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AN ASSESSMENT OF THE POTENTIAL

FOR DRIFT DURING

FORESTRY HERBICIDE USE

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**AN ASSESSMENT OF THE POTENTIAL FOR DRIFT
DURING FORESTRY HERBICIDE USE**

by

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Environmental Protection Service
Atlantic Region**

EPS-5-AR-84-3

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ABSTRACT

This report details the results of a study evaluating the aerial off-target movement of forestry herbicide formulations associated with aerial and ground applications. Spray particle deposit was measured within and at distances up to 200 metres outside areas treated with a 2,4-D/2,4,5-T mixture. Results indicated that deposit of pesticide formulation outside the treatment areas was a very small percentage of that deposited within the treatment areas. The mean deposits outside the treatment area expressed as a percentage of mean deposit inside the treatment area did not vary appreciably between the two modes of delivery.

Précis

Ce rapport détaille les résultats d'une étude traitant l'évaluation de mouvement aérienne dérangé des formulations herbicides forestiers associé avec les applications aériennes et terrestres. Le dépôt de brins d'épandage a été mesuré à moins de et jusqu'à 200 metres dehors les quartiers traités avec un mélange de 2,4-D/2,4,5-T.

Les résultats indiquent que le dépôt de formulation de pesticide dehors les quartiers traités était un pourcentage miniscule de cela déposé dans les quartiers traités. Les dépôts moyens dehors le quartier traité, exprimé comme pourcentage du dépôt moyen dans le quartier traité, n'a pas varié tellement entre les deux méthodes de distribution.

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1. INTRODUCTION

The application of herbicides is an integral part of modern agricultural and silvicultural practice. Concerns have been raised, however, about the potential for forestry herbicide sprays to move off-target via aerial drift.

The forestry herbicides most commonly used in the Atlantic Region are ester derivatives of 2,4-dichlorophenoxyacetic acid (2,4-D) and 2,4,5-trichlorophenoxyacetic acid (2,4,5-T). These esters have a greater solubility in oil than the free acid but are also more volatile than the parent compounds.

The attractive feature of these chemicals, from a forestry management standpoint, is their selectivity among vegetation. They are phytotoxic to a variety of plants, such as red maple (Acer rubrum) and white birch (Betula papyrifera). In addition, 2,4,5-T is effective against species resistant to 2,4-D, most notably certain brambles (Rubus spp.). Because of this, the chemicals are often combined in commercial herbicide formulations (Bovey and Young, 1980).

Two major objectives in the forestry application of 2,4-D and 2,4,5-T are those of conifer release and site preparation. In the former, the herbicide suppresses the growth of unwanted competitive species, thereby stimulating growth of the conifers. In the latter, a high percentage of defoliation and topkill is achieved to allow reforestation (Gratowski, 1975).

Delivery equipment may vary, depending on site specific conditions. In small areas of relatively even terrain, ground sprayers are most effective. This method involves spraying with hand-held guns or wands, or with booms which contain one or more

nozzles. Aerial spraying is effective over large areas or where ground application is precluded due to wet soils, rough terrain, or tall vegetation.

This report details the results of a study to quantify and compare the extent of herbicide drift, outside intended treatment areas, associated with aerial and ground forestry herbicide applications.

2. MATERIALS AND METHODS

Field monitoring was conducted at three sites scheduled to receive either aerial or ground herbicide applications.

Site I received coverage through aerial application. The vegetation cover, predominantly broadleaved, averaged 2.5 m in height throughout the treatment area. This height approximated that of the sampling equipment so that sampling deposit was unobstructed by any vegetation canopy. Esteron 3-3E (300 g of 2,4-D iso-octyl ester and 300 g of 2,4,5-T propylene butyl ester per litre) was applied at 3.36 kg ai/ha in a formulation of one part product to five parts water. Delivery was with a Bell G-28 helicopter using a Simplex spray unit equipped with 43 Tee Jet nozzles mounted 180° to the direction of flight. Nozzle pressure was 5.8 KPa. Aircraft height and velocity were 15 m above ground and approximately 80 km/hr respectively.

Site II also received aerial treatment. The vegetation type and height was similar to Site I within the target area. Outside the target area and throughout the sampling zone the vegetative coverage consisted of conifers which were approximately 18 m high. Deposit samplers were mounted at the same height as in Site I (2.5 m) and, therefore, the overhead canopy tended to intercept some of the spray cloud. Herbicide delivery specifications were identical to Site II.

Site III was sprayed with a ground rig. Brush height within and outside the treatment site averaged 1.0-1.5 m and the path of spray particles to the deposit equipment was unobstructed by foliage. This site received a treatment of Pfizer Brushkiller (290 g of 2,4-D and 290 g of 2,4,5-T per litre) in a formulation of one part product to 90 parts water. The dosage rate was 5.38 kg ai/ha. Delivery was with a Tree Farmer Forwarder (Hawker-Siddeley) mounted spray rig

which employed hand-held spray wands with maximum pressures of 21.7 KPa. The resultant swath width was 12 m and the average speed of travel 1.6 km/hr. Six round disc standard nozzles were used.

Sites I and II were located on the free-hold land of Bowater Mersey Ltd., approximately 60 km north of Liverpool, Nova Scotia, while Site III was situated on the woodlands of Scott Paper International Inc., approximately 55 km north of Sheet Harbour, Nova Scotia.

At each site, prior to herbicide application, two transects were established at right angles to the path of the delivery vehicle. Prevailing wind directions were evaluated and sampling equipment was located downwind to capture spray particles. Each transect consisted of six stations, situated as follows: one 50 m inside the target area; one located directly under the location of the most leeward pass; and the other four at 50 m intervals outside the treated block (Figures 1 and 2). At each of the stations, wooden stakes (8 x 2.5 x 150 cm) were erected and aluminum pie plates (22.9 x 2.9 cm) attached at the top (Figure 3) to capture pesticide deposit.

One hour after spray, deposit samples were collected by rinsing the collectors with reagent grade acetone (approx. 40 ml) and reagent grade hexane (approx. 40 ml) sequentially into hexane rinsed 250 ml amber glass bottles whose caps were lined with hexane washed aluminum foil. Samples were stored at 4°C in the dark for approximately two weeks until analysis.

Analysis was performed by the EPS laboratories at the Bedford Institute of Oceanography, Dartmouth, Nova Scotia, according to the methods outlined in Appendix I.

Meteorological and spray conditions were monitored during the spray event (Table 1).

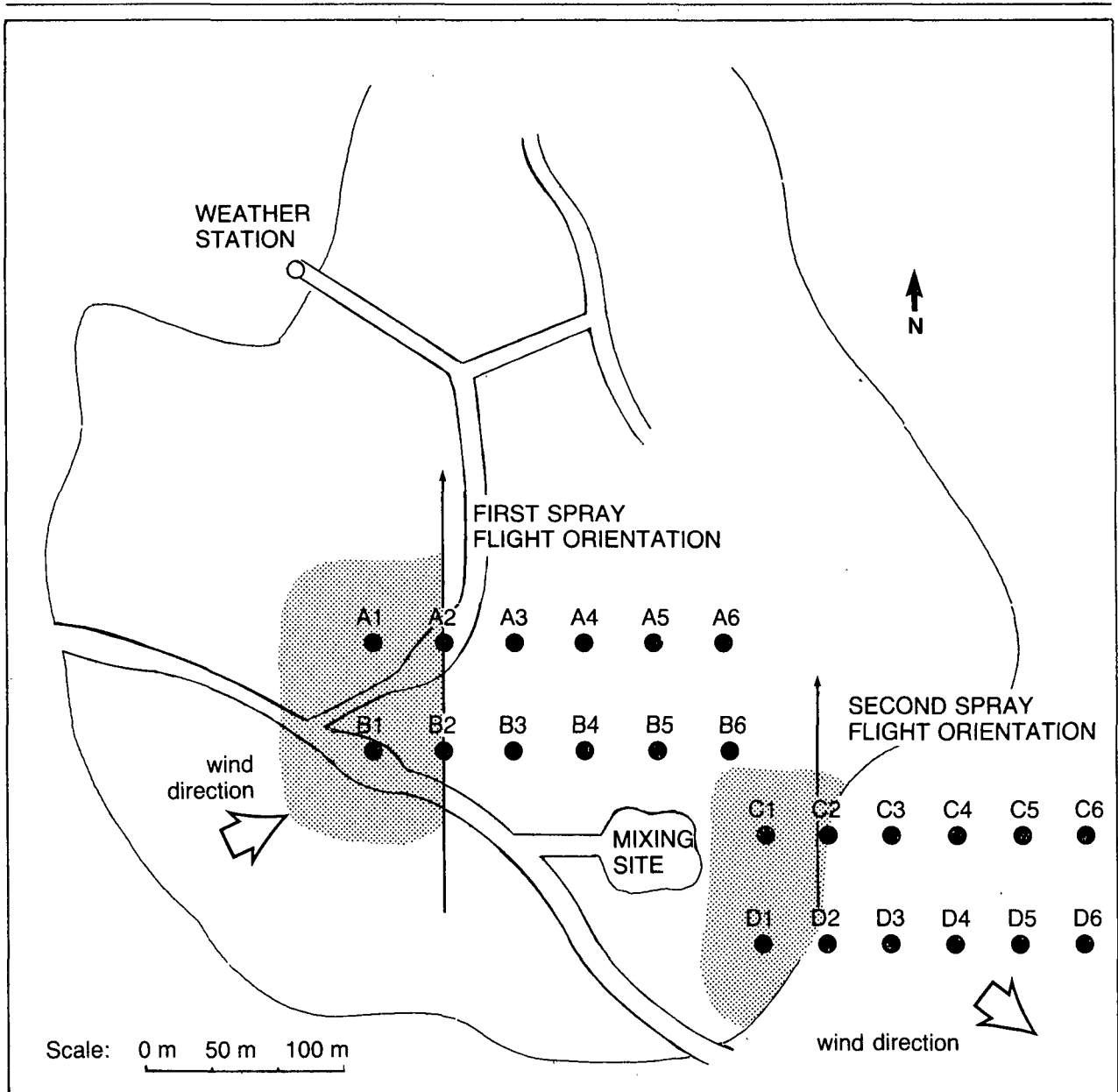
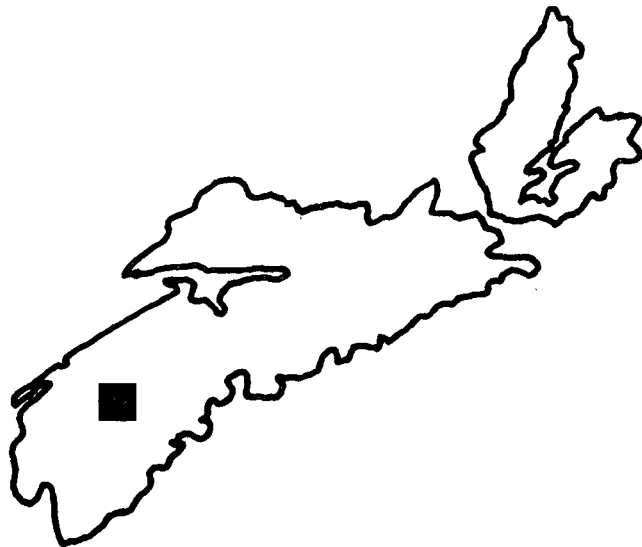


FIGURE 1 – Aerial Application
Monitoring Site
(60 km north of Liverpool, N.S.)



Shaded area = sprayed area

First Spray

Date: 25/07/81

Wind direction: W-SW

Wind speed: 0-8 km/hr

● Sampling Stations: A1 - B6

Second Spray

Date: 26/07/81

Wind direction: N-NW

Wind speed: 8-16 km/hr

● Sampling Stations: C1 - D6

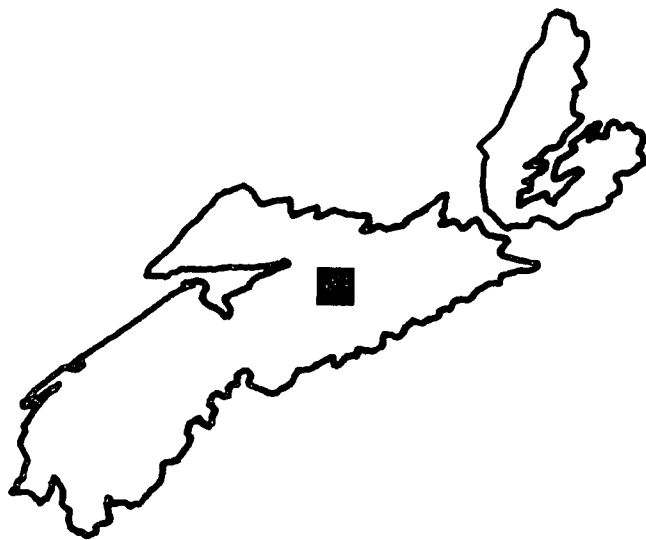
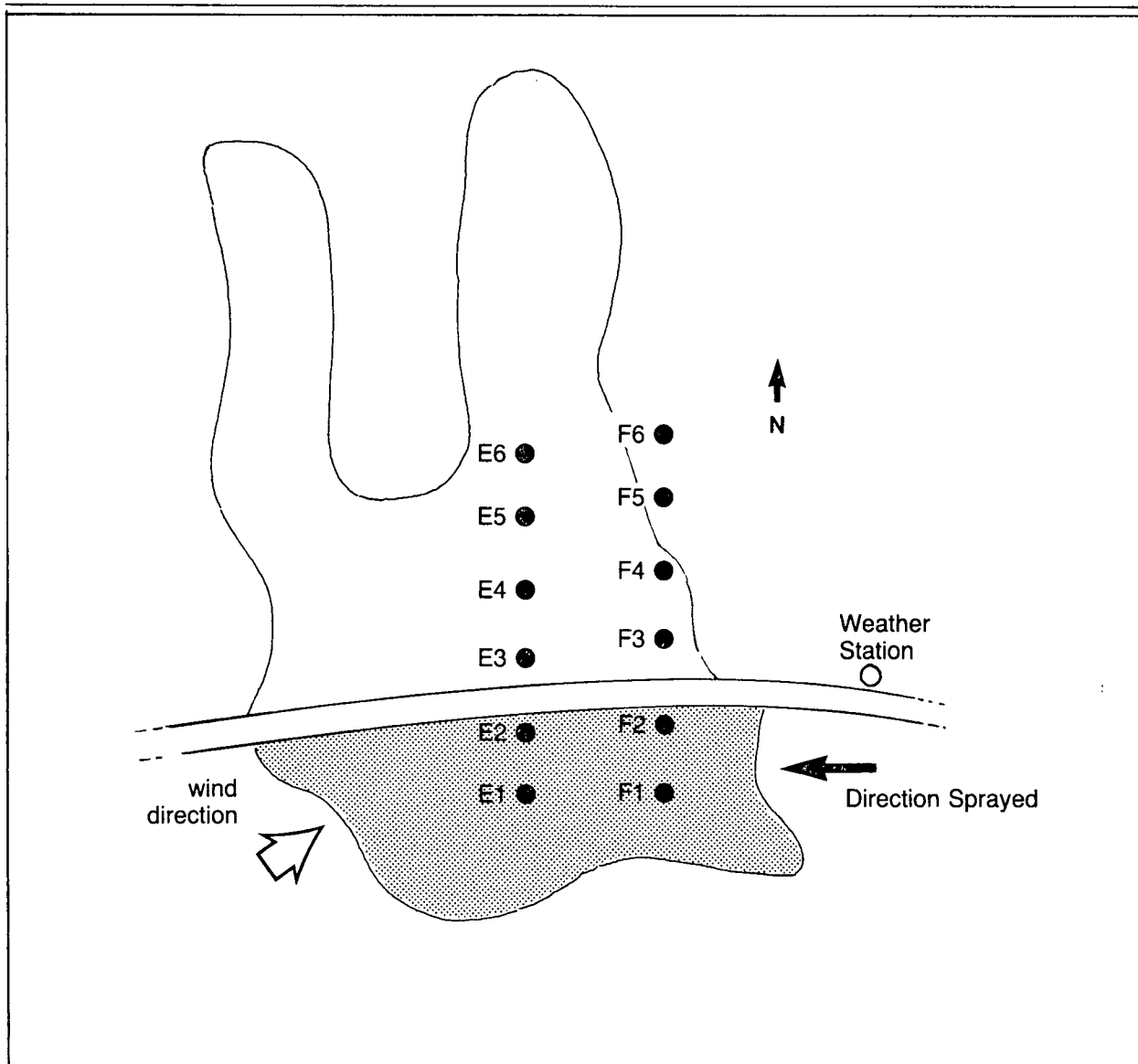


FIGURE 2 – Ground Application
Monitoring Site
(55 km north of Sheet Harbour, N.S.)

Shaded area = sprayed area

Third Spray
Date: 14/08/81
Wind direction: W-SW
Wind speed: 0-8 km/hr.

● Sampling Stations: E1-F6

Scale 0 m 5 m 100 m

Herbicide Deposit Sampling Apparatus

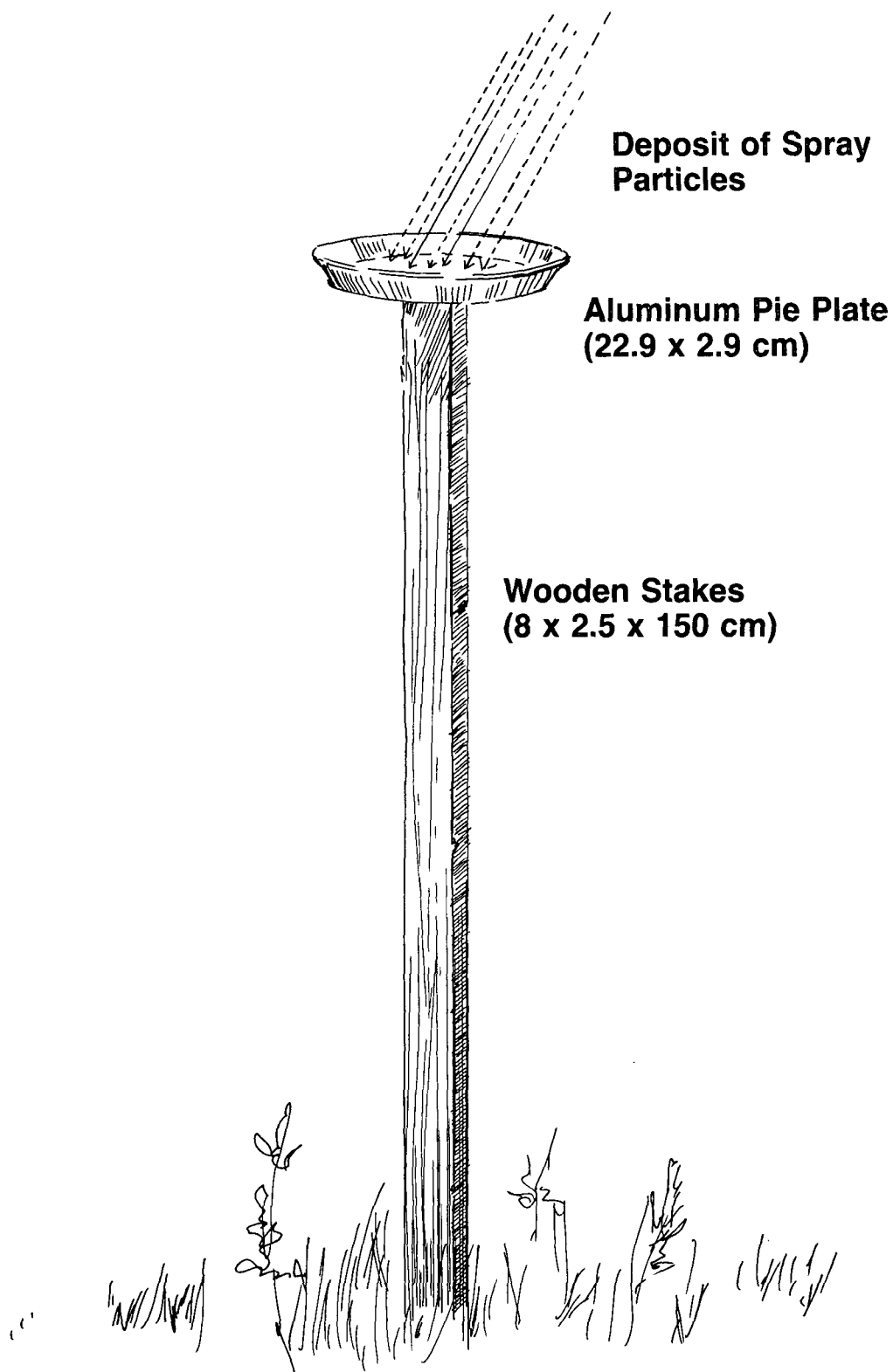


FIGURE 3

TABLE 1

METEOROLOGICAL AND SPRAY CONDITIONS DURING APPLICATION

	SITE I	SITE II	SITE III
Spray Date	25/07/81	26/07/81	14/08/81
Temperature (°C)	17.5	10.2	13.5
Relative Humidity (%)	68	91	83
Barometric Pressure (mm Hg)	1007.3	1009.5	1005.0
Dew Point (°C)	11.5	8.5	10.7
Wind Direction	W-SW	N-NW	W-SW
Wind Speed (km/hr)	0-8	8-16	0-8
Sky Conditions	clear	clear	overcast
Time Spray Initiated	2030	0700	0810
Time Spray Completed	2045	0732	-
Precipitation During Spray	0	0	0

3. RESULTS

The results of the deposit sample analysis are presented in Table 2. With the exception of transect C at Site II, the collected mean deposit was greater at the two stations within the spray blocks than the stations outside the spray blocks. The deposit generally decreased with distance from the spray block, but the pattern was inconsistent. This trend of decreasing deposit with distance is most evident in the tabulated data from Site I, where little vegetation obstructed the path of drift from aircraft to samplers. The mean deposit within the treatment area expressed as percent of amount emitted (theoretical) and the mean deposit outside the treatment area expressed as percent of mean deposit inside the treatment area are given in Tables 3 and 4 respectively.

TABLE 2
MEASURED HERBICIDE FROM DEPOSIT SAMPLERS

STATION	2,4-D DEPOSIT (ug/cm ²)	2,4,5-T DEPOSIT (ug/cm ²)	STATION	2,4-D DEPOSIT (ug/cm ²)	2,4,5-T DEPOSIT (ug/cm ²)
<u>First Spray (Aerial-Low Adjacent Vegetation)</u>					
<u>Inside Treatment Area</u>					
A 1	0.0063	0.0046	B 1	0.44	0.46
A 2	10	10	B 2	3.7	3.4
<u>Outside Treatment Area</u>					
A 3	0.073	0.076	B 3	0.12	0.10
A 4	0.18	0.19	B 4	0.044	0.044
A 5	0.017	0.014	B 5	0.041	0.039
A 6	0.016	0.016	B 6	0.027	0.024
<u>Second Spray (Aerial-High Adjacent Vegetation)</u>					
<u>Inside Treatment Area</u>					
C 1	LO.0012	LO.0012	D 1	1.7	1.7
C 2	LO.0012	LO.0012	D 2	0.0083	0.0088
<u>Outside Treatment Area</u>					
C 3	0.0024	0.0029	D 3	0.015	0.015
C 4	LO.0012	LO.0012	D 4	0.0016	0.0019
C 5	LO.0012	LO.0012	D 5	0.0020	0.0021
C 6	LO.0012	LO.0012	D 6	0.0085	0.0090
<u>Third Spray (Ground-Low Adjacent Vegetation)</u>					
<u>Inside Treatment Area</u>					
E 1	0.54	0.56	F 1	0.59	0.76
E 2	0.49	0.51	F 2	0.027	0.032
<u>Outside Treatment Area</u>					
E 3	0.0049	0.0044	F 3	0.0023	0.0020
E 4	0.0083	0.0071	F 4	0.0012	0.0014
E 5	0.0041	0.0029	F 5	0.0085	0.0054
E 6	0.010	0.0053	F 6	0.0056	0.0034

TABLE 3

MEAN DEPOSIT WITHIN THE TREATMENT AREA EXPRESSED
AS PERCENT OF THEORETICAL AMOUNT EMITTED

	THEORETICAL EMITTED DOSE	MEAN MEASURED DEPOSIT INSIDE TREATMENT AREA	% THEORETICAL EMITTED DOSE MEASURED AS DEPOSIT IN TREATMENT AREA*
First Aerial Spray	3,360 g/ha	7.0 ug/cm ²	21%
Second Aerial Spray**	3,360 g/ha	1.7 ug/cm ²	5.1%
Ground Spray	5,380 g/ha	0.9 ug/cm ²	1.7%

* % Theoretical Emitted =
Dose Measured as
Deposit in Treatment
Area

$$100 \times \frac{\text{Mean Measured Deposit Inside Treatment Area}}{\text{Theoretical Emitted Dose}}$$

** Calculations are for D transect only. C is omitted due to the lack of detectable results.

TABLE 4

MEAN DEPOSIT OUTSIDE THE TREATMENT AREA EXPRESSED AS PERCENT OF MEAN DEPOSIT INSIDE THE TREATMENT AREA

	FIRST AERIAL SPRAY	SECOND AERIAL SPRAY*	GROUND SPRAY
Mean Deposit Inside (ug/cm ²) the Treatment Area	7.0	1.7	0.9
% Deposit	100	100	100
Mean Deposit 50 m (ug/cm ²) Outside the Treatment Area	0.18	0.03	0.0068
% Deposit	2.6	1.8	0.76
Mean Deposit 100 m (ug/cm ²) Outside the Treatment Area	0.23	0.0035	0.0090
% Deposit	3.3	0.21	1.0
Mean Deposit 150 m (ug/cm ²) Outside the Treatment Area	0.056	0.0041	0.010
% Deposit	0.8	0.24	1.1
Mean Deposit 200 m (ug/cm ²) Outside the Treatment Area	0.042	0.018	0.012
% Deposit	0.6	1.1	1.3

$$\% \text{ Deposit} = 100 \times \frac{\text{Mean Deposit on Plate}}{\text{Mean Deposit Inside the Treatment Area}}$$

* Calculations are for D transect.

4. DISCUSSION

Suggested estimates of off-target losses from aerial applications have ranged from over 60% (NRC, 1978), to 40-50% (Medved, 1972), to as little as 10% immediately downwind of the spray swath (Akesson and Yates, 1981).

The estimates which have been made for off-target losses during ground applications are somewhat smaller, ranging from less than 3% (Maybank, 1973) to 10-30% (NRC, 1978; Grover et al., 1972).

The results obtained in this study indicate that a major portion of the emitted dose may not be deposited within the spray block. As denoted in Table 3, the measured mean percent deposits within the treatment area expressed as a percentage of the theoretical amount emitted for the three spray operations were 21%, 5.1%, and 1.7%. However, there are a number of unquantifiable factors which should be recognized during the interpretation of these results. First, since the recoveries of the deposit plates were not measured, the loss attributable to sample collection and analytical errors cannot be estimated accurately. Recovery efficiencies from deposit plates were obtained in the laboratory using 2,4-D and 2,4,5-T acid standards (Appendix II), however, the ester formulations used in the field may behave much differently. It is possible that a considerable amount of the herbicide deposit on the sampling plates may have been lost due to herbicide volatilization. Second, deposition may not have been uniform, in which case a number of the samplers in the spray block might not have received direct coverage. Third, since the ground application technique involved considerable operator control in directing the spray, there may have been an intentional or subconscious effort to direct the spray away from the conspicuous deposit samplers. This would help to explain the anomalous observation that spray deposit was much less in the ground application treatment area than in that of the aerial application.

Finally, since these observations were made during operational spray programs and the calibration of the delivery equipment was not monitored, it is possible that theoretical calculated dose rates may not be reflective of actual dose rates.

Comparisons of the mean measured deposit outside the treatment area with mean measured deposit inside the treatment area (Table 4) eliminate the unquantifiable factors of recovery efficiencies and equipment calibration, assuming they are constant within a spray event, and provide a reasonable indication of the amount of drift within the 200 m zone outside the treatment area.

Spray drift has been demonstrated to be a combination of both particulate drift and vapour cloud drift (Warren, 1976). The volatilization of pesticide droplets is a function of meteorological conditions such as relative humidity and temperature (Gratkowaki, 1975). Volatilization may be expected to occur during the droplet journey from application vehicle to ground and continue after deposition. As particulate drift is primarily due to wind speed and fall distance (Warren, 1976), ground applications should result in considerably less drift than aerial application. Mean deposits outside the treatment area expressed as a percentage of mean deposit inside the treatment area do not vary appreciably between ground and aerial application. Therefore, it cannot be concluded from this study that aerial application results in greater deposit outside the treatment area than ground application. This may be partially due to the previously mentioned factors of variable operator control and calibration.

5. RECOMMENDATIONS

In order to obtain generalized interpretations of deposit within and drift outside the treatment area during herbicide applications, a number of modifications should be incorporated in future experimental design. It is recommended that:

- (a) The efficiency of the deposit apparatus as a collection vehicle be evaluated. This would permit extrapolation of the deposit data to model deposition in natural foliage.
- (b) The sample size, in terms of number of collectors, be greatly increased in order to reduce variability of results.
- (c) The calibration of the spray equipment be assessed prior to application to ensure that actual deposit is equivalent to theoretical deposit.

REFERENCES

- Akesson, N.B. and W.E. Yates, 1981. Drift Loss Control: Anything New? Aerial Applicator. 19(9) 4-5.
- American Public Health Association, 1975. Standard Methods for Examination of Water and Wastewater. 14th Edition. Washington.
- Bovey, R.W., L. Young, 1980. The Science of 2,4,5-T and Associated Phenoxy Herbicides. John Wiley and Sons, Inc. Canada.
- Gratkowski, H., 1975. Silvicultural Use of Herbicides in Pacific Northwest Forests. USDA Forest Service General Technical Report PNW-37, 44 pp.
- Grover, R., L.A. Kerr, 1978. Evaluation of Silica Gel and XAD-4 as Absorbents for Herbicides in Air. J. Envir. Sci. Health, B 13 (3), 311-321.
- Maybank, J., 1973. Physical Aspects of Pesticide Mass Balance in the Atmosphere. In Pesticide Accountancy Workshop, NRCC AFA Tech. Rep. #13.
- Maybank, J., K. Yashida, R. Grover, 1974. Droplet Size Spectra, Drift Potential, and Ground Deposition Pattern of Herbicide Sprays. Can. J. Plant Sci., 54: 541-546.
- Medved, L.I., 1972. Circulation of Pesticides in the Biosphere. Pure Appl. Chem., 42 (1-2): 119-128.

National Research Council, 1978. Phenoxy Herbicides - Their Effects on Environmental Quality. NRCC No. 16075.

Warren, L.E., 1976. Controlling Drift of Herbicides. The World of Agricultural Aviation, Parts 1-5, March-June.

APPENDIX I

Sample Analysis

Analysis was performed according to the method of the American Public Health Association (1975), with some modifications.

Deposit samples were transferred to round bottom flasks containing 2 mL 37% potassium hydroxide. Fifteen mL distilled water and solvent rinsed boiling chips were added. The flask was fitted with a three-ball Snyder column and placed in a steam bath (70-80°C) for one hour to hydrolyze the solution and to remove the solvents. The concentrate was transferred to a 60 mL separatory funnel and washed with 2 x 20 mL benzene. The concentrate was then acidified with cold sulphuric acid until a pH of less than 2.0 was obtained.

The solution was extracted with 20 mL benzene, followed by two additional extractions with 10 mL benzene. The benzene layers were combined and dried with anhydrous sodium sulfate. After standing for 10 minutes, the solution was filtered and concentrated to approximately 10 mL on a rotovap. After transfer to a 15 mL centrifuge tube, the extract was concentrated to 0.25 mL under a stream of dry nitrogen.

The extract was esterified by addition of 2 mL diazomethane to the solution, which was then placed in a warm bath for 30 minutes to ensure complete reaction. Following this, 2 mL hexane were added and the contents reduced to 1 mL under nitrogen. This was repeated with two 5 mL aliquots of hexane.

Columns were extracted four times with 30 mL diethyl ether into an evaporating flask containing 2 mL 37% KOH solution. The columns were then extracted with 2 x 30 mL 0.5 N KOH in 20% methanol. The resultant mixture was acidified to pH less than 2 with a 50 mL aliquot of 0.1 M H₂SO₄ and extracted with 2 x 50 mL diethyl ether. These extracts were then added to the initial ether extracts. Hydrolysis and esterification were as described for the deposit sample.

A Tracor gas chromatograph (GC) equipped with a Hall conductivity detector was utilized for sample analysis. Operating parameters were as follows:

- Glass column: 1.8 m x 64 mm, 3%-OV-17
- Carrier gas: helium
- Injection volume: 5 uL
- Voltage: 4
- Sensitivity: 3
- Hydrogen flow rate: 50 mL/min
- Temperature (oven): 925°C
- Temperature (column initial): 190°C
- Solvent: hexane
- Retention times - 2,4-D: 3.2 min.
- 2,4,5-T: 5.4 min.

Two sample injections were followed by two standard injections, and mean peak heights were used in calculations. The detectable limits of the GC were determined to be 0.5 ug/extract (1.2×10^{-3} ug/cm² for deposit samples).

APPENDIX II

Laboratory Percent Recovery

Deposit plates were spiked with 2,4-D and 2,4,5-T acid standards. Following a one hour time period, the standards were extracted and analyzed according to the above procedure. For the two recovery experiments conducted, the following percent recoveries were obtained: 2,4,5-T - 88.4% and 88.7%; 2,4-D - 90.0% and 94.3%.