Sulfometuron methyl (OUST) - FINAL DRAFT

Prepared for:

USDA, Forest Service

Task No. **9**
USDA/FS Contract No. **53-3187-5-12**
USDA/FS Order No. **43-3187-7-0408**

Submitted to:
Leslie Rubin, COTR
Animal and Plant Health Inspection Service (APHIS)
Biotechnology, Biologics and Environmental Protection
Environmental Analysis and Documentation
United States Department of Agriculture
Suite 5B05
4700 River Road
Riverdale, MD 20737

Submitted by:
Syracuse Environmental Research Associates, Inc.
5100 Highbridge St., 42C
Fayetteville, New York 13066-0950
Telephone: (315) 637-9560
Fax: (315) 637-0445
Internet: SERA_INC@msn.com

Report Date: September 11, 1998
PDF File Date: April 25, 1999

TABLE OF CONTENTS

TABLE OF CONTENTS (*continued*)

TABLE OF CONTENTS (*continued*)

APPENDICES

WORKSHEETS

LIST OF TABLES

LIST OF FIGURES

ACRONYMS, ABBREVIATIONS, AND SYMBOLS

a.e.	acid equivalents
a.i.	active ingredient
AEL	adverse-effect level
ACGIH	American Conference of Governmental Industrial Hygienists
AChE	acetylcholinesterase
ATSDR	Agency for Toxic Substances and Disease Registry
BCF	bioconcentration factor
bw	body weight
CBI	confidential business information
cm	centimeter
CNS	central nervous system
DAA	days after application
DF	dry flowable
d.f.	degrees of freedom
EC_{25}	concentration causing 25% inhibition of a process
EC_{50}	concentration causing 50% inhibition of a process
F	female
F_1	first filial generation
g	gram
HQ	hazard quotient
k_a	absorption coefficient
k_e	elimination coefficient
kg	kilogram
$K_{o/c}$	organic carbon partition coefficient
$K_{o/w}$	octanol-water partition coefficient
Kp	skin permeability coefficient
L	liter
lb	pound
LC_{50}	lethal concentration, 50% kill
LD_{50}	lethal dose, 50% kill
LOAEL	lowest-observed-adverse-effect level
m	meter
M	male
MCS	multiple chemical sensitivity
mg	milligram
mg/kg/day	milligrams of agent per kilogram of body weight per day
mL	milliliter
mM	millimole
MW	molecular weight
MOS	margin of safety
MSDS	material safety data sheet
NCI	National Cancer Institute

ACRONYMS, ABBREVIATIONS, AND SYMBOLS (*continued*)

NOAEL	no-observed-adverse-effect level
NOEL	no-observed-effect level
NRC	National Research Council
OPPTS	Office of Pesticide Planning and Toxic Substances
ppm	parts per million
PSP	phenolsulfonphthalein
RBC	red blood cells
RfD	reference dose
UF	uncertainty factor
ULW	ultra low weight
U.S.	United States
U.S. EPA	U.S. Environmental Protection Agency
>	greater than
≥	greater than or equal to
<	less than
≤	less than or equal to
=	equal to
≃	approximately equal to
~	approximately

COMMON UNIT CONVERSIONS AND ABBREVIATIONS

To convert ...	Into ...	Multiply by ...
acres	hectares (ha)	0.4047
acres	square meters (m^2)	4,047
atmospheres	millimeters of mercury	760
centigrade	Fahrenheit	1.8C°+32
centimeters	inches	0.3937
cubic meters (m^3)	liters (L)	1,000
Fahrenheit	centigrade	0.556F°-17.8
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 (cm^3)	1,000
liters (L)	gallons (gal)	0.2642
liters (L)	ounces, fluid (oz)	33.814
miles (mi)	kilometers (km)	1.609
miles per hour (mi/hr)	cm/sec	44.70
milligrams (mg)	ounces (oz)	0.000035
meters (m)	feet	3.281
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 (cm^3)	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/m^2)	112.1
pounds per acre (lb/acre)	µg/square centimeter ($µg/cm^2$)	11.21
pounds per gallon (lb/gal)	grams per liter (g/L)	119.8
square centimeters (cm^2)	square inches (in^2)	0.155
square centimeters (cm^2)	square meters (m^2)	0.0001
square meters (m^2)	square centimeters (cm^2)	10,000
yards	meters	0.9144

Note: All references to pounds and ounces refer to avoirdupois weights unless otherwise specified.

CONVERSION OF SCIENTIFIC NOTATION

Scientific Notation	Decimal Equivalent	Verbal Expression
$1 \cdot 10^{-10}$	0.0000000001	One in ten billion
$1 \cdot 10^{-9}$	0.000000001	One in one billion
$1 \cdot 10^{-8}$	0.00000001	One in one hundred million
$1 \cdot 10^{-7}$	0.0000001	One in ten million
$1 \cdot 10^{-6}$	0.000001	One in one million
$1 \cdot 10^{-5}$	0.00001	One in one hundred thousand
$1 \cdot 10^{-4}$	0.0001	One in ten thousand
$1 \cdot 10^{-3}$	0.001	One in one thousand
$1 \cdot 10^{-2}$	0.01	One in one hundred
$1 \cdot 10^{-1}$	0.1	One in ten
$1 \cdot 10^{0}$	1	One
$1 \cdot 10^{1}$	10	Ten
$1 \cdot 10^{2}$	100	One hundred
$1 \cdot 10^{3}$	1,000	One thousand
$1 \cdot 10^{4}$	10,000	Ten thousand
$1 \cdot 10^{5}$	100,000	One hundred thousand
$1 \cdot 10^{6}$	1,000,000	One million
$1 \cdot 10^{7}$	10,000,000	Ten million
$1 \cdot 10^{8}$	100,000,000	One hundred million
$1 \cdot 10^{9}$	1,000,000,000	One billion
$1 \cdot 10^{10}$	10,000,000,000	Ten billion

EXECUTIVE SUMMARY

INTRODUCTION

The USDA Forest Service uses the herbicide, sulfometuron methyl, in its vegetation management programs. Only one commercial formulation, Oust, is used by the Forest Service. The present document provides risk assessments for human health effects and ecological effects to support an assessment of the environmental consequences of using Oust in Forest Service programs. Each of the two risk assessment chapters—human health and ecological effects—has four major sections, including an identification of potential hazards, an assessment of potential exposure to the product, an assessment of the dose-response relationships, and a characterization of the risks associated with plausible levels of exposure.

The human health and ecological risk assessments presented in this document are not, and are not intended to be, comprehensive summaries of all of the available information. Nonetheless, 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. 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 to this document.

For the most part, the risk assessment methods used in this document are similar to those used in risk assessments previously conducted for the Forest Service as well as risk assessments conducted by other government agencies. Although risk assessments are usually expressed with numbers, those numbers are never exact. Variability and uncertainty can be dominant factors in any risk assessment, and should be expressed. 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.

PROGRAM DESCRIPTION

Sulfometuron methyl is a non-selective, sulfonyl urea herbicide used primarily to control the growth of broadleaf weeds and grasses. The Forest Service uses only one commercial formulation of sulfometuron methyl, Oust. Oust is manufactured by DuPont as a water dispersible granule. The composition of the product is 75% sulfometuron methyl and 25% inert ingredients. Site preparation entails the primary use of Oust by the Forest Service. Relatively minor uses include conifer release, noxious weed control, rights-of-way management, and facilities maintenance. Although sulfometuron methyl is applied as the sole herbicide under certain conditions, it is most often applied in combination with other herbicides such as diuron, glyphosate, or hexazinone. The most common methods of ground application for Oust involve backpack (selective foliar) and boom spray (broadcast foliar) operations. Although Oust is registered for aerial applications (helicopter only), the Forest Service does not and does not intend to use Oust in aerial applications. The typical application rate in Forest Service programs is 0.1 lbs a.i./acre. The range of application rates likely to be used in Forest Service programs is 0.023-0.38 lbs a.i./acre.

HUMAN HEALTH EFFECTS

Hazard Identification

The phytotoxicity of sulfonylurea herbicides, including sulfometuron methyl, is fairly well characterized. Not as well characterized, however, is the mechanism of toxicity of sulfometuron methyl in mammals or other animal species. In any case, sulfometuron methyl appears to have a low order of acute oral toxicity. Some studies report no apparent signs of overt toxicity in rats after single gavage doses of up to 17,000 mg/kg bw. The lowest dose reported to cause any apparent effects after single gavage administration to rats is 5000 mg/kg.

Several subchronic and chronic animal studies regarding exposure to sulfometuron methyl are available in the literature. The most common signs of toxicity involve changes in blood 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 the metabolism of sulfometuron methyl to sulfonamide and saccharin. In a 1-year dog feeding study, several effects, in addition to those on the blood, were observed, including increased alkaline phosphatase activity, increased serum cholesterol (females only), decreased serum albumin and creatinine, as well as changes in liver and thymus weights. These effects, however, were not clearly attributable to sulfometuron methyl exposure. In chronic feeding studies with rats and mice and in several *in vitro* assays, sulfometuron methyl did not display carcinogenic or mutagenic activity.

There is some concern for the potential reproductive and teratogenic effects of 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 discussed 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 formulation, Oust, can cause skin and eye irritation. It is difficult to make a direct comparison between the irritant effects of sulfometuron and the irritant effects of Oust since the available studies use different exposure levels. Nonetheless, there appears to be no remarkable difference between the irritant effects of sulfometuron methyl and the commercial formulation.

As discussed in the exposure assessment, dermal exposure is the primary route of concern for workers. The available data, albeit relatively sparse, suggest that sulfometuron methyl can be absorbed through the skin in amounts that may cause systemic toxic effects. Data regarding the dermal absorption kinetics of sulfometuron methyl, however, were not found in the available 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. These estimates are then used with the available dose-response data to characterize risk. The lack of experimental data on the 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.

Information regarding the inhalation toxicity of sulfometuron methyl is sparse. There is evidence that sulfometuron methyl and Oust may 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 the compound.

Based on a comparison of the toxicity of sulfometuron methyl to the toxicity of the commercial formulation, there is no reason to suspect that Oust contains impurities or adjuvants that have a substantial impact on the risk assessment. All of the toxicology studies on sulfometuron methyl involve technical sulfometuron methyl, which is presumed to be the same as or comparable to the active ingredient in Oust. Thus, if toxic impurities are present in technical sulfometuron methyl, they are likely to be encompassed by the available toxicity studies using technical grade sulfometuron methyl.

Exposure Assessment

Studies regarding occupational exposures associated with the application of sulfometuron methyl were not found in the available literature. 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 (Rubin et al. 1998). Separate exposure assessments are given for backpack and boom spray ground applications. For both types of applications, central estimates of worker exposure are similar: 0.0013 mg/kg/day for backpack applications and 0.0011 mg/kg/day for boom spray applications. The upper limits of the exposure estimates are 0.03 mg/kg/day for backpack applications and 0.064 mg/kg/day for boom spray applications. Although Oust is labeled for aerial applications (helicopter only), the Forest Service is not using and does not plan to use that application method for Oust. Consequently, aerial applications are not considered in this risk assessment.

Except for accidental exposure scenarios, the general public should be exposed to sulfometuron methyl at levels far less than those for workers. Longer-term exposure scenarios for the general public lead to central estimates of daily doses in the range of 0.00000077-0.00015 mg/kg/day with upper limits of exposure in the range of 0.0001-0.0016 mg/kg/day. While these exposure scenarios are intended to be conservative, they are, nonetheless, plausible. Accidental exposure scenarios result in central estimates of exposure of up to 0.025 mg/kg/day with upper ranges of 0.25 mg/kg/day. All of the accidental exposure scenarios involve relatively brief periods of exposure and most should be regarded as extreme, some to the extent of limited plausibility.

Dose-Response Assessment

There is no current U.S. EPA RfD for sulfometuron methyl. The U.S. EPA Office of Pesticide Programs will prepare a re-registration eligibility document (RED) for sulfometuron methyl, but the registrant, DuPont, is in the process of submitting additional data to the U.S. EPA and the RED has not been initiated.

In terms of species sensitivity, rats appear to be most sensitive with reported NOAELs of 2-3 mg/kg/day and an AEL of 20 mg/kg/day. 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. Mice appear to be much less sensitive than either rats or dogs to the hematological effects of sulfometuron methyl with a NOAEL of 27.5 mg/kg/day and a LOAEL of 275 mg/kg/day. Although these data are not amenable to formal statistical analysis, they lend qualitative support to the use of an uncertainty 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).

In the absence of an RfD derived by the U.S. EPA, a provisional reference dose of 0.02 mg/kg/day is used in this risk assessment. The provisional reference dose is based on the 2 mg/kg/day 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. A dose of 20 mg/kg/day, caused hematological effects in male rats. Thus, at a dose that is 10-fold higher than the provisional reference dose, 0.2 mg/kg/day, there would be concern for hematologic effects in humans. At intermediate levels of exposure (i.e., those between 0.02 and 0.2 mg/kg/day) the concern for potential adverse effects cannot be defined well.

Based on reproduction studies in rats, a dose of 0.2 mg/kg/day (i.e., 100-fold below a reported AEL of 20 mg/kg/day) could be taken as a level of concern for potential reproductive effects. One reservation about using this approach involves the available data on reproductive effects in rabbits. Increased fetal anomalies were observed in rabbits exposed to doses as low as 30 mg/kg/day (Serota et al. 1981), which is quite close to the LOAEL of 20 mg/kg/day for hematological effects in rats. Furthermore, although it can be argued that modest levels of anemia may be regarded merely as an AEL (adverse effect level), doses associated with fetal anomalies are more properly regarded as FELs (frank effect levels) and are of substantial concern in any risk assessment.

For this risk assessment, the increased number of fetal anomalies in rabbits exposed to 30 mg/kg/day (Serota et al. 1981) is interpreted as a reproductive FEL. This is a conservative interpretation of the gavage studies in rabbits (Hoberman et al. 1981, Serota et al. 1981). This judgment influences the risk assessment primarily in the interpretation of risks above the provisional reference dose of 0.02 mg/kg/day based on hematological effects. If the dose of 20-26 mg/kg/day from the dietary study by Mullin (1984) is taken as a reproductive NOAEL, a provisional reference dose for reproductive toxicity can be derived that is about 10- fold higher than the reference dose based on anemia. In that case, relatively modest (i.e., less than a factor of 10) excursions above the provisional reference dose could be a cause for concern regarding hematological effects but not reproductive effects. On the other hand, if the 30 mg/kg/day dose from Serota et al. (1981) is accepted as a reproductive FEL,

the proximity of the FEL to the reproductive NOAEL reported by Mullin (1984) suggests that a lower reference dose for reproductive effects is justified and that modest excursions above the reference dose are causes for concern regarding both hematological and reproductive effects.

As a supplement to this judgmental approach, categorical regression analyses were conducted on the animal toxicity data. Again using a conservative interpretation of the reproductive toxicity studies in rabbits, this analysis suggests that at the provisional reference dose of 0.02 mg/kg/day, the probability of an adverse effect (AEL/FEL) is about 0.000007 (7 in 1,000,000). At a 10-fold higher dose, 0.2 mg/kg/day, the probability of an adverse effect, including reproductive toxicity, is about 0.0004 (4 in 10,000).

Risk Characterization

In general, workers will be exposed to sulfometuron methyl at higher levels of exposure than members of the general public and will be subject to greater potential risk. The upper limit of general exposure scenarios for backpack and boom spray applications result in a modest excursion above the provisional RfD. 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 the typical rather than the maximum application rate) the hazard indices would be at or below unity (i.e., below 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. In other words, the quantitative risk characterization suggests that under the most conservative set of exposure assumptions, workers could be exposed to sulfometuron methyl levels regarded as unacceptable. And that if sulfometuron methyl is not applied at the highest application rate or if appropriate steps are taken to ensure that workers are not exposed at the maximum plausible rates (i.e., worker hygiene practices and/or reduced areas of treatment per day) there is no indication that the workers would be at risk of incurring systemic toxic effects.

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 the general public, none of the longer-term exposure scenarios approach a level of concern. In addition, none of the acute/accidental scenarios exceed a level of concern, based on central estimates of exposure, although a hazard index of unity is reached for the consumption of water after an accidental spill. Based on the most extreme exposure assumptions, two of the acute/accidental scenarios approach a level of concern (i.e., consumption of contaminated fruit and consumption of fish by subsistence populations), and the scenario for an accidental spill into water substantially exceeds a level of concern. The exposure scenario for the consumption of contaminated water is an arbitrary scenario. In other words, scenarios that are more or less severe, all of which may be equally probable or improbable, could be easily constructed. Nonetheless, the acute exposure scenarios for the general public help to identify the types of scenarios that are of greatest concern and may warrant

the greatest efforts to mitigate. For sulfometuron methyl, the exposure scenarios of greatest concern involve oral rather than dermal exposure.

The potential of sulfometuron methyl to induce reproductive effects—fetal mortality or abnormalities—suggest that pregnant women should avoid exposure to sulfometuron methyl. Based on the available dose/duration/severity data, however, it appears that exposure levels below those associated with the most sensitive effect (i.e., anemia) are not likely to be associated with reproductive toxicity. In addition, the available dose-response data on the reproductive effects of sulfometuron methyl in rabbits is weak (i.e., there are no statistically significant dose-response relationships). The major study on which the hazard identification for reproductive effects is based, nonetheless, reports adverse reproductive effects at all dose levels of sulfometuron methyl exposure. Thus, the qualitative decision to consider sulfometuron methyl as a potential reproductive hazard may be regarded as extremely conservative; however, this determination seems prudent at this time.

ECOLOGICAL EFFECTS

Hazard Identification

The mammalian toxicity of sulfometuron methyl is relatively well-characterized in experimental mammals. There is, however, relatively little information regarding the toxicity of sulfometuron methyl to non-target wildlife species. It seems reasonable to assume that the most sensitive effects in wildlife mammalian species will be the same as those in experimental mammals (i.e., changes to blood and as well as decreased body weight gain). There are only four studies regarding the toxicity of sulfometuron methyl to birds. Because the avian studies are designed differently from the mammalian studies, it is difficult to assess the sensitivity of birds, relative to mammals. Based on the limited comparisons that can be made, birds appear to be somewhat less sensitive than experimental mammals to the toxic effects of sulfometuron methyl. There is only one study regarding the toxicity of sulfometuron methyl to a terrestrial invertebrate: the standard contact toxicity test in bees that is required by the U.S. EPA for pesticide registration. Based on this study, bees appear to be less sensitive than either mammals or birds to sulfometuron methyl. The available data, however, are not sufficient to determine if this apparent low level of toxicity can be generalized to other species of terrestrial invertebrates.

The toxicity of sulfometuron methyl to terrestrial plants was studied extensively and is well characterized. Sulfometuron methyl inhibits acetolactate synthase (ALS), an enzyme that catalyzes the biosynthesis of three branched-chain amino acids, all of which are essential for plant growth. Drake (1990) assayed the toxicity of sulfometuron methyl to a number of non-target as well as target dicots and monocots. At an application rate of 0.01 kg/ha [0.00892 lbs a.i./acre] sulfometuron methyl is highly toxic to seedlings of several broadleaves and grasses, either preemergence or postemergence. Moreover, 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 times less than the application rate that the Forest Service would typically use. This study predominates in both the dose-response assessment for the effect of sulfometuron methyl on terrestrial plants as well as the risk characterization for the potential ecological effects of sulfometuron methyl applications. Concern for the sensitivity of non-target plant species is increased further by field reports of substantial and

prolonged damage to crops or ornamentals after the application of sulfometuron methyl in both an arid region, presumably due to the transport of soil contaminated with sulfometuron methyl by the wind, and in a region with heavy rainfall, presumably due to the wash-off of sulfometuron methyl contaminated soil.

Terrestrial microorganisms have an enzyme that is involved in the synthesis of branched chain amino acids, which is functionally equivalent to the target enzyme in terrestrial macrophytes. While there are some laboratory studies on the effects of sulfometuron methyl to soil microorganisms, there are no field studies that allow for an assessment of the potential effects of sulfometuron methyl on soil microorganisms under conditions of application anticipated by the Forest Service.

As with potential effects on terrestrial species and as would be expected for a herbicide, the available data suggest that sulfometuron methyl is much more toxic to aquatic plants than to aquatic animals. Frank toxic effects in fish are not likely to be observed at concentrations less than or equal to 150 mg/L. Based on assays of fathead minnow embryo hatch, larval survival, or larval growth over 30-day exposure periods, no adverse effects would be expected at concentrations up to 1.17 mg sulfometuron methyl/L. Sulfometuron methyl also appears to be relatively non-toxic to aquatic invertebrates, based on acute bioassays in daphnids, crayfish, and field-collected species of other aquatic invertebrates. One daphnid reproduction study notes a reduction in the number of neonates at 24 mg/L but not at 97 mg/L or any of the lower concentrations tested. Although the effect observed at 24 mg/L may have been a random variation, it is treated as an AEL for the purpose of this risk assessment. Although this approach may be regarded as conservative, it seems prudent in the absence of additional studies regarding reproductive effects of sulfometuron methyl in aquatic invertebrates.

Aquatic plants are far more sensitive than aquatic animals to the effects of sulfometuron methyl although there appear to be substantial differences in sensitivity among species of macrophytes and unicellular algae. The macrophytes, however, appear to be generally more sensitive. There are no published or unpublished data regarding the toxicity of sulfometuron methyl to aquatic bacteria or fungi. By analogy to the effects on terrestrial bacteria and aquatic algae, it seems plausible that aquatic bacteria and fungi will be sensitive to the effects of sulfometuron methyl.

Exposure Assessment

The exposure assessments for terrestrial animals are generally parallel (i.e., use as many common assumptions as possible) to the exposure assessments for potential human health effects. In general, the exposure assessments focus on a small animal with a body weight of 20 g. This weight approximates the body weight of small mammals such as mice, voles, shrews, and bats. In some scenarios, the available toxicity data support specific assessments for other species, like birds or invertebrates. In the risk characterization, these exposure estimates are compared with the dose-response estimates based on the most sensitive species, regardless of body weight. This approach is admittedly conservative but has only a minor impact on the characterization of risk because of the substantial potential for adverse effects on non-target plants.

The primary hazard to non-target terrestrial plants associated with the application of most herbicides is unintended direct deposition or spray drift, particularly in aerial applications. In addition, a field report suggests that toxicologically significant amounts of sulfometuron methyl may be transported by wind erosion of soil. Unintended direct spray will result in an exposure level equivalent to the application rate. Most plants that are sprayed directly with sulfometuron methyl at or even substantially below the recommended application rate will be damaged, as discussed in the dose-response assessment for terrestrial plants. The available literature does not include data regarding the drift of sulfometuron methyl during ground or aerial applications. Because off-site drift is more or less a physical process that depends on droplet size and meteorological conditions rather than the specific properties of the herbicide, estimates of off-site drift can be made based on relatively extensive data on other compounds. The available literature also does not include studies on wind erosion as a method of transport for sulfometuron methyl. Nonetheless, rates of soil loss, although highly variable, can be estimated. This risk assessment uses average soil losses ranging from 1 to 10 tons/ha·year, with a typical value of 5 tons/ha·year.

The amount of sulfometuron methyl that might be transported by wind erosion depends on several factors, including the application, the depth of incorporation into the soil, the persistence in the soil, the wind speed, and the topographical and surface conditions of the soil. Under desirable conditions, like relatively deep (10 cm) soil incorporation, low wind speed, and surface conditions that inhibit wind erosion, it is likely that wind transport of sulfometuron methyl would not be substantial or significant. A reasonable 'worst case' scenario is one in which 8.4% of the applied sulfometuron methyl is lost due to wind erosion over a 2-month period. The potential impact of such erosion will depend significantly on the re-deposition patterns of the herbicide, which will vary substantially with local conditions. Under desirable conditions, the soil might be dispersed over a very large area and be of no toxicological consequence. In some cases, however, local topographical conditions might favor the deposition and concentration of contaminated dust from a large treated area into a relatively small off-site area. An objective approach for modeling these types of events is not available in the literature. For this risk assessment, neither concentration nor dispersion is quantitatively considered. Nonetheless, these factors together with the general and substantial uncertainties in the exposure assessment are considered in the risk characterization

Sulfometuron methyl could also be transported in or through the soil by run-off or percolation. Two detailed studies that investigate the fate and transport of sulfometuron methyl in soil are useful for assessing the potential for off-site vegetation exposure to the compound. These studies generally support the supposition that at least 1% of the applied sulfometuron methyl could run off from the application site to adjoining areas after a moderate rain. In the case of a heavy rain, losses could be much greater and might approach 50% in cases of a very heavy rain and a steep soil slope.

Dose-Response Assessment

For terrestrial mammals, the dose-response assessment is based on the same data as the human health risk assessment (i.e., a NOEL of 2 mg/kg/day from a 2-year feeding study in rats). All of the potential longer-term exposures and all but one of the acute exposures of terrestrial mammals to sulfometuron methyl are substantially below the NOEL of 2 mg/kg/day. Consequently, a dose of 2

mg/kg/day is used to assess the consequences of all exposures. There is some ambiguity in the dose-response assessment regarding potential species differences. The major uncertainty is whether the reproductive effects observed in rabbits can be clearly attributed to sulfometuron methyl exposure. If so, it is not clear whether the effects represent a true species sensitivity or are attributable primarily to the method of administration (gavage in rabbits and dietary in rats). Although the available data do suggest that the sensitivity of birds to sulfometuron methyl is similar to that of mammals, the available data on birds are not as extensive or of the same quality as the data on experimental mammals. This limitation adds uncertainty to the risk assessment, which is qualitatively considered in the risk characterization. Because there are few data regarding the toxicity of sulfometuron methyl to terrestrial invertebrates, no quantitative consideration can be given to potential subchronic or non-lethal effects. This limitation in data also adds substantial uncertainty to the risk assessment, which is discussed in more detail in the risk characterization.

There is ample and very good data on the toxicity of sulfometuron methyl to terrestrial plants. Sulfometuron methyl is a relatively non-specific herbicide that causes adverse effects in a variety of target and non-target plant species. The most relevant study for assessing these effects was conducted by Drake (1990). The study shows that at low application rates, 0.001 kg/ha [0.000892 lb a.i./acre], sulfometuron methyl induces grossly observable signs of toxicity in the seedlings of several broadleaves and grasses, either preemergence or postemergence.

Fish and aquatic invertebrates appear to have a similar sensitivity to sulfometuron methyl; hence, it does not seem justified to develop separate dose-response assessments for these aquatic animals. Mortality is not likely to occur in aquatic species exposed to sulfometuron methyl concentrations less than or equal to about 150 mg a.i./L. Based on a chronic daphnid study, the longer-term reproductive NOEL is approximately 100 mg a.i./L. In fish, the highest concentration level tested for effects on egg and fry, 1.17 mg a.i./L, had no effect on hatchability, growth, or survival. A potential chronic hazard to fish at concentrations between 1.17 and 100 mg a.i./L cannot be dismissed but does not seem plausible. This uncertainty has relatively little impact on this risk assessment because long-term exposure to sulfometuron methyl at levels greater than 1 mg a.i./L is highly implausible.

Aquatic plants are much more sensitive than aquatic animals to sulfometuron methyl. Sensitive plant species may be affected at concentrations greater than 0.3 µg/L, and effects on several aquatic plants, both macrophytes and algae, would be expected at concentrations equal to or greater than10 µg/L. There is no information that would permit a quantitative dose-response assessment for aquatic microorganisms. By analogy to terrestrial plants and terrestrial microorganism, it appears likely that aquatic microorganisms have sensitivities to sulfometuron methyl that are similar to those of aquatic plants.

Risk Characterization

The primary concern with sulfometuron methyl is that the application rate used to control target plant species, typically on the order of 0.1 lbs a.i./acre, is about 100 greater than the rate that may damage non-target species (i.e., 0.001 kg/ha or 0.000892 lbs/acre). Different kinds of exposure to non-target terrestrial plant species are considered: direct spray, drift, wind erosion, and water erosion. Direct

deposition through unintentional direct spraying presents a clear hazard in the application of sulfometuron methyl and virtually all other herbicides. If non-target plants are accidentally sprayed at application rates that effectively control weeds, they are likely to be damaged, particularly in the upper ranges of anticipated application rates. Although spray drift could cause damage to vegetation, the impact would be limited and damage to non-target species probably could be minimized or avoided during the application process. Wind erosion is, at least potentially, a much more serious problem. Although no significant transport of sulfometuron methyl by soil erosion is anticipated under conditions that inhibit wind erosion of soil (i.e., a rough gravely surface or heavy vegetation covering or when the sulfometuron methyl is incorporated relatively fast into the root zone by irrigation or rainfall), substantial erosion could occur under arid conditions in flat sandy or otherwise fine soil with a sparse covering of vegetation. Consistent with a reported incident in the literature, the transport of sulfometuron methyl by wind erosion of soil could lead to overt signs of damage in non-target vegetation. Off-site soil contamination with sulfometuron methyl by soil run-off is another mechanism that might cause effects in non-target vegetation. As with wind erosion, there is likely to be substantial variability in the deposition of run-off . In some cases, run-off from a relatively small area could be dispersed over a very wide area and have little impact. In other cases, run-off from a relatively wide area could be concentrated in a relatively small low lying area and damage non-target vegetation. This interpretation is supported by and consistent with a reported incident involving damage to non-target vegetation from sulfometuron methyl run-off after application in a roadside hydraulic spray operation.

The duration of adverse effects on non-target terrestrial vegetation could be highly variable because the persistence of sulfometuron methyl in soil is highly variable. Dissipation half-times of 10-20 days are expected in moist fields. In arid fields, however, dissipation half-times of 100-202 days are expected. Considering all of the uncertainties and variability as well as value judgments that must be involved in this risk characterization for terrestrial plants, the most balanced interpretation is that damage caused by inadvertent contamination of soil with sulfometuron methyl will generally take from a few to several months to recover. Under some extreme conditions, recovery could occur within a matter of weeks; however, under other conditions, recovery might take more than 1 year and possibly several years.

Compared with the potential effects on non-target vegetation, the potential effects on terrestrial animals is of less concern. The weight of the data suggests that frank or even observable effects in terrestrial mammals exposed to sulfometuron methyl are not expected under most conditions of use. At the highest anticipated application rate and under conservative assumptions of exposure, short-term and probably transient changes in the blood are plausible for mammals that consume vegetation primarily. Nonetheless, the possibility of adverse reproductive effects in some potentially sensitive species cannot be dismissed. These qualifications and uncertainties cannot be resolved with the available data.

Similarly, while the data on potential effects on soil microorganisms is far less complete than the data on non-target vegetation or terrestrial animals, this paucity of information has relatively little impact on the risk assessment. Sulfometuron methyl applied to plants at rates that control undesirable

vegetation will cause substantial damage to vegetation. This damage would probably be accompanied by secondary changes in the local environment affecting the soil microbial community to a greater extent or at least more certainly than any direct toxic action by sulfometuron methyl on the microorganisms.

As with terrestrial species, aquatic plants are more likely than aquatic animals to show signs of adverse effects from the application of sulfometuron methyl. Like terrestrial plants, aquatic plants are very sensitive to sulfometuron methyl. Under normal and anticipated conditions of use, it is plausible that sulfometuron methyl contamination of water will cause adverse effects (i.e., reduction in growth and biomass) in sensitive aquatic macrophytes and algal species. The duration of these effects will depend substantially on dilution rates of the contaminated body of water and weather conditions. For less sensitive species, effects are not likely to be seen. Over relatively brief periods shortly after application, a much wider range of aquatic plants could be affected and the duration of these effects could be highly variable.

For aquatic animals, the risk characterization is unambiguous. There is no evidence that sulfometuron methyl concentrations in the range of concentrations likely to be found in ambient water after a plausible application program or after a spill will cause adverse effects in fish or aquatic invertebrates. Like any attempt to characterize effects in numerous species using data on a relatively small number of species, this risk characterization must be tempered by the limited number of species that were tested and the paucity of field studies on aquatic animals. Nonetheless, this assessment is based on apparently well-conducted studies that include sensitive life-stage testing of both invertebrates and fish. Notwithstanding the low potential for direct toxic effects on aquatic animals, effects on fish and invertebrate populations are plausible, given the toxicity of sulfometuron methyl to aquatic plants.

1. INTRODUCTION

The USDA Forest Service uses the herbicide, sulfometuron methyl, in its vegetation management programs. Only one commercial formulation, Oust, is used by the Forest Service. In 1989, the Southern Region of the Forest Service prepared a series of environmental impact statements with accompanying risk assessments concerning the use of these products (USDA 1989a,b,c). The present document provides updated risk assessments for human health effects and ecological effects to support a reassessment of the environmental consequences of using Oust in future Forest Service programs.

This document has four chapters, including the introduction, program description, risk assessment for human health effects, and risk assessment for ecological effects or effects on wildlife species. Each of the two risk assessment chapters has four major sections, including an identification of the hazards associated with Oust, the commercial formulation of sulfometuron methyl used by the Forest Service, an assessment of potential exposure to the product, 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 can 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 1998a). Furthermore, the technical terms are defined in the glossary (chapter 6) to this risk assessment. Some of the more complicated terms and concepts are defined, as necessary, in the text.

The human health and ecological risk assessments presented in this document are not, and are not intended to be, comprehensive summaries of all of the available information. Some of the early literature on sulfometuron methyl 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 contains two recent, 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. 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 to this document. In the interest of economy, however, an updated chemical background statement was not prepared with the current risk assessment. The information presented in the

appendices and the detailed discussions in chapters 2, 3, and 4 of the risk assessment are intended to be detailed enough to support an independent review of the risk analyses; however, they are not intended to be as detailed as the information generally presented in Chemical Background documents.

For the most part, the risk assessment methods used in this document are similar to those used in risk assessments previously conducted for the 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 (1998), while detailed explanations of specific methods used in estimating occupational exposure are provided in Rubin et al. (1998). Similar documentation for methods used in assessing dermal absorption are provided in Durkin et al. (1998).

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 a 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 a 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 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, not analytical methods, 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, a set of worksheets is included as an attachment to the risk assessment. 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.

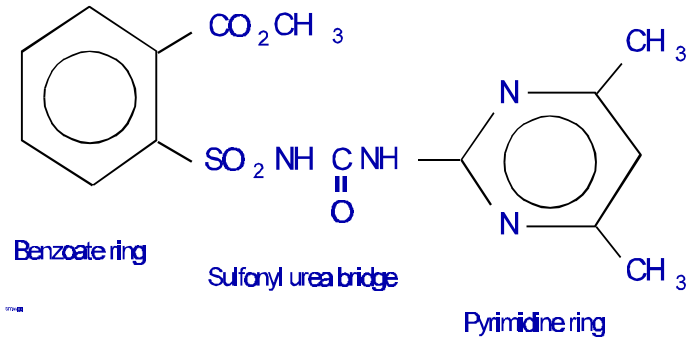
2. PROGRAM DESCRIPTION

2.1. OVERVIEW

Sulfometuron methyl is a non-selective, sulfonyl urea herbicide used primarily to control the growth of broadleaf weeds and grasses. The Forest Service uses only one commercial formulation of sulfometuron methyl, Oust. Oust is manufactured by DuPont as a water dispersible granule. The composition of the product is 75% sulfometuron methyl and 25% inert ingredients. Site preparation entails the primary use of Oust by the Forest Service. Relatively minor uses include conifer release, noxious weed control, rights-of-way management, and facilities maintenance. Although sulfometuron methyl is applied as the sole herbicide under certain conditions, it is most often applied in combination with other herbicides such as diuron, glyphosate, or hexazinone. The most common methods of ground application for Oust involve backpack (selective foliar) and boom spray (broadcast foliar) operations. Although Oust is registered for aerial applications (helicopter only), the Forest Service does not and does not intend to use Oust in aerial applications. The typical application rate in Forest Service programs is 0.1 lbs a.i./acre. The range of application rates likely to be used in Forest Service programs is 0.023-0.38 lbs a.i./acre.

2.2. CHEMICAL DESCRIPTION AND COMMERCIAL FORMULATIONS

Oust is a commercial formulation of sulfometuron methyl, a non-selective sulfonyl urea herbicide. Sulfometuron methyl is the common name for 2-[[[[(4,6-dimethyl-2-pyrimidinyl)- amino] carbonyl] amino] sulfonyl] benzoic acid methyl ester and is essentially a methyl ester of a benzoate ring linked to a dimethyl substituted pyrimidine ring by a sulfonyl urea bridge:



Selected chemical and physical properties of sulfometuron methyl are summarized in Table 2-1. Additional information is presented in worksheet12.

Oust is the only formulation of sulfometuron methyl used by the Forest Service. It is formulated as a dry flowable water dispersible granule, which is usually mixed with water and applied as a spray (section 2.4). Oust is produced by Du Pont and contains 75% (w/w) sulfometuron methyl and 25% (w/w) inerts. Two other commercial formulations of sulfometuron methyl listed on the California EPA database include Knockout Granular Weed Killer from SSI Mobley Co., Inc. and Stampro by Rohm and Haas Co. (www.cdpr.ca.gov/cgi-bin/epa/mkrep3.pl, 4/24/98). Neither of these formulations is included in the 1997 edition of the Crop Protection Reference (CPR 1997).

Table 2-1. Selected physical and chemical properties of sulfometuron methyl with selected additional properties for the commercial formulation, OUST.

Synonyms	Aa 5648, DPX 5648, Oust [formulation] (Budavari 1989)
CAS number	74222-97-2 (Budavari 1989)
Molecular weight	364.38 (Budavari 1989)
Density	Oust: 33 lb/ft^3 loose (Du Pont 1996) Oust: 39 lb/ft^3 packed (Du Pont 1996)
Appearance, ambient	white solid (Budavari 1989) Oust: dry flowable granule, dispersible in water (Du Pont 1996)
Vapor pressure (mm Hg)	5.5×10^{-16} (Tomlin 1997, WSSA 1989)
Water solubility (mg/L)	10 mg/L at 25°C, pH 5 (Budavari 1989) 300 mg/L at 25°C, pH 7 (Budavari 1989)
Henry's law constant	$<5\times10^{-17}$ (atm-m^3/mole), calculated from vapor pressure
pKa	5.7 (Budavari 1989)
K_{ow}	pH 5: 11 (Cadwgan 1990a) [MRID 93206001] pH 7: 0.346 (Cadwgan 1990a) [MRID 93206001] pH 9: 0.0136 (Cadwgan 1990a) [MRID 93206001]
Soil adsorption K_d	highly variable: 0.04 to ~3 (see appendix 1 and text for details)
Foliar half-life (days)	10 (Knisel et al. 1992)
Soil half-life (days)	first order $t_{½}$ of about 1 month (Anderson and Dulka 1985, Anderson 1980) [MRID 00078701] biphasic: $t_{½}$ 17 days and 96 days (Monson and Hoffman 1990) [MRID 42091401]
Water half-life (days)	stable at pH 7 or pH 10. Appreciable at pH 5 (see appendix 1 and text for details)
Air half-life (days)	0.3 (estimated for gas-phase reaction only; note: compound will exist almost entirely in particulate-phase in air (Meylan and Howard 1993)
Plant uptake rate	≈10%in 72 hours [≈0.033 day^{-1}] (Lym 1992)

Du Pont considers the identity of the inerts in Oust proprietary information. Hence, the inerts are not identified on the general product label (Du Pont 1997a), the product label for California (Du Pont 1997b) or the material safety data sheet (Du Pont 1996). This lack of disclosure indicates that none of the inerts are classified as hazardous. Nonetheless, as discussed by Levine (1996), the testing requirements for inerts are less rigorous than the testing requirements for active ingredients (i.e., sulfometuron methyl).

Oust is used in forestry applications to control the growth of broadleaf weeds and grasses. It has no labeled uses for crops (Du Pont 1997a,b).

Table 2-2. Uses of sulfometuron methyl (SM) by the Forest Service in 1997.

Herbicide or Herbicide Mixture	Use	Acres Treated	Amount Used (lbs)	lbs/acre
SM as sole herbicide	site preparation	681.5	65.6	0.096
	facilities maintenance	3	1	0.33
	noxious weed control	20	0.13	0.0065
	sole herbicide subtotal	704.5	66.73	0.095
Diuron with SM	rights-of-way management	40		
Glyphosate with SM	site preparation	950		
	conifer release	13.5		
	noxious weed control	40		
	research, NOS	6		
Hexazinone with SM	site preparation	2098		
	conifer release	331		
	mixture subtotal	3478.5		
Total (sole herbicide plus mixture subtotals)		4183		

2.3. APPLICATION METHODS

Detailed descriptions regarding the use of herbicides in silviculture and the various methods of herbicide application are available in the general literature [e.g., Cantrell and Hyland (1985)] and in risk assessments conducted previously by the Forest Service (USDA 1989a,b,c). The following summary focuses on those aspects of application that are most relevant to the exposure assessments (sections 3.2 and 4.2).

The most common methods of ground application for Oust involve backpack (selective foliar) and boom spray (broadcast foliar) operations. In selective foliar applications, the herbicide sprayer or container 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. Usually, a worker treats approximately 0.5 acres/hour with a plausible range of 0.25-1.0 acre/hour.

Boom spray is used primarily in rights-of-way management. Spray equipment mounted on tractors or trucks is used to apply the herbicide on either side of the roadway. Usually, about 8 acres are

treated in a 45-minute period (approximately 11 acres/hour). Special truck mounted spray systems may be used to treat up to 12 acres in a 35-minute period with approximately 300 gallons of herbicide mixture (approximately 21 acres/hour and 510 gallons/hour) (USDA 1989b, p 2-9 to 2-10). In ground broadcast applications of Oust, 15-40 gallons of water are used per acre to dilute the granular formulation (Du Pont 1997a,b).

Although Oust is registered for aerial applications (helicopter only), the Forest Service does not and does not intend to use Oust in aerial applications.

2.4. MIXING AND APPLICATION RATES

Previously, in Forest Service vegetation management programs (USDA 1989a,b,c), Oust was applied in relatively small amounts, compared with the application of other herbicides. For example, in Forest Service Region 8 (comprised of Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, North California, Oklahoma, South Carolina, Tennessee, Texas, Virginia, and part of West Virginia), there are approximately 12,000,000 acres of National Forests and Grassland, of which up to 600,000 acres were treated with various herbicides each year. In the late 1980s, Oust was applied to 2400 acres (USDA 1989b, p.2-4). More recently, the Forest Service use of herbicides in Region 8 was reduced to treatment of fewer than 100,000 acres/year.

The use of sulfometuron methyl by the Forest Service in 1997, the most recent year for which statistics are available, is summarized in Table 2-2. As indicated in this table, the Forest Service treated 704.5 acres with 66.73 lbs of sulfometuron methyl as the only herbicide for an average application rate of 0.095 lbs/acre. A much greater acreage was treated with mixtures containing sulfometuron methyl: a total of 3478.5 acres. Of this acreage, nearly 70% (2429 acres) involved mixtures with hexazinone for conifer release or site preparation. The second most common use in terms of area treated (1009.5 acres) involved mixtures with glyphosate (about 30% of mixture use, 950 acres for site preparation, 13.5 acres for conifer release, 6 acres for research, and 40 acres for weed control). Sulfometuron methyl was also used with diuron (40 acres for rights-of-way management).

The specific application rates used in a ground application vary according to local conditions and the nature of the target vegetation. The application rates directly used in this risk assessment for various exposure scenarios are summarized in Table 2-3. As with several other tables included in this risk assessment, the first column of Table 2-3 contains row labels. Rows B through D provide the sequential calculations for application rate in units of oz. Oust/acre, lb. Oust/acre, and lb. sulfometuron methyl (a.i.)/acre. Simple calculations are specified in brackets *[]* in the *item* column. For example, in row D, the formula, *[C·0.75]*, indicates that the values in this row were calculated like the corresponding values given in row C multiplied by 0.75—in this case because Oust contains 75% sulfometuron methyl by weight. Row E provides the range of concentrations of sulfometuron methyl in applied solutions. Details of these latter calculations are given in worksheets 10 and 11.

The typical application rate of 0.1 lbs a.i./acre is approximately the average application rate that the Forest Service used in 1997, when sulfometuron methyl was applied as the sole herbicide (see Table

Table 2-3. Application rates and concentrations of sulfometuron methyl in applied solutions of Oust.

	Item	Typical	Lowest	Highest
A	Description[a]	approximate average rate used in Forest Service programs in 1997	lowest labeled application rate	highest labeled application rate
B	Oust (oz/acre)	2.1	0.50	8.0
C	Oust (lb/acre) [B/16]	0.13	0.031	0.5
D	Sulfometuron methyl, (lb/acre) [C·0.75]	0.1	0.023	0.38
E	Concentration of sulfometuron methyl in applied solution, mg/mL[b]	0.44	0.070	3.03

[a] See table 2-2 for Forest Service use in 1997. Range of labeled application rates is taken from DuPont 1997a,b.
[b] See worksheet 11.

2-2). This application rate corresponds to an application rate of approximately 2 oz Oust/acre, which is the lower end of the application rate recommended for conifer site preparation and release as well as for the control of several broadleaf weeds and grass in arid areas (Du Pont 1997a,b).

The use of a single *typical* application rate is somewhat of an over simplification because the typical rate of application is likely to vary according to the method and purpose of the application. For example, the 1989 Forest Service Record of Decision for the Final Environmental Impact Statement: Vegetation Management in the Appalachian Mountains specifies typical application rates for sulfometuron methyl as 0.17 lbs/acre for mechanical liquid treatment and 0.06 lbs/acre for manual foliar broadcast (USDA1989d, p. A-11). Since this document specifies *sulfometuron methyl* rather than a specific commercial formulation, the underlying assumption is that these rates are expressed as lbs a.i./acre rather than lbs gross formulation/acre. The same rates are specified in the 1989 Forest Service Record of Decision for the Final Environmental Impact Statement: Vegetation Management in the Coastal/Plain/Piedmont (USDA 1989a, p. A-10). Because the variation in these typical application rates is relatively modest compared with other factors that affect this risk assessment, a single *typical* rate of 0.1 lbs a.i./acre is used for most of the exposure assessments. The impact of the application method specific rates is considered further in the risk characterization for human health and ecological effects (sections 3.4 and 4.4).

The lower limit of the application rate is taken as 0.023 lbs a.i./acre or 0.50 oz. Oust/acre, which is the lowest application rate recommended for the release of Bahiagrass and seedhead suppression (Du

Pont 1997a,b). This application rate is about 3 times greater than the application rate of 0.0065 lbs a.i./acre reported by the Forest Service in 1997 for the control of noxious weeds using sulfometuron methyl as the sole herbicide (see Table 2-2).

The upper end of the range of application rates is taken as 0.38 lbs sulfometuron methyl a.i./acre or 8 oz Oust/acre. This is the highest labeled application rate and is recommended as the upper limit for conifer site preparation and release in the southeast, the control of jack or Virginia pine in the northeast and Lake States, the control of various grasses, and as the upper limit in tank mixes with various other herbicides including glyphosate, dicamba, hexazinone, 2,4-D, and triclopyr (Du Pont 1997a,b). In general, the Forest Service will not use such a high application rate. Nonetheless, this maximum rate is only modestly above the rate of 0.33 lbs sulfometuron methyl/acre used by the Forest Service in 1997 for facilities maintenance (see Table 2-2).

3. HUMAN HEALTH RISK ASSESSMENT

3.1. HAZARD IDENTIFICATION

3.1.1. Overview. The mechanism of phytotoxic action of sulfonylurea herbicides including sulfometuron methyl is fairly well characterized. Not well as well characterized, however, is the mechanism of toxicity of sulfometuron methyl in mammals or other animal species is not well characterized. In any case, sulfometuron methyl appears to have a low order of acute oral toxicity. Some studies report no apparent signs of overt toxicity in rats after single gavage doses of up to 17,000 mg/kg bw. The lowest dose reported to cause any apparent effects after single gavage administration to rats is 5000 mg/kg.

There are several subchronic and chronic studies regarding exposure to sulfometuron methyl in the available literature. 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 and mice 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 formulation, Oust, 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.

As discussed in the exposure assessment, dermal exposure is the primary route of concern for workers. The available data, albeit relatively sparse, suggest that sulfometuron methyl can be absorbed through the skin in amounts that may cause systemic toxic effects. Data regarding the dermal absorption kinetics of sulfometuron methyl, however, were not found in the available

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. These estimates are then used with the available dose-response data to characterize risk. The lack of experimental data on the 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.

Very little information is available on the inhalation toxicity of sulfometuron methyl. 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.

Based on a comparison of the toxicity of sulfometuron methyl to the toxicity of the commercial formulation, there is no reason to suspect that Oust contains impurities or adjuvants that have a substantial impact on the risk assessment. All of the toxicology studies on sulfometuron methyl involve technical sulfometuron methyl, which is presumed to be the same as or comparable to the active ingredient in Oust. Thus, if toxic impurities are present in technical sulfometuron methyl, they are likely to be encompassed by the available toxicity studies using technical grade sulfometuron methyl.

3.1.2. Acute Toxicity. Other than standard bioassays for acute toxicity, there is not much information regarding the acute toxicity of sulfometuron methyl. Apparently, acute oral exposure to sulfometuron methyl results in a low order of toxicity. As summarized in appendix 3, 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 1980, Filliben 1995a, Trivits 1979). 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.

3.1.3. Subchronic or Chronic Systemic Toxic Effects. As summarized in appendix 3, several subchronic and chronic studies were conducted on sulfometuron methyl. All of these studies were submitted to the U.S. EPA in support of the registration of sulfometuron methyl and none are published in the open literature. The most common signs of toxicity involve changes in blood (Wood and O'Neal 1983, Summers 1990a, 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).

No other specific signs of toxicity were noted consistently among the different subchronic or chronic bioassays summarized in appendix 3. In one subchronic study, 3400 mg/kg bw/day sulfometuron methyl was administered to six rats for 14 days (Hinckle 1979). The investigators observed reduced testicular size in one rat and mild testicular lesions in another. No such effects were observed in any of the six control rats.

In a 1-year 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), decreased serum albumin and creatinine. At dietary concentrations of 5000 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 1000 ppm but not at 5000 ppm. No pathological changes in the thymus were noted in either sex at any dose level.

3.1.4. Reproductive and Teratogenic Effects. As detailed in appendix 3, two teratogenicity studies were conducted in which rabbits were exposed to sulfometuron methyl by gavage. The study by Hoberman et al. (1981) involved relatively high dose levels (100-1000 mg/kg bw), while the study by Serota et al. (1981) involved dose levels of 30-300 mg/kg bw. In the Hoberman et al. (1981) study, signs of maternal toxicity, including death in some dams, were apparent at all dose levels. Furthermore, possible spontaneous abortions were noted at doses of 300 mg/kg or greater. In the lower dose study by Serota et al. (1981), there were no signs of toxicity in the dams or offspring. Nonetheless, the investigators observed an increased number of fetuses with anomalies as well as an increase in the proportion of fetal anomalies per litter, compared with controls. At the 30 and 100 mg/kg dose levels, the increased incidences of fetal anomalies were dose related; 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. This pattern of effects is discussed further in the dose-response assessment (section 3.3).

In addition to the two teratogenicity studies in rabbits, there are three reproduction studies involving dietary exposure of rats to sulfometuron methyl (Wood et al.1980, Lu 1981, Mullin 1984). As appendix 3 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. Dietary levels of 5000 ppm were associated with changes in developmental parameters, including decreased fetal weight (Lu 1981) and 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 (Mullin 1984).

3.1.5. Carcinogenicity and Mutagenicity. In chronic bioassays conducted in mice (Summers 1990a) and rats (Mullin 1984), toxicity was indicated by hematological changes in the high dose groups of both studies (appendix 3). 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. Carcinogenicity was not demonstrated in either study.

Sulfometuron methyl did not show mutagenic activity in assays in *Salmonella typhimurium* strains TA 1535, TA 1537, TA 98, and TA 100 (Taylor 1979) 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.

3.1.6. Effects on the Skin and Eyes. Both sulfometuron methyl and the commercial formulation, Oust, were tested for irritant effects on the skin and eyes as well as for sensitization resulting from dermal exposure (appendix 3). Neither sulfometuron methyl nor Oust caused sensitization in guinea pigs (Edwards 1979a, Dashiell and Silber 1980a,b, Moore 1995); however, mild skin irritation was observed in guinea pigs exposed to 50% sulfometuron methyl in dimethyl phthalate (Dashiell and Silber 1980b; Edwards 1979a).

Sulfometuron methyl and Oust also induced skin irritation in rabbits (appendix 3). A direct comparison between the irritant effects of sulfometuron and those of Oust is difficult to make because of the dissimilarities in the protocols of the two studies. Nonetheless, there appears to be no remarkable difference between the irritant effects of sulfometuron methyl (i.e., Dashiell and Silber 1980c, Dashiell and Henry 1980a) and the commercial formulation, Oust (Filliben 1995b,c).

Although sulfometuron methyl and Oust both cause eye irritation (appendix 3), 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 concentration of 46 mg or approximately 34.5 mg a.i.(Filliben 1995d).

3.1.7. 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.

The available toxicity studies summarized in appendix 3 indicate that 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. As

discussed in sections 3.1.2. and 3.1.3, hematological effects are the most common effects observed after oral exposure to sulfometuron methyl. The results of the dermal studies with Oust (Filliben 1995b,c) suggest that there is no substantial difference between the dermal toxicity of Oust and its active ingredient, sulfometuron methyl.

The available literature does not contain data regarding the dermal absorption kinetics of sulfometuron methyl. As discussed in Durkin et al. (1995), 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 0.0000051 cm/hour with a 95% confidence interval of 0.0000020-0.0000132 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 worksheet 14.

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. Using the methods detailed in Durkin et al. (1998), the estimated first-order dermal absorption coefficient is 0.00022 $hour^{-1}$ with 95% confidence intervals of 0.000048-0.00098 $hour^{-1}$. The calculations for these estimates are presented in worksheet 13.

The lack of experimental data regarding the dermal absorption of sulfometuron methyl adds substantial uncertainties to this risk assessment. Nonetheless, the available data, albeit relatively sparse, suggest that sulfometuron methyl can be absorbed through the skin in amounts that may cause systemic toxic effects. Uncertainties in the rates of dermal absorption, although they are substantial, can be estimated quantitatively and are incorporated in the human health exposure assessment (section 3.2).

3.1.8. Inhalation Exposure. As summarized in appendix 3, there is only one inhalation toxicity study on sulfometuron methyl (Kinney 1982) and one inhalation toxicity study on Oust (Sarver 1995). Both 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.

The extremely limited data suggest only that sulfometuron methyl can induce irritant effects as well as systemic toxic effects at very high exposure levels. As discussed in section 3, this finding is not directly relevant to this risk assessment because of the implausibility of exposure to such high concentrations of the compound.

3.1.9. Impurities and Metabolites.

3.1.9.1. Impurities -- There is no published information regarding the impurities in technical grade sulfometuron methyl or Oust. As discussed above, the limited data that permit a comparison between the toxicity of sulfometuron methyl and the toxicity of Oust suggest that there are no substantial differences, particularly for the most relevant routes of exposure (i.e., oral and dermal). Thus, there is no basis for arguing that the commercial formulation presents hazards that are qualitatively different from the active ingredient, sulfometuron methyl. All of the toxicology studies on sulfometuron methyl involve technical sulfometuron methyl, which is presumed to be the same as or comparable to the active ingredient in Oust. Thus, if toxic impurities are present in technical sulfometuron methyl, they are likely to be encompassed by the available toxicity studies using technical grade sulfometuron methyl.

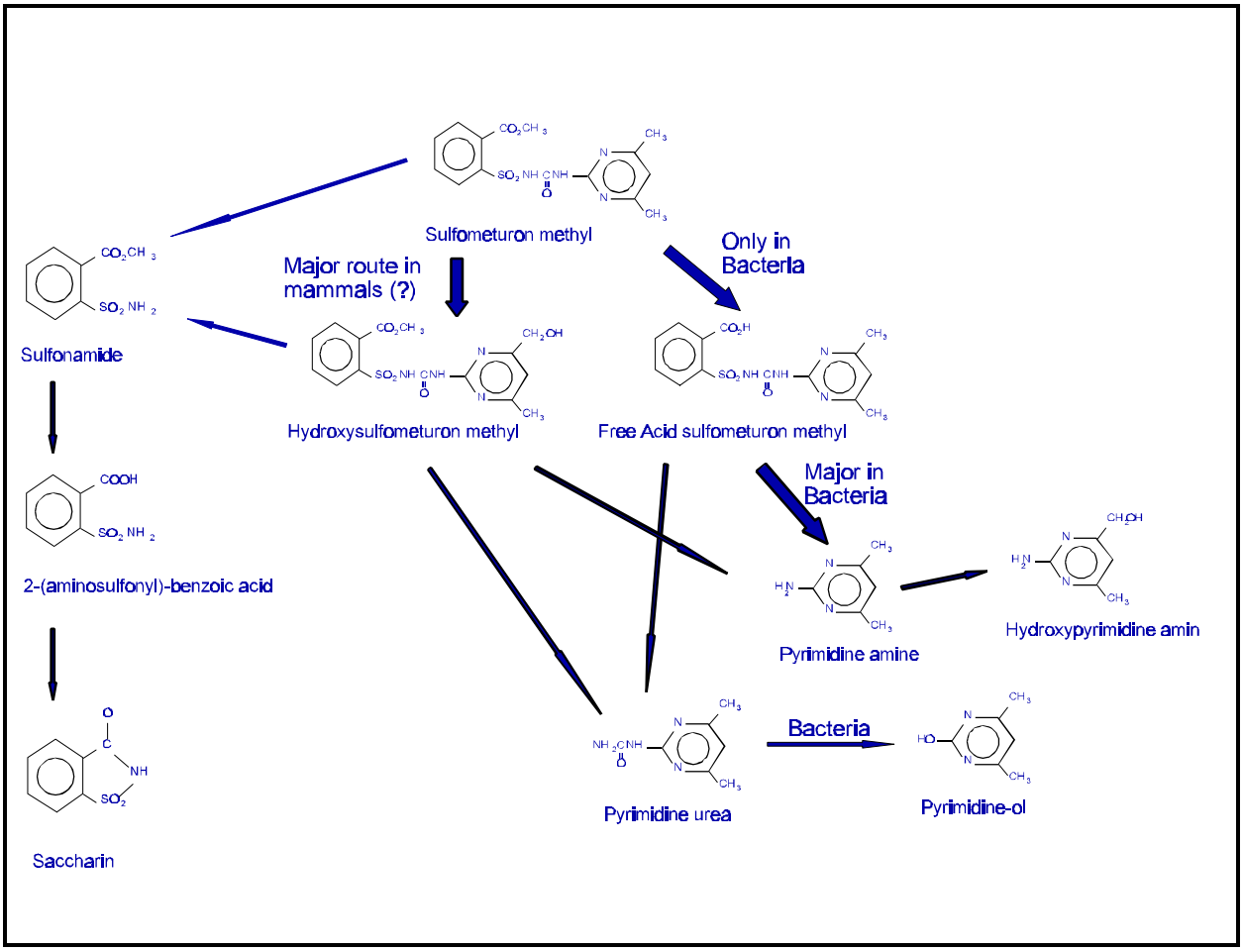


Figure 3-1: Proposed metabolic pathway of sulfometuron methyl in the goat (adapted and modified from Cambon et al. 1992, Koeppe and Mucha 1991, Monson and Hoffman 1990).

3.1.9.2. Metabolites -- An overview of the metabolism of sulfometuron methyl is presented in Figure 3-1. Because of the apparent similarities in metabolism of the compound by mammals and

environmental media, information on both mammalian metabolism and environmental transformation are summarized in the figure.

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 (Keoppe 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. Keoppe 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% of which was in the form of hydroxysulfometuron 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-times of 28 and 40 hours in rats after gavage doses of 16 and 3000 mg/kg, respectively (DuPont 1989).

3.1.10. Toxicological Interactions. As indicated in section 2.3, the Forest Service usually applies Oust in combination with other herbicides, particularly glyphosate, imazapyr, hexazinone, and bromacil/diuron. The only available information about a mixture containing sulfometuron methyl involves a mixture with Karmex, a water dispersible granular commercial formulation containing 20% diuron (3-(3,4-dichlorophenyl)-1,1-dimethylurea).

Several acute toxicity studies were submitted to the U.S. EPA on an unspecified mixture of Oust and Karmex (Kuhn 1989a-l). Because the relative amounts of the two products in the mixture are not specified and concurrent studies with the two components were not conducted, these studies cannot be used to assess the joint action of sulfometuron methyl with diuron. None of these studies report hematological effects or changes to the thymus. The studies dealing with dermal or ocular effects report mild to moderate irritation, which is consistent with the available data on Oust. Kuhn (1989h) reports that a dose of 5050 mg/kg of the Oust/Karmex mixture did not cause mortality or

histopathological changes in albino rats. This result is consistent with other findings regarding the apparently low toxicity of sulfometuron methyl.

3.1.11. Mechanism of Action. Although the mechanism of phytotoxic action of sulfonylurea herbicides including sulfometuron methyl is characterized in some detail (section 4.1.2.4), 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. As summarized in section 3.1.3, hemolytic anemia is the most consistent systemic effect of exposure to sulfometuron methyl. As discussed further in section 3.3 (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 (section 3.2.3). 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) (section 3.3).

Sulfonamide administration of 2000 mg/kg 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). These effects were not observed, however, in any of the comparable studies on sulfometuron methyl.

3.2. EXPOSURE ASSESSMENT

3.2.1. Overview. 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 (Rubin et al. 1998). Separate exposure assessments are given for backpack and boom spray ground applications. For both types of applications, central estimates of worker exposure are similar: 0.0013 mg/kg/day

for backpack applications and 0.0011 mg/kg/day for boom spray applications. The upper limits of the exposure estimates are 0.03 mg/kg/day for backpack applications and 0.064 mg/kg/day for boom spray applications. Although Oust is labeled for aerial applications (helicopter only), the Forest Service is not using and does not plan to use that application method for Oust. Consequently, aerial applications are not considered in this risk assessment.

Except in the case of accidental exposure, the levels of sulfometuron methyl to which the general public might be exposed should be far less than the levels for workers. Longer-term exposure scenarios for the general public lead to central estimates of daily doses in the range of 0.00000077-0.00015 mg/kg/day with upper limits of exposure in the range of 0.0001-0.0016 mg/kg/day. While these exposure scenarios are intended to be conservative, they are nonetheless plausible. Accidental exposure scenarios result in central estimates of exposure of up to 0.025 mg/kg/day with upper ranges of 0.25 mg/kg/day. All of the accidental exposure scenarios involve relatively brief periods of exposure and most should be regarded as extreme, some to the extent of limited plausibility.

3.2.2. Workers. A summary of the exposure assessments for workers is presented in Table 3-1. 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 all of these exposure assessments are presented in the worksheets that accompany this risk assessment, as indicated in Table 3-1.

3.2.2.1. General Exposures **--** As outlined in the program description (see chapter 2), this risk assessment is concerned primarily with backpack and boom spray ground applications. Although Oust is labeled for aerial applications (helicopter only), the Forest Service is not using and does not plan to use that application method for Oust. Consequently, aerial applications are not considered in this risk assessment.

The assumptions used in worker exposure assessments for both backpack and boom spray applications are detailed in worksheets 2 and 3. No worker exposure studies with sulfometuron methyl were found in the literature. As described in Rubin et al. (1998), 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 (Rubin et al.1998, Table 2). As summarized in Table 2-1 of this risk assessment on sulfometuron methyl, the molecular weight of sulfometuron methyl is about 364 and the log K_{ow} at pH 7 is about -0.46 [$\log_{10}(0.346)$=-0.4609]. Thus, the range of

Table 3-1. Summary of worker exposure scenarios.

Scenario	Dose (mg/kg/day or event)		
	Typical	Lower	Upper
General Exposures (dose in mg/kg/day)			
Directed ground spray (Backpack) [a]	1.3e-03	1.0e-05	3.0e-02
Broadcast ground spray (Boom spray) [b]	1.1e-03	1.5e-05	6.4e-02
Accidental/Incidental Exposures (dose in mg/kg/event)			
Immersion of Hands, 1 minute [c]	4.5e-07	2.8e-08	7.9e-06
Contaminated Gloves, 1 hour [c]	2.7e-05	1.7e-06	4.7e-04
Spill on hands, 1 hour [d]	9.3e-06	3.2e-07	2.9e-04
Spill on lower legs, 1 hour [d]	2.3e-05	7.9e-07	7.0e-04

[a] See worksheet 17.
[b] See worksheet 18.
[c] Assumes zero-order absorption. See worksheet 15 for details.
[d] Assumes first-order absorption. See worksheet 15 for details.

molecular weights and log K_{ow} values for the compounds on which the estimated exposure rates are based encompass the molecular weight and log K_{ow} for sulfometuron methyl.

As further described in Rubin et al. (1998), the ranges of estimated occupational exposure rates vary substantially among individuals and groups, (i.e., by a factor of 50 for backpack applicators and a factor of 100 for mechanical ground sprayers). It seems that much of the variability can be attributed to the hygienic measures taken by individual workers (i.e., how careful the workers are to avoid unnecessary exposure).

The estimated number of acres treated per hour is taken from previous USDA risk assessments (USDA 1989a,b,c). The number of hours worked per day is expressed as a range, the lower end of which is based on an 8-hour work day with 1 hour at each end of the work day spent in activities that do not involve herbicide exposure. The upper end of the range, 8 hours per day, is based on an extended (10-hour) work day, allowing for 1 hour at each end of the work day to be spent in activities that do not involve herbicide exposure.

It is recognized that the use of 6 hours as the lower range of time spent per day applying herbicides is not a true lower limit. It is conceivable and perhaps common for workers to spend much less time in the actual application of a herbicide if they are engaged in other
activities. Thus, using 6 hours can be regarded as conservative. In the absence of any published or otherwise documented work practice statistics to support the use of a lower limit, this conservative approach is used.

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.

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 boom spray workers, the use of the arithmetic mean rather than some other measure of central tendency such as the geometric mean has no marked effect on the risk assessment.

The range of application rates and the typical application rate are taken directly from the program description (see section 2.4). The central estimate of 0.1 lbs sulfometuron methyl/acre is almost equal to the 1997 average application rate of 0.095 lbs a.i./acre when sulfometuron methyl was used as the sole herbicide (see Table 2-2). The upper end of the range of application rates is the maximum labeled application which is somewhat higher than the average application of 0.33 lbs/acre used by the Forest Service in facilities maintenance in 1997 (see Table 2-2).

The central estimate of the amount handled per day is calculated as the product of the central estimate of the acres treated per day and the typical 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 range of application rates.

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.

Although these exposure estimates are intended to support a risk assessment that is conservative and protective against potential health effects in workers, the exposure assessment is not intended to be unrealistically conservative. In this respect, it is worth noting that the upper range of exposure and absorbed doses for hydraulic ground spray applicators is based on an estimated use of 168 lbs of sulfometuron methyl in a single day. While this use is conceivable and may be reasonable, the total amount of sulfometuron methyl applied in Forest Service programs during 1997 was only 704.5 lbs. If one team of workers were to apply sulfometuron methyl and handle 168 lbs of sulfometuron methyl

per day, the total amount used by the Forest Service in 1997 would be applied in about 4.2 days. Given that sulfometuron methyl is likely to be used by different groups of workers in different locations, it seems implausible that an individual worker or a single group of workers would incur the highest estimates of absorbed dose as a consequence of handling the highest estimates of the compound over a prolonged period of time. The significance of this qualification to the exposure assessment is discussed further in the risk characterization (section 3.4).

3.2.2.2. 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 (van Hemmen 1992). Typical multi-route exposures are encompassed by the methods used in section 3.2.2.1 on general exposures. Accidental exposures, on the other hand, are most likely to involve splashing a solution of herbicides into the eyes or a variety of dermal exposure scenarios.

Sulfometuron methyl can cause irritant effects in the eyes (see section 3.1.6). 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, reasonable approaches to modeling this type of exposure scenario quantitatively are not apparent. Consequently, accidental exposure scenarios of this type are considered qualitatively in the risk characterization (section 3.4).

There are various methods for estimating absorbed doses associated with accidental dermal exposure (U.S. EPA 1992, Durkin et al. 1995,1998). Two general types of exposure are modeled: those involving direct contact with a solution of the herbicide 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. Details of these exposure estimates are presented in the worksheets appended to this risk assessment as specified in Table 3-1.

Exposure scenarios involving direct contact with solutions of the chemical are characterized by immersion of the hands for 1 minute and 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 (1992), Fick's first law is used to estimate dermal exposure.

Exposure scenarios involving chemical spills on to the skin are characterized by a spill on to the lower legs as well as a spill on to 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 taken from Durkin et al. (1998).

Confidence in these exposure assessments is diminished by the lack of experimental data on the dermal absorption of sulfometuron methyl. Nonetheless, there is a noteworthy similarity between the exposure scenario in which contaminated gloves are worn for 1 hour and the exposure scenario in which a chemical solution is spilled on to the skin surface of the hands and cleaned after 1 hour.

3.2.3. General Public.

3.2.3.1. General Considerations -- Under normal conditions, members of the general public should not be exposed to substantial levels of sulfometuron methyl. 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 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 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 exposure scenarios developed for the general public are summarized in Table 3-2. As with the worker exposure scenarios, details of the assumptions and calculations involved in these exposure assessments are given in the worksheets that accompany this risk assessment (worksheets 21-29). The remainder of this section focuses on a qualitative description of the rationale for and quality of the data supporting each of the assessments.

3.2.3.2. Direct Spray **--** Direct sprays involving ground applications are modeled in a manner similar to accidental spills for workers (see section 3.2.2.2.). 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. As with the similar worker exposure scenarios, the first-order absorption kinetics are estimated from the empirical relationship of first-order absorption rate coefficients to molecular weight and octanol-water partition coefficients (Durkin et al. 1998), as defined in worksheet 7a.

For these exposure scenarios, it is assumed that during a ground application, a naked child is sprayed directly with sulfometuron methyl. These scenarios also assumes that the child is completely covered (that is, 100% of the surface area of the body is exposed). These are extremely conservative exposure scenarios and are likely to represent upper limits of plausible exposure. An additional set of scenarios are included involving a young 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. These assumptions are taken from various U.S. EPA reports (U.S. EPA 1985, 1992, 1996) and are relatively well documented.

3.2.3.3. 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.

For these exposure scenarios, some estimates of dislodgeable residue and the rate of transfer from the contaminated vegetation to the surface of the skin must be available. No such data are directly available for sulfometuron methyl, and the estimation methods of Durkin et al. (1995) are used as defined in worksheet 23. 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.

3.2.3.4. 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 aerial applications. Although sulfometuron methyl is chemically stable in pure aqueous solutions, it is degraded in natural waters by microbial activity (Lym and Swenson1991), and concentrations of sulfometuron methyl in water are further reduced by dispersal. For this risk assessment, the two types of estimates made for the concentration of sulfometuron methyl in ambient water are acute/accidental exposure and longer-term exposure.

Table 3-2. Summary of exposure scenarios for the general public.				
Scenario	Dose (mg/kg/day)			Worksheet
	Typical	Lower	Upper	
Acute/Accidental Exposures				
Direct spray of child, entire body	0.00036	0.00001	0.011	22
Direct spray of woman, lower legs	0.000035	0.0000012	0.0011	22
Dermal, contaminated vegetation	0.00056	0.000025	0.0106	23
Contaminated fruit, acute exposure	0.0011	0.00024	0.019	24
Contaminated water, acute exposure	0.025	0.0025	0.26	26
Consumption of fish, general public	0.0007	0.00012	0.0052	28
Consumption of fish, subsistence populations	0.00363	0.00055	0.025	28
Chronic/Longer-Term Exposures				
Contaminated fruit	0.000028	0.0000065	0.0012	25
Consumption of water	0.00015	0.0000064	0.0016	27
Consumption of fish, general public	0.00000077	0.000000046	0.0001	29
Consumption of fish, subsistence populations	0.000006	0.00000037	0.0005	29

3.2.3.4.1. ACUTE EXPOSURE -- As detailed in worksheet 26, the acute exposure scenario assumes that a young child (2- to 3-years old) consumes 1 L of 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. Because this scenario is based on the assumption that exposure occurs shortly after the spill, no dissipation or degradation of sulfometuron methyl is considered.

This is an extremely conservative scenario dominated by arbitrary variability. The actual concentrations in the water would depend heavily on the amount of compound spilled, the size of the water body into which it is spilled, the time at which water consumption occurs relative to the time of the spill, and the amount of contaminated water that is consumed. As indicated in Table 3-2, there is about a 100-fold difference in the upper and lower limits of the exposure assessment. As detailed in worksheet 26, this wide range is attributable primarily to differences in the field dilutions of the commercial formulation (a factor of about 45) rather than differences in the estimated amounts of water that might be consumed (only a factor of about 2.5).

3.2.3.4.2. LONGER-TERM EXPOSURE -- The scenario for chronic exposure to sulfometuron methyl from contaminated water is detailed in worksheet 27. This scenario assumes that an adult (70 kg male) consumes contaminated ambient water for a lifetime. The levels of compound in the water are estimated from monitoring data. Thus, environmental processes such as dissipation, degradation, and others are implicit in the assessment.

Monitoring data from the study by Neary and Michael (1989) are used to estimate longer-term levels in ambient water after the application of sulfometuron methyl. Additional details are taken from Michael and Neary (1993) and Neary and Michael (1996). In the Neary and Michael (1989) study, 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). Broadcast aerial applications were made in an area of Mississippi with predominantly clay soil, while broadcast ground applications were made in an area of Florida with predominantly sandy soil.

At the Florida site (broadcast ground applications), sulfometuron methyl was monitored at maximum concentrations of 5 µg/L(P) and 7 µg/L (DG) (Neary and Michael 1989). Nevertheless, 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. Fewer details are available from the application site in Mississippi (Michael and Neary 1993, Neary and Michael 1996). At this site, the maximum reported levels of sulfometuron methyl in surface water were 23 µg/L(P) and 44 µg/L (DG).

For this risk assessment, the average of concentrations reported by Michael and Neary (1993), 19.57 µg/L, is used as the basis for the central estimate of sulfometuron methyl in surface water. The extreme values, 5 and 44 µg/L, are used to estimate the range of exposure. These values are normalized for application rate, as detailed in worksheet 16.

In some respects, this approach may be viewed as extremely conservative. The higher concentrations from the 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. Since the Forest Service does not anticipate using aerial applications for sulfometuron methyl, a case could be made for using only the lower values for estimating potential human exposure from ground applications. On the

other hand, this risk assessment is intended to encompass the broad use of sulfometuron methyl in several different regions of the country. The relatively sparse monitoring data from only two locations are not likely to reflect the diversity of meteorological or hydrogeological conditions under which sulfometuron methyl may be applied. Consequently, the aerial data, which may not be representative of ground applications, are included to encompass application conditions that could lead to higher levels of water contamination.

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 (section 3.4), 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, as discussed in section 4.2.3.

3.2.3.5. 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. Generally, bioconcentration is measured as the ratio of the concentration in the organism to the concentration in the water. For example, if the concentration in the organism is 5 mg/kg and the concentration in the water is 1 mg/L, the bioconcentration factor (BCF) is 5 L/kg [5 mg/kg ÷ 1 mg/L]. As with most absorption processes, bioconcentration depends initially on the duration of exposure but eventually reaches steady state. Details regarding the relationship of bioconcentration factor to standard pharmacokinetic principles are provided in Calabrese and Baldwin (1993).

The literature includes only one study regarding the bioconcentration of sulfometuron methyl. Harvey (1981a) exposed bluegill sunfish to sulfometuron methyl at concentrations of 0.01 and 1.0 mg/L for 28 days and found no indication of bioconcentration. In addition, no bioconcentration occurred in channel catfish exposed to aged sediment containing sulfometuron methyl. A lack of bioconcentration is consistent with the low octanol-water partition coefficient for sulfometuron methyl. As illustrated in worksheet 12, the expected BCF for sulfometuron methyl is about 0.75, based on the general relationship of BCF values to octanol-water partition coefficients. For exposure assessments based on the consumption of contaminated fish, a BCF of 1 is used (i.e., the concentration in the fish will be equal to the concentration in the water).

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 (see section 3.2.3.4). The acute exposure scenario is based on the assumption that an adult angler 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. Because of the available and well-documented information and substantial differences in the amount of caught fish consumed by the general public and native American subsistence populations (U.S. EPA 1996), separate exposure estimates are made for these two groups, as illustrated in worksheet

28. The chronic exposure scenario is constructed in a similar way, as detailed in worksheet 29, except that estimates of sulfometuron methyl concentrations in ambient water are based on the monitoring data by Neary and Michael (1989).

3.2.3.6. Oral Exposure from Contaminated Vegetation **--** Sulfometuron methyl is not applied to crops. Under normal circumstances and in most types of applications, it is extremely unlikely that humans will consume vegetation contaminated with sulfometuron methyl. Nonetheless, any number of scenarios could be developed involving either accidental spraying of crops or the spraying of edible wild vegetation, like berries. Again, in most instances and particularly for longer-term scenarios, treated vegetation would probably show signs of damage from exposure to sulfometuron methyl (section 4.3.2.4), thereby reducing the likelihood of consumption that would lead to significant levels of human exposure.

Notwithstanding that assertion, it is conceivable that individuals could consume contaminated vegetation. One of the more plausible scenarios involves the consumption of contaminated berries after treatment of a right-of-way or some other area in which wild berries grow. The two accidental exposure scenarios developed for this exposure assessment include one scenario for acute exposure, as defined in worksheet 24 and one scenario for longer-term exposure, as defined in worksheet 25. 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 Hoerger and Kenaga (1972). These relationships are defined in worksheet 05a. For the acute exposure scenario, the estimated residue level is taken as the product of the application rate and the residue rate given in worksheet 05a.

For the longer-term exposure scenario, a duration of 90 days is used and the dissipation on the vegetation is estimated using a foliar half-time of 10 days (Knisel, et al. 1992). Although the duration of exposure appears to be somewhat arbitrarily chosen, it is intended to represent the consumption of contaminated vegetation 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). The central estimate of dose for the longer-term exposure period is taken as the geometric mean of the initial concentration and concentration after 90 days.

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 (1996) and presented in worksheet 04, 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 3-2 is based on the range of concentrations on vegetation from Hoerger and Kenaga (1972) and the range of application rates for sulfometuron methyl. The longer-term exposure scenario is constructed in a similar way, except that the estimated exposures include the range of vegetable consumption (U.S. EPA 1996) as well as the range of concentrations on vegetation and the range of application rates for sulfometuron methyl.

3.3. DOSE-RESPONSE ASSESSMENT

3.3.1. Overview. There is no current U.S. EPA RfD for sulfometuron methyl. The U.S. EPA Office of Pesticide Programs will prepare a re-registration eligibility document (RED) for sulfometuron methyl, but the registrant, DuPont, is in the process of submitting additional data to the U.S. EPA and the RED has not been initiated.

With regard to species sensitivity, rats appear to be most sensitive with reported NOAELs of 2-3 mg/kg/day and an AEL of 20 mg/kg/day. 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. Mice appear to be much less sensitive than either rats or dogs to the hematological effects of sulfometuron methyl with a NOAEL of 27.5 mg/kg/day and a LOAEL of 275 mg/kg/day. 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).

In the absence of an RfD derived by the U.S. EPA, a provisional reference dose of 0.02 mg/kg/day is used in this risk assessment. The provisional reference dose is based on the 2 mg/kg/day 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. At 20 mg/kg/day, hematological effects were observed in male rats. Thus, at a dose that is 10-fold higher than the provisional reference dose, 0.2 mg/kg/day, there would be concern for hematologic effects in humans. At intermediate levels of exposure (i.e., those between 0.02 and 0.2 mg/kg/day) the concern for potential adverse effects cannot be defined well.

Based on reproduction studies in rats, a dose of 0.2 mg/kg/day (i.e., 100-fold below a reported AEL of 20 mg/kg/day) could be taken as a level of concern for potential reproductive effects. One reservation about using this approach involves the available data on reproductive effects in rabbits. Increased fetal anomalies were observed in rabbits exposed to doses as low as 30 mg/kg/day (Serota et al. 1981), which is quite close to the LOAEL of 20 mg/kg/day for hematological effects in rats. Furthermore, although it can be argued that modest levels of anemia may be regarded merely as an AEL (adverse effect level), doses associated with fetal anomalies are more properly regarded as FELs (frank effect levels) and are of substantial concern in any risk assessment.

For this risk assessment, the increased number of fetal anomalies in rabbits exposed to 30 mg/kg/day (Serota et al. 1981) is interpreted as a reproductive FEL. This is a conservative interpretation of the gavage studies in rabbits (Hoberman et al. 1981, Serota et al. 1981). This judgment influences the risk assessment primarily in the interpretation of risks above the provisional reference dose of 0.02 mg/kg/day based on hematological effects. If the dose of 20-26 mg/kg/day from the dietary study by Mullin (1984) is taken as a reproductive NOAEL, a provisional reference dose for reproductive toxicity can be derived that is about 10- fold higher than the reference dose based on anemia. In that case, relatively modest (i.e., less than a factor of 10) excursions above the provisional reference dose could be a cause for concern regarding hematological effects but not reproductive effects. On the other hand, if the 30 mg/kg/day dose from Serota et al. (1981) is accepted as a reproductive FEL,

the proximity of the FEL to the reproductive NOAEL reported by Mullin (1984) suggests that a lower reference dose for reproductive effects is justified and that modest excursions above the reference dose are causes for concern regarding both hematological and reproductive effects.

As a supplement to this judgmental approach, categorical regression analyses were conducted on the animal toxicity data. Again using a conservative interpretation of the reproductive toxicity studies in rabbits, this analysis suggests that at the provisional reference dose of 0.02 mg/kg/day, the probability of an adverse effect (AEL/FEL) is about 0.000007 (7 in 1,000,000). At a 10-fold higher dose, 0.2 mg/kg/day, the probability of an adverse effect, including reproductive toxicity, is about 0.0004 (4 in 10,000).

3.3.2. Existing Guidelines. There is no current U.S. EPA RfD for sulfometuron methyl. The U.S. EPA Office of Pesticide Programs will prepare a re-registration eligibility document (RED) for sulfometuron methyl, but the registrant, DuPont, is in the process of submitting additional data to the U.S. EPA and the RED has not been initiated (Rowland 1998).

In previous Forest Service risk assessments (USDA 1989a,b,c), a systemic NOEL of 2.5 mg/kg/day and a reproductive NOEL of 25 mg/kg/day were used to characterize risk using margins of safety. The systemic NOEL of 2.5 mg/kg/day from "a combined 2-year rat feeding and 2-generation reproduction study," which is attributed to a 1986 DuPont MSDS. The narrative seems to refer to the 50 ppm dietary exposure group from Mullin (1984), summarized in appendix 3, in which the actual average doses over the 2-year exposure period, based on measured food consumption and body weight data, were 2 mg/kg/day for males and 3 mg/kg/day for females. Apparently, the reproductive NOEL of 25 mg/kg/day refers to the 500 ppm exposure group from the same study in which the actual doses were 20 mg/kg/day for males and 26 mg/kg/day for females. These and additional studies are discussed further in the following section.

3.3.3. Dose-Response and Dose-Severity Relationships. Table 3-3 summarizes the studies used to assess the dose-response and dose-severity relationships for sulfometuron methyl. Details for all of the studies summarized in this table are provided in appendix 3. In Table 3-3, all doses are expressed in units of mg chemical/kg body weight. For the studies that involve dietary, rather than gavage exposure, estimates of mg/kg bw doses are based on measured food consumption and body weight. A brief description of the effects noted at each dose level is included, and each effect is classified as a NOEL, NOAEL, AEL, or FEL. For studies that involve exposing groups of male animals and female animals, comparable doses for the two groups are averaged and presented as a single entry if the effects in the two groups are qualitatively similar. For example, with the Mullin (1984) study, the NOAEL of 2 mg/kg/day for males and the NOAEL of 3 mg/kg/day for females are averaged to 2.5 mg/kg/day, as in previously prepared Forest Service risk assessments. The next higher dose groups, 20 mg/kg/dayfor males and 26 mg/kg/day for

Table 3-3. Summary of dose/response/severity data for sulfometuron methyl[a].

Species (sex[b]), Type of Exposure	Dose (mg/kg/day)	Duration (days)	Effect Classification	Description of Effect	Reference
Dog, Dietary	5.00	365	NOEL	No effects	Wood and O'Neal 1983
	28.00	365	AEL	Anemia	Wood and O'Neal 1983
	150.00	365	AEL	Anemia [thymus (F)]	Wood and O'Neal 1983
Mice, Dietary	1.30	548	NOEL	No effect	Summers 1990a
	5.50	548	NOEL	No effect	Summers 1990a
	27.50	548	NOEL	No effect	Summers 1990a
	275.00	548	AEL	Anemia (F)	Summers 1990a
Rabbits, Gavage	100.00	12	FEL	Mortality (1/5), anorexia, depression, and decreased weight	Hoberman et al. 1981
	300.00	12	FEL		Hoberman et al. 1981
	750.00	12	FEL		Hoberman et al. 1981
	1000.00	12	FEL	Mortality in 2/5 animals. No viable fetuses.	Hoberman et al. 1981
Rabbits, Gavage	30.00	12	FEL	Increased fetal anomalies	Serota et al. 1981
	100.00	12	FEL		
	300.00	12	FEL		
Rats, Gavage	7500.00	1	AEL	Weight loss	Trivits 1979
	11000.00	1	AEL	Weight loss and stained perineal area	Trivits 1979
	17000.00	1	AEL		Trivits 1979
Rats, Gavage	5000.00	1	AEL	Weight loss and lung pathology. 'Pink thymus' in females.	Dashiell and Hinckle 1980
	5000.00	1	AEL	Alopecia (M)	Dashiell and Hall 1980
Rats, Gavage	3400.00	14	AEL	Testicular effects	Hinckle 1979
Rats, Gavage	5000.00	1	AEL	Alopecia (F, 1/15)	Filliben 1995a
Rats, Dietary	9.00	90	NOAEL	No adverse effects. [Increased thyroxine in females.]	Wood et al. 1980
	82.50	90	AEL	Hematologic effects. [Increased thyroxine in females.]	Wood et al. 1980
	400.00	90	AEL	Hematological effects	Wood et al. 1980
Rats (F), Dietary	4.33	6	NOAEL	No reproductive effects	Lu 1981
	86.60	6	NOAEL	No reproductive effects	Lu 1981
	433.00	6	AEL	Decreased body weight and fetal weight	Lu 1981
Rats, Dietary (M&F)	2.50	730	NOAEL	No effects	Mullin 1984
(M)	20.00	730	AEL	Decreased erythrocytes	Mullin 1984
(F)	26.00	730	AEL	Bile duct hyperplasia	Mullin 1984
(M)	199.00	730	AEL	Decreased erythrocytes and brain weight	Mullin 1984
(F)	260.00	730	AEL	Bile duct hyperplasia. Decreased numbers of offspring.	Mullin 1984

[a] Dietary exposures converted to mg/kg bw based on measured food consumption as detailed in appendix 3.
[b] Sexes combined unless effects were qualitatively different at comparable dose levels. When sexes are combined, the doses for males and females are averaged for dietary exposures described in appendix 3.
M = male; F = female

females, however, are presented separately because the effects observed in males are qualitatively different from the effects observed in females.

The data summarized in Table 3-3 are illustrated in Figure 3-2. In the dose/severity plot (Figure 3-2), a common logarithm of dose is plotted on the x-axis. The severity of effects is plotted on the y-axis with data on NOELs and NOAELs combined. This approach is taken because the various studies reporting NOELs examined only a limited number of toxicological endpoints. Thus, the report of a NOEL is essentially the same as a NOAEL (i.e., of the effects examined, no effects were observed). Some of the points are offset somewhat on the y-axis so that they may be distinguished from other adjacent or overlapping points.

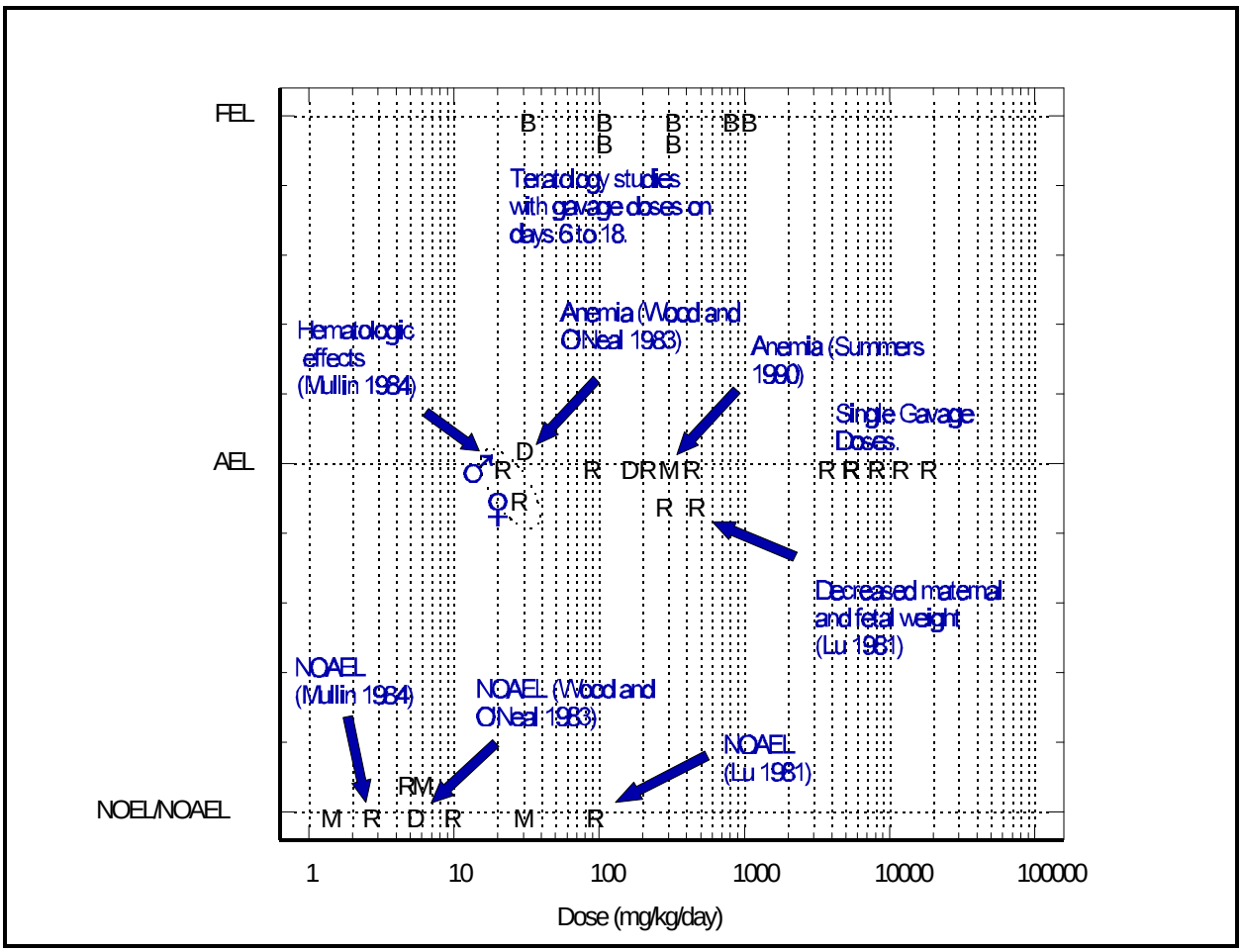


Figure 3-2: Dose/severity relationships for sulfometuron methyl (see Table 3-3 for details. **B**=rabbits, **D**=dogs, **M**=mice, **R**=rats).

Details of the key studies are labeled in Figure 3-2. The available data on dogs, mice, and rats are relatively consistent, indicating that effects on the blood (i.e., hemolytic anemia) are the most sensitive endpoint for sulfometuron methyl. In other words, for each of these species, effects on the blood

—characterized by the investigators as either anemia or, the equivalent, a decrease in erythrocytes—is the adverse effect seen at the lowest dose level for each species.

In terms of species sensitivity, rats appear to be most sensitive with reported NOAELs of 2-3 mg/kg/day and an AEL of 20 mg/kg/day (Mullin 1984). 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. Mice appear to be much less sensitive than either rats or dogs to the hematological effects of sulfometuron methyl with a NOAEL of 27.5 mg/kg/day and a LOAEL of 275 mg/kg/day (Summers 1990a). 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). In other words, in the absence of specific data regarding the sensitivity of humans to sulfometuron methyl, it would be prudent to assume that humans are more sensitive than experimental mammals.

In the absence of an RfD derived by the U.S. EPA, the provisional reference dose of 0.02 mg/kg/day will be used in this risk assessment. The provisional reference dose is based on the 2 mg/kg/day NOAEL for hematological effects in male rats (Mullin 1984) and an uncertainty factor of 100: 10 for species-to-species extrapolation and 10 for sensitive subgroups in the human population. Because the study by Mullin (1984) entailed a 2-year exposure period which approximates the life span of rats, there is no need for an additional uncertainty factor to account for subchronic to chronic exposure. At 20 mg/kg/day, hematological effects were observed in male rats. Thus, at a dose that is 10-fold higher than the provisional reference dose, 0.2 mg/kg/day, there would be concern for hematological effects in humans.

Analogous to the approach taken in previous Forest Service risk assessments (USDA 1989a,b,c), the mid-exposure group in the study by Mullin (1984)—20 mg/kg/day for male rats and 26 mg/kg/day for female rats over a 2-year period—could be used to estimate a higher reference dose for reproductive effects (i.e., decreased numbers of offspring). Taking 25 mg/kg/day as the approximate dose and NOAEL in females and using an uncertainty factor of 100, the provisional reference dose would be 0.25 mg/kg/day. As illustrated in Figure 3-2, this dose-response relationship is supported by the shorter term (6-day) dietary reproductive NOAEL of 86.6 mg/kg/day and dietary reproductive AEL of 433 mg/kg/day, both from Lu (1981). Again, this is analogous to the approach taken in the previous Forest Service risk assessments and assumes that reproductive effects are of concern at doses that are about 10-fold higher than those associated with hematological effects.

One reservation about using this approach involves the available data on reproductive effects in rabbits. As summarized in Table 3-3 and illustrated in Figure 3-2, increased fetal anomalies were observed in rabbits exposed to doses as low as 30 mg/kg/day (Serota et al. 1981), which is quite close to the LOAEL of 20 mg/kg/day for hematological effects in rats. Furthermore, although it can be argued that modest levels of anemia may be regarded merely as an AEL (adverse effect level), doses associated with fetal anomalies are more properly regarded as FELs (frank effect levels).

A key issue in assessing concern for reproductive effects, however, involves the interpretation of the teratology studies in rabbits by Hoberman et al. (1981) and Serota et al. (1981). The study by Hoberman et al. (1981) appears to have been a range-finding study for the study by Serota et al. (1981). The two studies were conducted at the same testing facility using the same general methods (i.e., gavage dosing on days 6-18 of gestation in a methyl cellulose/distilled water vehicle). Both studies were conducted at about the same time. The Hoberman et al. (1981) study was completed on December 5, 1980 and the Serota et al. (1981) study was initiated on December 30-31, 1980 (i.e., the day that the test animals were impregnated). Furthermore, both studies used the same batch of test material from the study sponsor, and the rabbits were of the same strain and from the same supplier. One of the very few differences in methodology between these two studies is that rabbits for the range finding study (Hoberman et al. 1981) were received on October 21, 1981 and held for only 16 days prior to the start of the study; whereas, for the full study (Serota et al. 1981), the rabbits were received on October 20, 1981 and held for about 70 days before the start of the study.

Details of the results of these studies, beyond those presented in appendix 3, are given in Table 3-4. In both studies, the number of litters with fetal anomalies per number of litters delivered were increased over control rates at some dose levels; however, the increases were not statistically significant and do not indicate a significant dose/response relationship. In the full study (Serota et al. 1981), there is no relationship between the exposure dose and the incidence of fetal anomalies—the number of fetuses with anomalies of all types divided by the total number of fetuses delivered. In the range finding study (Hoberman et al. 1981), there is an apparent increase in the incidence of fetal anomalies in the 300 and 750 mg/kg dose groups. The mean incidence of fetal resorptions was not increased in the Serota et al. (1981) study. There was an increase in this parameter, however, in the study by Hoberman et al. (1981), particularly at the 1000 mg/kg dose group.

Serota et al. (1981) concluded that their study does not indicate that sulfometuron methyl is teratogenic. Given the lack of statistically significant responses, this is a reasonable conclusion. Nonetheless, the Serota et al. (1981) appears to be limited in that it is not clear that the compound was administered at the maximum tolerated dose. Based on the screening study by Hoberman et al. (1981), some signs of toxicity would have been expected in the 300 mg/kg dose group in the Serota et al. (1981) study. As indicated in Table 3-4, no such effects were seen. The reason for this discrepancy is not apparent.

Conversely, the increased number of fetal anomalies at all dose levels (Serota et al. 1981), the adverse effects in pregnant rabbits at high dose levels (Hoberman et al. 1981), and the decreased numbers of offspring at high dose levels (Lu 1981, Mullin 1984) suggest that sulfometuron methyl may have adverse effects on reproductive capacity.

Table 3-4. Summary of teratology studies in rabbits.

Response	Study[a]	Dose (mg/kg/day) [days 6-18 of gestation]					
		0	30	100	300	750	1000
Number of dams in the study [b]	H	5		5	6	5	5
	S	17	17	17	17		
Dams dying before the end of study (%)	H	0		20	0[b]	60	40
	S	0	0	0	0		
Dams displaying signs of toxicity (%)	H	20		40	80	100	100
	S	0	0	0	0		
Mean incidence of resorptions per litter (%)	H	13.6		32.5	18.3	35.5	100 [c]
	S	17.7	18.3	19.4	14.2		
Incidence of fetal anomalies (%)	H[e]	2.2		0.0	13.0	25.0	N/A [d]
	S[f]	3	1.1	4.4	2.1		
Number of litters with fetal anomalies/number of litters delivered [g]	H	1/5		0/3	2/3 [p=0.28]	1/2 [p=0.52]	N/A [d]
	S	1/17	2/17 [p=0.5]	4/17 [p=0.16]	3/17 [p=0.30]		

[a] H = Hoberman et al. 1981; S=Serota et al. 1981. Shaded areas indicate dose levels not used in study.
[b] The one dam that died in this group may have been injured by tracheal intubation and was excluded from the group survival rate.
[c] One litter only.
[d] Not applicable because there were no fetuses.
[e] Mean incidence of gross fetal anomalies per litter.
[f] 100 × number of fetuses with variants (gross, skeletal, or visceral anomalies.)/number of fetuses examined.
[g] p values in brackets based on Fischer's Exact Test relative to response in control group.

For this risk assessment, the increased number of fetal anomalies in rabbits exposed to 30 mg/kg/day (Serota et al. 1981) is interpreted as a reproductive FEL. This admittedly conservative interpretation of the gavage studies in rabbits (Hoberman et al. 1981, Serota et al. 1981) influences the risk assessment primarily in the interpretation of risks above the provisional reference dose of 0.02 mg/kg/day based on hematological effects. If the dose of 20-26 mg/kg/day from the dietary study by Mullin (1984) is taken as a reproductive NOAEL, a provisional reference dose for reproductive toxicity can be derived that is about 10-fold higher than the reference dose based on anemia. In that case, relatively modest (i.e., less than a factor of 10) excursions above the provisional reference dose could be a cause for concern regarding hematological effects but not reproductive effects. On the

other hand, if the 30 mg/kg/day dose from Serota et al. (1981) is accepted as a reproductive FEL, the proximity of the FEL to the reproductive NOAEL reported by Mullin (1984) might suggest that a lower reference dose for reproductive effects is justified and that modest excursions above the reference dose are causes for concern regarding both hematological and reproductive effects.

As a supplement to the judgmental approach discussed above, categorical regression analyses were conducted on the animal data summarized in Table 3-3. This method assumes that each effect level can be associated with a distribution (e.g., normal or logistic) and that the shape of the distributions of the various severity levels are identical. At any given dose, the probability of observing an effect at a particular level of severity can be expressed. Although, categorical regression is not a novel method in statistics (McCullagh 1980), it was not applied to dose-severity relationships in risk assessment until recently (Dourson et al. 1997, Durkin et al. 1993). The use of categorical regression in Forest Service risk assessments is discussed in greater detail in SERA (1998). All analyses were conducted in JMP Version 3.2.2 (SAS 1997), and summary tables of each analysis are presented in worksheets 30-34, which accompany this risk assessment.

Initially, categorical regression was conducted on exposure dose and duration, using natural log transformations of both parameters and a three category model (i.e., NOELs/NOAELs combined, AELs, and FELs), as defined in worksheet 30 (Model Run #1). The effect of dose was marginally statistically significant (p=0.043) but the effect of duration was not statistically significant (p=0.81). When duration was omitted as an explanatory variable (worksheet 30, Model Run #2), dose was statistically significant with a p-value of 0.01.

The data also were analyzed by standard logistic regression (i.e., a two-category model in which NOELs/NOAELs were treated as one category and AELs/FELs were treated as the other category (worksheet 30, Model Runs #3 and #4). Including duration of exposure as well as dose as explanatory variables (Model Run #3) resulted in estimates of model coefficients that were again statistically significant for dose (p=0.0255) but not duration (p=0.2581). Using only dose as the explanatory variable, the model coefficient for dose was statistically significant (p=0.015).

The results of this analysis are illustrated in Figure 3-3. The dose administered to the experimental animals is plotted on the x-axis, and

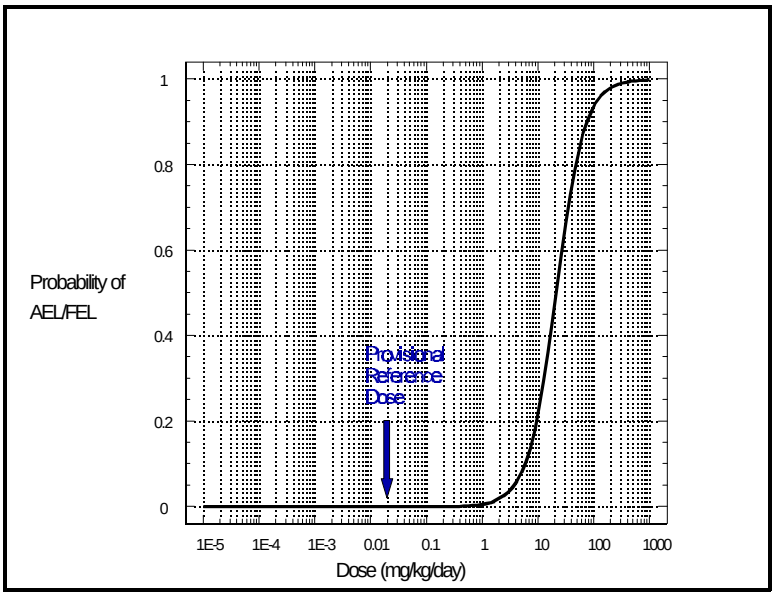


Figure 3-3: Categorical regression of dose/severity relationships for sulfometuron methyl using all data in Table 3-3 and combining AELs and FELs.

the y-axis gives the probability of observing an adverse effect—either an AEL or FEL. At the provisional reference dose of 0.02 mg/kg/day, the probability of an adverse effect (AEL/FEL) is about 0.000007 (7 in 1,000,000). At a 10-fold higher dose, 0.2 mg/kg/day, the probability of an adverse effect is about 0.0004 (4 in 10,000).

Several categorical regression analyses were conducted on subsets of the data given in Table 3-3. These additional analyses are summarized in worksheets 32-34, which accompany this risk assessment. The major subsets involve the exclusion of the teratology studies in rabbits as well as the exclusion of all gavage studies. The teratology studies were excluded because, as discussed above, the lack of a consistent dose-response relationship within these studies makes their inclusion in the analysis as FELs a conservative and questionable approach. Similarly, all the gavage studies were excluded because gavage administration may result in more severe toxic stress than would be expected from routes of exposure relevant to potential human exposure. In all cases, however, the basic results were consistent with analyses using all of the available data in that the duration of exposure failed to demonstrate a statistically significant relationship to the severity of the effect.

3.4. RISK CHARACTERIZATION

3.4.1. Overview. In general, workers will be exposed to sulfometuron methyl at higher levels of exposure than members of the general public and will be subject to greater potential risk. The upper limit of general exposure scenarios for backpack and boom spray applications results in a modest excursion above the provisional RfD. 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 the typical rather than the maximum application rate) the hazard indices would be at or below unity (i.e., below 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. The simple verbal interpretation of the quantitative characterization of risk is that under the most conservative set of exposure assumptions, workers could be exposed to levels of sulfometuron methyl that are regarded as unacceptable . If sulfometuron methyl is not applied at the highest application rate or if appropriate steps are taken to ensure that workers are not exposed at the maximum plausible rates (i.e., worker hygiene practices and/or reduced areas of treatment per day) there is no indication that the workers would be at risk of incurring systemic toxic effects.

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 the general public, none of the longer-term exposure scenarios approach a level of concern. In addition, none of the acute/accidental scenarios exceed a level of concern, based on central estimates of exposure, although a hazard index of unity is reached for the consumption of water after an accidental spill. Based on the most extreme exposure assumptions, two of the acute/accidental scenarios approach a level of concern (i.e., consumption of contaminated fruit and consumption of

fish by subsistence populations). Moreover, the exposure scenario involving an accidental spill into water substantially exceeds a level of concern. The exposure scenario for the consumption of contaminated water is an arbitrary scenario: scenarios that are more or less severe, all of which may be equally probable or improbable, easily could be constructed. Nonetheless, the acute exposure scenarios for the general public help to identify the types of scenarios that are of greatest concern and may warrant the greatest steps to mitigate. For sulfometuron methyl, such scenarios involve oral rather than dermal exposure.

The potential of sulfometuron methyl to induce reproductive effects—fetal mortality or abnormalities—suggest that pregnant women should avoid exposure to sulfometuron methyl. Based on the available dose/duration/severity data, however, it appears that exposure levels below those associated with the most sensitive effect (i.e., anemia) are not likely to be associated with reproductive toxicity. In addition, the available dose-response data regarding the reproductive effects of sulfometuron methyl in rabbits are weak (i.e., there are no statistically significant dose-response relationships). The major study on which the hazard identification for reproductive effects is based, nonetheless, did note adverse reproductive effects at all dose levels of sulfometuron methyl exposure. Thus, although the qualitative decision to consider sulfometuron methyl a potential reproductive hazard may be regarded as extremely conservative, this determination seems prudent at this time.

3.4.2. Workers. A quantitative summary of the risk characterization for workers is presented in Table 3-5. The quantitative risk characterization is expressed as the hazard quotient, which is the ratio of the estimated exposure doses from Table 3-1 to the provisional RfD of 0.02 mg/kg/day, as derived in section 3.3.3.

Given the very low hazard quotients 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. Given that the highest hazard quotient is a factor of 25 below the level of concern (i.e., a hazard quotient of 0.02 as the upper limit for a spill on the lower legs), far more severe and less plausible scenarios would be required to suggest a potential for systemic toxic effects. As discussed in section 3.2, however, confidence in this assessment is diminished by the lack of information regarding the dermal absorption kinetics of sulfometuron methyl in humans. 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. Again, these estimates would have to be in error by a factor of 25 or greater in order for the basic characterization of risk to change.

The upper limit of general exposure scenarios for backpack and boom spray applications result in a modest excursion above the provisional RfD. As discussed in section 3.2 and detailed in worksheets 17 and 18, 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 the typical rather than the maximum application rate) the hazard indices would be at or below

Table 3-5. Summary of risk characterization for workers[a]			
RfD	0.02	mg/kg/day	Sect. 3.3.3.
Scenario	Hazard Quotient		
	Typical	Lower	Upper
General Exposures			
Directed ground spray (Backpack)	0.1	0.0005	2
Broadcast ground spray (Boom spray)	0.06	0.0008	3
Accidental/Incidental Exposures			
Immersion of hands, 1 minute	0.00002	0.000001	0.0004
Contaminated gloves, 1 hour	0.001	0.00008	0.02
Spill on hands, 1 hour	0.0005	0.00002	0.01
Spill on lower legs, 1 hour	0.001	0.00004	0.04

[a] Hazard quotient is the level of exposure divided by the provisional RfD (0.02 mg/kg/day) then rounded to one significant decimal place or digit. See Table 3-1 for exposure assessment.

unity. Given the conservative nature of the RfD itself, it is unlikely that there would be any signs of toxicity. For example, based on the extremely conservative categorical regression analysis summarized in Figure 3-4, the probability of an adverse effect occurring in a group of experimental mammals exposed to a dose equivalent to a hazard quotient of 3 (i.e., a dose of 0.06 mg/kg/day) is less than 1 in 10,000. Generally accepted methods for quantifying human risk using the results of categorical regression analyses are not available. The simple verbal interpretation of this quantitative characterization of risk is that under the most conservative set of exposure assumptions, workers could be exposed to levels of sulfometuron methyl that are regarded as unacceptable . If sulfometuron methyl is not applied at the highest application rate or if appropriate steps are taken to ensure that workers are not exposed at the maximum plausible rates (i.e., worker hygiene practices and/or reduced areas of treatment per day) there is no indication that the workers would be at risk of incurring systemic toxic effects.

As discussed in section 3.1.6, sulfometuron methyl can cause irritation and damage to the skin and eyes. Quantitative risk assessments for irritation are not derived; however, 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.

3.4.3. General Public. The quantitative hazard characterization for the general public is summarized in Table 3-6. Like the quantitative risk characterization for workers, the quantitative risk characterization for the general public is expressed as the hazard quotient using the provisional RfD of 0.02 mg/kg/day.

None of the longer-term exposure scenarios approach a level of concern. Furthermore, none of the acute/accidental scenarios exceed a level of concern, based on central estimates of exposure, although a hazard index of unity is reached for the consumption of water after an accidental spill. Based on the most extreme exposure assumptions, two of the acute/accidental scenarios approach a level of concern (i.e., consumption of contaminated fruit and consumption of fish by subsistence populations), and the scenario for an accidental spill substantially exceeds a level of concern.

Although there are several uncertainties in the longer-term exposure assessments for the general public, as discussed in section 3.2, the upper limits for hazard indices are sufficiently far below a level of concern that the risk characterization is relatively unambiguous: based on the available information and under the foreseeable conditions of application, there is no route of exposure or scenario suggesting that the general public will be at any substantial risk from longer-term exposure to sulfometuron methyl.

For the acute/accidental scenarios, exposure resulting from the consumption of contaminated water is of greatest concern and exposure resulting from the consumption of contaminated vegetation and fish is of marginal concern. As discussed in some detail in section 3.2.3.4.1, the exposure scenario for the consumption of contaminated water is an arbitrary scenario: scenarios that are more or less severe, all of which may be equally probable or improbable, easily could be constructed. All of the specific assumptions used to develop this scenario have a simple linear relationship to the resulting hazard quotient. Thus, if the accidental spill were to involve 20 rather than 200 gallons of a field solution of sulfometuron methyl, all of the hazard quotients would be a factor of 10 less. Nonetheless, this and other acute scenarios help to identify the types of scenarios that are of greatest concern and may warrant the greatest steps to mitigate. For sulfometuron methyl, such scenarios involve oral rather than dermal exposure.

3.4.4. Sensitive Subgroups. There is limited information to suggest that specific groups or individuals may be especially sensitive to the systemic effects of sulfometuron methyl. As indicated in section 3.1.3, the most sensitive effect of sulfometuron methyl appears to be hemolytic anemia. Thus, individuals with pre-existing conditions that involve anemia or other impairments of the blood or circulatory system may be more sensitive to this compound.

The potential of sulfometuron methyl to induce reproductive effects—fetal mortality or abnormalities described in section 3.1.4—suggest that pregnant women should avoid exposure to sulfometuron methyl. Based on the available dose/duration/severity data, however, it appears that exposure levels

Table 3-6. Summary of risk characterization for the general public.[a]

RfD	0.02	mg/kg/day	Sect. 3.3.3.	
Scenario	Hazard Quotient			Worksheet
	Typical	Lower	Upper	
Acute/Accidental Exposures				
Direct spray of child, entire body	0.02	0.0006	0.5	21
Direct spray of woman, lower legs	0.002	0.0000600	0.06	22
Dermal, contaminated vegetation	0.03	0.001000	0.5	23
Contaminated fruit, acute exposure	0.06	0.01	1	24
Contaminated water, acute exposure	1	0.1	13	26
Consumption of fish, general public	0.03	0.006	0.3	28
Chronic/Longer-Term Exposures				
Contaminated fruit	0	0	0.2	25
Consumption of water	0.007	0.0003	0.08	27
Consumption of fish, general public	0.00004	0.000002	0.005	29
Consumption of fish, subsistence populations	0.0003	0.00002	0.03	29

[a] Hazard quotient is the level of exposure divided by the provisional RfD (0.02 mg/kg/day) then rounded to one significant decimal place or digit. See Table 3-2 for exposure assessment.

below those associated with the most sensitive effect (i.e., anemia) are not likely to be associated with reproductive toxicity. In addition, as detailed in section 3.3.3., the available dose-response data on the reproductive effects of sulfometuron methyl in rabbits is considerably weak (i.e., there are no statistically significant dose-response relationships). The major study on which the hazard identification for reproductive effects is based (Serota et al. 1981), however, did note increases in adverse effects at all dose levels of sulfometuron methyl. Thus, the qualitative decision to consider

sulfometuron methyl a potential teratogen may be regarded as extremely conservative; however, the determination seems prudent at this time.

3.4.5. Connected Actions. As indicated in section 3.1.10, Oust may be applied in combination with other herbicides, particularly glyphosate, imazapyr, hexazinone, and bromacil/diuron. There are no data in the literature suggesting that sulfometuron methyl will interact, either synergistically or antagonistically.

3.4.6. Cumulative Effects. As noted above, this risk assessment specifically considers the effect of repeated exposure in that the chronic RfD is used as an index of acceptable exposure. As discussed in the dose-response and dose-severity relationships (see section 3.3.3), the daily dose rather than the duration of exposure appears to determine the toxicological response. Consequently, repeated exposure to levels below the toxic threshold should not be associated with cumulative effects.

4. ECOLOGICAL RISK ASSESSMENT

4.1. HAZARD IDENTIFICATION

4.1.1. Overview. The mammalian toxicity of sulfometuron methyl is relatively well-characterized in experimental mammals; however, there is relatively little information regarding non-target wildlife species. It seems reasonable to assume the most sensitive effects in wildlife mammalian species will be the same as those in experimental mammals (i.e., changes to blood and decreased body weight gain). There are only four studies are available on the toxicity of sulfometuron methyl to birds. Because the studies on birds are different in design from those on experimental mammals, it is difficult to assess the sensitivity of birds, relative to mammals. Nonetheless, on the basis of the limited comparisons that can be made, birds appear to be somewhat less sensitive than experimental mammals to the toxic effects of sulfometuron methyl. There is only one available study regarding the toxicity of sulfometuron methyl to a terrestrial invertebrate: the standard contact toxicity test in bees that is required by the U.S. EPA for pesticide registration. The results of this study suggest that bees are less sensitive than either mammals or birds to sulfometuron methyl. But the available data are not sufficient to determine whether this apparent low level of toxicity can be generalized to other species of terrestrial invertebrates.

The toxicity of sulfometuron methyl to terrestrial plants was studied extensively and is well characterized. Sulfometuron methyl inhibits acetolactate synthase (ALS), an enzyme that catalyzes the biosynthesis of three branched-chain amino acids, all of which are essential for plant growth. Drake (1990) assayed the toxicity of sulfometuron methyl to several non-target as well as target dicots and monocots. At an application rate of 0.01 kg/ha [0.00892 lbs a.i./acre] sulfometuron methyl is highly toxic to seedlings of several broadleaves and grasses, either preemergence or postemergence. Moreover, 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 a factor of about 100-fold less than the application rate that the Forest Service would typically use. This study predominates in both the dose-response assessment for the effect of sulfometuron methyl on terrestrial plants as well as the risk characterization for the potential ecological effects of sulfometuron methyl applications. Concern for the sensitivity of non-target plant species is further increased by field reports of substantial and prolonged damage to crops or ornamentals after the application of sulfometuron methyl in both an arid region, presumably due to the transport of soil contaminated with sulfometuron methyl by wind, and in a region with heavy rainfall, presumably due to the wash-off of sulfometuron methyl contaminated soil.

Terrestrial microorganisms have an enzyme that is involved in the synthesis of branched chain amino acids, which is functionally equivalent to the target enzyme in terrestrial macrophytes. While there are some laboratory studies on the effects of sulfometuron methyl to soil microorganisms, there are no field studies that allow for an assessment of the potential effects of sulfometuron methyl on soil microorganisms under the conditions of application anticipated by the Forest Service.

As with potential effects on terrestrial species and as would be expected for a herbicide, the available data suggest that sulfometuron methyl is much more toxic to aquatic plants than to aquatic animals. Frank toxic effects in fish are not likely to be observed at concentrations less than or equal to 150

mg/L. Based on assays of fathead minnow embryo hatch, larval survival, or larval growth over 30-day exposure periods, no adverse effects would be expected at concentrations up to 1.17 mg sulfometuron methyl/L. Sulfometuron methyl also appears to be relatively non-toxic to aquatic invertebrates, based on acute bioassays in daphnids, crayfish, and field-collected species of other aquatic invertebrates. One daphnid reproduction study noted a decrease in the number of neonates at 24 mg/L but not at 97 mg/L or any of the lower concentrations tested. Although the effect observed at 24 mg/L may have been a random variation, it is treated as an AEL for the purpose of this risk assessment. This approach may be regarded as conservative; nonetheless, it seems prudent in the absence of additional studies regarding reproductive effects of sulfometuron methyl in aquatic invertebrates.

Aquatic plants are far more sensitive than aquatic animals to the effects of sulfometuron methyl, although there appear to be substantial differences in sensitivity among species of macrophytes and unicellular algae. The macrophytes, however, appear to be generally more sensitive. There are no published or unpublished data regarding the toxicity of sulfometuron methyl to aquatic bacteria or fungi. By analogy to the effects on terrestrial bacteria and aquatic algae, it seems plausible that aquatic bacteria and fungi will be sensitive to the effects of sulfometuron methyl.

4.1.2. Toxicity to Terrestrial Organisms.

4.1.2.1. Mammals– As summarized in the human health risk assessment (see section 3), there are several toxicity studies regarding adverse effects in experimental mammals, specifically rats, mice, rabbits, and dogs, exposed to sulfometuron methyl. Sulfometuron methyl is a plant toxin and its mode of action is well understood; however its mode of action for causing toxicity in mammals is not determined. The most consistent toxic effects observed in mammals after exposure to sulfometuron methyl include body weight loss and wet genital areas. The toxicological significance of the latter effect is unclear.

The acute toxicity of sulfometuron methyl is relatively low. In rats, doses of up to 17,000 mg/kg are tolerated without mortality (Trivits 1979). On the other hand, doses as low as 100 mg/kg are associated with mortality in pregnant rabbits (Hoberman et al. 1981). This study, however, involved very small numbers of animals, and the mortality at 100 mg/kg, 1 out of 5 animals, was not statistically significant, compared with the control response (0 out of 5 animals). The available data are not sufficient for determining whether the response in rabbits represents a species specific sensitivity, a special sensitivity in pregnant animals, or just a random event.

The subchronic and chronic toxicity studies on sulfometuron methyl were conducted in dogs, mice, and rats. As discussed in section 3.1.3., the most sensitive effects involve changes to blood and as well as decreased body weight gain.

4.1.2.2. Birds– As summarized in appendix 4, there are only four available studies regarding the toxicity of sulfometuron methyl to birds. In one of these studies, Dudeck and Bristol (1981a), 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, two dietary (Dudeck and Twigg 1980, Fink et al. 1981) and one gavage (Fink et al. 1981), assayed only

for relatively gross effects (i.e., overt signs of toxicity, changes in body weight and food consumption). Nonetheless, as discussed above, decreased body weight is among the most sensitive effects of sulfometuron methyl in experimental mammals.

It is difficult to assess the sensitivity of birds, relative to mammals. Based on the studies summarized in appendix 4, birds seem to be less sensitive than experimental mammals to the toxic effects of sulfometuron methyl. The lowest reported adverse effect level in birds is 625 mg/kg given as a single gavage dose (Dudeck and Bristol 1981a). Dose levels of 312 mg/kg or less were not associated with signs of toxicity or changes in body weight. As illustrated in Figure 3-2 and summarized in Table 3-3, however, adverse effects in experimental mammals were observed at dose levels as low as 20 mg/kg (Mullin 1984). A major reservation with this assessment, however, is that all of the studies in birds are relatively short term (i.e., less than 30 days). Although there does not appear to be a strong time-response relationship in mammals (see section 3.3), the duration of exposure might be a more important factor in birds.

4.1.2.3. Terrestrial Invertebrates–There is only one available study regarding the toxicity of sulfometuron methyl to a terrestrial invertebrate: the standard contact toxicity test in bees that is required by the U.S. EPA for pesticide registration. In this study, nominal doses of 13, 22, 36, 60, or 100 µg/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. No mortality was noted (Hoxter and Smith 1990). Using a body weight of 0.093 g for the honey bee (USDA 1993), these values correspond to doses ranging from about 140 mg/kg [0.013 mg/0.000093 kg] to 1075 mg/kg [0.1 mg/0.000093 kg]. Thus, based on these data, bees appear to be less sensitive than either mammals or birds to sulfometuron methyl.

Like the hazard identification for birds, this assessment must be qualified by the very short-term exposure period used in the study by Hoxter and Smith (1990). In addition, the available data are not sufficient to determine whether this apparent lack of toxicity can be generalized to other species of terrestrial invertebrates.

4.1.2.4. Terrestrial Plants (Macrophytes)–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. The quantitative use of these studies for this risk assessment is discussed in section 4.3.

In terms of a hazard identification, however, it is noteworthy that some target species, like the leafy splurge (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. Drake (1990) reports that at an application rate of 0.01 kg/ha [0.00892 lbs a.i./acre] sulfometuron methyl is highly toxic to seedlings of several broadleaves and grasses, either preemergence or postemergence. Moreover, 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-fold less than the application rate that the Forest Service would typically use .

The species differences in sensitivity may be attributable to differences in metabolism. For example, centipede grass, compared with bahiagrass, is more resistant to the effects of sulfometuron methyl because of the higher rate at which it metabolizes the compound. Another factor regarding sensitivity differences among plant species may relate to genetic differences in the form of the ALS enzyme, as appears to be the case with the dicotyledonous weed, *Sonchus oleraceus* (Boutsalis and Powles 1995).

As reviewed by Cox (1993), concern for the sensitivity of non-target species is further increased by a report of non-target plant damage after the application of sulfometuron methyl in rights-of-way maintenance. Extensive and prolonged damage to crops or ornamentals was observed after the application of sulfometuron methyl in an arid region, presumably due to wind transport of soil contaminated with sulfometuron methyl (Turner 1987), and in a region with heavy rainfall, presumably due to the wash-off of sulfometuron methyl contaminated soil (Bridges 1992).

4.1.2.5. Terrestrial Microorganisms– Terrestrial microorganisms have an enzyme that is involved in the synthesis of branched chain amino acids, which is functionally equivalent to the target enzyme in terrestrial macrophytes. Sulfometuron methyl, at concentrations as low as 0.2 µM [~73 µg/L] in a liquid glucose medium, caused significant growth inhibition 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.

Burnet and Hodgson (1991) suggest that soil residues of sulfometuron methyl may alter the composition of soil microorganisms and speculate further that such changes to the microbial populations in soil may lead to the proliferation of plant pathogens. This speculation is not supported by any experimental evidence or field observations. At least one terrestrial microorganism, *Streptomyces griseolus,* metabolizes sulfometuron methyl by an inducible cytochrome P-450 (O'Keefe et al. 1988). The extent to which the induction may alter the toxicity of sulfometuron methyl to microorganisms with an inducible cytochrome P-450 was not determined. Like plants, at least some forms of bacteria may develop resistence to sulfometuron methyl (Xie and Jimenez 1996).

4.1.3. Aquatic Organisms.

4.1.3.1. Fish– Standard toxicity bioassays to assess the effects of sulfometuron methyl on fish and other aquatic species are summarized in appendix 6. The lowest concentration at which 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). Based on this study and all of the bioassays summarized in appendix 6, it appears that compound-related mortality is not likely to be observed in fish exposed to concentrations less than or equal to 150 mg/L. As discussed further in the dose-response assessment (section 4.3), substantial mortality is likely to occur only at much higher concentrations.

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 sulfometuron methyl/L.

4.1.3.2. Amphibians– Neither the published literature nor the U.S. EPA files include data regarding the toxicity of sulfometuron methyl to amphibian species.

4.1.3.3. Aquatic Invertebrates– 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). As with the fish bioassays, mortality was observed in 1 of 10 daphnids in the low exposure group (0.125 ppm) (Muska and Trivits 1980a) but not in groups exposed to concentrations of up to 12.5 mg/L. The studies by Naqvi involve exposure to the Oust formulation rather than technical grade sulfometuron methyl. Acute toxicity studies using Oust with daphids yielded an LC_{50} of 8500 (6500-12,200) mg Oust DF/L with a NOEL of 2400 mg/L (Wetzel 1984).

One daphnid reproduction study was conducted (Baer 1990). As indicated in appendix 6, 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. Although the effect observed at 24 mg/L may have been a random variation, it is treated as an AEL for the purpose of this risk assessment. Although this approach may be regarded as conservative, in the absence of additional studies regarding reproductive effects in aquatic invertebrates, the approach seems prudent.

4.1.3.4. Aquatic Plants– As might be expected for a herbicide, aquatic plants are far more sensitive than aquatic animals to the effects of sulfometuron methyl. The available information summarized in appendix 6 and discussed in section 4.3.3.2 suggest that there may be substantial differences in sensitivity among species of macrophytes and unicellular algae. The macrophytes, however, appear to be generally more sensitive.

4.1.3.5. Other Aquatic Microorganisms– There are no published or unpublished data regarding the toxicity of sulfometuron methyl to aquatic bacteria or fungi. By analogy to the effects on terrestrial bacteria and aquatic algae, it seems plausible that aquatic bacteria and fungi will be sensitive to the effects of sulfometuron methyl.

4.2. EXPOSURE ASSESSMENT

4.2.1. Terrestrial Animals. Terrestrial animals might be exposed to any applied herbicide from direct spray, the ingestion of contaminated media (vegetation, prey species, or water), grooming activities, indirect contact with contaminated vegetation, or inhalation.

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 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 absorbed by the animal. Inhalation exposure is calculated, in a similar way, as the proportion of the compound retained in the animal after exposure. Sometimes, it is appropriate to combine oral, dermal, or inhalation exposure in order to estimate the total impact on the organism, as discussed further in the risk characterization (section 4.4).

For the exposure assessments discussed below, general allometric relationships are used to model exposure. In the biological sciences, allometry is the study of the relationship of body size or mass to various anatomical, physiological, or pharmacological parameters (e.g., Boxenbaum and D'Souza 1990). Allometric relationships take the general form:

$$y = aW^x$$

where W is the weight of the animal, y is the variable to be estimated, and the model parameters are **a** and **x**.

For most allometric relationships used in this exposure assessment, such as the relationship of body weight to surface area as well as the consumption of food and water, **x** ranges from approximately 0.65 to 0.75. These relationships dictate that, for a fixed level of exposure (e.g., levels of a chemical in food or water), small animals will receive a higher dose, in terms of mg/kg body weight, than large animals will receive.

For many compounds, allometric relationships for interspecies sensitivity to toxins 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 section 4.3, the available information is not adequate to quantify species differences in sensitivity to sulfometuron methyl, despite the suggestion that larger mammals (rats, dogs, and rabbits) may be somewhat more sensitive than mice to sulfometuron methyl. For this exposure assessment, generic estimates of exposure are given for a small mammal. In the dose-response

assessment (section 4.3) the estimated effect and no effect levels are derived primarily for larger mammals.

A body weight of 20 g is used for a small animal, which approximates the body weight of small mammals such as mice, voles, shrews, and bats. All body weight values are taken from U.S. EPA (1989a), unless otherwise specified. In some scenarios, the available toxicity data support specific assessments for other species, like birds or invertebrates. In the risk characterization, these exposure estimates are compared with the dose-response estimates based on the most sensitive species, regardless of body weight.

This approach is admittedly conservative but, as discussed in section 4.3, the differences in sensitivity among species are not substantial. Thus, this conservative approach has only a minor impact on the characterization of risk, as discussed in section 4.4.

The exposure assessments for terrestrial animals are summarized in Table 4-1. As with the human health exposure assessment, the computational details for each exposure assessment presented in this section are provided in the attached worksheets.

4.2.1.1. Direct Spray – In the broadcast application of any herbicide, wildlife species may be sprayed directly. This scenario is similar to the accidental exposure scenarios for the general public discussed in section 3.2.3.2. 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.

For this risk assessment, three groups of direct spray exposure assessments are conducted. The first, which is defined in worksheet 39, 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 (see section 3.1.7). 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.

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 (Moore 1964).

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 worksheet 40, is developed in which complete absorption over day 1 of exposure is assumed.

Table 4-1. Summary of Exposure Scenarios for terrestrial animals.

Scenario	Dose (mg/kg/day)			Worksheet
	Typical	Lower	Upper	
Acute/Accidental Exposures				
Direct spray, small mammal, first-order absorption	0.013	0.00064	0.22	39
Direct spray, small mammal, 100% absorption	2.4	0.56	9.3	40
Direct spray, bee, 100% absorption	16	3.7	62	41
Consumption of contaminated vegetation, acute exposure	0.53	0.12	7.1	42
Consumption of contaminated water, acute exposure	0.083	0.013	0.57	44
Longer-Term Exposures				
Consumption of contaminated vegetation, chronic exposure	0.023	0.0054	0.32	43
Consumption of contaminated water, chronic exposure	0.0014	0.000081	0.011	45

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 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 41, also assumes complete absorption over the first day of exposure.

4.2.1.2. Indirect Contact – As in the human health risk assessment (see section 3.2.3.3), 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) (worksheet 23) 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 (section 3.2.3.5) 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 in the risk characterization for ecological effects (section 4.4), 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 on in this document.

4.2.1.3. Ingestion of Contaminated Vegetation or Prey – For this component of the exposure assessment, the estimated amounts of residue on food are based on the relationship between application rate and residue rates on leaves and leafy vegetables. For the lower and central estimates of absorbed dose, the 'typical' value given in worksheet 5a is used because Hoerger and Kenaga (1972) do not provide estimates of the lower range of expected residues.

Allometric relationships and species specific data (U.S. EPA 1989a) suggest that 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. All of the estimates of ingested dose are based on the assumption that 100% of the diet is contaminated. Under the assumption that only 10% of the diet is contaminated, the dose estimates decrease by a factor of 10. Details regarding the calculations for these acute exposure scenarios are given in worksheet 42.

As discussed in section 4.4, the exposure estimates discussed above are of minimal concern for acute exposure. For estimating the effects of longer-term exposures, time-weighted average concentrations are used, which is similar to the approach taken in the human health risk assessment and using the k_e of 0.0693 $days^{-1}$. Also, the longer-term exposure scenario is based on a 90-day post-spray period and uses the geometric mean over this period as the central estimate of the exposed dose, as in the human health risk assessment. Like the acute exposure scenario, this exposure scenario assumes that 100% of the diet is contaminated. Details regarding the calculations for these chronic exposure scenarios are given in worksheet 43.

4.2.1.4. Ingestion of Contaminated Water -- Estimated concentrations of sulfometuron methyl in water are identical to those used in the human health risk assessment. 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 (1989a)]. 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 (20g) 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 chronic exposure scenario, the factors that affect the variability are the water contamination rate, (see section 3.2.3.4.2) and the application rate. Details regarding these calculations are summarized in worksheet 44 (acute exposure) and worksheet 45 (chronic exposure).

4.2.2. 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, particularly in aerial applications (e.g., Bird 1995). In addition, the report by Turner (1987) suggests that toxicologically significant amounts of sulfometuron methyl may be transported by wind erosion of soil.

4.2.2.1. Direct Spray – Unintended direct spray will result in an exposure level equivalent to the application rate. Most plants that are sprayed directly with sulfometuron methyl at or even substantially below the recommended application rate will be damaged (section 4.3.2.4).

4.2.2.2. Off-Site Drift – Data regarding the drift of sulfometuron methyl during ground or aerial applications were not found in the literature. Because off-site drift is more or less a physical process that depends on droplet size and meteorological conditions rather than the specific properties of the herbicide, estimates of off-site drift can be made based on data for other compounds. The potential for spray drift was investigated in numerous field studies reviewed recently by Bird (1995), as summarized in worksheet 06. The monitoring studies involved low-flight agricultural applications of pesticides and employed various types of nozzles under a wide range of meteorological conditions. The central estimates of off-site drift for single swath applications were approximately 0.03 at 100 feet, 0.002 at 500 feet, 0.0006 at 1000 feet, and 0.0002 at 2500 feet (Bird 1995, Figure 2, p. 204). Although multiple swath applications lead to higher rates of off-site deposition, they are less suitable for estimating drift from ground spray applications of sulfometuron methyl.

Another approach to estimating drift involves the use of Stoke's law, which describes the viscous drag on a moving sphere. According to Stoke's law:

$$v = \frac{D^2 \cdot g}{18n}$$

or

$$v = 2.87 \cdot 10^5 \cdot D^2$$

where $\boldsymbol{v}$ is the velocity of fall (cm sec^{-1}) ,$\boldsymbol{D}$ is the diameter of the sphere (cm), $\boldsymbol{g}$ is the force of gravity (980 cm sec^{-2}), and $\boldsymbol{n}$ is the viscosity of air ($1.9 \cdot 10^{-4}$ g sec^{-1} cm^{-1} at 20°C) (Goldstein et al. 1974).

In typical backpack ground sprays, droplet sizes are greater than 100 µ, 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 400 µ, 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,

$$91.4 \div (2.87 \cdot 10^{5}(0.01)^{2}).$$

The comparable time for a 400 µ droplet to fall 6 feet (182.8 cm) is approximately 0.4 seconds,

$$182.8 \div (2.87 \cdot 10^{5}(0.04)^{2}).$$

Under typical conditions of application, the wind velocity should 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, 100 µ particles falling from 3 feet above the surface could drift as far as 23 feet (3 seconds · 7.5 feet/second). A raindrop or 400 µ particle applied at 6 feet above the surface could drift about 3 feet (0.4 seconds · 7.5 feet/second).

If the wind speed is greater than 5 miles/hour, the Forest Service will not apply sulfometuron methyl because of the concern for drift. For example, at wind speeds of 15 miles/hour, a 100 µ droplet can drift as far as 68 feet (3 seconds · 15 · 1.5 feet/second). 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.

4.2.2.3. Wind Erosion – The incident reported by Turner (1987) suggests an additional mechanism by which sulfometuron methyl drift could affect non-target vegetation [i.e., sulfometuron methyl bound to soil may be transported off-site by wind (see section 4.1.2.4)]. 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 numerous models were developed for wind erosion (e.g., Strek and Spaan 1997, Strek and Stein 1997), the quantitative aspects of soil erosion by wind are extremely complex and site specific. Field studies conducted on agricultural sites found that annual wind erosion may account for annual soil losses ranging from 2 to 6.5 metric tons/ha (Allen and Fryrear 1977). The upper range reported by Allen and Fryrear (1977) is nearly the same as the rate of 2.2 tons/acre (5.4 tons/ha) recently reported by the USDA (1998). The temporal sequence of soil loss (i.e., the amount lost after a specific storm event involving high winds) depends heavily on soil characteristics as well as meteorological and topographical conditions.

This risk assessment uses average soil losses ranging from 1 to 10 tons/ha·year, with a typical value of 5 tons/ha·year. The value of 5 tons/ha·year is equivalent to 500 g/m^2 [1 ton=1000 kg and 1 ha =

10,000 m^2] or 0.05 g/cm^2 [$1m^2$=10,000 cm^2]. Thus, using a soil density of 2 g/cm^3, the depth of soil removed from the surface per year would be 0.025 cm[(0.05 g/cm^2)÷ (2 g/cm^3)]. The average amount per day would be about 0.00007 cm/day [0.025 cm per year ÷ 365 days/year]. The upper range of the typical daily loss would thus be about 0.00014 cm/day.

The amount of sulfometuron methyl that might be transported by wind erosion depends on several factors, including the application, the depth of incorporation into the soil, the persistence in the soil, the wind speed, and the topographical and surface conditions of the soil. Under desirable conditions, like relatively deep (10 cm) soil incorporation, low wind speed, and surface conditions that inhibit wind erosion, it is likely that wind transport of sulfometuron methyl would be neither substantial or nor significant.

Any number of undesirable exposure scenarios could be constructed. As summarized in Table 2-1, dissipation half-times for sulfometuron methyl in soil are highly variable, ranging from about 10-20 days in moist fields to 100-200 days in arid fields.

As a reasonable 'worst case' scenario, it is assumed that sulfometuron methyl is applied to arid soil, that it is incorporated into the top 1 cm of soil, that minimal rainfall occurs for a 2-month period, that the degradation and dispersion of sulfometuron methyl in the soil is negligible over the 2-month period, and that local conditions favor a high rate of soil loss (i.e., smooth, sandy surface with high wind speeds) that is a factor of 10 greater than the upper limit of the typical rate (i.e., 0.00014 cm/day × 10 = 0.0014 cm/day). Under those conditions, 0.084 [0.0014 cm/day × 60 days ÷ 1 cm] or 8.4% of the applied sulfometuron methyl would be lost due to wind erosion.

The deposition of the sulfometuron methyl contaminated soil also will vary substantially with local conditions. Under desirable conditions, the soil might be dispersed over a very large area and be of no toxicological consequence. In some cases, however, local topographical conditions might favor the deposition and concentration of contaminated dust from a large treated area into a relatively small off-site area. An objective approach for modeling these types of events was not available in the literature. For this risk assessment, neither concentration nor dispersion is considered quantitatively. Nonetheless, these factors together with the general and substantial uncertainties in the exposure assessment are considered in the risk characterization (see section 4.4).

4.2.2.4. Soil Contamination by Run-off – Other mechanisms of transport for herbicides, in addition to aerial transport, involve movement in the soil either by run-off or percolation. 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 run-off. Rainfall rates of 125, 75, and 43 mm/hour were then simulated for 2 hours, and run-off and percolation were measured. Concentrations of sulfometuron methyl in

run-off were less than 2.4 µg/mL (2.4 ppm), and the concentrations in percolate were less than 0.1 µg/mL (0.1 ppm). Under low rainfall conditions (43 mm/hour), relatively little sulfometuron methyl was removed by run-off: 0-4.2% 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 run-off. 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 run-off. In all instances, GLEAMS under-predicted run-off, 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 run-off 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 run-off 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 run-off 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 run-off. 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 run-off losses of 0.7-1.4% from sandy loam soil after 12-30 mm of rain, observed by Wauchope et al. (1990), are comparable to the 0-4.2% run-off losses after a total rainfall of 84 mm (43 mm/hour for 2 hours), reported by Hubbard et al. (1989).

For this exposure assessment, these studies generally support the supposition that at least 1% of the applied sulfometuron methyl could run off from the application site to adjoining areas after a moderate rain. In the case of a heavy rain, losses could be much greater and might approach 50% in cases of extremely heavy rain and a steep soil slope.

The functional level of off-site exposure will depend largely on site specific conditions. If run-off water were to disperse over a very large area, the soil concentrations would decrease. Conversely, if run-off were to pool or accumulate in a relatively small area, the off-site levels would tend to increase. Although somewhat speculative, the incident reported by Bridges (1992), described in section 4.1.2.4, may be a case in which sulfometuron methyl run-off to a relatively low area was

associated with damage to non-target vegetation. The potential variability in run-off exposures and their impact on this risk assessment are discussed further in the risk characterization (section 4.4).

4.2.3. Aquatic Organisms. For aquatic organisms, the estimated amount of sulfometuron methyl in ambient water and in water bodies associated with an accidental spill (see section 3.2.3.4.1) may be used as a very conservative estimate of exposure.

A substantial reservation regarding this approach has an impact on the characterization of risk to aquatic plants. As detailed in worksheet 16, monitored levels of sulfometuron methyl in ambient water rounded to one significant digit, are 0.02 (0.005-0.04) mg/L, based on the study by Neary and Michael (1989) using an application rate of 0.36 lbs a.i./acre (see worksheet 16). Nevertheless, as discussed in section 3.2.3.4.2, these are maximum or peak levels likely to occur immediately after a major rainfall. Adjusted for an application rate of 0.1 lb a.i./acre, the expected levels in ambient water would be 0.005 (0.001-0.01) mg/L (i.e., the last column in worksheet 16 multiplied by 0.1 and rounded to one significant digit). Based on the frequency of occurrence reported in Neary and Michael (1989) (i.e., 10 out of 185 samples), time- weighted average longer-term concentrations would be lower by a factor of about 20 [185÷10=18.5]. Thus, concentrations that more realistically represent long-term exposure levels will be about 0.0002(0.00005-0.0005) mg/L [0.005 (0.001-0.01) mg/L ÷ 20]. As discussed further in section 4.4, this temporal adjustment has a substantial impact on the risk characterization for aquatic plants.

4.3. DOSE-RESPONSE ASSESSMENT

4.3.1. Overview. For terrestrial mammals, the dose-response assessment is based on the same data as the human health risk assessment (i.e., a NOEL of 2 mg/kg/day NOEL from a 2-year feeding study in rats). All of the potential longer-term exposures and all but one of the acute exposures of terrestrial mammals to sulfometuron methyl are substantially below the NOEL of 2 mg/kg/day. Consequently, a dose of 2 mg/kg/day is used to assess the consequences of all exposures. There is some ambiguity in the dose-response assessment regarding potential species differences. The major uncertainty is whether the reproductive effects observed in a rabbit study can be clearly attributed to sulfometuron methyl exposure. If so, it is not clear whether the effects represent a true species sensitivity or are attributable primarily to the method of administration (gavage in rabbits and diet in rats). Although the available data seem to suggest that the sensitivity of birds to sulfometuron methyl is similar to that of mammals, the available bird data are not as extensive or of the same quality as the data on experimental mammals. This limitation adds uncertainty to the risk assessment, which is qualitatively considered in the risk characterization. There is considerably little data regarding the toxicity of sulfometuron methyl to terrestrial invertebrates. Hence, the potential subchronic or non-lethal effects of exposure to sulfometuron methyl cannot be considered quantitatively. This limitation also adds substantial uncertainty to the risk assessment, which is discussed in more detail in the risk characterization.

There are ample and good data regarding the toxicity of sulfometuron methyl to terrestrial plants. Sulfometuron methyl is a relatively non-specific herbicide that causes adverse effects in a variety of target and non-target plant species. The most relevant study for assessing these effects was conducted by Drake (1990). The study shows that at a low application rates, 0.001 kg/ha [0.000892

lb a.i./acre], sulfometuron methyl induces grossly observable signs of toxicity in the seedlings of several broadleaves and grasses, either preemergence or postemergence.

Fish and aquatic invertebrates appear to have a similar sensitivity to sulfometuron methyl; hence, it does not seem justified to develop separate dose-response assessments for these aquatic animals. Mortality is not likely to occur in aquatic species exposed to sulfometuron methyl concentrations less than or equal to approximately 150 mg a.i./L. Based on a chronic daphnid study, the longer-term reproductive NOEL is approximately 100 mg a.i./L. In fish, the highest concentration level tested for effects on egg and fry, 1.17 mg a.i./L, had no effect on hatchability, growth, or survival. A potential chronic hazard to fish at concentrations between 1.17 mg a.i./L and 100 mg a.i./L cannot be dismissed but does not seem plausible. This uncertainty has relatively little impact on this risk assessment because long-term exposure to greater than 1 mg a.i./L sulfometuron methyl is highly implausible.

Aquatic plants are much more sensitive than aquatic animals to sulfometuron methyl. Sensitive plant species may be affected at concentrations greater than 0.3 µg/L, and effects on several aquatic plants, both macrophytes and algae are likely to occur at concentrations greater than or equal to 10 µg/L. There is no information that would permit a quantitative dose-response assessment for aquatic microorganisms. By analogy to terrestrial plants and terrestrial microorganisms, it seems likely that sensitivity to sulfometuron methyl is similar for aquatic microorganisms and aquatic plants.

4.3.2. Toxicity to Terrestrial Organisms.

4.3.2.1. Mammals– As summarized in the dose-response assessment for the human health risk assessment (see section 3.3.3.), a provisional reference dose of 0.02 mg/kg/day is derived for the characterization of potential effects in humans. This estimate is based on a 2 mg/kg/day NOEL from a 2-year feeding study in rats. All of the potential longer-term exposures and all but one of the acute exposures of terrestrial mammals to sulfometuron methyl are substantially below the NOEL of 2 mg/kg/day (see Table 4-1); thus, it is not necessary to elaborate much more on the dose-response assessment. A dose of 2 mg/kg/day is used to assess the consequences of all exposures.

The upper limit of the exposure scenario for the consumption of contaminated vegetation does exceed the NOEL by a factor of about 3. For this exposure scenario, the categorical regression analysis developed in section 3.3.3 and illustrated in Figure 3-2 is used to characterize the likelihood of observing adverse effects.

There is some ambiguity in the dose-response assessment regarding potential species differences. As discussed in section 3.1.4, doses as low as 100 mg/kg/day are associated with mortality in rabbits and doses as low as 30 mg/kg/day are associated with fetal anomalies. As indicated in Figure 3-3, the dose-response relationship is not monotonic (i.e., progressively increasing). Nonetheless, the observations in the relatively low dose region cannot be dismissed, particularly because rabbits are a wildlife species that consumes large amounts of vegetation. On the other hand, the rabbit studies all involve gavage administration instead of dietary exposure. Moreover, in the rat studies involving dietary exposure, adverse reproductive effects were not observed at dose levels exceeding 400 mg/kg/day.

The major uncertainty is whether the effects reported in rabbits can be clearly attributed to sulfometuron methyl exposure. If so, it is not clear whether the effects represent a true species sensitivity or are attributable primarily to the route of exposure (gavage).

4.3.2.2. Birds – As noted in section 4.1.2.2, oral toxicity studies suggest that birds may be somewhat less sensitive than mammals to the effects of sulfometuron methyl. Thus, for exposure scenarios involving the ingestion of sulfometuron methyl from either contaminated vegetation or water, the dose-response relationships for mammals may serve as conservative estimates for avian species. Notwithstanding this approach and as discussed in section 4.1.2.2, the available data on birds are not as extensive or of the same quality as the data on experimental mammals. This limitation adds uncertainty to the risk assessment, which is qualitatively considered in the risk characterization (section 4.4).

4.3.2.3. Terrestrial Invertebrates–There is practically no information regarding the toxicity of sulfometuron methyl to terrestrial invertebrates. As discussed in section 4.1.2.3, the one available study (Hoxter and Smith 1990) indicates that doses up to approximately 1075 mg/kg are not lethal. Although this suggestion is consistent with the data on mammals, no quantitative consideration can be given to other potential subchronic or non-lethal effects. This limitation also adds substantial uncertainty to the risk assessment, which is discussed in more detail in the risk characterization (section 4.4).

4.3.2.4. Terrestrial Plants (Macrophytes)-- As discussed in section 4.1.2.4, sulfometuron methyl is a relatively non-specific herbicide that causes adverse effects in a variety of non-target plant species. The most relevant study for assessing these effects was conducted by Drake (1990). The study shows that at a low application rates, 0.001 kg/ha [0.000892 lb a.i./acre], sulfometuron methyl induces grossly observable signs of toxicity in the seedlings of several broadleaves and grasses, either preemergence or postemergence.

In the greenhouse study, 27 species of terrestrial plants were exposed to sulfometuron methyl at application rates ranging from 0.001 kg/ha [0.000892 lb/acre] to 0.5 kg/ha [0.446 lb/acre] to postemergent plants in soil, preemergent plants in sand, or preemergent plants in soil. The soil was characterized as Sassafras sandy loam with a pH of 6.5 and 1% organic matter. Plants were evaluated for damage after 15 days using a semi-quantitative scale in which ‘0' signified a NOEL and ‘10' signified 100% mortality. The plant species were classified as grass or broadleaf weeds as well as grass or broadleaf crops.

The results of this study are illustrated for weeds in Figure 4-1 and for crops in Figure 4-2. In both figures, the apparent number of points is far less than the actual number of points because of duplicate results (i.e., the same severity at the same application rate) in different experimental groups. In total, there are 492 experimental observations for weeds and 283 observations for crops. In both of these figures, upper case letters are used to indicate broadleaf vegetation and lower case letters are used to indicate grasses.

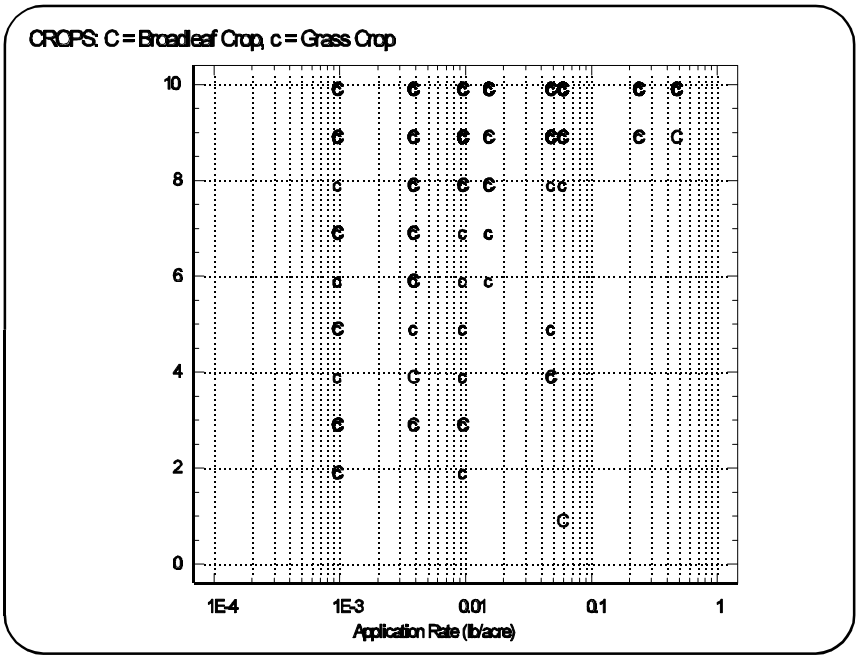


Figure 4-1: Relationship of application rate to severity of effects in broadleaf (C) and grass (c) crop species in the study by Drake (1990).

Qualitatively, these figures do not suggest remarkable differences in sensitivity between weeds and crops, although there appears to be a slight tendency for grasses to be somewhat less sensitive than broadleaves, at least at application rates of 0.01 lbs/acre or more.

This type of study could be analyzed a number of ways. The type of grading system for damage, for example, could be used in a standard categorical regression analysis, like that done with the mammalian toxicity studies.

One of the more significant features of this study, however, is the frequency in the number of effects scores rated as '10' across the range of doses tested, as illustrated in Figure 4-3. This figure is essentially an absolute histogram of the scores for all plants across all treatment methods and application rates. As illustrated in Figure 4-3, almost 45% of all responses were ranked at level '10' and approximately 70% of all responses were ranked as either a '9' or a '10'.

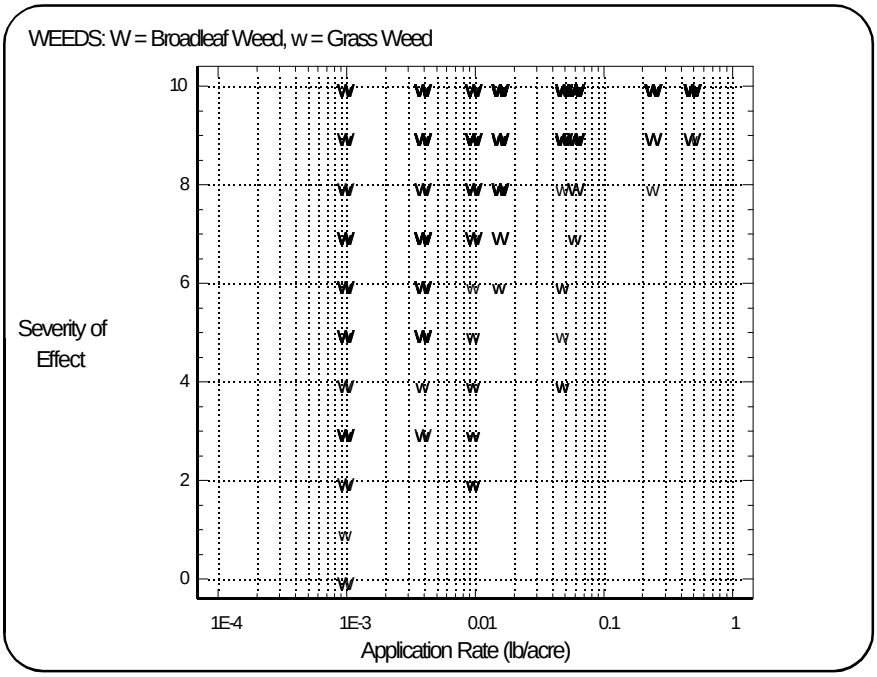


Figure 4-2: Relationship of application rate to severity of effects in broadleaf (W) and grass (w) weed species in the study by Drake (1990).

As detailed in worksheet 48, two sets of categorical regression analyses were conducted on the data from Drake (1990). The first analysis involved crops versus weeds, including both broadleaves and grasses in each group, as illustrated in Figure 4-4. In this figure, two sets of the lines are plotted: the two lines on the left most

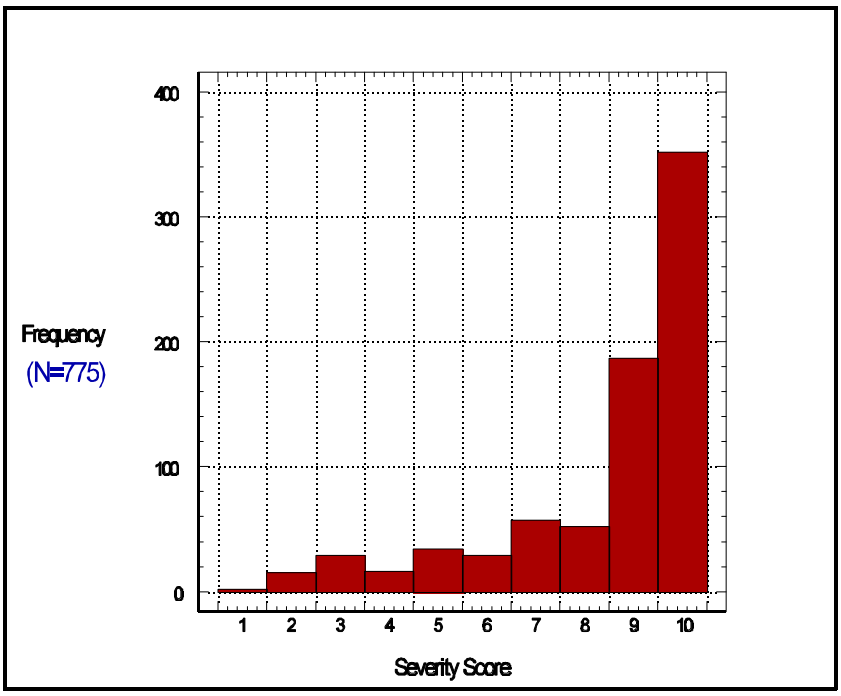


Figure 4-3: Frequency of observations of different severity levels from the study by Drake (1990) for all species and application rates.

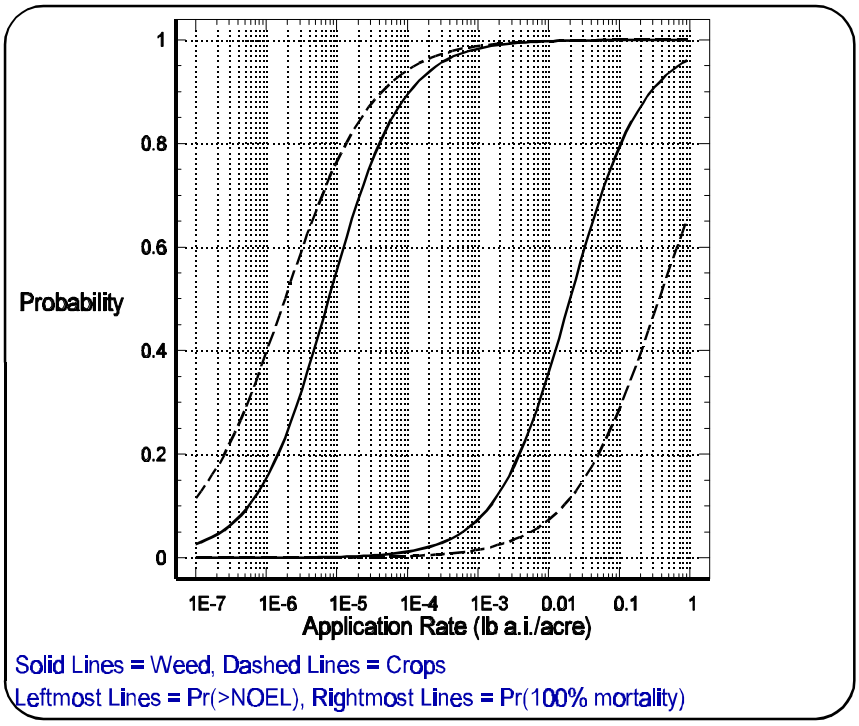


Figure 4-4: Summary of categorical regression analyses of crops and weeds from the study by Drake (1990).

side are the probabilities of observing an effect more severe than a NOEL for either weeds (solid line) or crops (dashed line) (i.e., the probability of not observing a NOEL). The two lines on the right-most side are the probabilities of observing the most severe effect, defined in Drake (1990) as 100% mortality.

Again, the solid line represents the dose-response relationship for weeds and the dashed line represents the dose-response relationship for crops. Over the anticipated range of application rates, weeds are substantially more sensitive to sulfometuron methyl (i.e., have a higher probability of response at a given dose level), compared with crops, based on the most severe effect. Nonetheless, at the typical anticipated application rate of 0.1 lb a.i./acre, there is a substantial probability ($\approx$30%) of observing a very high rate of mortality in the non-weed or crop species. Even at the lowest anticipated application rate, 0.023 lbs a.i./acre, the probability of observing 100% mortality in crop species is somewhat greater than 10%. In the region of the NOEL, the reverse pattern is apparent, with weeds being somewhat less sensitive than crops. These estimates, however, are

based on relatively few observations, as illustrated in Figure 4-3, and, therefore, may be less reliable.

As indicated in the discussion of Figures 4-1 and 4-2, there is a qualitative suggestion that grasses may be generally less sensitive than broadleaves. To test this impression, a categorical regression was conducted on all grasses (weeds and crops combined) as well as all broadleaves. This analysis is presented in Figure 4-5. As illustrated in this figure, there are not substantial differences in sensitivity between these two groups.

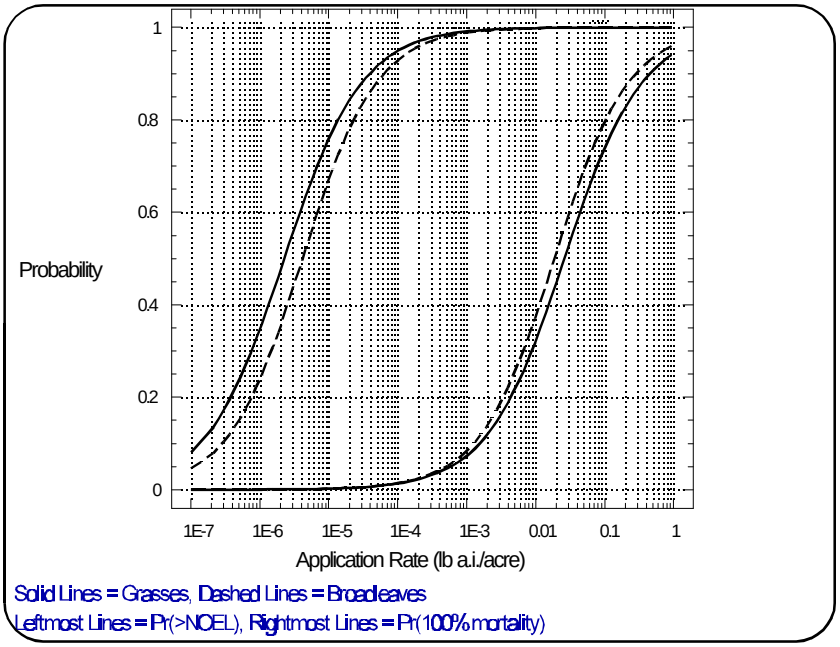


Figure 4-5: Summary of categorical regression analyses of grasses and broadleaves from the study by Drake (1990).

There are several other studies regarding the toxicity of sulfometuron methyl to plants. Much of this literature is reviewed in various publications (e.g., Aulger 1996, Barnes et al. 1990, Boutsalis and Powles 1995, Stidham 1991). The published literature is generally consistent with, albeit not as detailed as, the data by Drake (1990). In terms of the practical use of sulfometuron methyl, however, it is noteworthy that pine species are substantially less sensitive than either broadleaves or grasses to sulfometuron methyl exposure. Nonetheless, over the range of typical to highest anticipated applications rates, sulfometuron methyl inhibited root development in loblolly pine (Barnes et al. 1990).

4.3.2.5. Terrestrial Microorganisms– As discussed in section 4.1.2.5, the sensitivity of terrestrial microorganisms appears to operate and be governed by the same mechanism involved in plant toxicity. The lowest reported effect level is 70 µg/L. At this concentration, exposure periods of less than 3 hours inhibited the growth of terrestrial/soil microorganisms in a liquid glucose medium (Epelbaum et al. 1996). The extent to which these findings can be applied to soil levels of sulfometuron methyl is uncertain.

4.3.3. Aquatic Organisms.

4.3.3.1. Animals– As indicated in sections 4.1.3.1 through 4.1.3.3, fish and aquatic invertebrates appear to have a similar sensitivity to sulfometuron methyl; hence, it does not seem justified to develop separate dose-response assessments for these aquatic animals. The fish bioassays in appendix 6 allow for a reasonably unambiguous estimate of exposure, which might be associated with fish mortality. Mortality is not likely to occur in fish exposed to sulfometuron methyl concentrations less

than or equal to150 mg a.i./L. In some respects, the study by Wetzel (1984) is the most relevant because it involves exposure to Oust—rather than just sulfometuron methyl—to relatively large numbers of organisms (i.e., 20 organisms per concentration level) at test concentrations ranging from 1000 to10,000 mg/L. The highest concentration at which no mortality was observed was 2400 mg/L, and the estimated LC_{50} with 95% confidence intervals was 8500 (6500-12,200) mg Oust DF/L corresponding to approximately 6400(4900-9200) mg a.i/L (i.e., Oust is 75% sulfometuron methyl).

Based on a chronic daphnid study, the longer-term reproductive NOEL is approximately 100 mg a.i./L (Baer 1990). In fish, the highest concentration level tested for effects on egg and fry, 1.17 mg a.i./L, had no effect on hatchability, growth, or survival.

4.3.3.2. Aquatic Plants– The relevant data on the toxicity of sulfometuron methyl to aquatic plants is summarized in appendix 6. For macrophytes, the most sensitive species appears to be *Lemna gibba*, a freshwater macrophyte. Reported EC_{50} values for the inhibition of frond development and biomass are less than 0.5 µg/L, with NOEC values of approximately 0.3 µg/L (Kannuck and Sloman 1995). Another freshwater macrophyte, *Hydrilla verticillata*, an aquatic angiosperm, has an EC_{50} for growth inhibition of approximately 10 µg/L.

Among the freshwater algae, the most sensitive species appears to be *Senenstrum capriconutum*, with a 120-hour EC_{50} of 4.6 µg a.i./L, which is based on a reduction in cell density relative to controls (Hoberg 1990). EC_{50} values for other freshwater algal species are generally greater than 10 µg/L, depending on the endpoint assayed (Thompson 1994, Landstein et al. 1993).

4.3.3.3. Aquatic Microorganisms– There is no information that would permit a quantitative dose-response assessment for aquatic microorganisms. As discussed in the hazard identification, this is a serious limitation. By analogy to terrestrial plants and terrestrial microorganism, it appears likely that aquatic microorganisms have sensitivities to sulfometuron methyl that are similar to those of aquatic plants.

4.4. RISK CHARACTERIZATION

4.4.1. Overview. The primary concern with sulfometuron methyl is that the application rate used to control the growth of target plant species, usually on the order of 0.1 lbs a.i./acre, is about 100-fold greater than the rate that may damage non-target species (i.e., 0.001 kg/ha or 0.000892 lbs/acre). Various kinds of exposure to non-target terrestrial plant species are considered, including direct spray, drift, wind erosion, and water erosion. Direct deposition through unintentional direct spraying presents a clear hazard in the application of sulfometuron methyl and almost all other herbicides. If non-target plants are accidentally sprayed at application rates that effectively control weeds, they are likely to be damaged, particularly in the upper ranges of anticipated application rates. Although spray drift could cause damage to vegetation, the impact would be limited and damage to non-target species probably could be minimized or avoided during the application process. Wind erosion is, at least potentially, a much more serious problem. Although no significant transport of sulfometuron methyl by soil erosion is anticipated under conditions that inhibit wind erosion of soil (i.e., a rough gravely surface or heavy vegetation covering or when the sulfometuron methyl is incorporated relatively fast into the root zone by irrigation or rainfall), substantial erosion could occur

under arid conditions in flat sandy or otherwise fine soil with a sparse covering of vegetation. Consistent with a reported incident in the literature, the transport of sulfometuron methyl by wind erosion of soil could lead to overt signs of damage in non-target vegetation. Off-site soil contamination with sulfometuron methyl by soil run-off is another mechanism that might cause effects in non-target vegetation. As with wind erosion, there is likely to be substantial variability in the deposition of run-off . In some cases, run-off from a relatively small area could be dispersed over a very wide area and have little impact. In other cases, run-off from a relatively wide area could be concentrated in a relatively small low lying area and damage to non-target vegetation would be evident. This interpretation is supported by and consistent with a reported incident involving damage to non-target vegetation from sulfometuron methyl run-off after application in a roadside hydraulic spray operation.

The duration of adverse effects on non-target terrestrial vegetation may vary substantially since the persistence of sulfometuron methyl in soil is highly variable. Dissipation half-times of 10-20 days are expected in moist fields. In arid fields, however, dissipation half-times of 100-202 days are expected. Considering all of the uncertainties and variability in addition to the value judgments that must be involved in the risk characterization for terrestrial plants, the most balanced interpretation is that damage due to inadvertent contamination of soil with sulfometuron methyl generally will take from a few to several months to recover. Under some extreme conditions, recovery could occur within a matter of weeks; however, under other conditions, recovery might take more than 1 year and possibly several years.

Compared with the potential effects on non-target vegetation, the risk characterization for terrestrial animals is of less concern. The weight of the data suggests that frank or even observable effects in terrestrial mammals exposed to sulfometuron methyl are not expected under most conditions of use. At the highest anticipated application rate and under conservative assumptions of exposure, short-term and probably transient changes in the blood are plausible for mammals that consume vegetation primarily. Nonetheless, the possibility of adverse reproductive effects in some potentially sensitive species cannot be dismissed. These qualifications and uncertainties cannot be resolved with the available data.

Similarly, while the data on potential effects on soil microorganisms is far less complete than the data on non-target vegetation or terrestrial animals, this paucity of information has relatively little impact on the risk assessment. Sulfometuron methyl applied to plants at rates that control undesirable vegetation will cause substantial damage to vegetation. This damage would probably be accompanied by secondary changes in the local environment affecting the soil microbial community to a greater extent or at least more certainly than any direct toxic action by sulfometuron methyl on the microorganisms.

As with terrestrial species, aquatic plants are more likely than aquatic animals to show signs of adverse effects from the application of sulfometuron methyl. Like terrestrial plants, aquatic plants are very sensitive to sulfometuron methyl. Under normal and anticipated conditions of use, it is plausible that sulfometuron methyl contamination of water will cause adverse effects (i.e., reduction in growth and biomass) in sensitive aquatic macrophytes and algal species. The duration of these

effects will depend mostly on the dilution rates of the contaminated body of water and weather conditions. For less sensitive species, the occurence of adverse effects is far less likely. For relatively brief periods shortly after application, a much broader range of aquatic plants might be affected, and the duration of these effects is likely to vary considerably.

For aquatic animals, the risk characterization is unambiguous. There is no evidence that concentrations of sulfometuron methyl in the range of those likely to be found in ambient water after any plausible application program or those that might occur after a spill will cause adverse effects in fish or aquatic invertebrates. As with any attempt to characterize effects in numerous species using data on a relatively small number of species, this risk characterization is tempered by the limited number of test species and the paucity of field studies on aquatic animals. Nonetheless, this assessment is based on apparently well-conducted studies that include sensitive life stage testing of both invertebrates and fish. Notwithstanding the low potential for direct toxic effects on aquatic animals, effects on fish and invertebrate populations are plausible, given the toxicity of sulfometuron methyl to aquatic plants.

4.4.2. Terrestrial Organisms.

4.4.2.1. Terrestrial Animals– The quantitative risk characterization for terrestrial animals is summarized in Table 4-2. Except for the direct spray scenario for the bee, all of the quantitative risk characterizations apply to a 20 g mammal. In Table 4-2, the hazard quotient for each scenario, except that for the honey bee, is calculated as the exposure estimate presented in Table 4-1 divided by the chronic NOAEL for rats of 2 mg/kg/day, discussed in section 4.3.2.1. In some respects, this approach may be regarded as extremely conservative, particularly in the application of the chronic NOAEL to acute exposure scenarios. Nonetheless, as discussed in section 3.3.3, there is no statistically significant relationship between the duration of exposure and the severity of the toxic effect in experimental mammals. In other words, the extent of the toxicity seems to be related more to the amount of compound consumed in 1 day than to the number of days over which exposure occurs.

For the honey bee, the hazard quotient is based on the non-lethal acute dose level of 1075 mg/kg from the study by (Hoxter and Smith 1990). As discussed in section 4.1, this is the only information available on the toxicity of sulfometuron methyl to terrestrial invertebrates.

As specified in Table 4-2, both the central estimates as well as the upper range of the hazard quotients associated with the longer-term exposure scenarios are below unity, indicating that toxic effects are not likely to occur.

For acute exposures of small mammals, none of the central values for the hazard quotient exceed unity, although the hazard quotient for the direct spray scenario with 100% absorption reaches unity. The upper limit of the estimated hazard quotients for direct spray with 100% absorption and the consumption of contaminated vegetation both substantially exceed unity. As indicated in Table 4-1, these hazard quotients are associated with dose levels of about 7-9 mg/kg. Based on the conservative dose-response assessment using all of the available data in the categorical regression analysis (see Figure 3-4), these dose levels would be associated with a 15-20% probability of an AEL. It is

Table 4-2. Summary of quantitative risk characterization for terrestrial animals.[a]

Scenario	Hazard Quotient[b]		
	Typical	Lower	Upper
Acute/Accidental Exposures			
Direct spray, small mammal, first-order absorption	0.007	0.0003	0.1
Direct spray, small animal, 100% absorption	1	0.3	5
Direct spray, bee, 100% absorption[c]	0.01	0.003	0.06
Consumption of contaminated vegetation, acute exposure	0.3	0.06	4
Consumption of contaminated water, acute exposure	0.04	0.007	0.3
Longer-Term Exposures			
Consumption of contaminated vegetation, chronic exposure	0.01	0.003	0.2
Consumption of contaminated water, chronic exposure	0.0007	0.00004	0.006

[a] See Table 4-1 for summary of exposure assessment.
[b] Except for the honey bee, the hazard quotient is calculated as the estimated exposure divided by the chronic rats NOAEL of 2 mg/kg/day and then rounded to one significant decimal or digit.
[C] The hazard quotient is based on the non-lethal acute dose level of 1075 mg/kg from the study by (Hoxter and Smith 1990) .

unlikely that these doses would elicit gross signs of toxicity. If adverse effects occurred, they probably would involve hemolytic anemia, as illustrated in Figure 3-2. Furthermore, given the short-term nature of the exposure, these effects would probably be transient.

This interpretation might be considered either insufficiently protective or overly conservative. The interpretation is conservative in that repeated dose studies, some extending for up to 2 years, are used to define the dose-response relationship. The NOAEL of 2 mg/kg/day is, in fact, from a 2-year feeding study by Mullin (1984) (see Table 3-3). These acute scenarios attempt to consider the consequences of very short-term exposures, and, therefore, might seem to be grossly over-protective. As indicated in Table 3-3, there is an adequate 90-day NOAEL of 9 mg/kg/day in rats with a corresponding AEL at about 80 mg/kg/day (Wood et al. 1980). Thus, it may be argued that the occurrence of toxicologically significant effects is implausible at doses between 7 and 9 mg/kg/day, which are associated with hazard quotients between 4 and 5 (see Table 4-2). Nonetheless, as discussed in section 3.3.3 and detailed in worksheets 30 through 34, various of kinds of analyses were conducted on the available data and none of them suggest that there is a statistically significant

relationship between duration of exposure and severity of effect. That is not to say that such a relationship does not exist; however, the relationship cannot be demonstrated with the available data. Thus, it may be appropriate to use longer-term toxicity studies to assess the consequences of shorter-term exposure.

The risk characterization summarized in Table 4-2 is not considered sufficiently protective, based on the evidence of reproductive effects in rabbits exposed to sulfometuron methyl. As discussed in section 3.3, rabbits may be more sensitive than mice, rats, or dogs to sulfometuron methyl, and this sensitivity may adversely affect reproductive performance. The available studies, however, are not adequate to determine whether the observed responses are caused by sulfometuron methyl exposure or result from gavage rather than dietary administration of the compound. Moreover, because of the small number of animals used in the rabbit studies and the lack of a consistent increase in the incidence of adverse effects with increasing dose (see Figure 3-3), the observed responses might be ascribed to incidental statistical variation. Nonetheless, if the responses in the low-dose region of the rabbit studies are ascribed to sulfometuron methyl, it may be argued that a dose of 30 mg/kg/day is an FEL for fetal abnormalities (Serota et al. 1981) (see Table 3-3) and that a NOAEL for this effect has not been identified. Thus, doses in the range of 7 to 9 mg/kg/day or even 2 mg/kg/day could be regarded as having the potential to cause adverse reproductive effects.

These qualifications and uncertainties cannot be resolved with the available data. Notwithstanding this limitation, the weight of the data suggests that frank or even observable effects in terrestrial mammals exposed to sulfometuron methyl are not expected under most conditions of use. At the highest anticipated application rate and under conservative assumptions of exposure, short-term and probably transient changes in the blood are plausible for mammals that consume vegetation primarily. Admittedly, however, the possibility of adverse reproductive effects in some potentially sensitive species cannot be dismissed.

4.4.2.2. **Terrestrial Plants–** The primary concern with sulfometuron methyl is that the application rate used for the control of target species, typically on the order of 0.1 lbs a.i./acre, is approximately 100-fold greater than the rate that may damage non-target species [i.e., 0.001 kg/ha or 0.000892 lbs/acre from the study by Drake (1990) discussed in section 4.3.2.4].

As discussed in section 4.2.2, three kinds of exposure are considered in the assessment for non-target plants species: direct spray, drift or wind erosion, and water erosion. As is the case with any herbicide, the likelihood of damage to non-target plant species is related directly to the difference between the sensitivity of target species—which dictates the application rate—and the sensitivity of the potential non-target species.

4.4.2.2.1. DIRECT SPRAY – Direct deposition through unintentional direct spraying presents a clear hazard in the application of sulfometuron methyl and almost all other herbicides. If non-target plants are accidentally sprayed at application rates that effectively control weeds, they are likely to be damaged, particularly in the upper ranges of anticipated application rates. The exceptions are plants that developed a resistance to or were engineered to be resistant to sulfometuron methyl. This kind of exposure may be regarded as accidental, which is relatively easy to control with proper

management and application. The extent and duration of damage will depend on the time of application and the species of plant.

4.4.2.2.2. SPRAY DRIFT – Based on estimates using Stoke's Law (see section 4.2.2.2), it is plausible that droplets ranging from 100 to 400 µ might drift about 3-23 feet at a wind speed of 5 miles per hour. Although this event might cause damage to vegetation, the impact would be limited and damage to non-target species probably could be minimized or avoided during the application process.

4.4.2.2.3. WIND EROSION – Wind erosion is, at least potentially, a much more serious problem. As discussed in section 4.2.2.3, no significant transport of sulfometuron methyl by soil erosion is anticipated under conditions that inhibit soil erosion (i.e., a rough gravely surface or heavy vegetation covering or when the sulfometuron methyl is incorporated relatively fast into the root zone by irrigation or rainfall). Under arid conditions, however, in flat sandy or otherwise fine soil with a sparse covering of vegetation, substantial erosion could occur. The quantity of sulfometuron methyl that might be transported and its distribution to non-target plant species would be highly variable. Based on the assumptions and calculations presented in section 4.2.2.3, a 'worst case' scenario may be developed in which 0.084 (8.4%) of the applied sulfometuron methyl is lost due to wind erosion. Further assuming that the sulfometuron methyl is evenly dispersed on adjacent vegetation, an application rate of 0.1 lbs a.i./acre could be associated with a functional exposure of about 0.0084 lbs/acre in an adjacent area. Based on the categorical regression analysis for crops illustrated in Figure 4-4, this level of exposure would be associated with a about a 99.7% probability of observing some damage (i.e., the probability of observing no effect is about 0.3%). The probability of observing 100% mortality, also illustrated in Figure 4-4, is approximately 6%.

This risk characterization for potential damage due to wind erosion may be conservative in terms of the exposure assessment but not in terms of the dose-response assessment. As clearly demonstrated in Drake (1990), there are likely to be observable signs of damage (i.e., overt toxic effects) at concentrations as low as 0.000892 lbs a.i./acre (0.001 kg/ha). It is noteworthy that more than one-half (56/98) of the observations from the Drake (1990) study for exposure to less than 0.001 lbs a.i./acre involved severity levels classified between 6 and 10 and that in about 10% (10/98) of the observations the severity classification was 10. Thus, although the categorical regression analysis involves some level of extrapolation from the available data, the extrapolation to the exposure levels of concern is relatively modest. Figure 4-4, also illustrates a greater than 50% probability that some effects would be observed at functional application rates as low as 0.00001 lbs a.i./acre. Thus, even if the exposure assessment leading to a functional/unintended application rate of 0.0084 lbs a.i./acre overestimates any plausible exposure by a factor of 840, some adverse effects are likely to be observed. Although these effects might not involve plant death, it is noteworthy that all of the effects recorded by Drake (1990) were, by definition, *observable*. That is to say, the effects would be classified as indications of frank toxicity.

This analysis is consistent with and supported by the Turner (1987) study, which indicates that the transport of sulfometuron methyl by wind erosion may lead to overt signs of damage in non-target vegetation.

4.4.2.2.4. SOIL RUN-OFF – Off-site soil contamination with sulfometuron methyl by soil run-off is another mechanism that might cause effects in non-target vegetation. Unlike the wind erosion scenario, there are field studies available for supporting the exposure assessment involving the run-off of sulfometuron methyl. As discussed in section 4.2.2.4., run-off losses of approximately 1% from sandy loam soil are plausible after 12-30 mm of rain. In general, run-off will be less in sandy soil, where percolation will predominate, and greater in clay and loam soils, where run-off will predominate. With greater amounts of rainfall shortly after application, run-off losses could reach 50%.

As in the wind erosion scenario, there is likely to be substantial variability in the deposition of run-off (i.e., situational variability). In some cases, run-off from a relatively small area could be dispersed over a very wide area and have little impact. In other cases, run-off from a relatively wide area could be concentrated in a relatively small low lying area. For this risk assessment, even dispersion is assumed for the quantitative characterization of risk. Thus, at a typical application rate of 0.1 lb a.i., 1% run-off to an off-site area would be equivalent to an application rate of 0.001 lbs a.i./acre and 50% run-off would be equivalent to an application rate of 0.05 lbs a.i./acre.

The consequences of this level of exposure to non-target vegetation may be characterized with reference to Figure 4-4 using the data from Drake (1990), which is similar to the approach taken in the previous section on wind erosion. Functional application rates that approach 0.05 lbs a.i./acre (i.e., the extreme scenario) would lead to clear and unequivocal signs of damage. Under a far less conservative scenario (an application rate of 0.1 lbs a.i./acre and a run-off fraction of 1%) the effective application rate would be 0.001 lbs a.i./acre. This application rate is approximately equal to the low dose level in the Drake (1990) study. Under those kinds of conditions, there is about a 10% likelihood of observing almost 100% mortality in plant species that are as sensitive to sulfometuron methyl as the crop species tested by Drake (1990). In this region of exposure, the mortality rate among less sensitive species [i.e., those species that are as sensitive as the weed species tested by Drake (1990)] is not likely to be as high. In both groups of species, however, there is certain to be some damage. Based on the categorical regression analysis illustrated in Figure 4-4, the probability of not observing any adverse effect is less than 2%.

As with the risk characterization for effects associated with wind erosion, the above interpretation is supported by and consistent with the incident reported by Bridges (1992) in which sulfometuron methyl run-off from roadside hydraulic spray operations was associated with substantial damage to a flower farm.

4.4.2.2.5. DURATION OF EFFECTS– The persistence of sulfometuron methyl in soil is highly variable. Based on USDA (1996) estimates, dissipation half-times of 10-20 days are expected in moist fields. In arid fields, however, dissipation half-times of 100-202 days are expected.

Based on the assumption of first-order dissipation, the proportion (***p***) of a material remaining at time, ***t***, can be calculated as:

$$p = e^{-ke \times t}$$

where k_e is equal to the natural log of 2 divided by the half-time. By rearrangement, the time necessary for a reduction to some fixed proportion of a material can be calculated as:

$$t = -\log_e(p) \div k_e.$$

The worst case scenario for wind erosion leads to a functional exposure of about 0.0084 lbs/acre in an adjacent area. As discussed in section 4.2.2.3, this scenario is most plausible in an arid environment. What constitutes an 'acceptable' level of sulfometuron methyl in soil is debatable. As illustrated in Figure 4-4, the categorical regression analysis indicates that there is about a 10% chance of observing some adverse effect at an effective application rate of 0.0000001 lbs a.i./acre for sensitive species. The proportion of decay necessary to reach this level is approximately 0.00001:

$$0.0000001 \text{ lbs a.i./acre} \div 0.0084 \text{ lbs/acre} = 0.0000119.$$

Using half-times of 100-200 days for arid soil or k_e values of 0.0035-0.0069, the time required to reach this level is approximately 4.5-9 years:

$$t = -\log_e(0.00001) \div 0.0035 = 3289 \text{ days} \approx 9 \text{ years.}$$
$$t = -\log_e(0.00001) \div 0.0069 = 1669 \text{ days} \sim 4.5 \text{ years.}$$

This is undoubtedly an extreme and probably not very useful calculation because it assumes arid conditions over implausible periods of time. In addition, these calculations assume no additional wind erosion, which is likely to occur and would tend to further disperse and dilute the sulfometuron methyl.

A less conservative but probably much more realistic assessment is based on the soil dissipation half-times of 10-20 days, corresponding to k_e values ranging from 0.035 to 0.069. Using these values, the time required to reach 0.00001 of the original amount is from approximately 5 to 11 months:

$$t = -\log_e(0.00001) \div 0.035 = 329 \text{ days} \approx 11 \text{ months.}$$
$$t = -\log_e(0.00001) \div 0.069 = 167 \text{ days} \approx 5 \text{ months.}$$

It is possible to make any number of calculations analogous to those provided. For example, taking 0.0001 lbs a.i./acre as an acceptable soil level and taking 0.001 lbs a.i./acre as an effective off-site application rate from the 'typical' run-off scenario, the relative reduction in residues would have to reach only 0.1. If the longer half-times for soil were used, the reduction in residue would require about 10 to 21 months:

$$t = -\log_e(0.1) \div 0.0035 = 657 \text{ days} \approx 21 \text{ months,}$$
$$t = -\log_e(0.1) \div 0.0069 = 333 \text{ days} \approx 10 \text{ months.}$$

Using the shorter half-times for soil, a reduction to 0.1 of the original level would require about 1 to 2 months:

$$t = -\log_e(0.1) \div 0.035 = 66 \text{ days} \approx 2 \text{ months},$$
$$t = -\log_e(0.1) \div 0.069 = 33 \text{ days} \approx 1 \text{ month}.$$

Just as the extreme values of 4.5 to 9 years should be discarded as too conservative, the values of 1 to 2 months calculated above may not be adequately protective. That is because, based on the Drake (1990) study, classifying a level of 0.0001 lbs a.i./acre as 'acceptable' is not appropriate because plants are likely to be visibly damaged at that exposure level.

Recognizing all of the uncertainties and variability as well as value judgments that must be involved in this risk characterization, the most balanced interpretation is that damage caused by inadvertent contamination of soil with sulfometuron methyl will generally take from a few to several months to recover. Under some extreme conditions, recovery could occur within a matter of weeks; however, under other conditions, recovery might take more than 1 year and possibly several years.

4.4.2.3. Terrestrial Microorganisms – Based on the study by Hubbard et al. (1989), sulfometuron methyl concentrations after light to heavy rainfalls were less than 2.4 µg/mL (2400 µg/L or 2.4 ppm) in run-off and 0.1 µg/mL (100 µg/L) in percolate at applications rates within the range used by the Forest Service. Data regarding the toxicity of soil-incorporated sulfometuron methyl to soil microorganisms is not available. Based on the study by Epelbaum et al. (1996), sulfometuron methyl concentrations of ≈73 µg/L in a liquid glucose medium inhibited the growth of soil microorganisms after exposure periods of less than 3 hours (see section 4.3.2.5). Although the level of sulfometuron methyl in run-off may be substantially greater than levels that might inhibit microbial growth, the compound would be diluted substantially in the soil column. Concentrations of sulfometuron methyl in the percolate are more directly relevant to soil bacteria. If the level used by Epelbaum et al. (1996) in glucose medium is relevant to soil exposure, microbial inhibition is likely to occur and could be substantial. There is no certainty, however, that the finding is relevant.

From a practical perspective, this uncertainty has relatively little impact on this risk assessment. As discussed in the previous section, sulfometuron methyl applied to vegetation at rates that control undesirable vegetation will cause substantial damage to the vegetation, target or non-target. This damage would probably be accompanied by secondary changes in the local environment affecting the soil microbial community to a greater extent or at least more certainly than any direct toxic action by sulfometuron methyl on the microorganisms.

4.4.3. Aquatic Organisms. As detailed in section 4.2.3, concentrations of sulfometuron methyl in ambient water over prolonged periods of time are estimated at 0.0002 (0.00005-0.0005) mg/L. In the accidental spill scenario used in this risk assessment (worksheet 26), ambient levels are likely to be about 0.33 mg/L with a range of 0.053-2.29 mg/L.

4.4.3.1. Fish and Invertebrates – In terms of effects due to the direct toxic action of sulfometuron methyl, the risk characterization is unambiguous. There is no evidence that concentrations of sulfometuron methyl in the range of those likely to be found in ambient water after any plausible application program or those that might occur after a spill will cause adverse effects in fish or aquatic invertebrates. Like any attempt to characterize effects in numerous species using data on a relatively

small number of species, this risk characterization must be tempered by the limited number of test species and the paucity of field studies on aquatic animals. Nonetheless, this assessment is based on apparently well-conducted studies that include sensitive life stage testing of both invertebrates and fish.

Notwithstanding the above risk characterization, adverse effects on fish and invertebrate populations are plausible, given the toxicity of sulfometuron methyl to aquatic plants.

4.4.3.2. Aquatic Plants – Like terrestrial plants, aquatic plants are very sensitive to sulfometuron methyl. The upper range of expected levels of sulfometuron methyl in ambient water associated with the normal use of this herbicide [i.e., 0.0002 (0.00005-0.0005) mg/L or 0.2(0.05-0.5) µg/L] are at the EC_{50} values for the most sensitive aquatic macrophyte, *Lemna gibba* (EC_{50} values for frond growth inhibition and biomass reduction are less than 0.5 µg/L with NOEC values of about 0.3 µg/L). Comparable EC_{50} values for other less sensitive aquatic plants range from 0.005 to 0.01 mg/L, which are ten times above the range of sulfometuron methyl levels expected to occur from the normal use of this compound. As discussed in section 4.2.3, transient concentrations of sulfometuron methyl in water shortly after application could be higher by a factor of about 20.

Thus, under normal and anticipated conditions of use, it is plausible that sulfometuron methyl contamination of water will cause adverse effects (i.e., reduction in growth and biomass) in sensitive aquatic macrophytes and algal species. As noted in Table 2-1 and appendix 1, sulfometuron methyl is chemically stable in water. The duration of these effects will depend heavily on the dilution rates of the contaminated body of water and weather conditions. For less sensitive species, the occurrence of adverse effects is far less likely. For relatively brief periods shortly after application, a much wider range of aquatic plants could be affected and the duration of these effects could vary considerably.

Levels that might be expected after a spill [i.e., 0.33 (0.053–2.29) mg/L] are greatly in excess of concentrations required to create a substantial reduction in the population of aquatic macrophytes and algae. Again, the duration over which these effects might be seen cannot be well characterized.

5. REFERENCES

Allen RR; Fryrear DW. 1977. Limited tillage saves soil, water, and energy. ASAE Annual Meeting, NC State Univ., Raleigh, NC. June 26-29, 1977. 14 pp.

Anderson JJ. 1980. Microbial metabolism of 14 C-phenyl labeled DPX-5648 in a viable soil ecosystem. Document No. AMR-34-81. (Unpublished study received Jun 17, 1981 under 352-EX-108; submitted by E.I. du Pont de Nemours and Co., Wilmington, Del.; CDL: 245375-B) MRID 00078701.

Anderson J. 1990a. Phase 3 summary of MRID 00143540: The fate of ^{14}C-DPX-T5648 in an anaerobic environment. du Pont Report No. 65-82, AMR-1848-90. Prepared by D.I. du Pont de Nemours and Co., Wilmington, DE. 10 p. MRID 93206025.

Anderson J. 1990b. Phase 3 summary of study MRID No. 78701: Microbial metabolism of ^{14}C-phenyl-labeled DPX-T5648 in a viable soil ecosystem. du Pont Report No. AMR 34-81. Guideline Reference: 162-1: Aerobic soil. (Unpublished study prepared by E.I. du Pont de Nemours and Co., DuPont Agricultural Products, Wilmington, DE.) 7 p. MRID 93206024.

Anderson JJ; Dulka JJ. 1985. Environmental fate of sulfometuron methyl in aerobic soils. J. Agric. Food Chem. 33(4): 596-602.

Anderson J. 1994. Microbial metabolism of ^{14}C-phenyl-labeled DPX-T5648 in a viable soil ecosystem. Lab Project No AMR 34-81. (Unpublished study prepared by E.I. du Pont de Nemours and Co., DuPont Agricultural Products, Wilmington, DE.) 7 p. MRID 43174102.

Aulgur LF. 1996. Du Pont OUST herbicide update. Proc. Ann. For. Veg. Manag. Conf. 17: 32-36.

Baer KN. 1990. Chronic toxicity of IN T5648-40 to *Daphnia magna*. Haskell Lab. Report No. 614-90. D.I. du Pont de Nemours and Co., Haskell Laboratory for Toxicology and Industrial Medicine, Newark, DE. MRID 41672806.

Barnes AD; Zedaker SM; Feret PP; Seiler JR. 1990. The effects of sulfometuron on the root growth of loblolly pine. New For. 3(4): 289-295.

Beck KG; Lym RG; Becker RL; Ferrel MA; Finnerty DW; Frank RJ; Henson MA; Peterson MA. 1993. Leaf spurge (*Euphorbia esula*) control and grass injury with sulfometuron. Weed Technol. 7(1): 212-215.

Bird SL. 1995. A compilation of aerial spray drift field study data for low-flight agricultural application of pesticides. In: Agrochemical Environmental Fate: State of the Art. ML Leng; EMK Leovey; PL Zubkoff (Eds). CRC Press: Lewis Publishers, New York, NY. p. 195-207.

Boutsalis P; Powles SB. 1995. Inheritance and mechanism of resistance to herbicides inhibiting acetolactate synthase in *Sonchus oleraceus* L. Theoret. Appl, Gen. 91(2): 242-247.

Boxenbaum J; D'Souza R. 1990. Interspecies pharmacokinetic scaling, biological design and neoteny. Adv. Drug Res. 19: 139-195.

Brattsten LB. 1987. Hydrolysis of [pyrimidine-2-^{14}C] sulfometuron methyl. Laboratory Project ID. AMR-541-86. (Unpublished study prepared by E.I. du Pont de Nemours and Co., Inc., Wilmington, DE). 10 p. MRID 41672811.

Bridges A. 1992. Roadside oust vs. a flower farm: It kills plants, but can't be detected in a lab. J. Pest. Reform. 12(2): 17.

Brown MR. 1994a. Static, acute, 96-hour LC50 of DPX-T5648-42 (sulfometuron methyl) to Bluegill Sunfish, *Lepomis macrochirus* (Limit test). Haskell Laboratory Report No. 590-94. (Unpublished study prepared by E.I. du Pont de Nemours and Co., Haskell Laboratory for Toxicology and Industrial Medicine, Newark, DE). 27 p. MRID 43501801.

Brown MR. 1994b. Static, acute, 48-hour EC50 of DPX-T5648-42 (sulfometuron methyl) to *Daphnia magna*. Haskell Laboratoary Report No. 588-94. (Unpublished study prepared by E.I. du Pont de Nemours and Co., Haskell Laboratory for Toxicology and Industrial Medicine, Newark, DE). 27 p. MRID 43501803.

Brown MR. 1994c. Static, acute, 96-hour LC50 of DPX-T5648-42 (sulfometuron methyl) to Rainbow trout, *Oncorhynchus mykiss*: (Limit test). Haskell Laboratory Report No. 589-94. (Unpublished study prepared by E.I. du Pont de Nemours and Co., Haskell Laboratory for Toxicology and Industrial Medicine, Newark, DE). 28 p. MRID 43501802.

Budavari S. (Ed). 1989. The Merck Index: An Encyclopedia of Chemicals, Drugs,and Biologicals, 11th ed. Merck & Co., Inc., Rahway, New Jersey.

Burnet M; Hodgson B. 1991. Differential effects of the sulfonylurea herbicides chlorsulfuron and sulfometuron methyl on microorganisms. Arch. Microbiol. 155 (6): 521-525.

Burnmaster DE. 1998. Lognormal distributions for total water intake and tap water intake by pregnant and lactating women in the United States. Risk Analysis. 18(2): 215-219.

Buser HR. 1990. Atrazine and other s-triazine herbicides in lakes and in rain in Switzerland. Environ. Sci. Technol. 24(7): 1049-1058.

Byl TD; Sutton HD; Klaine S. 1994. Evaluation of peroxidase as a biochemical indicator of toxic chemical exposure in the aquatic plant *Hydrilla verticillata*, Royle. Environ. Toxicol. Chem. 13(3): 509-515.

Cadwgan GE. 1990a. Phase 3 summary study of MRID No. 41273602: n-Octanol/water partition coefficient of sulfometuron methyl at pH 5, 7, and 9. du Pont Report No. AMR-1203-88. Guideline Reference: Series 63-11: Octanol/Water Partition Coefficient. (Unpublished study prepared by E.I. du Pont de Nemours and Co., Wilmington, DE). 7 p. MRID 93206001.

Cadwgan GE. 1990b. Phase 3 summary study of MRID Nos. 71423 and 78702: Soil mobility of sulfometuron methyl. du Pont Report Nos. AMR-25-80 and AMR -11-81. Guideline Reference: Series 163-1: Leaching/Adsorption/Desorption. (Unpublished study prepared by E.I. du Pont de Nemours and Co., Wilmington, DE). 12 p. MRID 93206026.

Calabrese EJ; Baldwin LA. 1993. Performing Ecological Risk Assessments. Lewis Publishers, Boca Raton, LA, pp. 12-24.

Cambon JP; Zheng SQ; Bastide J. 1992. Chemical or microbial degradation of sulfonylurea herbicides in soil. I. Sulfometuron methyl. Weed Res. 32(1): 1-7.

Cantrell RL; Hyland JR. 1985. Application techniques. In: A Guide to Silvicultural Herbicide Use in the Southern United States. Auburn University School of Forestry, Alabama Agricultural Experiment Station. November 1985. 612 pp.

Cox C. 1993. Sulfometuron methyl (Oust). J. Pest. Reform. 13 (4): 30-35.

CPR (Crop Protection Reference). 1997. Crop Protection Reference. 13th ed. C&P Press, Inc., New York, NY.

Dashiell OL; Hall JA. 1980. Oral LD50 test in rats--EPA proposed guidelines. Haskell Laboratory Report No. 965-80. (Unpublished study received Jan 23, 1981 under 352-EX-107; submitted by E.I. du Pont de Nemours & Co., Wilmington, Del.; CDL: 244195-K) MRID 00071409.

Dashiell OL; Henry JE. 1980a. Skin Irritation test on rabbits for EPA pesticide registration. Haskell Laboratory Report No. 964-80. (Unpublished study received Jan 23, 1981 under 352-EX-107; submitted by E.I. du Pont de Nemours & Co., Wilmington, DE; CDL:244195-M). MRID 00071411.

Dashiell OL; Henry JE. 1980b. Eye irritation in rabbits--EPA pesticide registration. Haskell Laboratory Report No. 963-80. (Unpublished study received Jan 23, 1981 under 352-EX-107; submitted by E.I. du Pont de Nemours, Wilmington, DE; CDL: 244195-N). MRID 00071412.

Dashiell OL; Hinckle L. 1980. Oral LD50 test in rats--EPA proposed guidelines. Haskell Laboratory Report No. 870-80. Rev. (Unpublished study received Jan 23, 1981 under 352-EX-107; submitted by E.I. du Pont de Nemours & Co., Wilmington, DE; CDL:244195-H). MRID 00071406.

Dashiell OL; Hinckle L. 1983. Subacute dermal toxicity study (21-days) in rabbits. Haskell Laboratory Report No. 792-82. (Unpublished study received Apr 5, 1983 under 352-401; submitted by E.I. du Pont de Nemours & Co., Inc., Wilmington, DE; CDL: 249865-A). MRID 00126714.

Dashiell OL; Silber LS. 1980a. Primary skin irritation and sensitization test on guinea pigs. Haskell Laboratory Report No. 966-80. (Unpublished study received Jan 23, 1981 under 352-EX-107; submitted by E.I. du Pont de Nemours & Co., Wilmington, DE; CDL:244195-O). MRID 00071413.

Dashiell OL; Silber L. 1980b. Acute skin absorption LD50 test on rabbits--EPA pesticide registration. Haskell Laboratory Report No. 1068-80. (Unpublished study received Jan 23, 1981 under 352-EX-107; submitted by E.I. du Pont de Nemours & Co., Wilmington, DE; CDL:244195-L). MRID 00071410.

Dashiell OL; Silber LS. 1980c. Primary skin irritation and sensitization test on guinea pigs. Haskell Laboratory Report No. 966-80. (Unpublished study received Jan 23, 1981 under 352-EX-107; submitted by E.I. du Pont de Nemours & Co., Wilmington, DE; CDL:244195-O). MRID 00071413.

Dashiell OL; Silber LS. 1981. Acute skin absorption LD50 test on rabbits--EPA pesticide registration. Haskell Laboratory Report No. 1078-80. (Unpublished study received Jul 1, 1981 under 352-401; submitted by E.I. du Pont de Nemours & Co., Wilmington, DE; CDL:245515-J). MRID 00078791.

Dickens R; Wehtje G. 1986. Mobility and soil solution characteristics of imazapyr (Arsenal) and sulfometuron methyl (Oust). Proc. South. Weed Sci. Soc. 39th Ann. Meet. p. 368.

Dickerman JD. 1981. A familial hemolytic anemia associated with sulfa administration. Hosp. Pract .(Off Ed). 16(9): 41, 44, 47.

Dourson ML; Knauf LA; Durkin PR; Stiteler WM. 1997. Categorical regression of toxicity data: A case study using aldicarb. Reg. Toxicol. Pharmacol. 25:121-129.

Drake D. 1990. Tier testing evaluation of sulfometuron methyl on plants grown under greenhouse. Lab Project No. DCD-90-2. (Unpublished study prepared by E. I. Du Pont de Nemours and Co., Wilmington DE). 13 p. MRID 41672809.

Driscoll R. 1984. Early life stage toxicity of INT-5648-18 to fathead minnow. Haskell Laboratory Report No. 765-82. (Unpublished study prepared by E.I. du Pont de Nemours and Co., Haskell Laboratory for Toxicology and Industrial Medicine, Newark, DE). 29 p. MRID 00143539.

Dudeck SH; Bristol KL. 1981a. Final report: Single-dose oral toxicity in mallard ducks. Project No. 201-552. (Unpublished study received Jun 17, 1981 under 352-EX-108; prepared by Hazleton Laboratories America, Inc.; submitted by E.I. du Pont de Nemours & Co., Wilmington, DE; CDL:245375-A). MRID 00078700.

Dudeck SH; Bristol KL. 1981b. Final report: Avian dietary toxicity study in Bobwhite quail. Project No. 201-549; HLO-17-81. (Unpublished study received Jan 23, 1981 under 352-EX-107; prepared by Hazleton Laboratories America, Inc.; submitted by E.I. du Pont de Nemours & Co., Wilmington, DE; CDL:244195-Q). MRID 00071415.

Dudeck SH; Twigg CJ. 1980. Final report: Avian dietary toxicity (LC50) study in Mallard ducks. Project No. 201-548; HLO-788- 80. (Unpublished study received Jan 23, 1981 under 352-EX-107; prepared by Hazleton Laboratories America, Inc.; submitted by E.I. du Pont de Nemours & Co., Wilmington, DE; CDL:244195-P). MRID 00071414.

Dulka J; Anderson J. 1982. The fate of [^{14}C-]-DPX-T5648 in an anaerobic environment. (Unpublished study prepared by E. I. du Pont de Nemours and Co., Inc., Wilmington, DE). 28 p. MRID 00143540.

DuPont. 1989. Metabolism of sulfometuron methyl in rats. Unpublished study by DuPont Chemical Company, February 3, 1989. Not submitted to the EPA. (Cited in Extoxnet 1994).

DuPont. 1996. DuPont Material Safety Data Sheet for "Oust" Herbicide. M0000028. Revised 19-NOV-1994.

DuPont. 1997a. Oust herbicide: Product label for states other than California. EPA Reg. 352-401. H-63401. E.I. du Pont de Nemours and Company, Agricultural Products, Wilmington, DE. 9 pp.

DuPont. 1997b. Oust herbicide: Product label for California. EPA Reg. 352-401. H-63246. E.I. du Pont de Nemours and Company, Agricultural Products, Wilmington, DE. 9 pp.

Durkin PR; Stiteler WM; Dourson ML; Knauf L. 1993. The Use of Categorical Regression Analysis to Express Risk Above the RfD: A Case Study Using Aldicarb. International Congress on the Health Effects of Hazardous Waste. Abstract 209. U.S. DHHS, PHS, Atlanta, Georgia. May 3-6

Durkin PR; Rubin L; Withey J; Meylan W. 1995. Methods of assessing dermal absorption with emphasis on uptake from contaminated vegetation. Toxicol. Indust. Health. 11(1): 63-79.

Durkin P; Rubin L; Withey J; Meylan W; Nakatsugawa T. 1998. A reevaluation of methods for assessing dermal absorption. Manuscript under review. Draft dated May 18, 1998.

Edwards DF. 1979a. Primary skin irritation and sensitization tests on guinea pigs. Haskell Laboratory Report No. 232-79. (Unpublished study received Jan 23, 1981 under 352-EX-107; submitted by E.I. du Pont de Nemours & Co., Wilmington, DE; CDL:244195-I). MRID 00071407.

Edwards DF. 1979b. Eye irritation test in rabbits. Haskell Laboratory Report No. 230-79. (Unpublished study received Jan 23, 1981 under 352-EX-107; submitted by E.I. du Pont de Nemours & Co., Wilmington, DE; CDL:244195-J). MRID 00071408.

Epelbaum S; Chipman DM; Barak Z. 1996. Metabolic effects of inhibitors of two enzymes of the branched-chain amino acid pathway in *Salmonella typhimurium*. J. Bacteriol. 178(4): 1187-96.

Extoxnet. 1994. Sulfometuron methyl. Pesticide Information Profile. Extension Toxicology Network, University of Oregon. http://ace.orst.edu/info/extoxnet/pips/sulfomet.htm

Filliben T. 1995a. Acute oral toxicity study with DPX-T5648-71 (Oust) in male and female rats. Laboratory Project No. HLR 721-95: 10360-001. (Unpublished study prepared by Haskell Laboratory for Toxicology and Industrial Medicine, E.I du Pont de Nemours and Co, Inc., Newark, DE). 26 p. MRID 43848401.

Filliben T. 1995b. Primary dermal irritation study with DPX-T5648-71 (Oust) in rabbits. Laboratory Project No. HLR 709-95: 10360-001. (Unpublished study prepared by Haskell Laboratory for Toxicology and Industrial Medicine, E.I du Pont de Nemours and Co, Inc., Newark, DE). 22 p. MRID 43848405.

Filliben T. 1995c. Acute dermal toxicity study with DPX-T5648-71 (Oust) in rabbits: Revision No.1. Laboratory Project No. HLR 720-95: 10360-001. (Unpublished study prepared by Haskell Laboratory for Toxicology and Industrial Medicine, E.I du Pont de Nemours and Co, Inc., Newark, DE). 28 p. MRID 43848402

Filliben T. 1995d. Primary eye irritation study with DPX-T5648-71 (Oust) in rabbits. Laboratory Project No. HLR 710-95: 10360-001. (Unpublished study prepared by Haskell Laboratory for Toxicology and Industrial Medicine, E.I du Pont de Nemours and Co, Inc., Newark, DE). 23 p. MRID 43848404.

Fink R; Beavers JB; Joiner G; et al. 1981. Final report: Eight-day dietary LC_{50}--Bobwhite Quail. Project No. 112-122. (Unpublished study received Dec 12, 1981 under 352-401; prepared by Wildlife International, Ltd., I.D. No. WI-734; submitted by E.I. du Pont de Nemours & Co., Inc., Wilmington, DE; CDL: 246409-A). MRID 00088813.

Ford LS. 1982. Unscheduled DNA synthesis/rat hepatocytes in vitro. Haskell Laboratory Report No. 769-82. (Unpublished study prepared by Haskell Laboratory for Toxicology and Industrial Medicine, E.I. du Pont de Nemours and Co., Inc., Newark, DE). MRID 00146847.

Gaeddert JW; Peterson DE; Horak MJ. 1997. Control and cross-resistance of an acetolactate synthase inhibitor-resistant Palmer amaranth (*Amaranthus palmeri*) biotype. Weed Technol. 11(1): 132-137.

Galloway SM. 1981. Mutagenicity evaluation of H#13,647-03: In an *in vitro* cytogenetic assay measuring chromosome abberation frequencies in Chinese hamster ovary (CHO) cells. (Unpublished study prepared by Litton Bionetics, Inc., Kensington, MD; LBI Project No. 20990; submitted to E.I. du Pont de Nemours Co., Inc., Wilmington, DE). MRID 00146846.

Goldstein A; Aronow L; Kaman SM. 1974. Principles of Drug Action: The Basis of Pharmacology. 2nd ed. John Wiley and Sons, New York, NY. 854 p.

Gunther P; Rahman A; Pestemer W. 1989. Quantitative bioassays for determining residues and availability to plants of sulphonylurea herbicides. Weed Res. UK. 29(2): 141-146.

Harris SA; Solomon KR. 1992. Human exposure to 2,4-D following controlled activities on recently sprayed turf. J. Environ. Sci. Health. B27(1): 9-22.

Harvey J Jr. 1981a. Bioaccumulation studies of [^{14}C]-phenyl-DPX-5648 in fish. (Unpublished study prepared by E.I. du Pont de Nemours Co., Inc., Wilmington, DE). MRID 00146279.

Harvey J Jr. 1981b. Hydrolysis of ^{14}C-DPX-5648. (Unpublished study received Jan 23, 1981 under 352-EX-107; submitted by E.I. du Pont de Nemours & Co., Wilmington, DE; CDL:244195-U). MRID 00071419.

Harvey J Jr. 1990a. Phase 3 summary of MRID No. 146279: Bioaccumulation of sulfometuron methyl in fish. AMR-41-81. Guideline Reference 165-4: Bioaccumulation in fish. (Unpublished study prepared by Haskell Laboratory for Toxicology and Industrial Medicine, E.I. du Pont de Nemours and Co., Newark DE and E.I. du Pont de Nemours and Co. Wilmington, DE). MRID 93206028.

Harvey J Jr. 1990b. Phase 3 summary of MRID No. 71429: Hydrolysis of sulfometuron methyl. Guideline Reference 161-1: Hydrolysis. (Unpublished study prepared by E.I. du Pont de Nemours and Co., Wilmington, DE). MRID 93206022.

Harvey J Jr; Bennett CT; Reiser RW. 1980. Photolysis of ^{14}C-DPX-5648: Document No. AMR-01-81. (Unpublished study received Jan 23, 1981 under 352-EX-107; submitted by E.I. du Pont de Nemours & Co., Wilmington, DE; CDL:244195-V). MRID 00071420.

Harvey J Jr; Dulka JJ; Anderson JJ. 1985. Properties of sulfometuron methyl affecting its environmental fate: Aqueous hydrolysis and photolysis, mobility and adsorption on soils, and bioaccumulation potential. J. Agric. Food Chem. 33(4): 590-596.

Harvey J Jr; Bennett CT; Reiser RW. 19??. Hydrolysis of ^{14}C-DPX-5648. (Unpublished study received Jan 23, 1981 under 352-EX-107; submitted by E.I. du Pont de Nemours & Co., Wilmington, Del.; CDL:244195-U). MRID No. 00071419.

Hinckle L. 1979. Ten-dose oral subacute test. Haskell Laboratory No. 523-79. (Unpublished study received Jul 1, 1981 under 352- 401; submitted by E.I. du Pont de Nemours & Co., Wilmington, DE; CDL:245515-M). MRID 00078794.

Hoberg J. 1990. Sulfometuron methyl-toxicity to the freshwater green alga *Selenastrum capricornutum*. Lab Project No. AMR- 1893-90. (Unpublished study prepared by Springborn Laboratories, Inc.). 24 p. MRID 41680102.

Hoberman AM; Bristol KL; Wolfe GW. 1981. Pilot oral teratology study in rabbits. Project No. 201-554; HLO-234-81. Final report. (Unpublished study received Jul 1, 1981 under 352-401; prepared by Hazleton Laboratories America, Inc., submitted by E.I. du Pont de Nemours & Co., Wilmington, DE; CDL:245515-P) MRID 00078797.

Hoerger F; Kenaga EE. 1972. Pesticide residues on plants: Correlation of representative data as a basis for estimation of their magnitude in the environment. In: Environmental Quality and Safety, Volume I: Global Aspects of Toxicology and Technology as Applied to the Environment. F. Coulston and F. Kerte (eds.). Academic Press, New York, NY. pp. 9-28.

Hoxter K; Smith G. 1990. An Acute contact toxicity study with the honey bee. Lab Project No. 112-243: 583-90. (Unpublished study prepared by Wildlife International, Ltd., Easton, MD). 14 p. MRID 41672810.

Hubbard RK; Williams RG; Erdman MD; Marti LR 1989. Chemical transport from Coastal Plain soils under simulated rainfall. II. Movement of cyanizine, sulfometuron-methyl, and bromide. Am. Soc. Agric. Eng. 32(4): 1250-1257.

ICRP (International Commission on Radiologic Protection). 1975. Report of the Task Group on Reference Man. Recommendations of the International Commission on Radiological Protection (ICRP) Publ. No. 23. Pergamon Press, New York, NY.

Issaragrisil S; Kaufman DW; Anderson T; Chansung K; Thamprasit T; Sirijirachai J; Piankijagum A; Porapakkham Y; Vannasaeng S; Leaverton PE; Shapiro S; Young NS. 1997. Low drug attributability of aplastic anemia in Thailand. The Aplastic Anemia Study Group. Blood. 89(11): 4034-4039.

James TK; Rahman A. 1992. Effect of simulated rainfall and adjuvants on the phytotoxicity of sulfonylurea herbicides. Proc 1st Internat. Weed Cont. Congr. 2: 229-232.

Kannuck R; Sloman T. 1995. Sulfometuron methyl (DPX-T5648): Influence on growth and reproduction of *Lemna gibba* G3. Lab Project No. AMR 2902-94. (Unpublished study prepared by Stine-Haskell Research Center, E.I. du Pont de Nemours and Co, Newark, DE). 41p. MRID 43538503.

Kinney L. 1982. Inhalation median lethal concentration (LC50) of INT-5648-18 by EPA protocol: [Benzoic acid, 2-[[[[(4,6-dimethyl-2-pyrimidinyl)amino]carbonyl]amino]-sulfonyl]-, methyl ester]. Haskell Laboratory Report No. 657-82; MR No. 0581-944. (Unpublished study prepared by Haskell Laboratory for Toxicology and Industrial Medicine, E.I. du Pont de Nemours and Co., Inc., Newark, DE). MRID 00146848.

Knisel WG; Davis FM; Leonard RA. 1992. GLEAMS Version 2.0, Part III: User Manual. File dated 07/01/92.

Koeppe MK; Mucha CF. 1991. Metabolism of sulfometuron methyl in lactating goats. J. Agric. Food Chem. 39(12): 2304-2309.

Koskinen WC; Stone DM; Harris AR. 1996. Sorption of hexazinone, sulfometuron methyl, and tebuthiuron on acid, low base saturated sands. Chemosphere. 32(9): 1681-1689.

Krahn DF; Fitzpatrick K. 1981. Chinese hamster ovary cell assay for mutagenicity. Haskell Laboratory Report No. 1074-80. (Unpublished study received Jul 1, 1981 under 352-401; submitted by E.I. du Pont de Nemours & Co., Wilmington, DE; CDL: 245515-L) MRID 00078793.

Kuhn JO. 1989a. Primary eye irritation study in rats: Knockout HC. Guideline No. 81-4. Laboratory Study No. 6418-89. (Unpublished study prepared by Stillmeadow, Inc., Houston, TX; submitted December 29, 1989 by Landis Associates, Inc., Valdosta, GA). MRID 41366606.

Kuhn JO. 1989b. Primary dermal irritation study in rabbits: Knockout HC. Guideline No. 81-5. Laboratory Study No. 6419-89. (Unpublished study prepared by Stillmeadow, Inc., Houston, TX; submitted December 29, 1989 by Landis Associates, Inc., Valdosta, GA). MRID 41366607.

Kuhn JO. 1989c. Primary eye irritation study in rats: Knockout HC. Guideline No. 81-4. Laboratory Study No. 6418-89. (Unpublished study prepared by Stillmeadow, Inc., Houston, TX; submitted December 29, 1989 by Landis Associates, Inc., Valdosta, GA). MRID 41366707.

Kuhn JO. 1989d. Acute dermal toxicity study in rabbits: Knockout HC. Guideline No. 81-2. Laboratory Study No. 6417-89. (Unpublished study prepared by Stillmeadow, Inc., Houston, TX; submitted December 29, 1989 by Landis Associates, Inc., Valdosta, GA). MRID 41366604.

Kuhn JO. 1989e. Dermal sensitization study in guinea pigs: Knockout HC. Guideline No. 81-6. Laboratory Study No. 6420-89. (Unpublished study prepared by Stillmeadow, Inc., Houston, TX; submitted December 29, 1989 by Landis Associates, Inc., Valdosta, GA). MRID 41366608.

Kuhn JO. 1989f. Primary dermal irritation study in rabbits: Knockout HC. Guideline No. 81-5. Laboratory Study No. 6419-89. (Unpublished study prepared by Stillmeadow, Inc., Houston, TX; submitted December 29, 1989 by Landis Associates, Inc., Valdosta, GA). MRID 41366607.

Kuhn JO. 1989g. Acute oral toxicity study in rats: Knockout. Guideline No. 81-1. Laboratory Study No. 6416-89. (Unpublished study prepared by Stillmeadow, Inc., Houston, TX; submitted December 29, 1989 by Landis Associates, Inc., Valdosta, GA). MRID 41366704.

Kuhn JO. 1989h. Dermal sensitization study in guinea pigs: Knockout. Guideline No. 81-6. Laboratory Study No. 6420-89. (Unpublished study prepared by Stillmeadow, Inc., Houston, TX; submitted December 29, 1989 by Landis Associates, Inc., Valdosta, GA). MRID 41366709.

Kuhn JO. 1989i. Acute oral toxicity study in rats: Knockout. Guideline No. 81-1. Laboratory Study No. 6416-89. (Unpublished study prepared by Stillmeadow, Inc., Houston, TX; submitted December 29, 1989 by Landis Associates, Inc., Valdosta, GA). MRID 41366603.

Kuhn JO. 1989j. Acute dermal toxicity study in rabbits: Knockout Guideline No. 81-2. Laboratory Study No. 6417-89. (Unpublished study prepared by Stillmeadow, Inc., Houston, TX; submitted December 29, 1989 by Landis Associates, Inc., Valdosta, GA). MRID 41366705.

Kuhn JO. 1989k. Acute pulmonary (intratracheal) toxicity study in rats: Knockout. Guideline No. 81-3. Laboratory Study No. 6421-89. (Unpublished study prepared by Stillmeadow, Inc., Houston, TX; submitted December 29, 1989 by Landis Associates, Inc., Valdosta, GA). MRID 41366706.

Kuhn JO. 1989l. Acute pulmonary (intratracheal) toxicity study in rats: Knockout H.C. Guideline No. 81-3. Laboratory Study No. 6421-89. (Unpublished study prepared by Stillmeadow, Inc., Houston, TX; submitted December 29, 1989 by Landis Associates, Inc., Valdosta, GA). MRID 41366605.

Landstein D; Arad S; Barak Z; Chipman DM. 1993. Relationships among the herbicide and functional sites of acetohydroxy acid synthase from Chlorella emersonii. Planta. 191(1): 1-6.

Landstein D; Epelbaum S; Arad S; Barak Z; Chipman DM. 1995. Metabolic response of Chlorella emersonii to the herbicide sulfometuron methyl. Planta. 197 (2):219-224.

Levine TE. 1996. The regulation of inert ingredients in the United States. In: Pesticide Formulation and Adjuvant Technology. CL Foy; DW Pritchard (Eds). CRC Press, New York, NY.

Lu M.H. 1981. Teratogenicity study by diet in the rat with benzoic acid: 2-[[[[(4,6-dimethyl-2-pyrimidinyl)-amino]-carbonyl]-amino]-sulfonyl]-methyl ester. Haskell Laboratory Report No. 316-81. (Unpublished study received Jul 1, 1981 under 352-401; submitted by E.I. du Pont de Nemours & Co., Wilmington, DE; CDL:245515-O). MRID 00078796.

Lu M. 1990. Phase 3 Reformat of MRID 00078796: Teratogenicity study by diet in the rat with benzoic acid: 2-[[[[(4,6-dimethyl-2-pyrimidinyl)-amino]-carbonyl]-amino]-sulfonyl]-methyl ester. Guideline Reference no. 83-3(a): Teratogenicity- Rat. Reformatted by Hurtt ME; Alvarez L; Murray SM. (Unpublished report prepared by E.I. du Pont de Nemours and Co., Newark, DE). 174 p. MRID 93206029.

Lym RG; Swenson OR. 1991. Sulfometuron persistence and movement in soil and water in North Dakota. J. Environ. Qual. 20(1): 209-215.

Lym RG. 1992. Absorption and translocation of foliar-applied sulfometuron in leafy spurge (Euphorbia esula). Weed Sci. 40(3): 477-481.

Malek DE. 1990. Primary eye irritation study with IN T5648-40 in rabbits. Medical Research No. 4581-804. Haskell Laboratory Report No. 126-90. (Unpublished study prepared by Haskell Laboratory for Toxicology and Industrial Medicine, E.I. du Pont de Nemours and Co., Inc., Newark, DE). MRID 41672807.

Malek D. 1994. Combined chronic toxicity/oncogenicity study with INT-5648: Long-term feeding and two-generation, four-litter reproduction study in rats: Supplement No. 2. Laboratory Project No. 4052-001: 367-84. (Unpublished study prepared by E.I. du Pont de Nemours and Co., Newark, DE). 145 p. MRID 43154101.

Manugistics. 1995. Statgraphics Pluss for Windows. Version 3. Available from Manugistics, Inc. Rockville, Maryland.

Mason RW; Johnson BL. 1987. Ergonomic factors in chemical hazard control. In: Handbook of Human Factors. Salveny, G; ed. John Wiley and Sons, New York, NY. pp. 772-741.

Matchett WH; Winnik W; Betowski LO; Brumley WC. 1997. A kinetic study of the methanolysis of the sulfonylureas bensulfuron methyl and sulfometuron methyl using capillary electrophoresis. Electrophoresis. 18(2): 205-13.

McCullagh P. 1980. Regression models for ordinal data. J. Roy. Statist. Soc. B. 42: 109-142.

Melander A; Bitzen P-O; Faber O; Groop L. 1989. Sulphonylurea antidiabetic drups: An update of their clinical pharmacology and rational therapeutic use. Drugs. 37: 58-72.

Mendenhall W; Scheaffer RF. 1973. Mathematical Statistics with Applications. Duxbury Press, North Scituate, Massachusetts. 461 pp. plus appendices.

Meylan WM; Howard PH. 1993. Computer estimation of the atmospheric gas-phase reaction rate of organic compounds with hydroxyl radicals and ozone. Chemosphere. 26: 2293-2299. (Computer estimation program available from Syracuse Research Corporation, Syracuse, NY.).

Michael JL; Neary DG. 1993. Herbicide dissipation studies in southern forest ecosystems. Environ. Toxicol. Chem. 12(3): 405-410.

Mitchell RJ; Runion GB; Kelley WD; Gjerstad DH; Brewer CH. 1991. Factors associated with loblolly pine mortality on former agricultural sites in the Conservation Reserve Program. J. Soil Water Conserv. 46(4): 306-311.

Monson K; Hoffman D. 1990. Aerobic soil metabolisim of [pyrimidine-2-^{14}C]sulfometuron methyl in keyport silt loam. Laboratory Project ID AMR-1113-88. (Unpublished study prepared by E.I. du Pont de Nemours and Company, Wilmington, DE). MRID 42091401.

Moore JA. 1964. Physiology of the Amphibia. Academic Press, New York, NY. (Cited in USDA 1989b).

Moore GS. 1995. Delayed contact hypersensitivity test (Buehler method) with DPX-T5648-71 (Oust) (H-21296) in guinea pigs. Haskell Laboratory Project ID 481-95. (Unpublished study prepared by Biosearch, Inc., Philadelphia, PA; prepared for Haskell Laboratory for Toxicology and Industrial Medicine, I.E. du Pont de Nemours and Co, Newark, DE). MRID 43848406.

Mullin LS. 1984. Long-term feeding study in rats with benzoic acid, 2-[[[[(4,6-dimethyl-2-pyrimidinyl)amino]carbonyl]-amino]sulfonyl]-, methyl ester (INT-5648). Medical Research Project - 4052-001; Haskell Laboratory Report 367-84. Final report on the feeding and two-generation reproduction study conducted 1/27/81-2/24/83. (Unpublished study prepared by Haskell Laboratory for Toxicology and Industrial Medicine, E.I. du Pont de Nemours and Co., Inc., Newark, DE). MRID 00146849.

Muska C; Driscoll R. 1982. Early life stage toxicity of INT-5648-18 to fathead minnow. Haskell Laboratory Report No. 765-82. (Unpublished study received March 28, 1983, under 352-401; submitted by Haskell Laboratory for Toxicology and Industrial Medicine, E.I. du Pont de Nemours and Co., Inc., Newark, DE). MRID 00126600.

Muska CF; Hall CL. 1980. 96-hour LC50 to Bluegill sunfish. Haskell Laboratory Report No. 629-80. (Unpublished study received Jan 23, 1981 under 352-EX-107; submitted by E.I. du Pont de Nemours and Co, Wilmington, DE; CDL:244195-S). MRID 00071417.

Muska CF; Trivits RL. 1980a. 48-hour LC50 to *Daphnia magna*. Haskell Laboratory Report No. 631-80. (Unpublished study received Jan 23, 1981 under 352-EX-107; submitted by E.I. du Pont de Nemours and Co, Wilmington, DE; CDL:244195-T). MRID 00071418.

Muska CF; Trivits RL. 1980b. 96-hour LC50 to Rainbow trout. Haskell Laboratory Report No. 630-80. (Unpublished study received Jan 23, 1981 under 352-EX-107; submitted by E.I. du Pont de Nemours and Co, Wilmington, DE; CDL:244195-R). MRID 00071416.

Naqvi SM; Hawkins R; Naqvi NH. 1987. Mortality response and LC50 values for juvenile and adult crayfish, *Procambarus clarkii* exposed to Thiodan (insecticide), Treflan, MSMA, Oust (herbicides) and Cutrine-plus (algicide). Environ. Pollut. 48(4): 275-283.

Naqvi SM; Hawkins RH. 1989. Responses and LC sub(50) values for selected microcrustaceans exposed to Spartan), Malathion, Sonar), Weedtrine-D) and Oust) pesticides. Bull. Environ. Contam. Toxicol. 43(3): 386-393.

Neary DG; Michael JL. 1996. Herbicides - protecting long-term sustainability and water quality in forest ecosystems. New Zeal. J. For. Sci. 26(½): 241-264.

Neary DG; Michael JL. 1989. Effect of sulfometuron methyl on ground water and stream quality in coastal plain forest watersheds. Wat. Res. Bull. 25(3): 617-623.

Nishikawa S. 1983a. Effects of sulfonamide on the pituitary-thyroid gland: 1. Morphological changes of thyroid gland and variation in plasma thyroxine and triiodothyronine. J. Toxicol. Sci. 8: 47-59.

Nishikawa S. 1983b. Effects of sulfonamide on the pituitary-thyroid gland: 2. Morphological changes of thyrotrophs in anterior pituitary gland. J. Toxicol. Sci. 8: 61-70.

NRC (National Research Council). 1983. Risk assessment in the Federal government: managing the process. Washington, DC: National Academy Press; 176 p. + app.

O'Keefe DP; Romesser JA; Leto KJ. 1988. Identification of constitutive and herbicide-inducible cytochromes P-450 in Streptomyces griseolus. Arch. Microbiol. 149(5): 406-412.

O'Neill AJ. 1990. Acute inhalation toxicity study with INT-5648-18 in rats. Medical Research No. 0581-944; Laboratory Project ID 657-82. (Unpublished study prepared by Haskell Laboratory for Toxicology and Industrial Medicine, E.I. du Pont de Nemours and Co., Inc., Newark, DE). MRID 43089203.

Oldham JD Jr. 1984. Combined chronic toxicity/oncogenicity study with INT-5648: Long-term feeding and two-generation, four litter reproduction study in rats. Medical Research Project No. 4052-001; Supplemental data to Haskell Laboratory Report No. 367-84. (Unpublished study prepared by Haskell Laboratory for Toxicology and Industrial Medicine, E.I. du Pont de Nemours and Co., Inc., Newark, DE). MRID 42385706.

Prasad O; Rai G. 1987. Hematological abnormalities induced by feeding a common artificial sweetener, saccharin, in ICR Swiss mice. Toxicol. Lett. 36(1): 81-8.

Rickard RW. 1992. Combined chronic toxicity/oncogenicity study with INT-5648: Long-term feeding and two-generation, four litter reproduction study in rats. Revision No.1. Medical Research Project No. 4052-001; Supplemental data to Haskell Laboratory Report No. 367-84. (Unpublished study prepared by Haskell Laboratory for Toxicology and Industrial Medicine, E.I. du Pont de Nemours and Co., Inc., Newark, DE). 1437 p. MRID 42385705.

Rowland J. 1998. Personal communication between J. Rowland, U.S. EPA, Office of Pesticide Programs, Health Effects Division, Phone: (703) 308-2719 and Patrick R. Durkin, SERA, Inc., Fayetteville, NY. January 15, 1998.

Rubin L; Mistretta P; Thomas D; Durkin P; Meylan W. 1998. A re-evaluation of methods for assessing occupational exposure in pesticide applicators. Manuscript under review.

Rudinsky JA; Kline LN; Diekman JD. 1975. Response-inhibition by four analogues of MCH, an antiaggregative pheromone of the Douglas-fir beetle. Journal of Economic Entomology. 68(4): 527-528.

Ruffle B; Burmaster DE; Anderson PD; Gordon HD. 1994. Lognormal distributions for fish consumption by the general U.S. population. Risk Analy. 14(4): 395-404.

Sarver JW. 1990a. Primary skin irritation and sensitization test with INT-5648-03 on guinea pigs. Medical Research No. 0581-790; Haskell Laboratory Report No. 232-79. (Unpublished study prepared by Haskell Laboratory for Toxicology and Industrial Medicine, E.I. du Pont de Nemours and Co., Inc., Newark, DE). 69 pp. MRID 43089204.

Sarver JW. 1990b. Primary dermal irritation and sensitization test with IN T5648-40 rabbits. Medical Research No. 0581-804; Haskell Laboratory Report No. 137-90. (Unpublished study prepared by Haskell Laboratory for Toxicology and Industrial Medicine, E.I. du Pont de Nemours and Co., Inc., Newark, DE). 13 pp. MRID 41672808.

Sarver JW. 1990c. Acute skin absorption LD50 test with INT-5648-13. Medical Research No. 0581-907; Haskell Laboratory Report No. 1078-80. (Unpublished study prepared by Haskell Laboratory for Toxicology and Industrial Medicine, E.I. du Pont de Nemours and Co., Inc., Newark, DE). 12 pp. MRID 43089202.

Sarver J. 1990d. Oral LD50 test with INT-5648-11 in male and female rats. Lab Project No. 0581-886; HLR 870-80. (Unpublished study prepared by E. I. du Pont de Nemours and Co., Wilmington, DE). 15 p. MRID 43089201.

Sarver J. 1995. Inhalation median lethal concentration (LC50) study with DPX-T5648-72 (Oust) in rats. Medical Research Project No. 10361-001; Haskell Laboratory Report No. 589-95. (Unpublished study prepared by Haskell Laboratory for Toxicology and Industrial Medicine, E.I. du Pont de Nemours and Co., Newark, DE). 42 p. MRID 43848403.

SAS. 1997. JMP® Statistics and Graphics Guide: Version 3 of JMP. Statistical Discovery Software, SAS Institute, Cary, NC. 593 pp.

Sauers RF; Levitt G. 1984. Sulfonylureas: new high potency herbicides (for control of weeds and grasses, chlorsulfuron, sulfometuron methyl, chemical structures). ACS Symposium series. Am. Chem. Soc. 255: 21-28.

Scheel D; Casida JE. 1985. Sulfonylurea herbicides: growth inhibition in soybean cell suspension cultures and in bacteria correlated with block in biosynthesis of valine, leucine and isoleucine. Pest. Biochem. Physiol. 23(3): 398-412.

Schloss JV; Ciskanik LM; Dyk DEvan. 1988. Origin of the herbicide binding site of acetolactate synthase. Nature, UK. 331(6154): 360-362.

Schneiders GE. 1993. Hydrolysis of [phenyl-^{14}C(U)]- and [pyrimidine-2-^{14}C]sulfometuron methyl in buffer solutions of pH 5, 7, and 9. DuPont Project ID AMR 2426-92. (Unpublished study prepared by E.I. du Pont de Nemours and Co., Wilmington, DE). 48 p. MRID 42715201.

SERA (Syracuse Environmental Research Associates, Inc.). 1998a. Methodology for Human Health Risk Assessments, SERA TR 96-21-07-03e, draft dated March 26, 1998. Prepared under USDA/FS Contract 53-3187-5-12, Order No. 43-3187-7-0407. Syracuse Environmental Research Associates, Inc., Fayetteville, NY.

SERA (Syracuse Environmental Research Associates, Inc.). 1998b. A Re-Evaluation of Methods for Assessing Worker Exposure to Pesticides, SERA TR 96-21-08-01b, draft dated December 31, 1997. Prepared under USDA/FS Contract 53-3187-5-12, Order No. 43-3187-7-0240. Syracuse Environmental Research Associates, Inc., Fayetteville, NY.

Serota DG.; Fieser S; Durloo RS; et al. 1981. Teratology study in rabbits: H-13647-02: Benzoic acid, 2-[[[[(4,6-dimethyl- 2-pyrimidinyl)amino]carbonyl]amino]sulfonyl]-, methyl ester. Project No. 201-555; HLO-331-81. Final report. (Unpublished study received Jul 1, 1981 under 352-401; prepared by Hazleton Laboratories America, Inc., submitted by E.I. du Pont de Nemours and Co., Wilmington, DE; CDL:245515-Q). MRID 00078798.

Serota DG. 1990. Phase 3 reformat of MRID 00078798 and related MRID 00078797: Teratology study in rabbits H-13647-02 benzoic acid, 2-[[[[(4,6-dimethyl-2-pyrimidinyl)-amino]carbonyl]amino]sulfonyl]- methyl ester. HLO 331-81; Project No. 201-555. (Unpublished study prepared by Hazleton Laboratories America, Inc., Vienna, VA; reformatted by E.I. du Pont de Nemours and Co., Wilimington, DE). 169 p. MRID 932060630.

Shaner DL; Singh BK; Stidham MA. 1990. Interaction of imidazolinones with plant acetohydroxy acid synthase: evidence for in vivo binding and competition with sulfometuron. J. Agric. Food Chem. 38(5): 1279-1282.

Stidham MA. 1991. Herbicides that inhibit acetohydroxyacid synthase. Weed Sci. 39(3): 428-434.

Stone DM; Harris AR; Koskinen WC. 1993. Leaching of soil-active herbicides in acid, low base saturated sands: Worst-case conditions. Environ. Toxicol. Chem. 12(3): 399-404.

Strek G; Spaan WP. 1997. Wind erosion control with crop residues in the Sahel. Soil Sci. Soc. Am. J. 61(3): 911-917.

Strek G; Stein A. 1997. Mapping wind-blown mass transport by modeling variability in space and time. Soil Sci. Soc. Am. J. 61(1): 232-239

Strek HJ; Dulka JJ; Parsells AJ. 1990. Humic matter content vs. organic matter content for making herbicide recommendations. Comm. Soil Sci. Plant Anal. 21(13-16): 1985-1995.

Summers JC. 1990a. Phase 3 summary of MRID 41273602: Oncogenicity study with INT-5648: Long-term feeding study in mice. Haskell Laboratory Report No. 355-87. Guideline Reference 83-2(b) Oncogenicity - Mouse. (Unpublished study prepared by Haskell Laboratory for Toxicology and Industrial Medicine, E.I. du Pont de Nemours and Co., Inc., Newark, DE). 26 p. MRID 93206015.

Summers JC. 1990b. Phase 3 summary of MRID 00126714: Subacute dermal toxicity study (21-days) in rabbits. Haskell Laboratory Report No. 792-82. (Unpublished study prepared by Haskell Laboratory for Toxicology and Industrial Medicine, E.I. du Pont de Nemours and Co., Inc., Newark, DE). 31 p. MRID 93206014.

Summers JC. 1990c. Phase 3 summary of MRID 00078798 and related MRID 0078797: Teratology study in rabbits H-13,647-02 for 78798 and pilot oral teratology study in rabbits H-13,647-02 for 78797. Guideline Reference 83-3(b) Teratogenicity - Rabbit. Orignial study prepared by Hazleton Laboratories America, Inc., Vienna, VA; HLO 331-81, Project No. 210-55 for '78/'79 and HLO 234-81, Project No. 210-554 for 78797. (Unpublished study submitted by E.I. du Pont de Nemours and Co., Wilmington, DE). 21 p. MRID 93206017.

Summers JC. 1990d. Phase 3 summary of MRID 00071406: Oral LD_{50} test in rats - EPA Proposed Guidelines: HLR 870-80. Guideline Reference: 81-1 Acute oral toxicity rat. (Unpublished study prepared by Haskell Laboratory for Toxicology and Industrial Medicine, E.I. de Pont de Nemours and Co., Inc., Newark, DE). MRID 93206009.

Summers JC. 1990e. Phase 3 summary of MRID 00146848: Inhalation median lethal concentration (LC_{50}) of INT-5648-18 by EPA protocol: HLR 657-82. (Unpublished study prepared by Haskell Laboratory for Toxicology and Industrial Medicine, E.I. du Pont de Nemours and Co., Inc., Newark, DE). MRID 93206011.

Summers J. 1990f. Phase 3 summary of MRID 00078796: Teratogenicity study by diet in the rat with benzoic acid, 2[[[[(4,6-dimethyl-2-pyrimidinyl) amino]carbonyl]amino]sulfonyl]-, methyl ester. Haskell Laboratory Report No. 316-81. (Unpublished study prepared by Haskell Laboratory for Toxicology and Industrial Medicine, E.I. du Pont de Nemours and Co, Inc., Newark, DE). 14 p. MRID 93206016.

Summers J. 1990g. Phase 3 Summary of MRID 00071407: Primary skin irritation and sensitization test on guinea pigs. Haskell Laboratory Report No. 232-79. (Unpublished study prepared by E.I. Haskell Laboratory for Toxicology and Industrial Medicine, E.I. de Pont de Nemours and Co., Inc., Newark, DE). 9 p. MRID 93206012.

Summers J. 1990h. Phase 3 Summary of MRID 00078793: Chinese hamster ovary cell assay for mutagenicity. Haskell Laboratory Report No. 1074-80. (Unpublished study prepared by E.I. Haskell Laboratory for Toxicology and Industrial Medicine, E.I. de Pont de Nemours and Co., Inc., Newark, DE). 10 p. MRID 93206019.

Summers JC. 1990i. Phase 3 summary of MRID 00071414: Avian dietary toxicity (LC_{50}) study in Mallard ducks H-13,647: HLO 788-80, Hazleton Project No. 210-548. Guideline Reference 71-1(a) Acute avian oral quail/duck. (Original unpublished study prepared by Hazleton Laboratories America, Inc., Vienna, VA; submitted by E.I. du Pont de Nemours and Co., Wilmington, DE). 12 p. MRID 93206004.

Summers JC. 1990j. Phase 3 summary of MRID 00078700: Single-dose oral toxicity study in Mallard ducks H-13,647: HLO 90-81, Hazleton Project No. 210-552. Guideline Reference 71-1(a) Acute avian oral quail/duck. (Original unpublished study prepared by Hazleton Laboratories America, Inc., Vienna, VA; submitted by E.I. du Pont de Nemours and Co., Wilmington, DE). 13 p. MRID 63206002.

Summers JC. 1990k. Phase 3 summary of MRID 00088813. Eight-day dietary LC50-Bobwhite quail H-13,647-03:HLO 464-81, Wildlife Project No. 112-122. (Original unpublished study prepared by Wildlife International Ltd., Easton, MD; submitted by E.I. du Pont de Nemours and Co., Wilmington, DE). 13 p. MRID 93206003

Summers JC. 1990l. Phase 3 summary of MRID 00143539: Early life stage toxicity of INT-5648-18 to fathead minnows: HLR 765-82: Supplement 1. Guideline Reference: 72-4(a) Early life stage fish. (Unpublished study prepared by Haskell Laboratory for Toxicology and Industrial Medicine, E.I. de Pont de Nemours and Co., Inc., Newark, DE). 76 p. MRID 42385704.

Summers JC. 1990m. Phase 3 summary of MRID 00143539: Early life stage toxicity of INT-5648-18 to fathead minnows: HLR 765-82: Supplement 1. Guideline Reference: 72-4(a) Early life stage fish. (Unpublished study prepared by Haskell Laboratory for Toxicology and Industrial Medicine, E.I. de Pont de Nemours and Co., Inc., Newark, DE). 16 p. MRID 93206008.

Summers JC. 1990n. Phase 3 summary of MRID 00071417: 96-Hour LC50 to bluegill sunfish: HLR 629-80: Supplement 1. Guideline Reference: 72-1(a) Fish toxicity bluegill. (Unpublished study prepared by Haskell Laboratory for Toxicology and Industrial Medicine, E.I. de Pont de Nemours and Co., Inc., Newark, DE). 5 p. MRID 42385701.

Summers JC. 1990o. Phase 3 summary of MRID 00071417: 96-Hour LC50 to bluegill sunfish: HLR 629-80: Supplement 1. Guideline Reference: 72-1(a) Fish toxicity bluegill. (Unpublished study prepared by Haskell Laboratory for Toxicology and Industrial Medicine, E.I. de Pont de Nemours and Co., Inc., Newark, DE). 11 p. MRID 93206005.

Summers JC. 1990p. Phase 3 summary of MRID 00071416: 96-Hour LC50 to rainbow trout: HLR 630-80: Supplement 1. Guideline Reference 72-1(c): Fish toxicity rainbow trout. (Unpublished study prepared by Haskell Laboratory for Toxicology and Industrial Medicine, E.I. de Pont de Nemours and Co., Inc., Newark, DE). MRID 93206006.

Summers JC. 1990q. Phase 3 summary of MRID 00071416: 96-Hour LC50 to rainbow trout: HLR 630-80: Supplement 1. Guideline Reference 72-1(c): Fish toxicity rainbow trout. (Unpublished study prepared by Haskell Laboratory for Toxicology and Industrial Medicine, E.I. de Pont de Nemours and Co., Inc., Newark, DE). 11 p. MRID 93206006.

Summers J. 1992r. Phase 3 Summary of MRID 00071418: 48-Hour LD50 to Daphnia magna. Haskell Laboratory Report No. 631-80. Supplement No. 1. (Unpublished study prepared by E.I. Haskell Laboratory for Toxicology and Industrial Medicine, E.I. de Pont de Nemours and Co., Inc., Newark, DE). 5 p. MRID 42385703.

Summers J. 1990s. Phase 3 Summary of MRID 00071418: 48-Hour LC50 to Daphnia magna. Haskell Laboratory Report No. 631-80. Guideline Reference 72-2(a) Invertebrate Toxicity. (Unpublished study prepared by E.I. Haskell Laboratory for Toxicology and Industrial Medicine, E.I. de Pont de Nemours and Co., Inc., Newark, DE). 11 p. MRID 93206007.

Summers J. 1990t. Phase 3 Summary of MRID 00146847: Unscheduled DNA synthesis/rat hepatocytes in vitro. Haskell Laboratory Report No. 769-82. (Unpublished study prepared by E.I. Haskell Laboratory for Toxicology and Industrial Medicine, E.I. de Pont de Nemours and Co., Inc., Newark, DE). 9 p. MRID 93206021.

Summers J. 1990u. Phase 3 Summary of MRID 00078792: Mutagenic activity in the Salmonella/microsome assay. Haskell Laboratory Report No. 271-79. (Unpublished study prepared by E.I. Haskell Laboratory for Toxicology and Industrial Medicine, E.I. de Pont de Nemours and Co., Inc., Newark, DE). 10 p. MRID 93206018.

Summers J. 1990v. Phase 3 summary of MRID 00078795: Ninety-day feeding and one-generation reproduction study with INT- 5648 in rats. Haskell Laboratory Report No. 928-80. (Unpublished study prepared by Haskell Laboratory for Toxicology and Industrial Medicine, E.I. du Pont de Nemours and Co., Inc., Newark, DE). 28 p. MRID 93206013

Summers JC. 1990w. Phase 3 summary of MRID 00146846: Mutagenicity evaluation of H 13, 647-03 in an *in vitro* cytogenetic assay measuring chromosome aberration frequencies in chinese hamster ovary (CHO) cells: HLO 792-81. (Original unpublished study prepared by Litton Bionetics, Inc., Kensington, MD; submitted by E.I. de Pont de Nemours and Co., Wilmington, DE). MRID 93206020.

Taylor JD. 1979. Mutagenic activity in the Salmonella/microsome assay: Haskell Laboratory Report No. 271-79. (Unpublished study received Jul 1, 1981 under 352-401; submitted by E.I. du Pont de Nemours & Co., Wilmington, DE; CDL:245515-K) MRID 00078792.

Thompson S. 1994. Sulfometuron methyl (DPX-T5648): Influence on growth and reproduction of three select algal species: Lab Project Number: AMR 2892-93: 112A-121. (Unpublished study prepared by Wildlife International Ltd, Easton, MD and Haskell Laboratory for Toxicology and Industrial Medicine, E.I. du Pont de Nemours and Co, Inc., Newark, DE). 58 p. MRID 43538502.

Tomlin C. 1997. The Pesticide Manual. 11th Ed. Crop Protection Publications, UK. p. 1128-1130.

Trivits RL. 1979. Acute oral test. Haskell Laboratory Report No. 210-79. (Unpublished study received Jan 23, 1981 under 352-EX-107; submitted by Haskell Laboratory for Toxicology and Industrial Medicine, E.I. du Pont de Nemours and Co., Wilmington, DE; CDL:244195-G). MRID 00071405.

Turner SA. 1987. Post-application movement of sulfometuron methyl from treated rights-of-way areas via wind (soil) erosion. Proc. 4th Symp. Environ. Concerns Rights-of-Way Manag., Indianapolis, IN, October 25-28, 1987. Purdue University, Depart. For. Nat. Res., West Layfayette, IN.

USDA (U.S. Department of Agriculture/Forest Service). 1989a. Final Environmental Impact Statement: Vegetation Management in the Coastal Plain/Piedmont, Management Bulletin R8-MB-23, dated January, 1989. 1213 pp.

USDA (U.S. Department of Agriculture/Forest Service). 1989b. Draft Environmental Impact Statement: Vegetation Management in the Ozark/Ouachita Mountains, Management Bulletin R8-MB-23, dated June, 1989. 499 pp.

USDA (U.S. Department of Agriculture/Forest Service). 1989c. Final Environmental Impact Statement: Vegetation Management in the Appalachian Mountains, Management Bulletin R8-MB-38, dated July, 1989. 1104 pp.

USDA (U.S. Department of Agriculture/Forest Service). 1989d. Sulfometuron Methyl. In: Pesticide Background Statements, Volume III. Nursery Pesticides. Forest Service, Agriculture Handbook Number 670. Avail. NTIS: PB89-226716. pp. SM1-SM13.

USDA (United States Department of Agriculture/Animal and Plant Health Inspection Service). 1993. Nontartget Risk Assessment for the MEDFLY Cooperative Eradication Program. APHIS, USDA, Riverdale, MD. [Pagination not continuous.]

USDA (U.S. Department of Agriculture). 1996. ARS Pesticides Property Database. U.S. Department of Agriculture. Internet Website access (http://ncsr.arsusda.gov/ppdb3/)

USDA (U.S. Department of Agriculture). 1998. Cropland acreage, soil erosion, and installation of conservation buffer strips: preliminary estimates of the 1997 National Resource Inventory. Http://www.nhq.nrcs.usda.gov/land/pubs/buffer1.html.

U.S. EPA (U.S. Environmental Protection Agency) 1985. Development of statistical distribution or ranges of standard factors used in exposure assessments. PB85-242667. [pagination not continuous].

U.S. EPA (U.S. Environmental Protection Agency). 1989a. Recommendations for and Documentation of Biological Values for use in Risk Assessment. U.S. EPA, Environmental Criteria and Assessment Office, Office of Health and Environmental Assessment, Cincinnati, OH. ECAO-CIN-554. [pagination not continuous].

U.S. EPA (U.S. Environmental Protection Agency). 1989b. Exposure Factors Handbook. U.S. EPA, Office of Health and Environmental Assessment, Office of Research and Development, Washington, DC. EPA/600/8-89/043. [pagination not continuous].

U.S. EPA (U.S. Environmental Protection Agency). 1992. Dermal Exposure Assessment: Principles and Applications. EPA/600/8-91/011B. Interim Report. Exposure Assessment Group, Office of Health and Environmental Assessment, Washington, DC.

U.S. EPA (U.S. Environmental Protection Agency). 1996. Exposure Factors Handbook: Volumes I-III. EPA/600/P-95/002Ba, Bb, and Bc. NTIS PB97-117683, 117691, and 117709. [pagination not continuous].

van Hemmen JJ. 1992. Agricultural pesticide exposure data bases for risk assessment. Rev. Environ. Contam. Toxicol. 126: 1-85.

Ward TJ; Boeri RL. 1990a. Static acute toxicity of IN T5648-40 to the sheepshead minnow, *Cyprinodon variegatus*. (Unpublished study prepared by EnviroSystems Division, Resource Analysts, Inc., Hampton, NH). 32 p. MRID 41672803.

Ward TJ; Boeri RL. 1990b. Static acute toxicity of IN T5648-40 to the bivalve mollusc embryos and larvae. (Unpublished study prepared by EnviroSystems Division, Resource Analysts, Inc., Hampton, NH). 32 p. MRID 41672805.

Ward TJ; Boeri RL. 1990c. Static acute toxicity of IN T5648-40 to the mysid, *Mysidopsis bahia*. (Unpublished study prepared by EnviroSystems Division, Resource Analysts, Inc., Hampton, NH). 32 p. MRID 41672804.

Wauchope RD; Williams RG; Marti LR. 1990. Runoff of sulfometuron-methyl and cyanazine from small plots: Effects of formulation and grass cover. J. Environ. Qual. 19(1): 119-125.

Wehtje G; Dickens R; Wilcut JW; Hajek BF. 1987. Sorption and mobility of sulfometuron and imazapyr in five Alabama soils. Weed Sci. 35(6): 858-864.

Wetzel J. 1984. 48-Hour EC50 to *Daphnia magna*. Haskell Laboratory Report No. 147-84. (Revised unpublished study prepared by Haskell Laboratory for Toxicology and Industrial Medicine, E.I. du Pont de Nemours and Co., Inc., Newark, DE). MRID 00145514.

Winegardner, DL. 1996. An Introduction to Soils for Environmental Professionals. Lewis Publishers, New York, NY.

Wolfram Research. 1997. Mathematica Version 3.0.1. Available from Wolfram Research, Inc. Champaign, IL.

Wood CK; McAlack JW; Schneider PW; Barba CM. 1980. Ninety-day feeding and one-generation reproduction study with benzoic acid, 2-[[(4m6-dimethy-2-pyrimidinyl)aminocarbonyl]-amonsulfonyl], methyl ester, INT-5648 in rats. Medical Research Project No. 3492; Haskell Laboratory Report No. 928-80. Final Report. (Unpublished study received Jul 1, 1981 under 352-401; submitted by Haskell Laboratory for Toxicology and Industrial Medicine, E.I. du Pont de Nemours and Co., Newark, DE; CDL:2455155N). MRID 00078795.

Wood C; O'Neal F. 1983. One-year feeding study in dogs with benzoic acid, 2-[[[[(4,6-dimethyl-2-pyrimidinyl)-amino]carbonyl]amino]sulfonyl]-, methyl ester, INT 5648. Haskell Laboratory Report No. 482-82. Final Report. (Unpublished study received Jul 1, 1981 under 352-401; submitted by Haskell Laboratory for Toxicology and Industrial Medicine, E.I. du Pont de Nemours and Co., Newark, DE; CDL:250950A). MRID 00129051.

WSSA (Weed Science Society of America). 1989. Herbicide Handbook of the Weed Science Society of America. Sixth edition. Champaign, IL: Weed Science Society of America. p. 239-240.

Xie Q; Jimenez A. 1996. Molecular cloning of a novel allele of SMR1 which determines sulfometuron methyl resistance in Saccharomyces cerevisiae. FEMS Microbiol. Lett. 137(2-3): 165-8.

6. GLOSSARY

Absorption -- The process by which the agent is able to pass through the body membranes and enter the bloodstream. The main routes by which toxic agents are absorbed are the gastrointestinal tract, lungs, and skin.

Acute exposure -- A single exposure or multiple exposure occurring within a short time (24 hours or less).

Additive effect -- A situation in which the combined effects of two chemicals is equal to the sum of the effect of each chemical given alone. The effect most commonly observed when two chemicals are given together is an additive effect.

Adjuvant(s) -- Formulation factors used to enhance the pharmacological or toxic agent effect of the active ingredient.

Adrenergic -- A type of nerve which uses an adrenaline like substance as a neurotransmitter.

Adsorption -- The tendency of one chemical to adhere to another material.

Adverse-effect level (AEL) -- Signs of toxicity that must be detected by invasive methods, external monitoring devices, or prolonged systematic observations. Symptoms that are not accompanied by grossly observable signs of toxicity. In contrast to Frank-effect level.

Alkaline phosphatase – An enzyme that occurs in various normal and malignant tissues. The activity of the enzyme in blood is useful in diagnosing many illnesses.

Allometric -- pertaining to allometry, the study and measure of growth. In toxicology, the study of the relationship of body size to various physiological, pharmacological, pharmacokinetic, or toxicodynamic processes among species.

Amphibian – A cold-blooded vertebrate capable of operating on land and in water.

Arid – A terrestrial region lacking moisture, or a climate in which the rainfall is not sufficient to support the growth of trees or woody plants.

Assay -- A kind of test (noun); to test (verb).

Bioconcentration factor (BCF) -- The concentration of a compound in an aquatic orgainism divided by the concentration in the ambient water of the organism.

Biologically sensitive -- A term used to identify a group of individuals who, because of their developmental stage or some other biological condition, are more susceptible than the general population to a chemical or biological agent in the environment.

Broadleaf weed -- A nonwoody dicotyledonous plant with wide bladed leaves designated as a pest species in gardens, farms, or forests.

Cancer potency parameter -- A model-dependent measure of cancer potency $(mg/kg/day)^{-1}$ over lifetime exposure. [Often expressed as a q_1^* which is the upper 95% confidence limit of the first dose coefficient (q_1) from the multistage model.]

Carcinogen -- A chemical capable of inducing cancer.

Carcinoma -- A malignant tumor.

Carrier -- In commercial formulations of insecticides or control agents, a substance added to the formulation to make it easier to handle or apply.

Chronic exposure -- Long-term exposure studies often used to determine the carcinogenic potential of chemicals. These studies are usually performed in rats, mice, or dogs and extend over the average lifetime of the species (for a rat, exposure is 2 years).

Conifer -- An order of the Gymnospermae, comprising a wide range of trees, mostly evergreens that bear cones and have needle-shaped or scalelike leaves; timber commercially identified as softwood.

Connected actions -- Exposure to other chemical and biological agents in addition to exposure to the control agent during program activities to control vegetation.

Contaminants -- For chemicals, impurities present in a commercial grade chemical. For biological agents, other agents that may be present in a commercial product.

Controls -- In toxicology or epidemiology studies, a population that is not exposed to the potentially toxic agent under study.

Creatine – An organic acid composed of nitrogen. It supplies the energy required for muscle contraction.

Creatinine – The end product of the metabolism of creatine. It is found in muscle and blood and is excreted in the urine.

Cumulative exposures -- Exposures that may last for several days to several months or exposures resulting from program activities that are repeated more than once during a year or for several consecutive years.

Dams – A term used to designate females of some species such as rats.

Degraded -- Broken down or destroyed.

Dermal -- Pertaining to the skin.

Dislodgeable residues – The residue of a chemical or biological agent on foliage as a result of aerial or ground spray applications, which can be removed readily from the foliage by washing, rubbing or having some other form of direct contact with the treated vegetation.

Dose-response assessment -- A description of the relationship between the dose of a chemical and the incidence of occurrence or intensity of an effect. In general, this relationship is plotted by statistical methods. Separate plots are made for experimental data obtained on different species or strains within a species.

Drift -- That portion of a sprayed chemical that is moved by wind off a target site.

EC_{50} -- A concentration that causes 50% inhibition or reduction. As used in this document, this values refers to a 50% inhibition of growth.

EC_{100} -- A concentration that causes complete inhibition or reduction. As used in this document, this values refers to a complete inhibition of growth.

Empirical -- Refers to an observed, but not necessarily fully understood, relationship in contrast to a hypothesized or theoretical relationship.

Enzymes -- A biological catalyst; a protein, produced by an organism itself, that enables the splitting (as in digestion) or fusion of other chemicals.

Epidemiology study -- A study of a human population or human populations. In toxicology, a study which examines the relationship of exposures to one or more potentially toxic agent to adverse health effects in human populations.

Exposure assessment -- The process of estimating the extent to which a population will come into contact with a chemical or biological agent.

Extrapolation -- The use of a model to make estimates outside of the observable range.

Fetal anomaly – An abnormal condition in a fetus, which is usually the result of a congenital defect.

Formulation -- A commercial preparation of a chemical including any inerts or contaminants.

Frank effects -- Obvious signs of toxicity.

Frank-effect level (FEL) -- The dose or concentration of a chemical or biological agent that causes gross and immediately observable signs of toxicity.

Gavage -- The placement of a toxic agent directly into the stomach of an animal, using a gastric tube.

Genotoxic -- Causing direct damage to genetic material. Associated with carcinogenicity.

Geometric mean -- The measure of an average value often applied to numbers for which a log normal distribution is assumed.

Gestation -- The period between conception and birth; in humans, the period known as pregnancy.

Half-time or half-life -- For compounds that are eliminated by first-order kinetics, the time required for the concentration of the chemical to decrease by one-half.

Hazard quotient (HQ) -- The ratio of the estimated level of exposure to the RfD or some other index of acceptable exposure.

Hazard identification -- The process of identifying the array of potential effects that an agent may induce in an exposed human population.

Hematological -- Pertaining to the blood.

Hematology -- One or more measurements regarding the state or quality of the blood.

Henry's law constant -- An index of the tendency of a compound to volatilize from aqueous solutions.

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. They include such categories as grasses and grass-like vegetation.

Herbicide -- A chemical used to control, suppress, or kill plants, or to severely interrupt their normal growth processes.

Histopathology -- Signs of tissue damage that can be observed only by microscopic examination.

Hydrolysis -- Decomposition or alteration of a chemical substance by water.

Hydroxylation -- The addition of a hydrogen-oxygen or hydroxy (-OH) group to one of the rings. Hydroxylation increases the water solubility of aromatic compounds. Particularly when followed by conjugation with other water soluble compounds in the body, such as sugars or amino acids, hydroxylation greatly facilitates the elimination of the compound in the urine or bile.

Hymolytic anemia – A medical condition in which the number of red blood cells is decreased due to intravascular fragmentation or destruction.

In vivo -- Occurring in the living organism.

In vitro **--** Isolated from the living organism and artificially maintained, as in a test tube.

Inerts -- Adjuvants or additives in commercial formulations of glyphosate that are not readily active with the other components of the mixture.

Interpolation -- The use of mathematical models within the range of observations

Intraperitoneal -- Injection into the abdominal cavity.

Invertebrate -- An animal that does not have a spine (backbone).

Irritant effect -- A reversible effect, compared with a corrosive effect.

LC_{50} (lethal concentration$_{50}$) -- A calculated concentration of a chemical in air to which exposure for a specific length of time is expected to cause death in 50% of a defined experimental animal population.

LD_{50} (lethal dose$_{50}$) -- The dose of a chemical calculated to cause death in 50% of a defined experimental animal population over a specified observation period. The observation period is typically 14 days.

Lowest-observed-adverse-effect level (LOAEL) -- The lowest dose of a chemical in a study, or group of studies, that produces statistically or biologically significant increases in frequency or severity of adverse effects between the exposed population and its appropriate control.

Lymphatic – Pertaining to lymph, a lymph vessel, or a lymph node.

Lymph – A clear water fluid containing white blood cells. Lymph circulates throughout the lymphatic system, removing bacteria and certain proteins from body tissue. It also is responsible for transporting fat from the small intestine and suppling mature lymphocytes to the blood.

Macrophyte – Terrestrial plant

Malignant -- Cancerous.

Margin of safety (MOS) -- The ratio between an effect or no effect level in an animal and the estimated human dose.

Metabolite -- A compound formed as a result of the metabolism or biochemical change of another compound.

Metameter -- Literally, the unit of measure. Used in dose-response or exposure assessments to describe the most relevant way of expressing dose or exposure.

Microorganisms -- A generic term for all organisms consisting only of a single cell, such as bacteria, viruses, and fungi.

Microsomal -- Pertaining to portions of cell preparations commonly associated with the oxidative metabolism of chemicals.

Minimal risk level (MRL) -- A route-specific (oral or inhalation) and duration- specific estimate of an exposure level that is not likely to be associated with adverse effects in the general population, including sensitive subgroups.

Mitochondria -- Subcellular organelles involved in the conversion of food to stored chemical energy.

Most sensitive effect -- The adverse effect observed at the lowest dose level, given the available data. This is an important concept in risk assessment because, by definition, if the most sensitive effect is prevented, no other effects will develop. Thus, RfDs and other similar values are normally based on doses at which the most sensitive effect is not likely to develop.

Multiple chemical sensitivity -- A syndrome that affects individuals who are extremely sensitive to chemicals at extremely low levels of exposure.

Mutagenicity -- The ability to cause genetic damage (that is damage to DNA or RNA). A mutagen is substance that causes mutations. A mutation is change in the genetic material in a body cell. Mutations can lead to birth defects, miscarriages, or cancer.

Non-target -- Any plant or animal that a treatment inadvertently or unavoidably harms.

No-observed-adverse-effect level (NOAEL) -- The dose of a chemical at which no statistically or biologically significant increases in frequency or severity of adverse effects were observed between the exposed population and its appropriate control. Effects may be produced at this dose, but they are not considered to be adverse.

No-observed-effect level (NOEL) -- The dose of a chemical at no treatment-related effects were observed.

Normal distribution -- One of several standard patterns used in statistics to describe the way in which variability occurs in a populations.

Octanol-water partition coefficient (K_{ow}) -- The equilibrium ratio of the concentrations of a chemical in n-octanol and water, in dilute solution.

Ocular -- Pertaining to the eye.

Oxidative phosphorylation -- An metabolic process in which the metabolism of molecules in or derived from nutrients is linked to the conversion (phosphorylation) of ADP to ATP, a major molecule for storing energy in all living things.

Parenteral -- Any form of injection.

Partition -- In chemistry, the process by which a compound or mixture moves between two or more media.

Pathogen – A living organism that causes disease; for example, a fungus or bacteria.

Pathway -- In metabolism, a sequence of metabolic reactions.

Perennial -- A plant species having a life span of more than 2 years.

Permeability – The property or condition of being permeable. In this risk assessment, dermal permeability refers to the degree to which a chemical or herbicide in contact with the skin is able to penetrate the skin.

pH -- The negative log of the hydrogen ion concentration. A high pH (>7) is alkaline or basic and a low pH (<7) is acidic.

pK_a -- The negative log of the hydrogen ion concentration or pH at which 50% of a weak acid is dissociated.

Pharmacokinetics -- The quantitative study of metabolism (i.e., the processes of absorption, distribution, biotransformation, elimination).

Precommercial thinning -- Cutting in immature stands to improve the quality and growth of the remaining stand.

Prospective -- looking ahead. In epidemiology, referring to a study in which the populations for study are identified prior to exposure to a presumptive toxic agent, in contrast to a retrospective study.

Pup – The offspring or young of various animal species.

Release -- A work done to free desirable trees from competition with overstory trees, less desirable trees or grasses, and other forms of vegetative growth.

Reference dose (RfD) -- Oral dose (mg/kg/day) not likely to be associated with adverse effects over lifetime exposure, in the general population, including sensitive subgroups.

Reproductive effects -- Adverse effects on the reproductive system that may result from exposure to a chemical or biological agent. The toxicity of the agents may be directed to the reproductive organs or the related endocrine system. The manifestations of these effects may be noted as alterations in sexual behavior, fertility, pregnancy outcomes, or modifications in other functions dependent on the integrity of this system.

Resorption -- Removal by absorption. Often used in describing the unsuccessful development and subsequent removal of post-implantation embryos.

Retrospective -- looking behind. In epidemiology, referring to a study in which the populations for study are identified after exposure to a presumptive toxic agent, in contrast to a prospective study.

RfD -- A daily dose which is not anticipated to cause any adverse effects in a human population over a lifetime of exposure. These values are derived by the U.S. EPA.

Right-of-way -- A corridor of low growing shrubs or grasses that facilitate the maintenance and protection of utility power lines and provide transport pathways for humans or wildlife.

Route of exposure -- The way in which a chemical or biological agent enters the body. Most typical routes include oral (eating or drinking), dermal (contact of the agent with the skin), and inhalation.

Scientific notation -- The method of expressing quantities as the product of number between 1 and 10 multiplied by 10 raised to some power. For example, in scientific notation, 1 kg = 1,000 g would be expressed as 1 kg = 1×10^3 g and 1 mg = 0.001 would be expressed as 1 mg = 1×10^{-3}.

Sensitive subgroup -- Subpopulations that are much more sensitive than the general public to certain agents in the environment.

Sensitization – A condition in which one is or becomes hypersensitive or reactive to an agent through repeated exposure.

Site preparation -- The removal of competition and conditioning of the soil to enhance the survival and growth of seedlings or to enhance the seed germination.

Species-to-species extrapolation -- A method involving the use of exposure data on one species (usually an experimental mammal) to estimate the effects of exposure in another species (usually humans).

Subchronic exposure -- An exposure duration that can last for different periods of time, but 90 days is the most common test duration. The subchronic study is usually performed in two species (rat and dog) by the route of intended use or exposure.

Substrate -- With reference to enzymes, the chemical that the enzyme acts upon.

Synergistic effect -- A situation is which the combined effects of two chemicals is much greater than the sum of the effect of each agent given alone.

Systemic toxicity -- Effects that require absorption and distribution of a toxic agent to a site distant from its entry point at which point effects are produced. Systemic effects are the obverse of local effects.

Teratogenic -- Causing structural defects that affect the development of an organism; causing birth defects.

Teratology -- The study of malformations induced during development from conception to birth.

Terrestrial – Anything that lives on land as opposed to living in an aquatic environment.

Threshold -- The maximum dose or concentration level of a chemical or biological agent that will not cause an effect in the organism.

Thymus – A small gland that is the site of T-cell production. The gland is composed largely of lymphatic tissue and is situated behind the breastbone. The gland play an important role in the human immune system.

Toxicity -- The inherent ability of an agent to affect living organisms adversely.

Uncertainty factor (UF) -- A factor used in operationally deriving the RfD and similar values from experimental data. UFs are intended to account or (1) the variation in sensitivity among members of the human population; (2) the uncertainty in extrapolating animal data to the case of humans; (3) the uncertainty in extrapolating from data obtained in a study that is less than lifetime exposure; and (4) the uncertainty in using LOAEL data rather than NOAEL data. Usually each of these factors is set equal to 10. See table 2-4 for additional details.

Vehicle -- A substance (usually a liquid) used as a medium for suspending or dissolving the active ingredient. Commonly used vehicles include water, acetone, and corn oil.

Vertebrate -- An animal that has a spinal column (backbone).

Volatile -- Referring to compounds or substances that have a tendency to vaporize. A material that will evaporate quickly.

7. INDEX

F

G

H

I

K

L

M

N

O

P

R

S

T

U

V

W

APPENDICES

Appendix 1: Laboratory and simulation studies on environmental sulfometuron methyl.
Appendix 2: Field studies on the environmental fate of sulfometuron methyl.
Appendix 3: Toxicity of sulfometuron methyl and Oust to experimental mammals.
Appendix 4: Toxicity to birds.
Appendix 5: Bioassays in terrestrial plants.
Appendix 6: Toxicity to fish, aquatic invertebrates, and aquatic plants.

Appendix 1: Laboratory and simulation studies on environmental sulfometuron methyl.

Data Summary	Reference
Aquatic Sediments	
Fate in sediment/pond water systems and flooded soil. $t_{½}$ of 1 month or less in fresh anaerobic aquatic environments. $t_{½}$ of 4 months in sterile soils. Major matabolites saccharin and 2-(aminosulfonyl)-benzoic acid. A.I. has no effect on catabolism of cellulose to $C0_2$ by anaerobic organisms.	Dulka and Anderson (1982) MRID 00143540 Also summarized by Anderson (1990a) MRID 93206025
Bioconcentration	
0.01 and 1.0 mg/L BCF in bluegill sunfish: no bioaccumulation over 28 day exposure. Also no bioaccumulaton in channel catfish exposed to aged sediment containing a.i.	Harvey (1981a) MRID 00146279 Also summarized by Harvey (1990a) MRID 93206028
Hydrolysis	
Hydrolysis of methyl ester to saccharin. Stable at pH 7 and 9 for 30 days. $t_{½}$ of 2 weeks at pH 5.	Harvey et al. (19??), MRID 00071419 Also summarized by Harvey (1990b) MRID 93206022
5 ppm in distilled water. UV Hydrolysis: $t_{½}$ of 1-3 days.	Harvey et al. (1980), MRID 00071420
5 ppm in dark sterile buffers pH 5: 0.026 day^{-1} pH 7: slow, 87% after 30 days pH 10: slow, 92% after 30 days. cleavage of sulfonylurea bridge.	Brattsten (1987) MRID 41672811
Hydrolyis in sterile, buffered, aqueous solutions at pH 5, 7, and 9 at conc. of 3-5 ppm. First order pH 5: $t_{½}$ 8.4 days pH 7: $t_{½}$ 113 days pH 9: $t_{½}$ 134 days Deg products: pH 5: sulfonamide and pyrimidene amine pH 7 and 9: saccharin and pyrimidine amine	Schneiders (1993) MRID 42715201
Hyrolysis in sterile and non-sterile soil. Unlike many studies, uses ^{14}C-pyrimidine ring labbled SM Main metabolite 2-amino-4,6-dimethylpyrimidene. [This may be more chemical/hydrolysis than microbial]. Studies relationship of temp to rates.	Cambon et al. (1992)

Appendix 1: Laboratory and simulation studies on environmental sulfometuron methyl.

Data Summary	Reference
K_{ow}	
K_{ow}, octanol/water partition coefficient pH 5: 11 pH 7: 0.346 pH 9: 0.0136 K_{ow} decrease as pH increase because of increasing ionization of SM (pKa 5.3)	Cadwgan (1990a) MRID 93206001
Soil Degradation/Transport	
Soil, Keyport silt loam, 0.12 ppm [120 g/ha] Soil $t_{½}$ of about 1 month.	Anderson (1980), MRID 00078701 Also summarized by Anderson (1990b) MRID 93206024. Supplemental note in Anderson (1994), MRID 43174102 responding to U.S. EPA questions.
^{14}C-SM, Keyport silt loam, 70% NMHC (normal moisture holding capacity), 25°C. 50% of ^{14}C converted to C02 after 21 weeks (Fig2). Halflife of parent in soil about 4 weeks at 0.14 ppm or 1.3 ppm. No mineralization in sterile flasks. In sterile flasks, disappearance of parent compound was comparable to non-sterile flasks at 1.3 ppm after 24 weeks (8%) but less so at 0.14 ppm (12% vs 8%). ^{14}C-saccharin was major non-volitile deg product. Over time, unextractable soil residues increased. In soil with 20, 50, or 90% SMHC, more degradation at higher higher moisture levels (Table 5).	Anderson and Dulka (1985)
aerobic soil degradation. Keyport silt loam, sterile and nonsterile. 'complete' degradation after 1 year. *non-sterile* biphasic: $t_{½}$ 17 days and 96 days. pyrimidine amine, CO2, residues incorporated in fulvic and humic acides and inol. humin fractions. *sterile* $t_{½}$ 53 days.	Monson and Hoffman (1990) MRID 42091401

Appendix 1: Laboratory and simulation studies on environmental sulfometuron methyl.

Data Summary	Reference

Soil Degradation/Transport (continued)

SM and metabolites from phenyl portion of molecule are mobile in most soils. More so in sandy vs loamy soils and less so in high organic matter soils. As soil pH decreases below 6, SM is protonated and thus less water soluble and less mobile.	Cadwgan (1990b) MRID 93206026

Batch equilibrium studies

Soil		Kd		
Kom				
Fallsington sandy loam		0.71		51
Keyport silt loam	0.97		35	
Myakka sand		1.0		41
Flanagan silt loam	2.85		71	

Abstract with Kd values. 0.29. Not very detailed.	Dickens and Wehtje (1986)
Kd's 0.04-0.6 at 0-20 cm Kd's 0.019-0.036 at 65-95 cm Once herb leaches past the top 10 cm of soil, retardation of hebicides would be slight. Contamination of ground water would depend on rate of decomposition.	Koskinen et al. (1996)
Kd's of 0.12-0.68 in various soils. Kfs/mobility high *lots of details.*	Wehtje et al. (1987)
lysimeters, various soil types, SM at 42.5 g a.i./ha. Mean concentration in soil water: 0.5 µg/L at 10 cm and 0.4 µg/L at 20 cm. Nothing at 40 or 150 cm. p. 401: 'By 80 d post-treatment, the ^{14}C- activity was new background level, suggesting that most of the compound had been degraded or irreversityly sorbed into the upper soil layers.' Rainwater acidity had not effect on leaching rate in acid sand soils. Not effected by litter humus.	Stone et al. (1993)
soil adsorption study. for SM, poor correlation with organic matter (r2=0.271) but a better correlation humic matter (r2=0.729) [see Fig. 3, p. 1991.] Kd values ranging from <0.05 at <1% HM to 5-6 with >2% HM.	Strek et al. (1990)

Appendix 1: Laboratory and simulation studies on environmental sulfometuron methyl.

Data Summary	Reference
Soil Degradation/Transport (continued)	
Field simulation study on percolation and runoff with comparisons to GLEAMS modeling. Application rate of 0.6 kg/ha. Little initial runoff. Generally <1 µg/ml with max of 2.3 µg/ml. Mostly lost from upper root zone by percolation. Rainfall on sandy soil may move most out of 0.1 m of soil quickly. Much slower percolation on clay soil - runoff will be more significant. GLEAMS modeling qualitatively similar but some quant. differences.	Hubbard et al. (1989)
Field simulation study. 0.4 kg/ha to 1.2x2.4 m plots. After 24 hrs, simulated rainfall of 69mm/h until 2 mm runoff occured. 1-2% lost by in runoff regardless of grass cover. Runoff conc.: 0.2-0.5 mg/L max and 0.2-0.09 mg/L mean. [see Table 4, p. 123 for additional details.] Excellent correlations with GLEAMS.	Wauchope et al. (1990)

Appendix 2: Field Studies on the environmental fate of sulfometuron methyl

Application/Field Conditions	Results	Reference
5 sites (Delaware (1.1 kg/ha), NC (0.91 kg/ha), OR (0.44 kg/ha), Colorado (0.15 kg/hr), and Saskatchewan (0.11 kg/ha). Different times of year.	See Figures 4 through 8, p 601. In eastern soils, about 1% of present after 1 year. In OR and CO soils, 6-12%. In SK, 16% at 43 weeks. After two years, 3% and 5% in OR and SK soils [others not measured.] 9% in CO soil at 78 weeks. All of these measurements refer to parent SM. Eastern soils (4.9-6.4 were more acidic than western soils (5.3-7.4). See Table 1 for other differences.	Anderson and Dulka 1985
lateral soil transport	very little lateral transport at slopes of up to 15% after 1 year. SM moved beyond soil column (70Cm) Dettected after >400 d.	Lym and Swenson 1991
0.4 kg/ha as either dispersible granules or pellets in Mississippi (clay) (broadcast aerial) or Florida (sand) (broadcast ground) as dispersible granules (DG) or pellets (P).	Levels in surface water: 23 (P) and 44 (DG) µg/L in Miss. and 5 (P) and 7 (DG) µg/L in Florida. [Pellets were an experimental formulation.] Halftime in soil 5-33 days, in plants 4-11 days	Michael and Neary 1993 additional details in Neary and Michael 1989 data are also in Neary and Michael 1996
see above, FLA	SM not detected in any sediment samples from treated or control waterds (?? Limit of Det 1 mg/m3 [1 mg/1000L or 0.001 mg/L] for water and 0.020 mg/kg for sediment. p. 619) Rain 24 hrs after applic and again 3 days later, 54 mm. Streamflow did not begin until 20 days after treatment. Detected in only 10/185 samples.	Neary and Michael 1989
0, 0.212, and 0.424 g/ha at five sites in Coastal Plain of Georgia. Soil pH 4.8-6.5.	No increase in loblolly pine seedling mortality (Table 2, p. 307) but a marked increase in plants with signs of phytoxicity (Table 3, p. 308, about 5-73% at low and 20-88% at high rate). Least damage at pH 4.8. Others seem comparable. [Could use for d/r curves but only 2 dose points, 1 d.f.]	Mitchell et al. 1991

Appendix 3: Toxicity of sulfometuron methyl and Oust to experimental mammals [a.i. unless specified as *Oust*, in which case the commercial formulation was used].

Animal	Dose/Exposure	Response	Reference
ORAL			
Dogs, Beagles, 1 to 2 years old, six per dose level	0, 200, 1000, and 5000 ppm in the diet for 1 year. Dose levels correspond to 5, 28, and 150 mg/kg respectively based on measured food consumption.	No changes in food consumption or body weight gain. At 1000 and 5000 ppm, mild hemolytic anemia - i.e. dose related decreases in erythrocyte counts, hematocrit, and hemoglobin. Potentially significant effects include increased alkaline phosphatase activity, increased serum cholesterol [females only], decreased serum albumin and creatinine. At 5000 ppm, increased liver weights in females [absolute] and males and females [relative] and increased absolute and relative thymus weights in females. Thymus weights (absolute) were increased in males at 200 and 1000 ppm but not at 5000 ppm. No pathological changes in the thymus at any dose level in either sex.	Wood and O'Neal 1983 MRID 00129051
Mice, Crl:CD-1 (ICR) BR, 80 per sex per dose level	Dietary exposure to 0, 5, 20, 100, and 1000 ppm for 18 months. Mean food consumption in all groups of about 5.5 grams/day.	Decreased body weight gain (6%) in females at 1000 ppm. Mild anemia and hypoproteinemia and a statistically significant increase in incidence of amyloidosis at 1000 ppm in females. No significant effects in males.	Summers 1990a MRID 93206015 This is a summary of Cadwgan 1990a MRID 41273602. This was not identified by EPA in U.S. EPA's search of its files.

Appendix 3: Toxicity of sulfometuron methyl and Oust to experimental mammals [a.i. unless specified as *Oust*, in which case the commercial formulation was used].

Animal	Dose/Exposure	Response	Reference
Rabbits, New Zealand White, 5 per dose at all doses except 300 mg/kg. At this dose level, 6 animals were used. This occurred because of an injury (NOS) in one of five animals originally assigned to this group. The injured animal was anticipated to die but survived the duration of the study.	0, 100, 300, 750, 1000 mg/kg bw on days 6-18 of gestation by gavage in 0.5% methylcellulose in distilled water.	2/5 animals at 1000 mg/kg and 1/5 animals at each of the 100, 300, and 750 mg/kg dose levels died or were sacrificed after evidence of abortion. One rabbit in the 300 mg/kg group was found dead due to possible tracheal intubation. One rabbit in the 750 mg/kg group was found dead during the study for no apparent reason. Five of the animals - one at 100 mg/kg, two at 750 mg/kg, and two at 1000 mg/kg were sacrificed upon evidence of abortion. Signs of toxicity included anorexia, depression, and thinness as well as decreased weight. In the post-treatment period, animals at 1000 mg/kg continued to loose weight. Animals at 300 and 750 mg/kg evidenced decreased weight gain. No clear association of pathology with dose levels. Possible spontaneous abortions in 1/5 at 300 mg/kg/day and 2/5 at 750 and 1000 mg/kg. Increased resorptions and no fetuses at 1000 mg/kg.	Hoberman et al. 1981 MRID 00078797
Rabbits, New Zealand White, 17 per dose level	0, 30, 100, and 300 mg/kg on days 6-18 of gestation by intubation in 0.5% methylcellulose in distilled water.	No statistically significant treatment related signs of toxicity to dams or offspring reported by authors. The total number of fetuses with anomalies was increased [1/100, 2/87, 5/90, 3/96] as was the mean percent of fetal anomalies per litter [0.7, 3.3, 7.2, 3.3].	Serota et al. 1981 MRID 00078798 Summarized by Summers 1990c MRID 93206017 Reformatted by Serota 1990 MRID 93206030

Appendix 3: Toxicity of sulfometuron methyl and Oust to experimental mammals [a.i. unless specified as *Oust*, in which case the commercial formulation was used].

Animal	Dose/Exposure	Response	Reference
Rats, ChR-DC, young adult male, 1 rat per dose level.	5000 and 7500 mg/kg by gavage.	weight loss, NOS	Trivits 1979 MRID 00071405
	11,000 and 17,000 mg/kg by gavage/	weight loss, NOS. Stained perineal area for 1-2 days after dosing	Summarized by Summers 1990b MRID 93206014
Rats, ChR-DC, young male and female, 5 rats per dose level per sex.	5000 mg/kg by gavage.	No mortality. Wet perineal area and slight weight loss. Increase (NOS) in lung weight in males and females with histological changes [apparent inflammation]. 'pink thymus' in 4/5 females.	Dashiell and Hinckle 1980a. MRID 00071406 Summarized by Summers 1990d MRID 93206009
Rats, Crl:CD, young male and female, 5 per dose level per sex.	5000 mg/kg. Gavage in corn oil.	Alopecia in males only	Dashiell and Hall 1980 MRID 00071409
Rats, ChR-DC, young adult male, 6 rats per dose level.	0 and 3400 mg/kg bw, 5 times per week for 2 weeks followed by 14 day recovery period. Gavage in corn oil.	Testis of 1 test rat weighted only 0.97 g, expected is 3 grams and another exhibited mild testicular lesions involving later stages of germ cell maturation. No other gross or microscopic pathology. No mortality.	Hinckle 1979 MRID 00078794
Rats, Crl:CD, male and female, 7-8 weeks old, 15 per sex	5000 mg/kg by gavage.	No mortality. Alopecia on left hind quarters of 1 female rate. No gross lesions on necropsy.	Filliben 1995a MRID 43848401 Summarized by Summers 1990e MRID 93206011

Appendix 3: Toxicity of sulfometuron methyl and Oust to experimental mammals [a.i. unless specified as *Oust*, in which case the commercial formulation was used].

Animal	Dose/Exposure	Response	Reference
Rats, CD, 16 animals per dose group per sex.	Dietary levels of 0, 100, 1000, or 5000 ppm for 90 days. [Average doses for males from Table IX, p. 30: 0, 9, 74, 370 mg/kg/day. Average doses for females from Table X, p. 31: 0, 9, 91, 432 mg/kg/day.] Partial sacrifice (10 per group) after 90 day. Other animals allowed to mate.	Elevated mean leukocyte and lymphocyte counts and decreased neutrophils in males at 5000 ppm. No effects on reproductive parameters. Other hematologic changes - not considered by the study authors to be treatment related - included reduced mean corpuscular hemoglobin concentrations in males at 1000 and 5000 ppm and decreased hemoglobin in females at 5000 ppm. Also elevated serum thyroxine content in female rats at 100 and 1000 ppm.	Wood et al. 1980 MRID 00078795
Rats, female, ChR-CD	0, 50, 1000, and 5000 ppm in the diet on days 6-15 of gestation. At 5000 ppm, the average daily dose was 433 mg/kg. Based similar values for food consumption [Summers 1990, Item 10, p. 9; Lu 1990, Table 3, p. 22], diets containing 50 and 1000 ppm are estimated to correspond to doses of 4.33 mg/kg/day and 86.6 mg/kg/day.	Decreased maternal weight gain associated with decrease food consumption at 5000 ppm. Also, decreased fetal weight at 5000 ppm.	Lu 1981 MRID 00078796 Summarized by Summers 1990f MRID 93206016 Also summarized by Lu 1990 MRID 93206029

Appendix 3: Toxicity of sulfometuron methyl and Oust to experimental mammals [a.i. unless specified as *Oust*, in which case the commercial formulation was used].

Animal	Dose/Exposure	Response	Reference
Rats, Crl:CD, 80 male and 80 female animals per group.	0, 50, 500, and 5000 ppm in the diet for 24 months. Partial sacrifice [10/group] at 1 year. Based on food consumption and body weights, doses were 0, 2, 20, and 199 mg/kg bw for males and 0, 3, 26, and 260 mg/kg bw for females. After 90 days on study, two-generation, four litter reproduction substudy was conducted using 20 animals from each group.	At 5000 ppm, females evidenced decreased weight gain and decreased food consumption. No gross signs of toxicity. Decreased erythrocyte count and hematocrit in males at 500 and 5000 ppm. Mean absolute brain weights in males at 5000 ppm were significantly lower than controls. Dose dependent increase in bile duct hyperplasia and fibrosis in females at 500 and 5000 ppm. At 5000 ppm, number of pups was decreased in the F1 and F2 generations.	Mullin 1984 MRID 00146849 Appears to be identical to Rickard 1992 MRID 42385705 Individual animal pathology given in Oldham 1984 MRID 42385706
DERMAL			
Guinea pigs, male, albino, 10 animals	50% w/v in dimethyl phthalate on day 1 with challenge on day 13.	Mild skin irritation in one challenged animal.	Edwards 1979a MRID 00071407 Individual animal data in Sarver 1990a, MRID 43089204 Summarized by Summers 1990g MRID 93206012
Guinea pigs, Duncan-Hartley, albino, male	0.05 ml of 5% and 50% in dimethyl phthalate on shaved and intact shoulder skin..	No irritation with 5% solution and no to mild irritation with 50% solution. No sensitization on challenge after 13 days.	Dashiell and Silber 1980b MRID 00071413
Guinea pigs, Hartly, male, n=20 in treatment group, n=10 in saline control group and n=5 in dinitrochlorobenzene positive control group. ***OUST: 75% ai***	0.5 g moistened in saline on to clipped skin covered. Removed after 6 hours and scored for irritation at 24 and 48 hours. Procedure performed once per week for 3 weeks.	No delayed contact hypersensitivity. Positive results found with positive control.	Moore 1995 MRID 43848406

Appendix 3: Toxicity of sulfometuron methyl and Oust to experimental mammals [a.i. unless specified as *Oust*, in which case the commercial formulation was used].

Animal	Dose/Exposure	Response	Reference
Rabbits, New Zealand, male, 5 per dose group.	1500, 2000, 5000, and 8000 mg/kg	moderate and mild redness, slight swelling, sporadic weight loss. One animal died in the 2000 mg/kg group. No compound related pathology.	Dashiell and Silber 1980c MRID 00071410
Rabbits, New Zealand, female, 5 per dose group.	2000 mg/kg	Severe to mild redness, severe to slight swelling, sporadic weight loss. No compound related pathology.	
Rabbits, New Zealand, male, 6 per dose group.	0.5 g applied to 2 areas each of intact and abraded skin.	No primary skin irritation.	Dashiell and Henry 1980a MRID 00071411
Rabbits, New Zealand, male and female, 5 per group	2000 mg/kg in physiological saline to the abraded back for 24 hours. Observed for 14-15 days.	Diarrhea, sporadic weight loss, slight erythema and edema.	Dashiell and Silber 1981 MRID 00078791 Summarized by Summers 1990h MRID 93206010
Rabbits, New Zealand, male and female, 5 per sex per dose group	0, 125, 500, 500, and 2000 mg/kg, 6 hours per day for 21 consecutive days.	No signs of toxicity, pathological changes, or changes in clinical chemistry attributed to treatment.	Dashiell and Hinckle 1983 MRID 00126714
Rabbits, New Zealand, male, young, n=6	0.5 g moistened with distilled applied to gauze on the shaved back. Observations at 30-60 minutes and 24, 48, and 72 hours.	No dermal irritation. During the study, one animal died. This was attributed to handling procedure rather than the test compound.	Sarver 1990b MRID 41672808 Individual animal data in Sarver 1990c MRID 43089202

Appendix 3: Toxicity of sulfometuron methyl and Oust to experimental mammals [a.i. unless specified as *Oust*, in which case the commercial formulation was used].

Animal	Dose/Exposure	Response	Reference
Rabbits, New Zealand White, 5 per sex ***OUST: 75.57% a.i.***	5000 mg/kg to the shaved intact skin occluded for 24 hours then removed. 14 day observation period.	No mortality or clinical signs of toxicity. Mild to sever erythema and slight to moderate edema after 2 hours post-removal. Most erythema and all edema resolved by 5 days. Slight to mild erythema and epidermal scaling, sloughing, or desquamation from day 5 to end of study. No gross lesions. Minimal and mild skin discoloration in 1 male and 1 female attributed to shaving prior to necropsy.	Filliben 1995c MDIR 43848402
Rabbits, New Zealand White, female, n=6 ***OUST: 75.57% a.i.***	0.5 g, occluded for 4 hours then removed. Observations at 1, 24, 48, and 72 hours.	Mild to slight primary irritation based on erythema in 1 of 6 animals at 1 hour after application. No effects at 24 hour or later. No signs of systemic toxicity. Weight loss of about 3% in one animal by end of study {this was *not* the animal that evidenced skin irritation.}.	Filliben 1995b MRID 43848405
EYES			
Rabbits, albino, 2 each group	1 mg a.i. in right conjunctival sac with or without washing after 20 seconds	Without washing, mild redness at 1 hour to 1 day and slight swelling at 1-4 hours. With washing, only mild redness at 1 hour.	Edwards 1979b [MRID 00071408]
Rabbits, albino, male, 9	61.8 mg a.i. in right eye with (n=3) or without washing (n=6) after 20 seconds. Observations at 1, 2, 3, and 4 days.	Without washing, slight transient corneal cloudiness in 2/6 animals. With washing, similar effects in 2/3 animals. All eyes were normal within 2-3 days.	Dashiell and Henry 1980a [MRID 00071411]
Rabbits, New Zealand White, male, young, n=6	0.079 g a.i. (0.1 mL) into the lower conjunctival sac of the right eye. No washing. Observations at 1, 24, 48, and 72 hours.	After 1 hour, redness and discharge from the conjunctiva of 3/6 animals. After 24 hours, conjunctival discharge in 1/6 animals. No effects at 48 or 72 hours.	Malek 1990 MRID 41672807

Appendix 3: Toxicity of sulfometuron methyl and Oust to experimental mammals [a.i. unless specified as *Oust*, in which case the commercial formulation was used].

Animal	Dose/Exposure	Response	Reference
Rabbits, New Zealand, White, young adult, n=6 ***Oust***	46 mg (~0.1 ml, ≈34.5 mg a.i.) in one eye. Evaluations at 1, 24, 48, and 72 hours.	At 24 to 48 hours, conjunctival redness, chemosis, and discharge. No corneal opacity or iritis. No effects after 48 hours.	Filliben 1995d MRID 43848404
INHALATION			
Rats, Crl:CD, 7-8 weeks old, male and female, 5 per group	Mean air concentrations of 6.4 or 11 mg/L air for 4 hours, head only.	No apparent signs of toxicity or pathology.	Kinney 1982 MRID 00146848 Individual animal data in O'Neill 1990 MRID 43089203
Rats, Crl:CD, male and female, 8 weeks old, 15 per sex ***OUST: 75.25% a.i.***	Mean air concentrations of 5.1 mg/L air for 4 hours, head only. 14 day recovery period.	Nasal and ocular discharge in male rats. Nasal discharge and wet perineum in female rats. Slight and generally transient weight loss. No gross pathology.	Sarver 1995 MDIR 43848403

Appendix 3: Toxicity of sulfometuron methyl and Oust to experimental mammals [a.i. unless specified as *Oust*, in which case the commercial formulation was used].

Animal	Dose/Exposure	Response	Reference
KINETICS			
Rats	16 mg/kg and 3000 mg/kg	$t_{½}$s of 28 and 40 hours respectively	DuPont 1989. Metabolism of Sulfometuron Methyl in Rats. Unpublished, Feb. 3, 1989, not submitted to EPA, summarized in EXTOXNET, 1994, ref. 10
Lactating goats, n=2, 40 kg bw	sufometuron methyl with double label: pyrimidine-2-^{14}C- and uniformly labelled phenyl ring, capsules, 0.575 mg/kg or 0.625 mg/kg, twice per day for 7 days. [Author give 'dietary' equivalent, apparently based on differences in food consumption of 25 ppm and 60 ppm but the dosing seems to have been by gavage.] Animals sacrificed 20 h after last dose.	94-99% of dose recovered in the urine.	Keoppe and Mucha 1991

Appendix 4: Toxicity to experimental birds.

Animal	Dose	Response	Reference
Ducks, Mallard, 16 days old at start, 10 per dose	0, 156, 312, 625, 1250, 2500, and 5000 ppm in diet for 9 days. [0, 10.3, 19.5, 39.7, 74.4, 141.3, and 332.5 mg/kg bw based on measured food consumption.]	No mortality. No effects on body weight or food consumption.	Dudeck and Twigg 1980 MRID 00071414 also summarized by Summers 1990i MRID 93206004
Ducks, Mallard, approximately 9 months old, 5 per dose per sex.	Single gavage doses in carboxymethylcellulose/distil led water: Vehicle, 312, 625, 1250, 2500, and 5000 mg/kg bw. 14 day observation period.	No mortality or signs of toxicity. In males, decreased weight gain at doses of 625 mg/kg and higher. Magnitude of decrease was not dose/related. No consistent effect of body weight in females.	Dudeck and Bristol 1981a MRID 00078700
Ducks, Mallard, males and females, 5 per sex per dose level	Gavage in carboxymethylcellulose at 0, 312, 625, 1250, 2500, and 5000 mg/kg. 14 day observation period.	No mortality. No dose/related trends in bw or food consumption. No overt signs of toxicity. No gross necropsies conducted.	Summers 1990j MRID 63206002 appears to be identical to Dudeck and Bristol 1981a
Quail, Bobwhite, 15 days old at start, 10 per dose	0, 156, 312, 625, 1250, 2500, and 5000 ppm in diet for 9 days. [0, 1.19, 2.81, 5.00, 9.23, 18.75, and 37.5 mg/kg bw based on measured food consumption.]	Mortality in 5 animials in control group and 1 animal each in the 156, 312, and 2500 ppm dose groups. Lethargy in two animals in the 1250 dose group on observation days 6 and 8. No dose related changes in body weight.	Dudeck and Bristol 1981b MRID 00071415
Quail, Bobwhite, 14 days old, males and females randomly assigned to dose groups, 10 per dose.	Dietary concentrations of 562, 1000, 1780, 2160, and 5620 ppm for 9 days. Dieldrin used as positive control. Based on the dose conversions given in Dudeck and Bristol (1981), the dietary concentrations correspond to dose levels of approximately 4.5, 7.3, 13, 16, and 42 mg/kg bw.	No mortality, overt signs of toxicity, or differences in body weight gain.	Fink et al. 1981 MRID 00088813 also summarized in Summers 1990k MRID 93206003

Appendix 5: Bioassays of sulfometuron methyl toxicity in terrestrial plants.

Plant	Exposure	Response			Reference
DIRECT SPRAY					
Dicots: Soybean, Cocklebur, Cotton, Morningglory, Velvetleaf, Sugar beet Monocots: Corn, Barnyardgrass, Rice, Nutsedge	Sassafras Sandy loam (pH 6.5, OM 1%.	Highly toxic to both broadleaves and grass at 0.01 kg/ha preemergence or postemergence to seedling plants in greenhouse. The minimum rate tested 0.001 kg/ha, significantly affected most plants. See section 4.3 for a detailed discussion and analysis of the dose/response pattern.			Drake 1990 MRID 41672809
Loblolly Pine	greenhouse study. Rates of 0.1, 0.21, and 0.42 kg/ha both foliar and soil as well as combined in fine sandy loam and unclassified loam. No substantial differences in soil types of application methods, so results are combined.	Rate 0 0.10 0.21 0.42	Root length 35.0 20.4 16.2, 12.5	# new roots 27.8 18.8 15.0 12.0	Barnes et al. 1990
	field application 0.30 kg/ha	inhibition over initial 45 days as in greenhouse study. by end of growing season, biomass accumulation was greater in treated plants because of control of competing weeds.			
leafy spurge	0.105 to 1.12 kg/ha	ineffective control. when combined with auxin herbicides, control was effective.			Beck et al. 1993
white mustard, 3 weeks post-emergence [6 true leaves, 50 mm high]	0.25 g/ha, simulated rainfall at 0.5, 1, and 2 hours after treatment. observation at 3 weeks after treatment.	about a 75% reduction in growth relative to controls with 2 hour rainfall. A 64% reduction with 0.5 or 1 hour rainfall. Various adjuvants had minor to moderate effects on 0.5 hour rainfall.			James and Rahman 1992

Appendix 5: Bioassays of sulfometuron methyl toxicity in terrestrial plants.

Plant	Exposure	Response	Reference
SOIL			
Turnips (Brassica rapa), plant selected because of its sensitivity.	pots, 10 days. four different soils (see table 2, p. 143 for differences in soils). greenhouse study. 10 conc from 0.01-40 µg/kg	EC_{50} (µg/kg with 95% conf. inter) for growth inhibition in different soils: Vermiculite: 0.12±0.03 BBA 0.19± 0.04 Wendhausen 0.17±0.04 Horotiu 0.47± 0.16	Gunther et al. 1989
SUSPENSIONS			
Soybean cells	suspension	EC_{50} for growth: 62 µg/L	Scheel and Casida 1985

Appendix 6: Toxicity to fish, aquatic invertebrates, and aquatic plants. [sulfometuron methyl technical unless specified as Oust].

Animal	Exposure	Response	Reference
		FRESHWATER	
Minnow, Fathead, 6 weeks old, 10 per dose group.	0.75 to 12.5 mg/L nominal; 0.6 to 7.3 mg/L measured average concentration. 96 hour exposure and observation period.	No mortality	Muska and Driscoll 1982 MRID 00126600
Minnow, Fathead, embryos and larvae	0, DMF [1]control, 0.15, 0.3, 0.6, 1.2, and 2.5 mg/L [nominal] for 30 days post-hatch. Mean measured concentrations in exposed groups were 0.06, 0.14, 0.32, 0.65, and 1.17 mg/L.	No effect on embryo hatch or larval survival or growth.	Muska and Driscoll 1982 MRID 00126600
Minnow, Fathead, embryos and larvae	This appears to be identical to Muska and Driscoll 1982 MRID 00126600, summarized above		Driscoll 1984 MRID 00143539 Comments by Summers 1990l MRID 42385704 Summarized by Summers 1990m MRID 93206007
Sunfish, Bluegill, 3.4 cm mean length, 0.99 g mean weight, 10 animals per concentration.	0, DMF [1] Control, 0.125, 1.25, 12.5 ppm for 96 hours, static, no aeration. DMF [1] used for stock solution because of poor solubility of test material.	1 of 10 fish at 1.25 ppm died by 48 hours. No mortality in other groups. Summers Comment: Problems with solubility and use of DMF as vehicle.	Muska and Hall 1980 MRID 00071417 Comments by Summers 1990n MRID 42385701 summarized by Summers 1990o MRID 93206005
Sunfish, Bluegill, 1.5-2.6 cm mean length, 0.07-0.42 g mean weight, 30 animials per concentration.	0 and 150 mg/L, pH adjusted and unadjusted, aeration. [nominal conc. was verified by analysis.]	No mortality or signs of toxicity.	Brown 1994a MRID 43501801 [this was missing from fiche and fax by U.S. EPA]

Appendix 6: Toxicity to fish, aquatic invertebrates, and aquatic plants. [sulfometuron methyl technical unless specified as Oust].

Animal	Exposure	Response	Reference
Trout, Rainbow, 4.3 cm mean length and 1.27 g mean weight, 10 animials per concentration.	0, DMF [1] Control, 0.125, 1.25, 12.5 ppm for 96 hours, static, no aeration. DMF [1] used for stock solution because of poor solubility of test material.	No mortality in any groups. No signs of toxicity. Summers Comment: Problems with solubility and used of DMF as vehicle.	Muska and Trivits 1980b MRID 00071416 Comments by Summers 1990p MRID 42385702 Summarized by Summers 1990q MRID 93206006
Trout, Rainbow, fingerlings, 32. to 4.8 cm, 0.47 to 1.79 g, 15 animials per replicate, 2 replicates per concentration.	148 mg/L adjusted to pH 9 to ensure solubility. Duration of 96 hours with observations at 24, 48, 72, and 96 hours. Static, no aeration. Used unadjusted water control and pH 9 adjusted water control.	No mortality in any groups.	Brown 1994b MRID 43501802
Daphnia magna, <24 hours old, 2 replicates per concentration, 10 animals per replicate	0, DMF [1] Control, 0.125, 1.25, 12.5 ppm for 48 hours, static, no aeration. DMF [1] used for stock solution because of poor solubility of test material.	No mortality in exposed groups except for 1 animal at 0.125 ppm. One animal also died in DMF control.	Muska and Trivits 1980a MRID 00071418 Comments by Summers 1990r MRID 42385703 Summarized by Summers 1990s MRID 93206007
Daphnia magna, <24 hours old, 2 replicates per concentration, 10 animals per replicate ***Oust Dispersible Granule (75 DF)***	Nominal concentrations ranging from 1000 mg/L to 10000 mg/L.	LC_{50} 8500 (6500-12200) mg Oust DF/L. [Data for each dose group are given. No mortality at 2400 mg/L or below. 10-30% mortality at 3200 mg/L.]	Wetzel 1984 MRID 00145514
Daphnia magna, seven replicates with 1 adult per replicate and 3 replicates with 5 adults/replicate per exposure level.	Nominal concentrations of 0.1, 0.39, 1.6, 6.3, 25, and 100 mg/L. Mean measured concentrations of 0.076, 0.4, 1.5, 6.1, 24, and 97 mg/L.	Number of neonates per surviving adult significantly reduced at 24 mg/L but not at 97 mg/L or any of the other lower concentrations. No significant effect on adult survival or length at any concentration.	Baer 1990 MRID 41672806

Appendix 6: Toxicity to fish, aquatic invertebrates, and aquatic plants. [sulfometuron methyl technical unless specified as Oust].

Animal	Exposure	Response	Reference
Daphnia magna, <24 hours old, 8 animals per replicate, 4 replicates per concentration.	Unadjusted water, pH 9 adjusted water, and 150 mg a.i./L for 48 hours. [150 mg/L was both nominal and measured value.]	No effects in any test animals exposed to SM. 1/32 test animals in pH adjusted water was immobile at 48 hours.	Brown 1994b MRID 43501803
Four field collected species, 48 duration, no carrier, Oust, acclimated for 96 hrs, pH 8.0-8.5	Group Diaptomus sp. Eucyclops sp. Alonella sp. Cypria sp.	LC_{50} 1315 mg/L 1230 mg/L 802 mg/L 2241 mg/L [see Table on p. 390 for d/r data from 100 to 2500 mg/L.]	Naqvi and Hawkins 1989.
Crayfish, juvenile, Procambarus clarkii, 3-3.4 cm, 1.1-1.5 g) collected, OUST	Acclimated for 96 hrs., exposure period of 24 hrs., pH 6.8±0.1.	LC_{50} 12,174 mg/L (11,980-12,359)	Naqvi et al. 1987
Freshwater Algae, Senenstrum capriconutum	0.63, 1.3, 2.5, 5.0, 10, 20 µg/L for 120 hours.	EC_{50} 4.6(2.6-8.2) µg a.i./L for reduction in cell density relative to controls. [See Table 2 for details. Looks like stimulation of growth at 0.63 µg/L at 120 hours. Some stimulation at higher conc. - up to 2.5 µg/L at 72 hours.]	Hoberg 1990 MRID 41680102
Anabaen flos-aquae, freshwater algae	Nominal concentrations of 13, 25, 50, 100, and 200 µg/L for 120 hours.	EC_{25} for Cell Density 17 (8.8-76) µg/L EC_{50} for Cell Density 65 (31-93) µg/L EC_{50} for Growth Rate 167 (157-182) µg/L	Thompson 1994 MRID 43538502
Navicula pelliculosa, freshwater diatom	370 µg a.i./L	-24% growth relative to controls	

Appendix 6: Toxicity to fish, aquatic invertebrates, and aquatic plants. [sulfometuron methyl technical unless specified as Oust].

Animal	Exposure	Response	Reference
Chlorella	0.3 µM [~110 µg/L]	EC_{50} for growth inhibition.	Landstein et al. 1993
Macrophytes			
Hydrilla verticillata, aquatic angiosperm, rooted aquatic plant - see description on rational for using on p. 509	1 µg/L to 1000 µg/L for 7 days. [Note that Kannuck and Sloman 1995 shows effects at much lower levels.]	see Fig. 3 p. 512, growth and peroxidase activity. Eye-fit on EC_{50} for growth of about 10 µg/L. Higher EC_{50} for induction of peroxidase activity.	Byl et al. 1994
Lemna gibba, macrophyte	0, 0.13, 0.207, 0.323, 0.590, and 1.045 µg a.i./L for 14 days	Frond Counts EC_{25} 0.344(0.305-0.358) µg/L EC_{50} 0.462 (0.436-0.493) µg/L NOEC 0.207 µg/L Biomass EC_{25} 0.451 (0.360-0.534) µg/L EC_{50} 0.785 (0.663-0.982) µg/L NOEC 0.323 µg/L	Kannuck and Sloman 1995 MRID 43538503
		SALT	
Minnow, Sheepshead, juvenile, 20 per level	0, 15, 25, 40, and 60 and 100 mg/L nominal. Measured averages of 0, 8.2, 14.4, 21.7, 29.8, and 45 mg/L. Static, unaerated. 99.1% purity.	No mortality in any group. Insoluble material observed in test chambers.	Ward and Boeri 1990a MRID 41672803
Eastern oyster, embryos and larvae, 2 treatment replicates per concentration and 4 replicates for control. Approx. 30,000 embryos per replicate.	Measured average concentrations of 0, 8.5, 13.9, 22.2, 27.8, and 38.2 mg/L for 48 hours. Unaerated, static.	No concentration related changes in number of animals or number of animals with abnormalities.	Ward and Boeri 1990b MRID 41672805

Appendix 6: Toxicity to fish, aquatic invertebrates, and aquatic plants. [sulfometuron methyl technical unless specified as Oust].

Animal	Exposure	Response	Reference
Shrimp, Mysid, <24 hours old, 20 per replicate, 2 replicates/dose	Measured mean concentrations of 0, 9.8, 15.6, 23.2, 31.5, and 44.8 mg/L for 96 hours. Unaerated, static.	No mortality. Insoluble material observed in test chambers.	Ward and Boeri 1990c MRID 41672804
Skeletonema costatum, marine diatom	410 µg a.i./L	-7.3% growth relative to controls	Thompson 1994 MRID 43538502

[1] **SUMMERS (DuPont) COMMENT ON SOLUBILITY**: Because of its toxicity to aquatic species, DMF (dimethyl formamide) is not one of the EPA preferred solvents. The use of the solvent limits the test concentration since SEP limits the solvent to 0.5 ml/L. The pka of sulfometuron methyl is 5.2. Under unbuffered normal aquatic test conditions, the sol. of SM is < 12.5 ppm at both pH 5 and 7. Under highly buffered conditions, the sol. at pH 7 is 244 ppm at 25°C.

WORKSHEETS FOR SULFOMETURON METHYL

Worksheet Table of Contents

Worksheet Table of Contents

Worksheet Table of Contents

GENERAL ASSUMPTIONS, VALUES, and MODELS

Worksheet 01: Constants and conversion factors used in calculations [CONST]		
Conversion	ID	Value
mg/lb	mg_lb	453,600
mL/gallon	ml_gal	3,785
lb/gallon to mg/mL	lbg_mgml	119.8
lb/acre to µg/cm^2	lbac_ugcm	11.21
lb/acre to mg/cm^2	lbac_mgcm	0.01121
gallons to liters	gal_lit	3.785

Worksheet 02: General Assumptions Used in Worker Exposure Assessments [STD]				
Parameter	Code	Value	Units	Reference
Body Weight (General)	BW	70	kg	ICRP (1975), p. 13
Surface area of hands	Hands	840	cm^2	U.S. EPA 1992
Surface area of lower legs	LLegs	2070	cm^2	U.S. EPA 1992
Weight of liquid adhering to surface of skin after a spill	Liq	0.008	mg/cm^2	Mason and Johnson 1987

Worksheet 03a: Directed Ground Sprays (includes backpack, cut surface, and streamline applications) - General Assumptions Used in Worker Exposure Assessments [BACKPACK]

Parameter/Assumption	Code	Value	Units	Reference
Hours of application per day				
Central estimate		7	hours	USDA 1989a,b,c
Lower estimate		6		
Upper estimate		8		
Acres treated per hour				
Central estimate		0.625	acres/hour	USDA 1989a,b,c
Lower estimate		0.25		
Upper estimate		1		
Acres treated per day				
Central estimate	ACREC	4.375	acres/day	N/A[1]
Lower estimate	ACREL	1.5		
Upper estimate	ACREU	8		
Absorbed dose rate (mg/day)				
Central estimate	RATEC	0.003	(mg agent/kg bw) ÷ (lbs agent handled per day)[2]	Rubin et al. 1998, Table 5
Lower estimate	RATEL	0.0003		
Upper estimate	RATEU	0.01		

[1] Calculated as the product of the number of hours of application and the number of acres treated per hour for each category - i.e., central estimate, lower estimate, and upper estimate.

[2] "Agent" refers to the material being handled and may be expressed in units of a.i. or a.e. Depending on the agent under consideration, additional exposure conversions may be made in the exposure assessment and dose response assessment. For the risk assessment, the only important point is that the exposure and dose/response assessments must use the same units - that is, a.i., a.e., etc. - or the units must be converted to some equivalent form in the risk characterization.

Worksheet 03b: Hydraulic/Broadcast Ground Sprays - General Assumptions Used in Worker Exposure Assessments [HYDSPRAY]

Parameter/Assumption	Code	Value	Units	Reference
Hours of application per day				
Central estimate		7	hours	USDA 1989a,b,c
Lower estimate		6		
Upper estimate		8		
Acres treated per hour				
Central estimate		16	acres/hour	USDA 1989a,b,c
Lower estimate		11		
Upper estimate		21		
Acres treated per day				
Central estimate	ACREC	112	acres/day	N/A[1]
Lower estimate	ACREL	66		
Upper estimate	ACREU	168		
Absorbed dose rate				
Central estimate	RATEC	0.0002	(mg agent/kg bw) ÷ (lbs agent handled per day) [2]	Rubin et al. 1988, Table 5
Lower estimate	RATEL	0.00001		
Upper estimate	RATEU	0.0009		

[1] Calculated as the product of the number of hours of application and the number of acres treated per hour for each category - i.e., central estimate, lower estimate, and upper estimate.

[2] "Agent" refers to the material being handled and may be expressed in units of a.i. or a.e. Depending on the agent under consideration, additional exposure conversions may be made in the exposure assessment and dose response assessment. For the risk assessment, the only important point is that the exposure and dose/response assessments must use the same units - that is, a.i., a.e., etc. - or the units must be converted to some equivalent form in the risk characterization.

Worksheet 03c: Aerial Broadcast Sprays (includes pilots, mixers, and loaders) - General Assumptions Used in Worker Exposure Assessments. [AERIAL]

Parameter/Assumption	Code	Value	Units	Reference
Hours of application per day				
Central estimate		7	hours	USDA 1989a,b,c
Lower estimate		6		
Upper estimate		8		
Acres treated per hour				
Central estimate		70	acres/hour	USDA 1989a,b,c
Lower estimate		40		
Upper estimate		100		
Acres treated per day				
Central estimate	ACREC	490	acres/day	N/A[1]
Lower estimate	ACREL	240		
Upper estimate	ACREU	800		
Absorbed dose rate				
Central estimate	RATEC	0.00003	(mg agent/kg bw) ÷ (lbs agent handled per day) [2]	Rubin et al. 1998, Table 5
Lower estimate	RATEL	0.000001		
Upper estimate	RATEU	0.0001		

[1] Calculated as the product of the number of hours of application and the number of acres treated per hour for each category - i.e., central estimate, lower estimate, and upper estimate.

[2] "Agent" refers to the material being handled and may be expressed in units of a.i. or a.e. Depending on the agent under consideration, additional exposure conversions may be made in the exposure assessment and dose response assessment. For the risk assessment, the only important point is that the exposure and dose/response assessments must use the same units - that is, a.i., a.e., etc. - or the units must be converted to some equivalent form in the risk characterization.

Worksheet 04: General Assumptions Used in Exposure Assessments for the General Public [PUBL]

Narrative: This table contains various values used in the exposure assessments for the general public. Three general groups of individuals are considered: adult male, adult female, and a 2 year old child. Values are specified for body weight, surface areas for various parts of the body, water intake, fish consumption, and the consumption of fruits or vegetables. ***NOTE****: Not all types of value are specified for each group. The only values specified are those used in the risk assessment.*

Description	ID	Value	Units	Reference
Body Weights				
Male, Adult	BWM	70	kg	ICRP (1975), p. 13.
Female, Adult	BWF	64	kg	Burnmaster 1998; U.S. EPA 1985[1]
Child, 2-3 years old	BWC	13.3	kg	U.S. EPA, 1996, page 7-1, Table 7-2
Body Surface Areas				
Female, feet and lower legs	SAF1	2915	cm^2	U.S. EPA, 1992a, p. 8-11, Table 8-3, total for feet and lower legs
Female, exposed skin when wearing shorts and a T-shirt	SAF2	5300	cm^2	U.S. EPA, 1992a, p. 8-11, Table 8-3, total for arms, hands, lower legs, and feet.
Child, male, 2-3 years old, total body surface area	SAC	6030	cm^2	U.S. EPA, 1996, p. 6-15, Table 6-6, 50th percentile.
Water Intake				
Adult				
typical	WCAT	2	L/day	U.S. EPA, 1996, p. 3-28, Table 3-30, midpoint of mean (1.4 L/day) and 90th percentile (2.4 L/day) rounded to one significant place.
lower range for exposure assessment	WCAL	1.4	L/day	U.S. EPA, 1996, p. 3-28, Table 3-30, mean
upper range	WCAH	2.4	L/day	U.S. EPA, 1996, p. 3-28, Table 3-30, 90th percentile
Child, <3 years old				
typical	WCT	1	L/day	U.S. EPA, 1996, p. 3-28, Table 3-30, midpoint of mean (0.61L/day) and 90th percentile (1.5 L/day) rounded to one significant place.
lower range for exposure assessment	WCL	0.61	L/day	U.S. EPA, 1996, p. 3-28, Table 3-30, mean
upper range	WCH	1.50	L/day	U.S. EPA, 1996, p. 3-28, Table 3-30, 90th percentile

Worksheet 04: General Assumptions Used in Exposure Assessments for the General Public [PUBL]

Narrative: This table contains various values used in the exposure assessments for the general public. Three general groups of individuals are considered: adult male, adult female, and a 2 year old child. Values are specified for body weight, surface areas for various parts of the body, water intake, fish consumption, and the consumption of fruits or vegetables. ***NOTE****: Not all types of value are specified for each group. The only values specified are those used in the risk assessment.*

Description	ID	Value	Units	Reference
Fish Consumption				
Freshwater anglers, typical intake per day over a prolonged period	FAT	0.010	kg/day	U.S. EPA, 1996, p. 10-51, average of means from four studies
Freshwater anglers, maximum consumption for a single day	FAU	0.158	kg/day	Ruffle et al. 1994
Native American subsistence populations, typical intake per day	FNT	0.081	kg/day	U.S. EPA, 1996, p. 10-51, median value of 94 individuals
Native American subsistence populations, maximum for a single day	FNU	0.770	kg/day	U.S. EPA, 1996, p. 10-51, highest value of 94 individuals
Consumption of Fruits or Vegetables				
Amount of food consumed per kg bw per day for longer term exposures scenarios.				
Typical	VT	0.0043	kg food/kg bw/day	U.S. EPA, 1996, Table 9-21, p. 9-39, mean intake of vegetables
Upper	VU	0.01	kg food/kg bw/day	U.S. EPA, 1996, Table 9-21, p. 9-39, 95th percentile for intake of vegetables
Worst-case scenario for consumption in a single day, acute exposure scenario only.	VAcute	0.454	kg food	1 lb. The approximate mid range of the above typical and upper limits based on the 64 kg body weight.
Miscellaneous				
Estimate of dislodgeable residue as a proportion of application rate shortly after application.	DisL	0.1	none	Harris and Solomon 1992, data on 2,4-D

[1]This is the average value (63.79 kg), rounded to the nearest kg for 3 different groups of women between 15-49 years old: control (62.07 kg), pregnant (65.90 kg), and lactating (63.48 kg). See Burnmaster 1998, p.218, Table III., Risk Analysis. 18(2): 215-219. This is identical to the body weight for females, 45-55 years old, 50th percentile from U.S. EPA, 1985, page 5, Table 2-2, rounded to nearest kilogram.

Worksheet 05a: Estimated concentrations of pesticides on or in various types of vegetation shortly after application at 1 lb a.i./acre [from Hoerger and Kenaga (1972), Table 9, p. 22]. [HK]

Type of Vegetation	Concentration (mg chemical/kg vegetation)			
	Typical		Upper Limit	
	ID	Value	ID	Value
Range grass	RGT	125	RGU	240
Grass	GST	92	GSU	110
Leaves and leafy crops	LVT	35	LVU	125
Forage crops	FCT	33	FCU	58
Pods containing seeds	PDT	3	PDU	12
Grain	GNT	3	GNU	10
Fruit	FRT	1.5	FRU	7

Worksheet 05b: Concentrations of chemical on spheres (berries) at the specified application rate. [FRUIT]

Diameter (cm)	Planar Surface Area (cm^2)[a]	Amount deposited (mg)[b]	Weight of sphere (kg)[c]	Concentration (mg/kg)[d]
1	0.7853981634	0.008796459	0.0005236	16.8
5	19.6349540849	0.21991148575	0.065449847	3.36
10	78.5398163397	0.87964594301	0.5235987756	1.68
	Application rate	1 lb/acre =	0.0112	mg/cm^2

a Planar surface area of a sphere = πr^2 where r is the radius in cm.

b Amount deposited is calculated as the application rate in mg/cm^2 multiplies by the planar surface area.

c Assumes a density of 1 g/cm^3 for the fruit. The volume of a sphere is$(1\div6)\times \pi \times d^3$ where d is the diameter in cm. Assuming a density of 1 g/cm^3, the weight of the sphere in kg is equal to:

$$kg= (1\div6)\times \pi \times d^3 \div 1000$$

d Amount of chemical in mg divided by the weight of the sphere in kg.

Worksheet 06: Central estimates of off-site drift associated with aerial application of pesticides (from Bird 1995, p. 205) [OFFSITE]

Distance Down Wind ()	ID	Drift as a proportion of application rate
100	DRFT100	0.05
200	DRFT200	0.02
300	DRFT300	0.01
400	DRFT400	0.008

Worksheet 07a: Estimate of first-order absorption rate (k_a in hours^{-1}) and 95% confidence intervals (from Durkin et al. 1998). [KAMODEL]

Model parameters	ID	Value	
Coefficient for $k_{o/w}$	C_KOW	0.233255	
Coefficient for MW	C_MW	0.005657	
Model Constant	C	1.49615	
Number of data points	DP	29	
Degrees of Freedom (d.f.)	DF	26	
Critical value of $t_{0.025}$ with 26 d.f.[1]	CRIT	2.056	
Standard error of the estimate	SEE		
Mean square error or model variance	MDLV	0	
Standard deviation of model (s)	MSD	0	$MDLV^{0.5}$
X′X, cross products matrix	0.307537	-0.00103089	0.00822769
	-0.00103089	0.000004377	-0.0000944359
	0.0082	-0.0000944359	0.0085286

[1] Mendenhall and Scheaffer, 1973, Appendix 3, 4, p. A31.

Central (maximum likelihood) estimate:

$$\log_{10} k_a = 0.233255 \log_{10}(k_{o/w}) - 0.005657\, MW - 1.49615$$

95% Confidence intervals for $\log_{10} k_a$

$$\log_{10} k_a \pm t_{0.025} \times s \times (a\, X\, X\, a)^{0.5}$$

where a is a column vector of {1, MW, $\log_{10}(k_{o/w})$}.

NB: Although the equation for the central estimate is presented with $k_{o/w}$ appearing before MW to be consistent with the way a similar equation is presented by EPA, MW must appear first in column vector a because of the way the statistical analysis was conducted to derive X′X .

See following page for details of calculating $a\, X\, X\, a$ without using matrix arithmetic.

Worksheet Worksheet 07a (continued)
Details of calculating a X X a

The term $\mathbf{a}' \cdot (\mathbf{X}'\mathbf{X})^{-1} \cdot \mathbf{a}$ requires matrix multiplication. While this is most easily accomplished using a program that does matrix arithmetic, the calculation can be done with a standard calculator.

Letting

$$\mathbf{a} = \{a\_1, a\_2, a\_3\}$$

and

$$(\mathbf{X}'\mathbf{X})^{-1} = \{ \{b\_1, b\_2, b\_3\}, \{c\_1, c\_2, c\_3\}, \{d\_1, d\_2, d\_3\} \},$$

$\mathbf{a}' \cdot (\mathbf{X}'\mathbf{X})^{-1} \cdot \mathbf{a}$ is equal to

Term 1: {a_1 ×([a_1×b_1] + [a_2×c_1] + [a_3×d_1])} +
Term 2: {a_2 ×([a_1×b_2] + [a_2×c_2] + [a_3×d_2])} +
Term 3: {a_3 ×([a_1×b_3] + [a_2×c_3] + [a_3×d_3])}.

Worksheet 07b: Estimate of dermal permeability (K_p in cm/hr) and 95% confidence intervals (data from U.S. EPA 1992). [PKMODEL]

Model parameters	ID	Value	
Coefficient for $k_{o/w}$	C_KOW	0.706648	
Coefficient for MW	C_MW	0.006151	
Model Constant	C	2.72576	
Number of data points	DP	90	
Degrees of Freedom (d.f.)	DF	87	
Critical value of $t_{0.025}$ with 87 d.f.[1]	CRIT	1.96	
Standard error of the estimate	SEE	45.9983	
Mean square error or model variance	MDLV	0.528716	
Standard deviation of model (s)	MSD	0.727129	$MDLV^{0.5}$
X′X, cross products matrix	0.0550931	-0.0000941546	-0.0103443
	-0.0000941546	0.0000005978	-0.0000222508
	-0.0103443	-0.0000222508	0.00740677

[1] Mendenhall and Scheaffer, 1973, Appendix 3, Table 4, p. A31.

NOTE: The data for this analysis is taken from U.S. EPA (1992), Dermal Exposure Assessment: Principles and Applications, EPA/600/8-91/011B, Table 5-4, pp. 5-15 through 5-19. The EPA report, however, does not provide sufficient information for the calculation of confidence intervals. The synopsis of the above analysis was conducted in STATGRAPHICS Plus for Windows, Version 3.1 (Manugistics, 1995) as well as Mathematica, Version 3.0.1.1 (Wolfram Research, 1997). Although not explicitly stated in the EPA report, 3 of the 93 data points are censored from the analysis because they are statistical outliers: [Hydrocortisone-21-yl]-hemipimelate, n-nonanol, and n-propanol. The model parameters reported above are consistent with those reported by U.S. EPA but are carried out to greater number of decimal places to reduce rounding errors when calculating the confidence intervals. See notes to Worksheet 07a for details of calculating maximum likelihood estimates and confidence intervals.

CHEMICAL SPECIFIC VALUES

Worksheet 10: Anticipated Application and Dilution Rates for sulfometuron methyl [WS10]				
Item	Code	Value	Units	Reference/Source
Typical application rate	Typ	0.1	lb a.i./acre	Table 2-3
Lowest application rate	Low	0.023	lb a.i./acre	Table 2-3
Highest application rate	Hi	0.38	lb a.i./acre	Table 2-3
Lowest dilution	LDil	15	gal./acre	DuPont 1997a,b
Highest dilution	HDil	40	gal./acre	DuPont 1997a,b

Typical concentration in applied solution:

Typical application rate divided by the average of the lowest and highest dilutions, converted to mg/mL, and rounded to two significant places after the decimal.

0.1 lb/acre ÷ [(15 gal/acre + 40 gal/acre)/2] × 119.8 (mg/mL)/(lb/gal) = **0.44 mg/mL** [TypDr]

Lowest estimated concentration in applied solution:

Lowest application rate divided by the highest dilution, converted to mg/mL, and rounded to two significant places after the decimal.

0.023 lb/acre ÷ 40 gal/acre) × 119.8 (mg/mL)/(lb/gal) = **0.07 mg/mL** [LowDr]

Highest estimated concentration in applied solution:

Highest application rate divided by the lowest dilution, converted to mg/mL, and rounded to two significant decimal places after the decimal.

0.38 lb/acre ÷ 15 gal/acre × 119.8 (mg/mL)/(lb/gal) = **3.03 mg/mL** [HI_Dr]

Worksheet 11: Summary of central estimate and range of concentrations of sulfometuron methyl in field solutions.				
Parameter	ID	Value	Units	Reference/Source
Typical	TypDR	0.44	mg/mL	see calculations above
Low	LowDR	0.07	mg/mL	
High	Hi_DR	3.03	mg/mL	

Worksheet 12: Chemical specific values used for sulfometuron methyl in exposure assessment worksheets. [WS12]

Parameter	ID	Value	Units	Source/Reference
Molecular weight	MW	364.38	grams/mole	Budivari 1989
Water Solubility, pH 7	WS	244	mg/L	Budivari 1989
$K_{o/w}$, pH 7	Kow	0.346	unitless	Cadwgan 1990a
Foliar half-time ($t_{½}$)	FT12	10	days	Knisel, et al.. 1992, Table P-2, p. 153.
Measured Bioconcentration factor ($\boldsymbol{BCF}_{(kg\ fish/L)}$)	BCFT	1	kg fish/L	[a] Harvey 1981a
Estimate BCF	BCFC	0.748	kg fish/L	[b] Calabrese and Baldwin, 1993
Provisional RfD[c]	RfDP	0.02	mg/kg bw/day	Section 3.3.3
lb a.i./lb Oust		0.75	unitless	Section 2

[a] No bioconcentration noted. This is equivalent to a BCF of 1 or unity.

[b] Recommended equation for concentration in fish muscle (edible portion) is:

$$\log(BCF) = 0.54 \log (K_{o/w}) + 0.124$$

Taken from Neely et al. (1974). Partition coefficient to measure bioconcentration potential of organic chemicals in fish. Env. Sci. Technol. 8:(13) 1113-1115.

[c] **NB: The U.S. EPA has not derived an RfD for sulfometuron methyl. The term provisional RfD is used simply to identify the use of the value of 0.02 mg/kg bw as derived as part of this risk assessment.**

Worksheet 13: Calculation of first-order dermal absorption rate (k_a) for sulfometuron methyl.							
Parameters	Value	Units	Reference				
Molecular weight	364.38	g/mole					
$K_{o/w}$ at pH 7	0.346	unitless					
$\log_{10} K_{o/w}$	-0.46092390121						
Column vector ***a*** for calculating confidence intervals (see Worksheet 08 for definitions.)							
a_1	1						
a_2	364.38						
a_3	-0.46092390121						
Calculation of $\mathbf{a}' \cdot (\mathbf{X}'\mathbf{X})^{-1} \cdot \mathbf{a}$ - see Worksheet Worksheet 07a for details of calculation.							
Term 1	-0.0718782742						
Term 2	0.22137142556						
Term 3	0.0138802157						
$\mathbf{a}' \cdot (\mathbf{X}'\mathbf{X})^{-1} \cdot \mathbf{a}$	0.1634	calculation verified in Mathematica 3.0.1.1					
$\log_{10} k_a = 0.233255 \log_{10}(k_{o/w}) - 0.005657\ MW - 1.49615$			WS07a				
$\log_{10}$ of first order absorption rate (k_a)							
Central estimate	-3.66496046458	±	$t_{0.025}$	×	s	×	$(\mathbf{a}' \cdot (\mathbf{X}'\mathbf{X})^{-1} \cdot \mathbf{a})^{0.5}$
Lower limit	-4.3192110987	-	2.0560	×	0.787218	×	0.4042276586
Upper limit	-3.01070983045	+	2.0560	×	0.787218	×	0.4042276586
First order absorption rates (i.e., antilog or 10^x of above values).							
Central estimate	0.00021629	$hours^{-1}$					
Lower limit	0.000048	$hours^{-1}$					
Upper limit	0.00097564	$hours^{-1}$					

Worksheet 14: Calculation of dermal permeability rate (K_p) in cm/hour for sulfometuron methyl.								
Parameters	Value	Units	Reference					
Molecular weight	364.38	g/mole						
$K_{o/w}$ at pH 7	0.346	unitless						
$\log_{10} K_{o/w}$	-0.46092390121							
Column vector ***a*** for calculating confidence intervals (see Worksheet 07a for definitions.)								
a_1	1							
a_2	364.38							
a_3	-0.46092390121							
Calculation of $\mathbf{a}' \cdot (\mathbf{X}'\mathbf{X})^{-1} \cdot \mathbf{a}$ - see Worksheet 07b for details of calculation.								
Term 1	0.025552982							
Term 2	0.0488005715							
Term 3	0.0100785638							
$\mathbf{a}' \cdot (\mathbf{X}'\mathbf{X})^{-1} \cdot \mathbf{a}$	0.0844	calculation verified in Mathematica 3.0.1.1						
$\log_{10} k_p = 0.706648 \log_{10}(k_{o/w}) - 0.006151\ MW - 2.72576$							Worksheet 07b	
$\log_{10}$ of dermal permeability								
Central estimate	-5.29277233294	±	$t_{0.025}$	×	s	×	$\mathbf{a}' \cdot (\mathbf{X}'\mathbf{X})^{-1} \cdot \mathbf{a}^{0.5}$	
Lower limit	-5.70680895868	-	1.9600	×	0.727129	×	0.2905167809	
Upper limit	-4.8787357072	+	1.9600	×	0.727129	×	0.2905167809	
Dermal permeability								
Central estimate	0.0000051	cm/hour						
Lower limit	0.0000020	cm/hour						
Upper limit	0.0000132	cm/hour						

Worksheet 15: Summary of chemical specific dermal absorption values used for sulfometuron methyl dermal absorption. [WS15]				
Description	Code	Value	Units	Reference/Source
Zero-order absorption (K_p)				
Central estimate	KpC	0.0000051	cm/hour	Worksheet 14, values rounded to two significant figures
Lower limit	KpL	0.0000020	cm/hour	
Upper limit	KpU	0.000013	cm/hour	
First-order absorption rates (k_a)				
Central estimate	AbsC	0.00022	$hour^{-1}$	Worksheet 13, values rounded to two significant figures
Lower limit	AbsL	0.000048	$hour^{-1}$	
Upper limit	AbsU	0.00098	$hour^{-1}$	

Worksheet 16: Estimates of the concentration of sulfometuron methyl in ambient water per lb a.i. applied per acre. [Used in chronic contaminated water exposure assessment.]					
Scenario	Ambient Conc. mg/L	Appl. Rate (lb a.i./acre)	ID	WCR[a] (mg/L) ÷ (lb a.i./acre)	Reference
Typical	0.01957	0.36	AWT	0.054	Michael and Neary 1993: see section 3.2.3.4. for discussion of estimates and data quality.
Low	0.0050	0.36	AWL	0.014	
High	0.0440	0.36	AWU	0.12	
[a] Expected water contamination rate - mg/L in water after the application of sulfometuron methyl at a given rate in lb a.i./acre.					

WORKER EXPOSURE ASSESSMENTS

Worksheet 17: Worker exposure estimates for directed foliar (backpack) applications of sulfometuron methyl [WS17]				
Parameter/Assumption	Code	Value	Units	Source/Designation
Application rates				
Central estimate	WS10C	0.1	lbs a.i./day	WS10.TYP
Lower estimate	WS10L	0.023	lbs a.i./day	WS10.LOW
Upper estimate	WS10U	0.38	lbs a.i./day	WS10.HI
Acres treated per day				
Central estimate	ACREC	4.375	acres/day	WS03.ACREC
Lower estimate	ACREL	1.5	acres/day	WS03.ACREL
Upper estimate	ACREU	8	acres/day	WS03.ACREU
Amount handled per day (product of application rate and acres treated per day)				
Central estimate	HANDLC	0.4375	lb/day	
Lower estimate	HANDLL	0.0345	lb/day	
Upper estimate	HANDLU	3.04	lb/day	
Absorbed dose rate (mg/day)				
Central estimate	RATEC	0.003	(mg agent/kg bw) ÷ (lbs agent handled per day)	WS03.RATEC
Lower estimate	RATEL	0.0003		WS03.RATEL
Upper estimate	RATEU	0.01		WS03.RATEU
Absorbed dose (product of amount handled and absorbed dose rate)				
Central estimate	DOSEC	0.0013	mg/kg bw/day	N/A
Lower estimate	DOSEL	0.000010		
Upper estimate	DOSEU	0.030		

Worksheet 18: Worker exposure estimates for boom spray (hydraulic ground spray) applications of sulfometuron methyl [WS17]				
Parameter/Assumption	Code	Value	Units	Source/Designation
Application rates				
Central estimate	WS10C	0.1	lbs a.i./day	WS10.TYP
Lower estimate	WS10L	0.023	lbs a.i./day	WS10.LOW
Upper estimate	WS10U	0.38	lbs a.i./day	WS10.HI
Acres treated per day				
Central estimate	ACREC	112	acres/day	WS04.ACREC
Lower estimate	ACREL	66	acres/day	WS04.ACREL
Upper estimate	ACREU	168	acres/day	WS04.ACREU
Amount handled per day (product of application rate and acres treated per day)				
Central estimate	HANDLC	11.2	lb/day	
Lower estimate	HANDLL	1.518	lb/day	
Upper estimate	HANDLU	63.84	lb/day	
Absorbed dose rate				
Central estimate	RATEC	0.00010	(mg agent/kg bw) ÷ (lbs agent handled per day)	WS04.RATEC
Lower estimate	RATEL	0.00001		WS04.RATEL
Upper estimate	RATEU	0.00100		WS04.RATEU
Absorbed dose (product of amount handled and absorbed dose rate)				
Central estimate	DOSEC	0.0011	mg/kg bw/day	N/A
Lower estimate	DOSEL	0.000015		
Upper estimate	DOSEU	0.06384		

Worksheet 19: Workers: Accidental Dermal Exposure Assessments Using Zero-Order Absorption			
Parameter	Value	Units	Source
Body weight (*W*)	70	kg	WS02.BW
Surface Area of hands (*S*)	840	cm^2	WS02.Hands
Dermal permeability (K_p, cm/hour) [see Worksheet 14]			
Typical	0.0000051	cm/hour	WS15.KpC
Lower	0.0000020	cm/hour	WS15.KpL
Upper	0.0000130	cm/hour	WS15.KpU
Concentration in solution (*C*) [see Worksheet 11]			
Typical	0.44	mg/mL	WS11.TypDr
Lower	0.07	mg/mL	WS11.LowDr
Upper	3.03	mg/mL	WS11.HI_Dr

Note that 1 mL is equal to 1 cm^3 and thus mg/mL = mg/cm^3.

Details of calculations for worker zero-order dermal absorption scenarios.

Equation (U.S. EPA 1992)

$$K_p \cdot C \cdot Time(hr) \cdot S \cdot \div W = Dose(mg/kg)$$

where: C = concentration in mg/cm^3 or mg/mL, S = Surface area of skin in cm^2, W = Body weight in kg.

Immersion of Hands or Wearing Contaminated Gloves for One-Minute

Typical Value: Use typical concentration and central estimate of K_p.
0.0000051 cm/hr × 0.44 mg/cm^3 × 1/60 hr × 840 cm^2 ÷ 70 kg = 4.5e-07 mg/kg [WZHT1M]

Lower Estimate: Use lower range of estimated concentration and lower limit of K_p.
0.0000020 cm/hr × 0.07 mg/cm^3 × 1/60 hr × 840 cm^2 ÷ 70 kg = 2.8e-08 mg/kg [WZHL1M]

Upper Estimate: Use upper range of estimated concentration and upper limit of K_p.
0.0000130 cm/hr × 3.03 mg/cm^3 × 1/60 hr × 840 cm^2 ÷ 70 kg = 7.9e-06 mg/kg [WZHU1M]

Wearing Contaminated Gloves for One-Hour

Typical Value: Use typical concentration and central estimate of K_p.
0.0000051 cm/hr × 0.44 mg/cm^3 × 1 hr × 840 cm^2 ÷ 70 kg = 2.7e-05 mg/kg [WZHT1H]

Lower Estimate: Use lower range of estimated concentration and lower limit of K_p.
0.0000020 cm/hr × 0.07 mg/cm^3 × 1 hr × 840 cm^2 ÷ 70 kg = 1.7e-06 mg/kg [WZHL1H]

Upper Estimate: Use upper range of estimated concentration and upper limit of K_p.
0.0000130 cm/hr × 3.03 mg/cm^3 × 1 hr × 840 cm^2 ÷ 70 kg = 4.7e-04 mg/kg [WZHU1H]

Worksheet 20: Worker Accidental Spill Based on the Assumption of First-Order Absorption			
Parameter	Value	Units	Source
Liquid adhering to skin after a spill (***L***)	0.008	mg/mL	WS02.Liq
Body weight (***W***)	70	kg	WS02.BW
Surface Areas (**A**)			
Hands	840	cm^2	WS02.Hands
Lower legs	2070	cm^2	WS02.LLegs
First-order dermal absorption rates (k_a)			
Central Estimate	0.00022	$hour^{-1}$	WS15.ABSC
Lower limit of range	0.000048	$hour^{-1}$	WS15.ABSL
Upper limit of range	0.00098	$hour^{-1}$	WS15.ABSU
Concentration in solution (***C***) [see Worksheet Worksheet 10]			
Typical	0.44	mg/mL	TypDr
Lower	0.07	mg/mL	LowDr
Upper	3.03	mg/mL	HI_Dr

Details of calculations.

Equation (from Durkin et al. 1995)

$$Dose_{(mg/kg\ bw)} = k_{a\ (1/hours)} \times L_{(mg/cmsq)} \times C_{(mg/mL)} \times T_{(hours)} \times A_{(cm\ sq)} \div W_{(kg)}$$

where ***T*** is the duration of exposure in hours and other terms are defined as above.

Lower Legs: Spill with 1 Hour (*T*) Exposure Period

Typical Value [WFLT1H],
$0.0002200\ h^{-1} \times 0.008\ mL/cm \times 0.44\ mg/cm^3 \times 1\ hr \times 2070\ cm^2 \div 70\ kg =$ 2.3e-05 mg/kg
Lower range [WFLL1H],
$0.0000480\ h^{-1} \times 0.008\ mL/cm \times 0.07\ mg/cm^3 \times 1\ hr \times 2070\ cm^2 \div 70\ kg =$ 7.9e-07 mg/kg
Upper range [WFLU1H],
$0.0009800\ h^{-1} \times 0.008\ mL/cm \times 3.03\ mg/cm^3 \times 1\ hr \times 2070\ cm^2 \div 70\ kg =$ 7.0e-04 mg/kg

Hands: Spill with 1 Hour (*T*) Exposure Period

Typical Value [WFHT1H],
$0.0002200\ h^{-1} \times 0.008\ mL/cm \times 0.44\ mg/cm^3 \times 1\ hr \times 840\ cm^2 \div 70\ kg =$ 9.3e-06 mg/kg
Lower range [WFHL1H],
$0.0000480\ h^{-1} \times 0.008\ mL/cm \times 0.07\ mg/cm^3 \times 1\ hr \times 840\ cm^2 \div 70\ kg =$ 3.2e-07 mg/kg
Upper range [WFHU1H],
$0.0009800\ h^{-1} \times 0.008\ mL/cm \times 3.03\ mg/cm^3 \times 1\ hr \times 840\ cm^2 \div 70\ kg =$ 2.9e-04 mg/kg

Worksheet 21: Direct spray of child.			
Verbal Description*: A naked child is accidentally sprayed over the entire body surface with a field dilution as it is being applied. The child is effectively washed - i.e., all of the compound is removed - after 1 hour. The absorbed dose is estimated using the assumption of first-order dermal absorption.*			
Parameter/Assumption	Value	Units	Source/Reference
Period of exposure (***T***)	1	hour	N/A
Body weight (***W***)	13	kg	WS04.BWC
Exposed surface area (***A***)	6030	cm^2	WS04.SAC
Liquid adhering to skin per cm^2 of exposed skin.(***L***)	0.008	mL/cm^2	WS02.LIQ
Concentrations in solution (***C***)			
Typical/Central	0.44	mg/mL	WS11.TYPDR
Low	0.07	mg/mL	WS11.LOWDR
High	3.03	mg/mL	WS11.HI_DR
First-order dermal absorption rate (k_a)			
Central	0.0002	$hour^{-1}$	WS15.AbsC
Low	0.000048	$hour^{-1}$	WS15.AbsL
High	0.00098	$hour^{-1}$	WS15.AbsU
Estimated Absorbed Doses (***D***) - ***see calculations below.***			
Central	0.00036	mg/kg	SPRYC
Low	0.000012	mg/kg	SPRYL
High	0.011	mg/kg	SPRYH

Details of calculations

Equation: $L \times C \times A \times k_a \times T \div W$

Central Estimate [SPRYCC]:
0.008 mg/mL × 0.44 mg/mL × 6030 cm^2 × 0.00022 h^{-1} × 1 h ÷ 13 kg = 0.00036 mg/kg

Lower Range of Estimate [SPRYCL]:
0.008 mg/mL × 0.07 mg/mL × 6030 cm^2 × 0.000048 h^{-1} × 1 h ÷ 13 kg = 0.000012 mg/kg

Upper Range of Estimate [SPRYCH]:
0.008 mg/mL × 3.03 mg/mL × 6030 cm^2 × 0.00098 h^{-1} × 1 h ÷ 13 kg = 0.011 mg/kg

Worksheet 22: Direct spray of woman.			
Verbal Description*: A woman is accidentally sprayed over the feet and legs with a field dilution as it is being applied. The woman washes and removes all of the compound after 1 hour. The absorbed dose is estimated using the assumption of first-order dermal absorption.*			
Parameter/Assumption	Value	Units	Source/Reference
Period of exposure (***T***)	1	hour	N/A
Body weight (***W***)	64	kg	WS04.BWF
Exposed surface area (***A***)	2915	cm^2	WS04.SAF1
Liquid adhering to skin per cm^2 of exposed skin.(***L***)	0.008	mL/cm^2	WS02.LIQ
Concentrations in solution (***C***)			
Typical/Central	0.44	mg/mL	WS11.TYPDR
Low	0.07	mg/mL	WS11.LOWDR
High	3.03	mg/mL	WS11.HI_DR
First-order dermal absorption rate (k_a)			
Central	0.0002	$hour^{-1}$	WS15.AbsC
Low	0.000048	$hour^{-1}$	WS15.AbsL
High	0.001	$hour^{-1}$	WS15.AbsU
Estimated Absorbed Doses (***D***) - ***see calculations below.***			
Central	0.000035	mg/kg	SPRYWC
Low	0.000001	mg/kg	SPRYWL
High	0.0011	mg/kg	SPRYWH

Details of calculations

Equation: $L \times C \times S \times k_a \times T \div W$

Central Estimate [SPRYWC]:
0.008 mg/mL × 0.44 mg/mL × 2915 cm^2 × 0.00022 h^{-1} × 1 h ÷ 64 kg = 0.000035 mg/kg

Lower Range of Estimate [SPRYWL]:
0.008 mg/mL × 0.07 mg/mL × 2915 cm^2 × 0.000048 h^{-1} × 1 h ÷ 64 kg = 0.0000012 mg/kg

Upper Range of Estimate [SPRYWH]:
0.008 mg/mL × 3.03 mg/mL × 2915 cm^2 × 0.00098 h^{-1} × 1 h ÷ 64 kg = 0.0011 mg/kg

Worksheet 23: Dermal contact with contaminated vegetation.			
Verbal Description*: A woman wearing shorts and a short sleeved shirt is in contact with contaminated vegetation for 1 hour shortly after application of the compound - i.e. no dissipation or degradation is considered. The chemical is effectively removed from the surface of the skin - i.e., washing - after 24 hours.*			
Parameter/Assumption	Value	Units	Source/Reference
Contact time (***Tc***)	1	hour	N/A
Exposure time (***Te***)	24	hours	N/A
Body weight (***W***)	64	kg	WS04.BWF
Exposed surface area (***A***)	5300	cm^2	WS04.SAF2
Dislodgeable residue (***Dr***) as a proportion of application rate	0.1	none	WS04.DisL
Application Rates(***R***)			
Typical/Central	0.1	lb a.i/acre	WS10.TYP
Low	0.023	lb a.i/acre	WS10.LOW
High	0.38	lb a.i/acre	WS10.HI
First-order dermal absorption rate (k_a)			
Central	0.00022	$hour^{-1}$	WS15.AbsC
Low	0.000048	$hour^{-1}$	WS15.AbsL
High	0.00098	$hour^{-1}$	WS15.AbsU
Estimated Absorbed Doses (***D***) - ***see calculations on next page.***			
Central	0.000560	mg/kg	VEGDWC
Low	0.000025	mg/kg	VEGDWL
High	0.0106	mg/kg	VEGDWH

Description of Calculations:

Step 1:

Use method of Durkin et al. (1995, p. 68, equation 4) to calculate dislodgeable residue (Dr) in units of µg/(cm^2·hr)) after converting application rate in lb a.i./acre to units of µg/cm^2:

$x = \log(\boldsymbol{Dr}\ (\mu g/(cm^2 \cdot hr))) = (1.09 \times \log_{10}(\boldsymbol{R} \times \text{WS01.lbac\_ugcm})) + 0.05$

$\boldsymbol{Dr}\ (\mu g/(cm^2 \cdot hr)) = 10^x$

Step 2:

Convert Dr from units of µg/(cm^2·hr)) to units of mg/(cm^2·hr)) by dividing by 1000:

$\boldsymbol{Dr}(mg/(cm^2 \cdot hr)) = \boldsymbol{Dr}(\mu g/(cm^2 \cdot hr))/1000$

Step 3:

Estimate amount (*Amnt*) transferred to skin in mg during the exposure period:

$\boldsymbol{Amnt}(mg) = \boldsymbol{Dr}(mg/(cm^2 \cdot hr)) \times \boldsymbol{Tc}\ (hours) \times \boldsymbol{A}\ (cm^2)$

Step 4:

Estimate the absorbed dose ($\boldsymbol{D_{Abs}}$) in mg/kg bw as the product of the amount on the skin , the first-order absorption rate, and the duration of exposure divided by the body weight:

$\boldsymbol{D_{Abs}} = \boldsymbol{Amnt}(mg) \times \mathbf{k_a}\ (hours^{-1}) \times \boldsymbol{Te}\ (hours) \div \boldsymbol{W}\ (kg)$

See next page for details of calculations.

Worksheet 23 Details of calculations: *Dermal Exposure to Contaminated Vegetation*

Central Estimate:

Step 1:

$\log_{10}(\boldsymbol{Dr}\ (\mu g/(cm^2 \cdot hr)))0.104 = (1.09 \times \log_{10}(0.1 \times 11.21)) + 0.05 = 0.104\ \mu g/(cm^2 \cdot hr)$

$\boldsymbol{Dr}\ (\mu g/(cm^2 \cdot hr)) = 10^{0.104} = 1.27\ \mu g/(cm^2 \cdot hr)$

Step 2:

$\boldsymbol{Dr}\ (mg/(cm^2 \cdot hr)) = 1.27\ \mu g/(cm^2 \cdot hr) \div 1000\ \mu g/mg = 0.00127\ mg/(cm^2 \cdot hr)$

Step 3:

$\boldsymbol{Amnt}(mg) = 0.00127\ mg/(cm^2 \cdot hr) \times 1\ hr \times 5300\ cm^2 = 6.731\ mg$

Step 4:

$\boldsymbol{D_{Abs}}\ (mg/kg\ bw) = 6.731\ mg \times 0.00022\ hr^{-1} \times 24\ hours \div 64\ kg = 0.00056$ [VEGDWC]

Lower Range of Estimate:

Step 1:

$\log_{10}(\boldsymbol{Dr}\ (\mu g/(cm^2 \cdot hr))) = (1.09 \times \log_{10}(0.023 \times 11.21)) + 0.05 = -0.592 \mu g/(cm^2 \cdot hr)$

$\boldsymbol{Dr}\ (\mu g/(cm^2 \cdot hr)) = 10^{-0.592} = 0.256\ \mu g/(cm^2 \cdot hr)$

Step 2:

$\boldsymbol{Dr}\ (mg/(cm^2 \cdot hr)) = 0.256\ \mu g/(cm^2 \cdot hr) \div 1000\ \mu g/mg = 0.000256\ mg/(cm^2 \cdot hr)$

Step 3:

$\boldsymbol{Amnt}(mg) = 0.000256\ mg/(cm^2 \cdot hr) \times 1\ hr \times 5300\ cm^2 = 1.36\ mg$

Step 4:

$\boldsymbol{D_{Abs}}\ (mg/kg\ bw) = 1.36\ mg \times 0.000048\ hr^{-1} \times 24\ hours \div 64\ kg = 0.0000245$ [VEGDWL]

Upper Range of Estimate:

Step 1:

$\log_{10}(\boldsymbol{Dr}\ (\mu g/(cm^2 \cdot hr))) = (1.09 \times \log_{10}(0.38 \times 11.21)) + 0.05 = 0.736\ \mu g/(cm^2 \cdot hr)$

$\boldsymbol{Dr}\ (\mu g/(cm^2 \cdot hr)) = 10^{0.736} = 5.45\ \mu g/(cm^2 \cdot hr)$

Step 2:

$\boldsymbol{Dr}\ (mg/(cm^2 \cdot hr)) = 5.45\ \mu g/(cm^2 \cdot hr) \div 1000\ \mu g/mg = 0.00545\ mg/(cm^2 \cdot hr)$

Step 3:

$\boldsymbol{Amnt}(mg) = 0.00545\ mg/(cm^2 \cdot hr) \times 1\ hr \times 5300\ cm^2 = 28.9\ mg$

Step 4:

$\boldsymbol{D_{Abs}}\ (mg/kg\ bw) = 28.9\ mg \times 0.00098\ hr^{-1} \times 24\ hours \div 64\ kg = 0.0106$ [VEGDWH]

Worksheet 24: Consumption of contaminated fruit, acute exposure scenario.			
Verbal Description*: A woman consumes 1 lb (0.4536 kg) of contaminated fruit shortly after application of the chemical - i.e. no dissipation or degradation is considered. Residue estimates based on relationships from Hoerger and Kenaga (1972) summarized in WS07.*			
Parameters/Assumptions	Value	Units	Source/Reference
Body weight (***W***)	64	kg	WS04.BWF
Amount of fruit consumed (***A***)	0.454	kg	N/A
Application rates (***R***)			
Typical	0.1	lb a.i./acre	WS10.Typ
Lower	0.023	lb a.i./acre	WS10.Low
Upper	0.38	lb a.i./acre	WS10.Hi
Residue rates (***rr***)			
Typical	1.5	RUD[1]	WS05a.FRT
Upper	7	RUD[1]	WS05a.FRU
Dose estimates (***D***) - **see details of calculations below**			
Typical	0.0011	mg/kg bw	VEGCWAT
Lower	0.000240	mg/kg bw	VEGCWAL
Upper	0.019	mg/kg bw	VEGCWAU
[1] RUD: Residue Unit Dosage, term used by Hoerger and Kenaga (1972) for anticipated concentration on vegetation (mg chemical per kg of vegetation) for each l lb a.i./acre applied.			

Equation (terms defined in above table):

D (mg/kg bw) = ***A***(kg) × ***R***(lb a.i./acre) × ***rr***(mg/kg÷lb a.i./acre) ÷***W***(kg bw)

Details of Calculations

Typical: Use typical application rate and typical RUD.

D = 0.454 kg × 0.1 lb a.i./acre × 1.5 mg/kg÷lb a.i./acre ÷ 64 kg = 0.0011 mg/kg bw

Lower: Use lowest estimated application rate. Use typical RUD because no lower estimate of the RUD is available.

D = 0.454 kg × 0.023 lb a.i./acre × 1.5 mg/kg÷lb a.i./acre ÷ 64 kg = 0.00024 mg/kg bw

Upper: Use highest estimated application rate and highest RUD.

D = 0.454 kg × 0.38 lb a.i./acre × 7 mg/kg÷lb a.i./acre ÷ 64 kg = 0.019 mg/kg bw

Worksheet 25: Consumption of contaminated fruit, subchronic exposure scenario.			
***Verbal Description**: A woman consumes contaminated fruit for a 90 day period starting shortly after application of the chemical. Initial residue estimates are based on relationships from Hoerger and Kenaga (1972) summarized in Worksheet 05a. The foliar half-time is used to estimate the concentration on vegetation after 90 days. The geometric mean of the initial and 90 day concentrations is used as a central/typical dose.*			
Parameters/Assumptions	Value	Units	Source/Reference
Foliar halftime (***t***$_{½}$)	10	days	WS12.FT12
Duration of exposure (***t***)	90	days	N/A
Body weight (***W***)	64	kg	WS04.BWF
Amount of vegetation consumed per unit body weight(***A***)			
Typical	0.0043	kg veg./kg bw	WS04.VT
Upper	0.01	kg veg./kg bw	WS04.VU
Application rates (***R***)			
Typical	0.1	lb a.i./acre	WS10.Typ
Lower	0.023	lb a.i./acre	WS10.Low
Upper	0.38	lb a.i./acre	WS10.Hi
Residue rates (***rr***)			
Typical	1.5	RUD[1]	WS05a.FRT
Upper	7	RUD[1]	WS05aFRU
Dose estimates (***D***) - **see details of calculations on next page**			
Typical	0.000028	mg/kg bw/day	VEGCWCT
Lower	0.0000065	mg/kg bw/day	VEGCWCL
Upper	0.0012	mg/kg bw/day	VEGCWCU
[1] RUD: Residue Unit Dosage, term used by Hoerger and Kenaga (1972) for anticipated concentration on fruit (mg chemical per kg of vegetation) for each l lb a.i./acre applied.			

Details of calculations on next page

Subchronic consumption of vegetation: Details of calculations

Equations (terms defined below or in table on previous page):

Step 1: Calculate $C_{0,}$ concentration in vegetation on Day 0 - i.e., day of application.

C_0 (mg/kg) = ***R***(lb a.i./acre) × ***rr***(mg/kg÷lb a.i./acre)

Step 2: Calculate $C_{90,}$ concentration in vegetation on Day 90 (t=90 days) based on dissipation coefficient (k) derived from foliar half-life ($t_{½}$).

k ($days^{-1}$) = ln(2) ÷ $t_{½}$ (days)

C_{90} (mg/kg) = C_0 (mg/kg) × e^{-tk}

Step 3: Use the geometric mean of C_0 and C_{90} to get a central estimate of concentration in vegetation (mg/kg veg.) and multiply this value by the vegetation consumption (kg veg/kg bw) to calculate the daily dose (mg/kg bw) over the exposure period.

D (mg/kg bw) = $(C_0 \times C_{90})^{0.5}$ (mg/kg veg.) × ***A*** kg veg./kg bw × ***W*** kg bw ÷ ***B***(kg bw)

= $(C_0 \times C_{90})^{0.5}$ (mg/kg veg.) × ***A*** kg veg./kg bw

Central Estimate:

Use the typical application rate, the typical vegetation consumption rate, and the typical residue rate along with the single available estimate of foliar half-time.

Step 1:

C_0 = 0.1 lb a.i./acre × 1.5 mg/kg veg. = 0.15 mg/kg veg.

Step 2:

k = ln(2) ÷10 $days^{-1}$ = 0.0693

C_{90} = 0.15 mg/kg × $e^{-0.0693 \times 90}$ = 0.00029 mg/kg veg.

Step 3:

D (mg/kg bw/day) = $(0.15 \times 0.00029)^{0.5}$ (mg/kg veg.) × 0.0043 kg veg/kg bw = 0.000028 mg/kg bw

Lower Estimate:

Use the lowest anticipated application rate along with the single available estimate of foliar half-time. Also the typical vegetation consumption rate and the typical residue rate because lower limits on these estimates are not available.

Step 1:

C_0 = 0.023 lb a.i./acre × 1.5 mg/kg veg. = 0.0345 mg/kg veg.

Step 2:

k = ln(2) ÷10 $days^{-1}$ = 0.0693

C_{90} = 0.0345 mg/kg × $e^{-0.0693 \times 90}$ = 0.000067 mg/kg veg.

Step 3:

$D_{(mg/kg\ bw)} = (0.0345 \times 0.000067)^{0.5}{}_{(mg/kg\ veg.)} \times 0.0043_{(kg\ veg/kg\ bw)} = 0.0000065_{(mg/kg\ bw)}$

Upper Estimate:

Use the highest anticipated application rate, the upper range of the vegetation consumption rate and the upper range of the residue rate along with the single available estimate of foliar half-time.

Step 1:

C_0 = 0.38 lb a.i./acre × 7 mg/kg veg. = 2.66 mg/kg veg.

Step 2:

k = ln(2) ÷10 $days^{-1}$ = 0.0693

C_{90} = 2.66 mg/kg × $e^{-0.0693 \times 90}$ = 0.0052 mg/kg veg.

Step 3:

$D_{(mg/kg\ bw)} = (2.66 \times 0.0052)^{0.5}{}_{(mg/kg\ veg.)} \times 0.01_{(kg\ veg/kg\ bw)} = 0.0012_{(mg/kg\ bw)}$

Worksheet 26: Consumption of contaminated water, acute exposure scenario.			
***Verbal Description**: A young child (2-3 years old) consumes 1 liter of 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.*			
Parameters/Assumptions	Value	Units	Source/Reference
Surface area of pond [SA]	1000	m^2	N/A
Average depth [DPTH]	1	m	N/A
Volume of pond in cubic meters [VM]	1000	m^3	N/A
Volume of pond in Liters [VL]	1000000	L	1 m^3 = 1,000 L
Volume of spill [VS]	200	gallons	N/A
Concentrations in solution ($C_{(mg/L)}$)			
Central	440	mg/L	WS11.TypDR
Low	70	mg/L	WS11.LowDR
High	3030	mg/L	WS11.Hi_DR
Body weight (***W***)	13	kg	WS04.BWC
Amount of water consumed (***A***)			
Typical	1	L/day	WS04.WCT
Lower	0.61	L/day	WS04.WCL
Upper	1.5	L/day	WS04.WCH
Dose estimates (***D***) - **see details of calculations on next page.**			
Typical	0.025	mg/kg bw	WATCCAT
Lower	0.0025	mg/kg bw	WATCCAL
Upper	0.26	mg/kg bw	WATCCAU

Details of calculations on next page

Acute Consumption of Contaminated Water from an Accidental Spill Details of calculations

Equations (terms defined below or in table on previous page)

Step 1: Calculate the concentration in the pond based on the concentration in the spilled solution, the volume spilled and the volume of the pond, assuming instantaneous mixing.

$$Conc._{(mg/L)} = VS_{(gal.)} \times 3.785_{L/gal} \times C_{(mg/L)} \div VL_{(liters)}$$

Step 2: Calculate the dose based on the concentration in the water, the amount of water consumed, and the body weight.

$$D_{(mg/kg\ bw)} = Conc._{(mg/L)} \times A_{(L)} \div W_{(kg)}$$

Calculations

Central Estimate:

Use the typical field dilution, and the typical water consumption.

Step 1:

$$\text{Conc.}_{(mg/L)} = 200_{(gal.)} \times 3.785_{L/gal} \times 440_{(mg/L)} \div 1000000_{(liters)} = 0.33_{(mg/L)}$$

Step 2:

$$D_{(mg/kg\ bw)} = 0.33_{(mg/L)} \times 1_{(L)} \div 13_{(kg)} = 0.025_{(mg/kg\ bw)}$$ [WATCCAT]

Lower Estimate:

Use the lowest estimated field dilution and the lower range of water consumption.

Step 1:

$$\text{Conc.}_{(mg/L)} = 200_{(gal.)} \times 3.785_{L/gal} \times 70_{(mg/L)} \div 1000000_{(liters)} = 0.053_{(mg/L)}$$

Step 2:

$$D_{(mg/kg\ bw)} = 0.053_{(mg/L)} \times 0.61_{(L)} \div 13_{(kg)} = 0.0025_{(mg/kg\ bw)}$$ [WATCCAL]

Upper Estimate:

Use the highest estimated field concentration and the upper range of water consumption.

Step 1:

$$\text{Conc.}_{(mg/L)} = 200_{(gal.)} \times 3.785_{L/gal} \times 3030_{(mg/L)} \div 1000000_{(liters)} = 2.29_{(mg/L)}$$

Step 2:

$$D_{(mg/kg\ bw)} = 2.29_{(mg/L)} \times 1.5_{(L)} \div 13_{(kg)} = 0.26_{(mg/kg\ bw)}$$ [WATCCAU]

Worksheet 27: Consumption of contaminated water, chronic exposure scenario.			
Verbal Description*: An adult (70 kg male) consumes contaminated ambient water for a lifetime. The levels in water are estimated from monitoring data and thus dissipation, degradation and other environmental processes are implicitly considered.*			
Parameters/Assumptions	Value	Units	Source/Reference
Application Rates (***R*** $_{(\text{lb a.i./acre})}$)			
Central	0.1	lb a.i./gal	WS10.Typ
Low	0.023		WS10.Low
High	0.38		WS10.Hi
Water Contamination Rate (WCR)(***C*** $_{(\text{mg/L})}$÷***R*** $_{(\text{lb a.i./gal})}$)			
Central	0.054	mg/L/lb a.i./acre	WS16.AWT
Low	0.014		WS16.AWL
High	0.12		WS16.AWU
Body weight (***W***)	70	kg	WS046.BWM
Amount of water consumed (***A*** $_{(\text{L/day})}$)			
Typical	2	L/day	WS04.WCAT
Lower	1.4	L/day	WS04.WCAL
Upper	2.4	L/day	WS04.WCAH
Dose estimates (***D***) - **see details of calculations on next page.**			
Typical	0.00015	mg/kg bw/day	WATCMCT
Lower	0.0000064	mg/kg bw/day	WATCMCL
Upper	0.0016	mg/kg bw/day	WATCMCU

Details of calculations on next page

Chronic Consumption of Contaminated Ambient Water
Details of calculations

Equations (terms defined in table on previous page)

Verbal Description: Multiply the application rate ($\boldsymbol{R}_{\text{(lb a.i./acre)}}$) by the water contamination rate ($\boldsymbol{WCR}_{\text{((mg/L)×(lb a.i./gal))}}$) to get the concentration in ambient water. This product is in turn multiplied by the amount of water consumed per day ($\boldsymbol{A}_{\text{(L/day)}}$) and then divided by the body weight ($\boldsymbol{W}_{\text{(kg)}}$)to get the estimate of the absorbed dose ($\boldsymbol{D}_{\text{(mg/kg bw)}}$).

$$\boldsymbol{D}_{\text{(mg/kg bw)}} = \boldsymbol{R}_{\text{(lb a.i./acre)}} \times \boldsymbol{WCR}_{\text{((mg/L)×(lb a.i./gal))}} \times \boldsymbol{A}_{\text{(L/day)}} \div \boldsymbol{W}_{\text{(kg)}}$$

Central Estimate:

Use the typical application rate, typical contamination rate (WCR), and the typical water consumption.

$$\boldsymbol{D}_{\text{(mg/kg bw)}} = 0.1_{\text{(lb a.i./acre)}} \times 0.054_{\text{((mg/L)×(lb a.i./gal))}} \times 2_{\text{(L/day)}} \div 70_{\text{(kg bw)}} = 0.00015_{\text{(mg/kg bw)}}$$ `[WATCMCT]`

Lower Range of Estimate:

Use the lowest anticipated application rate, the low end of the range of the water contamination rate (WCR), and the low end of the range for water consumption.

$$\boldsymbol{D}_{\text{(mg/kg bw)}} = 0.023_{\text{(lb a.i./acre)}} \times 0.014_{\text{((mg/L)×(lb a.i./gal))}} \times 1.4_{\text{(L/day)}} \div 70_{\text{(kg bw)}} = 0.0000064_{\text{(mg/kg bw)}}$$ `[WATCMCL]`

Upper range of Estimate:

Use the lowest anticipated application rate, the low end of the range of the water contamination rate (WCR), and the low end of the range for water consumption.

$$\boldsymbol{D}_{\text{(mg/kg bw)}} = 0.38_{\text{(lb a.i./acre)}} \times 0.12_{\text{((mg/L)×(lb a.i./gal))}} \times 2.4_{\text{(L/day)}} \div 70_{\text{(kg bw)}} = 0.0016_{\text{(mg/kg bw)}}$$ `[WATCMCU]`

Worksheet 28: Consumption of contaminated fish, acute exposure scenario.

Verbal Description*: An adult angler 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. Because of the available and well documented information and substantial differences in the amount of caught fish consumed by the general public and native American subsistence populations, separate exposure estimates are made for these two groups.*

Parameters/Assumptions	Value	Units	Source/Reference
Surface area of pond [SA]	1000	m^2	N/A
Average depth [DPTH]	1	m	N/A
Volume of pond in cubic meters [VM]	1000	m^3	N/A
Volume of pond in Liters [VL]	1000000	L	1 m^3 = 1,000 L
Volume of spill [VS]	200	gallons	N/A
Concentrations in spilled solution (***C*** $_{(mg/L)}$)			
Central	440	mg/L	WS11.TYPDR×1000
Low	70	mg/L	WS11.LOWDR×1000
High	3030	mg/L	WS11.HI_DR×1000
Body weight (***W***)	70	kg	WS04.BWM
Amount of fish consumed (***A***)			
General Population	0.158	kg/day	WS04.FAU
Native American subsistence populations	0.77	kg/day	WS04.FNU
Bioconcentration factor (***BCF*** $_{(kg\ fish/L)}$)	1	kg fish/L	WS12.BCFT
Dose estimates (***D***) - **see details of calculations on next page.**			
General Population			
Typical	0.0007	mg/kg bw	FISHAMGPT
Lower	0.00012	mg/kg bw	FISHAMGPL
Upper	0.0052	mg/kg bw	FISHAMGPU
Native American subsistence populations			
Typical	0.0036	mg/kg bw	FISHAMNAT
Lower	0.00055	mg/kg bw	FISHAMNAL
Upper	0.025	mg/kg bw	FISHAMNAU

Details of calculations on next page

Acute Consumption of Contaminated Fish after an Accidental Spill
Details of calculations
Equations (terms defined below or in table on previous page)

Step 1: As in the acute drinking water scenario, calculate the concentration in the pond based on the concentration in the spilled solution, the volume spilled and the volume of the pond, assuming instantaneous mixing.

$$\textbf{\textit{Conc.}}_{(mg/L)} = \textbf{\textit{VS}}_{(gal.)} \times 3.785_{L/gal} \times \textbf{\textit{C}}_{(mg/L)} \div \textbf{\textit{VL}}_{(liters)}$$

Step 2: Calculate the dose based on the concentration in the water, the bioconcentration factor, the amount of fish consumed, and the body weight.

$$\textbf{\textit{D}}_{(mg/kg\ bw)} = \textbf{\textit{Conc.}}_{(mg/L)} \times \textbf{\textit{BCF}}_{(kg\ fish/L)} \times \textbf{\textit{A}}_{(kg\ fish)} \div \textbf{\textit{W}}_{(kg\ bw)}$$

General Public

Central Estimate:

Use the typical field dilution as well as the experimental BCF and upper range of daily fish consumption for the general public.

Step 1:

$$\text{Conc.}_{(mg/L)} = 200_{(gal.)} \times 3.785_{L/gal} \times 440_{(mg/L)} \div 1000000_{(liters)} = 0.33_{(mg/L)}$$

Step 2:

$$\text{D}_{(mg/kg\ bw)} = 0.33_{(mg/L)} \times 1_{(L/kg)} \times 0.158_{(kg\ fish)} \div 70_{(kg)} = 0.00070_{(mg/kg\ bw)}$$ `[FISHAMGPT]`

Lower End of Range for the Estimate:

Use the lower field dilution as well as the experimental BCF and upper range of daily fish consumption for the general public.

Step 1:

$$\text{Conc.}_{(mg/L)} = 200_{(gal.)} \times 3.785_{L/gal} \times 70_{(mg/L)} \div 1000000_{(liters)} = 0.053_{(mg/L)}$$

Step 2:

$$\text{D}_{(mg/kg\ bw)} = 0.053_{(mg/L)} \times 1_{(L/kg)} \times 0.158_{(kg\ fish)} \div 70_{(kg)} = 0.00012_{(mg/kg\ bw)}$$ `[FISHAMGPL]`

Upper End of Range for the Estimate:

Use the upper field dilution as well as the experimental BCF and upper range of daily fish consumption for the general public.

Step 1:

$$\text{Conc.}_{(mg/L)} = 200_{(gal.)} \times 3.785_{L/gal} \times 3030_{(mg/L)} \div 1000000_{(liters)} = 2.29_{(mg/L)}$$

Step 2:

$$\text{D}_{(mg/kg\ bw)} = 2.29_{(mg/L)} \times 1_{(L/kg)} \times 0.158_{(kg\ fish)} \div 70_{(kg)} = 0.0052_{(mg/kg\ bw)}$$ `[FISHAMGPU]`

(continued on next page)

Acute Consumption of Contaminated Fish after an Accidental Spill Details of calculations (continued)

Native American Subsistence Populations

Central Estimate:

Use the typical field dilution as well as the experimental BCF and upper range of daily fish consumption for the native American subsistence populations.

Step 1:

Conc. $_{(mg/L)}$ = 200 $_{(gal.)}$ × 3.785 $_{L/gal}$ × 440 $_{(mg/L)}$ ÷ 1000000 $_{(liters)}$ = 0.33 $_{(mg/L)}$

Step 2:

D $_{(mg/kg\ bw)}$ = 0.33 $_{(mg/L)}$ × 1 $_{(L/kg)}$ × 0.77 $_{(kg\ fish)}$ ÷ 70 $_{(kg)}$ = 0.0036 $_{(mg/kg\ bw)}$ [FISHAMNAT]

Estimate of Lower End of Range:

Use the lower field dilution as well as the experimental BCF and upper range of daily fish consumption for the native American subsistence populations.

Step 1:

Conc. $_{(mg/L)}$ = 200 $_{(gal.)}$ × 3.785 $_{L/gal}$ × 70 $_{(mg/L)}$ ÷ 1000000 $_{(liters)}$ = 0.050 $_{(mg/L)}$

Step 2:

D $_{(mg/kg\ bw)}$ = 0.05 $_{(mg/L)}$ × 1 $_{(L/kg)}$ × 0.77 $_{(kg\ fish)}$ ÷ 70 $_{(kg)}$ = 0.00055 $_{(mg/kg\ bw)}$ [FISHAMNAL]

Estimate of Upper End of Range:

Use the upper field dilution as well as the experimental BCF and upper range of daily fish consumption for the native American subsistence populations.

Step 1:

Conc. $_{(mg/L)}$ = 200 $_{(gal.)}$ × 3.785 $_{L/gal}$ × 3030 $_{(mg/L)}$ ÷ 1000000 $_{(liters)}$ = 2.290 $_{(mg/L)}$

Step 2:

D $_{(mg/kg\ bw)}$ = 2.29 $_{(mg/L)}$ × 1 $_{(L/kg)}$ × 0.77 $_{(kg\ fish)}$ ÷ 70 $_{(kg)}$ = 0.025 $_{(mg/kg\ bw)}$ [FISHAMNAU]

Worksheet 29: Consumption of contaminated fish, chronic exposure scenario.			
***Verbal Description**: An adult (70 kg male) consumes fish taken from contaminated ambient water for a lifetime. The levels in water are estimated from monitoring data and thus dissipation, degradation and other environmental processes are implicitly considered.*			
Parameters/Assumptions	Value	Units	Source/Reference
Application Rates (***R*** $_{(\text{lb a.i./acre})}$)			
Central	0.1	lb a.i./gal	WS10.Typ
Low	0.023		WS10.Low
High	0.38		WS10.Hi
Water Contamination Rate (WCR)(***C*** $_{(\text{mg/L})} \div$ ***R*** $_{(\text{lb a.i./gal})}$)			
Central	0.054	mg/L/lb a.i./acre	WS16.AWT
Low	0.014		WS16.AWL
High	0.12		WS16.AWU
Bioconcentration factor (***BCF*** $_{(\text{kg fish/L})}$)	1	kg fish/L	WS12.BCFT
Body weight (***W***)	70	kg	WS04.BWM
Amount of fish consumed (***A***)			
General Population typical	0.01	kg/day	WS04.FAT
upper limit	0.158	kg/day	WS04.FAU
Native American subsistence populations typical	0.081	kg/day	WS04.FNT
upper limit	0.77	kg/day	WS04.FNU
Dose estimates (***D***) - **see details of calculations on next page.**			
General Public			
Typical	0.00000077	mg/kg bw/day	FISHMCT
Lower	0.000000046	mg/kg bw/day	FISHMCL
Upper	0.00010	mg/kg bw/day	FISHMCU
Native American Subsistence Population			
Typical	0.0000062	mg/kg bw/day	FISHNMCT
Lower	0.00000037	mg/kg bw/day	FISHNMCL
Upper	0.00050	mg/kg bw/day	FISHNMCU

Details of calculations on next page

Chronic Consumption of Contaminated Fish, Details of calculations

Equations (terms defined below or in table on previous page)

Verbal Description: Multiply the application rate ($R_{(\text{lb a.i./acre})}$) by the water contamination rate ($WCR_{((\text{mg/L})\times(\text{lb a.i./gal}))}$) to get the concentration in ambient water. This product is in turn multiplied by the bioconcentration factor ($BCF_{(\text{kg fish/L})}$) and the amount of fish consumed per day ($A_{(\text{kg fish/day})}$) and then divided by the body weight ($W_{(\text{kg bw})}$) to get the estimate of the absorbed dose ($D_{(\text{mg/kg bw})}$).

$$D_{(\text{mg/kg bw})} = R_{(\text{lb a.i./acre})} \times WCR_{((\text{mg/L})\times(\text{lb a.i./gal}))} \times A_{(\text{kg/day})} \times BCF_{(\text{kg fish/L})} \div W_{(\text{kg})}$$

General Public

Central Estimate:

Use the typical application rate, typical contamination rate (WCR), the typical fish consumption, the measured bioconcentration factor, and standard body weight.

$$D_{(\text{mg/kg bw})} = 0.1_{(\text{lb a.i./acre})} \times 0.054_{((\text{mg/L})\times(\text{lb a.i./gal}))} \times 1_{(\text{kg fish/L})} \times 0.01_{(\text{kg fush/day})} \div 70_{(\text{kg bw})} = 0.00000077_{(\text{mg/kg bw})}$$ [FISHMCT]

Lower Range of Estimate:

Use the lowest anticipated application rate, lower range of contamination rate (WCR), the typical fish consumption, the measured bioconcentration factor, and standard body weight. Typical fish consumption is used because there is no published lower estimate.

$$D_{(\text{mg/kg bw})} = 0.023_{(\text{lb a.i./acre})} \times 0.014_{((\text{mg/L})\times(\text{lb a.i./gal}))} \times 1_{(\text{kg fish/L})} \times 0.01_{(\text{kg fush/day})} \div 70_{(\text{kg bw})} = 0.000000046_{(\text{mg/kg bw})}$$ [FISHMCL]

Upper Range of Estimate:

Use the highest labelled application rate, upper range of contamination rate (WCR), the maximum l fish consumption, the measured bioconcentration factor, and standard body weight.

$$D_{(\text{mg/kg bw})} = 0.38_{(\text{lb a.i./acre})} \times 0.12_{((\text{mg/L})\times(\text{lb a.i./gal}))} \times 1_{(\text{kg fish/L})} \times 0.158_{(\text{kg fush/day})} \div 70_{(\text{kg bw})} = 0.00010_{(\text{mg/kg bw})}$$ [FISHMCU]

Chronic Consumption of Contaminated Fish
Details of calculations (continued)

Native American Subsistence Populations

Central Estimate:

Use the typical application rate, typical contamination rate (WCR), the typical fish consumption for native American subsistence populations, the measured bioconcentration factor, and standard body weight.

$$\boldsymbol{D}_{(\text{mg/kg bw})} = 0.1_{\text{(lb a.i./acre)}} \times 0.054_{\text{((mg/L)×(lb a.i./gal))}} \times 1_{\text{(kg fish/L)}} \times 0.081_{\text{(kg fush/day)}} \div 70_{\text{(kg bw)}} = 0.0000062_{\text{(mg/kg bw)}}$$ `[FISHNMCT]`

Lower Range of Estimate:

Use the lowest anticipated application rate, lower range of contamination rate (WCR), the typical fish consumption for native American subsistence populations, the measured bioconcentration factor, and standard body weight. Typical fish consumption is used because there is no published lower estimate.

$$\boldsymbol{D}_{(\text{mg/kg bw})} = 0.023_{\text{(lb a.i./acre)}} \times 0.014_{\text{((mg/L)×(lb a.i./gal))}} \times 1_{\text{(kg fish/L)}} \times 0.081_{\text{(kg fush/day)}} \div 70_{\text{(kg bw)}} = 0.00000037_{\text{(mg/kg bw)}}$$ `[FISHNMCL]`

Upper Range of Estimate:

Use the highest labelled application rate, upper range of contamination rate (WCR), the maximum l fish consumption for native American subsistence populations, the measured bioconcentration factor, and standard body weight.

$$\boldsymbol{D}_{(\text{mg/kg bw})} = 0.38_{\text{(lb a.i./acre)}} \times 0.12_{\text{((mg/L)×(lb a.i./gal))}} \times 1_{\text{(kg fish/L)}} \times 0.77_{\text{(kg fush/day)}} \div 70_{\text{(kg bw)}} = 0.00050_{\text{(mg/kg bw)}}$$ `[FISHNMCU]`

CATEGORICAL REGRESSION

Worksheet 30: Summary of categorical regression analyses based on experimental dose and duration in days with all of the available data (see Table 3-3 in text of risk assessment for data points).		
Model Run #1	All dose/duration/severity data. Three category model (NOAEL, AEL, and FEL) using natural log transformations on dose (mg/kg/day) and duration of exposure (days).	
Parameter	Estimate	P=value
Model Chi Square, 2 D.F.	7.97	0.0186
Intercept NOAEL/AEL	1.1432	0.50
Intercept AEL/FEL	4.0332	0.029
Log_e(Dose)	-0.4312	0.043
Log_e(Days)	-0.0491	0.81
Model Run #2	All dose/severity data. Three category model (NOAEL, AEL, and FEL) using natural log transformations on dose (mg/kg/day) but excluding duration of exposure.	
Parameter	Estimate	P=value
Model Chi Square, 1 D.F.	7.91	0.0049
Intercept NOAEL/AEL	0.7747	0.3222
Intercept AEL/FEL	3.6671	0.0006
Log_e(Dose)	-0.3958	0.0102
Model Run #3	All dose/severity data. Two category model (NOAEL, AEL/FEL combined) using natural log transformations on dose (mg/kg/day) and duration of exposure in days.	
Parameter	Estimate	P=value
Model Chi Square, 1 D.F.	24.54	<0.0001
Intercept NOAEL/AEL&FEL	9.633	0.0648
Log_e(Dose)	-2.2116	0.0255
Log_e(Days)	-0.5650	0.2581
Model Run #4	All dose/severity data. Two category model (NOAEL, AEL/FEL combined) using natural log transformations on dose (mg/kg/day) but excluding duration of exposure.	
Parameter	Estimate	P=value
Model Chi Square, 1 D.F.	23.06	<0.0001
Intercept NOAEL/AEL&FEL	5.222	0.0299
Log_e(Dose)	-1.7160	0.0150

Worksheet 31: Summary of categorical regression analyses excluding teratology studies in rabbits using experimental doses and duration in days (see Table 3-4 in text of risk assessment for data points).		
Parameter	Estimate	P=value
Model Run #1	All dose/duration/severity data except studies in rabbits. Two category model (NOAEL, AEL) using natural log transformations on dose (mg/kg/day) and duration of exposure.	
Parameter	Estimate	P=value
Intercept (NOAEL/AEL)	25.01	0.2148
Log_e(Dose)	-4.1520	0.2159
Log_e(Days)	-2.0217	0.2079
Model Run #2	Dose/severity data excluding studies in rabbits. Two category model (NOAEL, AEL) using natural log transformations on dose (mg/kg/day) but omitting duration of exposure.	
Parameter	Estimate	P=value
Intercept (NOAEL)/AEL)	4.9616	0.0346
Log_e(Dose)	-1.5403	0.0236
Model Run #3	Dose/severity data excluding studies in rabbits. Two category model (NOAEL/ AEL) using natural log transformations on the product of experimental dose (mg/kg/day) and fraction of life span.	
Parameter	Estimate	P=value
Model Chi Square, 1 D.F.	19.58	<0.0001
Intercept NOAEL/AEL	19.19	0.0256
Log_e(Dose×Duration)	-2.386	0.0221

Worksheet 32: Summary of categorical regression analyses using only dietary exposures with experimental doses (mg/kg/day) and duration of exposure in days (see Table 3-4 in text of risk assessment for data points).		
Parameter	Estimate	P=value
Model Run #1	Dietary dose/duration/severity data. Two category model (NOAEL/ AEL) using natural log transformations on dose (mg/kg/day) and duration of exposure (days).	
Intercept (NOAEL)/AEL)	24.9966	0.2160
Log_e(Dose)	-4.1496	0.2176
Log_e(Days)	-2.0208	0.2085
Model Run #2	Dietary dose/duration/severity data. Two category model (NOAEL/AEL) using natural log transformations on dose (mg/kg/day) but omitting duration of exposure (days).	
Intercept (NOAEL)/AEL)	4.9494	0.0360
Log_e(Dose)	-1.5362	0.0250
Model Run #3	Dietary dose/severity data. Two category model (NOAEL/AEL) using natural log transformations on the product of human equivalent dose (mg/kg/day) and fraction of life span.	
Parameter	Estimate	P=value
Model	Chi Square = 15.98	<0.0001 (1 DF)
Intercept NOAEL/AEL	16.27	0.0332
Log_e(Dose×Duration)	-1.935	0.0316

Worksheet 33: Summary of categorical regression analyses based on estimated human equivalent dose and duration in fraction of life span with all of the available data (see Table 3-4 in text of risk assessment for data points).

Assumptions	Life spans:	Body Weights:
	Human: 70 years	70 kg
	Dog: 10 years	10 kg
	Rat: 2 years	0.35 kg
	Mouse: 2 years	0.025 kg
	Rabbit: 4 years	4.0 kg

Model Run #1	All dose/duration/severity data. Three category model (NOAEL, AEL, and FEL) using natural log transformations on estimated human equivalent dose (mg/kg/day) and duration of exposure fraction of life span.

Parameter	Estimate	P=value
Model Chi Square, 2 D.F.	11.46	0.0033
Intercept NOAEL/AEL	0.5310	0.4314
Intercept AEL/FEL	3.6868	0.0002
Log_e(Dose)	-0.5106	0.0214
Log_e(Life span)	-0.0300	0.8911

Model Run #2	All dose/severity data. Three category model (NOAEL, AEL, and FEL) using natural log transformations on dose (mg/kg/day) but excluding duration of exposure.

Parameter	Estimate	P=value
Model Chi Square, 1 D.F.	11.44	0.0007
Intercept NOAEL/AEL	0.5410	0.4107
Intercept AEL/FEL	3.7034	0.0002
Log_e(Dose)	-0.4902	0.0028

Model Run #3	All dose/severity data. Two category model (NOAEL, AEL/FEL combined) using natural log transformations on dose (mg/kg/day) and duration of exposure in fraction of life span.

Parameter	Estimate	P=value
Model Chi Square, 1 D.F.	29.04	<0.0001
Intercept NOAEL/AEL&FEL	5.2546	0.1583
Log_e(Dose)	-3.8066	0.0896
Log_e(Days)	-1.201	0.1389

Model Run #4	All dose/severity data. Two category model (NOAEL, AEL/FEL combined) using natural log transformations on dose (mg/kg/day) but excluding duration of exposure.

Parameter	Estimate	P=value
Model Chi Square, 1 D.F.	25.35	<0.0001
Intercept NOAEL/AEL&FEL	3.5135	0.0473
Log_e(Dose)	-1.8730	0.0174

Worksheet 34: Summary of categorical regression analyses using only dietary exposures with estimated human equivalent doses (mg/kg/day) and duration in fraction of life span (see Table 3-4 in text of risk assessment for data points).			
Assumptions	Life spans: Human: 70 years Dog: 10 years Rat: 2 years Mouse: 2 years	Body Weights: 70 kg 10 kg 0.35 kg 0.025 kg	
Parameter		Estimate	P=value
Model Run #1	Dietary dose/duration/severity data. Two category model (NOAEL/ AEL) using natural log transformations on human equivalent dose (mg/kg/day) and duration of exposure as the fraction of life span.		
Score test for proportional odds assumption		Model would not converge.	Reject model.
Model Run #2	Dietary dose/severity data. Two category model (NOAEL/ AEL) using natural log transformations on human equivalent dose (mg/kg/day) but excluding duration of exposure.		
Parameter		Estimate	P=value
Model Chi Square, 1 D.F.		14.67	0.0001
Intercept NOAEL/AEL		3.35	0.0526
Log_e(Dose)		-1.706	0.0266
Model Run #3	Dietary dose/severity data. Two category model (NOAEL/ AEL) using natural log transformations on the product of human equivalent dose (mg/kg/day) and fraction of life span.		
Parameter		Estimate	P=value
Model Chi Square, 1 D.F.		16.47	<0.0001 (1 DF)
Intercept NOAEL/AEL		0.5756	0.5392
Log_e(Dose×Duration)		-2.081	0.0407

SUMMARY TABLES

Worksheet 35: Summary of Worker Exposure Scenarios

Scenario	Dose (mg/kg/day or event)			Exposure Assessment Worksheet
	Typical	Lower	Upper	
General Exposures (dose in mg/kg/day)				
Directed ground spray (Backpack)	1.3e-03	1.0e-05	3.0e-02	WS17
Broadcast ground spray (Boom spray)	1.1e-03	1.5e-05	6.4e-02	WS18
Accidental/Incidental Exposures (dose in mg/kg/event)				
Immersion of Hands, 1 minute	4.5e-07	2.8e-08	7.9e-06	WS19
Contaminated Gloves, 1 hour	2.7e-05	1.7e-06	4.7e-04	WS19
Spill on hands, 1 hour	9.3e-06	3.2e-07	2.9e-04	WS20
Spill on lower legs, 1 hour	2.3e-05	7.9e-07	7.0e-04	WS20

Worksheet 36: Summary of risk characterization for workers[1]

RfD	0.02	mg/kg/day	Sect. 3.3.3.	
Scenario	Hazard Quotient			Exposure Assessment Worksheet
	Typical	Lower	Upper	
General Exposures				
Directed ground spray (Backpack)	0.1	0.0005	2	WS17
Broadcast ground spray (Boom spray)	0.06	0.0008	3	WS18
Accidental/Incidental Exposures				
Immersion of Hands, 1 minute	0.00002	0.000001	0.0004	WS19
Contaminated Gloves, 1 hour	0.001	0.00008	0.02	WS19
Spill on hands, 1 hour	0.0005	0.00002	0.01	WS20
Spill on lower legs, 1 hour	0.001	0.00004	0.04	WS20

[1] Hazard quotient is the level of exposure divided by the provisional RfD then rounded to one significant decimal place or digit. See Worksheet 35 for summary of exposure assessment.

Worksheet 37: Summary of Exposure Scenarios for the General Public

Scenario	Target	Dose (mg/kg/day)			Worksheet
		Typical	Lower	Upper	
Acute/Accidental Exposures					
Direct spray, entire body	Child	0.00036	0.00001	0.011	WS21
Direct spray, lower legs	Woman	0.000035	0.0000012	0.0011	WS22
Dermal, contaminated vegetation	Woman	0.00056	0.000025	0.0106	WS23
Contaminated fruit, acute exposure	Woman	0.0011	0.00024	0.019	WS24
Contaminated water, acute exposure	Child	0.025	0.0025	0.26	WS26
Consumption of fish, general public	Man	0.0007	0.00012	0.0052	WS28
Consumption of fish, subsistence populations	Man	0.00363	0.00055	0.025	WS28
Chronic/Longer Term Exposures					
Contaminated fruit	Woman	0.000456	0.0001049	0.0188	WS25
Consumption of water	Man	0.00015	0.0000064	0.0016	WS27
Consumption of fish, general public	Man	0.00000077	0.000000046	0.0001	WS29
Consumption of fish, subsistence populations	Man	0.00001	0.00000037	0.0005	WS29

Worksheet 38: Summary of risk characterization for the general public [1] .

Provisional RfD		0.02	mg/kg/day	Sect. 3.3.3.	
Scenario	Target	Hazard Quotient			Worksheet
		Typical	Lower	Upper	
Acute/Accidental Exposures					
Direct spray, entire body	Child	0.02	0.0006	0.5	WS21
Direct spray, lower legs	Woman	0.002	0.0000600	0.06	WS22
Dermal, contaminated vegetation	Woman	0.03	0.001000	0.5	WS23
Contaminated fruit, acute exposure	Woman	0.06	0.01	1	WS24
Contaminated water, acute exposure	Child	1	0.1	13	WS26
Consumption of fish, general public	Man	0.03	0.006	0.3	WS28
Consumption of fish, subsistence populations	Man	0.2	0.03	1	WS28
Chronic/Longer Term Exposures					
Contaminated fruit	Woman	0.001	0.0003	0.06	WS25
Consumption of water	Man	0.007	0.0003	0.08	WS27
Consumption of fish, general public	Man	0.00004	0.000002	0.005	WS29
Consumption of fish, subsistence populations	Man	0.0003	0.00002	0.03	WS29

[1] Hazard quotient is the level of exposure divided by the provisional RfD then rounded to one significant decimal place or digit. See Worksheet 36 for summary of exposure assessments.

Worksheet 39: Direct spray of small mammal assuming first order absorption kinetics.			
Verbal Description*: A 20 g mammal is directly sprayed 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 on dermal absorption in a small mammal, the estimated absorption rate for humans is used. An empirical relationship between body weight and surface area (Boxenbaum and D'Souze 1990) is used to estimate the surface area of the animal.*			
Parameter/Assumption	Value	Units	Source/Reference
Period of exposure (***T***)	24	hour	N/A
Body weight (***W***)	0.020	kg	Section 4.2.1.
Exposed surface area (***A***)	$cm^2=1110\times BW(kg)^{0.65}$		Boxenbaum and D'Souza 1990
	87	cm^2	
Application rate (***R***)			
Typical/Central	0.1	lb a.i. /acre	WS10.TYP
Low	0.023		WS10.LOW
High	0.38		WS10.HI
Conversion Factor (***F***) for lb/acre to mg/cm^2	0.01121		WS01.LBAC_MGCM
First-order dermal absorption rate (k_a)			
Central	0.00022	$hour^{-1}$	WS15.AbsC
Low	0.000048	$hour^{-1}$	WS15.AbsL
High	0.00098	$hour^{-1}$	WS15.AbsU
Estimated Absorbed Doses (***D***) - ***see calculations below.***			
Central	0.013	mg/kg	SMDSDC
Low	0.00064	mg/kg	SMDSDL
High	0.22	mg/kg	SMDSDH

Details of calculations on next page.

Direct Spray of Small Mammal, first-order absorption, Details of calculations

Equation: $0.5 \times F \times R \times A \times 1^{-ka \times T} \div W$

Verbal Description: *Multiply by 0.5 because only one half of the body surface is assumed to be sprayed. Calculate the amount deposited on the animal as the product of the application rate converted to mg/cm^2 and the surface area of the animal in cm^2. Get the proportion of the amount that is absorbed using the assumption of first order absorption kinetics. Divide by the body weight.*

Central Estimate: Use the central estimate of the application rate and dermal absorption rate,
0.5 × 0.01121 (mg/cm^2÷lb/acre) × 0.1 lb/acre × 87 cm^2
× 1-e$^{-0.00022/h \times 24h}$ ÷ 0.02 kg = 0.013 mg/kg [SMDSDC]

Lower Range of Estimate: Use the lowest anticipated application rate and lower 95% limit of the estimated dermal absorption rate,
0.5 × 0.01121 (mg/cm^2÷lb/acre) × 0.023 lb/acre × 87 cm^2
× 1-e$^{-0.000048/h \times 24 h}$ ÷ 0.02 kg = 0.00064 mg/kg [CMDSDL]

Upper Range of Estimate: Use the highest anticipated application rate and upper 95% limit of the estimated dermal absorption rate,
0.5 × 0.01121 (mg/cm^2÷lb/acre) × 0.38 lb/acre × 87 cm^2
× (1-e-0.00098/h × 24 h) ÷ 0.02 kg = 0.22 mg/kg [DMDSDH]

Worksheet 40: Direct spray of small mammal assuming 100% absorption over the first 24 hour period.			
Verbal Description*: A 20 g mammal is directly sprayed over one half of the body surface as the chemical is being applied. The deposited dose is assumed to be completely absorbed during the first day. An empirical relationship between body weight and surface area (Boxenbaum and D'Souze 1990) is used to estimate the surface area of the animal.*			
Parameter/Assumption	Value	Units	Source/Reference
Period of exposure (***T***)	24	hour	N/A
Body weight (***W***)	0.020	kg	Section 4.2.1.
Exposed surface area (***A***)	$cm^2=1110\times BW(kg)^{0.65}$		Boxenbaum and D'Souza 1990
	87	cm^2	
Application rate (***R***)			
Typical/Central	0.1	lb a.i. /acre	WS10.TYP
Low	0.023		WS10.LOW
High	0.38		WS10.HI
Conversion Factor (***F***) for lb/acre to mg/cm^2	0.01121		WS01.LBAC_MGCM
Estimated Absorbed Doses (***D***) - ***see calculations below.***			
Central	2.4	mg/kg	SMDS2DC
Low	0.56	mg/kg	SMDS2DL
High	9.3	mg/kg	SMDS2DH

Direct Spray of Small Mammal, Complete absorption, Details of calculations

Equation: $0.5 \times F \times R \times A \div W$

Verbal Description: *Multiply by 0.5 because only one half of the body surface is assumed to be sprayed. Calculate the amount deposited on the animal as the product of the application rate converted to mg/cm^2 and the surface area of the animal in cm^2. Divide by the body weight.*

Central Estimate: Use the central estimate of the application rate,
0.5×0.01121 ($mg/cm^2 \div$ lb/acre) $\times$ 0.1 lb/acre $\times$ 87 $cm^2 \div$ 0.02 kg = 2.4 mg/kg [SMDS2DC]

Lower Range of Estimate [WS382DL]: Use the lowest anticipated application rate,
0.5×0.01121 ($mg/cm^2 \div$ lb/acre) $\times$ 0.023 lb/acre $\times$ 87 $cm^2 \div$ 0.02 kg = 0.56 mg/kg [SMDS2DL]

Upper Range of Estimate [WS382DH]: Use the highest anticipated application rate,
0.5×0.01121 ($mg/cm^2 \div$ lb/acre) $\times$ 0.38 lb/acre $\times$ 87 $cm^2 \div$ 0.02 kg = 9.3 mg/kg [SMDS2DU]

Worksheet 41: Direct spray of bee assuming 100% absorption over the first 24 hour period.			
Verbal Description*: A 0.093 g bee is directly sprayed over one half of the body surface as the chemical is being applied. The deposited dose is assumed to be completely absorbed during the first day. An empirical relationship between body weight and surface area (Boxenbaum and D'Souze 1990) is used to estimate the surface area of the animal.*			
Parameter/Assumption	Value	Units	Source/Reference
Period of exposure (***T***)	24	hour	N/A
Body weight (***W***)	0.000093	kg	Section 4.2.1.
Exposed surface area (***A***)	$cm^2=1110\times BW(kg)^{0.65}$		Boxenbaum and D'Souza 1990
	2.7	cm^2	
Application rate (***R***)			
Typical/Central	0.1	lb a.i. /acre	WS10.TYP
Low	0.023		WS10.LOW
High	0.38		WS10.HI
Conversion Factor (***F***) for lb/acre to mg/cm^2	0.01121		WS01.LBAC_MGCM
Estimated Absorbed Doses (***D***) - ***see calculations below.***			
Central	16	mg/kg	BEEDS2DC
Low	3.7	mg/kg	BEEDS2DL
High	62	mg/kg	BEEDS2DH

Direct Spray of Bee, Complete absorption, Details of calculations

Equation: $0.5 \times F \times R \times A \div W$

Verbal Description: *Multiply by 0.5 because only one half of the body surface is assumed to be sprayed. Calculate the amount deposited on the animal as the product of the application rate converted to mg/cm^2 and the surface area of the animal in cm^2. Divide by the body weight.*

Central Estimate: Use the central estimate of the application rate,
0.5×0.01121 ($mg/cm^2 \div$ lb/acre) $\times$ 0.1 lb/acre $\times$ 2.7 $cm^2 \div$ 0.000093 kg = 16 mg/kg [BEEDS2DC]

Lower Range of Estimate: Use the lowest anticipated application rate,
0.5×0.01121 ($mg/cm^2 \div$ lb/acre) $\times$ 0.023 lb/acre $\times$ 2.7 $cm^2 \div$ 0.000093 kg = 3.7 mg/kg [BEEDS2DL]

Upper Range of Estimate: Use the highest anticipated application rate,
0.5×0.01121 ($mg/cm^2 \div$ lb/acre) $\times$ 0.38 lb/acre $\times$ 2.7 $cm^2 \div$ 0.000093 kg = 62 mg/kg [BEEDS2DH]

Worksheet 42: Consumption of contaminated vegetation by a small mammal, acute exposure scenario.

Verbal Description*: A 20 g mammal consumes vegetation shortly after application of the chemical - i.e. no dissipation or degradation is considered. The contaminated vegetation accounts for 100% of the diet. Residue estimates based on relationships for leaves and leafy vegetables from Hoerger and Kenaga (1972) summarized in Worksheet 05a.*

Parameters/Assumptions	Value	Units	Source/Reference
Body weight (***W***)	0.020	kg	N/A
Food consumed per day (***A***)	0.003	kg	U.S. EPA 1989a
Duration of exposure (***D***)	1	day	N/A
Application rates (***R***)			
Typical	0.1	lb a.i./acre	WS10.Typ
Lower	0.023	lb a.i./acre	WS10.Low
Upper	0.38	lb a.i./acre	WS10.Hi
Residue rates (***rr***)			
Typical	35	RUD[1]	WS05a.LVT
Upper	125	RUD[1]	WS05a.LVU
Dose estimates (***D***) - **see details of calculations below**			
Typical	0.53	mg/kg bw	VGCSMAC
Lower	0.12	mg/kg bw	VGCSMAL
Upper	7.1	mg/kg bw	VGCSMAU

[1] RUD: Residue Unit Dosage, term used by Hoerger and Kenaga (1972) for anticipated concentration on vegetation (mg chemical per kg of vegetation) for each l lb a.i./acre applied.

Equation (terms defined in above table):

D (mg/kg bw) = ***A***(kg) × ***R***(lb a.i./acre) × ***rr***(mg/kg veg.÷lb a.i./acre) ÷ ***W***(kg bw)

Details of Calculations

Typical: Use typical application rate and typical RUD.

D = 0.003 kg × 0.1 lb a.i./acre × 35 mg/kg÷lb a.i./acre ÷ 0.02 kg = 0.53 mg/kg bw [VGCSMAC]

Lower: Use lowest estimated application rate. Use typical RUD because no lower estimate of the RUD is available.

D = 0.003 kg × 0.023 lb a.i./acre × 35 mg/kg÷lb a.i./acre ÷ 0.02 kg = 0.12 mg/kg bw [VGCSMAL]

Upper: Use highest estimated application rate and highest RUD.

D = 0.003 kg × 0.38 lb a.i./acre × 125 mg/kg÷lb a.i./acre ÷ 0.02 kg = 7.1 mg/kg bw [VGCSMAU]

Worksheet 43: Consumption of contaminated vegetation by a small mammal, subchronic exposure scenario.

Verbal Description*: A 20 g mammal consumes contaminated vegetation for a 90 day period starting shortly after application of the chemical. It is assumed that 100% of the diet is contaminated. Initial residue estimates are based on relationships for leaves and leafy vegetables from Hoerger and Kenaga (1972) summarized in Worksheet 05a. The foliar half-time is used to estimate the concentration on vegetation after 90 days. The geometric mean of the initial and 90 day concentrations is used as the estimate of the dose.*

Parameters/Assumptions	Value	Units	Source/Reference
Duration of exposure (***D***)	90	days	N/A
Body weight (***W***)	0.02	kg	
Food consumed per day (***A***)	0.003	kg	U.S. EPA 1989a
kg food consumed per kg bw	0.15	Unitless	0.003/0.02
Application rates (***R***)			
Typical	0.1	lb a.i./acre	WS10.Typ
Lower	0.023	lb a.i./acre	WS10.Low
Upper	0.38	lb a.i./acre	WS10.Hi
Residue rates (***rr***)			
Typical	35	RUD[1]	WS05a.LVT
Upper	125	RUD[1]	WS05a.LVU
Dose estimates (***D***) - **see details of calculations on next page**			
Typical	0.023	mg/kg bw	VGCSMCT
Lower	0.0054	mg/kg bw	VGCSMCL
Upper	0.32	mg/kg bw	VGCSMCU

[1] RUD: Residue Unit Dosage, term used by Hoerger and Kenaga (1972) for anticipated concentration on fruit (mg chemical per kg of vegetation) for each l lb a.i./acre applied.

Equations (terms defined below or in above table):

Step 1: Calculate $C_{0,}$ concentration in vegetation on Day 0 - i..e., day of application.

C_0 (mg/kg) = ***R***(lb a.i./acre) × ***rr***(mg/kg÷lb a.i./acre)

Step 2: Calculate $C_{90,}$ concentration in vegetation on Day 90 (t=90 days) based on dissipation coefficient (k) derived from foliar half-life ($t_{½}$).

k ($days^{-1}$) = ln(2) ÷ $t_{½}$ (days)

C_{90} (mg/kg) = C_0 (mg/kg) × e^{-tk}

Step 3: Use the geometric mean of C_0 and C_{90} to get a central estimate of concentration in vegetation (mg/kg veg.) and multiply this value by the vegetation consumption (kg veg/kg bw) to calculate the daily dose (mg/kg bw) over the exposure period.

D (mg/kg bw) = $(C_0 \times C_{90})^{0.5}$ (mg/kg veg.) × ***A*** kg veg./kg bw

Details of calculations on next page

Subchronic consumption of vegetation by a small mammal:
Details of calculations

Central Estimate:

Use the typical application rate, the typical vegetation consumption rate, and the typical residue rate along with the single available estimate of foliar half-time.

Step 1:

C_0 = 0.1 lb a.i./acre × 35 mg/kg veg. = 3.5 mg/kg veg.

Step 2:

k = ln(2) ÷10 $days^{-1}$ = 0.0693

C_{90} = 3.5 mg/kg × $e^{-0.0693 \times 90}$ = 0.0068 mg/kg veg.

Step 3:

D (mg/kg bw/day) = $(3.5 \times 0.0068)^{0.5}$ (mg/kg veg.) × 0.15 kg veg/kg bw = 0.023 mg/kg bw [VGCSMCT]

Lower Estimate:

Use the lowest anticipated application rate along with the single available estimate of foliar half-time.. Also the typical vegetation consumption rate and the typical residue rate because lower limits on these estimates are not available.

Step 1:

C_0 = 0.023 lb a.i./acre × 35 mg/kg veg. = 0.805 mg/kg veg.

Step 2:

k = ln(2) ÷10 $days^{-1}$ = 0.0693

C_{90} = 0.805 mg/kg × $e^{-0.0693 \times 90}$ = 0.0016 mg/kg veg.

Step 3:

$D_{(mg/kg\ bw)} = (0.805 \times 0.0016)^{0.5}{}_{(mg/kg\ veg.)} \times 0.15_{(kg\ veg/kg\ bw)} = 0.0054_{(mg/kg\ bw)}$ [VGCSMCL]

Upper Estimate:

Use the highest anticipated application rate, the upper range of the vegetation consumption rate and the upper range of the residue rate along with the single available estimate of foliar half-time.

Step 1:

C_0 = 0.38 lb a.i./acre × 125 mg/kg veg. = 47.5 mg/kg veg.

Step 2:

k = ln(2) ÷10 $days^{-1}$ = 0.0693

C_{90} = 47.5 mg/kg × $e^{-0.0693 \times 90}$ = 0.093 mg/kg veg.

Step 3:

$D_{(mg/kg\ bw)} = (47.5 \times 0.093)^{0.5}{}_{(mg/kg\ veg.)} \times 0.15_{(kg\ veg/kg\ bw)} = 0.32_{(mg/kg\ bw)}$ [VGCSMCU]

Worksheet 44: Consumption of contaminated water by a small mammal, acute exposure scenario.			
***Verbal Description**: A small (20g) mammal consumes 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.*			
Parameters/Assumptions	Value	Units	Source/Reference
Surface area of pond [SA]	1000	m^2	N/A
Average depth [DPTH]	1	m	N/A
Volume of pond in cubic meters [VM]	1000	m^3	N/A
Volume of pond in Liters [VL]	1000000	L	1 m^3 = 1,000 L
Volume of spill [VS]	200	gallons	N/A
Concentrations in solution ($C_{(mg/L)}$)			
Central	440	mg/L	WS11.TYPDR×1000
Low	70	mg/L	WS11.LOWDR×1000
High	3030	mg/L	WS11.HI_DR×1000
Body weight (***W***)	0.02	kg	N/A
Amount of water consumed (***A***)	0.005	L/day	U.S. EPA 1989a
Dose estimates (***D***) - **see details of calculations below.**			
Typical	0.083	mg/kg bw	WTCSMAT
Lower	0.0130	mg/kg bw	WTCSMAL
Upper	0.57	mg/kg bw	WTCSMAU

Equations (terms defined below or in table)

Step 1: Calculate the concentration in the pond based on the concentration in the spilled solution, the volume spilled and the volume of the pond, assuming instantaneous mixing.

$$\text{Conc.}_{(mg/L)} = VS_{(gal.)} \times 3.785_{L/gal} \times C_{(mg/L)} \div VL_{(liters)}$$

Step 2: Calculate the dose based on the concentration in the water, the amount of water consumed, and the body weight.

$$D_{(mg/kg\ bw)} = \text{Conc.}_{(mg/L)} \times \boldsymbol{A}_{(L)} \div W_{(kg)}$$

Central Estimate: Use the typical field dilution,

Step 1: $\text{Conc.}_{(mg/L)} = 200_{(gal.)} \times 3.785_{L/gal} \times 440_{(mg/L)} \div 1000000_{(liters)} = 0.33_{(mg/L)}$

Step 2: $D_{(mg/kg\ bw)} = 0.33_{(mg/L)} \times 0.005_{(L)} \div 0.02_{(kg)} = 0.083_{(mg/kg\ bw)}$ [WTCSMAT]

Lower Estimate: Use the lowest estimated field dilution,

Step 1: $\text{Conc.}_{(mg/L)} = 200_{(gal.)} \times 3.785_{L/gal} \times 70_{(mg/L)} \div 1000000_{(liters)} = 0.053_{(mg/L)}$

Step 2: $D_{(mg/kg\ bw)} = 0.053_{(mg/L)} \times 0.005_{(L)} \div 0.02_{(kg)} = 0.013_{(mg/kg\ bw)}$ [WTCSMAL]

Upper Estimate: Use the highest estimated field concentration,

Step 1: $\text{Conc.}_{(mg/L)} = 200_{(gal.)} \times 3.785_{L/gal} \times 3030_{(mg/L)} \div 1000000_{(liters)} = 2.29_{(mg/L)}$

Step 2: $D_{(mg/kg\ bw)} = 2.29_{(mg/L)} \times 0.005_{(L)} \div 0.02_{(kg)} = 0.57_{(mg/kg\ bw)}$ [WTCSMAU]

Worksheet 45: Consumption of contaminated water by a small mammal, chronic exposure scenario.			
Verbal Description*: A small (20 g) mammal consumes contaminated ambient water for a lifetime. The levels in water are estimated from monitoring data and thus dissipation, degradation and other environmental processes are implicitly considered.*			
Parameters/Assumptions	Value	Units	Source/Reference
Application Rates ($R_{(\text{lb a.i./acre})}$)			
Central	0.1	lb a.i./gal	WS10.Typ
Low	0.023		WS10.Low
High	0.38		WS10.Hi
Water Contamination Rate (WCR)($C_{(\text{mg/L})} \div R_{(\text{lb a.i./gal})}$)			
Central	0.054	mg/L/lb a.i./acre	WS16.AWT
Low	0.014		WS16.AWL
High	0.12		WS16.AWU
Body weight (W)	0.02	kg	U.S. EPA 1989a
Amount of water consumed ($A_{(\text{L/day})}$)	0.005	L/day	U.S. EPA 1989a
Dose estimates (D) - **see details of calculations on next page.**			
Typical	0.0014	mg/kg bw	WTCSMCT
Lower	0.000081	mg/kg bw	WTCSMCL
Upper	0.011	mg/kg bw	WTCSMCU

Equations (terms defined in table)

Verbal Description: Multiply the application rate ($R_{(\text{lb a.i./acre})}$) by the water contamination rate ($WCR_{((\text{mg/L})\times(\text{lb a.i./gal}))}$) to get the concentration in ambient water. This product is in turn multiplied by the amount of water consumed per day ($A_{(\text{L/day})}$) and then divided by the body weight ($W_{(\text{kg})}$)to get the estimate of the absorbed dose ($D_{(\text{mg/kg bw})}$).

$$D_{(\text{mg/kg bw})} = R_{(\text{lb a.i./acre})} \times WCR_{((\text{mg/L})\times(\text{lb a.i./gal}))} \times A_{(\text{L/day})} \div W_{(\text{kg})}$$

Central Estimate: Use the typical application rate and typical water contamination rate (WCR)

$$D_{(\text{mg/kg bw})} = 0.1_{(\text{lb a.i./acre})} \times 0.054_{((\text{mg/L})\times(\text{lb a.i./gal}))} \times 0.005_{(\text{L/day})} \div 0.02_{(\text{kg bw})} = 0.0014_{(\text{mg/kg bw})}$$ [WTCSMCT]

Lower Range of Estimate: Use the lowest anticipated application rate and the low end of the range of the water contamination rate (WCR)

$$D_{(\text{mg/kg bw})} = 0.023_{(\text{lb a.i./acre})} \times 0.014_{((\text{mg/L})\times(\text{lb a.i./gal}))} \times 0.005_{(\text{L/day})} \div 0.02_{(\text{kg bw})} = 0.000081_{(\text{mg/kg bw})}$$ [WTCSMCL]

Upper range of Estimate: Use the lowest anticipated application rate and the low end of the range of the water contamination rate (WCR)

$$D_{(\text{mg/kg bw})} = 0.38_{(\text{lb a.i./acre})} \times 0.12_{((\text{mg/L})\times(\text{lb a.i./gal}))} \times 0.005_{(\text{L/day})} \div 0.02_{(\text{kg bw})} = 0.011_{(\text{mg/kg bw})}$$ [WTCSMCU]

Worksheet 46: Summary of Exposure Scenarios for terrestrial animals

Scenario	Dose (mg/kg/day)			Worksheet
	Typical	Lower	Upper	
Acute/Accidental Exposures				
Direct spray, small mammal, first-order absorption	0.013	0.00064	0.22	WS39
Direct spray, small animal, 100% absorption	2.4	0.56	9.3	WS40
Direct spray, bee, 100% absorption	16	3.7	62	WS41
Consumption of contaminated vegetation, acute exposure	0.53	0.12	7.1	WS42
Consumption of contaminated water, acute exposure	0.083	0.013	0.57	WS44
Longer Term Exposures				
Consumption of contaminated vegetation, chronic exposure	0.023	0.0054	0.32	WS43
Consumption of contaminated water, chronic exposure	0.0014	0.000081	0.011	WS45

Worksheet 47: Summary of quantitative risk characterization for terrestrial animals[1]

Scenario	Hazard Quotient[2]		
	Typical	Lower	Upper
Acute/Accidental Exposures			
Direct spray, small mammal, first-order absorption	0.007	0.0003	0.1
Direct spray, small animal, 100% absorption	1	0.3	5
Direct spray, bee, 100% absorption[3]	0.01	0.003	0.06
Consumption of contaminated vegetation, acute exposure	0.3	0.06	4
Consumption of contaminated water, acute exposure	0.04	0.01	0.3
Longer Term Exposures			
Consumption of contaminated vegetation, chronic exposure	0.01	0.003	0.2
Consumption of contaminated water, chronic exposure	0.001	0.00004	0.006

[1] See Worksheet 45 for details of exposure assessment.
[2] Except for the honey bee, the hazard quotient is calculated as the estimated exposure divided by the chronic rats NOAEL of 2 mg/kg/day and then rounded to one significant decimal or digit.
[3] The hazard quotient is based on the non-lethal acute dose level of 1075 mg/kg from the study by (Hoxter and Smith 1990) .

Worksheet 48: Toxicity of sulfometuron methyl to terrestrial Plants (data Drake 1990)

Summary of Categorical Regressions

Crops: 1-10 Scale Categorical Regression Using Data from Drake(1990)

Converged by Objective

Whole-Model Test

Model	-LogLikelihood	DF	ChiSquare	Prob>ChiSq
Difference	45.01322	1	90.02643	<.0001
Full	415.08027			
Reduced	460.09348			

RSquare (U)	0.0978
Observations (or Sum Wgts)	283

Lack of Fit

Source	DF	-LogLikelihood	ChiSquare
Lack of Fit	62	56.76950	113.539
Pure Error	211	358.31077	Prob>ChiSq
Total Error	273	415.08027	<.0001

Parameter Estimates

Term	Estimate	Std Error	ChiSquare	Prob>ChiSq
Intercept	-9.2198084	1.0953051	70.86	<.0001
Intercept	-7.2220712	0.5820894	153.94	<.0001
Intercept	-5.9780389	0.4830854	153.13	<.0001
Intercept	-5.6690125	0.4680098	146.73	<.0001
Intercept	-5.2025167	0.448154	134.76	<.0001
Intercept	-4.8896674	0.4359819	125.78	<.0001
Intercept	-4.5284173	0.4225368	114.86	<.0001
Intercept	-4.0966428	0.4071074	101.26	<.0001
Intercept	-2.503497	0.3546713	49.82	<.0001
lograte	-0.6982576	0.0794472	77.25	<.0001

Effect Test

Source	Nparm	DF	Wald ChiSquare	Prob>ChiSq
lograte	1	1	77.245634	0.0000

Worksheet 48 (continued)

Weeds: 1-10 Scale Categorical Regression Using Data from Drake(1990)

Converged by Objective

Whole-Model Test

Model	-LogLikelihood	DF	ChiSquare	Prob>ChiSq
Difference	106.66140	1	213.3228	<.0001
Full	700.36529			
Reduced	807.02669			

RSquare (U)	0.1322
Observations (or Sum Wgts)	492

Lack of Fit

Source	DF	-LogLikelihood	ChiSquare
Lack of Fit	69	65.33916	130.6783
Pure Error	412	635.02612	Prob>ChiSq
Total Error	481	700.36529	<.0001

Parameter Estimates

Term	Estimate	Std Error	ChiSquare	Prob>ChiSq
Intercept	-9.8535755	0.798518	152.27	<.0001
Intercept	-9.4387689	0.6861033	189.26	<.0001
Intercept	-8.0034005	0.4701751	289.75	<.0001
Intercept	-7.1088373	0.4133502	295.77	<.0001
Intercept	-6.7396663	0.3976758	287.22	<.0001
Intercept	-6.1503709	0.3769076	266.28	<.0001
Intercept	-5.753485	0.3643918	249.30	<.0001
Intercept	-5.0045201	0.3416375	214.58	<.0001
Intercept	-4.5103922	0.3273375	189.86	<.0001
Intercept	-3.2659004	0.2931572	124.11	<.0001
lograte	-0.8366653	0.0649626	165.87	<.0001

Effect Test

Source	Nparm	DF	Wald ChiSquare	Prob>ChiSq
lograte	1	1	165.87361	0.0000

Worksheet 48 (continued)

Broadleaves, Crops and Weeds Combined: 1-10 Scale Categorical Regression Using Data from Drake(1990)

Converged by Objective

Whole-Model Test

Model	-LogLikelihood	DF	ChiSquare	Prob>ChiSq
Difference	67.30252	1	134.605	<.0001
Full	443.91981			
Reduced	511.22233			

RSquare (U)	0.1317
Observations (or Sum Wgts)	335

Lack of Fit

Source	DF	-LogLikelihood	ChiSquare
Lack of Fit	69	45.62650	91.253
Pure Error	255	398.29331	Prob>ChiSq
Total Error	324	443.91981	0.0377

Parameter Estimates

Term	Estimate	Std Error	ChiSquare	Prob>ChiSq
Intercept	-10.058212	1.1042825	82.96	<.0001
Intercept	-9.358495	0.8432719	123.16	<.0001
Intercept	-8.6489938	0.6747536	164.30	<.0001
Intercept	-7.2148028	0.5106541	199.62	<.0001
Intercept	-7.0032516	0.4977106	197.99	<.0001
Intercept	-6.3320672	0.4651652	185.30	<.0001
Intercept	-5.8824851	0.4474293	172.85	<.0001
Intercept	-5.0790487	0.4180632	147.60	<.0001
Intercept	-4.6410068	0.4028248	132.74	<.0001
Intercept	-3.2339241	0.3544685	83.23	<.0001
lograte	-0.811872	0.0778512	108.75	<.0001

Effect Test

Source	Nparm	DF	Wald ChiSquare	Prob>ChiSq
lograte	1	1	108.75370	0.0000

Worksheet 48 (continued)

Grasses, Crops and Weeds Combined: 1-10 Scale Categorical Regression Using Data from Drake(1990)

Response: sev

Converged by Gradient

Whole-Model Test

Model	-LogLikelihood	DF	ChiSquare	Prob>ChiSq
Difference	84.85667	1	169.7133	<.0001
Full	671.26292			
Reduced	756.11958			

RSquare (U)	0.1122
Observations (or Sum Wgts)	440

Lack of Fit

Source	DF	-LogLikelihood	ChiSquare
Lack of Fit	69	85.04760	170.0952
Pure Error	360	586.21531	Prob>ChiSq
Total Error	429	671.26292	<.0001

Parameter Estimates

Term	Estimate	Std Error	ChiSquare	Prob>ChiSq
Intercept	-10.061926	1.0569449	90.63	<.0001
Intercept	-9.3589898	0.7923874	139.50	<.0001
Intercept	-7.2708842	0.4508885	260.04	<.0001
Intercept	-6.3730764	0.4023392	250.91	<.0001
Intercept	-5.966297	0.3866954	238.05	<.0001
Intercept	-5.4802597	0.3701154	219.24	<.0001
Intercept	-5.1586346	0.3598201	205.54	<.0001
Intercept	-4.6753898	0.3448617	183.80	<.0001
Intercept	-4.1877735	0.3304779	160.58	<.0001
Intercept	-2.8247901	0.2940979	92.25	<.0001
lograte	-0.7741466	0.0661317	137.03	<.0001

Effect Test

Source	Nparm	DF	Wald ChiSquare	Prob>ChiSq
lograte	1	1	137.03369	0.0000