Woody weed control using bark application methods

Guideline

Contents

I. Purpose

The purpose of this document is to provide guidelines for applying a low volume of herbicide for ground-based and aerial basal bark control operations on woody weeds. It provides information to help DOC staff and others to plan and undertake successful basal bark control operations on woody weeds, provides useful information on health and safety issues and personal protective equipment requirements, information on the chemicals and carriers and the effect of these on the environment

This guideline should be followed to achieve the best results and to protect operators who use the basal bark herbicide application methods.

If you have any suggestions for improvements, please contact Peter Raal, Technical Advisor - Threats, Science and Capability Group. Email: praal@doc.govt.nz; 03 474 6945.

II. About this document

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Amendments

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1. Introduction

Control of woody weeds in New Zealand is based on two activities, physical and chemical control methods. Although effective, physical control can be used only where trees are accessible, however these methods are labour-intensive.

When they work, chemical control methods are more cost effective and less labour-intensive than physical control methods. In situations where trees are inaccessible, chemical control is the only solution.

An important aspect of biodiversity protection requires the killing of invasive plant species to favour the growth of desirable species. For woody weeds, this is best achieved by killing them in place using herbicides that do not affect the surrounding vegetation. This allows annual and perennial grasses and other desired plants to thrive because they are freed from competition for moisture, nutrients and sunlight.

The low-volume ground-based basal bark, cut stump, winter shoot treatment and frilling, and aerial bark application (ABA) methods are designed to control sparse, isolated and/or scattered woody weeds chemically and to favour the surrounding vegetation. These methodologies provide a mechanism whereby these trees can be relatively quickly and cost-effectively controlled. Ground-based and aerial bark applications provide effective, highly selective control of trees, shrubs and vines for conservation purposes, farming operations and forestry uses such as conifer release or thinning.

This guideline identifies:

- The concept of the basal bark methodologies
- The basal bark technical details including the different herbicide mixtures, products and methods that can be used
- Health and safety issues
- Equipment maintenance and
- References.

2. The concept

A bark treatment consists of applying low volumes of an herbicide mixture to the base of the trunk (ground-based basal bark or cut stump), winter shoots, frills or higher up the trunk (ABA) of an unwanted woody weed (individual stem), rootstock (multiple stems) or cut stump. The herbicide mixture usually consists of an ester (oil-based) herbicide and an oil carrier. The oil carrier moves the herbicide through the bark into the cambium and conductive vascular tissue for translocation throughout the plant.

The vascular system of plants runs vertically, which means that nutrients and other substances cannot be moved sideways. Therefore, the complete control of a woody weed depends on the stem being entirely encircled with the herbicide mixture so that it is translocated to all parts of the plant. The encircling of the entire stem with herbicide is termed ‘wrap’

Young bark is lipophilic (having an affinity for oil), meaning its structure acts like an open lattice, and allows fatty substances to move readily within it. That is why ester herbicides mixed with an oil carrier are able to move through and within young bark tissue. Basal bark treatments work best on young, tender bark (Dow AgroSciences fact sheet, undated). Optimal results are achieved when applications are made to young, vigorously growing stems which have not developed the thicker bark characteristic of slower-growing older trees, i.e. small stems are more easily controlled than larger, older stems.

Triclopyr butoxyethyl ester (Triclopyr BEE) is a pyridine carboxylic-acid-based herbicide (Group 03) which has the disrupters of plant cell growth mode of action.

3. Herbicide details

A treatment method for woody weeds that favours the protection of surrounding vegetation consists of the use of low-volume basal bark, cut stump, winter shoot, frilling or aerial bark applications of Triclopyr BEE in a non-aqueous organic oil carrier. These particular methods are highly attractive because they provide highly efficient and effective woody weed control, and also the highly specific placement of the herbicidal mixture onto the trunks and/or branches of target species, which effectively eliminates non-target damage and minimises contamination of the surrounding environment.

- For most woody trees, shrubs and vines use a 20% basal bark mixture comprising 200 mL of a 600 g/L triclopyr BEE herbicide (see Section 3.1) in 800 mL of oil carrier. This gives 120 g of active ingredient per 1 L of herbicide mixture. This is often referred to as a 20% volume to volume (v/v) solution.
- For difficult-to-control species (Table 1), use a 30% solution (300 mL triclopyr BEE herbicide in 700 mL oil). This gives 180 g of active ingredient per litre of herbicide mixture.
- After purchasing or making up an herbicide mixture of oil and triclopyr BEE, be sure to mix it well by vigorously shaking the container before use. If you stop for a break, shake the knapsack again before you resume your work just to make sure that the herbicide has not separated out from the oil.
- When stored appropriately, and as long as the container is properly sealed, the shelf-life and efficacy of Triclopyr BEE in oil is almost indefinite.
- Water or water-based products such as dye, for example, must not be added to the mix. This is because an invert emulsion will be formed which will clog up your knapsack. If you want/need to mark the trees you have treated, spray them with spray paint or add oil-based white enamel paint to the herbicide mixture (250 mL per 5 L of mixture). These methods work well and help you keep track of where you have been.

- All basal bark herbicide mixtures must be applied in accordance with the New Zealand Standard for the Management of Agrichemicals (NZS8409).
- Some naturally occurring individual woody weeds may be resistant to this herbicide. In these cases, alternate herbicides need to be used to kill the weeds.

Table 1: Woody weed species known to be effectively treated with the basal bark herbicide mixture.

Common name	**Species**	**Basal bark solution**	**Comments**
Alder	*Alnus* species	20%	
Ash	*Fraxinus* species	30%	Retreatment may be necessary
Barberry	*Berberis* species	20%	
Birch	*Betula* species	20%	
Blackberry	*Rubus fruticosus*	20%	
Black locust	*Robinia pseudoacacia*	30%	Retreatment of surviving stems and root suckers may be necessary
Boxthorn	*Lycium ferocissimum*	30%	Retreatment of surviving stems may be necessary
Brazilian pepper	*Schinus* species	20%	
Briar	*Rosa* species	20%	
Brush cherry	*Syzygium australe*	20%	
Buckthorn	*Rhamnus species*	20%	
Buddleia	*Buddleja davidii*	20%	
Cherry family	*Prunus* species	20%	
Climbing spindle berry	*Celastrus orbiculatus*	20%	Treat all the stems and exposed roots at ground level. Retreatment of surviving stems may be necessary
Cotoneaster	*Cotoneaster* species	20%	Retreatment of surviving stems may be necessary
Douglas fir	*Pseudotsuga menziesii*	20%	
Elder	*Sambucus nigra*	20%	
Elm	*Ulmus* species	20%	
European olive	*Olea europaeus*	20%	
Gorse	*Ulex europaeus*	20%	

Gum	*Eucalyptus* species	20%	
Hakea	*Hakea* species	20%	
Hawthorn	*Crataegus monogyna*	30%	
Heather	*Calluna vulgaris*	20%	
Holly	*Ilex aquifolium*	20%	
Ivy	*Hedera helix*	20%	Retreatment of surviving vines may be necessary
Kudzu	*Pueraria lobata*	20%	Retreatment of surviving vines may be necessary
Lantana	*Lantana camara*	20%	
Larch	*Larix decidua*	20%	
Montpellier broom	*Teline monspessulana*	20%	
Oak	*Quercus* species	20%	
Old Man's Beard and other Clematis species	*Clematis vitalba* and other *Clematis* species	20%	Treat all the stems and exposed roots to ground level
Pine	*Pinus* species	20%	Pinus mugo can take up to 4 years to die
Poplar	*Populus* species	20%	
Privet	*Ligustrum* species	30%	
Rhododendron	*Rhododendron ponticum*	30%	Effective on shrubs up to 2m tall. Shrubs >2m tall should be cut down followed by cut stump treatment. Treat any regrowth the following summer. Cut stems should be removed because they can layer.
Rowan	*Sorbus aucuparia*	20%	
Scotch broom	*Cytisus scoparius*	20%	
Spanish heath	*Erica lusitanica*	20%	
Spindle tree	*Euonymus* species	20%	
Sycamore	*Acer pseudoplanatus*	20%	
Tree Lucerne	*Chamaecytisus palmensis*	30%	
Tutsan	*Hypericum androsaemum*	20%	

Wattle	*Acacia* and *Paraserianthes* species	20%	
Willow	*Salix* species	20%	
Woolly nightshade	*Solanum mauritianum*	20%	
Yucca	*Yucca* species	20%	

3.1 X-Tree Basal: pre-mixture of Triclopyr BEE herbicide in oil

- X-Tree Basal is a 20% pre-mixed triclopyr BEE and oil product which uses biodiesel and a special penetrant as the oil carrier. X-Tree Basal is marketed by ETEC Crop Solutions; contact Peter de Jong; Tel: 03 547 3303; 021 790 775; pdejong@etec.co.nz, www.etec.co.nz/products/107.html
- To increase the concentration of X-Tree Basal to 30% for the harder-to-kill species, 100 mL of 600 g/L Triclopyr BEE needs to be added to 900mL of X-Tree Basal.
- It is recommended that staff use X-Tree Basal as it removes the need for operators to mix the herbicide and oils, which can be messy.

3.2 Triclopyr BEE herbicide

- Field trials to date have predominantly used Grazon® (600 g/L active ingredient) manufactured by Dow AgroSciences, which is recommended for staff making up their own herbicide mixtures.
- Other generic forms of 600 g/L Triclopyr BEE could be considered for use; check the Novachem Agrichemical Manual or the AVCM Register website for alternative trade names.
- DOC staff need to adhere to DOCs national procurement procedures for the purchase of the herbicide component.

4. Method details

Which method?

Basal bark herbicide treatments are most useful where the target tree or shrub density is moderate to low, where manual labour and/or a helicopter is available and where small dead standing trees and shrubs can be tolerated (except for the cut stump method when the trees are felled). These methods can be used selectively with little to no damage to surrounding vegetation. Basal bark treatment is not recommended where there are thousands of stems per acre to treat (boom spraying is a better option). Additionally, basal bark treatments cannot be used where spraying into water is inevitable.

Table 2: Summary of method use

Ground based basal bark	The herbicide penetrates thinner bark best and it is found that trees up to 20 cm in diameter can be effectively treated using this mixture. For larger trees which have thicker bark, treat the stem up to 2 m from the ground. If correctly applied, you should get a greater than 95% kill. Although much quicker and more efficient than cutting and pasting, frilling or drilling and filling, basal bark treatments are still labour-intensive because each and every trunk needs to be treated.
Cut stump herbicide	Where aesthetics is an issue and dead standing trees cannot be tolerated, the trees can be cut down and the herbicide mixture applied to the cut stump.
Winter shoot spray	Certain deciduous species including buckthorn, ash and hawthorn are more susceptible to shoot spraying in the winter than the spring (Table 2).
Frill girdling	Traditionally used on trees which have a trunk greater than 30 cm in diameter and where the ground based basal bark method is known not to work. This method can be considered for use where it is acceptable to leave large trees standing after they die.
Aerial bark application	The technique is effective on all woody weeds of all sizes. It is, however, more effective on trees less than 10 m tall. Because of the length of time it may take to walk from tree to tree and/or the potential dangers to operators from traversing difficult terrain, highly scattered and/or inaccessible woody weeds should be treated using the ABA method where dead standing trees and shrubs can be tolerated.

What time of year is best?

Basal bark herbicide treatments can be done any time of the year with most invasive trees, large woody vines and shrubs. While late summer through autumn is often best, late autumn is often the easiest time from an operational standpoint, especially with deciduous trees. At this time temperatures are cooler (i.e. less chance of volatilisation) and herbaceous vegetation is dormant.

The only time basal bark treatments should not be applied is when trees are experiencing strong upward sap flow in the early spring. This upward sap flow may reduce herbicide translocation to the roots and result in poor control. Additionally, do not cut treated trees for at least six months as herbicide absorption and translocation may be very slow in some species.

4.1 Ground-based basal bark method

Basal bark herbicide treatments are most useful where the target trees or shrubs are accessible, their density is moderate to low, where manual labour is available, and where small dead standing trees and shrubs can be tolerated. Basal bark treatment is not recommended where there are thousands of stems per hectare to treat and boom spraying would be more appropriate.

- Use an adjustable cone nozzle or a narrow angle flat fan spray tip (see Section 4.1 Equipment) at **very low pressure** (one or two pumps of the knapsack) to prevent spatter, over application and herbicide waste (Figure 1).

Figure 1: The correct and wrong ways to apply the basal bark herbicide mixture.

Correct – low knapsack pressure with no spatter

Wrong – high pressure causing spatter

- For best and reliable basal bark results, spray to saturate the entire circumference of the bottom 30–50 cm (up to 2 m for bigger trees) of the trunk, including the root collar area, until the bark is saturated but without runoff onto the ground, using a knapsack (one dedicated for oil use only) and a solid cone or flat fan nozzle. This is best achieved by starting at ground line and moving up with each pass of the wand gradually circling the trunk, with any excess spray occurring at the top of the treated area to then soak in as it runs down the trunk.
- Apply the herbicide mixture to the stems as you would apply spray paint.

- If practical, clear debris away from the base of the tree so that you can treat the trunk all the way down to ground level.
- Spray any exposed roots.
- Complete control of the stems, leaves and roots depends on the stem and any exposed roots being entirely circled and treated with chemical (i.e. 'wrap' must be achieved).
- The nozzles should be held 2–4 cm from the target point on the stem (Figure 2).

Figure 2: Correct application of the basal bark herbicide mixture to a *Pinus contorta* tree using very low pressure and a flat fan spray tip orientated in a vertical position. (Photos: Peter Willemse).

- Apply the herbicide to at least twice the height of the diameter of the tree being treated and use slightly more rather than less herbicide to ensure good kills.
- Treat the greater height of the trunk when the bark is thick and penetration will be difficult.
- As bark thickness increases, more herbicide is needed and efficacy is sometimes reduced.
- With sufficient volume, the herbicide should spread to encircle the entire stem circumference and give 'wrap' within 30 minutes.
- Do not apply herbicide if the bark is wet
- Care must be taken to minimise the amount of spray drift and chemical/oil that runs into the soil which could potentially damage adjacent non-target trees. This is only because there is the possibility of injury to plants whose roots may extend into areas treated with the herbicide.
- Particular care must be taken to ensure that the oil does not get into water in a wetland situation (you may want to apply the solution using a paintbrush in these instances).
- Application can be made at any time of the year, including the winter months when deciduous woody weeds are dormant, except when snow, frost or water prevents spraying to the ground line.
- Although much quicker and more efficient than cutting and pasting, frilling or drilling and filling, basal bark treatments are still labour-intensive because each and every trunk needs to be treated. For this reason it can reasonably be expected that some trees and saplings will be missed during a poisoning operation.

- Follow-up operations should be planned for incompletely killed and/or missed stems, new saplings and root suckers.
- Usually one or two follow-up spot treatments at 6-month intervals will provide a complete kill if the trees are susceptible. Retreatment should include any living parts of a treated trunk(s), exposed roots and re-sprouted stems.
- Do not treat when wind is blowing towards susceptible native species, crops or ornamental plants near enough to be possibly injured. With this method you can treat in windier conditions compared to high pressure spraying or mist blower as you do not create small droplets.
- We believe application in standing conifer crops should be delayed until late summer when extension growth has ceased.
- Treat entire seedlings and small saplings with the herbicide mixture to kill them.
- Do not cut treated trees for at least 6 months as herbicide absorption and translocation may be very slow in some species.
- It is important to make the application during cooler weather or a cooler part of the day (<28°C) to give the herbicide time to be absorbed into the tree and to prevent evaporation (vaporisation) of the oil and herbicide. Vaporisation may lead to poor efficacy.
- Autumn and winter applications provide the best access for treatment of deciduous species due to the lack of foliage.

Equipment

- Basal bark treatments are most easily applied with 5 or 7.5 L very low pressurised knapsack sprayers in a customised backpack (Figure 3), electrically operated knapsack (Figure 4) or hand- or gas-powered drench gun (Figure 5).
- A closed-system herbicide container exchange methodology incorporating leak-proof containers and a series of non-leak, one-way valves to prevent leakage is the best way to prevent operators from being contaminated and to replenish herbicide supplies (see Figures 3 and 4)
- A positive shutoff, non-drip valve to eliminate drips is a definite requirement (Figure 3).
- The knapsack must be operated at the lowest possible pressure sufficient to generate a straight stream ‘braided trickle’ and to prevent spatter (see Figure 1).
- Use a spray gun with a light trigger and a wand of at least 40 cm.
- An advantage of using a smaller knapsack is that it can be transported in a helicopter.
- Use separate, oil-dedicated knapsacks sprayers for basal bark applications to prevent invert emulsion from residual water forming.
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Figure 3: The components of a 7.5 L backpack spraying system for applying a basal bark treatment to invasive trees. Note non-drip valve for spray nozzle. (Photographs: Peter Willemse).


Figure 4: The components of a closed-system, 5 L electrically operated knapsack developed by Marty Grounds of Groundspray Ltd. The photograph on the right shows an example of a closed-system herbicide container used to protect operators from spillage. These knapsack systems are available from Marty Grounds (027 228 6566) for $1500 each. (Photographs: Mark Dean)


- Although narrow angle, flat fan nozzles can be used, the ideal nozzles are Teejet 5500-X3 adjustable solid cone spray nozzles. These nozzles are available from Richards Custom Machinery, Line Road, Methven, New Zealand. (Contact Jeff Richards on 03 302 8756).
- When using an adjustable solid cone spray nozzle, adjust the size of the cone to accommodate the average size of the trunk/stems being treated.
- If a flat fan is used it must be orientated vertically to ensure targeted herbicide mixture application onto the stem and 'wrap'.
- Ensure all rubber seals are replaced with oil resistant Viton®, aflack®, or nitrile® ones.

Results

- Don't expect all species to act the same and to get an instant kill. Treated trees may take up to 2 years to die. Some species may require a follow-up spray, may need to be sprayed with a higher rate or may take a longer period to die.
- It is recommended that treated trees be re-visited after 2 years and those that have not died be re-treated.

- With 7.5 L you can treat about 200 small trees (i.e. about 35 mL of herbicide per tree). It will cost about $150 to make up a 7.5 L mixture of Grazon®/oil mixture which equates to between $0.25 and $0.75 per tree. However, you can expect to kill 4 to 8 times more trees for the same amount of time as traditionally cutting them down.

Limitations

- The spray should not be used if there is 'free water' caused by melting frost, wet snow or rain on the trunks which would cause the herbicide and oil/diesel mixture to emulsify (turns a milky white colour) and run down the trunk without penetrating the bark. Emulsified herbicide runs down the treated stem like water, showing no evidence of 'wrap' and control is unlikely to be complete.
- Know what emulsification is, what it looks like and what it means and **stop spraying when you see it**.
- To check for excessive moisture, press the bark with your thumb. If moisture is visible, the bark is too wet.
- The basal bark herbicide mixture may be repelled by charcoal-coated stems. Previously burnt trees and shrubs should be controlled using another method.
- Basal bark treatments cannot be used where spraying into water is inevitable.
- Some plants may not die if they are treated when they are experiencing strong upward sap flow in the early spring. This upward sap flow may reduce herbicide translocation to the roots and result in poor control.
- The oils and ester herbicide have the potential to volatilise at high temperatures. For this reason, do not spray when temperatures exceed 28°C.
- The use of diesel as a carrier is unsafe from an environmental and human safety perspective.
- Although basal spraying is a very quick, effective and cheap tool to use, it is not the quick fix for every weed in every location. Field conditions and a site evaluation will dictate the most appropriate weed control method to use.
- The basal bark method should not be used in grazed areas supporting lactating dairy animals.

4.2 Cut stump herbicide method

Where aesthetics is an issue and dead standing trees cannot be tolerated, the trees can be cut down and the herbicide mixture applied to the cut stump. The application of the herbicide to the cut stump will kill the root system and prevent the woody weed from re-growing. It also reduces the need for repeated cutting of large diameter stumps of species that sprout from the base or sucker from roots.

The cut stump method works very well for small-diameter shrubs or large, multi-stemmed clones.

- For cut stump treatments, large stems are usually cut with a chain saw or pruning saw; smaller stems can be cut with pruning shears or any method that produces a clean cut.
- Best results are obtained when the stems are cut less than 15 cm above ground (Figure 6).

- Cut stumps so that they are approximately level in order to facilitate uniform coverage of the herbicide mixture.
- Smooth, level stumps, which are free of bark tears, sawdust or other debris, can be most easily and effectively treated.
- Cut stems must be treated with a 20% (easy-to-kill species – see Table 1) or 30% (harder-to-kill species – see Table 1) basal bark herbicide mixture.
- Thoroughly wet the stump, including the cut surfaces, especially the cambium layer just inside the bark and the remaining bark to the ground line, including the root collar (Figures 6 and 7).
- It is important to also spray any exposed roots.
- For stems smaller than 8 cm in diameter, treat the entire stump surface. For larger stems, apply herbicide to the outer 20% of the stump. The cambium area next to the bark is the most vital to wet.
- A pressurised backpack sprayer at **very low pressure** (one or two pumps of the knapsack) or spray bottle should be used to apply the herbicide mixture.
- Stumps cut previously can be treated effectively by spraying the outer edges and sides of the stump. If the stump height is 25 cm or more, the application should be made as a basal bark treatment.

Figure 6: Photographs showing a multi-stemmed woody weed being cut down near ground level (i.e. below 15 cm) with a hand saw and the treated cut surface after using a basal bark herbicide mixture with an oil soluble dye.

- Treatment may be applied throughout the year, except when snow or water prevents spraying to the ground line but the method works best when done late during the growing season.
- Unless they are capable of rooting themselves by layering, in which case they must be removed, the cut stems can be left on the ground to rot.

Figure 7: Photographs showing the technique of applying herbicide mixture to the cut stump of wilding conifers of differing sizes using a modified scrub bar.

Equipment

- Saw, loppers, hand clippers, powered scrub bar, brush cutter or chain saw.
- Apply the herbicide mixture using a knapsack sprayer system (see Section 4.1 Equipment) or a squirt bottle with chemical-resistant seals.

Results

- Treated cut stumps may take up to 1 year (or more) to die.
- Any living plants will need to be retreated to ensure a kill. Usually one or two follow-up spot treatments at 6 month intervals will provide a complete kill if the trees are susceptible. Retreatment should include any living parts of a treated trunk(s), exposed roots and re-sprouted stems.

Limitations

- The same limitations as for basal bark treatment apply (see Section 4.1 Limitations).
- Control may be reduced with treatment during periods of moisture stress such as occur in late summer.
- Some plants may not die if they are treated in spring when they are experiencing strong upward sap flow. This upward sap flow may reduce herbicide translocation to the roots and result in poor control.

4.3 Winter shoot spray method

- Certain deciduous species including buckthorn, ash and hawthorn are more susceptible to shoot spraying in the winter than the spring (Table 3).
- Apply a medium volume of basal bark herbicide mixture by hand-lance/wand from knapsack, vehicle-mounted sprayer or helicopter to thoroughly wet all shoots.

Table 3: Woody weed species that are known to be effectively treated using the winter shoot spray method.

Common name	Species	Basal bark solution	Comments
Alder	*Alnus* species	20%	

Ash	*Fraxinus* species	30%	
Birch	*Betula* species	20%	
Blackberry	*Rubus fruticosus*	20%	
Boxthorn	*Lycium ferocissimum*	30%	
Briar	*Rosa* species	20%	
Broom	*Cytisus scoparius*	20%	
Buckthorn	*Rhamnus* species	20%	
Elder	*Sambucus nigra*	20%	
Elm	*Ulmus* species	20%	
Gorse	*Ulex europaeus*	20%	
Hawthorn	*Crataegus monogyna*	30%	
Maple	*Acer* species	20%	
Oak	*Quercus* species	20%	
Poplar	*Populus* species	20%	
Privet	*Ligustrum* species	30%	
Rhododendron	*Rhododendron* species	30%	More effective on plants less than 2 m high
Rowan	*Sorbus aucuparia*	20%	
Willow	*Salix* species	20%	

Equipment

- If treating from the ground use a knapsack the same as for basal bark (see Section 4.1 Equipment).
- For large infestations, a vehicle-mounted sprayer can be used.
- For isolated trees, use a lance/wand as for ABA (see Section 4.5).

Limitations

- This method should not be used in areas where spray drift may be an issue.
- The method should not be used in windy (>8 knots or 15 kph) conditions.

4.4 Frill girdling

This method can be considered for use where it is acceptable to leave large trees standing after they die.

Frill girdling is traditionally used on trees which have a trunk greater than 30 cm in diameter with thick bark and where the ground-based basal bark method (see Section 4.1) is known not to work.

- Use an axe or hatchet to prepare a frill of downward sloping **overlapping** cuts around the whole circumference of the trunk as near to the ground as possible (Figure 8). It is important not to ring bark the trunk entirely, as this will decrease the uptake of the herbicide into the plant.

Figure 8: Photographs showing examples of frill girdling pine trees.

- Make sure that the cuts penetrate the cambium and into the outer sapwood.
- Using a squirt bottle or a small pressurised spray unit to squirt the herbicide around the full circumference of the trunk just above the frills so that it runs down into the cuts.
- The optimum time to do frilling is late in the growing season.

Equipment

- An axe or hatchet
- A knapsack sprayer the same as for basal bark (see Section 4.1 Equipment) or squirt bottle with chemical-resistant seals.

Limitations

- Large dead standing trees are a major hazard so this method should not be used in areas that are frequented by people.

4.5 Aerial bark application

Because of the length of time it may take to walk from tree to tree and/or the potential dangers to operators from traversing difficult terrain, highly scattered and/or inaccessible woody weeds should be treated using the ABA method where dead standing trees and shrubs can be tolerated

The technique is effective on all woody weeds of all sizes. It is, however, more effective on trees less than 10 m tall.

- **The minimum amount of air disturbance and rotor wash occurs when the helicopter is moving forwards**. Therefore, if possible, trees should be treated upon approach, rather than in the hover.

- Having the **lance/wand aimed straight down or a little towards the back of the helicopter** are the optimum positions to treat a tree and will cause no rotor wash.
- Single leader trees of any size should be treated by squirting the herbicide mixture into the tree and onto the bark of the upper branches and tree trunk in sufficient quantity that it runs down the trunk to the ground (Figure 9).
- Larger trees with many upper branches and thick rough bark require more herbicide to be applied. The principle to be followed is to treat each large branch in the crown as a single tree and to squirt on enough herbicide mixture so that it runs down each branch onto the intersecting trunk and, from there, to the ground.
- For bushy shrubs like Scotch broom, sweet briar and gorse, squirt the herbicide mixture into the crown of the weed to get it onto as many stems and branches as possible.
- The ideal height to treat a woody weed using ABA is to have the lance/wand within 1 m of the top of the tree. This will minimise the chances of spray drift from occurring.
- Care must be taken by the operator **not to overspray the target weed or attempt to get full coverage of the foliage**. This is because any overspray will result in collateral damage on surrounding vegetation, including tussock grasses and native trees and shrubs, which intercept the herbicide.

Figure 9: Photograph showing the squirting of herbicide into a wilding pine tree using the ABA technique (Photograph: Peter Willemse).

- This technique is effective year-round for the selective control of all woody weeds (i.e. it can be applied at any time of the year, including winter months except when the trunks of the trees are wet).
- As an alternative method in winter, the wand/lance can be used for the winter shoot spray method on deciduous species (see Section 4.3).
- In order to minimise the potential occurrence of collateral damage due to possible spray drift, the method should not be used in wind stronger than a moderate breeze (i.e. >8 knots or 15 kph).

- All specimens to be treated must be positively identified as weeds before treatment occurs.
- A note should be recorded against the waypoints of destroyed seeding woody weeds so that these sites can be revisited after 2 years to check for seedlings

Equipment

- Depending on the altitude and local flying conditions, use experienced pilots in a R44 or Hughes 500 helicopter.
- There are pros and cons for and against the use of R44 versus a Hughes 500 (Table 4).

Table 4: Pros and cons of R44 and Hughes 500.

Issue	**R44**	**Hughes 500**
Rotor wash	Greater rotor diameter, meaning less blowback of chemical	Smaller rotor diameter meaning rotor wash is more likely to occur.
Comfort	More comfortable to work with in terms of noise and can be shut down and restarted more easily than a Hughes 500.	Much noisier machine which could make it uncomfortable for the operator.
Power	Limited by altitude and the amount of weight it can carry For many of the high altitude areas that are worked, the R44 does not have enough power to handle the situation which could result in accidents. In many situations, the R44 is not capable of hovering for long enough to be able to properly and thoroughly treat the target trees.	The Hughes 500, has sufficient power and manoeuvrability to work and hover at high altitudes with a relatively heavy load.

- The performance criteria for the Hughes 500 and Raven II R44 are presented in the Appendix
- The decision as to which helicopter type should be used must be based on the conditions in which it will work. The most difficult conditions that the machine will encounter (e.g. altitude and manoeuvrability requirements) must be the key criteria for all decisions made.
- The positioning of the lance/wand operator relative to the pilot in a Hughes 500 is optional (Figure 10). The operator positioned in the rear of the machine on the same side as the pilot allows for the operator to operate the wand with a retractable seat belt and safety harness. The pilot can also see the tree that is being sprayed, which means that less communication between the pilot and crewman is required. The situation where the operator works from the front passenger seat requires constant communication between pilot and crewman because the tree is unsighted by the pilot.

Figure 10: Photographs showing the different positions that the lance/wand operator can occupy in a Hughes 500 for ABA.

Operator in back seat on same side as pilot (Photograph: Ian Cox)

Operator in passenger seat (Photograph: Mark Mawhinney)

- In a R44, the lance/wand operator is always in the front passenger seat.
- The wand material (stainless steel or carbon fibre) is optional and at the discretion of the pilot and/or operator.
- The length of the lance/wand is optional and at the discretion of the pilot and/or operator. Lance/wands from 1.5–4 m long are currently being used. The shape of the lance/wand is optional and at the discretion of the operator. Either straight (most common) or lances/wands with a 45° bend on the end are currently in operation. There are limitations with the 'bent' wand in properly treating trees directly below the helicopter, which is the preferred option.
- The mechanism to secure the lance/wand from striking the main or tail rotors is optional and at the discretion of the pilot. If lanyards or bungee cords are used, they should be checked before each operation to ensure that there is no wear which would require their replacement.
- A holder or clip to secure the wand during transit is recommended but is at the discretion of the pilot. However, holding the wand against the body of the helicopter while in transit appears to be a safe comfortable way of stowing it without the addition of a holder.
- Internal or external pump-driven or electric pumps can be used to deliver the herbicide. The type of pump system used is at the discretion of the pilot.
- The helicopter pump delivering the herbicide to the lance/wand should be operated between 3 (**preferred to minimise misting of the herbicide and the potential incidence of collateral damage**) and 5 bar pressure.
- The herbicide holding tanks should have an internal agitator to constantly mix the herbicide. This will prevent any potential settling out of the active ingredient from the oil.
- The operator must wear a helmet or noise-reduction headset, cotton overalls and eye protection (goggles, eyeglasses or visor). The pilot should also wear eye protection (see Section 6).
- Foam should be put over the headset mouth piece of the operator to reduce wind noise and improve communications.

- The use of naturally derived oils, such as biodiesel, is generally less offensive to the applicator and the environment and does less damage to the Perspex of the helicopter.
- Spare oil-resistant O-rings for the handguns and diaphragms for the nozzles must be carried on the helicopter so that if there is a failure they can be replaced without compromising the operation.
- It is recommended that a GPS/flow meter unit be incorporated as part of the lance/wand. This piece of equipment will keep a waypoint record (i.e. tree location), how much herbicide mixture is used per tree treated and a running total of herbicide mixture used. The GPS waypoints mark and map each individual woody weed treated so that a comprehensive GIS-generated weed control locality map can be produced. The flow rate information can be interpreted to determine the average quantity of herbicide used per tree and how much herbicide mixture was used for the whole operation. An electronic device that has an in-built GPS and a flow rate meter and that is attached directly to the lance/wand is available from Clayson Howell (National Office, VPN 8113; chowell@doc.govt.nz).
- A handheld or helicopter GPS in tracking mode must be used for control operations so that a map showing the sites resurveyed can be produced. These maps will facilitate the planning of future operations.
- The treated woody weed waypoints should be superimposed on the tracking map (see point above) to facilitate the production of a comprehensive weed control locality map.
- Helicopter pilots with Ag GPS capability can import shapefiles of the area to be treated which can be read on their relatively large screens. The use of other GPSs will require that hard copy maps will be required to locate the helicopter.

Limitations

- To avoid potential contamination of water, ABA must not be used on trees occurring within 10 m of a river or wetland area.
- To avoid the possible occurrence of collateral damage due to spray drift, ABA operations should not be undertaken in wind speeds of >8 knots (>15 kph), which is considered to be a moderate breeze.
- Woody weeds occurring within deep fissures or other inaccessible areas will need to be treated from a greater height, which may result in some collateral damage especially if there is a breeze. An evaluation of the impacts that the weed versus the effects of the collateral damage should be undertaken before treatment is done.

5. Equipment maintenance and cleaning

- Basal bark equipment using herbicide in oil should be dedicated to these operations and not be used for any other purposes.
- Unless it is to be used for another purpose, there is no need to clean equipment after use.
- If the equipment is required to be cleaned, first flush it through thoroughly with kerosene, shake and drain.

- Quarter-fill the tank with clean water and add 10 drops or more of hand soap. Shake the soapy water around the sprayer and spray the solution through the nozzle to thoroughly clean the lines and nozzle.
- Rinse well with clean water to remove the detergent.
- Dispose of cleaning kerosene/herbicide mixture and waste water onto a designated disposal area or, if this is unavailable, onto unused land away from desirable plants and water courses.
- To clean paintbrushes and container, spray liberally with degreaser. Hose off thoroughly with water and repeat using detergent (see above).
- Do not use chlorine-based cleaners.

6. Health and safety

6.1 General

Good agricultural practice dictates that the use of an herbicide should consider not only its impact on the target weeds but also how it affects the applicators' health and safety. The basal bark methodologies provide excellent woody weed control whilst at the same time presenting a relatively low hazard to the applicator.

- The hazard classification of basal bark herbicide mixtures is 3.1C, 6.1D, 6.3B, 6.4A, 6.5B, 6.9B, 9.1A, 9.2A and 9.3C
- Any container containing any basal bark herbicide mixture must be appropriately labelled. This is a requirement of the Environmental Protection Agency (EPA).
- The label on any container of basal bark herbicide mixture that is taken out into the field must contain the hazard statements and precautionary information that are listed on the Grazon (or Triclopyr BEE generic) label (Dow AgroSciences 2013). The other information on the Grazon label does not need to be listed.
- If the oil carrier poses any risk to the environment, these risks will need to be listed on the label on any container of basal bark herbicide mixture that is taken out into the field.
- Records of how much basal bark herbicide mixture is used (especially the active ingredient, Triclopyr BEE) must be recorded in the local or contractor daily herbicide use diaries (ground-based work) or by the helicopter pilot (ABA). This is a requirement of the EPA.
- It is preferable to have the oil and active ingredient mixed prior before going to the field.
- Any basal bark herbicide mixture must be under the personal control of an approved handler when: (a) applied in a wide dispersive manner or (b) used by a commercial contractor.

- Records of use, as described in the relevant HSNO regulations and the New Zealand Standard for the Management of Agrichemicals (NZS8409), must be kept if more than 6 L of any basal bark herbicide mixture is applied, or discharged within 24 hours in a place where members of the public may be present.
- Any basal bark herbicide mixture may be harmful if swallowed (especially the oil component) or absorbed through the skin. If swallowed do not induce vomiting. For advice, contact the National Poisons Centre 0800 POISON (0800 764 766) or a doctor immediately.
- To prevent inadvertent ingestion of the herbicide mixture, there should be no smoking, eating or drinking when mixing or applying the agrichemical and no water bottles or food should be carried by any operator.
- Wash hands and face before eating, drinking or using the toilet and after work.
- The herbicide mixture is not particularly harmful when in contact with skin (see Section 7.2) but the oil may de-fat the skin (dissolve the fat near the surface) leaving white patches. If left unattended this could result in dermatitis conditions. Immediate washing with soap (capable of dealing with oil) and water will prevent this condition. All work sites should have good quantities of soap and water immediately available.
- If skin or hair contact occurs, remove contaminated clothing, wash with an appropriate detergent and flush washed skin and hair with running water.
- If splashed in eyes, wash out immediately with running water or an eye-bath using sufficient quantities of saline. All work sites should have an eye bath with a good quantity of saline solution immediately available.
- Any basal bark herbicide mixture may cause organ damage from repeated oral exposure at high doses. Do not eat, drink or smoke while using.
- Remove protective clothing immediately after handling this product and wash as soon as possible.
- A contaminated clothing box should be available to place contaminated items of clothing in at any time but especially at the end of the day. A non-porous plastic box with a lid is ideal for this purpose.
- Should clothing become contaminated due to an incident or spill in the field, then this must be removed and placed inside the contaminated clothing box prior to boarding a vehicle.
- Clothes washing procedures and/or policies should be developed to protect applicators from contamination.
- All operations must have an emergency response kit for use if there is a major spill. The kit must contain as a minimum:
    - a first aid kit suitable for multiple persons
    - a fire extinguisher
    - a minimum of 20 litres fresh water
    - suitable oil dissolving citrus-based cleaner or automotive degreaser
    - disposable nitrile gloves, paper towels, eye wash, and pairs of fleece lined overalls which can be used should a major clothing spill occur and the applicator needs to be undressed.

The kit needs to be able to fit inside a helicopter or vehicle and be self-contained in a clearly identifiable box.

- Apply using properly maintained equipment in accordance with the New Zealand Standard for the Management of Agrichemicals (NZS8409).
- Storage of any basal bark herbicide mixture must be in accordance with the New Zealand Standard for the Management of Agrichemicals (NZS8409).
- All containers of any basal bark herbicide mixture must be stored upright on flat ground with lids firmly tightened. This includes containers used in the field.
- Stores containing more than 100 L of any basal bark herbicide mixture require bunding and are subject to signage. See the EPA Regulations for Emergency Management and Identification and the New Zealand Standard for the Management of Agrichemicals (NZS8409) for further information.
- All operations should have a designated mixing area away from waterways, areas of high biological importance and unexposed sites; and a separate area for eating, briefings etc. (similar as for a 1080 operation).
- The risk of a spill and/or clothing and/or skin contamination is highest when mixing or filling the basal bark herbicide mixture. In order to minimise this risk, a designated person should be assigned the role of being the mixer and to undertake all filling requirements for the applicators.
- Diesel as a carrier oil presents a risk to the applicator. The risks of exposure are greatest when the applicator is mixing the herbicide with the diesel. Diesel is a low-grade petroleum product containing impurities, such as benzene, benzo(a)pyrene, and polycyclic aromatic hydrocarbons, which could pose a potential risk to human health. The transport of diesel in difficult terrain is not safe.
- A spill kit and contaminated clothing bin need to be on site in the mixing area.
- The oil component of any basal bark herbicide mixture is very toxic to aquatic organisms, therefore do not contaminate an aquatic environment with herbicide mixture or empty containers.
- All work areas should be equipped with washing facilities with a suitable de-greaser hand wash (e.g. a citrus-based hand cleaner). Towels (preferably single-use paper) should also be available.
- A basal bark herbicide mixture may be harmful to terrestrial vertebrates, therefore store chemical and empty containers away from animals and birds.
- Do not touch or walk through spilled material. Wear the protective equipment recommended below. Stop leak when safe to do so and dike the area to prevent entry into waterways, and drains. Absorb with material such as sand, soil or sawdust. Collect spilled product and place in sealable container for disposal. Spill residues may be cleaned using water and detergent. Contain and absorb wash water for disposal. Absorb and collect washings and place in the same sealable container for disposal.
- A requirement of Land Transport New Zealand is that a spill kit must be available on site. Two or three 20 L sealable buckets, a spade, a broom, and a brush and pan are minimum requirements.
- Do not carry any basal bark herbicide mixture in a passenger service vehicle.
- Disposal requirements:

    - Non-refillable containers 20 L or less: Triple-rinse empty container with an oil-based product such as kerosene and then wash out with 10 drops or more of a liquid hand soap and water. Crush or puncture and bury in a suitably approved landfill. Do not burn empty containers. Offer for recycling if available.
    - Equipment cleaning or spill residues: Dispose onto ground away from susceptible crops and plants or at an approved landfill. Do not dispose down drains or sewers.
- Any transportation of any basal bark herbicide mixture is to be done in accordance with NZS8049-1999. In this regard, the supervisor needs to be aware of the 'trigger' amount for dangerous goods classification.
- Personal items should not be transported alongside any basal bark herbicide mixture.
- Do not apply any basal bark herbicide mixture in a way that will contact workers or other persons, either directly or through drift.
- Do not allow any basal bark herbicide mixture to contact non-target species. Treat target weeds only.
- Do not use any basal bark herbicide mixture on food crops.
- Do not apply any basal bark herbicide mixture with a mist blower.
- Applicators should always wear the proper personal protective equipment when dealing with the basal bark herbicide mixture:
    - When mixing the chemical, persons should wear safety eyewear (a face shield is best), a long-sleeved cotton shirt, long cotton pants, covered footwear, elbow-length chemical resistant gloves and an impervious apron.
    - Applicators should wear a hat, safety eyewear (safety glasses or wrap around sunglasses), a long-sleeved cotton shirt and long cotton pants or cotton overalls, covered footwear, and chemical resistant gloves made of any oil proof material such as barrier laminate, nitrile rubber, neoprene, or Viton®.
- Care to be taken removing contaminated clothing, especially gloves. A good supply of gloves should be available to replace contaminated ones.
- Waterproof boots, e.g. Gortex® or other waterproof membrane lined leather boots, must be worn at all times. Gumboots are not safe to wear in rough terrain.
- The lower leg should be protected from herbicide contamination by wearing knee-length Gortex® or other waterproof gaiters.
- Contaminated clothing, gloves or gaiters should not be worn whilst travelling in a vehicle.
- Applicators should carry spill and first aid kits for back country. The first aid kits should cater for the use of oils and must contain suitable eye wash.

6.2 Aerial bark application

- The general health and safety measures described in Section 6.1 also pertain to ABA. However, there are a few additional health and safety measures that need to be considered for these operations.
- Helicopter pilots contracted to do ABA work must have their own safety plans for these operations which must be in accordance with OSH, CAA and DOC regulations. Aspects to be addressed include, but are not limited to, chemical transport and use, aviation requirements and vehicle use.
- It is strongly recommended that two operators who alternate roles each time the helicopter refuels be used for each ABA operation. One operator is responsible for ground operations (loading helicopter with herbicide mixture, on-ground logistics, troubleshooting etc.) while the other is responsible for operating the lance/wand during the search and destroy operation. It is considered that the alternating of roles between the operators is essential for safe operating for the following reasons:
    - reduced exposure to the herbicide mixture and helicopter fumes
    - reduced exposure to noise (especially in the Hughes 500)
    - gives the opportunity to replace any contaminated personal protective clothing
    - can communicate any issues regarding equipment failure
    - the appropriate level of concentration required for these difficult operations can be maintained.
- If the option exists for pilots to swap between runs then this should happen too.
- Regardless of whether the swapping of operators and/or pilots is occurring, both pilot and operator are to get out of the machine and stretch, drink etc. at each refuelling/refilling.
- If necessary wash any contaminated body parts (especially the face) and the helicopter windscreen with soap and water.
- A briefing sheet of the intended operation should be provided to the pilot/s prior to any work being undertaken.
- Pilots should only fly to their level of fatigue/comfort and this should be encouraged by the lance/wand operators.
- Good and constant communication between the pilot and the operator is essential. This is to ensure that the operator gets into the correct position (having the wand aimed straight down or a little towards the back are the optimum positions) to treat the tree rather than moving the wand around too much and therefore into the rotor wash which will cause spray drift.
- All communications, especially instructions, should be confirmed by both parties and, if there is a misunderstanding, repeating the instructions before treatment of any tree occurs.
- There must be no reluctance to express concern about any part of the operation and the operation cancelled if necessary (e.g. due to rising winds or poor operator technique).

- The noise level in a Hughes 500 helicopter is very high especially with the doors off. It is strongly recommended that an approved flying helmet and ear plugs or headsets with electronic noise reduction be worn by the wand/lance operator.
- Three obvious potential causes of personal contamination with herbicide mixture doing ABA work are:
    - Not wearing proper personal protective equipment: rubber gloves, full-body, cotton (not disposable plastic) overalls and, most importantly, eye protection (glasses, goggles or visor) must be worn. The pilot should also wear eye protection.
    - O-ring failure in the handgun: this can be minimised by replacing daily or, if a long day's work is anticipated, replacing twice.
    - Rotor wash: is the most common and severe cause of chemical exposure. It is more likely to occur in the Hughes 500 helicopter which has a relatively small rotor disc. Most rotor wash can be eliminated by positioning the helicopter directly above a tree in order to remove the temptation to overextend the wand into the rotor wash zone (i.e. trees should be treated directly below the helicopter whenever possible). The pilot should be encouraged to turn off the pump if he sees rotor wash of the herbicide mixture occurring as a result of poor application. The use of an extendable carbon fibre rod which can reach outside the rotor wash zone is an option for treating trees in difficult locations.
- Contaminated clothing, gloves or gaiters should not be worn whilst travelling inside a helicopter.
- Should clothing become contaminated due to an incident or spill in the field, then this must be removed and placed inside the contaminated clothing box prior to boarding the helicopter.
- A pump, water and soap should be carried to wash down all equipment, especially the helicopter, at the end of the day due to the corrosive nature of the herbicide.
- Operators using the lance/wand must be restrained with a retractable seat belt and safety harness.
- The lance/wand should be restrained to prevent it from coming into contact with the main or tail rotor. This is especially true if the lance/wand slips from the grip of the operator. The system used is optional and at the discretion of the pilot and/or operator. The bungee option for the Hughes 500 and the skid maze for the R44 are adequate.
- A bag containing eye wash, ear plugs, spare sunglasses, washing water and soap, drying rags, personal locator beacon and safety plan should be taken on board by the operator for every operation.

7. Environmental fate

7.1 Fate in the field

Triclopyr BEE does not remain active in the soil or treated plants for long as it is dissipated by microbial action into triclopyr acid.

Because the formulation is sprayed directly onto the trunks of the trees, there is very little risk of the chemical getting onto the ground, let alone leaching into/through the soil. Triclopyr rapidly coverts to triclopyr acid once in the ground and is quickly dissipated by microbial action into inert substances (i.e. it is not residual).

Triclopyr BEE rapidly degrades into the parent chemical, triclopyr acid, after application. Thus it is considered to be only slightly mobile in soil (California Department of Pesticide Regulation, 1997).

The following websites provide all the relevant information on the environmental fate of triclopyr BEE in the environment:

www.cdpr.ca.gov/docs/emon/pubs/fatememo/triclopyr.pdf

http://npic.orst.edu/factsheets/triclotech.pdf

7.2 Signs of toxicity in humans

Triclopyr has a low rate of absorption and is rapidly eliminated and, therefore, has a very low potential to become acutely toxic through dermal exposure (Carmichael et al, 1989). Also, there have been no reports of systemic poisoning resulting from ingestion of triclopyr.

Greater than 80% of the triclopyr ingested by six human volunteers appeared unchanged in the urine within 48 hours. From these data the half-life of triclopyr was determined to be 5.1 hours in humans (Carmichael et al, 1989).

Triclopyr was applied at a rate of 3.7 mg/kg body weight to the forearm of human volunteers for 8 to 12 hours and approximately 1.7% of the dose was absorbed. Less than 0.5% of triclopyr ingested by the volunteers was detected as TCP in the urine (Carmichael et al, 1989).

The Carcinogenicity Peer Review Committee (CPRC) at the United States of America Environmental Protection Agency classified triclopyr as a group D carcinogen, that is, not classifiable as to human carcinogenicity (US Environmental Protection Agency, 1998).

Triclopyr BEE (97.1% active ingredient) is only a slight eye irritant and causes only minimal eye irritation (US Environmental Protection Agency. 1998).

7.3 Signs of toxicity in terrestrial invertebrates

Triclopyr is practically non-toxic to birds and honey bees (*Apis. mellifera*) in acute contact exposure (LD50 > 100 µg/bee) and only slightly toxic to fish and aquatic life (US Environmental Protection Agency. 1998).

8. References

California Department of Pesticide Regulation. *Triclopyr*. 1997. www.cdpr.ca.gov/docs/emon/pubs/fatememo/triclopyr.pdf

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Etec Crop Solutions, X-tree basal documents (label, product safety card, safety data sheet) www.etec.co.nz/products/107.html

Grazon label. http://msdssearch.dow.com/PublishedLiteratureDAS/dh_0906/0901b803809062d7.pdf?filepath=nz/pdfs/noreg/012-00019.pdf&fromPage=GetDoc

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US Environmental Protection Agency, Office of Pesticide Programs. 1998. Re-registration eligibility decision (RED) for triclopyr; EPA-738-R-98-011; U.S. Government Printing Office: Washington, DC; 3-58. www.epa.gov/opp00001/chem_search/reg_actions/reregistration/red_G-82_1-Sep-97.pdf

9. Appendix

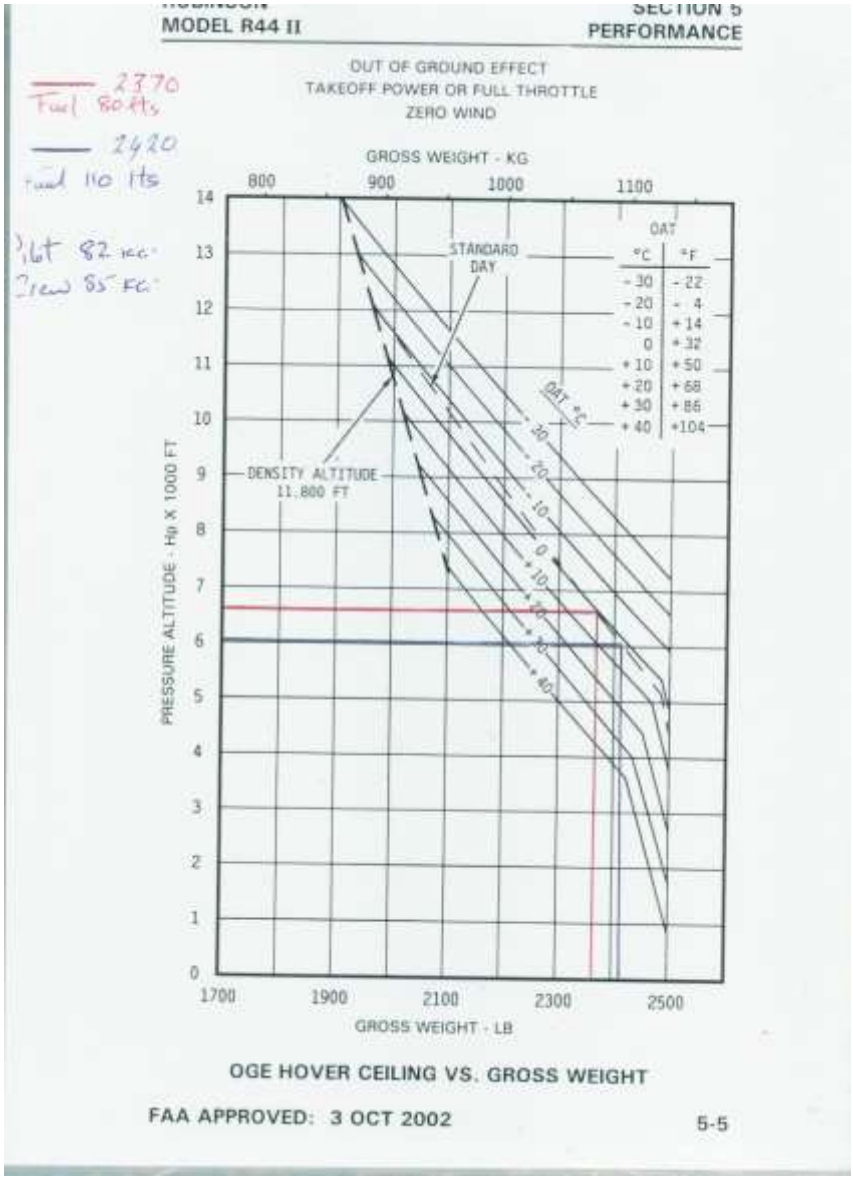
Performance criteria for the Hughes 500 and the R44 Raven II helicopters (courtesy Tony Michelle of Amuri Helicopters).

The diagrams show that both aircraft have In Ground Effect (IGE) hover capability in excess of 10,000 ft at 90% of the aircrafts all up weight – this is the weight that the aircraft are normally restricted for extra safety margin on ABA operations.

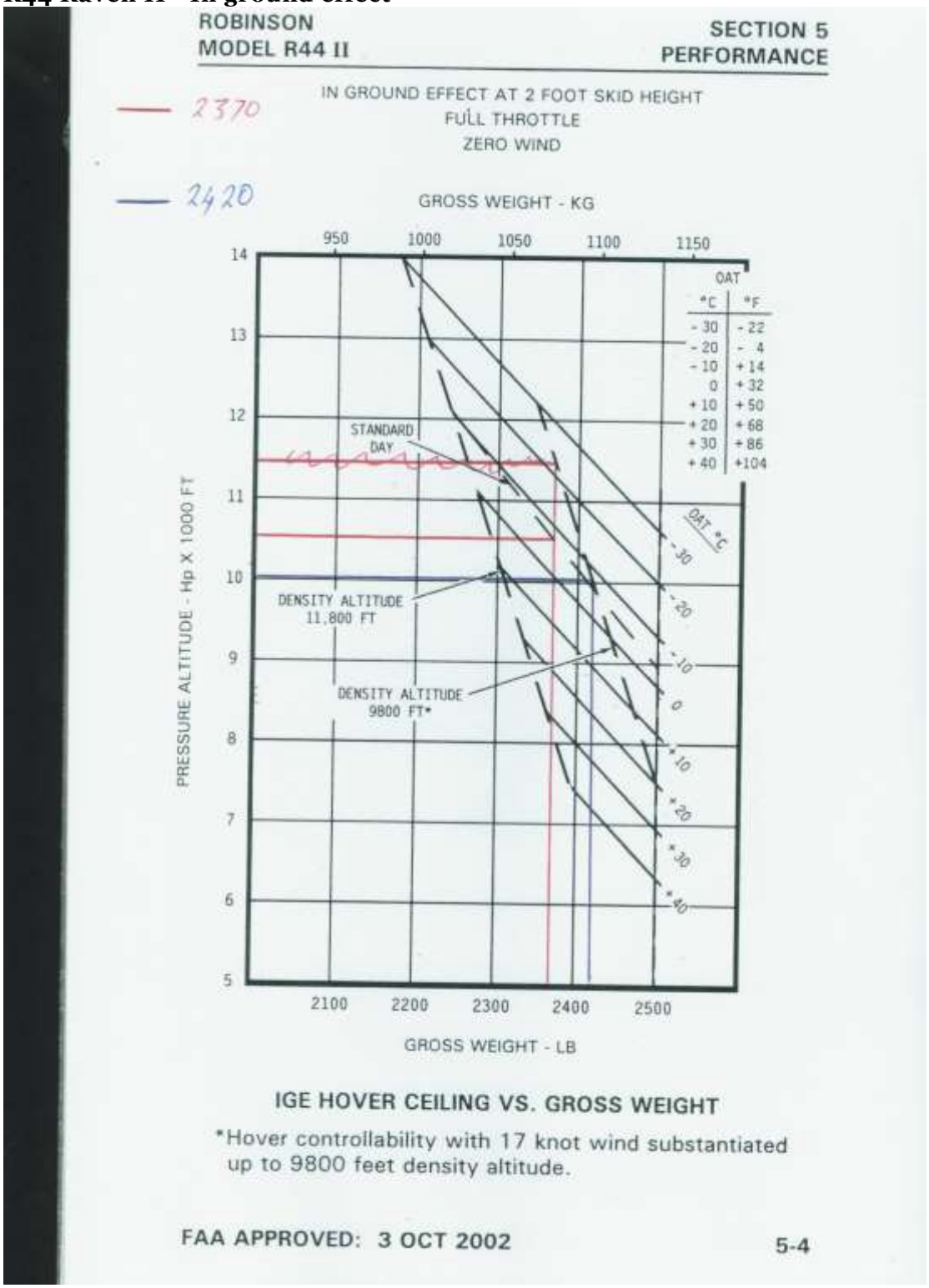
ABA operations are generally Out of Ground Effect (OGE). The Raven II performance chart shows it can perform satisfactorily up to 6,500 ft, substantially below the IGE level and the same factor will apply to the OGE performance of the Hughes 500.

This data is direct from the manufactures Aircraft Flight Manual which they are required by the Federal Aviation Administration (FAA) to substantiate as part of the aircraft certification process.

R44 Raven II - Out of ground effect



R44 Raven II - In ground effect



Hughes D500 - In ground effect

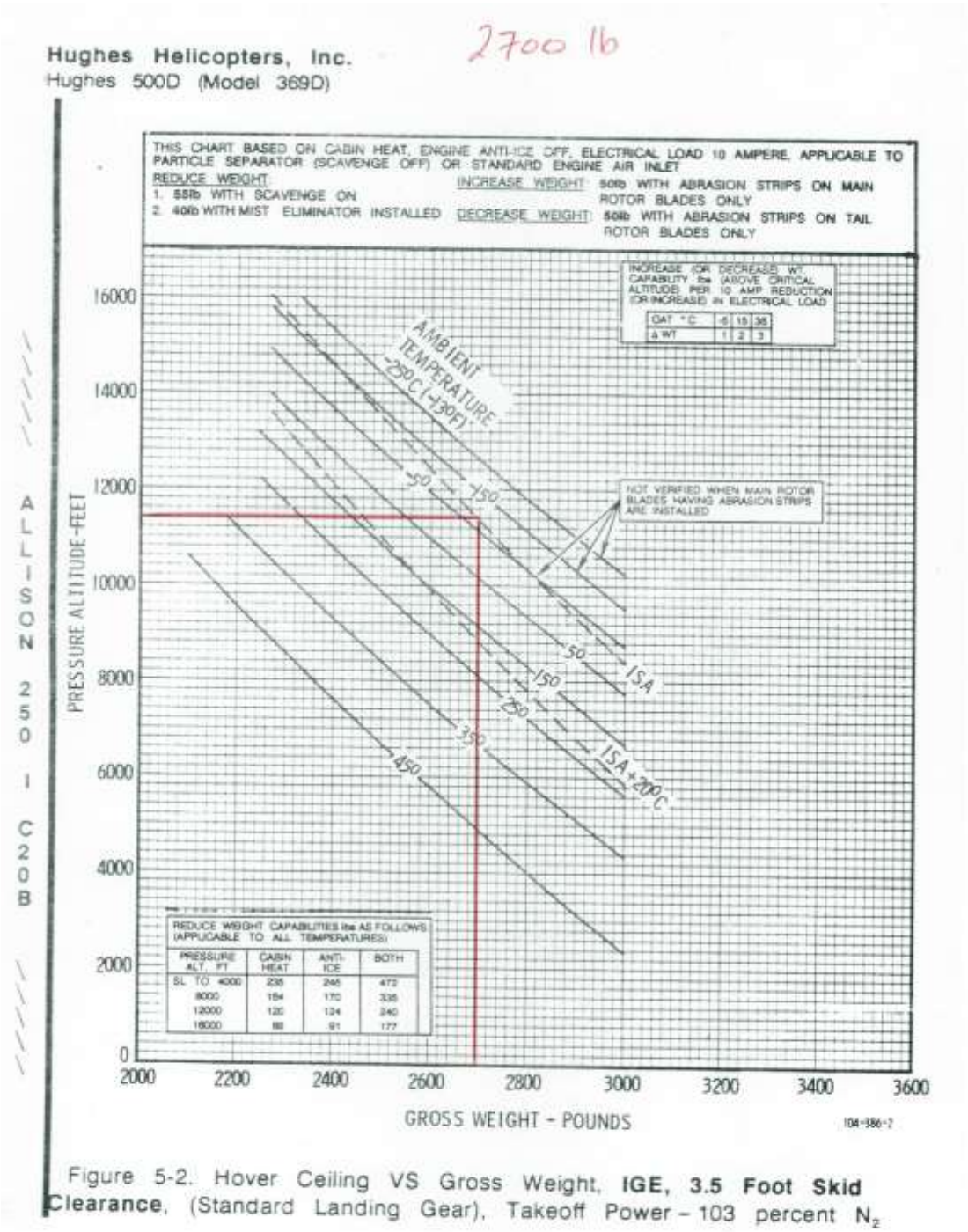


Figure 5-2. Hover Ceiling VS Gross Weight, **IGE, 3.5 Foot Skid Clearance**, (Standard Landing Gear), Takeoff Power – 103 percent N_2

FAA Approved 2 May 1989

5-2R