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A REVIEW OF HERBICIDE DRIFT AT ATHOL AND SURROUNDING AREAS AND RECOMMENDATIONS FOR THE FUTURE OF THE WILDING PINE SPRAY PROGRAMME

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1.0 TERMS OF REFERENCE

1.1 The terms of reference for this report are as follows;

(i) To investigate and report in writing as to the cause of the alleged spray drift from herbicide applications at Mid Dome; and,

(ii) To advise the Department of Conservation as to practical steps that can be taken to avoid any recurrence of possible spray drift.

2.0 QUALIFICATIONS AND EXPERIENCE OF THE AUTHOR

2.1 The Author has the following qualifications;

(i) A Degree of Bachelor of Agricultural Science in Horticulture (1962) from the University of New Zealand, Massey College.

(ii) A Foundation, Full and Honorary Life Member of the New Zealand Society for Horticultural Science.

(iii) A Full Member of the New Zealand Institute of Agricultural Science.

(iv) A Full Member of the Australian Society of Horticultural Science.

(v) Has been assessed for proficiency within the disciplines in which he practices by the Primary Industry Consultants' Registration Board and holds a current "Certificate of Public Practice".

(vi) Has been recognised by the Councils of the Australian and New Zealand Institutes of Agricultural Science as a “Leading Professional - Stage 3”.

(vii) Has been awarded the status of Certified Practising Agriculturist (CPag) by achieving the professional standards and continuing education as prescribed by the Australian Institute of Agricultural Science and Technology and the New Zealand Institute of Agricultural Science.

2.2 The author has the following experience appropriate to this report;

(i) Has 44 years experience as an advisor, researcher and consultant to the horticultural industry in New Zealand over a wide range of crops and locations.

(ii) Is the author of the accepted university text "VGH 2000 - Vegetable Growers' Handbook" and the emergency response handbook "HRH 2002 Manual of Agrichemical Identification and Emergency Response".

(iii) Is the co-author of the New Zealand Standard 8409:1995, "Agrichemical Users' Code of Practice", and New Zealand Standard 8409:1999, “Management of agrichemicals” working documents commissioned by the main horticulture primary industry groups and Federated Farmers through Standards New Zealand for voluntary regulation of their industries in order to avoid misuse of agrichemicals.

(iv) Was an independent member of the Hawke's Bay Hazardous Substances Technical Liaison Committee for 24 years and represented the New Zealand Chemical Industry Council on that committee.

(v) After graduating from university in 1960 he worked for the New Zealand Department of Agriculture as an Horticultural Advisory Officer, until 1967, being based in Hastings, New Zealand. During that time he was required to investigate herbicide contamination of crops under the Vineyard Regulations 1959.

(vi) From 1967 until 1977 he was employed as a Research and Development Officer of a major international agrichemical company during which time he continued to investigate problems of herbicide contamination of crops.

(vii) During 1977 he established his own general consultancy practice, a specialist horticultural consultant company to undertake contract research into horticultural problems.

(viii) Over the past 44 years he has undertaken numerous investigations into problems of crop injury and crop performance relating to horticultural, agricultural and forestry crops both in Australia and New Zealand.

(ix) Over his professional forensic horticultural career he estimates that he has fully investigated in excess of 1100 serious incidents of chemical drift and contamination, as follows:

Gaseous drift	424
Droplet drift	410
Aerosol drift	27
Over-spray	71
Water, fertiliser and cross contamination	48
Mixing and loading spillage	6
Equipment checking and calibration	3
Malicious and self-inflicted activities	12
General minor spray drift allegations	121

3.0 INTRODUCTION

3.1 This report relates to a visit by the writer to the Lumsden, Athol and Kingston areas of Southland along, and about, State Highway 6 (SH6). The visit took place over the two days of 18 and 19 February 2004.

3.2 The writer was accompanied at all times by Messrs. Andy Roberts and Peter Willemse of the Department of Conservation, Invercargill, and Mr. John Maber, engineering consultant of Raglan.

3.3 Phoenix Aviation limited at Gore who undertook the aerial application over Mid Dome were visited and discussions held with Messrs. Bill Sutherland and Brian Casey.

3.4 At all times throughout the visit all persons visited and spoken with freely gave of information and data and access to any property for inspection was freely granted.

4.0 THE SITE AND TOPOGRAPHY

4.1 The target site of the herbicide application was “Mid Dome” situated at, and about, grid reference 627043 on Topographic map 260-E43, Eyre, Edition 1 1992, Limited Revision 1998.

4.2 The target site consisted of approximately 473 hectares of dense wilding pine (*Pinus contorta* and other Pinus species). The target area ranged between approximately 1000 and 1478 metres above sea level and rose from SH 6 by approximately 1000 metres over a distance of three kilometres.

5.0 THE HERBICIDE APPLICATION

5.1 A contract was let between the Department of Conservation and Phoenix Aviation Limited to apply herbicide to several target species growing on the upper reaches of Mid Dome. The contract specified that 111 litres of herbicide spray mix was to be applied per hectare. The spray mix was to consist of 100 litres of water, 10 litres of Reglone® (diquat) and one litre of Penetra® (adjuvant).

5.2 Applications of the Reglone® herbicide mix were made by fixed wing aircraft on 28 and 29 January 2004. 240 hectares of wilding pine were treated with 30 loads of herbicide

6.0 SPRAY DRIFT NOTIFICATIONS

6.1 The first observation of spray drift injury was made between 0730 and 0900 on 30 January 2004 on Mr Peter Taylor's property and five spray drift notifications causing plant injury were received on Friday 30 January 2004.

6.2 Subsequent spray drift notifications continued to be received from locations of up to approximately 27 kilometres away from Mid Dome.

7.0 THE HERBICIDE DIQUAT

7.1 Diquat is a contact desiccant herbicide of the bipyridyl group which relies on complete cover of the plant's foliage to provide control. It has no direct selectivity towards any green foliage material of plants.

7.2 Diquat has no systemic activity and only has herbicide activity where there is plant coverage. Some trans-laminate activity can be expected. Diquat has no long term activity after the initial kill of the plant tissue it covers.

7.3 Diquat is marketed under the trade name of Reglone® a 200 grams per litre soluble concentrate of the dibromide salt. It is soluble in water at the rate of 700 grams per litre at 20^{o}C.

7.4 On soft foliage plants the diquat herbicidal effects can be observed within 12 to 24 hours from its contact with the foliage.

8.0 RATES OF APPLICATION AND APPLICATION CONDITIONS

8.1 The spray mix used consisted of that prescribed in the contract with the addition of an anti-foaming agent to reduce spray tank foaming.

8.2 Weather conditions were considered suitable for aerial application by the contractor.

8.3 The aircraft herbicide application equipment and air speed were calibrated to apply the recommended rate of the water and herbicide.

8.4 Suitable management for aerial herbicide applications is prescribed in the New Zealand Standard 8409:1999, “The Management of Agrichemicals”. This standard provides information as to the conditions to avoid if the likelihood of spray drift is to be minimised. In some cases the document has become legally binding upon the aerial applicator where it has been harmonised into the environmental plans of regional councils and territorial authorities. NZS 8409:1999 is not legally binding in the Southland Region.

9.0 IDENTIFICATION OF SPRAY DRIFT SITES

9.1 Five specific areas inspected for plant injury were identified, as follows;

(i) A triangular area (**Athol**) in a general northerly direction from the north Mid Dome spray site, to an approximate distance of eight kilometres and including the township of Athol.

(ii) A semi-circular lineal area (**Kingston**) from the Athol township though to Kingston a distance of approximately 27 kilometres to north-east of the spray target area.

(iii) A gully between State Highway 6 and Mid Dome in the Jollies Hill area (**Jollies**) at approximately one kilometre to the west of the spray target area.

(iv) A fodder cropping area around the SH 6 and Bixter Road intersection (**Bixter**) approximately two kilometres to the west of the spray target area.

(v) A fodder cropping area around the airstrip at Five Rivers Road (**Five Rivers**) to the south-west at approximately four kilometres from the spray target area.

9.2 Two other areas of alleged plant injury to the east of the spray target area along the Mataura River were not inspected.

10.0 TIMING PLANT INJURY OBSERVATIONS

10.1 The initial observation of plant injury was made on 30 January 2004 at approximately 45-46 hours after the commencement of the aerial spraying of the diquat herbicide. The initial injury was found at Taylor’s property approximately 2.3 kilometres from the north Mid Dome application site. It is known that much of the north Mid Dome spray site was sprayed on the first day of application.

10.2 Under warm conditions initial slight chlorosis (yellowing) due to diquat uptake will be visible within 12-18 hours after contamination. This will be followed by necrosis within 24-36 hours after contamination.

10.3 Under conditions of very high concentrations of diquat contamination the speed of symptom development will increase. The inclusion of an adjuvant to a diquat spray mix will further increase the speed of symptom development.

10.4 Soft leaved crops will show injury earlier than those with heavy leathery leaves.

10.5 The timing of the crop injury observations were consistent with diquat contamination.

11.0 SYMPTOMS OF PLANT INJURY

11.1 In all cases the plant injury consisted of necrotic spotting ranging in diameter of less than one millimetre to 20 millimetres. On soft foliage crops of swedes and pasja the necrotic areas of the spots had dropped out leaving a distinct hole with a narrow necrotic edge. On ornamental dicotyledon crops and grapes the necrotic spots were still intact.

11.2 The areas of Athol, Jollies, Bixter and Five Rivers had the preceding symptoms on all of those leaves that would have been exposed at the time of the Mid Dome diquat applications. These symptoms were consistent with an off-target diquat drift scenario.

11.3 It should be noted that several other plant injury symptoms were observed within the areas visited such as leaf collapse, leaf reddening, leaf insect damage and centre tree needle necrosis and drop of conifers. None of these symptoms were consistent with diquat drift injury.

12.0 NECROTIC SPOT SIZE

12.1 The typical necrotic spot size was two to three millimetres in diameter and given that there was an adjuvant included in the herbicide mixture these would have originated from a droplet of, at most, one tenth of the ultimate spot size. Given that the aircraft application equipment was delivering a rated droplet size of approximately 410 microns with a significant proportion of these being less in size this would relate well to the size of the ultimate necrotic spot size.

12.2 Given the prevailing weather conditions at the time of application the leaves of the plants would have been wet from dew which would mean that the multiplication of the droplet's area of affect would have been considerable.

12.3 The necrotic spot size relates well to other field observations under similar conditions.

13.0 INJURY GRADIENTS

13.1 A definite decreasing gradient of plant injury expression by willows away from the target application sites was observed in the Jollies area.

13.2 A general decreasing gradient of plant injury expression by crops and ornamentals away from the target application sites was observed in the Athol area. On several densely leaved ornamental trees the intensity of necrotic spotting of the leaves was significantly greater on the south side than the north side.

13.3 Although plant injury was observed, no decreasing or increasing injury gradients were observed in the Kingston area.

13.4 No injury gradients were observed in the Bixter or Five Rivers areas.

14.0 INJURY SEVERITY

14.1 The most severe injury was found in the Athol area, particularly in those crops and ornamentals within six kilometres from the nearest diquat application site.

14.2 Moderate injury was found at the Jollies and Bixter sites and minor injury was observed at the Five Rivers site.

14.3 Consistent moderate injury was found at the Kingston township but no diquat injury was found on two crops up to 19 kilometres south of Kingston.

14.4 Apart from one questionable plant injury site beyond the end of Quoich Station Road all confirmed diquat injury symptoms were only found where Mid Dome was visible in the direct line of sight.

15.0 THE KINGSTON AREA

15.1 Along SH6 from Kingston to a point approximately three kilometres north of the Athol township many trees were showing the necrotic spotting that has been identified with diquat drift. Of these trees the Rowans were consistently showing new autumn growth that was not affected by any necrotic spotting. This growth would have been highly sensitive to diquat injury and was not in any way protected from drift of herbicide.

15.2 A similar necrotic spotting can be the end-result of droplet drift of other herbicides such as glyphosate (Roundup®) or metsulfuron-methyl (Escort®, Answer®), two herbicides commonly used for weed control around roadside poles, markers and bridge approaches. From site appearances such herbicide application had been undertaken during the late spring of 2003. It was subsequently established that roadside spraying was carried out by Tranzit New Zealand contractors on 02 December 2003.

15.3 In each and every case the Rowan necrotic leaf spotting was associated with roadside spraying or other use of these herbicides. For these reasons any diquat drift as a cause of necrotic spotting has been eliminated in the Kingston area.

16.0 THE ECONOMIC AFFECT OF THE DIQUAT INJURY

16.1 Diquat is a non-systemic herbicide and the injury observed during the visit was in its terminal state with no further injury expected.

16.2 The annual crops of swedes and pasja had grown sufficiently, due to advantageous rainfall, to mask much of the diquat injury expression. There is unlikely to be any quantifiable loss due to diquat injury in these annual crops.

16.3 The ornamental and garden crops were showing very visible diquat spotting but as most of the affected crops are deciduous and would shortly be undergoing their annual leaf drop the diquat injury is largely cosmetic.

16.4 There is unlikely to be any quantifiable loss due to diquat injury on these ornamental crops.

16.5 It should be noted that in some private gardens in Athol there were ornamentals that were in a moribund state and had been for some considerable time prior to the diquat drift. This is due to the environmental conditions that they are growing being unsuitable for their survival. It is unlikely that any diquat contamination of these trees would assist their demise.

17.0 CONTROL OF WILDING PINE

17.1 A close range inspection of the wilding pine in the target spray area was not made due to time constraints. The apparent surface coverage as observed from SH 6 was adequate as seen from the significant necrosis of the needles.

17.2 According to North Island experience based on 10 years experience of the Army at Waiouru and Department of Conservation managers in the Wanaka and Queenstown areas of the South Island 110 litres per hectare of a nine percent solution of diquat would be sufficient to provide control of dense wilding pine infestations on Mid Dome.

18.0 DROPLET DRIFT CONSIDERATIONS

18.1 From the writer's experience with drift of diquat and similar products, Gramoxone® (paraquat) and Preeglone® (diquat plus paraquat), there are only two scenarios applicable to their off-target drift, these being direct droplet drift and aerosol drift.

18.2 Diquat has insufficient volatility to drift by way of vapour drift or thermal lift and dump drift from either aerial or ground application. I have no records of such occurring over the past 44 years.

18.3 Droplet drift consists of larger droplets being blown laterally away before targeting and practical aerial drift distances in high wind velocities on flat ground seldom exceeds 250 metres down wind from the release point.

18.4 Given the topography of the Mid Dome application site and its surrounds it is unlikely that droplet drift was the contamination scenario. Further, there are straight line boundaries between the treatment spray runs over the wilding pine on Mid Dome and distinct untreated areas which would indicate that much of the diquat was properly targeted. Typical balloons of off-target affect would have been observable at the time of the visit had droplet drift been the cause.

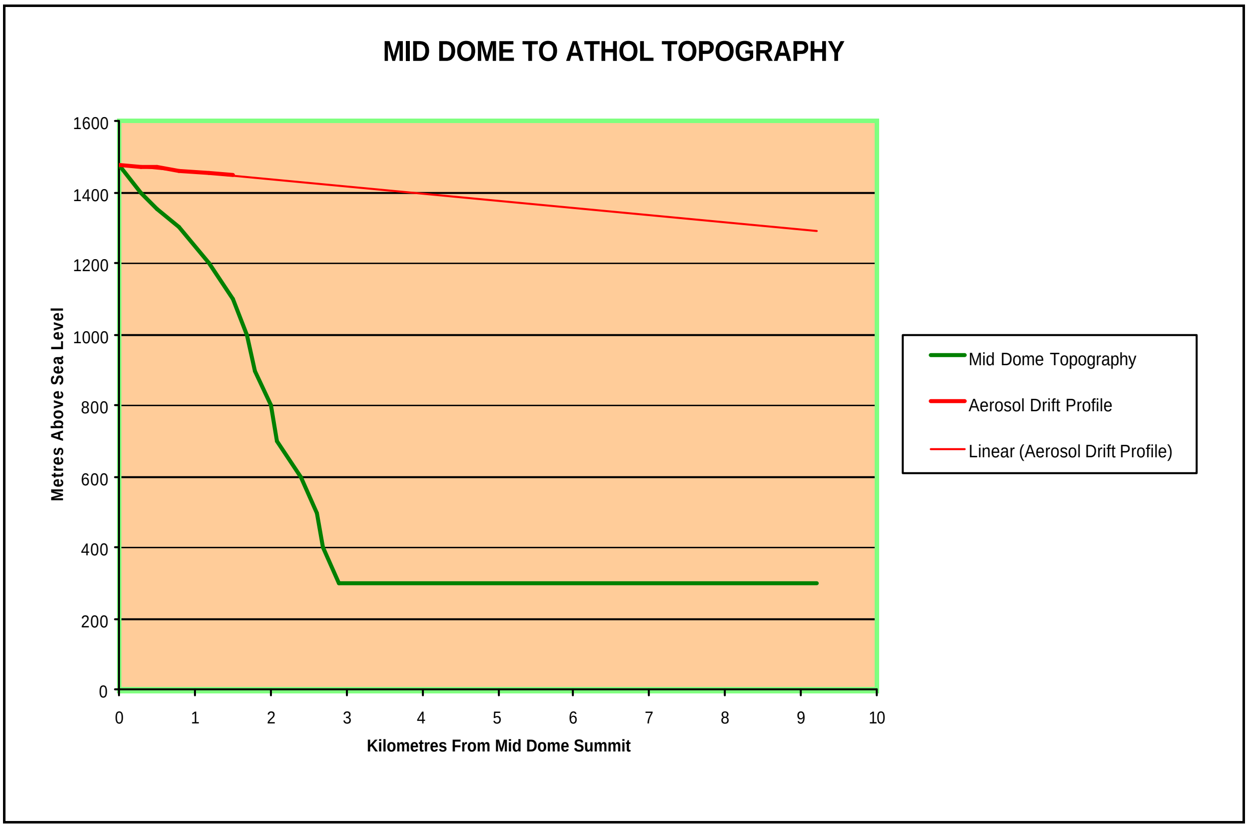
19.0 AEROSOL DRIFT CONSIDERATIONS

19.1 Aerosol drift of very small particles of herbicide has been recognised in New Zealand for some time. This is a situation where meteorological conditions allow very small droplets to hang in the air to move laterally with light air movement, coalesce to fall out once they have sufficient weight to overcome upward air currents.

19.2 Aerosol drift only occurs where low water rates per hectare are used. In order to obtain full coverage of the target droplet sizes for application have to be relatively small. To date, in the writer's experience, aerosol drift from both aerial and ground applications has only occurred where water rates used have been less than 150 litres per hectare.

19.3 Conditions suitable for aerosol drift are light air movement as generated by catabatic or anabatic air movements, inversions layers, cool air temperatures and applications made after fog or near fog conditions. In such conditions aerosol particles can travel in excess of 1500 metres on flat ground before falling out onto plant material.

19.4 All of my experience with aerosol drift has been on relatively flat topography, whereas the area of the Mid Dome applications is anything but flat. By transposing aerosol and droplet drift data established for flat topography onto the Mid Dome topography the following Chart shows the likely termination of the droplets.



19.5 Given the circumstances of droplet size used for the application to Mid Dome it appears that aerosol drift was the mechanism which carried the herbicide away from the target site towards the sensitive crops.

19.6 Aerosol drift is nowhere as common as droplet drift as it occurs only when a combination of low water rates of application, small droplet sizes and specific weather conditions are combined. Compared with droplet drift and gaseous drift it is a relatively new field drift situation. Of the drift investigations undertaken over 44 years the aerosol drift content has only been three percent of these. In recent years with less volatile chemicals being used in agriculture the percentage of aerosol drift has risen to about 20 percent.

20.0 MID DOME WEATHER CONDITIONS

20.1 Weather conditions were not recorded at the actual application sites on the Mid Dome target area.

20.2 Limited details of weather were recorded at the Five Rivers airstrip, some 1000 metres lower in altitude than the Mid Dome application sites which was used for loading the aircraft, as follows;

Date	Time	Temp (^oC)	Wind Direction	Wind Speed (km/h)	Observations
28.01.04	0545				Fog
28.01.04	0730				Fog breaking
28.01.04	0900				Fog at 900 metres
28.01.04	1000				Fog clearing on top of Mid Dome
28.01.04	1030	18	East	5.6	
28.01.04	1430	24	East	9.3	Wind building
29.01.04	0545				Fog
29.01.04	0630				Fog breaking at Jollies Pass
29.01.04	0800				Fog clearing
29.01.04	0900				Fog clearing at airstrip
29.01.04	0930	18	East	5.6	
29.01.04	c1000				Rain on Eyre Mountains

20.3 These weather details would indicate that on each of the mornings before application started there was likely to be an inversion layer which most likely continued through into the application period and that winds were light and could well be influenced by the topography of Mid Dome to flow in directions other than that indicated by the airstrip weather observations.

21.0 LUMSDEN WEATHER CONDITIONS

21.1 Details of the weather conditions before and during application from the NIWA meteorological station at Lumsden some 15 kilometres to the south-west and approximately 1300 metres lower in altitude of the application site were, as follows;

Date	Time	Temperature (^oC)	Wind Direction	Wind Speed (km/h)	Relative Humidity (%)
28.01.04	0600	11	0	0	94
28.01.04	0700	11	0	0	94
28.01.04	0800	12	Variable	6	89
28.01.04	0900	13	Variable	6	88
28.01.04	1000	15	South-east	7	77
28.01.04	1100	17	South-east	11	70
28.01.04	1200	21	East	11	57
28.01.04	1300	23	South-east	9	46
28.01.04	1400	24	East	6	44
29.01.04	0600	13	0	0	97
29.01.04	0700	13	0	0	97
29.01.04	0800	14	0	0	95
29.01.04	0900	15	0	0	84
29.01.04	1000	17	Variable	4	77
29.01.04	1100	18	Variable	4	68
29.01.04	1200	19	0	0	63

21.2 Overall the limited meteorological data relating to the Mid Dome application site would indicate that weather conditions were suitable for the generation of aerosol drift and that this drift would have caused the plant injury in all but two of the defined areas.

21.3 Given this the following is the probability of diquat aerosol drift contamination in the various crop and ornamental areas;

High probability – Athol, Jollies, Bixter, Five Rivers

Medium probability – Areas to the east of Mid Dome

Zero probability – Kingston

22.0 HERBICIDE ANALYSIS

22.1 A swede leaf sample collected at approximately 1500 hours on Friday 30 January 2004 from Mr. Peter Taylor's property, one of the closest and most affected by the herbicide drift, was analysed as a whole leaf sample by the Agriquality Laboratory in Lower Hutt for the presence of diquat. The chain of custody and treatment of this sample was acceptable to preserve its integrity and any residues that may have remained in this sample.

22.2 Diquat was unable to be detected at the limit of detection of 0.05 mg/kg (ppm).

22.3 Given that the level of diquat in the sample was below the limit of detection the possibility of other higher organisms being affected by the herbicide would have been most unlikely.

23.0 OTHER PLANT PROBLEMS

23.1 Several other plant problems were observed within the identified areas of the diquat drift. These problems consisted of normal disease infections, pest infestations, natural leaf ageing, water and nutrient deficiencies and the personal use of herbicides, particularly that of glyphosate.

23.2 Some of these problems have been highlighted by the news media as being the result of diquat drift. This is not the case.

24.0 CONCLUSION AS TO CAUSE OF THE DIQUAT AEROSOL DRIFT

24.1 The root cause of the off-target movement of the diquat applications to the Mid Dome wilding pine infestation on 28 and 29 January 2004 was that the weather conditions combined with the low water rates used and the topography of the area allowed aerosol sized droplets of a nine per cent concentrate Reglone® herbicide mixture to stay aloft and gradually float down onto sensitive targets.

24.2 Primarily the Mid Dome topography, and weather conditions at the time of application, would be outside the experience of most contractors in New Zealand. With most of the applications of diquat for the control of wilding pine prior to the Mid Dome applications being made in the North Island where the less rugged topography does not allow for such long distance aerosol drift a false sense of security of accurate targeting would occur.

25.0 AVOIDANCE OF REPEAT INCIDENT(S)

25.1 Some past limited experimental aerial application of diquat in the Mid Dome area indicated that water rates of 400 to 800 litres per hectare gave the best herbicidal result. If these higher water rates were adopted it would allow for larger droplets to be used to give full coverage of the target. Whilst this would not completely eliminate aerosol drift under the atmospheric conditions experienced during the Mid Dome application it would go some way to relieving the potential of aerosol drift.

25.2 As a result of this unfortunate herbicide drift experience the following matters need attention if future herbicide applications are to be fully targeted;

(i) **Applications must be made under conditions where no atmospheric inversion layers exist** –Inversion layers appear to allow the stability of aerosol formation.

(ii) **Unpredictable light air movement conditions at application must be avoided** – These do not allow the dispersion of the aerosol. Anabatic and catabatic air movements can give rise to greater travel distances of the intact aerosol.

(iii) **Applications must be made when there is positive light wind direction away from any sensitive areas but not to such an extent that there is an increase over normal of the hazards of aerial application** – Light winds will assist with the dispersion of the aerosol but here has to be a balance of wind strength and flying safety.

(iv) **Droplet sizes have to be increased to avoid small droplets forming aerosols before targeting** – This implies the use of higher water rates as low water rates with large droplets do not give the full coverage and penetration of the target required for contact herbicides to be efficient.

(v) **Water rate increases achieved by double or triple spraying the same target area with lower concentrations of diquat will not avoid aerosol drift occurring under the correct environmental conditions** – Such practice does not increase the droplet size which is one critical factor of aerosol avoidance.

(vi) **Investigations should be made as to the pertinence of using application equipment other than conventional boom and hydraulic nozzle** – Modification and reconfiguration of conventional hydraulic boom equipment may provide suitable reduction of aerosol drift. However, the aerosol drift reduction potential of Through Valve Boom (TVB) application equipment and any other pertinent application equipment should investigated.

(vii) **The use of controlled droplet application (CDA) equipment should be avoided at any cost due to its greater propensity to generate droplet sizes that are highly susceptible to aerosol drift** – This type of equipment was not used for the Mid Dome applications.

(viii) **The efficacy of any new equipment or technique must be fully field tested prior to it being used on a large scale** – This can be achieved by undertaking a monitored on-site trial of up to 75 hectares under appropriate weather conditions for aerosol drift minimisation.

(ix) **In order to make higher water rates more cost effective the construction of a water reservoir on the top of Mid Dome should be seriously considered** – This action would imply that helicopter application would be used.

(x) **The installation of smoke generators on aircraft used for application should be considered to be able to ascertain the ultimate destination of droplet targeting** – Whilst this is not common practice in New Zealand it is in Australia.

(xi) **The installation of meteorological monitoring equipment both at and around the target areas of Mid Dome should be implemented** – These should be continuously monitored before and during any spray application and once there is an indication of adverse targeting conditions application should be immediately ceased.

(xii) **Consideration should be given to any future herbicide applications to Mid Dome being made over a period of several separate days** – This will allow use to be made of several small windows of suitable weather conditions for accurate targeting, where aerosol drift would not occur and any drift potential would be away from sensitive crops.

(xiii) **Any future contractor should undertake work in a way that it complies with NZS 8409:1999, "The Management of Agrichemicals".**

AGRO-RESEARCH

(Euan Wallace) 23 April 2004