Literature review of impacts of glyphosate herbicide on amphibians: What risks can the silvicultural use of this herbicide pose for amphibians in B.C.?

by

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BRITISH COLUMBIA
The Best Place on Earth
Ministry of Environment

Victoria, B.C.

Wildlife Report No. R-28

June 2008

Library and Archives Canada Cataloguing in Publication Data

Govindarajulu, Purnima P.

Literature review of impacts of glyphosate herbicide on amphibians [electronic resource] : What risks can the silvicultural use of this herbicide pose for amphibians in B.C.?

(Wildlife report ; no. 28)

Available on the Internet.
Includes bibliographical references: p.
ISBN 978-0-7726-6013-8

1. Amphibians - Effect of pesticides on. Glyphosate - Environmental aspects. 2. Amphibians - Effect of pesticides on - British Columbia. 3. Glyphosate - Environmental aspects. 4. Glyphosate - Toxicology. 5. Surface active agents - Toxicology. I. British Columbia. Ecosystems Branch. II. Series: Wildlife report (Victoria, B.C.) ; no. 28.

QL644.7.G68 2008 597.8'17279 C2008-960118-1

Copies of this report are available online through B.C. Ministry of Environment at http://www.env.gov.bc.ca/wld/

Citation

Govindarajulu, P. P. 2008. Literature review of impacts of glyphosate herbicide on amphibians: What risks can the silvicultural use of this herbicide pose for amphibians in B.C.?. B.C. Ministry of Environment, Victoria, BC. Wildlife Report No. R-28.

ACKNOWLEDGEMENTS

This literature review was funded by the B.C. Ministry of Forests and Range, the Forest Investment Account, and the B.C. Ministry of Environment. The report was greatly improved by information and insightful comments provide by Jen-ni Kuo, John Pasternak, Bruce Pauli, Iulia Popa, and Michael Wan, Environment Canada; Jacob Boateng, B.C. Ministry of Forests and Range; Rob Adams, Dean Cherkas, Bob Cox, Dan Cronin, Laura Friis, Nicole Pressey, and Sylvia von Schuckmann, B.C. Ministry of Environment; and Doug Wahl, Snowy River Resources.

EXECUTIVE SUMMARY

Glyphosate herbicides are the most widely used non-selective broad-spectrum herbicides in the world. In Canada they are extensively used in forestry for site preparation and for conifer release. This report summarizes current literature on the non-target impacts of glyphosate herbicides on amphibians. This review of published studies, combined with a review of the application guidelines and the use patterns of this herbicide in silviculture in B.C., identifies knowledge gaps in the assessment of herbicide impacts on native amphibians in this province.

Recent studies have shown that amphibians are one of the most sensitive vertebrate groups to the toxicological effects of this herbicide. The LC_{50} (lethal concentration) value for many amphibians is between 10 and 1 mg a.e./L, and for some amphibians the LC_{50} is between 1 and 0.1 mg a.e./L (acid equivalent, a.e., is a measure of the amount of the active glyphosate ingredient in herbicide formulations). Therefore, glyphosate herbicides are classified as moderately to highly toxic to amphibians. In addition, the expected environmental concentration (EEC) of glyphosate herbicides of 1.43 mg a.e./L is at or above the estimated LC_{50} value for some amphibians, particularly when water pH is above 7. Amphibians may also suffer from a variety of sublethal effects (e.g., impaired growth and development, behaviour, physiological parameters, and genomic characteristics) and indirect impacts (e.g., mediated through interaction with competitive and predatory stress, and changes to the food resources, temperature, pH, and UV light) arising from the use of glyphosate herbicides.

There is evidence to suggest that the surfactant (polyethoxylated tallow amine or POEA) rather than the active ingredient (isopropylamine salt of glyphosate) in these formulations is responsible for the toxic effects in amphibians. Alternative formulations that do not use POEA are now available in some parts of the world (but not in Canada) and these formulations have been shown to have much lower toxicity to amphibians.

In most jurisdictions, the use of glyphosate herbicides in silviculture requires that label directions are followed and also that sensitive areas are protected by a buffer zone. In B.C. pesticide-free zones (PFZ) are required around sensitive areas and buffer zones are required to protect these PFZs around the sensitive areas. In B.C. these requirements apply to large and moderate-sized wetlands and streams and are intended to protect aquatic organisms from impacts of glyphosate herbicides. Although most waterbodies and many riparian areas are afforded protection, glyphosate may be sprayed over dry creeks as well as over certain types of temporary isolated ponds that are habitats frequently used by amphibians.

British Columbia ranks second in Canada in the use of glyphosate in forestry. In B.C. glyphosate herbicides are used over approximately 20,000 ha of forested land, primarily for conifer release. Most of this area is in the Northern Interior Forestry Region and this region accounts for 95% of the aerial application and 57% of the ground application of this herbicide. The commercial formulation most commonly used is Vision (Monsanto, Winnipeg, Manitoba), although Monsanto recently introduced a more concentrated formulation, VisionMax. Other manufacturers now also supply glyphosate-based herbicides to the Canadian market. Glyphosate herbicides are applied once during the silvicultural cycle (50 to 80 years), primarily during summer and early fall (July to September), but applications may be repeated if further weed suppression is required.

This review suggests that the silvicultural use of glyphosate needs to be re-evaluated with respect to non-target impacts on amphibians in B.C. In addition, knowledge gaps hinder effective and realistic assessment of these impacts. Glyphosate impacts can be species-specific in amphibians, but acute toxicity values are known for only two native B.C. amphibians (the Wood Frog, *Rana sylvatica*, and the Leopard Frog, *R. pipiens*). The impact of glyphosate herbicides on salamander species and on terrestrial stages of amphibians is not well understood. There is insufficient information on the levels of glyphosate contamination in small ephemeral wetlands, which are favoured habitats of amphibians, and which may be exposed to direct overspraying with herbicide under current use guidelines. Although the surfactant in glyphosate herbicides, POEA, has been identified as potentially the primary ingredient causing toxicity to amphibians, the option of using surfactants of lower toxicity has not been assessed. These knowledge gaps need to be addressed so that best management practices can be developed to minimize non-target impacts on amphibians from the use of glyphosate herbicides in forestry.

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INTRODUCTION

Although chemical pesticides have greatly improved yields in agriculture and forestry (Guynn et al. 2004), their non-target impacts have caused considerable concern since Rachel Carson published *Silent Spring* in 1962 (Carson 1962). Pesticides, including insecticides and herbicides, are believed to be particularly detrimental to amphibians because of their aquatic life habit, sensitive skin, and unprotected eggs (Bishop and Pettit 1992). Surveys have shown that amphibian declines are correlated with pesticide use (Sparling et al. 2000; Davidson et al. 2001, 2002). However, historically there has been a relative paucity of data on the effect of pesticides on amphibians. Amphibian ecotoxicology studies constitute only 2.9% of all vertebrate ecotoxicology studies, but, based on their relative class size, amphibian studies should represent 11.4% of the ecotoxicology literature (Sparling et al. 2000). This imbalance is the result of pesticide licensing regulations that required extensive testing on birds, mammals, fish, and aquatic invertebrates, but until recently did not require testing on amphibians (Hall and Henry 1992; Relyea 2005b). Amphibians were assumed to be similar to fish and aquatic invertebrates for calculating susceptibility values. However, recent studies and reviews have shown that amphibians can be more sensitive than these other groups for a number of pesticides and other environmental contaminants (Birge et al. 2000; Westerman et al. 2003; Thompson et al. 2004; Wojtaszek et al. 2004).

This report reviews current knowledge on the impact of a particular herbicide, glyphosate, on amphibians. Glyphosate is a broad-spectrum, non-selective, post-emergence herbicide. Glyphosate herbicides are extensively used in agriculture to suppress annual and perennial weeds. In forestry, these herbicides are used to suppress undesirable competing vegetation in high-yield coniferous plantations to increase rates of succession after harvesting. In Canada, B.C. ranks second (17%) to Ontario (43%) in the use of glyphosate herbicides in forestry (Thompson and Pitt 2003). The commercial formulation Vision (Monsanto, Winnipeg, MB, Canada) accounts for 90% of herbicide use in forestry (Thompson and Pitt 2003; Chen et al. 2004; Edginton et al. 2004a).

The report consists of five sections. Section 1 summarizes the current literature on the direct and indirect impacts of glyphosate herbicides on amphibians. Section 2 provides general information on glyphosate herbicides and their chemistry and summarizes the guidelines for their use. Section 3 summarizes glyphosate use patterns in forestry, with particular emphasis on its use in B.C. Section 4 identifies the species and life stages of amphibians that may be most susceptible to glyphosate impacts given the use patterns in B.C. Section 5 summarizes current knowledge of glyphosate impacts on amphibians, and Section 6 identifies knowledge gaps that need to be addressed. A Glossary provides definitions of some of the terms used in ecotoxicological studies and in this report.

1. LITERATURE REVIEW OF DIRECT AND INDIRECT IMPACTS OF GLYPHOSATE HERBICIDES ON AMPHIBIANS

The studies discussed in this section have used a variety of methods, studied different species and life stages, measured different response variables and effects (direct or synergistic), and used differing dosages, making it difficult to comparatively evaluate potential effects. To facilitate comparisons, this section is structured in the following manner.

Most amphibians exhibit complex life cycles that alternate between an aquatic larval stage and a terrestrial adult stage, although there are variations to this general pattern. Some salamanders spend a good portion of the adult phase in the aquatic environment, whereas other salamanders remain completely terrestrial. To account for these complex life histories, this section is divided into two parts:

1. Effects of glyphosate on the aquatic stages of amphibians.
2. Effects of glyphosate on the terrestrial stages of amphibians.

When discussing the effects of glyphosate on aquatic stages of amphibians, to account for the different response variables measured by different studies, this report distinguishes between direct impacts and synergistic effects. *Direct impacts* are defined as those that affect the survival, growth and development, behaviour, physiological parameters, and genomic characteristics (gene expression and genetic damage) of the tested amphibian species. *Synergistic effects* are defined as those that arise because interactions with biotic and abiotic conditions serve to exacerbate or diminish the impact of the herbicide (Relyea 2003; Chen et al. 2004; Edginton et al. 2004a).

The studies discussed in this section also used different formulations of glyphosate and various experimental dosages. Most studies to date have examined the effects of Roundup Original, the most common formulation of the glyphosate herbicides, which is used for agricultural or domestic use. Only a few studies have examined the effect of Vision, which is used primarily for silvicultural purposes. However, Vision is chemically identical to Roundup Original (Edginton et al. 2004a), and the two can be expected to have similar impacts on amphibians. In addition, many different commercial formulations of glyphosate herbicides are available worldwide that differ in the amount of active ingredient (isopropylamine salt of glyphosate), in the exact chemical composition of the active ingredient, and in the other formulation ingredients including surfactants.

To enable easy comparison among studies in this review, all treatment concentrations are expressed as milligrams of acid equivalents per litre (a.e./L), where the acid equivalent is the primary active form of glyphosate in the herbicidal formulation (Edginton et al. 2004a). Some studies used milligrams of active ingredient (a.i.) to denote glyphosate concentration. For converting a.i. concentrations to a.e. concentrations, 1 mg a.i. is estimated to contain 0.75 mg a.e. (Giesy et al. 2000).

The name of the commercial formulation used in each study is indicated if this information is provided in the original report. If the exact commercial formulation was not documented, the formulation was assumed to be Roundup Original in agricultural settings and Vision in silvicultural settings for calculating treatment concentrations in mg a.e./L. Roundup is often mentioned in studies without information on the exact trademarked formulation and these were assumed to indicate Roundup Original.

1.1 Effect of Glyphosate on Aquatic Stages of Amphibians

1.1.1 Direct Impacts

Almost all the amphibian studies to date have focussed on anuran larvae (tadpoles) and therefore little information is available on the impact of glyphosate on salamander larvae or aquatic adult salamanders.

Survival

A standard endpoint in ecotoxicological testing is the concentration of chemical required to kill 50% of the test population within a set time period (LC_{50}). This measure is routinely used to set application rates and to calculate hazard quotients (see Glossary). For ease of comparison, glyphosate LC_{50} values from all available studies for amphibians is summarized in Table 1. The smaller the LC_{50} value the higher the toxicity of glyphosate to a given species. The lethal impact of glyphosate herbicide on amphibians depends most importantly on dosage, but also on the species tested, commercial formulation used, experimental set-up, and duration of the experiment (Cauble and Wagner 2005).

At high concentrations (5 to 20 mg a.e./L) commercial formulations of glyphosate herbicide (Vision and Roundup Original) are highly toxic to all North American amphibian species tested as tadpoles: Leopard Frog (*Rana pipiens*), Green Frog (*R. clamitans*), Bullfrog (*R. catesbeiana*), American Toad (*Bufo americanus*), Gray Treefrog (*Hyla versicolor*), and Wood Frog (*R. sylvatica*) (Howe et al. 2004; Wojtaszek et al. 2004; Relyea 2005b).

At a concentration of 2.1 mg a.e./L, which represents the maximum agricultural application rate of Roundup Original sprayed directly over a wetland 15 cm deep, 97–100% mortality was observed in Leopard Frog, American Toad, and Gray Treefrog tadpoles (Relyea 2005a,c). Spring Peeper (*Pseudacris crucifer*) tadpole survival, although decreased by Roundup Original at this dosage, was not significantly different from the survival in the control treatment in one study (Relyea 2005c).

At a concentration of 1.43 mg a.e./L, which is the expected environmental concentration (EEC; see Glossary) after Vision application in Canadian forestry at the maximum allowed label rate, a Roundup formulation caused a 71% decrease in survival of American Toad tadpoles and a 29% decrease in survival of Leopard Frog tadpoles, but did not affect the survival of Gray Treefrog tadpoles (Relyea et al. 2005). At a concentration of 1.5 mg a.e./L, the commercial formulation GLY-F (48% a.e.) caused 80% mortality in the tadpoles of the South American treefrog species *Scinax nasicus* (Lajmanovich et al. 2003). In a laboratory study, Leopard Frog tadpoles chronically exposed to 1.8 mg a.e./L of Roundup Original exhibited significantly lower survival to metamorphosis (Howe et al. 2004). However, in a field enclosure study, mortality of Leopard Frog and Green Frog tadpoles was not increased by exposure to 1.43 mg a.e./L of Vision herbicide (Wojtaszek et al. 2004).

At concentrations of 1 mg a.e./L or less, amphibians seem to be less susceptible to glyphosate toxicity. However, LC_{50} values of 1 mg a.e./L or less have been recorded for Wood Frog and Gray Treefrog tadpoles (Relyea 2005b). Leopard Frog tadpoles chronically exposed to 0.6 mg a.e./L of Roundup Original for the first 42 days after hatching showed reduced survival to metamorphosis (Howe et al. 2004). At concentrations less than 1 mg a.e./L, mortality effects were not observed for Green Frog and Leopard Frog tadpoles (Thompson et al. 2004; Wojtaszek et al. 2004).

In addition to dosage, the duration of the experiment is also an important influence on the lethality of glyphosate herbicides (Relyea and Mills 2001; Lajmanovich et al. 2003; Cauble and Wagner 2005). For example, at low concentrations of glyphosate herbicide, increasing mortality was not observed until after 120 hours of exposure (Relyea 2005b). If the experiment had been terminated before 96 hours, no significant effect of herbicide on survival would have been observed. Standard toxicological experiments estimating LC_{50} values usually extend to 24 hours, 48 hours, or 96 hours. Given that the larval stage in most amphibians extends over many weeks, longer term exposure studies should be considered more appropriate when assessing population-level impacts of these herbicides.

Some laboratory risk assessments have been criticized as being unrealistic because of the absence of soil in experimental mesocosms. Soil can adsorb pesticides, making them unavailable to aquatic organisms. However, a study examining the effect of adding loam and sand to experimental mesocosms found no difference in tadpole mortality between mesocosms with and without soil additions (Relyea 2005a).

In general, experiments that renewed herbicide treatments (static renewal design) to maintain treatment concentration for the duration of the experiment estimated lower LC_{50} values than studies that did not renew herbicide treatments after the initial dosing. In the non-renewal studies, microbial degradation of herbicidal ingredients as well as partitioning to sediment and other environmental dissipation processes could have resulted in lowering treatment concentrations over time, resulting in higher LC_{50} values.

No studies have specifically examined the effect of glyphosate herbicides on larval or adult aquatic salamanders. However, salamanders have been used as tadpole predators in studies of glyphosate impact on tadpoles. These studies recorded no negative impact of Roundup on newts (*Notophthalmus viridescens*) or newly hatched Spotted Salamanders (*Ambystoma maculatum*) (Relyea 2005c; Relyea et al. 2005).

Some studies have examined whether it is the glyphosate active ingredient or other ingredients in the commercial formulation that have caused mortality in amphibians. These studies demonstrated the following: (1) technical grade glyphosate is much less toxic than some of the commercial formulations; (2) commercial glyphosate formulations with the surfactant polyoxyethyleneamine (POEA) are similar in toxicity to the surfactant POEA alone; (3) glyphosate herbicide formulations, such as Rodeo, that are formulated without a surfactant are much less toxic than formulations with the surfactant POEA; 4) glyphosate herbicides with alternative surfactants (the identity and composition of these surfactants are trademark protected) such as RoundupBiactive and Glyfos BIO (Cheminova) are also much less toxic to frogs than Roundup Original/Vision (Mann and Bidwell 1999; Perkins et al. 2000; Edginton et al. 2004b; Howe et al. 2004). These studies support the conclusion that the toxic effect of POEA-containing glyphosate herbicides is due to POEA rather than to the active glyphosate ingredient.

Table 1: Toxicity values for Roundup Original/Vision LC_{50} summarized from studies done on amphibians around the world
Note that there is considerable variation in LC_{50} values among species and even within species.

Species	Duration	Experiment	LC_{50} (mg a.e./L)	Notes	Reference
North America					
Rana clamitans Green Frog	96 hours	Field enclosure	4.34 (3.05–6.02) 2.70 (2.06–3.67)	Site A tadpole Site B tadpole	Wojtaszek et al. 2004
	96 hours	Laboratory, static exposure	2.0 (1.9–2.2) 7.1 (6.6–7.6)	Gosner stage 25 Gosner stage 20	Howe et al. 2004
	96 hours	Laboratory, static renewal	5.3 (3.9–9.2) 4.1 (3.4–6.4) 3.5 (3.0–4.6) 1.4 (1.2–1.7)	pH 6.0 embryo pH 7.5 embryo pH 6.0 tadpole pH 7.5 tadpole	Edginton et al. 2004b
	16 days	Laboratory, static renewal	1.63		Relyea 2005b
Rana pipiens Leopard Frog	96 hours	Field enclosure	11.47 (9.50–14.5) 4.25 (2.45–7.10)	Site A Site B	Wojtaszek et al. 2004
	96 hours	Laboratory, static exposure	2.9 (not avail.) 6.5 (6.1–6.8)	Gosner stage 25 Gosner stage 20	Howe et al. 2004
	96 hours	Laboratory, static renewal	15.1 (14.0–17.5) 7.5 (7.0–9.0) 1.8 (1.5–2.2) 1.1 (0.96–1.14)	pH 6.0 embryo pH 7.5 embryo pH 6.0 tadpole pH 7.5 tadpole	Edginton et al. 2004b
	16 days	Laboratory, static renewal	1.85		Relyea 2005b
Rana sylvatica Wood Frog	96 hours	Laboratory, static exposure	5.1 (4.9–5.4) >8	Gosner stage 25 Gosner stage 20	Howe et al. 2004
	16 days	Laboratory, static renewal	1.0 0.41	No predator Predator present	Relyea 2005b

Species	Duration	Experiment	LC_{50} (mg a.e./L)	Notes	Reference
Bufo americanus American Toad	96 hours	Laboratory, static exposure	<4 8 (not avail.)	Gosner stage 25 Gosner stage 20	Howe et al. 2004
	96 hours	Laboratory, static renewal	4.8 (4.0–5.7) 6.4 (5.8–7.0) 2.9 (2.3–10.5) 1.7 (1.5–1.9)	pH 6.0 embryo pH 7.5 embryo pH 6.0 tadpole pH 7.5 tadpole	Edginton et al. 2004b
	16 days	Laboratory, static renewal	1.89	Tadpole	Relyea 2005b
Rana catesbeiana American Bullfrog	16 days	Laboratory, static renewal	1.55	Tadpole	Relyea 2005b
Hyla versicolor Gray Treefrog	16 days	Laboratory, static renewal	1.0	Tadpole	Relyea 2005b
Africa					
Xenopus laevis African Clawed Frog	96 hours	Laboratory, static renewal	9.3 (9.1–9.6)*	Embryo	Perkins et al. 2000
South America					
Scinax nasicus	96 hours	Laboratory, static renewal	0.95 (0.76–1.02)	Tadpole	Lajmanovich et al. 2003
Australia					
Crinia insignifera Western Sign-bearing Froglet	48 hours	Laboratory, static renewal	3.6 (3.3–4.1)	Tadpole	Mann and Bidwell 1999
Crinia insignifera post-metamorphic stages	48 hours	Laboratory, static renewal	51.8 (42.1–63.8)	Metamorph	Mann and Bidwell 1999
	48 hours	Laboratory, static renewal	49.4 (40.5–60.2)	Adult	Mann and Bidwell 1999
Heleioporus eyrie Moaning Frog	48 hours	Laboratory, static renewal	6.3 (5.6–7.1)	Tadpole	Mann and Bidwell 1999
Limnodynastes dorsalis Pobblebonk/ Banjo Frog	48 hours	Laboratory, static renewal	3.0 (2.8–3.2)	Tadpole	Mann and Bidwell 1999
Litoria moorei Motorbike Frog	48 hours	Laboratory, static renewal	2.9 (2.6–3.2)	Tadpole	Mann and Bidwell 1999
	48 hours	Laboratory, static renewal	11.6 (10.3–13.1)	Tadpole	Bidwell and Gorrie 1995

Growth and development rate

Studies have shown that pesticides, in general, can decrease amphibian growth and development rates, although the mechanism of these effects remains unknown (Relyea and Mills 2001). Only a few studies have examined the effect of glyphosate herbicides on the growth and development rate of amphibians. In a laboratory study, after 96 hours of exposure to Vision herbicide at concentrations of 1.4 to 3.3 mg a.e./L, growth of African Clawed Frog (*Xenopus laevis*), Leopard Frog, and Green Frog embryos was decreased, but growth of American Toad embryos was not affected (Edginton et al. 2004a). In another laboratory study of Leopard Frogs, tadpole development rate (days to metamorphosis) was decreased at a concentration of 1.8 mg a.e./L, and metamorph size was decreased at concentrations of 0.6 and 1.8 mg a.e./L (Howe et al. 2004). The increased time to metamorphosis is of concern because under field conditions the small wetlands that are most likely to receive direct overspraying are also the ponds that are prone to drying early. Smaller size at metamorphosis has been associated with lower post-metamorphic survival rate (Berven 1990; Goater 1994; Scott 1994; Beck and Congdon 1999; Morey and Reznick 2001; Altwegg 2003), which has been shown to be a pivotal vital rate in population dynamics (Taylor and Scott 1997; Biek et al. 2002; Vonesh and De la Cruz 2002).

In a mesocosm study, exposure to 1.3 mg a.e./L of Roundup Original did not decrease the growth rate of Leopard Frog tadpoles or newts (*Notophthalmus viridescens*) (Relyea et al. 2005). In a field enclosure study, exposure to 1.43 mg a.e./L of Vision herbicide did not affect growth rate of Leopard Frog and Green Frog tadpoles (Wojtaszek et al. 2004). In both these studies, herbicide treatment was applied only once during the study, but in the laboratory studies cited above, the herbicide treatment was repeated at regular intervals in a static renewal design. This result indicates that, as with survival effects, growth and development are affected both by treatment concentrations and duration of exposure at those concentrations.

Behaviour

Pesticide exposure can either increase or decrease activity levels of aquatic amphibians (Semlitsch et al. 1995; Bridges 1997; Mann and Bidwell 2001; Relyea and Mills 2001). For example, the herbicide atrazine has been shown to increase the foraging activity of tadpoles, but this effect was mainly due to reduced algal food resources (Rohr and Crumrine 2005). The effect of glyphosate herbicides on the behaviour of amphibians has not been extensively studied. Embryos and newly hatched tadpoles of a number of amphibians exhibited paralysis and an inability to move away from gentle prods during the first 24 hours of exposure to low levels (1.2 to 4 ppm) of glyphosate (Pauli et al. 2001). In Leopard Frog and Green Frog tadpoles, the extent of impaired predator avoidance response was positively correlated to Vision herbicide concentrations. However, impairment was not statistically different from control treatment at the Vision EEC concentration of 1.43 mg a.e./L (Wojtaszek et al. 2004).

Physiological and morphological effects

Abnormal gonadal development was observed in metamorphic Leopard Frogs when they were exposed as tadpoles to concentrations of 0.6 and 1.8 mg a.e./L of Roundup Original for 42 days (Howe et al. 2004). The same study also noted increased incidence of tail damage and decreased tail length in tadpoles exposed to the 1.8 mg a.e./L concentration of Roundup Original. High levels (75%) of tadpole malformation (craniofacial and mouth deformities, eye abnormalities, and bent or curved tails) were documented for the South American species *Scinax nasicus*, even at low concentrations of glyphosate herbicide GLY-F, 1.47 mg a.e./L after 96 hours of exposure (Lajmanovich et al. 2003). Similar malformations were also documented in Green Frog tadpoles and Leopard Frog embryos after 96 hours of exposure to Vision (Edginton et al. 2004a). It is hypothesized that the malformation is due to the surfactant in the herbicide interfering with the synthesis of collagen in amphibians (Mann and Bidwell 2001). Tadpoles exposed to concentrations as low as 1.5 mg a.e./L showed reduction in the gill branchial cartilage, which would result in reduced ability of the tadpoles to breath (Tyler 1997; Lajmanovich et al. 2003). Similar effects have been documented in fish, where surfactants have been shown to cause lysis of gill epithelial cells, resulting in osmotic instability and asphyxiation (Abel 1974; Partearroyo et al. 1991; Abdelghani et al. 1997). Howe et al. (2004) hypothesized that the tail damage observed in Leopard Frog tadpoles was caused by damage to the fragile tail tissue by the POEA surfactant.

Although there is evidence of endocrine disruption in mammalian cell cultures (Richard et al. 2005), the endocrine-disrupting potential of glyphosate herbicides in amphibians has not been extensively examined. Exposure of Leopard Frog tadpoles to 1.8 mg a.e./L Roundup Original increased nuclear transcription of TRβ, suggesting that there may be disruption of the thyroid hormone signalling system by glyphosate herbicides (Howe et al. 2004). The same study documented abnormal gonadal development, which suggests that the formulated herbicide could inhibit steroidogenesis by interfering with cholesterol transport (Walsh et al. 2000).

Glyphosate herbicides have been shown not to bioaccumulate or biomagnify in vertebrates (Giesy et al. 2000; Solomon and Thompson 2003).

Genomic effects

Exposure of Bullfrog tadpoles to low concentrations (0.70 mg a.e./L) of Roundup Original did not cause DNA damage, but exposure to higher concentrations (2.7 and 11 mg a.e./L) caused significant DNA damage (Clements et al. 1997). Roundup Original has been detected in the environment at 0.1 to 2.3 mg a.e./L, which suggests that the potential genotoxic effects of glyphosate herbicides on amphibians needs further study. Clements et al. (1997) classified Roundup Original as clastogenic (causing visible damage to DNA and chromosomes) in tadpoles and as one of the most worrisome of the common herbicides they tested because of the low dosage levels at which DNA damage was noted. At low dosages, glyphosate herbicides have also been shown to induce cell cycle dysfunction and to inhibit transcription in sea urchin embryos (Marc et al. 2002, 2004, 2005). Such detailed studies have not been conducted using amphibian embryos.

1.1.2 Synergistic Impacts

The lethality of pesticides has been shown to be altered by interaction with competitive and predatory stress, by changes in food resources, and by changes in temperature, pH, and UV light (Lohner and Fisher 1990; Zaga et al. 1998; Boone and Bridges 1999; Boone and Semlitsch 2001, 2002; Boone and James 2003; Relyea 2003). To clarify, the removal of competing vegetation upland of and around wetlands may change the abiotic and biotic conditions experienced by amphibians, potentially leading to impacts (Reynolds 1989; Russell et al. 2002a). Information on these potential impacts is limited, but, since removal of competing vegetation is the goal of this silvicultural practise, these impacts will arise whatever method is used and are not included in this discussion. This section is confined to how biotic and abiotic factors interact with the use of glyphosate herbicide to increase or decrease its potential impacts on amphibians.

Effects mediated through predators

Changes in the behaviour of tadpoles, such as paralysis and impaired predator avoidance response, could cause the tadpoles to become more vulnerable to predators. Tadpoles exposed to concentrations of glyphosate of 3 mg a.e./L or higher exhibit impaired predator avoidance response but remain unaffected by lower concentrations (Berrill et al. 1997; Wojtaszek et al. 2004). Decreased tail length and tail damage due to exposure to Roundup Original (0.6 and 1.8 mg a.e./L) (Howe et al. 2004) could affect burst swim speed and increase predation rates (Wilbur and Semlitsch 1990).

The fear of predation is a common stress experienced by amphibians. Even caged predators can increase the time amphibians spend on antipredator behaviour, and that can negatively affect growth and survival (Werner 1991; Werner and Anholt 1993; Skelly 1994; Anholt et al. 1996). The nonlethal presence of caged predators increases negative impacts of herbicides and insecticides in some amphibians (Relyea and Mills 2001; Relyea 2004; Rohr and Crumrine 2005). A recent study of glyphosate herbicide on Wood Frog tadpoles found similar effects; the presence of caged predators decreased survival and time to death at Roundup Original concentrations of 0.1 to 1 mg a.e./L (Relyea 2005b). The presence of predators made Roundup Original twice as toxic for these tadpoles by decreasing LC_{50} values from 1.0 mg a.e./L in the absence of predators to 0.41 mg a.e./L in the presence of predators (Table 1). The five other amphibian species tested in the same study, Leopard Frog, Green Frog, Bullfrog, American Toad, and Gray Treefrog, did not exhibit this synergistic effect (Relyea 2005b). Therefore, the synergistic effect between predatory stress and pesticides seems to differs with the species and pesticide tested (Relyea 2003, 2004, 2005b). The mechanism of this interaction is currently not known.

Tadpoles suffer high levels of predation from various predators, including dragonfly larvae, diving beetle larvae, other predacious aquatic insects, aquatic salamanders and their larvae, and fish. If glyphosate herbicides negatively affect these predators, we could expect a compensatory survival benefit to tadpoles. However, two recent studies found that these tadpole predators are not greatly affected by Roundup Original at a dosage of 2.9 mg a.e./L (Relyea 2005c; Relyea et al. 2005).

Effects mediated through competitors

Increasing tadpole density decreases survival, growth, and development of a number of species of tadpoles due to intraspecific competition (Werner 1992; Altwegg 2003). The impact of the herbicide atrazine has been shown to be modified by intraspecific competition (Boone and James 2003). Atrazine has also been shown to intensify interspecific competitive interactions between snails and tadpoles (Rohr and Crumrine 2005). To date no studies have examined whether these competitive effects influence the impact of glyphosate herbicides.

Effects mediated through food source or prey

Although glyphosate is primarily used to control broadleaf weeds, some algal species are susceptible to the herbicidal effects of glyphosate (Peterson et al. 1994; Gardner et al. 1997; Giesy et al. 2000; Chen et al. 2004). Since most tadpoles feed extensively on periphyton (algae growing attached to submerged surfaces), we would expect that tadpole growth rate would be indirectly reduced due to herbicide effects on algal growth (Kupferberg 1997; Kiffney and Richardson 2001; Rohr and Crumrine 2005). However, two studies that examined the impact of glyphosate herbicide on periphyton and phytoplankton growth found no significant decrease in plankton growth in mesocosms treated with 1.0 to 2.9 mg a.e./L Roundup Original compared with control treatments (Relyea 2005c; Relyea et al. 2005). In a field-based stream trough study, low concentrations of glyphosate (0.001–0.3 mg a.e./L) were found to actually stimulate periphyton growth, probably due to phosphorous enrichment of the oligotrophic stream waters (Austin et al. 1991). However, direct overspraying of wetlands could result in the loss of aquatic macrophytes that tadpoles graze on for periphyton and also use as refuge from predation.

Larval salamanders feed primarily on zooplankton, larval insects, and tadpoles. The effect of glyphosate herbicides on the prey base of larval salamanders has not been examined in detail. However, Vision at expected environmental concentrations (0.75 and 1.5mg a.e./L) has been shown to decrease survival, growth, and reproduction of the zooplankton *Simocephalus vetulus* (Cladocera, Daphniidae) at pH 7.5 but not at pH 5.5 (Chen et al. 2004). Roundup Original and Rodeo at expected environmental concentrations have little or no effect on zooplankton, diving beetle larvae, midge larvae, and other aquatic invertebrates (Buhl and Faerber 1989; Gardner and Grue 1996; Relyea et al. 2005). Also, drift patterns of aquatic invertebrates have been shown to be minimally affected by aerial-sprayed glyphosate herbicides (Kreutzweiser et al. 1989).

Effects mediated through changes in temperature

It is commonly believed that the toxicity of chemicals increases with increasing temperature due to increased absorption and higher rates of chemical reactions (Mayer and Ellersieck 1994; Mann and Bidwell 2001). The toxicity of the insecticide carbaryl to Green Frog tadpoles increased rapidly with increasing temperature, such that the 96-hour LC_{50} at 27°C was only half that at 17°C (Boone and Bridges 1999). Loss of shading due to defoliation of surrounding vegetation after Vision application causes an increase in water temperature in wetlands (Holtby 1989), but no studies have examined the synergistic effects of temperature on the lethality of glyphosate herbicide.

Effects mediated by UV exposure

As little as 1.5% intensity of ambient solar UV-B radiation photoactivated the insecticide carbaryl such that its toxicity to tadpoles increased 10-fold (Zaga et al. 1998). No studies have examined whether the glyphosate molecule would be susceptible to photoactivation in ways that would increase its toxicity to amphibians.

Interaction with pH

In Canada, forest wetlands are highly variable in pH, ranging from pH 4.5 to 9.1 (Thompson et al. 2004). Roundup Original was more toxic to fish and aquatic invertebrates in alkaline (pH 7.5) than in acidic (pH 6) water (Folmar et al. 1979), and more toxic in hard water than in soft water (Wan et al. 1989). The 96-hour LC_{50} for both embryos and tadpoles of the African Clawed Frog, American Toad, Green Frog, and Leopard Frog decreased from pH 5.5 to pH 7.5 (Chen et al. 2004; Edginton et al. 2004a). Of particular concern is that the 96-hour LC_{50} value at pH 7.5 was close to or below the EEC of Vision (1.4 mg a.e./L) for the tadpoles of all four species tested (Edginton et al. 2004a). Almost no Leopard Frog tadpoles survived to 10 days when exposed to Vision at 0.75 or 1.5 mg a.e./L at a pH of 7.5 (Chen et al. 2004). It is hypothesized that at higher pH a greater proportion of the surfactant POEA is in the nonionized form (-N), which results in its accelerated accumulation in the gill tissues (Folmar et al. 1979; Edginton et al. 2004a). Higher toxicity of glyphosate herbicide at higher pH is the reverse of the trend with other stressors and contaminants that show more negative impacts at lower pH levels (Horne and Dunson 1995; Hatch and Blaustein 2000; Pahkala et al. 2002; Brodkin et al. 2003). It is particularly important to note that amphibians actively avoid low-pH ponds. Amphibian diversity is higher in ponds of pH 6 or higher (Bradford et al. 1998; Vatnick et al. 1999; Eason and Fauth 2001).

Interaction with soil

Both glyphosate and the surfactant POEA can be absorbed by soil and broken down by soil microbes (Giesy et al. 2000). Since most toxicity testing is done under laboratory conditions, the presence of soil under natural conditions may decrease the negative impacts of the herbicide. In a laboratory test of this hypothesis, the presence of sand or loam did not mitigate the negative effects of Roundup on Leopard Frog, Gray Treefrog, and American Toad tadpoles (Relyea 2005a). The half-life of Roundup Original due to soil adsorption and breakdown varies from 7 to 70 days, depending on site conditions (Giesy et al. 2000), but survival rates start to decrease steeply in laboratory studies 5 days after pesticide application (Relyea 2005b). This suggests that breakdown of the herbicide in the soil may not be a major factor in decreasing acute toxicity to amphibians immediately after application. Also, tadpoles are detritivores and may therefore ingest glyphosate and POEA even when they have been adsorbed to bottom sediments.

1.2 Effect of Glyphosate on Adult Stages of Amphibians

Almost all our knowledge of pesticide effects on amphibians comes from studies on larval stages. Most amphibians spend only a small fraction of their life cycle in the aquatic phase and some amphibians are exclusively terrestrial. The skin of adult amphibians is a permeable organ used for respiration and water balance and may be particularly sensitive to the effects of environmental contaminants (Beebee and Griffiths 2005). To date only two studies have addressed the effect of glyphosate exposure on the terrestrial, post-metamorphic stages of amphibians. In the first study, frogs were placed in beakers with varying concentrations of herbicide (Mann and Bidwell 1999). This would simulate conditions where frogs enter a pond contaminated with glyphosate herbicide by overspraying, drift, or runoff. This study found that the post-metamorphic stages of the Australian Sign-bearing Froglets (*Crinia insignifera*) were 14 times less sensitive than the tadpoles of the same species (Table 1). The authors suggest that the reduced sensitivity is due to decreased exposure of sensitive respiratory tissue to the herbicide, as cutaneous respiration accounts for only 4 to 20% of the total O_2 uptake in the post-metamorphic stages. However, the frogs in this study were not exposed to the spray droplets, which could stick to the skin, increasing uptake of both glyphosate and the surfactants and causing direct damage (lysis) to the skin.

The second study addressed this question to some extent. In a laboratory experiment, using the maximum spray dosage of domestic use Roundup Original (1.6 mg a.e./L), survival was decreased to 32% in Wood Frogs (control 96%), 18% in Gray Treefrogs (control 100%), and 14% in American Toads (control 100%) within 24 hours of spraying (Relyea 2005a). In this study, the frogs were placed on moist paper towels and the herbicide was sprayed directly over them to simulate exposure conditions during aerial spraying should the animals be basking at the surface. Under these conditions, the post-metamorphic anurans were equally sensitive or more sensitive than the respective tadpoles. This suggests that herbicide exposure and impacts on the amphibian terrestrial stages may be non-trivial and should not be ignored. The frequency and magnitude of these impacts needs further study.

Few studies have addressed the direct impact of glyphosate on terrestrial salamanders. It is assumed to be minimal because these salamanders spend much of their lives underground, but there is some concern that they may be affected (Cole et al. 1997). A recent study showed that exposure to ecologically relevant concentrations of the herbicide atrazine in the larval stage increased risk of desiccation in the post-metamorphic stages, even eight months after exposure, in the Streamside Salamander (*Ambystoma barbouri*; Rohr and Palmer 2005). This is of particular concern because defoliation after herbicide treatment will increase temperature and moisture loss in salamander microhabitats.

These studies taken together indicate clearly that more research is needed to assess the effects of glyphosate herbicides on terrestrial amphibian stages.

2. GENERAL INFORMATION AND CURRENT GUIDELINES FOR GLYPHOSATE HERBICIDES

Detailed ecological risk assessments of the use of glyphosate have been conducted by research groups and government agencies in a number of countries including Canada, the United States, Australia, and the European Union (U.S. Environmental Protection Agency 1993; WHO International Program on Chemical Safety 1994; Australian Pesticides and Veterinary Medicines Authority 1996; Giesy et al. 2000; Williams et al. 2000; Solomon and Thompson 2003; National Council for Air and Stream Improvement Inc. (NCASI) 2004; Guiseppe et al. 2006). Except for the Australian review, these assessments did not specifically look at the risk of glyphosate to amphibians, but the information from these assessments can be used to:

1. Provide a background on the chemistry of these herbicides with reference to potential ecological risks.
2. Provide information on permitted application rates, expected environmental concentrations, potential for off-target deposition, and field estimates of the contamination and dissipation routes of these herbicides; also, to identify known breakdown products and toxicity of these products.
3. Review current guidelines and restrictions on the use of these herbicides in B.C., Canada, and abroad, with reference to how they may provide protection to amphibians.

2.1 General Chemistry of Glyphosate Herbicides

Glyphosate (*N*-[phosphonomethyl]glycine) is a weak organic acid comprising a glycine moiety and a phosphonomethyl moiety. Glyphosate prevents the synthesis of aromatic amino acids in plants and some microorganisms by inhibiting the enzyme 5-enolpyruvyl shikimate-3-P synthetase (Devine et al. 1993). Many animals do not possess this pathway of synthesis and obtain the necessary aromatic amino acids from plants and other sources. Because of this, glyphosate is relatively non-toxic to animals while it is very effective as an herbicide.

There are many different commercial formulations of glyphosate herbicide that, in addition to the active ingredient, contain a number of additives to increase efficacy. Most of these additives are inert and their identities are protected as trade secrets. Of these additives, the available information shows that certain surfactants pose the greatest ecotoxicological risk. Surfactants reduce surface tension and increase wetting of hydrophobic plant cuticles, increasing penetration of glyphosate into plant tissues. A common surfactant in glyphosate herbicides is polyoxyethylene tallowamine (also called polyoxyethyleneamine, POEA, or MON 0818). The toxicological effect of POEA to amphibians is described in Section 1 of this report.

In addition to POEA, several other surfactants are used in commercial formulations of glyphosate (Solomon and Thompson 2003). The surfactants are not single substances and may contain a mixture of ingredients blended to provide desirable properties to each commercial formulation of glyphosate herbicide. Some commercial formulations of glyphosate herbicide, such as Rodeo and Accent, are sold without surfactants, but they need surfactants blended in before use (NCASI 2004). Even products such as Vision, which are preformulated with POEA surfactants, sometimes require additional silicon-based surfactants (e.g., Sylgard 309) to be effective against certain weed species. Although there is some understanding of the toxic effects of POEA, the ecotoxicological properties of the other surfactants are virtually unknown (but see Mann 2000).

2.2 Application Rates, Expected Environmental Concentrations (EEC), and Field Concentrations

In Canada, the glyphosate formulation Vision (Monsanto) was registered federally in 1984 and currently accounts for 80–90% of the herbicide use in forestry (Feng and Thompson 1990; Edginton et al. 2004a; Thompson et al. 2004; CCFM 2005). Recently, a more concentrated product called VisionMax has been introduced by Monsanto. In addition, glyphosate herbicides from other manufacturers are now being used in forestry applications in Canada.

Vision herbicide is formulated with a guarantee of 356 g a.e./L as isopropylamine salt (see Vision label in Appendix) and VisionMax is formulated with a guarantee of 540 g a.e./L as potassium salt (see VisionMax label in Appendix). The surfactant in Vision is polyethoxylated tallowamine blended at 15% weight:weight ratio with the glyphosate isopropylamine salt. The surfactant in VisionMax is currently trademark protected.

2.2.1 Application Rates

The label-recommended application rates of these herbicides applied using aerial, ground boom or boomless, or mist blower equipment are as follows:

Vision (Appendix 9.1):

- To control or suppress herbaceous weeds, woody brush, and trees, use 3 to 6 L/ha (1.07–2.1 kg a.e./ha).
- To control maple, alder, and willow, use 6 L/ha (2.1 kg a.e./ha).
- To control perennial herbaceous weeds in site-preparation applications, use 7–12 L/ha (2.5–4.3 kg a.e./ha).

VisionMax (Appendix 9.2):

- To control or suppress herbaceous weeds, woody brush and trees, use 2–4 L/ha (1.08–2.2 kg a.e./ha).
- To control perennial herbaceous weeds in site-preparation applications, use 4.6–7.9 L/ha (2.5–4.3 kg a.e./ha).

2.2.2 Expected Environmental Concentrations (EEC)

VisionMax has only recently been introduced to the Canadian market and there is no literature on its use or impacts. The following discussion is restricted to Vision.

In Canada, the regulatory authorities calculate the EEC as the concentration of active ingredient predicted to occur in a body of water 15 cm deep if it is directly oversprayed at the maximum allowed application rate.

Vision sprayed at 2.1 kg a.e./ha will result in an EEC of 1.43 mg a.e./L of glyphosate and 0.20 mg/L of POEA (Edginton et al. 2004a; Wojtaszek et al. 2004). Although the label-recommended application rates for site preparation are much higher, no documentation or discussion could be found in the literature about whether such high concentrations are ever used in forestry in Canada. Using the maximum allowed application rate for site preparation of 4.3 kg a.e./ha will result in an EEC of 2.93 mg a.e./L of glyphosate and 0.41 mg/L of POEA. An application rate of 1.7 kg a.e./ha has been suggested as the optimum for conditions in B.C. (Reynolds et al. 1989).

The EEC exceed the Canadian water quality interim guidelines for the protection of aquatic life, which is set at 0.065 mg/L (CCME 1999). The guideline is derived by multiplying the lowest acceptable 96-hour LC_{50} value for the most sensitive organism tested (Rainbow Trout, *Oncorhynchus mykiss*) by a safety factor of 0.05 and represents a highly stringent standard of safety (CCME 1999). However, toxicity to amphibians was not considered in setting these guidelines.

In assessing exposure of amphibians to the herbicide, all the published studies focus on aquatic exposure. However, an amphibian basking on the shore of a wetland or along a stream bank might be exposed directly to the herbicide spray in the absence of overhead vegetation. Using an application rate of 2.1 kg a.e./ha, the terrestrial exposure of an amphibian will be 0.021 mg/cm^2 or a maximum of 0.043 mg/cm^2 during site preparation.

2.2.3 Field Concentrations

Herbicide application techniques aim to maximize the amount intercepted by vegetation, but a percentage of the applied herbicide lands directly on the ground. Wetlands can be contaminated directly through overspray or drift, or indirectly through runoff (Newton et al. 1994). The environmental fate of glyphosate and its breakdown products has recently been reviewed in detail by a number of ecological risk assessments, in particular Giesy et al. (2000) and NCASI (2004), and is only briefly summarized in this report. Research has focussed on aerial spraying because it is the most common technique of herbicide application in forestry and also because it has the highest probability of off-target deposition.

Direct overspraying

Most of the information for B.C. comes from Carnation Creek where Roundup Original was aerially sprayed for conifer release, and herbicide residues and breakdown products were monitored for a year after application (Reynolds 1989; Feng and Thompson 1990; Feng et al. 1990). Roundup Original was sprayed at a nominal rate of 2 kg a.e./ha from a helicopter travelling at an airspeed of 40 km/h, using a MICROFOIL boom with a swath width of 12.1 m, from a height of 6 to 18 m (Reynolds et al. 1989). Initial deposit concentration ranged from 0.60 kg/ha to 3.42 kg/ha, indicating chances for application error due to swath overlap and nozzle malfunction (Feng and Thompson 1990). There was not much penetration into soils beyond 15 cm (Feng and Thompson 1990; Newton et al. 1994). Aminomethylphosphonic acid (AMPA), the main breakdown product of glyphosate, was detected at 2–14% nominal glyphosate application rates soon after deposition (Feng and Thompson 1990; Newton et al. 1994). The rate that glyphosate concentrations in the soil decrease depends on microbial activity. The time for 50% dissipation (half-life) from forest soils ranges from 1.4 to 60 days for glyphosate, 76 to 240 days for AMPA, and 7 to 14 days for POEA (Feng and Thompson 1990; Newton et al. 1994; Giesy et al. 2000).

Surface water of wetlands (average depth 34 cm) that were directly oversprayed at an application rate of 1.92 kg a.e./ha from heights of 10–20 m had an average glyphosate concentration of 0.33 mg a.e./L, with a maximum of 1.95 mg a.e./L (Thompson et al. 2004). In a similar study of direct overspraying of streams and ponds in Michigan, Georgia, and Oregon, at an application rate of 1.7 kg a.e./ha concentrations peaked at around 1.0 mg/L, but declined to 0.01 or lower within a few days (Newton et al. 1994). Stream channels directly oversprayed with glyphosate herbicide recorded residual concentrations of 0.100 to 0.006 mg a.e./L (Wan 1986; Kreutzweiser et al. 1989; Feng et al. 1990).

Glyphosate is dissipated in surface waters through stream dilution, microbial degradation to AMPA and CO_2, and adsorption to suspended particulate matter and sediment. The time for 50% dissipation from surface water is estimated to be 7 to 14 days for glyphosate and AMPA and 21 to 42 days for POEA (Giesy et al. 2000).

These data show that in areas directly oversprayed with glyphosate herbicides, environmental concentrations can equal or exceed the LC_{50} values of some amphibians.

Drift

The potential for spray drift will depend on the application technique, droplet size, and wind speed. Published information on drift from ground spraying of glyphosate in forestry is lacking. However, based on studies in agricultural and estuarine settings, the concentration at 5–10 m horizontal distance from the edge of the spray zone is expected to be approximately 1% of application rate (Giesy et al. 2000; Major et al. 2003).

Drift can be greater in aerial applications because the boom sprayer is higher off the ground. In forestry applications, drift is 10% or less of the application rate at 25 m, and less than 1% at 75 m (Wan 1986; Gluns 1989; Payne et al. 1990). In general, surface water concentrations of glyphosate due to drift from aerial spraying at a distance of more than 10 m is at or below 0.2 mg a.e./L (Kreutzweiser et al. 1989; Thompson et al. 2004).

Leaching and runoff

Although glyphosate is highly soluble in water, it adsorbs strongly to soil, organic particles in water, and to sediment. Soon after the first rainfall, field measurements of glyphosate concentrations in streams and wetlands adjacent to sprayed areas are below 0.1 mg a.e/L and are often below 0.01 mg a.e./L under various conditions (Feng et al. 1989, 1990; USEPA 1993; WHO IPCS 1994; Giesy et al. 2000; Solomon and Thompson 2003). These extensive environmental reviews of glyphosate concluded that 2 to 7% of applied rates are lost due to runoff and leaching depending on soil conditions (WHO IPCS 1994; NCASI 2004). However, in an experiment that simulated heavy rainfall within 24 hours of spraying, glyphosate concentrations of 0.242 to 0.552 mg a.e./L were detected in surface runoff waters (Wood 2001).

The Canadian water quality guideline for the protection of aquatic life is set at 0.065 mg/L (CCME 1999). The field concentrations of glyphosate in surface waters caused by all three methods have been shown in the sections above (direct overspraying, drift, and runoff) to exceed this limit.

2.3 Guidelines and Restrictions on the Use of Glyphosate Herbicides

In Canada, the Pest Management Regulatory Agency (PMRA) of Health Canada is responsible for evaluating and granting registration to products that meet the *Pest Control Products Act*. The product label that is approved as part of the registration process contains the terms and conditions that govern the use of the product. In effect, the label is a legislative document (see Appendix). Use of the product in a manner that is not consistent with the directions or limitations on the label is prohibited (PMRA 2003).

The provinces and territories may regulate the sale, use, storage, transportation, and disposal of registered pesticides in their jurisdictions as long as the regulations are consistent with the *Pest Control Products Act* and other federal legislation. A province or territory may prohibit the use of a registered pesticide in its jurisdiction or add more restrictive conditions on its use, but a province or territory cannot permit the use of a product that is not registered federally or relieve the user of obligations under the federal *Pest Control Products Act* (PMRA 2003; B. Pauli, pers. comm., 2005). For example, although Vision is registered nationally in Canada, Quebec has banned the use of all herbicides in forestry since 2001 (Thompson and Pitt 2003).

Pesticide labels set out safety and use guidelines that usually focus on three aspects: rates of application (single and cumulative) for registered crops and pests, timing of application, and restrictions on areas of application (including required buffer zones).

2.3.1 Restrictions on Application Rates

The hazard quotient for a pesticide is calculated as the ratio of expected environmental concentration (EEC) divided by standard acute toxicity endpoints such as LC_{50} values. Although LC_{50} values are commonly used to calculate hazard quotients, more recent research on risk assessment suggests that LC_{10} values should be used to protect against adverse effects at the population level (Giesy et al. 2000; Solomon and Thompson 2003). A hazard quotient of less than 0.1 is considered acceptable for "valued ecosystem components" such as fish, but a hazard quotient of less than 1.0 is considered acceptable for other organisms with shorter reproductive cycles such as algae and invertebrates (Solomon and Thompson 2003). Current risk assessment procedures are more sophisticated than these simple calculations of hazard quotients, but the underlying principle remains valid.

Maximum application rates as discussed above are then specified on the label to minimize risk to environmental and human health. International and Canadian guidelines strongly suggest that users adhere to the rates recommended on the product label. As pointed out above, the maximum application rate for site preparation with Vision is 2.5 times that of average current application rates in B.C. (Thompson and Pitt 2003). It is important to assess whether these higher concentrations are ever used in forestry in B.C., because EECs under these higher application rates are higher than LC_{50} values of some amphibians (Table 1). Overall in Canada, burning is the most common method of site preparation, and chemical treatment accounts for only 5.1% of all site-preparation techniques (Thompson and Pitt 2003).

Glyphosate herbicides can be repeatedly applied within a year in agricultural settings. The maximum annual total set by the US Environmental Protection Agency is 6.73 kg a.e./ha (Giesy et al. 2000), but repeat applications are rare in forestry practices.

2.3.2 Restrictions on Timing of Application

The timing of herbicide application can be restricted to protect wildlife at particularly sensitive phases of their life cycle. For example, ground and aerial spraying of glyphosate for controlling *Phragmites australis* was delayed until September when the locally endangered Southern Gray Treefrog (*Hyla chrysoscelis*) had moved away from treatment sites (Dodici 2004). Most often however, the timing of application of glyphosate is governed by targeting the most vulnerable stages of the problem plant species. In Canada label guidelines for the timing of glyphosate application focus on maximizing impact on vegetation to be controlled and minimizing impact on desirable vegetation. Currently, glyphosate forestry applications in B.C. are carried out mainly between July and the first frost, but the timing may vary depending on location (D. Cherkas, pers. comm., 2005).

2.3.3 Spatial Restrictions on Application

The most extensively used – and sometimes the most contentious – restriction on the use of herbicides is the delineation of pesticide free zones (PFZ) and buffer zones. Pesticide free zones are zones where no pesticide contamination is permitted either through direct overspraying or due to drift from sprayed areas. Buffer zones are intermediate areas where direct spraying is prohibited but some herbicide contamination may occur due to drift from the sprayed area. Buffer zones and PFZs are used to protect sensitive areas such as drinking water sources and human habitation. The following discussion focusses mainly on protective zones used around wetlands and streams to protect wildlife.

There are no general Canadian federal regulations on the size of PFZs (I. Popa, pers. comm., 2005), although an effort to study this has recently been initiated (Pest Management Regulatory Agency 2005). The Vision and VisionMax labels do not delineate specific PFZs, but the following sections of the labels are applicable to wetlands:

- *Precautionary Statements, Environmental Hazards* – "Avoid direct application to any body of water. Do not contaminate water by disposal of waste or cleaning of equipment."
- *Mixing and Application Instructions, Application Instructions* – "Do not apply directly to any body of water populated with fish or used for domestic purposes. Do not use in areas where adverse impact on domestic water or aquatic species is likely."
- *Aerial Equipment, Use Precautions* – "Do not apply to any body of water. Avoid drifting of spray onto any body of water or other non-target areas. Specified buffer zones should be observed."

The delineation of PFZs and buffer zones under different jurisdictions in Canada and the United States has been reviewed for the Ministry of Environment. This review showed that, in various jurisdictions, buffer zones to protect sensitive areas ranged from 20 to 200 m for aerial applications and from 3 to 5 m for ground applications (Wahl and Whetter 2003).

Many jurisdictions use size limits (e.g., channel width >0.5 m, or water body size >0.01 ha) or the presence of fish to determine waterbodies around which buffer zone requirements apply. In Ontario, buffer zones are required to be maintained only on waterbodies that could be identified on 1:20,000 topographical maps (Edginton et al. 2004a). The buffer zone requirements may not adequately protect amphibians because small waterbodies used by amphibians for breeding often are not visible on maps or from the air, which can result in direct overspray (Edginton et al. 2004a). These small wetlands do not contain fish and are therefore prime habitats for native amphibians (Bradford et al. 1998; Russell et al. 2002b).

In B.C., pesticide free zones (PFZs) are used in addition to buffer zones. Buffer zones are used to protect PFZs around sensitive areas from drift during aerial spraying (R. Adams, pers. comm., 2007). The requirements for PFZs and buffer zones were recently changed in B.C. During review of this document, Rob Adams (manager, IPM Regulation Implementation, Environmental Management Branch, B.C. Ministry of Environment) clarified the difference between the old and the updated regulation:

> Under the former B.C. pesticide regulations (*Pesticide Control Act*), permits were required for pesticide use in forestry. Permit applications for each proposed treatment area were reviewed by a committee of specialists who helped to develop a set of conditions that would be specified on the permits. These conditions generally included a clause that around waterbodies and dry stream channels there must be a 10-m pesticide free zone plus the appropriate buffer zone (no treatment zone) to prevent spray drift or runoff into the PFZ. There was, however, ongoing debate about whether this requirement should apply to very small and often temporary waterbodies, including the puddles in tire tracks that formed after a rainfall and soon dried up. Also, there were practical difficulties in identifying and setting up PFZs around every small water body at the time of treatment.
>
> Under the new B.C. pesticide regulations (*Integrated Pest Management Act* brought into force in 2005), permits are generally not required for silvicultural use of glyphosate. Instead, the requirements for PFZs around waterbodies are specified directly in the regulations. A PFZ also requires an adjacent no-treatment zone to prevent spray drift or

runoff into the PFZ. For use of glyphosate herbicide in forestry the following PFZs are required:

- For waterbodies with fish (most lakes, rivers, and year-round streams), a 10-m PFZ is required to protect aquatic organisms and the adjacent riparian zone.
- For non–fish-bearing waters, the PFZ can be reduced to 2 m if selective application is used between 2 and 10 m from the high water mark of the water body.
- For non–fish-bearing waterbodies that are temporary, free-standing, and are not a *classified wetland*,[1] glyphosate can be applied down to the high water mark (which generally means that when treatment occurs in summer, a dry zone between the water and high water mark will not be treated with glyphosate).
- Glyphosate can be applied over dry streams that do not have fish when wet and non–fish-bearing waterbodies that are temporary and free-standing and are either not a wetland or if they are a *wetland,*[2] are smaller than 25 m^2.

Under the new B.C. pesticide regulations, the buffer zones around required PFZs are determined individually for each location by professionals when developing and registering Pesticide Management Plans (PMP) (D. Cherkas, pers. comm., 2005). Under the old B.C. pesticide permitting system, buffer zones were recommended to protect the PFZs from spray drift and were designated depending on site conditions (D. Cherkas, pers. comm., 2005).

In a field study in Ontario, vegetated buffers of 30 to 60 m reduced herbicide residue to below detection levels (Thompson et al. 2004). After conducting a study that combined field observations and computer modelling of different droplet sizes, release heights, wind speeds, and dispersal systems, Payne (1998) recommended a buffer width of 25 m for rotary wing and 50 m for fixed wing aerial spraying.

PFZs and buffer zones are designed to protect fish and most riparian areas from exposure to unacceptable levels of glyphosate herbicides. Recent research has shown that in some cases amphibians are more sensitive than fish and may also be exposed to higher environmental concentration of glyphosate because some species breed in shallow temporary ponds (Relyea 2005a,b). Australia is the first country to respond to this new research (Bidwell and Gorrie 1995; Mann and Bidwell 1999, 2001) by reassessing the use of glyphosate herbicides. As a consequence, the National Registration Authority for Agricultural and Veterinary Chemicals (NRA) placed restrictions on the use of 84 glyphosate products near or over water or in dry stream channels (APVMA 1996). In addition, studies of a new product, Roundup Biactive, registered for use in Australia, indicate that it has a much lower toxicity to amphibians than Roundup Original (Mann and Bidwell 1999; Howe et al. 2004).

In addition to general PFZs and buffer zones, further protection may be afforded to sensitive

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[1] A "classified wetland" in the IPMR is a wetland referred to as having a class W1, W2, W3, W4, or W5 designation under the Forest Planning and Practices Regulation. Classified wetlands include all wetlands that are: (1) Not less than 0.25 ha (2500 m^2) in size in one of the following biogeoclimatic zones or subzones: (a) Ponderosa Pine (b) Bunch Grass (c) Interior Douglas-fir, very dry hot, very dry warm or very dry mild; or (2) Not less than 0.5 ha (5000 m^2) in size in one of the following biogeoclimatic zones or subzones: (a) Coastal Douglas-fir (b) Coastal Western Hemlock, very dry maritime, dry maritime or dry submaritime.

areas and areas critical to wildlife (OME 2003). In B.C., applicants who develop and register Pesticide Management Plans are expected to designate no-treatment zones (250 m) around Red- and Blue-listed species, and to take into account Recovery Plans for endangered and threatened species in the area. Within established Wildlife Habitat areas, listed species are afforded protection under the Identified Wildlife Management Strategy of the Forest Practices Code of B.C. Currently, no specific protection is afforded to Yellow-listed species or species of "special concern" (L. Friis, pers. comm., 2005). In the United States, to ensure such protection at the national level, the US Environmental Protection Agency is considering requiring that registrants provide precautionary instructions about endangered species (e.g., to protect Houston Toads) directly on the product registration labels (USEPA 1993).

3. PATTERNS OF SILVICULTURAL USE OF GLYPHOSATE HERBICIDE IN B.C.

This section includes data from the National Forest Database Program (http://nfdp.ccfm.org) and from interviews with forestry and integrated pest management experts in B.C. (J. Boateng, D. Cherkas, D. Cronin, and N. Pressey, pers. comm., 2005).

In the United States, 4 to 6 million kg of glyphosate are used for commercial and industrial applications (Relyea 2005b). The total annual use of glyphosate in Canada is estimated to be approximately 4.6 million kg (Brimble et al. 2005). In Canadian forestry, an average of 157,500 ha of forest are sprayed each year, which represents a usage of 300,000 kg per year. B.C. ranks second in silvicultural glyphosate use (17%) in Canada, next to Ontario which accounts for most glyphosate use (43%) (Thompson and Pitt 2003). During most of the 1990s, in B.C. an average 26,275 ha of forest were sprayed annually with glyphosate herbicide (Table 2). There has been a slight decrease in usage rate from 2000 to 2004. During this period the total hectares chemically treated remained below the average of the previous decade (Tables 3 and 4). Tables 3 and 4 present the total amount of herbicides used in the province and do not distinguish among products. However, glyphosate is estimated to account for 90% of the usage and triclopyr accounts for the rest. Glyphosate accounts for all the aerial application of herbicides to B.C. forests and approximately 70% of the ground applications (J. Boateng, pers. comm., 2005).

Glyphosate herbicides are used for two silvicultural activities: site preparation and conifer release (brushing). In B.C., most of the site-preparation activities are carried out in the Northern and Southern Interior regions, and the most common method of site preparation is mechanical (Table 3). In most years, chemical treatments, including glyphosate, account for less than 1% of the total site-preparation activity. In the Southern Interior, chemical treatment for site preparation increased between 2002 and 2004. Although the usage is still very small, label application concentrations for glyphosate are much higher for site-preparation activities (see Section 2). These usages may warrant further investigation with reference to impacts on small ephemeral wetlands that may be important for amphibians.

Chemical treatments are more extensively used in conifer release operations than in site preparation (Table 4). Aerial spraying accounts for 21% and ground spraying for 12% of the total

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[2] "Wetland" in the IPMR means a swamp, marsh, bog, or other similar area that supports natural vegetation, that is distinct from adjacent upland areas.

Table 2: Glyphosate use in Canada, 1992–1998

	Forest area treated with glyphosate (ha)								
Year	NL	PEI	NS	NB	QUE	ONT	MAN	ALTA	B.C.
1992	1,949	413	6,440	22,360	31,723	63,089	954	480	35,006
1993	1,039	673	6,627	26,664	32,936	54,000	786	1,793	32,264
1994	66	507	7,257	24,856	23,263	74,313	1,164	537	28,410
1995	73	498	8,300	24,567	13,434	56,929	1,965	6,196	18,536
1996	444	202	11,716	26,450	11,838	79,417	1,856	9,238	29,830
1997	481	299	8,728	28,682	11,865	63,031	2,666	12,080	23,550
1998	146	286	8,312	27,226	10,041	89,641	1,380	16,955	16,330
Average	600	411	8,197	25,829	19,300	68,631	1,539	6,754	26,275

Source: Data from the National Forest Database Program (http://nfdp.ccfm.org).

Data on glyphosate use are not available for Saskatchewan and Yukon and Northwest territories.

conifer release operations in the province (Table 5). The Northern Interior region accounts for 95% of the aerial spraying activity and 57% of the ground spraying activity in the province (Table 5). There is much less use of chemical herbicide treatments in the Coast and Southern Interior regions and ground spraying is the most common technique used in these regions. Almost all the aerial glyphosate spraying is currently applied by helicopter (Table 6). In the 1990s, the average application rate of 1.53 kg a.e./ha was below the label maximum of 2.1 kg/ha (Table 6). An application rate of 1.7 kg a.e./ha is suggested as the optimum for conditions in B.C. (Reynolds et al. 1989).

In most cases in B.C., the herbicide is applied only once per year and only once per silvicultural cycle (50 to 80 years) (J. Boateng and D. Cherkas, pers. comm., 2005). Under some conditions these applications may be repeated more often during a silvicultural cycle (D. Wahl and M. Wan, pers. comm., 2006). Most spraying is done between July and September. The spray blocks vary in size, ranging from 10 to 100 ha. In Ontario, spray blocks average 83 ha (range, 43–133 ha) (Thompson et al. 2004).

Currently, there appear to be no real alternatives to glyphosate use in forestry in B.C. (J. Boateng, pers. comm., 2005). Vision is the only commercial glyphosate formulation used in forestry in B.C., except for VisionMax, which has been used recently. The potential for using other formulations of glyphosate herbicide without POEA with lower impacts on amphibians remains to be evaluated.

It should be emphasized that the information in this section pertains only to silvicultural use of glyphosate herbicides. Approximately 120,000 to 127,000 kg (a.i.) of glyphosate herbicides were sold in B.C. in 2003 (Brimble et al. 2005; ENKON 2005). Extrapolating from the average number of forest hectares sprayed per year and the spray rate, silvicultural use of glyphosate accounts for approximately 41,000 kg or 34% of the total glyphosate usage in B.C. Most of the glyphosate herbicides are used in agriculture and horticulture, and this report does not address the potential impacts of this use on amphibians.

Table 3: Treatments used in site-preparation in three forestry regions in B.C. (chemical treatments include both glyphosate and triclopry treatments)

		B.C. forestry region			
Year	Treatment	Coast (ha)	North. Int. (ha)	South. Int. (ha)	Total (ha)
2000–2001	Biological	0	0	0	0
	Burn	1,482	4,196	5,851	11,529
	Chemical air	2	60	0	62
	Chemical ground	23	64	47	134
	Grass seeding	295	750	49	1,094
	Manual	859	2,889	1,116	4,864
	Mechanical	3,863	26,914	19,048	49,825
	Not specified	6	0	1	7
	Total	6,530	34,873	26,112	67,515
2001–2002	Biological	0	20	12	32
	Burn	916	3,062	4,579	8,557
	Chemical air	36	33	11	80
	Chemical ground	42	3	0	45
	Grass seeding	83	37	118	238
	Manual	800	2,721	3,268	6,789
	Mechanical	3,199	24,583	16,410	44,192
	Not specified	32	0	0	32
	Total	5,108	30,459	24,398	59,965
2002–2003	Biological	0	0	48	48
	Burn	694	2,271	3,615	6,580
	Chemical air	16	0	0	16
	Chemical ground	7	0	232	239
	Grass seeding	99	33	44	176
	Manual	1,638	2,862	1,620	6,120
	Mechanical	2,233	19,338	17,779	39,350
	Not specified	18	0	0	18
	Total	4,705	24,504	23,338	52,547
2003–2004	Biological	0	0	48	48
	Burn	492	1,980	5,219	7,691
	Chemical air	0	0	32	32
	Chemical ground	0	5	315	320
	Grass seeding	97	9	4	110
	Manual	41	2,323	4,602	6,966
	Mechanical	272	6,646	24,287	31,205
	Not specified	0	0	278	278
	Total	902	10,963	34,785	46,650

Source: Data provided by J. Boateng, B.C. Ministry of Forests and Range.

Table 4: Treatments used in conifer release in the three forestry regions in B.C. (chemical treatments include both glyphosate and triclopry treatments)

		B.C. forestry region			
Year	Treatment	Coast (ha)	North. Int. (ha)	South. Int. (ha)	Total (ha)
2000–2001	Biological	591	3,318	289	4,198
	Chemical air	368	12,665	167	13,200
	Chemical ground	4,453	3,864	1,067	9,384
	Manual Non-motorized	6,202	8,218	8,686	23,106
	Manual motorized	7,043	17,106	5,268	29,417
	Manual other	0	29	0	29
	Mechanical	56	0	101	157
	Not specified	1,079	2,026	524	3,629
	Total	19,792	47,226	16,102	83,120
2001–2002	Biological	604	4,164	0	4,768
	Chemical air	218	20,207	0	20,425
	Chemical ground	2,423	5,594	729	8,746
	Manual Non-motorized	6,986	9,374	7,885	24,245
	Manual motorized	6,273	15,438	7,389	29,100
	Manual other	0	7	173	180
	Mechanical	8	9	30	47
	Not specified	78	1,347	594	2,019
	Total	16,590	56,140	16,800	89,530
2002–2003	Biological	0	1,858	0	1,858
	Chemical air	665	14,139	65	14,869
	Chemical ground	3,008	5,741	123	8,872
	Manual Non-motorized	415	814	701	1,930
	Manual motorized	2,958	10,110	6,169	19,237
	Manual other	5,049	4,648	6,291	15,988
	Mechanical	0	0	5	5
	Not specified	230	45	146	421
	Total	12,325	37,355	13,500	63,180
2003–2004	Biological	0	1,356	234	1,590
	Chemical air	538	9,803	740	11,081
	Chemical ground	1,326	3,537	1,399	6,262
	Manual Non-motorized	728	7,665	7,287	15,680
	Manual motorized	1,251	2,813	5,982	10,046
	Manual other	–	–	–	0
	Mechanical	4	37	72	113
	Not specified	468	649	1,062	2,179
	Total	4,315	25,860	16,776	46,951

Source: Data provided by J. Boateng, B.C. Ministry of Forests and Range.

Table 5: Estimated proportional use of treatments for conifer release in B.C. and within regions

Chemical herbicide treatments are used 33% of the time. Manual motorized and non-motorized techniques, which include girdling, stem bending, mulching, and cutting with power saws, are the most common technique used (59%). Chemical treatments are most commonly used in the Northern Interior Forest Region.

	Provincial total	Treatment use by forest region		
Treatment	Proportion	Coast	North. Int.	South. Int.
Biological	0.04 ± 0.01	0.07 ± 0.08	0.88 ± 0.09	0.05 ± 0.07
Chemical air	0.21 ± 0.04	0.03 ± 0.02	0.95 ± 0.04	0.02 ± 0.03
Chemical ground	0.12 ± 0.02	0.33 ± 0.11	0.57 ± 0.11	0.11 ± 0.09
Manual motorized	0.30 ± 0.06	0.18 ± 0.05	0.48 ± 0.14	0.34 ± 0.18
Manual non-motorized	0.23 ± 0.13	0.20 ± 0.11	0.41 ± 0.06	0.38 ± 0.06
Manual other	0.06 ± 0.13	0.11 ± 0.18	0.44 ± 0.50	0.45 ± 0.48
Mechanical	0.00 ± 0.00	0.14 ± 0.16	0.13 ± 0.16	0.73 ± 0.18
Not specified	0.03 ± 0.02	0.27 ± 0.21	0.41 ± 0.25	0.32 ± 0.14

Source: Summarized from data for 2000–2004 provided by J. Boateng, B.C. Ministry of Forests and Range.

Note: Proportional use within B.C. was calculated by (# of ha subject to a treatment in B.C.) ÷ (total # of ha subject to conifer release in B.C.).

Proportional use among forest regions was calculated by (# of ha subject to a treatment in a region) ÷ (total # of ha subject to that treatment in B.C.).

Table 6: Method of application (fixed wing, helicopter, and ground), application rate, and total amount of glyphosate herbicide used in B.C., 1992–1998

	Application method				
Year	Fixed wing (ha)	Helicopter (ha)	Ground (ha)	Application rate (kg a.i./ha)	Total amount (kg)
1992	6,712	22,678	5,616	1.60	54,493
1993	3,584	23,252	5,428	1.54	49,760
1994	–	22,160	6,250	1.52	43,300
1995	–	12,824	5,706	1.70	28,603
1996	–	21,680	8,150	1.58	50,986
1997	–	19,360	4,190	1.40	37,233
1998	–	12,558	3,772	1.40	26,256
Average 1992–1998	5,148	19,216	5,587	1.53	41,519
2000–2001	–	13,200	6,569	–	–
2001–2002	–	20,425	6,122	–	–
2002–2003	–	14,869	6,210	–	–
2003–2004	–	11,081	4,383	–	–

Source: Adapted from the National Forest Database Program.

Note: Glyphosate use for 2000 to 2004 was estimated from chemical herbicide treatment data for B.C. by J. Boateng, B.C. Ministry of Forests and Range.

4. B.C. AMPHIBIAN SPECIES, THEIR LIFE HISTORIES AND HABITAT USAGE

British Columbia is home to 9 salamander species and 11 native frog species. These amphibians differ in their conservation status, distribution in the province, and habitat usage (Table 7). They are therefore differentially susceptible to the effect of glyphosate herbicide application. The discussion in this section highlights only aspects of their natural history relative to their susceptibility to herbicide use. More complete descriptions of their biology and natural history can be found on the B.C. Frogwatch website (http://www.env.gov.bc.ca/wld/frogwatch) and the Canadian Amphibian and Reptile Conservation Network website (www.carcnet.ca/english/tour/b_1.html).

4.1 Salamanders

4.1.1 Rough-skinned Newt (*Taricha granulosa*)

This species is limited to the Pacific coast of B.C. including Vancouver Island. Rough-skinned Newts alternate between terrestrial and aquatic stages and may be exposed to glyphosate effects in either habitat. Their preferred aquatic habitats are ponds, lakes, and the slow-moving streams where they breed in early spring. Larvae may transform in late summer or may spend additional seasons in the aquatic phase. Because they remain in wetlands in late summer, they may be exposed to glyphosate herbicides, which are sprayed from July to September. Terrestrial stages are sometimes found on cool, humid days wandering on the surface in search of food. During this time they may be exposed to direct spraying of glyphosate herbicides. No data are available on the toxicity of glyphosate to Rough-skinned Newts.

4.1.2 Long-toed Salamander (*Ambystoma macrodactylum*)

This salamander is found throughout most of B.C. Although these salamanders are found in both terrestrial and aquatic habitats, their chance of exposure to glyphosate is higher in the aquatic phase. Long-toed Salamanders prefer to breed in ponds without fish. This increases their chances of being exposed to glyphosate because fishless, temporary ponds are often not protected with PFZs and buffer zones. Such ponds are also shallow and residues of glyphosate may be higher than in large permanent ponds. The larvae of this salamander spend at least one winter in the pond before transforming to the terrestrial phase and are therefore in the ponds during the glyphosate-spraying season (July–September). No data are available on the toxicity of glyphosate to Long-toed Salamanders.

4.1.3 Northwestern Salamander (*Ambystoma gracile*)

This salamander is found in coastal B.C. and on Vancouver Island. The threats posed by glyphosate herbicides to this species are similar to those discussed for Long-toed Salamanders. In addition, some Northwestern Salamanders remain neotenic, attaining sexual maturity in the larval form and never transforming into terrestrial adults. This means that in neotenic populations, glyphosate contamination of wetlands has the potential to cause mortality in both the breeding adult and the larval stages, potentially making population-level impacts of such mortality much more severe. No data are available on the toxicity of glyphosate to Northwestern Salamanders.

4.1.4 Tiger Salamander (*Ambystoma tigrinum*)

This salamander has a very restricted range in the Okanagan Valley in B.C. They are found in different habitats from short grass prairie, to aspen parkland, boreal forest, and even subalpine areas. Their risk from glyphosate is similar to that described for Northwestern Salamanders. Tiger Salamanders can also be neotenic in fishless ponds. This makes them particularly susceptible if glyphosate herbicides are used within their distribution range in B.C. No data are available on the toxicity of glyphosate to Tiger Salamanders.

4.1.5 Pacific Giant Salamander (*Dicamptodon tenebrosus*)

This salamander is restricted to a small area in southwestern B.C. Fast-flowing mountain streams with fallen logs that form rapids, falls, and splash pools are important habitats. Pacific Giant Salamanders breed in spring. Larvae stay in streams for 2 or more years before transforming. These salamanders can also be neotenic. As with the other salamanders, Pacific Giant Salamanders prefer fishless streams. The potential risk of glyphosate herbicides are similar to that described for the salamanders above. In addition, Pacific Giant Salamanders can be seen crawling in the leaf litter and on rare occasion climbing bushes. This makes them additionally susceptible to glyphosate exposure in the terrestrial habitat. No data are available on the toxicity of glyphosate for this species.

4.1.6 Lungless Salamanders

The Western Red-backed Salamander (*Plethodon vehiculum*), the Ensatina (*Ensatina eschscholtzii*), and the Clouded Salamander (*Aneides vagrans*) are restricted to the southwestern corner of B.C. The Coeur d'Alene Salamander (*Plethodon idahoensis*) is restricted to two sites in extreme southeastern B.C. Little is known about the potential impact of glyphosate or other herbicides on these terrestrial salamanders. Terrestrial salamanders may not be directly exposed to glyphosate because they are found mainly under cover and because they do not enter the aquatic environment for breeding. Terrestrial salamanders are most active during spring rains and at night, although they are rarely seen on the surface. However, synergistic impacts cannot be ruled out because defoliation will change moisture retention and temperature conditions in their preferred habitat. Indirect impacts are also possible through the effects of glyphosate on the soil invertebrates and microflora that these salamanders feed on. No data are available on the toxicity of glyphosate for any terrestrial salamander species.

4.2 Frogs

4.2.1 Rocky Mountain Tailed Frog (*Ascaphus montanus*) and Coastal Tailed Frog (*A. truei*)

Until 2000, these two species were considered as one species. The Rocky Mountain Tailed Frog is restricted to a few small populations in the Kootenay region and the Coastal Tailed Frog is distributed throughout the coastal forestry region, but not on Vancouver Island. Tailed frogs are found in clear, cool, shaded, permanent mountain streams without fish. Tadpoles spend multiple years in the stream before they reach metamorphosis. Adults are also found very close to the stream edge. Defoliation following glyphosate application has increased stream water temperature, and this may have synergistic impacts on the toxicity of the herbicide on tadpoles and adults (Bull and Wales 2001). Tailed frogs also take a very long time to reach sexual maturity (approximately 8 years) and therefore populations may be especially sensitive to even slight increases in mortality rates. These two species might be very vulnerable to impacts by glyphosate herbicides if the streams are not protected by PFZs and buffer zones. No data are available on the toxicity of glyphosate for tailed frogs.

4.2.2 Great Basin Spadefoot (*Spea intermontana*)

The Great Basin Spadefoot is restricted to the Okanagan and Thompson/Nicola valleys in B.C. Populations of this amphibian are found in arid regions, in grasslands, and open woodlands. They breed in vernal ponds and semipermanent alkali lakes. The areas preferred by spadefoot toads are not likely to be subject to silvicultural practices, but they may be exposed to glyphosate herbicides used in weed control on agricultural and pasturelands.

4.2.3 Western Toad (*Bufo boreas*)

This species is found in all three forestry regions of B.C., in boreal forest, subalpine, and alpine environments up to 2250 m elevation. The Western Toad breeds in shallow ponds and along lake margins. Their habitat preference overlaps with prime forestry habitats and therefore this species can be particularly vulnerable to the effects of glyphosate. The tadpoles do not metamorphose until August and can be exposed to glyphosate in the aquatic environment in the absence of buffer zones. Western Toads are unique among B.C. amphibians in that they form large post-metamorphic aggregations. These aggregations are often found in open habitats and may be subject to direct overspraying with glyphosate herbicide. The one study that examined the impact of direct spraying of glyphosate herbicide on terrestrial amphibians found that it resulted in high levels of mortality (Relyea 2005a; see Section 1). Although it is on the Yellow list in B.C., it has been designated as a Species of Special Concern by COSEWIC because of steep population declines in other parts of its range. No data are available on the toxicity of glyphosate for the aquatic or the terrestrial environment.

4.2.4 Boreal Chorus Frog (*Pseudacris triseriata*) and Pacific Treefrog (*P. regilla*)

Although the Boreal Chorus Frog is found in northeastern B.C. and the Pacific Treefrog in southwestern B.C., they are similar in their vulnerability to glyphosate impacts. Both species will breed in very shallow ponds, including splash pools, roadside ditches, flooded fields, beaver ponds, marshes, swamps, or shallow lakes. Some of these wetlands will not be protected by buffer zones and PFZs and so there is a possibility that some of these waterbodies with tadpoles will receive direct overspray of herbicide. These tadpoles metamorphose in July and often the breeding ponds start to dry at this time. However, the newly metamorphosed frogs remain in the damp depressions feeding on the abundant insects that have also emerged as the ponds dry. Under current pesticide management practices these depressions receive no protection and may receive direct overspraying. As stated earlier, terrestrial amphibians may be very sensitive to direct overspraying with glyphosate herbicides. The LC_{50} value for a similar species, the Gray Treefrog, has been shown to be as low as 1.0 mg a.e./L in laboratory studies (Table 1).

4.2.5 Red-legged Frog (*Rana aurora*), Wood Frog (*R. sylvatica*), and Columbia Spotted Frog (*R. luteiventris*)

Although these three frogs differ in their range distribution, they are probably similar in their vulnerability to glyphosate impacts. All three species breed in waterbodies of various sizes and are therefore vulnerable to glyphosate impacts if sufficient buffer zones are not observed. Tadpoles of Red-legged Frogs and Wood Frogs can remain in the ponds until late summer and Columbia Spotted Frog tadpoles can overwinter in ponds. As a result, the tadpoles are vulnerable to exposure to glyphosate in the aquatic environment during the herbicide-spraying season. Of the B.C. amphibians, Wood Frog tadpoles are the only species for which LC_{50} values are available (Table 1). Laboratory studies have shown that LC_{50} values for Wood Frogs can be less than 1 mg a.e./L. Red-legged Frog tadpoles are also very sensitive to temperature increases that may result from defoliation of the surrounding vegetation (Cole et al. 1997). As with the other amphibians, the risk of exposure or the impacts of glyphosate on the terrestrial stages of these three species are unknown.

4.2.6 Oregon Spotted Frog (*Rana pretiosa*) and Leopard Frog (*R. pipiens*)

Both these species are Red-listed in B.C. and classified as endangered by COSEWIC. Only a few populations of the two species survive and most of these are in decline. Using the precautionary principle, neither species should be exposed to pollution of any kind, including exposure to glyphosate herbicides.

Table 7: Amphibian species of B.C., their national (COSEWIC) and provincial (B.C.) conservation status, presence in each B.C. forestry region, and habitat distribution

Common Name / Scientific Name	Conservation status		Presence in forestry region[c]			Habitat type	
	COSEWIC[a,b]	B.C.	Coast	North Int.	South Int.	Aquatic	Terrestrial
Salamanders							
Rough-skinned Newt *Taricha granulosa*	–	Yellow	X	–	–	X	X
Long-toed Salamander *Ambystoma macrodactylum*	–	Yellow	X	X	X	X	X
Northwestern Salamander *Ambystoma gracile*	NAR	Yellow	X	–	–	X	X
Tiger Salamander *Ambystoma tigrinum*	E	Red	–	–	X	X	X
Pacific Giant Salamander *Dicamptodon tenebrosus*	T	Red	X	–	–	X	X
Western Red-backed Salamander *Plethodon vehiculum*	NAR	Yellow	X	–	–	–	X
Coeur d'Alene Salamander *Plethodon idahoensis*	SC	Blue	–	–	X	–	X
Ensatina *Ensatina eschscholtzi*i	NAR	Yellow	X	–	–	–	X
Clouded Salamander *Aneides vagrans*	–	Yellow	X	–	–	–	X
Frogs							
Rocky Mountain Tailed Frog *Ascaphus montanus*	E	Red	–	–	X	–	–
Coastal Tailed Frog *Ascaphus truei*	SC	Blue	X	–	–	–	–
Great Basin Spadefoot *Spea intermontana*	T	Blue	–	–	X	X	X
Western Toad *Bufo boreas*	SC	Yellow	X	X	X	X	X
Pacific Treefrog *Pseudacris regilla*	–	Yellow	X	X	X	X	X

Common Name Scientific Name	Conservation status		Presence in forestry region[c]			Habitat type	
	COSEWIC[a,b]	B.C.	Coast	North Int.	South Int.	Aquatic	Terrestrial
Boreal Chorus Frog *Pseudacris triseriata*	–	Yellow	–	X	–	X	X
Red-legged Frog *Rana aurora*	SC	Blue	X	–	–	X	X
Wood Frog *Rana sylvatica*	–	Yellow	X	X	X	X	X
Columbia Spotted Frog *Rana luteiventris*	NAR	Yellow	–	X	X	X	X
Oregon Spotted Frog *Rana pretiosa*	E	Red	X	–	–	X	X
Northern Leopard Frog *Rana pipiens*	E	Red	–	–	X	X	X

Note: [a] COSEWIC = Committee on the Status of Endangered Wildlife in Canada.

[b] COSEWIC conservation codes: Not At Risk (NAR), Special Concern (SC), T (Threatened), E (Endangered).

[c] Regions: Coast, Northern Interior (North Int.), and Southern Interior (South Int.).

A map of the forest regions of B.C. is available at www.for.gov.bc.ca/mof/maps/regdis/regdis.htm .

5. SUMMARY OF GLYPHOSATE IMPACTS ON AMPHIBIANS

This summary is derived almost entirely from toxicological studies on tadpoles and late-stage anuran embryos. The impact of glyphosate herbicides on other amphibians and other life stages is virtually unknown.

- Recent studies have shown that tadpoles are one of the vertebrate groups most sensitive to the toxicity effects of most commercial formulations of glyphosate herbicides, including Vision.
- The estimated LC_{50} values for some species of amphibians are at or below the expected environmental concentration (EEC) of 1.43 mg a.e./L of Vision (Table 1). Most LC_{50} values are calculated from experimental durations of 24 to 96 hours, but at low concentrations death may not occur until after 96 hours. This suggests that amphibians may be even more sensitive than the published LC_{50} values suggest.
- Although LC_{50} values have traditionally been used to set hazard quotients, recent risk analysis methodology suggests that LC_{10} values are better for judging population-level impacts of environmental contaminants (Solomon and Thompson 2003). In at least one published study, all North American amphibian larvae tested to date had LC_{10} values estimated at or below the EEC for Vision, especially at pH higher than 7.0.
- In addition to direct mortality effects, glyphosate herbicides also cause sublethal effects, including reduced growth and development rates, behavioural impairment, and genomic effects. The population-level consequences of these sublethal effects have not been tested under field conditions. For example, reduced growth and development rates, which have been documented under laboratory conditions, could translate into increased mortality if amphibian larvae are unable to metamorphose before the end of the season. Similarly, impaired behavioural response to prodding under laboratory conditions could translate to increased susceptibility to predators under field conditions.
- Impacts have been shown to be synergistically enhanced by interaction with some environmental factors. Of particular concern is that the effects of glyphosate herbicide may be greater when pond pH is 7 or higher (Edginton et al. 2004a). Amphibians in general avoid acidic conditions, preferring to breed in ponds with higher pH, which could increase their vulnerability to glyphosate herbicide impacts.
- More detailed toxicological studies indicate that the toxicity of glyphosate herbicides arises not from the active ingredient, glyphosate, but from the surfactant, POEA.
- POEA is thought to interfere with the synthesis of collagen and to reduce the branchial cartilage in the gills of tadpoles and to cause lysis of gill epithelial cells in fish. This could result in loss of osmotic stability and asphyxiation. The toxic mode of action in terrestrial, post-metamorphic amphibians is not known.
- Glyphosate formulations without POEA surfactants, such as Rodeo, and formulations with other surfactants, such as Roundup Biactive, have reduced toxicity to amphibians.

6. KNOWLEDGE GAPS

There is sufficient research to suggest that glyphosate herbicide use could pose a risk to amphibians and that its use needs to be re-evaluated (Berrill et al. 1997; Mann and Bidwell 1999, 2001; Perkins et al. 2000). Some studies of glyphosate impacts on amphibians have estimated hazard quotients above 1 and most have shown hazard quotients above 0.1. Hazard quotients at or below 0.1 are considered the acceptable level of risk for vertebrates. However, almost no research has been conducted to assess the impact on amphibians from silvicultural use of glyphosate herbicides in B.C.

- Estimates of LC_{50} values are available for only two species of native amphibians in B.C., the Wood Frog and the Leopard Frog. LC_{50} values differ significantly among species (Table 1) and species-specific research is required for B.C. amphibians.
- Little information is available on the risk of exposure or impacts on terrestrial stages of amphibians. Some B.C. amphibians, such as newly metamorphosed Boreal Chorus Frogs and Pacific Treefrogs, and post-metamorphic aggregations of Western Toads, may be at significant risk of overspraying with glyphosate herbicides (Section 4). Research is needed to assess the extent of this risk and to determine if changes in the timing of herbicide application and/or the designation of buffer zones could reduce this risk.
- Very little information is available on the impact of glyphosate herbicides on all species of salamanders. Salamander larvae may be as susceptible as tadpoles to the effects of POEA, given that they both use fragile gill surfaces for respiration. In addition, some populations of B.C. salamanders are neotenic and remain in the aquatic environment for their entire lives. Impacts of glyphosate herbicides might be particularly severe in these populations because both the breeding and larval cohorts may suffer increased mortality.
- The impact of glyphosate on lungless salamanders is unknown. It is assumed to be minimal because these salamanders spend much of their lives underground, but there is some concern that they may be affected (Cole et al. 1997).
- The EEC of Vision is calculated from theoretical expectations. Field data from B.C. is lacking on the actual concentrations of glyphosate in wetlands and moist forest areas, which are the preferred habitats of amphibians.
- Analytical techniques for measuring field concentrations of POEA have not been published (Edginton et al. 2004a), although POEA has been recently measured in microcosms (Wang et al. 2005).
- Few data are available on the environmental concentration, and the acute and sublethal toxicities to amphibians, of aminomethylphosphonic acid (AMPA), the major breakdown product of glyphosate.
- There has been much recent controversy over whether glyphosate poses a threat to amphibian populations (Relyea 2006; Thompson et al. 2006). Much of the controversy comes from the scarcity of information on field concentration of glyphosate, the surfactant, and breakdown products in ponds after routine application of Vision during forestry operations. This knowledge is essential to evaluate the ecological relevance of treatment concentrations used in

experiments assessing glyphosate impact on amphibians.

- In Ontario, buffer zones are designed to decrease impacts on fish and they apply only to wetlands marked on 1:20,000 topographic maps (Edginton et al. 2004 a). Buffer zones and PFZs required in B.C. are designed to protect fish and most riparian areas (R. Adams, pers. comm., 2007). When available, field data show that buffer zones around wetlands are successful in decreasing glyphosate input into wetlands (Feng et al. 1990; Payne et al. 1990). However, more research is needed to determine the efficacy of current requirements in protecting amphibian habitats and to assess how these requirements can be improved to specifically protect amphibians.
- Current PFZ requirements (R. Adams, pers. comm., 2007) and buffer zone recommendations do not protect small, shallow, isolated, seasonal, fishless wetlands and streams (Edginton et al. 2004a; Wojtaszek et al. 2004). Recent research found that these habitats are prime amphibian habitats and rich in amphibian diversity (Gyug 2000; Russell et al. 2002b). More research is essential to determine the impact of glyphosate use on amphibian populations using these habitats.
- No field studies have examined multi-year effects on amphibians that may result from biotic and abiotic changes due to defoliation caused by glyphosate herbicide spraying in silviculture. Multi-year field studies have been conducted to study the impact on bird and mammal populations (Guiseppe et al. 2006). However, all the field studies examining the impact of herbicide spraying on amphibians have been short-term studies (few days to few weeks) and focussed on one life stage (larval stage). Long-term monitoring of both life stages is needed to accurately assess population-level impacts of glyphosate use on amphibians.
- A new forestry glyphosate herbicide, VisionMax, has recently been introduced to the Canadian market. According to the Monsanto website, VisionMax is a more concentrated formulation of Vision. The ecotoxicology of this product to amphibians needs to be examined. Other glyphosate-based forestry herbicides from other manufacturers are also being used in Canada; their toxicological properties and formulation ingredients should be examined.
- Mounting evidence indicates that the main toxic effect of commercial formulations of glyphosate herbicides is due to the surfactant, POEA. More research is needed to identify alternative surfactants and to test the efficacy of less toxic formulations such as Roundup Biactive for silvicultural purposes.
- Although amphibians are strongly associated with forested and woodland habitats, in amphibian ecotoxicology research, a disproportionate emphasis has been placed on agricultural scenarios. The usage patterns of glyphosate herbicides in the two settings are very different. In agriculture, herbicides are typically used at higher concentrations, sometimes applied several times a year, and repeated annually, whereas in forestry they are usually applied at lower concentrations, once per year, and once per silvicultural cycle (50 to 80 years). However, in forestry the spray block sizes are much larger (10 to 100 ha) and this could have a larger impact on source–sink and metapopulation dynamics. Therefore, the impact on population dynamics of amphibians can be very different in the two settings, and forest-based research is needed to assess the best management practices for the use of glyphosate-based herbicides in silviculture.

- Established risk assessment protocols recommend a hierarchical, multi-tired approach (Thompson 2004), and such studies are necessary to assess specific risk to B.C. amphibians. *Tier I* studies involve standard single-species toxicity testing to assess standard end-points such as LC values for native amphibians. LC values have been estimated for only two native B.C. amphibian, and 13 of the 19 native amphibians are unique to B.C. and are found nowhere else in Canada. *Tier II* studies involve laboratory studies using multiple species and multiple stressors to assess potential indirect and synergistic effects. *Tier III* studies involve in-situ enclosure and mesocosm studies to assess impacts under representative natural forest wetland conditions. *Tier IV* studies involve chemical and biological monitoring under an operating silvicultural setting in B.C. The lower tier studies provide more experimental control and standardization, which enables comparisons across species and species-specific risk categorization. The higher tier studies involve higher ecological complexity but increased environmental relevance. Such studies need to be conducted to assess the potential risk that silvicultural use of glyphosate-based herbicides pose to amphibians in B.C.

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8. GLOSSARY

Acid equivalent (a.e.) – The unit used to measure the concentration of the active glyphosate ingredient in herbicide formulations. Vision is formulated with a guarantee of 356 g glyphosate a.e. per litre as the isopropylamine salt (Appendix 1).

Active ingredient (a.i.) – The unit used to indicate the amount of pesticidally active material in a pesticide formulation. In Roundup Original and Vision formulations, the active ingredient is the isopropylamine salt and its concentration is expressed as milligrams per litre of liquid (e.g., 2.3 mg a.i./L). A conversion factor of 1 mg a.i. = 0.75 mg a.e is used in this report (Giesy et al. 2000).

Brushing – Forestry term used to denote treatment that is applied after regeneration is established (seeding, planting, or natural regeneration), to free crop trees from vegetative competition (Thompson and Pitt 2003). Also called *conifer release*.

Conifer release – Forestry term used to denote treatment that is applied after regeneration is established (seeding, planting, or natural regeneration), to free crop trees from vegetative competition (Thompson and Pitt 2003). Also called *brushing*.

Expected environmental concentration (EEC) – According to the Canadian regulatory authorities, EEC is calculated as the maximum concentration of active ingredient predicted to occur in a body of water 15 cm deep if directly oversprayed at the maximum application rate. The EEC for Vision at the maximum application rate of 2.1 kg glyphosate a.e./ha is 1.4 mg/L of glyphosate and 0.20 mg/L of surfactant POEA.

Half-life – The time required for residual concentrations of pesticide in the environment to decline to half the application rate or zero-time residue concentration. Dissipation in water depends on density of phytoplankton, suspended sediment loads, microbial degradation rates, and other routes of dissipation such as photodegradation, volatilization, and hydrolysis. In terrestrial environments, dissipation depends on soil properties that determine leaching, and on in-situ microbial degradation rates, among other routes of dissipation such as photodegradation, volatilization, and hydrolysis.

Hazard quotients – The hazard quotient for a particular pesticide is calculated as the ratio of the expected environmental concentration (EEC) divided by the value of a standard acute toxicity endpoint, such as LC_{50} or LC_{10} values. A hazard quotient of 0.1 is recommended as acceptable for fish, but a hazard quotient of 1 is considered acceptable for organisms with shorter lifespan such as invertebrates and algae (Giesy et al. 2000; Solomon and Thompson 2003).

IPA salt of glyphosate – Isopropylamine salt of glyphosate is the active ingredient in the herbicide Vision.

Lethal concentration ($LC_{\#}$) – The concentration of pesticide required to kill a specified proportion of a test population within a given amount of time. These values are estimated using standard ecotoxicological methods. The acronym LC represents Lethal Concentration, followed by a number that denotes the proportion killed. The USEPA ranks substances with LC_{50} values between 1 and 10 as moderately toxic and values between 1 and 0.1 as highly toxic (Giesy et al. 2000).

POEA (polyoxyethyleneamine) – Also called polyethoxylated tallow amine or MON 0818, it is the surfactant used in Vision and Roundup herbicides and some other glyphosate based herbicides.

Pre-commercial thinning – Forestry term applied to management of juvenile commercial tree stands of either natural or artificial origin to control stand density and composition. In Canada, release and pre-commercial thinning treatments are often grouped and discussed together as "stand tending" (Thompson and Pitt 2003).

Site preparation – Forestry term used to denote treatment that modifies a site before planting, seeding, or natural regeneration that provides conditions favourable to regeneration establishment (Thompson and Pitt 2003).

Surfactant – In the case of glyphosate herbicides, a chemical added to increase adherence to foliage and increase penetration of the active ingredient into plant tissues. The surfactant used in Vision is POEA (polyoxyethyleneamine, polyethoxylated tallow amine or MON 0818). Vision contains 15% of the surfactant in a weight:weight ratio with the isopropylamine salt of glyphosate.

APPENDICES

Appendix 1. Vision Label

VISION

Silviculture herbicide

COMMERCIAL

CAUTION  **IRRITANT**

Water soluble herbicide for silvicultural sites

REGISTRATION NO. 19899 PEST CONTROL PRODUCTS ACT

GUARANTEE: Glyphosate 356 grams acid equivalent per litre, present as isopropylamine salt

READ THE LABEL BEFORE USING.

MONSANTO CANADA, INC.
Box 667
Mississauga, Ontario L5M 2C2

Table of Contents

1.0 PRECAUTIONARY STATEMENTS

KEEP OUT OF REACH OF CHILDREN.
MAY CAUSE EYE IRRITATION.
HARMFUL IF SWALLOWED.
Avoid contact with eyes or prolonged contact with skin.
For good hygiene practice, wear a long-sleeved shirt, long pants, and chemical-resistant gloves during mixing, loading, clean-up or repair activities.

1.1 FIRST AID

IF IN EYES, immediately flush eyes with plenty of water for at least 15 minutes. Call a physician or contact a poison control centre.
IF ON SKIN, immediately flush with plenty of water. Remove contaminated clothing. Wash clothing before re-use.
IF SWALLOWED, this product will cause gastro-intestinal irritation. Immediately dilute by swallowing water or milk. Call a physician or contact a poison control centre.

Take container, label or product name and Pest Control Registration number with you when seeking medical attention.

1.2 TOXICOLOGICAL INFORMATION

Treat symptomatically.

1.3 NOTICE

Read NOTICE before buying or using. If notice terms are not acceptable, return at once unopened.

NOTICE TO BUYER: Seller's guarantee shall be limited to the terms set out on the label and subject thereto, the buyer assumes the risk to persons or property arising from the use or handling of this product and accepts the product on that condition.

NOTICE TO USER: This control product is to be used only in accordance with the directions on this label. It is an offence under the Pest Control Products Act to use a control product under unsafe conditions.

Not for reformulation or repackaging

1.4 PHYSICAL OR CHEMICAL HAZARDS

Spray solutions of this product should be mixed, stored and applied only in stainless steel, aluminum, fiberglass, plastic and plastic-lined steel containers.
DO NOT MIX, STORE OR APPLY THIS PRODUCT OR SPRAY SOLUTIONS OF THIS PRODUCT IN GALVANIZED STEEL OR UNLINED STEEL (EXCEPT STAINLESS STEEL) CONTAINERS OR SPRAY TANKS. This product or spray solutions of this product react with such containers and tanks to produce hydrogen gas which may form a highly combustible gas mixture. This gas mixture could flash or explode, causing serious personal injury, if ignited by open flame, spark, welder's torch, lighted cigarette or other ignition source.

1.5 STORAGE

Store product in original container only.
Avoid contamination of seed, feed and foodstuffs.

1.6 SPILLS

Soak up small amounts with absorbent clays.
Sweep or scoop up spilled materials and dispose of in an approved landfill.
Wash down surfaces (floors, truckbeds, streets, etc.) with detergent and water solution.

1.7 ENVIRONMENTAL HAZARDS

Avoid direct applications to any body of water.
Do not contaminate water by disposal of waste or cleaning of equipment.

1.8 DISPOSAL

RECYCLABLE CONTAINERS:
Do not reuse this container for any purpose. This is a recyclable container, and is to be disposed of at a container collection site. Contact your local distributor/dealer or municipality for the location of the nearest collection site. Before taking the container to the collection site:
1) Triple- or pressure-rinse the empty container. Add the rinsings to the spray mixture in the tank.
2) Make the empty, rinsed container unsuitable for further use.
If there is no container collection site in your area, dispose of the container in accordance with provincial requirements.

RETURNABLE CONTAINERS:
Do not reuse container for any other purpose. For disposal, this empty container may be returned to the point of purchase (distributor/dealer).

REFILLABLE CONTAINERS:
For disposal, this container may be returned to the point of purchase (distributor/dealer). It must be refilled by the distributor/dealer with the same product. Do not reuse this container for any other purpose.

For information on the disposal of unused, unwanted product, contact the manufacturer or the provincial regulatory agency. Contact the manufacturer and the provincial regulatory agency in case of a spill, or for the clean-up of spills.

1.9 EMERGENCY NUMBERS

In case of emergency involving this product, Call Monsanto Collect, day or night:
Accidents/Spills/MedicalEmergency..(314) 694-4000
or…………….....1-800-332-3111
CANUTEC.......(613) 996-6666

For additional information on this or other Monsanto agricultural products, call the Monsanto Canada Custom Care Line at: 1-800-667-4944

Vision is a registered trademark, Monsanto and the vine symbol are trademarks of Monsanto Company, U.S.A.
Monsanto Canada Inc. - Licensee.

2.0 GENERAL INFORMATION

When applied as directed under conditions described, this product controls undesirable vegetation listed on this label. This product also suppresses or controls undesirable vegetation listed on this label, when applied at recommended rates for release of established coniferous or deciduous species listed in the "**Conifer Release**" and "**Deciduous Release**" sections of this label.

This product may be applied using aerial and ground spray or wiper equipment for silvicultural site preparation, rights of ways, and conifer release, and ground spray or wiper equipment for deciduous release, forest road-side vegetation management and forest tree planting nurseries. Woody vegetation may be controlled by injection application of this product. See the "**Mixing", "Application Instructions**" and "**Selective Equipment**" sections of this label for information on how to properly apply this product.

For herbaceous weeds, woody brush, and trees controlled, see the "**Vegetation Controlled**" section of this label.

For specific site preparation instructions, see the "**Site Preparation, Forest Roadside and Rights of Way Vegetation Management**" section of the label.

For specific conifer or deciduous release instructions see the "Conifer Release" or "**Deciduous Release**" sections of this label.

Treatments should not be made to trees or brush after fall leaf drop has begun.

For specific forest tree planting nursery instructions, see the **"Forest Tree Planting Nurseries**" section of this label.

For specific injection application instructions, see the "**Injection Applications**" section of this label.

For specific instructions on use of wick or wiper applicators for vegetation control, see the "**Selective Equipment**" section of this label.

This product moves through the plant from the point of foliage contact to and into the root system. Visible effects on most annual weeds occur within 2 to 4 days, but on most susceptible perennial weeds, trees and woody brush, may not occur until 7 to 14 days. Extremely cool or cloudy weather at treatment time may slow down activity of this product and delay visual effects or control. Visible effects are a gradual wilting and yellowing of the plant which advance to complete browning of above-ground growth and deterioration of underground plant parts.

Delay application until vegetation has emerged to the stages described for control of such vegetation under the "**Vegetation Controlled**" section of this label to provide adequate leaf surface to receive the spray. Unemerged plants arising from underground rhizomes or root stocks of perennials will not be affected by the spray and will continue to grow. For this reason best control of most perennial herbaceous vegetation is obtained when treatment is made at late growth stages approaching maturity.

Always use the higher rate of this product per hectare within the recommended range on hard to control species or when vegetation growth is heavy or dense.

Do not treat vegetation under poor growing conditions such as drought stress, disease or insect damage as reduced vegetation control may result. Reduced results may also occur when treating vegetation heavily covered with dust.

Rainfall occurring soon after application may reduce effectiveness. Heavy rainfall within 2 hours after application may wash the product off the foliage and a repeat treatment may be required.

Do not mix with any surfactant, pesticide, herbicide oils or any other material other than water unless specified in this label.

For best results spray coverage should be uniform and complete. Do not spray weed foliage to the point of runoff.

ATTENTION

AVOID DRIFT. EXTREME CARE MUST BE USED WHEN APPLYING THIS PRODUCT TO PREVENT INJURING DESIRABLE PLANTS AND CROPS. Do not allow spray mist to drift, since even minute quantities of spray can cause severe damage or destruction to nearby crops, plants or other areas on which treatment is not intended, or may cause other unintended consequences. Apply only in wind conditions in compliance with local and/or provincial regulations. Do not apply when other climatic conditions, including lesser wind velocities, will allow significant drift to occur. When spraying, avoid combinations of pressure and nozzle type that will result in fine particles (mist) which are more likely to drift.
NOTE: Use of this product in any manner not consistent with this label may result in injury to persons, animals or crops, or other unintended consequences. Keep container closed to prevent spills and contamination.

Clean sprayer parts immediately after using this product by thoroughly flushing with water. Do not contaminate water sources by disposal of wastes or cleaning of equipment.

3.0 MIXING & APPLICATION INSTRUCTIONS

3.1 **MIXING**

This product mixes readily with water.

For ground, aerial or industrial type sprayers, fill the spray tank with one half the required amount of water. Add the proper amount of herbicide (see "**Application Instructions**" section of the label) and mix well before adding the remaining portion of water. Placing the filling hose below the surface of the liquid solution will prevent excessive foaming. Removing hose from tank immediately will avoid back siphoning into to water source. Use of mechanical agitators may cause excessive foaming. By-pass lines should terminate at the bottom of the tank.For use in knapsack sprayers, it is suggested that the proper amount of this herbicide be mixed with water in a larger container. Fill sprayer with the mixed solution.

NOTE: REDUCED RESULTS MAY OCCUR IF WATER CONTAINING SOIL IS USED, SUCH AS WATER FROM PONDS AND UNLINED DITCHES.

3.2 **APPLICATION INSTRUCTIONS**

APPLY THESE SPRAY SOLUTIONS IN PROPERLY MAINTAINED AND CALIBRATED EQUIPMENT CAPABLE OF DELIVERING DESIRED VOLUMES.
HAND GUN APPLICATIONS SHOULD BE PROPERLY DIRECTED TO AVOID SPRAYING DESIRABLE PLANTS.

AVOID DRIFT--Drift may cause damage to any vegetation contacted for which treatment is not intended. Applications in wind conditions in excess of local and/or provincial aerial spray regulations are not recommended.

To prevent injury to adjacent vegetation, appropriate buffer zones must be maintained.

Do not apply directly to any body of water populated with fish or used for domestic purposes. Do not use in areas where adverse impact on domestic water or aquatic species is likely.

3.2.1 APPLICATION RATES

To control or suppress herbaceous weeds, woody brush and trees, apply 3 to 6 litres of this product per hectare using aerial, ground boom or boomless, or mist blower equipment, or apply as a 1 to 2 percent solution using hand-held high volume equipment. Use the 6 litres rate for control of maple, alder or willow species. For control of perennial herbaceous weeds in site preparation applications using aerial, ground boom or boomless, or mist blower equipment, apply 7 to 12 litres of this product per hectare as directed in the recommended volume of clean water to the foliage of actively growing vegetation.

For specific rates for wick or wiper applicators, see the "Selective Equipment" section of this label.

3.2.2 AERIAL EQUIPMENT

Apply only by fixed-wing or rotary aircraft equipment which has been functionally and operationally calibrated for the atmospheric conditions of the area and the application rates and conditions of this label. Label rates, conditions and precautions are product specific. Read and understand the entire label before opening this product. Apply only at the rate(s) recommended for aerial application on this label in 20 to 100 litres of water per hectare. For control of perennial weeds in site preparation applications using 7 to 12 litres of this product, use 50 to 100 litres of water per hectare. Where no rate for aerial application appears for the specific use, this product cannot be applied by any type of aerial equipment. As density of vegetation increases, spray volume should be increased within the recommended range to ensure complete coverage.

Ensure uniform application. To avoid streaked, uneven or overlapped application, use appropriate marking devices, or equivalent electronic positioning systems (GPS).

Thoroughly wash aircraft, especially landing gear, after each day of spraying to remove residues of this product accumulated during spraying or from spills. **PROLONGED EXPOSURE OF THIS PRODUCT TO UNCOATED STEEL SURFACES MAY RESULT IN CORROSION AND POSSIBLE FAILURE OF THE PART. LANDING GEAR ARE MOST SUSCEPTIBLE**. The maintenance of an organic coating (paint) which meets aerospace specification MIL-C-38412 may prevent corrosion.

Use Precautions

Apply only when meteorological conditions at the treatment site allow for complete and even crop coverage. Do not apply to any body of water. Avoid drifting of spray onto any body of water or other non-target areas. Specified buffer zones should be observed.

Coarse sprays are less likely to drift. Therefore, avoid combinations of pressure and nozzle type that will result in the production of fine particles (mist). Do not angle nozzles forward into the airstream and do not increase spray volume by increasing nozzle pressure. Do not spray during periods of dead calm or when wind velocity and direction pose a risk of spray drift. Do not spray when the wind is blowing towards a nearby sensitive crop, garden, terrestrial habitat (such as a shelter belt)

Applicator Precautions

Do not allow the pilot to mix chemicals to be loaded onto the aircraft. Loading of premixed chemicals with a closed system is permitted.

It is desirable that the pilot have communication capabilities at each treatment site at the time of application.

The field crew and mixer/loaders must wear chemical resistant gloves, coveralls and goggles or face shield during mixing/loading, cleanup and repair. Follow the more stringent label precautions in cases where the operator precautions exceed the generic label recommendations on the existing ground boom label.

All personnel on the job must wash hands and face thoroughly before eating or drinking. Protective clothing, aircraft cockpit and vehicle cabs must be decontaminated regularly.

3.2.3 BOOM EQUIPMENT

For control of herbaceous weeds and woody brush and trees listed in the "Vegetation Controlled" section of this label using conventional boom equipment--Apply this product in 100 to 300 litres of clean water per hectare as a broadcast spray using no more pressure than 275 kPa.

3.2.4 BOOMLESS EQUIPMENT

For control of herbaceous weeds, woody brush and trees listed in the "Vegetation Controlled" section of this label using boomless equipment such as cluster nozzles--Apply this product in 100-350 litres of clean water per hectare as a broadcast spray using no more pressure than 275 kPa.

3.2.5 HAND HELD AND HIGH VOLUME EQUIPMENT (USE COARSE SPRAYS ONLY)

For control of herbaceous weeds, woody brush and trees listed in the "Vegetation Controlled" section of this label using knapsack sprayers or high volume spraying equipment utilizing handguns or other suitable nozzle arrangements.

Applications should be made on a spray-to-wet basis. Spray coverage should be uniform and complete. Do not spray to point of runoff.

3.2.6 MIST BLOWER EQUIPMENT

For control of herbaceous weeds, woody brush and trees listed in the "Vegetation Controlled" section of this label--Use the recommended rate of this product in at least 200 litres of water per hectare.

4.0 VEGETATION CONTROLLED

AVOID CONTACT WITH FOLIAGE, GREEN STEMS, OR FRUIT OF NON-TARGET CROPS, SINCE DAMAGE TO THESE PLANTS MAY RESULT.

A PARTIAL LIST OF PERENNIAL HERBACEOUS WEEDS, WOODY BRUSH AND TREE SPECIES CONTROLLED INCLUDES:

4.1 PERENNIAL GRASSES / SEDGES

Blue Grass (Canada)
Poa compressa
Blue Grass (Kentucky)
Poa pratensis
Brome Grass (smooth)
Bromus inermis
Cattail (common)
Typha latifolia
Foxtail Barley
Hordeum jubatum
Quackgrass
Agropyron repens
Yellow Nutsedge
Cyperus esculentus

4.2 PERENNIAL BROADLEAVED WEEDS

Alfalfa
Medicago spp.
Cottontop
Eriophorum chamissionis
Curled Dock
Rumex crispus
Dandelion
Taraxacum officinale
Field Bindweed
Convolvulus arvensis
Hemp Dogbane
Milkweed (common)
Asclepias syriaca
Poison Ivy
Rhus radicans
Purple Loosestrife
Lythrum salicaria
SowThistle *(peren.)*
Sonchus arvensis
Thistle (Canada)
Cirsium arvense
Toad Flax

Apocynum cannabinum	*Linaria vulgaris*
Hoary Cress	**Wormwood (Absin.)**
Cardaria draba	*Artemisia absinthium*
Knotweed (Japanese)	
Polygonum cuspidatum	

4.3 **WOODY BRUSH AND TREES**

Alder	**Maple**
Alnus spp.	*Acer spp.*
Birch	**Pine**
Betula spp.	*Pinus spp.*
Broadleaved meadowsweet*	**Poplar**
Spiraea latifolia	*Populus spp.*
Canadian rhododendron*	**Sheep laurel***
Rhododendron canadenses	*Kalmia angustifolia*
Cedar	**Sweet fern***
Thuja spp.	*Comptonia peregrina*
Cherry	**Willow****
Prunus spp.	*Salix spp.*
Douglas Fir	**Withrod***
Pseudotsuga spp.	*Viburnum cassinoides*
Ericaceous species ***	
Ericaceae spp.	
Hemlock	
Tsuga spp.	
Mountain-fly honeysuckle*	
Lornica villosa	
Raspberry / Salmonberry	
Rubus spp.	
Snowberry (Western)	
Symphoricarpos occidentalis	

* Apply as a 1-2 percent solution.
** Suppression only.
*** Used in conjunction with an additional silicon-based surfactant (such as Sylgard 309®)

Sylgard 309 is a registered trademark of Dow AgriSciences.

See "**Mixing & Application Instructions**" and "**Forest-**" or "**Woodland- Management**" sections of this label for additional information.

For perennial broadleaf weeds, apply when most weeds have reached early head or early bud stage of growth. For annual and perennial grasses, apply when most weeds are at least 20 cm in height (the 3-4 leaf stage of growth).

If herbaceous weeds have been mowed, tilled, or scarified, do not treat until regrowth has reached the recommended stages, as reduced effectiveness will result. Most herbaceous weeds can be treated after a mild frost, provided the leaves are still green and actively growing at the time of application. Do not apply after the first damaging frost. Allow 7 or more days after application before tillage or other soil disturbance. Repeat treatments may be necessary to control weeds regenerating from underground parts or seed.

5.0 DIRECTIONS FOR USE

Spray coverage should be uniform and complete. Do not spray to the point of runoff.
Do not allow spray drift to contact non-target desirable vegetation as severe damage may occur.

5.1 RESTRICTED USES - FOREST AND WOODLANDS MANAGEMENT

Ground/Aerial Application for Sites greater than 500 hectares (Forestry Use)

Aerial Application for Sites 500 hectares or less (Woodlands Use)

NOTICE TO USER: This control product is to be used only in accordance with the directions on this label. It is an offense under the Pest Control Products Act to use a control product under unsafe conditions.

NATURE OF RESTRICTION: This product is to be used only in the manner authorized; consult local pesticide regulatory authorities about use permits which may be required.

Do not apply to any body of water populated with fish or used for domestic purposes. Do not use in areas where adverse impact on domestic water or aquatic species is likely.

In order to reduce the drift hazard to non-target plants and aquatic species when aerially treating silvicultural sites, ensure that appropriate buffer zones are maintained.

5.1.1 SITE PREPARATION

Use this product as broadcast treatment at recommended rates, as listed in the "**Application Rates**" section, to control herbaceous weeds, woody brush and tree species listed in the "**Vegetation Controlled**" section. Apply when brush and tree species are actively growing and when foliage is full and well-developed. For best results apply in late summer or early fall. Some autumn colours on undesirable deciduous species are acceptable provided no major leaf fall has occurred. Following site preparation application of this product, any silvicultural species may be planted.

For control of vegetation on sites with infestations of ericaceous species (eg. Kalmia spp - sheep laurel, lamb kill), use 6 litres per hectare Vision and an additional silicon-based surfactant (such as Sylgard 309) as per label instructions. Apply between mid-August and mid-September for maximum performance.

5.1.2 CONIFER RELEASE

Use this product as a broadcast spray at recommended rates, as listed in the "**Application Rates**" section, to control herbaceous weeds, woody brush and tree species, as listed in "**Vegetation Controlled**" section of this label, to release from competition the coniferous species listed below:

Douglas Fir *Pseudotsuga spp.*	**Pine** *Pinus spp.*
Fir *Abies spp.*	**Spruce** *Picea spp.*
Hemlock *Tsuga spp.*	

For conifer release of spruce seedlings in the year of transplanting, apply 2 to 6 litres of this product per hectare in plantations of summer planted spruce species (Picea glauca, P. engelmannii and their hybrids). Conifers must be planted in the same year as treatment and in the field for at least 18 days prior to treatment. Seedlings to be treated must clearly show bud set and bud hardening following a dormancy induction regime in the nursery. The need for such early release treatments is expected on sites which are subject to the rapid development of herbaceous and shrub communities.

Most annual and perennial weeds will be controlled or suppressed. Applications must be made after formation of final conifer resting buds. Applications made during period of active conifer growth may result in conifer injury. Avoid application during Lammas or late season conifer growth. Some autumn colors are acceptable provided no major leaf fall has occurred on undesirable brush and tree species.

For conifer release, apply where conifers have been established for more than a year. Vegetation should not be disturbed immediately prior to treatment or until visual signs appear after treatment. Symptoms of treatment are slow to appear, especially in woody species treated in late fall. Injury may occur to conifers treated for release, especially where spray patterns overlap or the higher rates are applied or when applications are made during periods of active conifer growth.

NOTE : This product is not recommended for use as an over-the-top broadcast spray in forest tree nurseries or in Christmas tree plantations. Applications in such sites should be limited to directed sprays (see section 5.2.2, "**Conifer Release by Directed Spraying").** DO NOT TREAT Christmas tree plantations in the year of anticipated harvest.

5.2 WOODLAND MANAGEMENT
Treatment of 500 hectares or less
SITE PREPARATION (Ground Only), FOREST ROADSIDE (Ground Only) and RIGHTS-OF-WAY VEGETATION MANAGEMENT (Ground or Aerial)

Use this product as a broadcast treatment at recommended rates, as listed in the "**Application Rates**" section, to control herbaceous weeds, woody brush and tree species listed in the "**Vegetation Controlled**" section. For control of herbaceous weeds, apply when most perennial broadleaf weeds have reached the early head or early bud stage of growth. For perennial grasses, apply when most weeds are 20 centimetres in height. Apply when brush and tree species are actively growing and when foliage is full and well-developed. For best results apply in late summer or early fall. Some autumn colors on undesirable deciduous species are acceptable provided no major leaf fall has occurred. Following site preparation application of this product, any silvicultural species may be planted.

For control of vegetation on sites with infestations of ericaceous species (eg. Kalmia spp - sheep laurel, lamb kill), use 6 litres per hectare Vision in the recommended water volume and an additional silicon-based surfactant (such as Sylgard 309) as per label instructions. Apply between mid-August and mid-September for maximum performance.

5.2.1 CONIFER RELEASE (Ground Only)

Use this product as a broadcast spray at recommended rates, as listed in the "**Application Rates**" section, to control herbaceous weeds, woody brush and tree species, as listed in "**Vegetation Controlled**" section of this label, to release from competition the coniferous species listed below:

Douglas Fir *Pseudotsuga spp.*	**Pine** *Pinus spp.*
Fir *Abies spp.*	**Spruce** *Picea spp.*
Hemlock *Tsuga spp.*	

For conifer release of spruce seedlings in the year of transplanting, apply 2 to 6 litres of this product per hectare in plantations of summer planted spruce species (Picea glauca, P. engelmannii and their hybrids). Conifers must be planted in the same year as treatment and in the field for at least 18 days prior to treatment. Seedlings to be treated must clearly show bud set and bud hardening following a dormancy induction regime in the nursery. The need for such early release treatments is expected on sites which are subject to the rapid development of herbaceous and shrub communities.

Most annual and perennial weeds will be controlled or suppressed. Applications must be made after formation of final conifer resting buds. Applications made during period of active conifer growth may result in conifer injury. Avoid application during Lammas or late season conifer growth. Some autumn colors are acceptable provided no major leaf fall has occurred on undesirable brush and tree species.

For conifer release, apply where conifers have been established for more than a year. Vegetation should not be disturbed immediately prior to treatment or until visual signs appear after treatment. Symptoms of treatment are slow to appear, especially in woody species treated in late fall. Injury may occur to conifers treated for release, especially where spray patterns overlap or the higher rates are applied or when applications are made during periods of active conifer growth.

NOTE : This product is not recommended for use as an over-the-top broadcast spray in forest tree nurseries or in Christmas tree plantations. Applications in such sites should be limited to directed sprays (see "**Conifer Release by Directed Spraying**" section). DO NOT TREAT Christmas tree plantations in the year of anticipated harvest.

5.2.2 CONIFER RELEASE BY DIRECTED SPRAYING

Use this product to control herbaceous and woody species as listed in the "**Vegetation Controlled**" section of the label.
Apply when the undesirable species are actively growing and the foliage is full and well-developed. This product does not provide pre-emergent weed control. Repeat treatments may be necessary to control weeds that generate from underground parts or seed.

Undesirable deciduous species may be treated when they already have autumn colours, provided there has been no major leaf fall. For perennial broadleaf species, apply when most weeds have reached early head or early bud stage of growth. For annual and perennial grasses, apply when most weeds are 20 centimetres in height (3-4 leaf stage of growth).

Direct spray so that the foliage of undesired vegetation is thoroughly wetted. Do not spray foliage to the point of run-off. Applying the product to conifers during their period of active growth (before lignification) may cause tree injury. Under such conditions, take the necessary precautions to ensure that spray, mist or spray drift does not come into contact with the foliage or green bark of conifers being cultivated.

The product may be applied on sites regenerated by the following species (partial list): SPRUCE (*Picea spp*.), PINE (*Pinus spp*.), HEMLOCK (*Tsuga spp.),* DOUGLAS FIR (*Pseudotsuga spp*.). No time interval is required between tree planting and application of the product. For specific rates and application instructions, see the "**Mixing Instructions**", "**Application Instructions**" and "**Vegetation Controlled**" sections of the product label.

Do not allow spray to come in contact with foliage, green stems or fruit of non-target crops, since they may be killed or severely damaged.

5.2.3 DECIDUOUS RELEASE (Ground Only)

Use this product to control herbaceous weeds and woody brush mentioned in the "**Vegetation Controlled**" section of the label.

Apply when the undesirable species are actively growing, and the foliage is well developed. This product has no pre-emergent activity. Repeat treatments may be required for species which regenerate from underground stems or from seeds. Applications may be made to undesirable deciduous species with some autumn colours, provided that major leaf fall has not yet occurred.

Use a directed spray to thoroughly cover the foliage of the undesirable vegetation. Take all necessary precautions to prevent contact of the spray, spray mist or spray drift with the foliage or green bark of desirable species.

A partial list of species for use with this product on regenerated sites includes: ASH (*Fraxinus spp*.); WALNUT (*Juglans spp*); LINDEN or BASSWOOD (*Tilia spp*); CHERRY (*Prunus spp*.); OAK (*Quercus spp*); ELM (*Ulmus spp*) and POPLAR (*Populus spp*). Product may be applied immediately after transplanting.

For use rates and application instructions, refer to the "**Application Rates**" and "**Application Instructions**" sections of this label.

5.2.4 INJECTION APPLICATIONS

Woody vegetation may be controlled by injection application of this product. Apply using suitable equipment, which must penetrate into living tissue, at a rate of at least 0.5 millilitres (either undiluted or 1:1 with water) per 5 centimetres tree diameter at breast height (DBH). The cuts should be spaced evenly around the tree and below all major branches. Application may be made at any time of year, except when cold temperatures prevent adequate penetration of injection equipment, or in the spring during periods of heavy sap flow. Control of tree species with tree diameters greater than 20 centimetres may not be acceptable at this rate.

Total control may not be evident for 1-2 years following treatment.

A partial list of species controlled includes:

Alder
Alnus spp.

Birch
Betula spp.

Cedar
Thuja spp.

Cherry
Prunus spp.

Maple*
Acer spp.

Pine
Pinus spp.

Poplar
Populus spp.

Willow
Salix spp.

Douglas-fir *Pseudotsuga spp.*	**Hemlock** *Tsuga spp.*

* This treatment may only provide suppression of Big-Leaf Maple. Late fall applications will provide optimum suppression of Big-Leaf Maple

5.2.5 CUT STUMP APPLICATION

Woody vegetation may be controlled by the application of this product to freshly cut stumps to prevent regrowth. Because the treatment uses a concentrated solution, application must be made using low-pressure equipment e.g squirt bottle or similar device. This product must be applied immediately to the surface of the freshly cut stump i.e within 5 minutes, for optimum control at the prescribed rates. Only the cambial tissues of the cut surface should be treated. Apply the herbicide solution at a rate equivalent to at least 0.5 mL Vision herbicide for every 5cm of DBH. Do not cover the remaining area nor any exposed roots, as this product does not penetrate bark well. This treatment may be used at any time of year, except during periods of heavy sap flow or when low temperatures prevent solution application due to freezing. A water soluble colourant may be added to the solution as a means of indicating which surfaces have been treated. Total control may not be evident until 1-2 years after treatment.

See the “INJECTION APPLICATIONS” section of this label for a partial list of species controlled.

5.2.6 FOREST TREE PLANTING NURSERIES (GROUND ONLY)

This product may be used to control most annual and perennial weeds for site preparation prior to establishing plantations, or as a post directed spray in established plantations. Application may be made to established deciduous plantings of ASH, *Fraxinus spp*.; CARAGANA, *Caragan spp.;* CHERRY, *Prunus spp*.; ELM, *Ulmus spp*.; LILAC, *Syringa spp*.; MAPLE, *Acer spp*.; MOUNTAIN ASH, *Sorbus spp*.; POPLAR*, Poplulus spp*.; RUSSIAN OLIVE, *Elaeagnus spp*.; and WILLOW, *Salix spp.* Applications may be made prior to or in established conifer plantings of FIR, *Abies spp*.; JUNIPER, *Juniperus spp*.; PINE*, Pinus spp*.; SPRUCE, *Picea spp*.; and YEW, *Taxus spp*.. SPRAY MAY CONTACT MATURE BARK ONLY. AVOID SPRAY CONTACT WITH FOLIAGE OR GREEN BARK OF ESTABLISHED PLANTINGS IN POST DIRECTED APPLICATIONS.

For specific rates and applications instructions, see “**Application Rates**” and "**Application Instructions**" section of this booklet. DO NOT APPLY UNDER WIND OR OTHER CONDITIONS WHICH ALLOW DRIFT TO OCCUR. If weeds have been mowed or tilled do not treat until regrowth has reached the recommended stages.

This product does not provide pre-emergence weed control. Repeat treatments may be necessary to control weeds generating from underground parts or seed.

NOTE : This product is not recommended for use as an over-the-top broadcast spray in forest tree nurseries or in Christmas tree plantations. Applications in such sites should be limited to directed sprays (see "**Conifer Release by Directed Spraying**" section). DO NOT TREAT Christmas tree plantations in the year of anticipated harvest.

5.2.7 SELECTIVE EQUIPMENT - WIPER APPLICATORS

This product may be applied with a wiper applicator, after dilution and thorough mixing water, to listed weeds in the “**Vegetation Controlled**” section of this label. It may be used in any forestry site specified in this label.

A wiper applicator applies the herbicide solution onto weeds by rubbing the weed with an absorbent material containing the herbicide solution. Equipment must be designed, maintained and operated to prevent the herbicide solution from contacting desirable vegetation, except in cases of conifer release operations where conifers are well hardened off (see "**Conifer Release**” Section); in these cases, a slight contact between the wiper and the conifer may be acceptable. Performance may be improved by reducing speed in areas of heavy infestations to insure adequate wiper saturation. Best results may be obtained if 2 applications are made in opposite directions.

AVOID CONTACT WITH DESIRABLE VEGETATION. Contact of the herbicide solution with desirable vegetation may result in damage or destruction. Applicators used above desired vegetation should be adjusted so that wiper contact point is at least 5 centimetres above the desirable vegetation. Droplets or foam of the herbicide solution settling on desirable vegetation may result in discoloration, stunting or destruction.

Applications should be made when the weeds are a minimum of 15 centimetres above the desirable vegetation. Best results may be obtained when more of the weed is exposed to the herbicide solution. Weeds not contacted by the herbicide solution will not be affected. This may occur in dense clumps, severe infestations, or when the height of the weeds varies so that not all weeds are contacted. In these instances, repeat treatments may be necessary.

NOTES

- Maintain equipment in good operating condition. Avoid leakage or dripping onto desirable vegetation.
- Adjust height of applicator to insure proper contact with weeds.
- Keep wiping surfaces clean.
- Keep wiper material at proper degree of saturation with herbicide solution.
- DO NOT use wiper equipment when weeds are wet.
- DO NOT operate equipment at ground speeds below 4 and greater than 10 kilometres per hour. Weed control may be affected by speed of application equipment. As weed density increases, reduce equipment ground speed to insure good coverage of weeds.
- Be aware that on sloping ground the herbicide solution may migrate, causing dripping on the lower end and drying on the upper end of the wiper applicator.
- Variation in equipment design may affect weed control. With wiper applicators, the wiping material and its orientation must allow delivery of sufficient quantities of the recommended herbicide solution directly to the weed.
- Care must be taken with all types of wipers to insure that the absorbent material does not become over-saturated, causing the herbicide to drip onto desirable vegetation.
- With all equipment, drain and clean wiper parts immediately after using this product, by thoroughly flushing with water.

For Wick or other Wiper Applicators--Mix 1 litre of this product in 2 litres of water to prepare a 33 percent solution.

Appendix 2. VisionMax Label

GROUP	9	HERBICIDE

VisionMax Silviculture Herbicide

COMMERCIAL

CAUTION **POISON**

WARNING – EYE AND SKIN IRRITANT

REGISTRATION NO. 27736 PEST CONTROL PRODUCTS ACT

GUARANTEE: Glyphosate, 540 grams acid equivalent per litre, present as potassium salt.

Water soluble herbicide for silvicultural sites

READ THE LABEL AND ATTACHED BROCHURE BEFORE USING.

MONSANTO CANADA INC.
67 Scurfield Blvd.
Winnipeg, Manitoba R3Y 1G4

2004

(FRANÇAIS AU VERSO)

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VisionMax Silviculture Herbicide

1.0 PRECAUTIONS

KEEP OUT OF REACH OF CHILDREN.
HARMFUL IF SWALLOWED.
HARMFUL IF INHALED.
CAUSES EYE AND SKIN IRRITATION.
Avoid contact with eyes, skin or clothing.
Avoid inhaling spray mist.

Wear a long-sleeved shirt and long pants during mixing, loading, application, clean-up and repair. In addition, wear goggles or a face shield and chemical-resistant gloves during mixing and loading, clean-up and repair.

Do not enter treated field within 12 hours of application.

1.1 FIRST AID

IF IN EYES, IMMEDIATELY flush with plenty of water for at least 15 minutes. Call a physician or contact a poison control center.
IF ON SKIN, IMMEDIATELY flush with plenty of water. Remove contaminated clothing. Wash clothing before re-use.
IF SWALLOWED, this product will cause gastro-intestinal tract irritation. **IMMEDIATELY** dilute by swallowing water or milk. Call a physician or contact a poison control center.
IF INHALED, remove individual to fresh air. If not breathing, give artificial respiration, preferably mouth-to-mouth. Call a physician or contact a poison control centre.

Take container, label or product name and Pest Control Registration Number with you when seeking medical attention.

1.2 TOXICOLOGICAL INFORMATION

Treat symptomatically.

1.3 NOTICE

Read NOTICE before buying or using. If notice terms are not acceptable, return at once unopened.

Not for reformulation or repackaging.

NOTICE TO BUYER – Seller's guarantee shall be limited to the terms set out on the label and subject thereto, the buyer assumes the risk to persons or property arising from the use or handling of this product and accepts the product on that condition.

NOTICE TO USER – This control product is to be used only in accordance with the directions on the label. It is an offence under the *Pest Control Products Act* to use a control product under unsafe conditions.

1.4 ENVIRONMENTAL HAZARDS

Avoid direct applications to any body of water. Do not use in areas where adverse impact on domestic water or aquatic species is likely. Do not contaminate water by disposal of waste or cleaning of equipment. Avoid all drift to or contact with other vegetation for which treatment is not intended as damage or destruction may occur.

1.5 PHYSICAL OR CHEMICAL HAZARDS

Spray solutions of this product should be mixed, stored and applied only in stainless steel, aluminum, fiberglass, plastic and plastic-lined steel containers. **DO NOT MIX, STORE OR APPLY THIS PRODUCT OR SPRAY SOLUTIONS OF THIS PRODUCT IN GALVANIZED STEEL OR UNLINED STEEL (EXCEPT STAINLESS STEEL) CONTAINERS OR SPRAY TANKS**. This product or spray solutions of this product react with such containers and tanks to produce hydrogen gas which may form a highly combustible gas mixture. This gas mixture could flash or explode, causing serious personal injury, if ignited by open flame, spark, welder's torch, lighted cigarette or other ignition source.

1.6 STORAGE

Store product in original container only.
Avoid contamination of seed, feed, and foodstuffs.

1.7 DISPOSAL

RECYCLABLE CONTAINERS:
Do not reuse this container for any purpose. This is a recyclable container, and is to be disposed of at a container collection site. Contact your local distributor/dealer or municipality for the location of the nearest collection site. Before taking the container to the collection site:

1) Triple or pressure-rinse the empty container. Add the rinsings to the spray mixture in the tank.
2) Make the empty, rinsed container unsuitable for further use.

If there is no container collection site in your area, dispose of the container in accordance with provincial requirements.

RETURNABLE CONTAINERS:
Do not reuse container for any other purpose. For disposal, this empty container may be returned to the point of purchase (distributor/dealer).

REFILLABLE CONTAINERS:
For disposal, this container may be returned to the point of purchase (distributor/dealer). It must be refilled by the distributor/dealer with the same product. Do not reuse this container for any other purpose.

For information on the disposal of unused, unwanted product, contact the manufacturer or the provincial regulatory agency. Contact the manufacturer and the provincial regulatory agency in case of a spill, and for the clean up of spills.

1.8 SPILLS

Soak up small amounts of spill with absorbent clays.
Sweep or scoop up spilled materials and dispose of in an approved landfill.
Wash down surfaces (floors, truckbeds, streets, etc.) with detergent and water solution.

1.9 EMERGENCY NUMBERS

In case of an emergency involving this product, call Monsanto collect, day or night:

Accident/Spills/Medical Emergency ……………….…………. (314) 694-4000
Or ……………………………...1-800-332-3111
Or CANUTEC …………………(613) 996-6666

DIRECTIONS FOR USE

2.0 GENERAL INFORMATION

When applied as directed under conditions described, this product controls undesirable vegetation listed on this label. This product also suppresses or controls undesirable vegetation listed on this label, when applied at recommended rates for release of established coniferous or deciduous species listed in the "**Conifer Release**" and "**Deciduous Release**" sections of this label.

This product may be applied using aerial and ground spray or wiper equipment for silvicultural site preparation, rights of ways, and conifer release, and ground spray or wiper equipment for deciduous release, forest road-side vegetation management and forest tree planting nurseries. Woody vegetation may be controlled by injection application of this product. See the "**Mixing**", "**Application Instructions**" and "**Selective Equipment**" sections of this label for information on how to properly apply this product.

For herbaceous weeds, woody brush, and trees controlled, see the "**Vegetation Controlled**" section of this label.

For specific site preparation instructions, see the "**Site Preparation, Forest Roadside and Rights of Way Vegetation Management**" section of the label.

For specific conifer or deciduous release instructions see the "**Conifer Release**" or "**Deciduous Release**" sections of this label.

Treatments should not be made to trees or brush after fall leaf drop has begun.

For specific forest tree planting nursery instructions, see the "**Forest Tree Planting Nurseries**" section of this label.

For specific injection application instructions, see the "**Injection Applications**" section of this label.

For specific instructions on use of wick or wiper applicators for vegetation control, see the "**Selective Equipment**" section of this label.

This product moves through the plant from the point of foliage contact to and into the root system. Visible effects on most annual weeds occur within 2 to 4 days, but on most susceptible perennial weeds, trees and woody brush, may not occur until 7 to 14 days. Extremely cool or cloudy weather at treatment time may slow down activity of this product and delay visual effects or control. Visible effects are a gradual wilting and yellowing of the plant which advances to complete browning of above-ground growth and deterioration of underground plant parts.

Delay application until vegetation has emerged to the stages described for control of such vegetation under the "**Vegetation Controlled**" section of this label to provide adequate leaf surface to receive the spray. Unemerged plants arising from underground rhizomes or rootstocks of perennials will not be affected by the spray and will continue to grow. For this reason best control of most perennial herbaceous vegetation is obtained when treatment is made at late growth stages approaching maturity.

Always use the higher rate of this product per hectare within the recommended range on hard to control species or when vegetation growth is heavy or dense.

Do not treat vegetation under poor growing conditions such as drought stress, disease or insect damage as reduced vegetation control may result. Reduced results may also occur when treating vegetation heavily covered with dust.

Rainfall occurring soon after application may reduce effectiveness. Heavy rainfall within 2 hours after application may wash the product off the foliage and a repeat treatment may be required.

Do not mix with any surfactant, pesticide, herbicide oils or any other material other than water unless specified in this label.

For best results spray coverage should be uniform and complete. Do not spray weed foliage to the point of runoff.

RESISTANCE-MANAGEMENT RECOMMENDATIONS

For resistance management, VisionMax Silviculture Herbicide is a Group 9 herbicide. Any weed population may contain or develop plants naturally resistant to VisionMax Silviculture Herbicide and other Group 9 herbicides. The resistant biotypes may dominate the weed population if these herbicides are used repeatedly in the same field. Other resistance mechanisms that are not linked to site of action, but specific for individual chemicals, such as enhanced metabolism, may also exist. Appropriate resistance-management strategies should be followed.

To delay herbicide resistance:

- Where possible, rotate the use of VisionMax Silviculture Herbicide or other Group 9 herbicides with different herbicide groups that control the same weeds in a field.
- Use tank mixtures with herbicides from a different group when such use is permitted.
- Herbicide use should be based on an IPM program that includes scouting, historical information related to herbicide use and crop rotation, and considers tillage (or other mechanical), cultural, biological and other chemical control practices.

- Monitor treated weed populations for resistance development.
- Prevent movement of resistant weed seeds to other fields by cleaning harvesting and tillage equipment and planting clean seed.
- Contact your local extension specialist or Monsanto Canada representative for any additional pesticide resistance-management and/or integrated management recommendations for specific target vegetation and weed biotypes.
- For further information or to report suspected resistance, contact Monsanto Canada at 1-800-667-4944 or at www.Monsanto.ca.

3.0 MIXING AND APPLICATION INSTRUCTIONS

3.1 PRECAUTIONS

ATTENTION: AVOID CONTACT WITH FOLIAGE, GREEN STEMS, OR FRUIT OF CROPS, DESIRABLE PLANTS AND TREES SINCE SEVERE INJURY OR DESTRUCTION MAY RESULT.

APPLY THESE SPRAY SOLUTIONS IN PROPERLY MAINTAINED AND CALIBRATED EQUIPMENT CAPABLE OF DELIVERING DESIRED VOLUMES.

AVOID DRIFT. EXTREME CARE MUST BE USED WHEN APPLYING THIS PRODUCT TO PREVENT INJURING DESIRABLE PLANTS AND CROPS.

Do not allow spray mist to drift, since even minute quantities of spray can cause severe damage or destruction to nearby crops, plants or other areas on which treatment is not intended, or may cause other unintended consequences. Apply only in wind conditions in compliance with local and/or provincial regulations. Do not apply when other climatic conditions, including lesser wind velocities, will allow significant drift to occur. When spraying, avoid combinations of pressure and nozzle type that will result in fine particles (mist) which are more likely to drift.

NOTE: Use of this product in any manner not consistent with this label may result in injury to persons, animals or crops, or other unintended consequences. Keep container closed to prevent spills and contamination.

Clean sprayer parts immediately after using this product by thoroughly flushing with water. Do not contaminate water sources by disposal of wastes or cleaning of equipment.

DO NOT USE IN GREENHOUSES, REDUCED RESULTS MAY OCCUR IF WATER CONTAINING SOIL IS USED, SUCH AS WATER FROM PONDS AND UNLINED DITCHES.

3.2 MIXING

This product mixes readily with water.

For ground, aerial or industrial type sprayers, fill the spray tank with one-half the required amount of water. Add the proper amount of herbicide (see "**Application Rates**" section of this booklet) and mix well before adding the remaining portion of water. Placing the filling hose below the surface of the liquid solution will prevent excessive foaming. Removing hose from tank immediately will avoid back siphoning into water source. Use of mechanical agitators may cause excessive foaming. Bypass lines should terminate at the bottom of the tank.

For use in knapsack sprayers, it is suggested that the proper amount of this herbicide be mixed with water in a larger container. Fill sprayer with the mixed solution.

3.3 APPLICATION INSTRUCTIONS

APPLY THESE SPRAY SOLUTIONS IN PROPERLY MAINTAINED AND CALIBRATED EQUIPMENT CAPABLE OF DELIVERING DESIRED VOLUMES. HAND GUN APPLICATIONS SHOULD BE PROPERLY DIRECTED TO AVOID SPRAYING DESIRABLE PLANTS.

AVOID DRIFT – Drift may cause damage to any vegetation contact for which treatment is not intended. Applications in wind conditions in excess of local and/or provincial aerial spray regulations are not recommended.

To prevent injury to adjacent vegetation, appropriate buffer zones must be maintained.

Do not apply directly to any body of water populated with fish or used for domestic purposes. Do not use in areas where adverse impact on domestic water or aquatic species is likely.

3.3.1 APPLICATION RATES

To control or suppress herbaceous weeds, woody brush and trees, apply 2.0 to 4.0 litres of this product per hectare using aerial, ground boom or boomless, or mist blower equipment, or apply as a 0.7 to 1.3% solution using hand-held high volume equipment. For control of perennial herbaceous weeds in site preparation applications using aerial, ground boom or boomless, or mist blower equipment, apply 4.6 to 7.9 litres of this product per hectare as directed in the recommended volume of clean water to the foliage of actively growing vegetation.

For specific rates for wick or wiper applicators, see the "**Selective Equipment**" section of this label.

3.3.2 AERIAL EQUIPMENT

Apply only by fixed-wing or rotary aircraft equipment which has been functionally and operationally calibrated for the atmospheric condition of the area and the application rates and conditions of this label. Label rates, condition and precautions are product specific. Read and understand the entire label before opening this product. Apply only at rate(s) recommended for aerial application on this label in 20 to 100 L of water per hectare. For control of perennial weeds in site preparation application using 4.6 to 7.9 litres of this product, use 50 to 100L of water per hectare. Where no rate for aerial application appears for the specific use, this product cannot be applied by any type of aerial equipment. As density of vegetation increases, spray volume should be increased within recommended range to ensure complete coverage.

Ensure uniform application -- to avoid streaked, uneven or overlapped application, use appropriate marking devices, or equivalent electronic positioning systems (GPS).

Thoroughly wash aircraft, especially landing gear, after each day of spraying to remove residues of this product accumulated during spraying or from spills. PROLONGED EXPOSURE OF THIS PRODUCT TO UNCOATED STEEL SURFACES MAY RESULT IN CORROSION AND POSSIBLE FAILURE OF THE PART. LANDING GEAR IS MOST SUSCEPTIBLE. The maintenance of an organic coating (paint) which meets aerospace specification MIL-C-38412 may prevent corrosion.

Use Precautions
Apply only when meteorological conditions at the treatment site allow for complete and even crop coverage. Do not apply to any body of water. Avoid drifting of spray onto any body of water or other non-target areas. Specified buffer zones should be observed.

Coarse sprays are less likely to drift; therefore do not use nozzles or nozzle configurations which dispense spray as fine spray droplets. Do not angle nozzles forward into the airstream and do not increase spray volume by increasing nozzle pressure. Do not spray during period of dead calm or when wind velocity and direction pose a risk of spray drift. Do not spray when wind is blowing towards nearby sensitive crop, garden, terrestrial habitat (such as a shelter belt).

Applicator Precautions
Do not allow the pilot to mix chemical to be loaded onto the aircraft. Loading of premixed chemicals with closed system is permitted.

It is desirable that the pilot has communication capabilities at each treatment site at the time of application.

The field crew and mixer/loader must wear chemical resistant gloves, coverall and goggles of face shield during mixing/loading, cleanup and repair. Follow more stringent label precautions in cases where the operator precautions exceed the generic label recommendations on existing ground boom label.

All personnel on the job must wash hands and face thoroughly before eating or drinking. Protective clothing, aircraft cockpit and vehicle cabs must be decontaminated regularly.

3.3.3 BOOM EQUIPMENT

For control of herbaceous weeds and woody brush and trees listed in the "**Vegetation Controlled**" section of this label using conventional boom equipment--Apply this product in 100 to 300 L of clean water per hectare as a broadcast spray using no more pressure than 275 kPa.

3.3.4 BOOMLESS EQUIPMENT

For control of herbaceous weeds, woody brush and trees listed in the "**Vegetation Controlled**" section of this label using boomless equipment such as cluster nozzles--Apply this product in 100-350 L of clean water per hectare as a broadcast spray using no more pressure than 275 kPa.

3.3.5 HAND HELD AND HIGH VOLUME EQUIPMENT (use coarse sprays only)

For control of herbaceous weeds, woody brush and trees listed in the "**Vegetation Controlled**" section of this label using knapsack sprayers or high volume spraying equipment utilizing handguns or other suitable nozzle arrangements.

Applications should be made on a spray-to-wet basis. Spray coverage should be uniform and complete. Do not spray to point of runoff.

3.3.6 MIST BLOWER EQUIPMENT

For control of herbaceous weeds, woody brush and trees listed in the "**Vegetation Controlled**" section of this label--Use the recommended rate of this product in at least 200 L of water per hectare.

4.0 VEGETATION CONTROLLED

A PARTIAL LIST OF PERENNIAL HERBACEOUS WEEDS, WOODY BRUSH AND TREE SPECIES CONTROLLED INCLUDES:

4.1 PERENNIAL GRASSES / SEDGES

Blue Grass (Canada)
Poa compressa
Blue Grass (Kentucky)
Poa pratensis
Brome Grass (smooth)
Bromus inermis
Cattail (common)
Typha latifolia

Foxtail Barley
Hordeum jubatum
Quackgrass
Agropyron repens
Yellow Nutsedge
Cyperus esculentus

4.2 PERENNIEL BROADLEAVED WEEDS

Alfalfa
Medicago spp.
Cottontop
Eriophorum chamissionis
Curled Dock
Rumex crispus
Dandelion
Taraxacum officinale
Field Bindweed
Convolvulus arvensis
Hemp Dogbane
Apocynum cannabinum
Hoary Cress
Cardaria draba
Knotweed (Japanese)
Polygonum cuspidatum
Milkweed (common)
Asclepias syriaca
Poison Ivy
Rhus radicans
Purple Loosestrife
Lythrum salicaria
SowThistle (peren.)
Sonchus arvensis
Thistle (Canada)
Cirsium arvense
Toad Flax
Linaria vulgaris
Wormwood (Absin.)
Artemisia absinthium

4.3 WOODY BRUSH AND TREES

Alder
Alnus spp.
Birch
Betula spp.
Broadleaved meadowsweet*
Spiraea latifolia
Canadian rhododendron*
Rhododendron canadenses
Cedar
Thuja spp.
Cherry
Prunus spp.
Douglas Fir
Pseudotsuga spp.
Ericaceous species***
Ericaceae spp.
Hemlock
Tsuga spp.
Maple
Acer spp.
Mountain-fly honeysuckle*
Lornica villosa
Pine
Pinus spp.
Poplar
Populus spp.
Raspberry/Salmonberry
Rubus spp.
Sheep laurel*
Kalmia angustifolia
Snowberry (Western)
Symphoricarpos occidentalis
Sweet fern*
Comptonia peregrina
Willow**
Salix spp.
Withrod*
Viburnum cassinoides

* Apply as a 0.7 to 1.3% solution.
** Suppression only.
*** Used in conjunction with an additional silicon-based surfactant (such as Sylgard 309®).

Sylgard 309 is a registered trademark of Dow AgroSciences.

See "**Mixing & Application Instructions**" and "**Forest-**" or "**Woodland- Management**" sections of this label for additional information.

For perennial broadleaf weeds, apply when most weeds have reached early head or early bud stage of growth. For annual and perennial grasses, apply when most weeds are at least 20 cm in height (the 3-4 leaf stage of growth).

If herbaceous weeds have been mowed, tilled, or scarified, do not treat until regrowth has reached the recommended stages, as reduced effectiveness will result. Most herbaceous weeds can be treated after a mild frost, provided the leaves are still green and actively growing at the time of application. Do not apply after the first damaging frost. Allow 7 or more days after application before tillage or other soil disturbance. Repeat treatments may be necessary to control weeds regenerating from underground parts or seed.

5.0 DIRECTIONS FOR USE

Spray coverage should be uniform and complete. Do not spray to the point of runoff.
Do not allow spray drift to contact non-target desirable vegetation as severe damage may occur.

5.1 RESTRICTED USES - FOREST and WOODLANDS MANAGEMENT

Ground/Aerial Application for Sites greater than 500 ha (Forestry Use)

Aerial Application for Sites 500 ha or less
(Woodlands Use)

NOTICE TO USER: This control product is to be used only in accordance with the directions on this label. It is an offence under the *Pest Control Products Act* to use a control product under unsafe conditions.

NATURE OF RESTRICTION: This product is to be used only in the manner authorized; consult local pesticide regulatory authorities about use permits which may be required.

Do not apply to any body of water populated with fish or used for domestic purposes. Do not use in areas where adverse impact on domestic water or aquatic species is likely.

In order to reduce the drift hazard to non-target plants and aquatic species when aerially treating silvicultural sites, ensure that appropriate buffer zones are maintained.

5.1.1 SITE PREPARATION

Use this product as broadcast treatment at recommended rates, as listed in the "**Application Rates**" section, to control herbaceous weeds, woody brush and tree species listed in the "**Vegetation Controlled**" section. Apply when brush and tree species are actively growing and when foliage is full and well-developed. For best results apply in late summer or early fall. Some autumn colours on undesirable deciduous species are acceptable provided no major leaf fall has occurred. Following site preparation application of this product, any silvicultural species may be planted.

For control of vegetation on sites with infestation of ericaceous species (e.g. *Kalmia spp.* – sheep laurel, lamb kill), use 4.0 L/ha VisionMax Silviculture Herbicide and an additional silicon based surfactant (such as Sylgard 309) as per label instructions. Apply between mid-August and mid-September for maximum performance.

5.1.2 CONIFER RELEASE

Use this product as a broadcast spray at recommended rates, as listed in the "**Application Rates**" section, to control herbaceous weeds, woody brush and tree species, as listed in "**Vegetation Controlled**" section of this label, to release from competition the coniferous species listed below:

Douglas Fir *Pseudotsuga spp.*	**Pine** *Pinus spp.*
Fir *Abies spp.*	**Spruce** *Picea spp.*
Hemlock *Tsuga spp.*	

For conifer release of spruce seedlings in the year of transplanting, apply 1.3 to 4.0 litres of this product per hectare in plantations of summer planted spruce species (*Picea glauca*, *P. Engelmanii* and their hybrids). Conifers must be planted in the same year as treatment and in the field for at least 18 days prior to treatment. Seedlings to be treated must clearly show bud set and bud hardening following a dormancy induction regime in the nursery. The need for such early release treatments is expected on sites which are subject to the rapid development of herbaceous and shrub communities.

Most annual and perennial weeds will be controlled or suppressed. Applications must be made after formation of final conifer resting buds. Applications made during period of active conifer growth may result in conifer injury. Avoid application during Lammas or late season conifer growth. Some autumn colours are acceptable provided no major leaf fall has occurred on undesirable brush and tree species.

For conifer release, apply where conifers have been established for more than a year. Vegetation should not be disturbed immediately prior to treatment or until visual signs appear after treatment. Symptoms of treatment are slow to appear, especially in woody species treated in late fall. Injury may occur to conifers treated for release, especially where spray patterns overlap or the higher rates are applied or when applications are made during periods of active conifer growth.

NOTE : This product is not recommended for use as an over-the-top broadcast spray in forest tree nurseries or in Christmas tree plantations. Applications in such sites should be limited to directed sprays (see "**Conifer Release by Directed Spraying**" section). DO NOT TREAT Christmas tree plantations in the year of anticipated harvest.

5.2 WOODLANDS MANAGEMENT

Treatment of 500 ha or less

SITE PREPARATION (Ground Only), FOREST ROADSIDE (Ground Only) and RIGHTS-OF-WAY VEGETATION MANAGEMENT (Ground or Aerial)

Use this product as a broadcast treatment at recommended rates, as listed in the "**Application Rates**" section, to control herbaceous weeds, woody brush and tree species listed in the "**Vegetation Controlled**" section. For control of herbaceous weeds, apply when most perennial broadleaf weeds have reached the early head or early bud stage of growth. For perennial grasses, apply when most weeds are 20 cm in height. Apply when brush and tree species are actively growing and when foliage is full and well-developed. For best results apply in late summer or early fall. Some autumn colours on undesirable deciduous species are acceptable provided no major leaf fall has occurred. Following site preparation application of this product, any silvicultural species may be planted.

For control of vegetation on sites with infestation of ericaceous species (e.g. *Kalmia spp.* – sheep laurel, lamb kill), use 4.0 L/ha VisionMax Silviculture Herbicide and an additional silicon based surfactant (such as Sylgard 309) as per label instructions. Apply between mid-August and mid-September for maximum performance.

5.2.1 CONIFER RELEASE (Ground Only)

Use this product as a broadcast spray at recommended rates, as listed in the "**Application Rates**" section, to control herbaceous weeds, woody brush and tree species, as listed in "**Vegetation Controlled**" section of this label, to release from competition the coniferous species listed below:

Douglas Fir *Pseudotsuga spp.*	**Pine** *Pinus spp.*
Fir *Abies spp.*	**Spruce** *Picea spp.*
Hemlock *Tsuga spp.*	

For conifer release of spruce seedlings in the year of transplanting, apply 1.3 to 4.0 litres of this product per hectare in plantations of summer planted spruce species (*Picea glauca*, *P.*

Engelmanii and their hybrids). Conifers must be planted in the same year as treatment and in the field for at least 18 days prior to treatment. Seedlings to be treated must clearly show bud set and bud hardening following a dormancy induction regime in the nursery. The need for such early release treatments is expected on sites which are subject to the rapid development of herbaceous and shrub communities.

Most annual and perennial weeds will be controlled or suppressed. Applications must be made after formation of final conifer resting buds. Applications made during period of active conifer growth may result in conifer injury. Avoid application during Lammas or late season conifer growth. Some autumn colours are acceptable provided no major leaf fall has occurred on undesirable brush and tree species.

For conifer release, apply where conifers have been established for more than a year. Vegetation should not be disturbed immediately prior to treatment or until visual signs appear after treatment. Symptoms of treatment are slow to appear, especially in woody species treated in late fall. Injury may occur to conifers treated for release, especially where spray patterns overlap or the higher rates are applied or when applications are made during periods of active conifer growth.

NOTE : This product is not recommended for use as an over-the-top broadcast spray in forest tree nurseries or in Christmas tree plantations. Applications in such sites should be limited to directed sprays (see "**Conifer Release by Directed Spraying**" section). DO NOT TREAT Christmas tree plantations in the year of anticipated harvest.

5.2.2 CONIFER RELEASE BY DIRECTED SPRAYING

Use this product to control herbaceous and woody species as listed in the "**Vegetation Controlled**" section of the label.

Apply when the undesirable species are actively growing and the foliage is full and well developed. This product does not provide pre-emergent weed control. Repeat treatments may be necessary to control weeds that generate from underground parts or seed.

Undesirable deciduous species may be treated when they already have autumn colours, provided there has been no major leaf fall. For perennial broadleaf species, apply when most weeds have reached early head or early bud stage of growth. For annual and perennial grasses, apply when most weeds are 20 cm in height (3-4 leaf stage of growth).

Direct spray so that the foliage of undesired vegetation is thoroughly wetted. Do not spray foliage to the point of run-off. Applying the product to conifers during their period of active growth (before lignification) may cause tree injury. Under such conditions, take the necessary precautions to ensure that spray, mist or spray drift does not come into contact with the foliage or green bark of conifers being cultivated.

The product may be applied on sites regenerated by the following species (partial list): SPRUCE (*Picea spp.*), PINE (*Pinus spp.*), HEMLOCK (*Tsuga spp.*), DOUGLAS FIR

(*Pseudotsuga spp*.). No time interval is required between tree planting and application of the product. For specific rates and application instructions, see the "**Mixing Instructions**", "**Application Instructions**" and "**Vegetation Controlled**" sections of the product label.

Do not allow spray to come in contact with foliage, green stems or fruit of non-target crops, since they may be killed or severely damaged.

5.2.3 DECIDUOUS RELEASE (Ground Only)

Use this product to control herbaceous weeds and woody brush mentioned in the "**Vegetation Controlled**" section of the label.

Apply when the undesirable species are actively growing, and the foliage is well developed. This product has no pre-emergent activity. Repeat treatments may be required for species which regenerate from underground stems or from seeds. Applications may be made to undesirable deciduous species with some autumn colours, provided that major leaf fall has not yet occurred.

Use a directed spray to thoroughly cover the foliage of the undesirable vegetation. Take all necessary precautions to prevent contact of the spray, spray mist or spray drift with the foliage or green bark of desirable species.

A partial list of species for use with this product on regenerated sites includes: ASH (*Fraxinus spp*.); WALNUT (*Juglans spp*); LINDEN or BASSWOOD (*Tilia spp*); CHERRY (*Prunus spp*.); OAK (*Quercus spp*); ELM (*Ulmus spp*) and POPLAR (*Populus spp*). Product may be applied immediately after transplanting.

For use rates and application instructions, refer to the "**Application Rates**" and "**Application Instructions**" sections of this label.

5.2.4 INJECTION APPLICATIONS

Woody vegetation may be controlled by injection application of this product. Apply using suitable equipment, which must penetrate into living tissue, at a rate of at least 0.33 mL (either undiluted or 1: 1 with water) per 5cm tree diameter at breast height (DBH). The cuts should be spaced evenly around the tree and below all major branches. Application may be made at any time of year, except when cold temperatures prevent adequate penetration of injection equipment, or in the spring during periods of heavy sap flow. Control of tree species with tree diameters greater than 20 cm may not be acceptable at this rate.

Total control may not be evident for 1-2 years following treatment.

A partial list of species controlled includes:

Alder *Alnus spp.*	**Maple*** *Acer spp.*

Birch	**Pine**
Betula spp.	*Pinus spp.*
Cedar	**Poplar**
Thuja spp.	*Populus spp.*
Cherry	**Willow**
Prunus spp.	*Salix spp.*
Douglas-fir	**Hemlock**
Pseudotsuga spp.	*Tsuga spp.*

* This treatment may only provide suppression of Big-Leaf Maple. Late fall applications will provide optimum suppression of Big-Leaf Maple

5.2.5 CUT STUMP APPLICATION

Woody vegetation may be controlled by the application of this product to freshly cut stumps to prevent regrowth. Because the treatment uses a concentrated solution, application must be made using low-pressure equipment e.g. squirt bottle or similar device. This product must be applied immediately to the surface of the freshly cut stump i.e. within 5 minutes, for optimum control at the prescribed rates. Only the cambial tissues of the cut surface should be treated. Apply the herbicide solution at a rate equivalent to at least 0.33 mL VisionMax Silviculture Herbicide for every 5cm of DBH. Do not cover the remaining area nor any exposed roots, as this product does not penetrate bark well. This treatment may be used at any time of year, except during periods of heavy sap flow or when low temperatures prevent solution application due to freezing. A water soluble colorant may be added to the solution as a means of indicating which surfaces have been treated. Total control may not be evident until 1-2 years after treatment.

See the INJECTION APPLICATIONS section of this label for a partial list of species controlled.

5.2.6 FOREST TREE PLANTING NURSERIES (Ground Only)

This product may be used to control most annual and perennial weeds for site preparation prior to establishing plantations, or as a post directed spray in established plantations. Application may be made to established deciduous plantings of ASH, *Fraxinus spp*.; CARAGANA, *Caragan spp*.; CHERRY, *Prunus spp*.; ELM, *Ulmus spp*.; LILAC, *Syringa spp*.; MAPLE, *Acer spp*.; MOUNTAIN ASH, *Sorbus spp*.; POPLAR, *Poplulus spp*.; RUSSIAN OLIVE, *Elaeagnus spp*.; and WILLOW, *Salix spp.* Applications may be made prior to or in established conifer plantings of FIR, *Abies spp*.; JUNIPER, *Juniperus spp*.; PINE, *Pinus spp*.; SPRUCE, *Picea spp*.; and YEW, *Taxus spp*.. SPRAY MAY CONTACT MATURE BARK ONLY. AVOID SPRAY CONTACT WITH FOLIAGE OR GREEN BARK OF ESTABLISHED PLANTINGS IN POST DIRECTED APPLICATIONS.

For specific rates and applications instructions, see "**Application Instructions**" section of this booklet. DO NOT APPLY UNDER WIND OR OTHER CONDITIONS WHICH

ALLOW DRIFT TO OCCUR. If weeds have been mowed or tilled do not treat until regrowth has reached the recommended stages.

This product does not provide pre-emergence weed control. Repeat treatments may be necessary to control weeds generating from underground parts or seed.

NOTE: This product is not recommended for use as an over-the-top broadcast spray in forest tree nurseries or in Christmas tree plantations. Applications in such sites should be limited to directed sprays (see "**Conifer Release by Directed Spraying**" section). DO NOT TREAT Christmas tree plantations in the year of anticipated harvest.

5.2.7 SELECTIVE EQUIPMENT - WIPER APPLICATORS

This product may be applied with a wiper applicator, after dilution and thorough mixing with water, to listed weeds in the "**Vegetation Controlled**" section of this label. It may be used in any forestry site specified in this label.

A wiper applicator applies the herbicide solution onto weeds by rubbing the weed with an absorbent material containing the herbicide solution. Equipment must be designed, maintained and operated to prevent the herbicide solution from contacting desirable vegetation, except in cases of conifer release operations where conifers are well hardened off (see "**Conifer Release Section**"); in these cases, a slight contact between the wiper and the conifer may be acceptable. Performance may be improved by reducing speed in areas of heavy infestations to insure adequate wiper saturation. Best results may be obtained if 2 applications are made in opposite directions.

AVOID CONTACT WITH DESIRABLE VEGETATION. Contact of the herbicide solution with desirable vegetation may result in damage or destruction. Applicators used above desired vegetation should be adjusted so that wiper contact point is at least 5 cm above the desirable vegetation. Droplets or foam of the herbicide solution settling on desirable vegetation may result in discoloration, stunting or destruction.

Applications should be made when the weeds are a minimum of 15 cm above the desirable vegetation. Best results may be obtained when more of the weed is exposed to the herbicide solution. Weeds not contacted by the herbicide solution will not be affected. This may occur in dense clumps, severe infestations, or when the height of the weeds varies so that not all weeds are contacted. In these instances, repeat treatments may be necessary.

NOTES

- Maintain equipment in good operating condition. Avoid leakage or dripping onto desirable vegetation.

- Adjust height of applicator to insure proper contact with weeds.

- Keep wiping surfaces clean.

- Keep wiper material at proper degree of saturation with herbicide solution.

- DO NOT use wiper equipment when weeds are wet.

- DO NOT operate equipment at ground speeds below 4 and greater than 10 km/h. Weed control may be affected by speed of application equipment. As weed density increases, reduce equipment ground speed to insure good coverage of weeds.

- Be aware that on sloping ground the herbicide solution may migrate, causing dripping on the lower end and drying on the upper end of the wiper applicator.

- Variation in equipment design may affect weed control. With wiper applicators, the wiping material and its orientation must allow delivery of sufficient quantities of the recommended herbicide solution directly to the weed.

- Care must be taken with all types of wipers to insure that the absorbent material does not become over-saturated, causing the herbicide to drip onto desirable vegetation.

- With all equipment, drain and clean wiper parts immediately after using this product, by thoroughly flushing with water.

For Wick or other Wiper Applicators--Mix 0.67 litre of this product in 2 litres of water to prepare a 25% solution.