	0.004	0.004	0.0003	0.0006	0.001	0.001	0.003	0.004	0.009	0.01
small animal, 100% absorption	0.1	0.2	0.4	0.4	0.1	0.2	0.4	0.4	0.1	0.2	0.4	0.4
bee, 100% absorption	0.2	0.4	0.8	0.9	0.2	0.4	0.8	0.9	0.2	0.4	0.8	0.9
Contaminated Vegetation												
small mammal	0.002	0.003	0.006	0.008	0.002	0.003	0.006	0.008	0.004	0.006	0.01	0.02
large mammal	0.08	0.1	0.2	0.3	0.08	0.1	0.2	0.3	0.2	0.4	0.8	0.9
large bird	0.04	0.06	0.1	0.2	0.04	0.06	0.1	0.2	0.1	0.2	0.4	0.4
Contaminated Water												
small mammal, spill	0.008	0.01	0.02	0.03	0.002	0.004	0.008	0.009	0.01	0.02	0.04	0.04
small mammal, stream	0.00001	0.00002	0.00004	0.00004	0.0000008	0.000001	0.000002	0.000003	0.0003	0.0004	0.0009	0.001
Contaminated Insects												
small bird	0.04	0.06	0.1	0.15	0.04	0.06	0.1	0.2	0.2	0.2	0.5	0.6
Contaminated Fish												
predatory bird, spill	0.0008	0.001	0.002	0.003	0.0001	0.0002	0.0004	0.0004	0.002	0.003	0.006	0.008
Longer-term Exposures												
Contaminated Vegetation												
small mammal, on-site	0.0001	0.0002	0.0004	0.0004	0.00004	0.00006	0.0001	0.0002	0.0004	0.0006	0.001	0.002
small mammal, off-site	0.000001	0.000002	0.000004	0.000004	0.0000003	0.0000005	0.000001	0.000001	0.000008	0.00001	0.00002	0.00003
large mammal, on-site	0.01	0.02	0.04	0.04	0.004	0.006	0.01	0.02	0.1	0.2	0.4	0.4
large mammal, off-site	0.0004	0.0006	0.001	0.002	0.0002	0.0004	0.0008	0.0009	0.002	0.004	0.008	0.009
large bird, on-site	0.03	0.06	0.1	0.1	0.01	0.02	0.04	0.04	0.3	0.5	1	1.2
large bird, off-site	0.001	0.002	0.004	0.004	0.0008	0.001	0.002	0.003	0.008	0.01	0.02	0.03
Contaminated Water												
small mammal	0.0000008	0.000001	0.000002	0.000003	0.00000008	0.0000001	0.0000002	0.0000003	0.000004	0.000006	0.00001	0.00002
Contaminated Fish												
predatory bird	0.0000004	0.0000006	0.000001	0.000002	0.00000002	0.00000003	0.00000006	0.00000008	0.000004	0.000006	0.00001	0.00002

Aquatic Organisms

The quantitative risk characterization for glyphosate for ANF aquatic species is summarized in Table 18. As in the corresponding tables for terrestrial species, the exposure component of the hazard quotients is based on the ANF proposed application rates of 1, 2, 3, and 4 a.i. lbs/acre. The HQ values were adjusted from the values in SERA (2003a, Table 4-5) by proportion to the rate of application. For instance if the ANF rate of application is ½ of the rate SERA used in Table 4-5 (SERA 2003a), the HQ value is halved in Table 12. If the ANF rate is twice the rate SERA used in their Table 4-5 (SERA 2003a), the HQ value is doubled in Table 12. ANF rates are expressed in pounds of active ingredient (a.i.) while SERA calculations used pounds of acid equivalent (a.e.), therefore values are based on a.e. and assumes that 4.0 lb a.i/gallon = 3 lb a.e./gallon. Rates in both a.i. and a.e. are shown in Table 18.

Table 18. Summary of quantitative risk characterization for aquatic species at ANF glyphosate application rates of 1, 2, 3 And 4 lbs a.i./acre (0.75, 1.25, 2.25, and 3.0 lbs a.e./acre, respectively)*
Risk is expressed as the hazard quotient (HQ).

Scenario	Central ANF Application Rates (lbs a.i./acre)*				Lower ANF Application Rates (lbs a.i./acre)				Upper ANF Application Rates (lbs a.i./acre)			
	1.0	2.0	3.0	4.0	1.0	2.0	3.0	4.0	1.0	2.0	3.0	4.0
Fish, Acute Exposures												
Typical Species	0.0002	0.0003	0.0005	0.0006	0.000008	0.00001	0.00003	0.00003	0.003	0.005	0.01	0.01
Sensitive Species	0.002	0.002	0.005	0.006	0.00008	0.0001	0.0002	0.0003	0.03	0.05	0.10	0.12
Fish, Chronic Exposures												
Typical Species	0.00003	0.00005	0.0001	0.0001	0.000003	0.000005	0.00001	0.00001	0.0002	0.0004	0.0008	0.0009
Sensitive Species	0.0003	0.0005	0.001	0.001	0.00003	0.00005	0.0001	0.0001	0.002	0.004	0.008	0.009
Aquatic Invertebrates												
Acute Exposures	0.00002	0.00003	0.00006	0.00008	0.000001	0.000002	0.000003	0.000004	0.0004	0.0006	0.001	0.002
Chronic Exposures	0.00002	0.00002	0.00005	0.00006	0.000002	0.000002	0.000005	0.000006	0.0001	0.0002	0.0004	0.0005
Aquatic Plants												
Acute	0.005	0.008	0.02	0.02	0.0002	0.0004	0.0008	0.001	0.10	0.17	0.34	0.40
Chronic	0.0002	0.0004	0.0008	0.001	0.00002	0.00004	0.00008	0.0001	0.002	0.003	0.007	0.008
Exposures (mg/L)												
Acute (stream)	0.02	0.02	0.05	0.06	0.0008	0.001	0.002	0.003	0.3	0.5	1	1.2
Longer-term (pond)	0.0008	0.001	0.002	0.003	0.00008	0.0001	0.0002	0.0003	0.006	0.01	0.02	0.02

*Values were derived from SERA (2003a Table 4-5). The critical toxicity values used were from SERA (2003a, Table 4-5).

The risk analysis (Table 18) shows that no HQ value exceeds one (the level of concern) for any rate of application on the ANF. The highest HQ (greatest risk) results from an application rate of 4 lb/acre. For fish the highest HQ is 0.12 for acute exposures of a sensitive species; for aquatic invertebrates the highest HQ is 0.002 for acute exposure, and for aquatic plants the highest HQ is 0.4. Aquatic plants appear to be somewhat less sensitive to glyphosate than the most sensitive aquatic animals. There is no indication that adverse effects on aquatic plants are plausible.

Based on this analysis we conclude that Accord Concentrate®, Glypro®, Foresters® and Rodeo® as proposed for use on ANF will not adversely affect aquatic organisms. The surfactants proposed for use on the ANF have inert ingredients classified by EPA as list 3 and 4b. List 3 indicates that there is unknown toxicity; for inerts where "there was no basis for placing it on any of the other lists. The Agency will continue to evaluate these chemical substances, as additional information becomes available, to determine if reclassification to List 1, 2, or 4 is appropriate." List 4 indicates minimal concern, further subdivided with List 4B for inerts with "*sufficient information to conclude that current use patterns in pesticide products will not adversely affect public health and the environment.*"

Sulfometuron Methyl Risk Analysis

This risk analysis for wildlife and aquatic organisms is based on and largely drawn from SERA (2004b, Tables G02–G05a and G05b) and from the Forest Service-wide risk analysis completed by SERA (2004a). The risk tables included at the end of this section are drawn from these worksheets with appropriate adjustments for ANF rates of application. The risk in this analysis is expressed as the hazard quotient (HQ), which is defined as the ratio of the exposure to the critical toxicity value. SERA states that an HQ value of less than 1.0 indicates that no adverse effects are likely to occur.

The results of the ANF risk analyses for terrestrial and aquatic species are in Tables 19 and 21. The tables are followed by a discussion of SERA's basis for and analysis of risk for terrestrial and aquatic species.

Table 19. Summary of sulfometuron methyl quantitative risk characterization for terrestrial animals for ANF application rates of 0.09 and 0.19 lbs a.i./acre*

Risk is expressed as the hazard quotient (HQ)

Scenario	Central		Lower		Upper	
	ANF Application Rates (lbs a.i./acre)					
	0.09	0.19	0.09	0.19	0.09	0.19
Acute/Accidental Exposure						
Direct Spray						
small mammal, first-order absorption	0.0001	0.000252	0.00002	0.000042	0.0006	0.00126
small animal, 100% absorption	0.02	0.042	0.02	0.042	0.02	0.042
honey bee, 100% absorption	0.01	0.0294	0.014	0.0294	0.014	0.0294
Contaminated Vegetation						
small mammal	0.001	0.002	0.001	0.002	0.002	0.004
large mammal	0.02	0.04	0.02	0.04	0.06	0.1
large bird	0.008	0.02	0.008	0.02	0.02	0.04
Contaminated Water						
small mammal, spill	0.001	0.002	0.0004	0.00084	0.002	0.004
small mammal, stream	0.0000002	0.0000003	0.00000001	0.00000002	0.000004	0.000008
Contaminated Insects						
small mammal	0.02	0.04	0.02	0.04	0.08	0.12
small bird	0.01	0.02	0.01	0.02	0.04	0.08
Contaminated Fish						
predatory bird, spill	0.001	0.003	0.0002	0.0004	0.006	0.01
Contaminated Small Mammal						
carnivorous mammal	0.002	0.004	0.002	0.004	0.002	0.004
carnivorous bird	0.001	0.002	0.001	0.002	0.001	0.002
Longer-term Exposures						
Contaminated Vegetation						
small mammal, on-site	0.001	0.002	0.0004	0.0008	0.004	0.008
small mammal, off-site	0.00001	0.00002	0.000002	0.000004	0.00008	0.0002
large mammal, on-site	0.04	0.08	0.01	0.02	0.4	0.84
large mammal, off-site	0.001	0.002	0.0008	0.002	0.006	0.01
large bird, on-site	0.06	0.13	0.02	0.04	0.6	1.26
large bird, off-site	0.002	0.004	0.001	0.002	0.01	0.021
Contaminated Water						
small mammal	0.0000002	0.0000004	0.00000006	0.0000001	0.0000004	0.0000008
Contaminated Fish						
predatory bird	0.000001	0.000002	0.0000001	0.0000003	0.000002	0.000004

* Values are derived from SERA (2004 B) Worksheet G03.

Terrestrial Wildlife

The quantitative risk characterization for mammals and birds is summarized in SERA (2004b, Worksheet G02). All exposures summarized in the Worksheet G01 (SERA 2004b) are based on the typical application rate of 0.045 lb a.e./acre. The ANF risk analysis for terrestrial species is in Table 19, and it is based on SERA values adjusted to reflect the rates of application used on ANF, specifically 0.09 and 0.19 lb/acre. Risk (HQ) is characterized as the estimated dose, taken from Table 15, divided by toxicity value. An HQ of one or less indicates that the estimated exposure is less than the critical toxicity value. When this is the case, there is no basis for asserting that adverse effects are plausible.

Based on Table 19, for vertebrate terrestrial species the highest HQ for any acute exposure is 1.26 for chronic exposure of a large bird consuming treated vegetation on a site treated with the highest rate of application (0.19

lb/acre). It very slightly exceeds the level considered acceptable, and the likelihood it would occur seems quite remote. All other HQ values are less than one. With this one exception the analysis shows there is no basis for asserting that adverse effects on terrestrial vertebrates are likely from the application of sulfometuron methyl in ANF programs. For this exception, an HQ of 1.26 is only slightly higher than the acceptable value of 1.0. Given the highly conservative assumptions used in this risk assessment, it is highly likely that this overestimates the actual risk. In addition, the HQ only exceeds 1.0 at the highest rate of application, which is rarely used.

Terrestrial Invertebrates

As shown in SERA (2004b, Worksheet G02), the HQ for the honey bee is 0.007 based on an application rate of 0.045 lb/acre. When adjusted for the ANF rates of application, the HQ value is 0.014 and 0.03 for the ANF application rates of 0.09 and 0.19 lb/acre, respectively. These values are well below the level of concern of one. Thus, there is no basis for anticipating the occurrence of adverse effects in bees exposed to sulfometuron methyl at application rates that might be used in ANF programs.

Terrestrial Plants

A quantitative summary of the risk characterization for terrestrial plants is presented in SERA (2004b) Worksheet G04 for runoff and Worksheets G05a and G05b for drift. Analogous to the approach taken for terrestrial animals, risk in these worksheets is characterized as a ratio of the estimated exposure to a benchmark exposure (i.e., exposure associated with a defined response). For both worksheets, the benchmark exposure is a NOEC, as derived in a dose-response assessment, for both sensitive and tolerant species. The NOEC is 0.00078 lb/acre for tolerant plant species and 0.000024 lb/acre for sensitive species.

Sulfometuron methyl is a very effective herbicide, and adverse effects on plants off-site can occur if drift results in off-site deposition greater than the NOEC values. SERA (2004b) estimates drift based on the AgDRIFT model. As discussed earlier AgDRIFT likely significantly overestimates drift in the conditions and circumstances of ANF operations. The key factors for the ANF not included in AgDRIFT are as follows:

- Application method–ANF uses primarily airblast rather than low boom ground.
- Application conditions–ANF treatment typically occurs in forested stands with understory vegetation; AgDRIFT operates in the open and over relatively bare ground.
- Droplet size–ANF droplets are 2 to 3 times larger than those evaluated by AgDRIFT.
- Wind speeds–under ANF forest canopies the maximum wind speed typically is significantly reduced (~ 4 mph) when winds in openings are 10 mph. AgDRIFT modeled 10 mph winds.

Accepting these overestimates from AgDRIFT and adjusting the values in SERA (2004b, Worksheet G05a) for ANF application rates of 0.19 or 0.09 lb/acre and the use of airblast rather than low boom ground application, Table 20 provides calculated estimates of off-site deposition and the associated hazard quotients for tolerant and sensitive terrestrial plant species.

Table 20. Down wind deposition for non-forested, bare ground conditions in lb/acre for ANF rates of airblast application of sulfometuron methyl and their associated hazard quotient values *

Down Wind Distance (feet)	0.09 lb/acre Application Rate	0.19 lb/acre Application Rate	Hazard Quotient for 0.09 lb/Application Rate		Hazard Quotient for 0.19 lb/Application Rate	
			Tolerant Plant Species	Sensitive Plant Species	Tolerant Plant Species	Sensitive Plant Species
25	0.0005	0.0011	0.64	20.8	1.4	45.8
50	0.0003	0.00056	0.38	12.5	0.72	23.3
100	0.00006	0.00013	0.08	2.5	0.17	5.4
300	0.00003	0.00007	0.04	1.25	0.09	2.9
500	0.000009	0.000019	0.01	0.38	0.02	0.79

*Based on off-site deposition values from Table 7 and NOEC values of 0.000024 lb/acre for sensitive plant species and 0.00078 lb/acre for tolerant plant species. The hazard quotient is Deposition/NOEC.

This analysis shows that with open conditions over relatively bare ground, no adjacent intercepting vegetation, and an on-site application rate of 0.09 lb/acre, tolerant plants downwind will not be harmed at 25 feet, and sensitive plants downwind will not be harmed at 500 feet. The HQ value for sensitive plants at 300 feet is 0.00003/0.000024 = 1.25, which is very close to the level of concern of one.

For higher application rates and similar open conditions, this analysis shows that with an on-site application rate of 0.19 lb/acre, tolerant plants downwind will not be harmed at 50 feet, and sensitive plants downwind will not be harmed at 500 feet. The HQ value for sensitive plants at 300 feet is 0.00007/0.000024 = 2.92, which is fairly close to the level of concern of one.

In a forested setting, damage observed due to drift of sulfometuron methyl would depend on several site-specific conditions, including wind speed and foliar interception by the target vegetation. We believe the analysis in Table 20 is extremely conservative for a forested setting, and it significantly overestimates the ANF hazard quotients for forested conditions. The key factors contributing to this overestimate for the ANF are low wind speed under the canopy and the high density of the treated understory vegetation providing significant surfaces for interception of spray droplets close to the point of release. AgDrift testing and modeling with an orchard airblast application (trees 14 feet tall) shows a marked reduction in deposition beyond the first two layers of intercepting vegetation, and downwind spray deposition was essentially zero at 100 feet (Teske et al. 2001). Significantly, monitoring for vegetation damage by ANF personnel shows little or no off site vegetation damage beyond the treatment area boundary.

With respect to exposure via runoff, SERA's (2004b) Worksheet G04 (adjusted for ANF rates of application and the use of values for loam soil and 50 inches annual precipitation) results in HQ values for sensitive plants of 4.2 and 2 for 0.19 and 0.09 lb/acre rates of application respectively. While this level of risk is less, it still exceeds the level of concern where HQ is greater than one. Tolerant plant HQ values are less than one at both ANF rates of application. However, we believe this is a significant overestimate of the risk because GLEAMS, on which this analysis is based, was developed for agricultural land and settings. Conditions of heavy litter and duff layers under the dense canopies of ANF treatment areas should virtually eliminate runoff.

Aquatic Organisms

The result of the Risk assessment for aquatic species is in Table 21. This table is derived from Table 4.9, SERA (2004b) with adjustments to reflect ANF rates of application.

Table 21. Summary of sulfometuron methyl quantitative risk characterization for aquatic species for ANF application rates of 0.09 and 0.19 lbs a.i./acre

Risk is expressed as hazard quotient (HQ)*

Scenario	Central		Lower		Upper	
	ANF Application Rates (lbs a.i./acre)					
	0.09	0.19	0.09	0.19	0.09	0.19
Fish (acute exposure)						
Tolerant Species	0.0000006	0.000001	0.00000004	0.00000008	0.00001	0.00002
Sensitive Species	0.00001	0.00002	0.0000008	0.000002	0.0002	0.0004
Fish (chronic exposure)						
Tolerant Species	0.000004	0.000008	0.0000008	0.000002	0.000006	0.00001
Sensitive Species	0.000004	0.000008	0.0000008	0.000002	0.000006	0.00001
Amphibians						
acute exposures	0.0002	0.0004	0.00001	0.00003	0.004	0.008
chronic exposures	0.004	0.008	0.001	0.002	0.008	0.02
Aquatic Invertebrates (acute exposure)						
Tolerant Species	0.00000006	0.0000001	0.000000004	0.000000008	0.000001	0.000002
Sensitive Species	0.000001	0.000002	0.00000008	0.0000002	0.00002	0.00004
Aquatic Invertebrates (chronic exposure)						
Tolerant Species	0.0000006	0.000001	0.0000001	0.0000003	0.000001	0.000002
Sensitive Species	0.00002	0.00004	0.000004	0.000008	0.00004	0.00008
Aquatic Plants, Algae (acute exposure)						
Tolerant Species	0.0002	0.0004	0.00001	0.00003	0.004	0.008
Sensitive Species	0.04	0.08	0.002	0.004	0.8	1.68
Aquatic Plants, Algae (chronic exposure)						
Tolerant Species	0.00001	0.00002	0.000002	0.000004	0.00002	0.00004
Sensitive Species	0.001	0.003	0.0004	0.0008	0.002	0.004
Aquatic Plants, Macrophytes						
acute exposures	0.4	0.84	0.02	0.04	8	16.8
chronic exposures	0.02	0.04	0.004	0.008	0.04	0.08

* Values are based on SERA (2004b) G03.

The risk characterization for aquatic animals is relatively simple and unambiguous. Sulfometuron methyl appears to have a very low potential to cause any adverse effects in aquatic animals. All HQ values are less than one. The highest HQ value is 0.02 for chronic exposure of an amphibian.

Aquatic plants are more sensitive to sulfometuron methyl than are aquatic animals. For algae, the only HQ value greater than one is for acute exposure of a sensitive species (HQ = 1.7). All other values for algae are less than one. Macrophytes appear to be more sensitive, exhibiting an HQ value of 8 and 16.8 for acute exposure following application of 0.09 and 0.19 lb/acre respectively at the “upper” scenario. ANF buffer mitigation measures make it very unlikely that application would result in exposures high enough to produce this level of risk. For chronic exposure all HQ values are less than one. The highest HQ value for chronic exposure is 0.04 for an application rate of 0.19 lb/acre.

SECTION F. FEDERAL LISTED OR PROPOSED THREATENED, ENDANGERED, OR SENSITIVE SPECIES RISK ASSESSEMENT

Introduction

This Section analyzes impacts to species federally listed as proposed, threatened, or endangered, and species listed as sensitive by the Regional Forester from the use of herbicides for vegetation management on the ANF. This analysis covers the proposed use of glyphosate (Rodeo®, Accord Concentrate ®, Glypro®, Foresters'®) and sulfometuron methyl (Oust® , Oust XP®) herbicides and surfactants (Timberland 90®, Chemsurf® 90, Alenza 90®, Red River 90® and Red River Adherent 90®). The following categories of species were analyzed.

Federal Listed Species

The U.S. Fish and Wildlife Service has six Federal listed plant and animal species that are known to occur within or near the ANF proclamation boundary, or have suitable habitat within the ANF (Table 22). In addition, two species are currently listed as candidate (Table 22). Of these eight species, six occur within the ANF or the Wild and Scenic River corridor. The northeast bulrush and small-whorled pogonia are the only species not documented on the ANF.

Regional Forester Sensitive Species (RFSS)

There are 60 plant and animal species on the ANF RFSS List (Table 22). Regional Forester sensitive species and species delisted by the U.S. Fish and Wildlife Service in the last five years are included. The list also includes two U.S. Fish and Wildlife Service candidate species, the same two that are mentioned above. All RFSS are evaluated in this risk assessment.

Table 22. Species federally listed as proposed, threatened or endangered and species listed as sensitive by the Regional Forester for the ANF, grouped by taxa

Species	General Habitat	Status[1]
Mammals		
Indiana bat (*Myotis sodalis*)	mature forest/ roost and raise young in caves	F
Northern flying squirrel (*Glaucomys sabrinus*)	mature forest/riparian; conifer or mixed hardwood; nest in conifers	R
Birds		
Bald eagle (*Haliaeetus leucocephalus*)	forest, near rivers, lakes, wet prairies	F
Osprey (*Pandion haliaetus carolinensis*)	riparian areas/ lakes and rivers	R
Yellow-bellied flycatcher (*Empidonax flaviventris*)	conifer, hardwood forests, nests on the ground	R
Northern goshawk (*Accipiter gentilis*)	mid to late structural mixed hardwood/conifer forests	R
Reptiles		
Timber rattlesnake (*Crotalus horridus*)	mature forest/riparian/wetland/grassland	R
Wood turtle (*Clemmys insculpta*)	mature forest hardwood, mixed conifer, oak/riparian/wetland	R
Molluscs, aquatic invertebrates		
Rabbitsfoot (*Quadrula cylindrica*)	medium to large rivers in mixed sand and gravel; seldom burrows	R
Rainbow mussel (*Villosa iris*)	small to medium streams in coarse sand or gravel	R
Rayed bean mussel (*Villosa fabalis*)	lakes, small to large streams in sand or gravel	C
Round pigtoe (*Pleurobema coccineum*)	medium to large rivers in mud, sand, or gravel	R
Sheepnose mussel (*Plethobasus cyphyus*)	medium to large rivers in gravel or mixed sand and gravel	C
Snuffbox (*Epioblasma triquetra*)	small to medium-sized rivers in sand, gravel, or cobble	R
Three-ridge (*Amblema plicata*)	small to large rivers and impoundments in mud, sand, or gravel	R
White heelspitter (*Lasmigona complanata*)	pools or sluggish streams with a mud, sand, or gravel bottom	R
Clubshell mussel (*Pleurbema clava*)	small to medium streams with gravel/sand substrate	F
Creek heelsplitter (*Lasmigona compressa*)	creeks and headwaters of small to medium rivers in fine gravel/sand	R
Long-solid mussel (*Fusconaia subrotunda*)	large rivers in gravel	R
Northern riffleshell (*Epioblasma torulosa rangiana*)	swift moving water/riffle and run areas with fine to coarse gravel	F
Wabash pigtoe (*Fusconaia flova*)	medium to large rivers in gravel or mixed sand and gravel	R
Fish		
Bluebreast darter (*Etheostoma camurum*)	large streams	R
Burbot (*Lota lota*)	deep cold waters of lakes and rivers	R
Channel darter (*Percina copelandi*)	large streams and rivers	R
Gilt darter (*Percina evides*)	large streams	R
Gravel chub (*Erimystax x-puncta*)	medium to large streams	R
Longhead darter (*Percina macrocephala*)	moderate to large streams; fast moving water	R
Mt. Brook Lamprey (*Ichthyoyzon greeleyi*)	streams, pools, and backwaters does not move into rivers	R
Mt. Madtom (*Norturs eleutherus*)	high gradient medium rivers, moderate gradient riffles/ benthic	R
Northern madtom (*Noturus stigmosus*)	small, medium, large rivers	R
Spotted darter (*Etheostoma maculatum*)	fast rocky riffles in small to medium streams	R
Tippecanoe darter (*Etheostoma tippecanoe*)	moderate gradient rivers and large streams	R

1 F Federally listed threatened or endangered species;
C Candidate species for federal listing and Regional Forester Sensitive Species (RFSS) list
R Currently on RFSS list

Table 22. (Continued) Species federally listed as proposed, threatened or endangered and species listed as sensitive by the Regional Forester for the ANF, grouped by taxa

Species	General Habitat	Status[1]
Invertebrates		
Ocellated darner (*Boyeria grafiana*)	nymphs-aquatic, adults-terrestrial/riparian	R
Green-faced clubtail (*Gomphus viridifrons*)	nymphs-aquatic, adults-terrestrial/riparian	R
Mustached clubtail (*Gomphus adelphus*)	nymphs-aquatic, adults-terrestrial/riparian	R
Resolute Damsel/Taiga bluet (*Coenagrion resolutum*)	nymphs-aquatic, adults-terrestrial/riparian	R
Maine snaketail (*Opiogomphus mainensis*)	nymphs-aquatic, adults-terrestrial/riparian	R
Ski-tailed emerald (*Somatochlora elongata*)	nymphs-aquatic, adults-terrestrial/riparian	R
Uhler's sundragon (*Helocordulia uhleri*)	nymphs-aquatic, adults-terrestrial/riparian	R
Harpoon clubtail (*Gomphus descriptus*)	nymphs-aquatic, adults-terrestrial/riparian	R
Midland clubtail (*Gomphus fraternus*)	nymphs-aquatic, adults-terrestrial/riparian	R
Rapids clubtail (*Gomphus quadricolor*)	nymphs-aquatic, adults-terrestrial/riparian	R
Zebra clubtail (*Stylurus scudderi*)	nymphs-aquatic, adults-terrestrial/riparian	R
Vascular Plants		
American fever-few (*Parthenium integrifolium*)	grassland; open woods; seedling/sapling forest	R
American ginseng (*Panax quinquefolius*)	hardwood forests but also conifer; upland not riparian	R
American yew (*Taxus canadensis*)	mature forest hardwood, mixed conifer	R
Bartram's shadbush (*Amelanchier bartramiana*)	wetland	R
Boreal bog sedge (*Carex magellanica*)	wetland	R
Bristly black current (*Ribes lacustre*)	riparian/wetland	R
Butternut (*Junglans cinerea*)	riparian	R
Checkered Rattlesnake plantain (*Goodyera tesselata*)	mature forest hardwood, mixed conifer	R
Creeping snowberry (*Gaultheria hispidula*)	riparian	R
Hooker's orchid (*Planathera hookeri*)	mature forest hardwood, mixed conifer	R
Kidney-leaved twayblade (*Listera smallii*)	riparian/wetland	R
Northeast bulrush (*Scripus ancistrochaetus*)	riparian/wetland	F
Mountain starwort (*Stellaria borealis*)	mature forest	R
Mountain wood fern (*Dryopteris campyloptera*)	mature forest hardwood, mixed conifer	R
Queen-of-the-prairie (*Filipendula rubra*)	grassland/wetland	R
Red currant (*Ribes triste*)	riparian/wetland	R
Rough cotton-grass (*Eriophorum tenellum*)	riparian/wetland	R
Small whorled pogonia (*Isotria medeoloides*)	mature oak	F
Stalked bulrush (*Scripus pedicellatus*)	riparian/wetland	R
Sweet-scented Indian plaintain (*Hasteola suaveolens*)	riparian	R
Thread rush (*Juncus filiformis*)	wetland	R
White trout lily (*Erythronium albidum*)	riparian/wetland	R
Wiegand's sedge (*Carex wiegandii*)	riparian	R

1 F Federal listed threatened or endangered species
C Candidate species for federal listing and Regional Forester Sensitive Species (RFSS) list
R Currently on RFSS list

Five of six species listed under the federal ESA as threatened or endangered are described in more detail in ANF (2000).

The objectives of this risk assessment are to:

1. Determine the effects of the proposed program of vegetation management activities on species federally listed or proposed as threatened, or endangered, and species listed as sensitive by the Regional Forester for the ANF.
2. Describe measures to be taken to mitigate potential adverse effects of proposed activities on these species.

This risk assessment was prepared in accordance with Forest Service Manual 2671.44 and 2672.43 and regulations set forth in section 7(a) of the Endangered Species Act (ESA).

Proposed Vegetation Management Program

This analysis concerns the impact of using herbicides as part of an integrated pest management strategy for the following management purposes:

- sustain forest cover over the long term,
- restore forest understories to more diverse vegetation conditions,
- maintain tree species diversity in young stands,
- maintain the integrity of improvements (such as electric fences),
- sustain and improve the production of forest products,
- assist in developing and maintaining certain types of wildlife habitat, heritage resources, and visual enhancements (such as scenic overlooks), and
- treatment/control of native and non-native invasive plant species.

Potential Effects upon Federally Listed or Proposed, Threatened, Endangered and Sensitive Species

Most of these species rarely occur on the type of sites proposed for treatment and analyzed for this risk assessment. However, if they are found, they potentially could be affected by either alteration of habitat, or from direct toxic effects of herbicide or surfactant. This risk assessment only considers the direct toxic effects of the various formulations and spray mixtures of glyphosate and/or sulfometuron methyl.

Direct ToxicEffects

The potential for direct toxic effects on wildlife species is covered in detail in Section E of this risk assessment. The wildlife and aquatic species risk analysis in Appendix G2, Section E is based on the dose response data for each herbicide as reported in SERA (2003a, b and 2004a, b). Because there are no studies that use Federal listed or proposed threatened, endangered, or sensitive species as the test organisms, it is assumed that these species would respond similar to the most sensitive species of similar type that is included in toxicity testing. The critical toxicity values are shown in Table 23. Note there are no values for reptiles or mollusks, reflecting the limited degree to which such organisms are included in toxicity testing. For purposes of this risk assessment we assume reptiles are reflected by amphibians, and mollusks are represented by aquatic invertebrates.

Note that SERA (2003a) includes critical toxicity values for herbicides with and without surfactant, and they also do analyses with less and more toxic forms of glyphosate. We believe the surfactant noted by SERA is a more toxic form, such as POEA, which results in an overestimate of the NOEC than would likely be the case considering the four surfactants and the commercial formulations of glyphosate proposed for use by the ANF. The glyphosate formulations proposed for use on the ANF are the less toxic form, and the surfactants have inert ingredients classified by EPA as list 3 and 4b. List 3 indicates that there is unknown toxicity; for inerts where "there was no basis for placing it on any of the other lists. The Agency will continue to evaluate these chemical substances, as additional information becomes available, to determine if reclassification to List 1, 2, or 4 is appropriate." List 4 indicates minimal concern, and was further subdivided with List 4B for inerts with "*sufficient information to conclude that current use patterns in pesticide products will not adversely affect public health and the environment.*"

The less toxic formulations of glyphosate are covered in Table 17.

Table 23. Critical toxicity values for ANF terrestrial and aquatic wildlife species selected as surrogates for ANF federally listed or proposed, threatened, endangered, and sensitive species categories (see Table 22)

Type of Species	Critical Toxicity Value, Glyphosate	Critical Toxicity Value, Sulfometuron Methyl
Mammals	175 mg/kg (NOAEL*)	2 mg/kg (NOAEL)
Birds	100 mg/kg (NOAEL)	2 mg/kg (NOAEL)
Fish (sensitive)	2.57 mg/l (NOEC)	1.17 mg/l (NOEC)
Aquatic Invertebrates	50 mg/l (Chronic NOEC)	0.19 mg/L (chronic NOEC, calculated)

[1] Toxicity values derived from SERA (2003a, b, 2004a, b)
* NOAEL, No Observed Adverse Effect Level
§ NOEC, No Observed Effect Concentration

Hazard quotients for Federal listed or proposed animal species are in Table 24. They are taken from the risk analyses for various wildlife species in this appendix (Tables 17, 18, 19, and 21). The highest HQ value reported for a particular type organism in these tables is listed in Table 24. To provide an increased margin of certainty for Federal listed or proposed threatened, endangered, or sensitive species, only the upper HQ value (meaning the upper end of the range within which the true value might fall) reported for a given species type is included here (see page G2-50 for additional discussion of the meaning of the term "upper").

Table 24. Quantitative risk characterization for ANF terrestrial and aquatic species selected as a surrogate for ANF Federal listed or proposed threatened, endangered, and sensitive species categories (see Table 22)[1]

Organism type/ Exposure Scenario	Glyphosate, Upper Hazard Quotient				Sulfometuron methyl, Upper Hazard Quotient	
	ANF Application Rates (lbs a.i./acre)[2]					
	1.0	2.0	3.0	4.0	0.09	0.19
Large Mammal						
acute exposure	0.22	0.38	0.75	0.90	0.06	0.10
chronic exposure	0.112	0.188	0.375	0.45	0.40	0.84
Bird						
acute exposure	0.15	0.25	0.50	0.60	0.04	0.08
chronic exposure	0.30	0.50	1.00	**1.20**	0.60	**1.26**
Fish, Sensitive Species						
acute exposure	0.03	0.05	0.10	0.12	***0.0002***	***0.0004***
chronic exposure	0.002	0.004	0.008	0.009	***0.000006***	***0.000001***
Aquatic Invertebrates						
acute exposure	0.0004	0.0006	0.001	0.002	***0.00002 (sensitive species)***	***0.00004 (sensitive species)***
chronic exposure	0.0001	0.0002	0.0004	0.0005	***0.00004 (sensitive species)***	***0.00008 (sensitive species)***

[1] Values derived from SERA (2003a,b, 2004a, b) with adjustments for ANF rates of application)

[2] ANF glyphosate application rates of 1, 2, 3, 4 lbs a.i./acre are equivalent to 0.75, 1.25, 2.25, and 3.0 lbs a.e./acre, respectively

The analysis shows nearly all HQs are less than 1, meaning there is no plausible basis for asserting that adverse effects are likely to occur (SERA 2003a) in these specific cases. No HQ values exceed 1 for acute exposure from use of either glyphosate or sulfometuron methyl. It is only one chronic exposure for the 4 lb/acre rate of application of glyphosate and one for the 0.19 lb/acre rate of sulfometuron methyl that produce an HQ value greater than 1 (Table 24). In each case this is for a large bird consuming vegetation, and the HQ value is 1.2 and 1.26 for glyphosate and sulfometuron methyl respectively. None of the bird species on the ANF federally listed or proposed threatened, endangered or sensitive lists are herbivores, therefore we conclude there will be no impact on listed birds. No HQ values are greater than 1 for aquatic species.

From this we conclude that Federal listed or proposed threatened, endangered and sensitive animal species will not be toxicologically adversely affected by the use of glyphosate or sulfometuron methyl as proposed by the ANF.

ANF Federally listed or proposed threatened, endangered, or sensitive plant species are likely to be impacted if either glyphosate or sulfometuron methyl are directly applied to them or if substantial herbicide drift reaches them. To use herbicides with safety to these species, a pretreatment survey to locate and mark such plants so they will not be sprayed will be required. It may be necessary to establish a no-spray buffer around sites that contain Federal listed or proposed threatened, endangered, and sensitive plant species or to physically cover the plants to prevent injury due to spray drift.

For glyphosate the analysis of downwind drift for ANF application rates with non-forested conditions over relatively bare ground and no adjacent intercepting vegetation and the use of airblast application equipment, the HQ is less than 1 at 25 feet for rates of applications of 4 lb/acre and less. However, the ANF uses the 4 lb/acre application rate only for directed backpack foliar invasive species control and the 3 lb/acre only for cut surface treatments, where virtually no drift is expected to occur. For sulfometuron methyl this same analysis, again for nonforest conditions, indicates that a buffer between 300 and 500 feet may be required for sensitive plants at application rates of 0.09 lb/acre and 0.19 lb/acre. However, AgDRIFT testing and modeling with an orchard airblast application (trees 14 feet tall) shows a marked reduction in deposition beyond the first two layers of intercepting vegetation, and downwind spray deposition was essentially zero at 100 feet (Teske et al. 2001).

We consider this analysis extremely conservative because it does not take into account the lower wind speeds that occur in the forest interior or the interception of spray particles by the dense intervening vegetation. The monitoring history on ANF indicates little off-site vegetation damage, suggesting smaller buffers will likely provide protection for sensitive plants, but rigorous monitoring may be required for verification.

We expect Federal listed or proposed threatened, endangered, or sensitive plant species mortality from direct spraying or drift to be highly unlikely for the following reasons:

- Treatment sites and their vicinity will be appropriately surveyed for these plant species.
- The majority of these plants occupy habitat that would not be scheduled for treatment.
- If such plants are found, buffers will be established based on site characteristics such as understory interference, slope, season of treatment, application rate, and the susceptibility of the plant's life stage to the herbicide.

In consultation with the U. S. Fish and Wildlife Service, the following determinations were made for all actions (including herbicide use) included in the ANF Land and Resource Management Plan.

Summary of Determinations

Federally Listed Species

Birds

- **Bald Eagle**–May effect, not likely to adversely effect.

Invertebrates

- **Clubshell**–May effect, not likely to adversely effect.
- **Northern riffleshell**–May effect, not likely to adversely effect.
- **Rayed-bean–**May effect, not likely to adversely effect.
- **Sheepnose–**May effect, not likely to adversely effect.

Mammals

- **Indiana bat–**May effect, not likely to adversely effect.

Plants

- **Northeastern bulrush–**No adverse effect.
- **Small-whorled pogonia–**No adverse effect.

CONCLUSION

Except for plants, no adverse toxicological impacts on Federal listed or proposed threatened, endangered, or sensitive species are expected to occur. For plants, it will be necessary to survey for their presence, and when found to implement mitigation measures to protect them. For non-native invasive species treatment, habitat degradation to Federal listed or proposed threatened, endangered, or sensitive species from invasive species over the long term presents a higher risk of extirpation than potential loss from direct spray or drift.

SECTION G. Carbon Dating and the Potential for carbon contamination due to the Proposed use of Herbicides on the ANF

Following is a brief description of carbon dating as derived from the sources indicated. It is meant to provide some understanding of the carbon dating method. It also provides perspective on potential problems with contamination of archaeological samples and how this affects the dating done by this method. Finally, we provide analysis of the potential for such problems due to the proposed program using herbicides on the Allegheny National Forest. In addition to the specific sources cited here, a number of other useful websites related to carbon dating were found in a Google search using the term “carbon dating.”

Carbon Dating: The following information is derived from Minnesota State University’s website and accessed on January 24, 2007, http://www.mnsu.edu/emuseum/archaeology/dating/radio_carbon.html, which uses information from McGraw-Hill Encyclopedia of Science and Technology, Volume 15, pp. 136-144.

Radio-carbon dating is a method of obtaining age estimates on organic materials for samples as old as 50,000 years. Radiocarbon determinations can be obtained on wood; charcoal; marine and fresh-water shell; bone and antler; peat and organic-bearing sediments, carbonate deposits such as tufa, caliche, and marl; and dissolved carbon dioxide and carbonates in ocean, lake and ground-water sources.

Radioactive carbon (C^{14}), produced when nitrogen 14 is bombarded by cosmic rays in the atmosphere, drifts down to earth and is absorbed from the air by plants. Animals eat the plants and take C^{14} into their bodies. When a living organism dies, it stops absorbing C^{14} and the C^{14} that is already in the object begins to disintegrate (decay) at a slow but steady rate and reverts to nitrogen 14. The rate at which Carbon decays (Half-life) is known: C^{14} has a half-life of 5730 years. Basically this means that half of the original amount of C^{14} in organic matter will have disintegrated 5730 years after the organism’s death; half of the remaining C^{14} will have disintegrated after another 5730 years and so forth. Scientists measure how much C^{14} has disintegrated and how much is left in the object to be dated by this method.

To discover how long an organism has been dead (hence its age), the number of beta radiations given off per minute per gram of material are counted. Modern C^{14} emits about 15 beta radiations per minute per gram of material, but C^{14} that is 5730 years old will only emit half that amount, (the half-life of C^{14}) per minute. So if a sample taken from an organism emits 7.5 radiations per minute in a gram of material, then the organism must be 5730 years old.

A measurement of the radiocarbon content of an organic sample will provide an accurate determination of the sample's age if it is assumed that (1) the production of radiocarbon by cosmic rays has remained essentially constant long enough to establish a steady state in the C^{14}/C^{12} ratio in the atmosphere, (2) there has been a complete and rapid mixing of radiocarbon throughout the various carbon reservoirs, (3) the carbon isotope ratio in the sample has not been altered except by radiocarbon decay, and (4) the total amount of carbon in any reservoir has not been altered. In addition, the half-life of radiocarbon must be known with sufficient accuracy, and it must be possible to measure natural levels of radiocarbon to appropriate levels of accuracy and precision.

In the vast majority of cases assumptions 1, 2, and 4 are known to be satisfied. Concern has been raised about Assumption 3 for archaeological sample materials from the Allegheny National Forest. The issue is potential contamination of samples with chemicals associated with the use of herbicides thereby violating assumption 3 by artificially changing the carbon isotope ratio. This would occur if the sample material contains herbicide related carbon compounds, which would change the ratio of C^{12} and C^{14}, resulting in an error in estimating the age of the sample material.

Each sample type has specific problems associated with its use for dating purposes, including contamination. Samples may be contaminated by materials which make any radiocarbon result either too old or too young.

Contamination may be artificially or naturally caused. Artificial contamination may be blamed on human negligence during the collection and processing of samples. Contaminants often include ash from tobacco, hair and fibers, paper from packing material and oil or grease. Natural contamination occurs in the post-depositional environment.

The most common source of contamination by modern carbon is caused by rootlet intrusion. Organic samples such as wood, charcoal, soil and bone are especially prone to this and should be examined closely before, and after collection, for evidence of root penetration. Contamination may also be caused by naturally occurring humic acids circulating throughout the soil. Humics are the decayed remnants of dead plants. They may exchange carbon or adhere to samples that have large surface areas and make any radiocarbon results too young. It is especially common in samples such as peats, charcoals and muds.

These problems of contamination are known and methods of sample pretreatment have been developed to deal with them. Following is a brief description of the major sample materials often submitted to radiocarbon laboratories and the methods most often used in pretreating and extracting fractions for dating.

(a) **Charcoal:** Any surface contamination is removed. The sample is crushed and rootlet contaminants removed. Acid washing is undertaken to remove non-sample carbonates. An alkali treatment is used with samples suspected of soil humic contamination. This is followed with an acid wash to remove atmospheric CO_2, absorbed during the alkaline wash.

(b) **Lake Muds, Peat and Soil:** The sample is sieved to create two fractions, coarse and fine. The coarse fraction is stored as a reference. The fine fraction is acid washed and may also have an alkali pretreatment depending on the characteristics of the environment from which it originated.

(c) **Shell:** The shell species which comprise the sample will need to be identified. Lacustrine and riverine shell may involve considerable errors unless some background research has been undertaken regarding the reservoir of the shell. Shell is cleaned in an ultrasonic bath, shell exteriors are scraped with a dental drill or acid washed using dilute acid and rinsed and dried. The samples are crushed prior to hydrolysis and dating.

(d) **Wood:** The exterior is removed using hammer and chisel, and solvent extraction is carried out using soxhlet extractor to remove waxes and resins. Starch fraction is removed using water. Various acid and base washes are used to isolate cellulose fraction and to obtain lignin. Alpha-cellulose obtained is rinsed and dried.

(e) **Bone:** There are five basic steps in the pretreatment of bone samples for conventional dating methods:

1. Cleaning removes roots and preservatives. If plenty of sample exists, the most contaminated bone is removed by blasting, scraping and/or washing in an ultrasonic bath. Preservatives may be treated with methanol at 60°C, or acetone at room temperature and evaporated to dryness.

2. Grinding to a diameter of 0.5mm to 5mm. The smaller fractions are generally used so that a shorter demineralization time is needed.

3. Decalcification is most commonly done with acid treatment which removes apatite but leaves humic contaminants as solid phases. The acid insoluble component is then filtered or centrifuged and rinsed with distilled water until neutral.

4. Alkali treatment (optional) is used to remove base-soluble contaminants such as humic acids and some lipids. The residue is then rinsed to neutrality.

5. Gelatinization (optional) is used to remove collagen residues, which leaves humic acids as residues. These are subsequently filtered off and the supernatant centrifuged or filtered, and air dried or freeze dried.

In any of these sample types solvent extractions may be undertaken if petrochemical contamination has occurred or if resins need to be removed. This would be the pretreatment method used if a sample were known or suspected of being contaminated with one or more herbicide-associated chemicals

Potential Contamination by Herbicide Related Chemicals of Sample Materials for Carbon Dating from the ANF

Most artifacts found on the ANF are buried under a minimum of one inch of forest litter and humus or under varying depths of soil (from zero up to as much as ten feet). Carbonized wood is expected to be the most frequently occurring culturally significant artifact found on the ANF and may be found under varying amounts of forest debris and/or soil. Given the limited movement and persistence of glyphosate and sulfometuron methyl, it is not likely they will contaminate materials of potential interest for carbon dating. Any contamination that did occur would alter the C^{14}/C^{12} ratio to such a minute degree that it would not result in an error in dating that would exceed the uncertainty inherent within the method. In the event samples for dating are collected in an area sprayed within the 2 previous years and it is believed that the sample material could have been exposed to direct spray, the carbon dating laboratory should be notified so they can use special sample preparation procedures to rinse the samples with appropriate solvents to remove any such residues.

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Appendix G3

Acronyms, Conversion Factors, and Glossary for Appendix G1 and G2

Allegheny National Forest

March 2007

Prepared by

Jeffrey Jenkins PhD, Logan A. Norris PhD, and Kathleen Maas-Hebner MS

Cascade Environmental Consultants

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ACRONYMS, ABBREVIATIONS, AND SYMBOLS

a.e.	acid equivalents
AEL	adverse-effect level
a.i.	active ingredient
ACGIH	American Conference of Governmental Industrial Hygienists
AChE	acetylcholinesterase
AHS	Agricultural Health Study
AMPA	aminomethylphosphonate
ATSDR	Agency for Toxic Substances and Disease Registry
ATV	all terrain vehicle
ANF	Allegheny National Forest
BCF	bioconcentration factor
bw	body weight
CalEPA	California Environmental Protection Agency
CBI	confidential business information
CFR	Code of Federal Regulations
CI	confidence interval
cm	centimeter
DAA	days after application
DAT	days after treatment
DBH	diameter at breast height
d.f.	degrees of freedom
EC_x	concentration causing X% inhibition of a process
EC_{25}	concentration causing 25% inhibition of a process
EC_{50}	concentration causing 50% inhibition of a process
EEC	Expected environmental concentration
e.g.	for example
EIS	Environmental Impact Statement
F	female
FAO	Food and Agriculture Organization (United Nations)
FDA	US Food and Drug Administration
FEIS	Final Environmental Impact Statement
FH	Forest Health
FIRFA	Federal Insecticide, Fungicide and Rodenticide Act
FSH	Forest Service Handbook
g	gram
gal	gallon
GLEAMS	Groundwater Loading Effects of Agricultural Management Systems

GPS	global positioning system
ha	hectare
HQ	hazard quotient
i.e.	that is
IPA	isopropylamine
IRIS	Integrated Risk Information System (U.S. EPA)
k_a	absorption coefficient
k_e	elimination coefficient
kg	kilogram
$K_{o/c}$	organic carbon partition coefficient
$K_{o/w}$	octanol-water partition coefficient
K_p	skin permeability coefficient
L	liter
lb	pound
LC_{50}	lethal concentration, 50% kill
LD_{50}	lethal dose, 50% kill
LOAEC	lowest-observed-adverse-effect concentration
LOAEL	lowest-observed-adverse-effect level
LOEC	lowest-observed-effect concentration
m	meter
M	mole
mg	milligram
mg/kg/day	milligrams of agent per kilogram of body weight per day
mL (or ml)	milliliter
mM	millimole
MOE	margin of exposure
MOS	margin of safety
MPH	miles per hour
MSDS	material safety and data sheets
MW	molecular weight
NCAP	Northwest Coalition for Alternatives to Pesticides
NHL	non-Hodgkin lymphoma
NNG	N-nitrosoglyphosate
NOAEL	no-observed-adverse-effect level
NOEC	no-observed-effect concentration
NOEL	no-observed-effect level
NOS	not otherwise specified
NRC	National Research Council
NTP	National Toxicology Program

ODW	Office of Drinking Water
OM	organic matter
OR	odds ratio
oz	liquid ounce
p.	page
pH	potential of hydrogen (acidity)
PHED	Pesticide Handlers Exposure Database
POEA	polyoxyethyleneamine
pp.	pages
ppm	parts per million
psi	pounds per square inch
RED	re-registration eligibility decision
RfD	reference dose
ROW	right-of-way
SERA	Syracuse Environmental Research Associates
µg	microgram
µm	micromole
UF	uncertainty factor
U.S.	United States
USDA	U.S. Department of Agriculture
U.S. EPA	U.S. Environmental Protection Agency
U.S. EPA/ODW	U.S. EPA/Office of Drinking Water
U.S. EPA/OPP	U.S. EPA/Office of Pesticide Programs
U.S. EPA/OPTS	U.S. EPA/Office of Pesticides and Toxic Substances
U.S. EPA/ORD	U.S. EPA/Office of Research and Development
USEPA/IRIS	U.S. EPA/ Integrated Risk Information System
USFS	U.S. Forest Service
WHO	World Health Organization
WRC	water concentration ratio
WSSA	Weed Science Society of America

Basic Conversions between English and Metric units

To convert:	Into:	Multiply by:
acres	hectares (ha)	0.4047
acres	square meters (m^2)	4,047
centimeters (cm)	inches (in.)	0.3937
centigrade (Cº)	Fahrenheit (Fº)	1.8Cº+32
cubic meters (m^3)	liters (L)	1,000
Fahrenheit (Fº)	centigrade	0.556Fº-17.8
feet	meters	0.305
feet per second (ft/sec)	miles/hour (mi/hr)	0.6818
gallons (gal)	liters (L)	3.785
gallons per acre (gal/acre)	liters per hectare (L/ha)	9.34
grams (g)	ounces, (oz)	0.03527
grams (g)	pounds, (oz)	0.002205
hectares (ha)	acres	2.471
inches (in)	centimeters (cm)	2.540
kilograms (kg)	ounces, (oz)	35.274
kilograms (kg)	pounds, (lb)	2.2046
kilograms per hectare (hg/ha)	pounds per acre (lb/acre)	0.892
kilometers (km)	miles (mi)	0.6214
liters (L)	cubic centimeters (cc or cm^3)	1,000
liters (L)	gallons (gal)	0.2642
liters (L)	ounces, fluid (oz)	33.814
miles (mi)	kilometers (km)	1.609
milligrams (mg)	ounces (oz)	0.000035
ounces (oz)	grams (g)	28.3495
ounces per acre (oz/acre)	grams per hectare (g/ha)	70.1
ounces per acre (oz/acre)	kilograms per hectare (kg/ha)	0.0701
ounces fluid	cubic centimeters (cm3)	29.5735
pounds (lb)	grams (g)	453.6
pounds (lb)	kilograms (kg)	0.4536
pounds per acre (lb/acre)	kilograms per hectare (kg/ha)	1.121
pounds per acre (lb/acre)	mg/square meter (mg/m2)	112.1
pounds per acre (lb/acre)	µg/square centimeter (µg/cm2)	11.21
pounds per gallon (lb/gal)	grams per liter (g/L)	119.8
square centimeters (cm2)	square inches (in2)	0.155
square centimeters (cm2)	square meters (m2)	0.0001
square meters (m2)	square centimeters (cm2)	10,000

Other Conversions

1 part per million (ppm)	= 1 milligram/liter (mg/L)
	= 1 milligram/kilogram (mg/kg)
	= 0.0001 percent
	= 0.013 ounces in 100 gallons of water (oz/gal)
1 percent	= 10,000 parts per million (ppm)
	= 10 gram/kilogram (g/kg)
	= 1.33 ounces by weight/gallon of water (oz/gal)
	= 8.34 ounces/100 gallon of water (oz/gal)

0.1 percent = 1,000 ppm	= 1,000 milligrams/liter (mg/L)	
0.01 percent	= 100 ppm	= 100 milligrams/liter (mg/L)
0.001 percent	= 10 ppm	= 10 milligrams/liter (mg/L)
0.0001 percent	= 1 ppm	= 1 milligram/liter (mg/L)

Glossary

Absorption—The movement of a substance from an exposed surface (skin, respiratory or digestive tract) into the circulation system to be distributed throughout the body. In most cases, a small fraction of material deposited on the skin and a high fraction of that taken into the digestive or respiratory tracts is absorbed.

Acceptable daily intake (ADI)—The daily intake of chemical which, during an entire lifetime, appears to be without appreciable risk on the basis of all known facts at the time. (World Health Organization)

Accord Concentrate®—A commercial of formulation glyphosate herbicide registered and manufactured by Dow Agrosciences.

Acid equivalent (a.e.)—The amount of active ingredient expressed in terms of the parent acid.

Active ingredient (a.i.)—The effective ingredient of a pesticide formulation.

Acute—Very short term. An acute intoxication is one that occurs with a single dose or a short (acute) period of exposure. The intoxication may last only a short time, or if the injury is severe a long recovery period may be necessary. (see also subacute)

Acute toxicity—The potential of a compound to cause injury or illness when given in a single dose or in multiple doses over a period of 24 hours or less. The quality or potential of a substance to cause injury or illness shortly after exposure to a relatively large dose.

Adjuvant—Substance added to a spray to act as a wetting or spreading agent, sticker, penetrant, or emulsifier in order to enhance the physical characteristics of herbicidal materials in such a way as to make them more effective.

Adsorption—The process by which a pesticide or other chemical is held or bound to a surface by chemical or physical attraction.

a.e.—See acid equivalent.

AEL—Adverse effects level.

Aerobic—Occurring in the presence of oxygen.

AgDRIFT—A computer model used to estimate spray drift from applied pesticides. Developed for U.S. EPA by the Spray Drift Task Force.

a.i.—See active ingredient.

ALS—acetolactate synthase

Anaerobic—Living or active in the absence of free oxygen.

Annual (plant)—A plant species living and growing for only one year or season.

Assay—A test or measurement used to evaluate a characteristic of a chemical or determine the amount in a sample. (see also bioassay)

Aquifer—An underground zone of earth or rock saturated with water whose upper limit is the water table.

BCF—See bioconcentration factor.

Biennial (plant)—A plant species that completes its life cycle, from seed germination to seed production, in two years. Also means "to occur every two years," as in biennial burns.

Bioaccumulation—The process of a plant or animal taking in a substance from the medium or the diet at a faster rate than it is excreted. Over a period of time, bioaccumulation results in a higher concentration of the substance in the organism than in the organism's environment.

Bioconcentration factor—A unitless value describing the degree to which a chemical can be concentrated in the tissues of an organism in the aquatic environment.

Bioassay—A method for determining the concentration of a substance by its effect on the growth of a suitable animal, plant or microorganism under controlled conditions.

Biocides—Any substance intended to kill a living pest.

Biological opinion—An official report by the USDA Fish and Wildlife Service or the National Marine Fisheries Service issued in response to a formal Forest Service request for consultation or conference. It states whether an action is likely to result in jeopardy to a species or adverse modification of its critical habitat.

Biomass—The total amount (weight) of living material in a given habitat.

Broadcast application—Uniform distribution of a pesticide over a defined treatment area.

Broadleaf weed—A non-woody dicotyledonous plant with wide, bladed leaves designated as a pest species in gardens, farms or forests.

Browse—That part of leaf and twig growth of shrubs, woody vines and trees on which browsing animals can feed; to consume browse.

Buffer strip—A strip of vegetation that is left unmanaged or is managed to reduce the impact that a treatment or action on one area would have on an adjacent area.

Cancer potency—A measure of the relative ability of a chemical to cause cancer.

Canopy—The cover of branches and foliage formed collectively by the crowns of adjacent trees and other woody growth.

Carcinogen—A substance capable of producing cancer.

Carginogenicity—Tendency of a substance to cause cancer.

Carrier—The liquid or solid material to which a chemical compound (pesticide) is added to facilitate its application in the field.

Chemical degradation—The breakdown of a chemical substance into simpler components through chemical reactions.

Chemical reaction—Interaction of two or more substances to produce new substances or materials. Reactions may be spontaneous due to inherent reactivity of substances, or may require energy input, as from sunlight, heat or microbial enzyme systems.

Chemsurf 90®—A non-ionic surfactant for use with herbicides that is registered and manufactured by Chemorse.

Chromosome—Microscopic structures within the cell nucleus that contain DNA, i.e. the genetic material.

Chronic—Long term, referring to either the period of exposure or intake of a chemical, or the duration of an effect. Exposures of from six months to a lifetime are usually considered chronic. (see also subchronic)

Chronic toxicity—See toxicity. The nature of adverse effects over a prolonged period. Chronic toxicity may result from continuous or intermittent intake over long periods, or may be the result of severe impact of a shorter exposure from which recovery is very slow.

Code of Federal Regulations (CFR)—A codification of the general and permanent rules published in the Federal Register by the executive departments and agencies of the Federal Government. The Code is divided into 50 titles that represent broad areas subject to Federal regulations. Each title is divided into chapters, which usually bear the name of the issuing agency. Each chapter is further subdivided into parts covering specific regulatory areas.

Compatible pesticides—Compounds or formulations that can be mixed and applied together without undesirably altering their separate effects.

Concentration (of a pesticide)—The amount of active ingredient or acid equivalent in a given volume of liquid or in a given weight of dry material.

Congenital—Existing at birth but acquired in the uterus rather than inherited.

Cut surface spraying—Applying a concentrated herbicide/water mixture to the surface of freshly cut stumps or stems by utilizing a backpack sprayer or hand held spray bottle.

Cycle—The period of time, expressed in years, between repeated vegetation management treatments.

Cytological aberration—A deviation from normal cell structure or function.

Data gap—Gaps in the information available regarding toxic properties, effects or environmental behavior of pesticides or inert ingredients.

DBH—Diameter at breast height. A standardized stem location (4.5 ft above the ground) to measure tree diameters.

Deciduous—Pertaining to any plant organ or group of organs that is shed naturally; perennial plants that are leafless for some time during the year.

Decomposition—Break up into constituent elements or compounds.

Degrade—To decompose or break up.

Deoxyribonucleic acid (DNA)—Collectively, the very long chains of nucleic acids that are the molecular basis of heredity in all organisms.

Deposit—The amount of pesticide on the leaves or skin or other surface immediately after pesticide application.

Dermal exposure—The amount of a toxic substance that comes into contact with the skin. (see exposure)

Dermal toxicity—The nature of toxicity exerted by a chemical when absorbed through the skin.

Dermatitis—Inflammation of the skin.

Developed Recreation—Recreation requiring constructed features or facilities that result in concentrated use of an area. Examples are campground and picnic areas. Facilities might include roads, parking lots, picnic tables, toilets, drinking water or a toilet building.

Diluent—Any liquid or solid material that dilutes an active ingredient in the preparation of a pesticide formulation.

Dispersed Recreation—Recreation (such as hunting, backpacking, and scenic driving) on lands and waters under Forest Service jurisdiction which are not developed for intensive recreation use. Dispersed areas include general undeveloped areas, roads, trails and water areas not treated as developed sites.

Diversity—The distribution and abundance of different plant and animal communities and species within an area.

DNA—See deoxyribonucleic acid.

Dormant—Not actively growing.

Dosage, target area—The amount of active ingredient (not formulated product) that is applied to an area or other target.

Dose—The amount of a chemical that is absorbed into the body, usually expressed in milligrams of chemical per kilogram body weight (mg/kg) (1 kg=1,000,000 mg). The dose resulting from skin exposure is usually a small fraction of the amount that reaches the skin, and usually a large part of exposure in the digestive or respiratory tracts is absorbed.

Dose response—The change in effect as dosage changes. As the dose increases so does the response, and the response lessens with lower dose. Every interaction between a chemical and a biological system is dose-responsive.

Drift—That portion of a sprayed pesticide that is moved off a target site by wind.

Duff—The lower portion of the organic layer covering the soil, consisting of decomposed litter.

EC_x—concentration causing X% inhibition of a process

EC_{25}—concentration causing 25% inhibition of a process

EC_{50}—concentration causing 50% inhibition of a process

Ecological niche—The physical space in a habitat occupied by an organism; its functional role in a community; and its position in environmental gradients of temperature, moisture, pH, soil, and other conditions of existence.

Ecosystem—The system formed of the biotic and abiotic components and their interaction within some defined area or space.

Edge—The more or less well-defined boundary between two or more elements of the environment; for example, field/woodland or right-of-way/woodland.

Endangered species—A plant or animal species that is in danger of extinction throughout all or a significant part of its range. Endangered species are identified by the Secretary of the Interior in accordance with the Endangered Species Act of 1973. (see threatened species)

Environmental assessment (EA)—A concise public document that briefly provides sufficient evidence and analysis for determining whether to prepare an Environmental Impact Statement or to return a finding of no significant impact, aids an agency's compliance with NEPA when no Environmental Impact Statement is necessary, or facilitates preparation of a statement when one is necessary. An EA normally includes an analysis of alternative actions and their predictable long and short-term environmental effects.

Environmental fate—The transport, accumulation and disappearance of pesticides in the environment.

Environmental impact statement (EIS)—A formal document required by the National Environmental Protection Act, as detailed in section 102(2)c (40 CFR 1508.11), and filed with the Environmental Protection Agency that considers significant environmental impacts expected from implementation of a proposed major Federal action and alternatives to it. The EIS is released as a draft to other agencies and the public for comment and review.

Ephemeral stream—A stream that flows briefly only in direct response to precipitation, with an unscoured channel that is always above the water table.

Exposure—Amount of a chemical in contact with a body surface (skin, respiratory tract, digestive tract) from which it can be absorbed into the body. Exposure does not include chemical that is intercepted by clothing or protective garments, or chemical that is nearby but not in contact.

Exposure analysis—The estimation of the amount of chemicals that organisms contact during the application of pesticides.

Federal Insecticide, Fungicide and Rodenticide Act (FIFRA)—An act administered by EPA that is the basis for the regulations governing distribution, sale and use of pesticides. (See registration)

Federal Register—A daily Federal publication that publishes regulations and legal notices that have been issued by Federal agencies.

Fetotoxic—Capable of producing adverse effects in a developing fetus.

Forb—Any herbaceous plant other than grass or grasslike plants.

Forest Service Manual (FSM)—An internal set of operating directives that governs Forest Service activities.

Foresters'®—A commercial formulation of glyphosate herbicide registered and manufactured by NuFarm Turf and Specialty.

Formulation—The form in which a pesticide is packaged or prepared for sale. A chemical mixture that includes a stated percentage of active ingredient (technical chemical), with appropriate solvents, emulsifiers, wetting agents, etc. Further dilutions or additions may be required for specific uses. (see also inert ingredients)

Gene—The basic unit of heredity. Each gene occupies a specific place (locus) on a chromosome.

Genotoxic—Harmful to genetic material (DNA).

GLEAMS—Groundwater Loading Effects of Agricultural Management Systems is a root zone model that can be used to examine the fate of chemicals in various types of soils under different meteorological and hydrogeological conditions

Glypro®—A commercial formulation of glyphosate herbicide registered and manufactured by Dow Agrosciences.

Ground water—Water residing in the interstices of soil and rock below the ground surface.

Habitat—The natural environment of a plant or animal. An animal's habitat includes the total environmental conditions for food, cover and water within its home range.

Habitat capability—The ability of the vegetative community to provide food, cover, and water for specific wildlife species.

Half-life—The time required for half the amount of a substance (such as an herbicide) in the environment or in a living system to be removed whether by excretion, dilution, metabolic decomposition or other natural process (also called half-time).

Hazard—The chance that danger or harm will come to the applicator, bystanders, consumers, livestock, wildlife or crops, etc. Also, the nature of adverse effect that may occur.

Hazard analysis—The determination of whether a particular chemical is or is not causally linked to particular harmful effects.

Hazard quotient—The ratio of the exposure to the critical toxicity value. Can be expressed as "HQ."

Hectare (ha)—10,000 square meters, or approximately 2.47 acres.

Hematology—The science concerned with blood and the blood-forming tissues.

Herbaceous—A plant that does not develop persistent woody tissue above the ground (annual, biennial or perennial), but whose aerial portion naturally dies back to the ground at the end of a growing season. Herbaceous plants include such categories as grasses, grass-like plants (sedges and rushes) and forbs.

Herbicide—A chemical used to control, suppress or kill plants, or to severely interrupt their normal growth processes.

Herbivore—An animal that exclusively eats plants.

Histology—The study of the microscopic structure of tissue.

Histopathology—Study of tissue changes characteristic of disease.

Hydric-wet—Usually used to describe a site that is wet, such as a wetland.

Hydrolysis—Decomposition or alteration of a chemical substance by water.

Hypertrophy—An increase in size of an organ or structure that does not involve tumor formation.

Inactive—Will not react chemically with anything; not involved in the pesticide action.

Inert ingredients—All ingredients in a formulated pesticide product which are not classified as an active ingredient. They are used to provide a carrier for the active ingredient that facilitates the mixing and effective application of the herbicide in the field. They may also stabilize the active ingredient during storage and transportation. Note that inert as used here is a defined usage; many inert products are biologically active.

Infiltration—The downward entry of water into the soil.

Inhalation—To take air into the lungs, to breathe in.

Inhalation toxicity—Toxicity resulting from inhalation exposure.

Intermittent stream—A stream that flows during wet portions of the year and has a defined channel and banks that transport water, sediment, and organics. It dries up when the water table drops below the stream bed.

Interval—The time period between two pesticide applications.

Intubation—Oral administration of a substance by means of a tube.

In vitro—Pertaining to a biological test or experiment that is conducted in an artificial environment such as a test tube or petri dish.

In vivo—Pertaining to a test or experiment that is performed with one intact living organism.

Is likely to adversely affect—The appropriate finding in a biological assessment (or conclusion during informal consultation) if any adverse effect to listed species may occur as a direct or indirect result of the proposed action or its interrelated or independent actions, and the effect is not: discountable, insignificant, or beneficial (see definition of "is not likely to adversely affect"). In the event the overall effect of the proposed action is beneficial to the listed species, but is also likely to cause some adverse effects, then the proposed action "is likely to adversely affect" the listed species. If incidental take is anticipated to occur as a result of the proposed action, an "is likely to adversely affect determination should be made. An "is likely to adversely affect" determination requires the initiation of formal section 7 consultation with the U.S. Fish and Wildlife Service. (Source: U. S. Department of Interior, Fish and Wildlife Service (1998) Endangered Species Consultation Handbook. USFWS and NMFS, March 1998, Final.)

Is not likely to adversely affect—The appropriate conclusion when effects on the listed species are expected to be discountable, insignificant, or completely beneficial. **Beneficial effects** are contemporaneous positive effects without any adverse effects to the species. **Insignificant effects** relate to the size of the impact and should never reach the scale where take occurs. **Discountable effects** are those extremely unlikely to occur. Based on best judgment, a person would not: (1) be able to meaningfully measure, detect, or evaluate insignificant effects; or (2) expect discountable effects to occur. (Source: U. S. Department of Interior, Fish and Wildlife Service (1998) Endangered Species Consultation Handbook. USFWS and NMFS, March 1998, Final.)

k_a—absorption coefficient

k_e—elimination coefficient

$k_{o/c}$—organic carbon partition coefficient

$k_{o/w}$—octanol-water partition coefficient

k_p—skin permeability coefficient

Label—All printed material on or attached to a pesticide container as required by law.

LC_{50}—See Median Lethal concentration.

LD_{50}—See Median Lethal Dose.

LDT—Lowest dose tested.

LEL—Lowest effect level. The lowest dose at which an effect is observed in an organism. (see also lowest-observed-effect-level)

Lethal concentration$_{50}$ (LC$_{50}$)—See Median Lethal Concentration.

Lethal dose$_{50}$ (LD$_{50}$)—See Median Lethal Dose.

Litter—The upper portion of the organic layer covering the soil, consisting of unaltered dead remains of plants and animals whose original form is still visible.

Leach—Usually refers to the movement of chemicals through soil by water; may also refer to the movement of herbicides out of leaves, stems or roots into the air or soil.

Lethal—Causing death of specified target or non-target species.

Leukemia—A form of cancer characterized by unrestrained proliferation of leukocytes (white blood cells) and their precursors in blood and blood forming tissues.

LOAEC—See lowest-observed-adverse-effect concentration.

LOEC—See lowest-observed-effect concentration.

LOEL—See lowest-observed-effect level.

Low volume foliar spraying—Ground spraying of vegetation foliage by utilizing backpack sprayers to apply a low volume of a higher concentration of an herbicide and water mixture.

Lowest-observed-adverse-effect concentration (LOAEC)—The lowest concentration of a substance that causes a detectable adverse effect in the test organism.

Lowest-observed-effect concentration (LOEC)—The lowest concentration of a substance that causes a detectable effect in the test organism.

Lowest-observed-effect level (LOEL)—The lowest level of a substance that causes a detectable effect in the test organism.

Macrophytes—Rooted aquatic plants including emerged, submerged, and floating vascular plants.

Material safety data sheets (MSDS)—An information sheet provided by a pesticide manufacturer describing chemical qualities, hazards, safety precautions and emergency procedures to be followed in case of a spill, fire or other emergency.

Median lethal concentration (LC$_{50}$)—The concentration of a chemical at which 50 percent of the test animals will be killed. It is usually used in testing of fish or other aquatic animals.

Median lethal dose (LD$_{50}$)—The dose, usually in mg/kg body weight, lethal to 50 percent of the test animals to which it is administered under the conditions of the experiment.

Mesic—A term used to describe an area which is of average or normal wetness, i.e. neither hydric or xeric.

Metabolism—The chemical processes in living cells by which energy is made available for vital processes, and living structures are produced and maintained. Also refers to processes that alter chemicals, such as pesticides, for detoxication and excretion.

Microbial degradation—The breakdown of a chemical substance by bacteria.

Microbiological—Very small living animals or plants.

Mitigate—To cause to become less harsh or harmful.

Mitigation measures—Actions taken to reduce the potential for environmental and human health risks. Such measures include: use of only certain herbicides, use of only certain herbicide application methods, use of non-herbicide control methods, drift control, timing of applications, buffer strips, signing, selectivity of applications and other such actions.

Mobility—The capability of a substance to move in the environment.

MOS—See margin of safety.

MSDS—See material safety data sheets.

Mutagen—A substance that tends to increase the frequency or extent of genetic mutations.

Mutagenic—Causing changes in genetic material.

Mutagenicity—The capacity of a substance to cause changes in genetic material.

Mutation—A change in a gene potentially capable of being transmitted to offspring or to subsequent generations of cells in the body.

National Environmental Policy Act (NEPA)—Congress passed NEPA in 1969 as the basic national charter for protection of the environment. NEPA establishes a national policy to encourage productive and enjoyable harmony between humankind and the environment, to promote efforts that will prevent or eliminate damage to the environment and stimulate the health and welfare of humans, to enrich the understanding of the ecological systems and natural resources important to the nation, and to establish a Council on Environmental Quality. One of the major tenets of NEPA is its emphasis on public disclosure of possible environmental effects of any major action on public lands.

Natural regeneration—The renewal of a tree crop by natural means or without efforts to seed or plant trees. The new trees grow from self-sown seeds or by vegetative means such as root suckers.

Necrosis—Death of a cell or group of cells as a result of injury, disease or other pathologic state.

Negligible residue—A tolerance which is set on a food or feed crop that will have a very small amount of pesticide at harvest as a result of indirect contact with the chemical.

NEPA—See National Environmental Policy Act.

Neurotoxic—Toxic to nerves or nervous tissue, including the central nervous system.

NOAEL—See No-observed-adverse-effect-level.

NOEL—See No-observed-adverse-effect-level.

Non-persistent—Lasts only a short time (a few weeks for less) after being applied; breaks down rapidly in the environment.

Non-selective pesticide—A pesticide chemical that will control a wide range of pests.

Non-target—Any plant, animal or other organism that a method of application is not aimed at, but may accidentally be injured by the method.

Non-target vegetation—Vegetation that is not planned to be affected by herbicide treatment.

Non-volatile—A pesticide chemical that does not evaporate (turn into a gas or vapor) at normal temperatures.

No-observed-adverse-effect level (NOAEL)—In a series of dose levels, it is the highest level at which no adverse effect is observed. It is also called the no-observed-effect level (NOEL). (See threshold)

Oncogenicity—Capable of producing or inducing tumors in animals, either benign (non-cancerous) or malignant (cancerous).

Opportunity cost—The value of benefits forgone or given up due to the effect of choosing another management alternative that either impacts existing outputs or shifts resources away from other activities so that they are no longer produced and their benefits are lost.

Oral—By gavage or fed in the diet.

Organic matter—An accumulation of decayed and resynthesized plant and animal residues with a high capacity for holding water and nutrients.

Organogenesis—The time period during embryonic development during which all major organs and organ systems are formed. During this period, the embryo is most susceptible to factors interfering with development.

Oust XP®—A commercial formulation of sulfometuron methyl herbicide registered and manufactured by DuPont.

Parenteral—Injection other than into the intestine.

Pastoral—Relating to a rural setting.

Percent stocking—The number of trees in a stand as compared to the desirable number for best growth and management, expressed as a percent.

Percolation—The flow of a liquid through a porous substance.

Perennial—A plant species having a life span of more than two years.

Perennial stream—A stream that flows year-round except during drought years, has a defined bed and banks, and is typically maintained by groundwater flow during the dry season.

Persistence—The resistance of a pesticide to metabolism and environmental degradation.

Pesticide—Any substance or mixture of substances intended for controlling insects, rodents, fungi, weeds or other forms of plant or animal life that are considered to be pests. This includes herbicides, insecticides, rodenticides, fungicides and other material used for these purposes.

Photodecomposition—The breakdown of a substance, especially a chemical compound, into simpler components by the action of light.

Photolysis—See photodecomposition.

Photosynthesis—Formation of carbohydrates in the tissues of plants exposed to light.

Phytotoxic—Poisonous or harmful to plants.

Plant community—An association of plants of various species found growing together in different areas with similar site and environmental characteristics.

POEA—polyoxyethyleneamine, a surfactant used with some commercial glyphosate formulations.

Poison—A substance that is capable at sufficient dosage of causing harm to an organism. Every chemical is toxic (poisonous) at a sufficient dose.

Pre-emergent—A herbicide that acts prior to emergence of the specified weed or planted crop.

Protocol—The standard procedure by which specific tests, studies or activities are carried out.

Raptors—Birds of prey such as owls, hawks and eagles.

Red River 90®—A non-ionic surfactant for use with herbicides that is registered and manufactured by Red River Specialists, Inc.

Red River Adherent 90®—A non-ionic surfactant for use with herbicides that is registered and manufactured by Red River Specialists, Inc.

Reference dose (RfD) —A reference dose is an estimate of the maximum amount of a chemical that a person can be exposed to on a daily basis that is not anticipated to cause adverse health effects over a person's lifetime.

Regeneration—The act of establishing young trees whether by natural or artificial means. Also, the actual young tree seedlings and saplings existing on a site.

Registration—Formal qualification by EPA of a pesticide before it can be sold or distributed. Registration is based on data demonstrating that use of the pesticide according to the label will not cause unreasonable adverse effects on human health or the environment.

Relative stand density—Measurement of stand density in mixed species stands which accounts for variation in tree growing space requirements for variable tree sizes and species composition. It compares the crowding in a forest stand to the crowding in a stand at the average maximum density observed in undisturbed stands of similar average tree size and species composition.

Reproductive effects or toxicity—Effects of chemicals or other factors on male and female reproductive capability. Usually evaluated through treatment of laboratory species, seeking information about effects on fertility of parents, effects on the developing fetus, postnatal survival, litter size, weight of offspring etc. Sometimes includes birth defects and direct fetal intoxication.

Re-registration eligibility decision (RED) —The final step in the EPA process of reviewing older pesticides (those initially registered prior to November 1984) under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) to ensure that they meet current scientific and regulatory standards. This process, called reregistration, considers the human health and ecological effects of pesticides and results in actions to reduce risks that are of concern.

Residue—The quantity of an herbicide or its metabolites remaining in or on soil, water, plants, animals or surfaces.

Rhizomes—A plant stem, generally modified for storing food materials, that grows along and below the ground surface and that produces adventitious roots, scale leaves and suckers irregularly along its length, not just at nodes.

Right-of-way—A corridor of land over which roadways or facilities such as railroads, power lines communication lines, pipelines, conduits or channels are located.

Riparian areas—Geographically delineated areas with distinctive resource values and characteristics that are comprised of the stream channel, aquatic, flood plain, wetland, and immediately adjacent terrestrial ecosystem.

Riparian ecosystem—A transition between the aquatic ecosystem and the adjacent terrestrial ecosystem which is identified by soil characteristics and distinctive vegetation communities that require free or unbound water.

Risk—The probability that a substance will produce harm under specific conditions.

Risk Analysis—The description of the nature and magnitude of risk to humans and other organisms, including attendant uncertainty.

Rodeo®—A commercial formulation of glyphosate herbicide registered and manufactured by Dow Agrosciences.

RoundUp®—A commercial formulation of the herbicide glyphosate, manufactured and marketed by Monsanto.

Runoff—That part of precipitation, as well as any other flow contributions, that appears in surface water, either perennially or intermittently.

Safety—The reciprocal of risk, i.e., the probability that harm will not occur under specified conditions.

Sediment—Organic matter or soil that settles to the bottom of a liquid.

Selective herbicide application—An herbicide application that is aimed at target vegetation with an attempt to avoid and preserve non-target vegetation.

Sensitive species—Those plant and animal species identified by a Regional Forester for which population viability is a concern, as evidenced by: significant current or predicted downward trends in population numbers or density; or significant current of predicted downward trends in habitat capability that would reduce a species' existing distribution.

Shrub—A plant with persistent woody stems and relatively low growth form; usually produces several basal shoots as opposed to a single bole; differs from a tree by its low stature and non-arborescent form.

Signal word—Word that must appear on pesticide labels to indicate the acute toxicity category of the pesticide. The signal words used are "Danger–Poison," "Warning," or "Caution."

Silviculture—Application of forestry principles underlying the growth and development of single trees and of the forest as a biological unit to control forest establishment, composition, structure, and growth. The selection of an appropriate silvicultural system for a management area depends on the stated resource objectives.

Site preparation—The removal of competition (including woody slash) and conditioning of the soil to enhance the survival and growth of seedlings or to enhance the germination of seed.

Slash—Woody debris left after logging, pruning, thinning, brush cutting or other forest disturbances, natural or human initiated. It includes logs, wood chunks, bark, branches, stumps and broken small trees or brush.

Snag—Standing dead or partially dead trees that are at least six inches in diameter at breast height (DBH) and 20 feet tall.

Soil fertility—the quality of a soil that enables it to provide essential chemical elements in quantities and proportions for the growth of specified plants

Spot treatment—An herbicide applied over a small continuous restricted area of a whole unit; i.e., treatment of spots or patches of brush within a larger field.

Spreader/sticker—A surfactant closely related to wetting agents that facilitates spreading and increases sticking of an herbicide on vegetation.

Stand—Trees that grow in the same location and which are fairly uniform in type, age and risk classes, vigor, stand-size class and stocking class. The similarity of these qualities distinguishes the stand from adjacent stands that contain trees with different features.

Standard—A required course of action, or level of attainment, that promotes the achievement of forest plan goals and objectives. Standards found in a forest plan impose limits on natural resource management activities, generally for environmental protection.

Subacute oral toxicity—Relatively short term. The manifestation of adverse effect(s) occurring as a result of the repeated daily exposure of experimental animals to a substance by the oral route for 14 days.

Subchronic exposure—Periods of medium duration. Repeated exposure by the oral, dermal, or inhalation route for more than 30 days, up to approximately 10% of the life span in humans (more than 30 days up to approximately 90 days in typically used laboratory animal species).

Succession—The progressive development of trees or other plants toward their highest role in their ecology; their climax. The replacement of one forest, or other plants, by others.

Surface water—Rivers, lakes, ponds, streams and so forth that are located above ground.

Surfactant—A material that improves the emulsifying, dispersing, spreading, wetting or other surface-modifying properties of liquids; substance added to the pesticide mixture to increase the effect of the active ingredient. Examples: wetting agent, spreader, adhesive, emulsifying agent, penetrant.

Susceptible—Can be killed or injured by the pesticide at the rate used.

Symptom—A warning that something is wrong. An outward signal of a disease or poisoning in a plant, animal or human.

Synergism—The interaction between two agents producing an effect that is greater than the additive effects of each agent operating by itself.

Systemic herbicide—An herbicide that is absorbed, moved within the plant and exerts its effect at a site removed from the point of absorption. An example is an herbicide that is applied to foliage and moves downward through living tissue to injure underground parts of the plant.

Systemic toxicity—Effects to tissues at a distance from the point of contact. General toxicity, usually including cancer, genetic injury and reproductive effects.

Technical chemical or pesticide—The pesticide as it is first manufactured by the company before formulation.

Teratogen—A substance tending to cause developmental malformations in unborn human or animal offspring. Teratogenicity is the capacity of a substance to cause anatomical, physiological or behavioral defects in animals exposed during early embryonic and fetal development.

Teratogenic—Capable of producing or inciting the development of malformations in an embryo.

Test animals—Laboratory animals, usually rats, fish, birds, mice or rabbits, used to determine the toxicity and hazards of different pesticides.

Threatened species—Those plant or animal species likely to become endangered throughout all or a specific portion of their range within the foreseeable future as designated by the U. S. Fish and Wildlife Service under the Endangered Species Act of 1973.

Threshold—The lowest dose that produces a response in a given system. See LOEL.

Timberland 90®—A non-ionic surfactant for use with herbicides that is registered and manufactured by Chemorse.

TL_m (TL_{50}) —Median tolerance limit; the concentration of chemical in water necessary to kill 50 percent of the test aquatic organisms during a specific exposure period. The TL_m is usually expressed as parts per million parts of water for 24, 48, 72, or 96 hours of exposure.

Tolerance—The amount of a pesticide that can remain on any food (plant or animal) that is to be eaten by livestock or humans. The tolerance is set by the Environmental Protection Agency.

Toxic—Capable of causing adverse effects in an organism or population.

Toxicant—A toxic substance.

Toxicity—The whole pattern of adverse effects that can be produced by a chemical. Toxicity is a property of a chemical and is consistent at a given dose in a given species and frequently similar among species.

Toxicology—The science dealing with the study of the adverse biological effect of chemicals.

Translocation—The transfer of substances from one location to another in the plant body.

Transmission line—An electric line of high voltage which moves bulk electric energy from power plants to distributing points and to large industrial customers. They are usually located on cross-country rights-of-way.

Tumor—A new growth of tissue in which all multiplication is uncontrolled and progressive. A tumor may be slow growing and encapsulated, (benign) or invasive and capable of disseminating to other tissues (malignant).

Understory (vegetation)—Plants growing below the canopy of other plants. The trees (generally seedlings and/or saplings), shrubs, and herbaceous plants growing beneath the forest canopy in a stand of trees.

Vertical diversity—The diversity in an area that results from the complexity of the above-ground structure of the vegetation; the more tiers of vegetation and/or the more diverse the species composition, the higher the degree of vertical diversity.

Visual resource—The composite of basic terrain, geologic features, water features, vegetative patterns and land-use effect that typify a land unit and influence the visual appeal the unit may have for visitors.

Volatile—A compound is volatile when it evaporates or vaporizes (changes from a liquid to a gas) at ordinary temperatures on exposure to air.

Water table—The upper limit of the part of the soil or underlying rock material that is wholly saturated with water.

Watershed—A geographic area in which water, sediments, and dissolved materials drain to a common outlet such as a point on a larger stream or river.

Weed—A plant growing where it is not desired.

Wetlands—Those areas that under normal circumstances are inundated by surface or ground water with a frequency sufficient to support a prevalence of vegetation or aquatic life that requires saturated or seasonally-saturated soil conditions for growth and reproduction. Wetlands generally include swamps, marshes, bogs, and similar area such as sloughs, potholes, wet meadows, river overflows, mud flats, natural ponds, springs, seeps, and vernal ponds. (FSM 2527.05)

Woody plants—Plants such as trees, shrubs and vines which have stems composed of wood.

Xeric-dry—A term used to describe an area that is much drier than normal for an area. For instance, a site with rocky, thin soil on a south facing slope well away from drainage channels might be xeric.