HELICOPTER SPRAY TRIAL WITH SEVIN XLR (CARBARYL), TULARE COUNTY 1982

ENVIRONMENTAL HAZARDS

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HELICOPTER SPRAY TRIAL WITH SEVIN XLR (CARBARYL), TULARE COUNTY 1982

by

R. Segawa, D. Weaver, R. Sava,
J. Marade, R. Oshima

Field Monitoring:	D. Weaver, L. Neher, T. Mischke, R. Sava, R. Segawa, F. Zalkin, M. Wilkerson, J. Franz, S. Simpson, D. Duncan, J. Marade, C. Garretson, J. Pratt, V. Bunac, J. Young, K. Bagley
Sampling Methods:	T. Mischke, J. Franz, B. Winters, V. Bunac
Chemical Analysis:	CDFA Chemistry Laboratory
Programming and Graphics:	T. Arnold, D. Sheeks, L. Neher
Statistics:	F. Zalkin, T. Younglove, M. Wilkerson

Environmental Hazards Assessment Program
California Department of Food and Agriculture

ABSTRACT

A helicopter spray trial with Sevin XLR (carbaryl) was conducted on a 14 acre area with dense oak, and other scattered trees. Sevin was applied from two altitudes, 180 and 50 feet above the tree tops. Samples were taken to determine mass deposition, particle sizes, and air concentrations of carbaryl; in the foliage canopy, on open ground, and downwind of the spray area.

Results for the two altitudes were similar in most respects. Mass deposition and volumetric median diameter of spray droplets on open ground was 3176 $\mu g/ft^2$ and 546.3 microns (μ) ,respectively for the 180 ft. altitude, and 3430 $\mu g/ft^2$ and 392.1 μ for the 50 ft. altitude. Canopy penetration of spray into tree canopies was also similar for both altitudes. Both showed that effective mass deposition of carbaryl was achieved, but that the droplets were too large and the droplet density too low, for the carbaryl to be efficacious against gypsy moth. Only 2 of the 1221 drops measured in the canopy were in the desired range of $<100\ \mu$. The highest droplet density measured for any site was 0.64 drops/cm^2. Air concentrations within and downwind of the spray area were very low for both altitudes, ranging from none detected to 7.95 $\mu g/m^3$.

This trial established that significant mass deposition of carbaryl can be obtained at higher elevations, but only by sacrificing effective coverage and droplet size.

ACKNOWLEDGMENTS

We are indebted to the Tulare County Agriculture Commisioner's staff, especially Ernie Crew and Lynn Thomas, for their assistance and cooperation.

Thanks is extended to Dr. Norman Akesson, University of California, Davis for his assistance in determining helicopter configurations.

DISCLAIMER

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I. INTRODUCTION

This report describes the second helicopter spray trial with carbaryl conducted by the Environmental Hazards Assessment Program (EHAP), and was designed to provide a more comprehensive data base than the first (3). The current study was conducted in a larger spray area, and with better weather conditions than the first. In addition, more emphasis was placed on determinining canopy penetration, and pesticide release at an altitude representative of an urban environment. Aerial applicaton of pesticides over urban areas must be made from higher altitudes than those used over agricultural areas because of safety considerations.

The specific objective of the study was to determine the efficacy of a potential gypsy moth aerial pesticide application over an urban location. Carbaryl deposition characteristics in terms of particle sizes, mass deposition, and air concentrations were compared for applications from two different altitudes. The first application was made from an altitude considered minimal for urban areas (180 ft. over tree tops), and the second from an altitude considered optimal (50 ft. over tree tops) for treatment efficacy. Helicopter configurations were chosen to maximize mass deposition from each altitude. The sampling scheme for the entire study can be found in the protocol (Appendix A).

II. STUDY SITE DESCRIPTION

The study was conducted in a county park located in Tulare County, California on November 10, 1982. A 14 acre (approx. 750 x 800 ft) section of the park, chosen as the treatment area, contained several mature valley oaks ranging from 40 to 75 feet tall and some scattered pine, sequoia, and mulberry trees. Grass sod covered the grounds which were mostly level or gently rolling.

III. WEATHER INFORMATION

Moderate to heavy rainfall occurred on the day before and during the pre-dawn hours on the day of the spray applications. However, shortly after sunrise the weather began to slowly clear.

A WeatherMeasure weather monitoring system was set up on a road located southeast of the treatment area and was used to record wind direction and speed during the entire day.

IV. FORMULATION AND APPLICATION OF CARBARYL SPRAYS

Sevin XLR (carbaryl, 43.4 % active ingredient by weight), was mixed with water and applied from two altitudes. Rhodamine B dye was added to the tank to allow for automated droplet quantification. Samples of the tank mixes were taken from the spray boom after each of the two spray applications.

All applications were made using a Bell 204 helicopter equipped with a 45 foot spray boom. The first spray was applied from an altitude of 180 ft. above tree top level (ca 250 ft. above ground level).

Forty gallons of carbaryl mixture was prepared at a concentration of 1 quart of XLR formulation in 7 quarts of water. The mixture was applied at the rate of 2 gallons per acre using 27 #8010 nozzles with a boom pressure of 45 p.s.i. and air speed of 70 mph. Five passes flying from east to west were required to cover the treatment area.

It was noted that water used to adjust the boom pressure was still in the boom when the first pass was made so that water, and not the carbaryl mixture, was sprayed during the first 400 ft. of the first pass. Additionally, after the spray was completed, one of the nozzles was found to have been leaking excessive amounts of spray mixture.

The second spray was made from an elevation of 50 ft. above tree top height (approximately 120 ft. above ground level). Sevin XLR was prepared at a concentration of 1 quart in 3 quarts of water. This was applied at the rate of 1 gallon per acre using 49 #8004 nozzles with the boom pressure adjusted to 25 p.s.i. Seven passes were made over the spray area, again flying from east to west.

Nozzle specifications on application rate were selected based on the recommendations of Dr. Norman Akesson, U.C. Davis.

V. MATERIALS AND METHODS

A. GENERAL

Each sample collected was accompanied by a chain of custody form documenting the sequence of transfers from sample preparation to chemical analysis (Appendix B). Each individual who handled the sample was required to sign and date the form; it was also designed for recording sampling data and results of chemical analyses.

All sampling was performed on 10 November. The spray application and sampling from 180 ft. began at 1250 hours. Application was completed at 1305 hours. Sampling was terminated at 1335 hrs., and sample pickup began immediately afterwards. The application from 50 ft. was made between 1600 and 1615 hours and sample pickup began 30 minutes later.

Samples collected for chemical analysis were cooled on wet ice (water, leaf, tank) or frozen on dry ice (air, mass deposition) immediately after collection. All chemical analyses were performed by the Chemistry Laboratory Services Unit of the California Department of Food and Agriculture at the Unit's main laboratory in Sacramento.

B. MASS DEPOSITION AND PARTICLE SIZE

Twenty-five sampling sites within the spray area were established to characterize ground level mass deposition and

particle sizes. The sites were organized in a 5 x 5 matrix, with approximately 100 ft. between each sample site (Figure 1).

At each site an 18 x 18 inch cardboard sheet was elevated 18 inches above the ground on wooden stakes. The cardboard was covered with waxed paper to provide a clean surface for each flight. A 14.5 x 10 inch sheet of plastic backed absorbant paper was attached to each board just prior to spraying and collected 30 minutes after spraying was completed. Results from the analyses of these sheets were used to calculate mass fallout of carbaryl per unit area.

One 4 x 5 inch Kromekote card was also attached to each board and collected with the absorbant paper. The cards were analyzed to determine the numbers and sizes of spray droplets at each location.

C. AIR AND DOWNWIND DRIFT

Three air sampling sites were established within the spray area. At each of the sites, three modified General Metal Works high-volume air samplers (HiVols) were set up. Each HiVol was equipped with a Kurz Instruments constant flow controller, calibrated at 40 cubic feet per minute. All air samplers were operated during the spray period plus 30 minutes following the application. The air samplers located within the spray area were protected from direct application by a shelter roof or by placement inside a covered area.

River

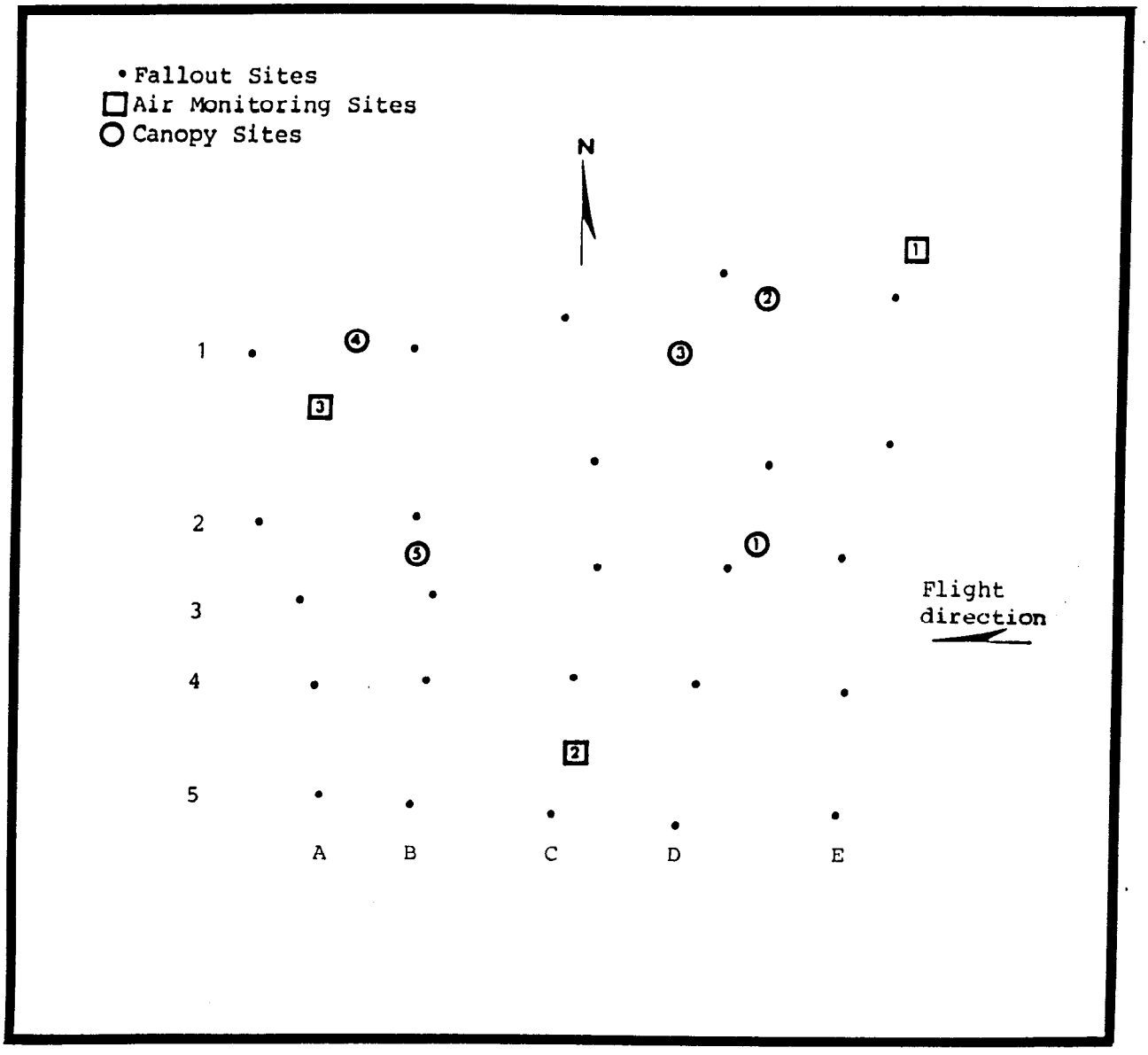

Figure 1. Ground level matrix site locations within the 14 acre spray area (1" = 40m). Reference codes for locations of fallout sites shown on the sides of the matrix, rows (1-5) and columns (A-E).

The three HiVols at each site had different sampling media, each designed to collect different constituents of airborne carbaryl. One of the HiVols employed a dual stage cascade impactor. This would separate the carbaryl particles into two fractions, particles with diameters less than 3.5 μ and greater than 3.5 μ. Due to a shortage of equipment, site #1 was not equipped with a cascade impactor. The second HiVol was equipped with an 8 x 10 inch glass fiber filter (GFF) as a sampling medium to collect total suspended particulates. The third HiVol air sampler was mounted with a glass cartridge packed with 125 ml of pre-cleaned XAD-2 macroreticular resin, an adsorbant material which traps gas phase carbaryl.

A background sample was taken at all five locations by running the XAD-2 resin samplers for 40 minutes before each of the sprays. Additionally, during the time between the background for the second spray (50 ft.), and the second spray application sample a jar containing XAD-2 resin was unpackaged and placed adjacent to the resin jar already mounted on the HiVol. This was done at sites #3 and #4 in order to detect any carbaryl that might have been adsorbed by the resin in the interim between the background sample for the 50 ft. application and the spray sample for the 50 ft. application.

Two downwind drift sites were established outside the spray area. Each site was equipped with three HiVols, an absorbent sheet, and two Kromekote cards as described previously. When the

test area was sprayed from the 180 ft. elevation, the two downwind sites were located north of the spray area at distances of 80 and 550 meters from the spray area (sites 4 & 5, Figure 2). Due to a change in wind direction prior to the 50 ft. spray, the downwind sites were moved to new locations south of the spray area. The furthest site was located 310 meters downwind, but the closest site was inadvertently placed in the flight path of the helicopter (sites 4A & 5A).

D. WATER SAMPLES

Water samples were collected in one liter amber glass bottles, from the river's edge at a location approximately in the middle of the spray area's northern boundary (Figure 2). Duplicate water samples were collected prior to any spraying and immediately after the helicopter completed spraying for both the 180 ft. and 50 ft. applications. All samples were collected from the first 2 inches of water depth and 2 ft. from the river bank.

E. CANOPY PENETRATION

Cardboard boxes (9 x 12 x 9.5 inches) were used as supports for sample collection materials to determine canopy penetration. One 4 x 5 inch Kromekote card and one 4 x 9 inch piece of plastic backed absorbant paper were stapled onto the top and each of the four vertical sides of the boxes. The top and sides of the box were numbered 1 through 5 for later identification. A piece of

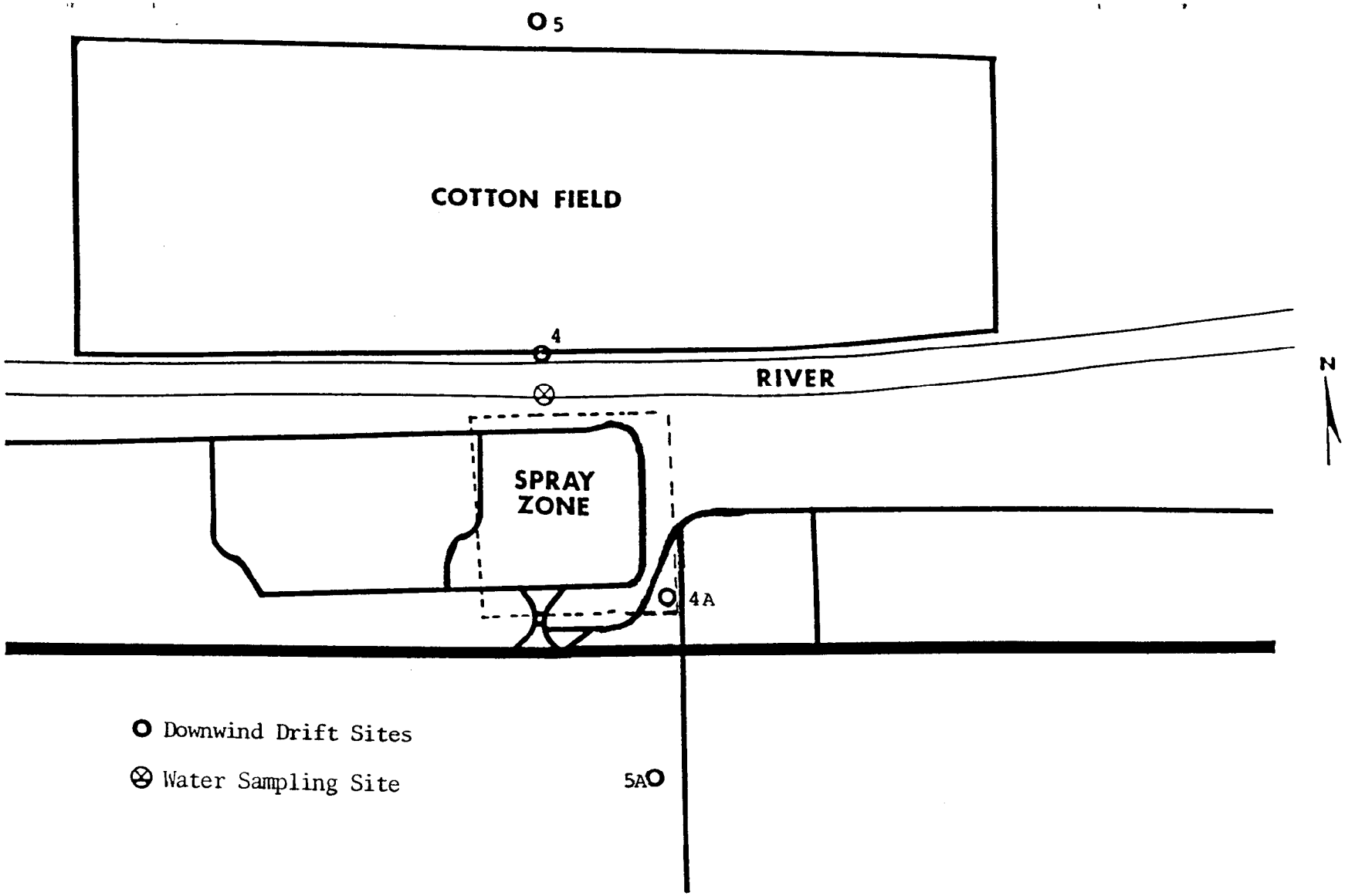

Figure 2. Drift sample site locations outside the spray area (1 in. = 200 m). Sites 4 and 5 were used during the 180 ft. flight and sites 4A and 5A were used during the 50 ft. flight.

twine 2 ft. long was attached to each of the four corners to serve as a means of securing the box in the tree. Sample boxes were sealed in plastic bags until ready for use. The boxes were oriented so that the top (side 1) was parallel to the ground and side 2 faced east, the direction from which the spray helicopter was to approach. Five sites were chosen for canopy penetration, three "tree and understory" sites (#2, #3, #5) and two "brush" (#1, #4) sites (Figure 1).

TREE SITES- Three mature Valley Oaks ranging from approximately 65 to 75 ft. in height were selected for use as "tree sites". Three boxes were placed in each tree site. One box was placed 5 to 10 ft. below the uppermost part of the canopy, one was placed at mid-height, and the third box was placed in the lower quarter of the canopy, 10 to 15 ft. above ground.

UNDERSTORY- An "understory" site was located on the ground near the trunk of each tree site. The purpose was to simulate shrubs that might be growing beneath trees. Branches 3 to 5 ft. long were cut from willows growing along the river and arranged in a 5 gallon bucket to form a dense bush. One sample box was placed towards the center of the bush.

BRUSH SITES- Two pine trees approximately 12 ft. tall and 8 ft. in diameter at the base of the canopy were used as "brush" sites. Both trees were growing out in the open away from other trees. One sample box was placed in each tree approximately 7 ft. high and midway from the outer edge of each tree.

LEAF SAMPLES- Leaf samples were collected from within a 5 ft. radius of the box from each of the three height locations at canopy site #3. Samples consisting of 15 leaves were taken 30 minutes before the first spray and within 45 minutes after each of the two sprays. A pair of pruning shears were rinsed with methanol before each sampling and then used to clip off leaves from the terminal 6 inches of small branches in the canopy. The leaves were dropped into a tared glass sample jar (foil-lined cap). The jar was then weighed a second time to determine the fresh weight of the leaf sample and then kept at 4° C until the leaves were analyzed.

VI. RESULTS

A. WEATHER

During the 180 ft. flight the wind was blowing approximately five miles per hour from the south (Figure 3). The temperature was 14° C and relative humidity 58%. Before the 50 ft. flight the wind shifted 180° and was blowing at one mile per hour from the north during application (Figure 4). The temperature and relative humidity were 12° C and 71%.

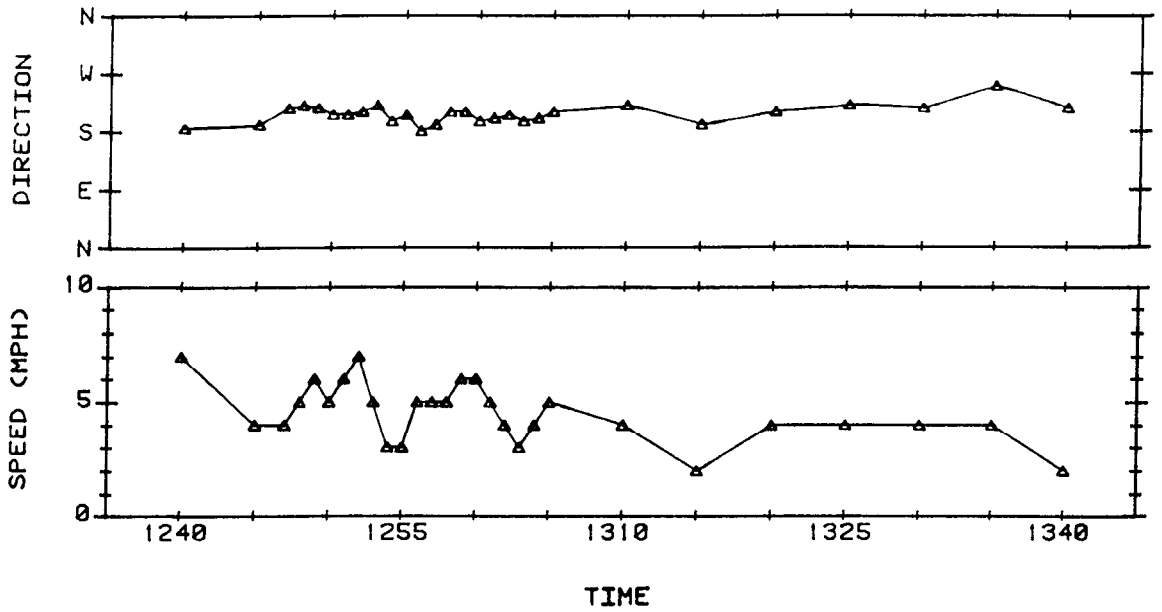

Figure 3. Wind speed and direction during flight 1 (180 ft.).

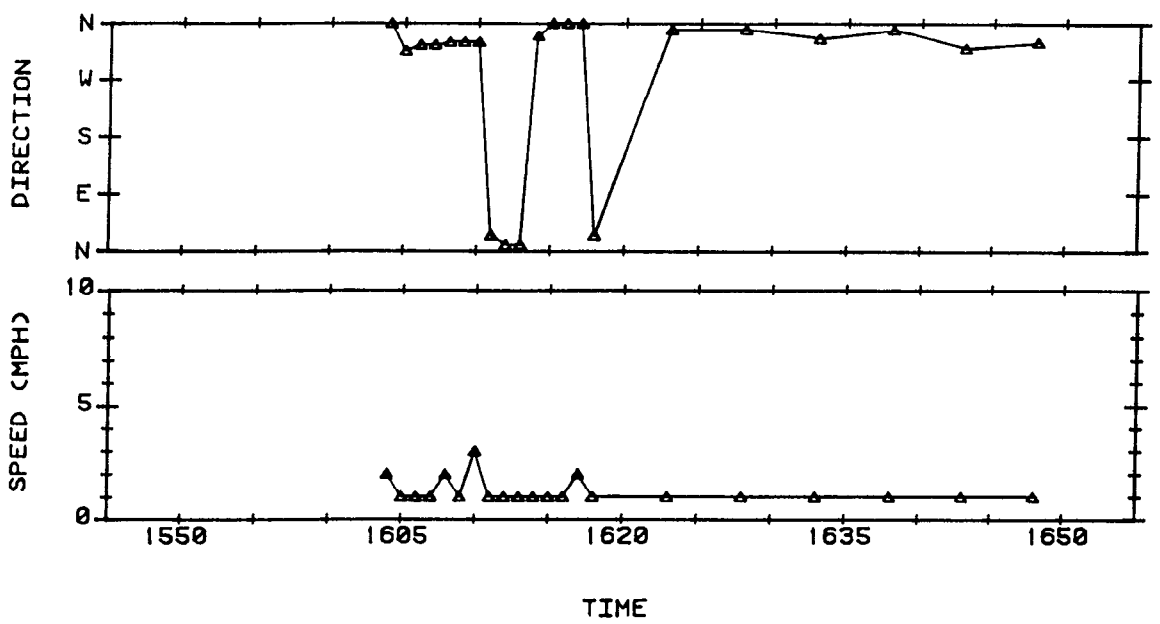

Figure 4. Wind speed and direction during flight 2 (50 ft.).

B. TANK SAMPLES

Results of the tank samples are shown below. The theoretical values of the tank mix for the 180 ft. and 50 ft. flights were determined by calculating the concentration of 1 quart of Sevin XLR in 2 gallons of mixture, and 1 quart of XLR in 1 gallon of mixture, respectively. Since the actual concentrations are less than the theoretical values, the amount of mass fallout would be decreased by the same proportion.

	Concentrations of Carbaryl (% wt:wt)		
Flight(ft)	Actual	Theoretical	% Theoretical
180	3.62	5.93	61.0
50	8.41	11.71	71.8

C. MASS DEPOSITION AND PARTICLE SIZE

Mass deposition at individual sites within the spray area was quite variable (Tables 1 & 2, Figure 5). However, the averages across the flight path (numbered) and along the flight path (lettered) were much more uniform. The range of values for the 180 ft. flight was 100 to 9900 micrograms per sq. ft., with an average of 3176 $\mu g/ft^2$(50% of theoretical). For the 50 ft. flight the range was 70 to 7000 $\mu g/ft^2$ with an average of 3430 $\mu g/ft^2$(46% of theoretical). Statistical analysis (Analysis of Variance) of the data did show a significant difference in mass deposition across the flight path. Data for the 50 ft. flight

Table 1. Mass deposition ($\mu g/ft^2$) of carbaryl from the ground level 5 x 5 matrix for flight 1 (180 ft)

Location	A*	B	C	D	E	Avg.
1	3400	9900	5600	4800	3900	5520
2	4050	6200	4700	2000	1500	3690
3	3400	3900	4700	2500	2450	3390
4	100	400	2500	2100	900	1200
5	1400	750	1200	1150	5900	2080
Avg.	2470	4230	3740	2510	2930	3176

* Individual values from locations in Figure 1.

Table 2. Mass deposition ($\mu g/ft^2$) of carbaryl from the ground level 5 x 5 matrix for flight 2 (50 ft)

Location	A*	B	C	D	E	Avg.
1	1800	3250	3100	70	1700	1984
2	2400	5400	540	2200	2200	2548
3	4300	5400	4400	4350	5600	4810
4	3600	7000	3600	6400	4800	5080
5	4900	2400	2900	2150	1300	2496
Avg.	3400	4690	2908	3034	2886	3430

*Individual values from locations in Figure 1.

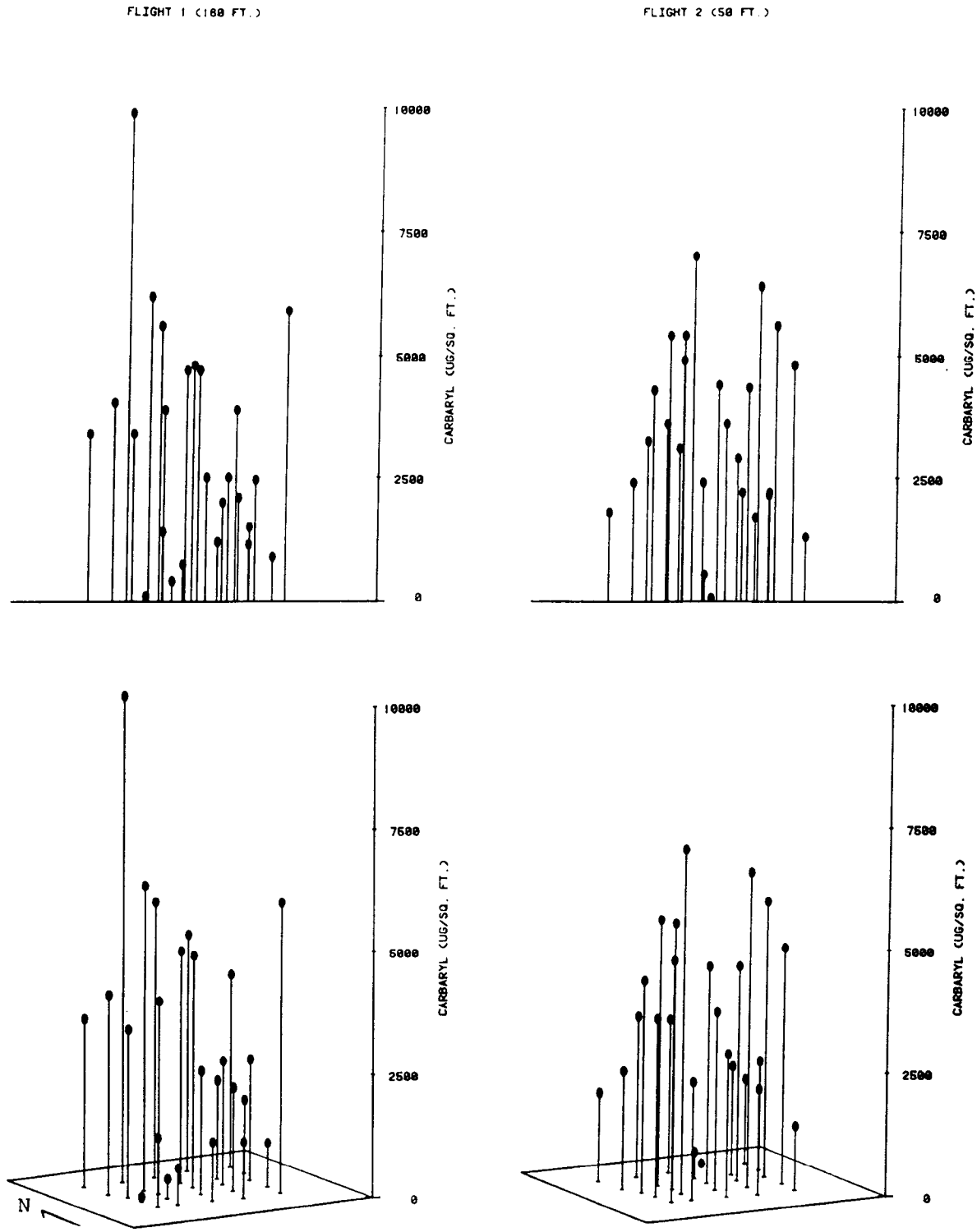

Figure 5. Mass deposition (μg/ft^2) of carbaryl from the ground level 5x5 matrix

shows the expected trend, higher levels in the middle, and lower levels at the edges of the spray area. For the 180 ft. flight the higher levels on the north side of the spray are probably due to wind. There was no significant difference in mass deposition along the flight path.

The particle size data shows that most of the mass was contained in a small number of relatively large droplets (Tables 3 & 4). The median particle diameter for the 180 ft. flight was 546.3 microns, but the droplets smaller than the median accounted for less than 3% of the mass. The same pattern was observed for the 50 ft. flight. The particles smaller than the median of 392.1 microns accounted for less than 5% of the mass. Additionally, only 1.05% of the droplets were in the desirable size range (less than 150 μ) and these accounted for 0.07% of the mass.

Swath width data was not obtained because of poor weather conditions the following day.

D. AIR AND DOWNWIND DRIFT

No results are reported on the dual stage cascade impactor or the 8 x 10 inch GFF samples. These two sampling media were analyzed for Rhodamine B dye and the sensitivity of the test failed to show the presence of any dye (detection limit = 4.4 ug/m^3).

Table 3. Droplet size characteristics from the ground level 5 x 5 matrix for flight 1 (180 ft).

Size Range Limit (μ)	Volumetric[a/] Mean Diameter (μ)	Number of Droplets	Droplet[b/] Density (no/cm^2)	Cumulative Droplet Density (no/cm^2)	Percent Number	Cumulative Percent Number	Calculated[c/] Mass Carbaryl (μg)	Calculated Percent Mass	Cumulative Percent Mass
75									
	94.38	0	0.00	0.00	0.00	0.00	0.0	0.00	0.00
108									
	132.33	8	0.017	0.017	0.89	0.89	0.4	0.00	0.00
150									
	186.81	14	0.029	0.046	1.56	2.46	1.8	0.01	0.01
213									
	263.67	79	0.163	0.209	8.83	11.28	27.7	0.11	0.12
300									
	372.32	156	0.322	0.531	17.43	28.72	154.1	0.60	0.72
424									
	526.70	169	0.349	0.880	18.88	47.60	472.7	1.85	2.57
600									
	745.29	230	0.475	1.355	25.70	73.30	1822.8	7.14	9.71
849									
	1051.78	114	0.236	1.591	12.74	86.03	2539.3	9.94	19.65
1197									
	1485.72	74	0.153	1.744	8.27	94.30	4645.9	18.19	37.84
1692									
	2101.60	30	0.062	1.806	3.35	97.65	5330.9	20.87	58.71
2394									
	2971.44	21	0.043	1.849	2.35	100.00	10547.4	41.29	100.00
3384									

a/ Calculation made by converting size range limits to volumes and obtaining the mean volumetric diameter
b/ Calculation based on the distribution of the total population, sized from 25 collection cards.
c/ Mass in micrograms carbaryl, calculated using the volumetric mean diameter and 1.01 g/ml density carbaryl, applied to the mix ratio of 3.62% carbaryl in water.

Table 4. Droplet size characteristics from sample sites within the ground level 5 x 5 matrix for flight 2 (50 ft).

Size Range Limit (μ)	Volumetric[a/] Mean Diameter (μ)	Number of Droplets	Droplet[b/] Density (no/cm^2)	Cumulative Droplet Density (no/cm^2)	Percent Number	Cumulative Percent Number	Calculated Mass Carbaryl (μg)	Calculated[c/] Percent Mass	Cumulative Percent Mass
75									
	94.38	0	0.000	0.000	0.00	0.00	0.0	0.00	0.00
108									
	132.33	11	0.023	0.023	1.05	1.05	1.1	0.01	0.01
150									
	186.81	43	0.089	0.112	4.10	5.15	12.6	0.07	0.08
213									
	263.67	175	0.362	0.474	16.70	21.85	144.1	0.81	0.89
300									
	372.32	264	0.546	1.020	25.19	47.04	612.0	3.44	4.33
424									
	526.70	242	0.500	1.520	23.09	70.13	1588.2	8.93	13.26
600									
	745.29	231	0.477	1.997	22.04	92.18	4295.2	24.15	37.40
849									
	1051.78	67	0.138	2.135	6.39	98.57	3501.4	19.68	57.08
1197									
	1485.72	9	0.019	2.154	0.86	99.43	1325.7	7.45	64.54
1692									
	2101.60	1	0.002	2.156	0.10	99.52	416.9	2.34	66.88
2394									
	2971.44	5	0.010	2.166	0.48	100.00	5892.0	33.12	100.00
3384									

a/ Calculation made by converting size range limits to volumes and obtaining the mean volumetric diameter.
b/ Calculation based on the distribution of the total population, sized from 25 collection cards.
c/ Mass in micrograms carbaryl, calculated using the volumetric mean diameter and 1.02 g/ml density carbaryl, applied to the mix ratio 8.41% carbaryl in water.

Data for carbaryl collected on XAD-2 resin at all sites and both spray elevations are presented in Table 5. Of the three air sampling sites within the spray area only site #3 employed a self-contained shelter to protect the resin sampler from direct spray (approx. 18" square). Site #1 and #2 were placed under large roofs inside picnic areas (minimum 10' wide). The large roofs afforded significantly more protection from spray than did the self-contained shelter tops. The data shows a difference in carbaryl concentration at each site relative to wind speed and direction at time of application. For the first application site #1, located at the northern border of the spray area, showed a higher concentration than site #2, located at the southern border of the spray area. This trend was reversed for the second application when the wind shifted to the south. Minimum detection limit for the air samples was 0.098 ug/m^3.

Pesticide drift for the 180 ft. flight was minimal. At site #4 gas phase carbaryl was 0.199 $\mu g/m^3$, and mass deposition was 17 $\mu g/ft^2$. Only 8 particles were collected at this site, all between 213 μ and 600 μ. No carbaryl was detected at the furthest site, #5.

Drift from the 50 ft. flight was unaccountably higher than the 180 ft. flight. Site #5 had an air concentration of 4.52 $\mu g/m^3$and the mass deposition was 125 $\mu g/ft^2$. No data was obtained from site #4 because of misplacement of the site.

Table 5. Air concentrations of carbaryl from the ground level 5 x 5 matrix and downwind drift sites

	Concentration of Carbaryl ($\mu g/m^3$)				
Location[a/]	1030-1110[b/] Background	1250-1330 Spray (180')	1405-1445 Background	1450-1600 Background	1600-1640 Spray (50')
1	0.0[c/]	0.324	0.0		0.0
2	0.0	0.118	0.0		0.397
3	0.0	7.95	0.0	0.0	6.18
Avg.	0.0[d/]	2.80	0.0		2.19
4	0.0	0.199	0.0	0.0	
5	0.0	0.0	0.0		
4A					N.D.[e/]
5A					4.52

a/ Refer to Figures 1 and 2.

b/ Time in Pacific Standard Time

c/ Individual sample value

d/ Average of values from 1, 2 and 3

e/ No data, sample lost

E. WATER SAMPLES

The results of the water sampling, shown below, indicate low levels of carbaryl were present in the river immediately after each spray. These levels would be expected to drop very quickly because of the high flow rate of the river. The higher levels after the 180 ft. flight were probably due to wind. The wind direction during the 180 ft. flight was toward the river and away from the river during the 50 ft. flight.

	Concentration of Carbaryl (ppb)		
Sample	Background	180' Spray	50' Spray
Rep 1	0.0	6.0	4.0
Rep 2	0.0	2.0	3.0

F. CANOPY PENETRATION

The total mass and number of droplets deposited on each face of a sampling box were influenced by many factors. Factors such as flight path and altitude of the helicopter, wind direction and speed, elevation and orientation in the tree interact to dictate actual spray deposition. The helicopter always flew from east to west, and the wind direction changed from the south during flight 1 to the north during flight 2. In this analysis the three tree and understory sites are considered replicate sites, and the two brush sites are considered replicates. The mass deposition data represents means of the replicates, while the particle size data is the sum of the replicates.

TREE AND UNDERSTORY - The mass deposition of carbaryl on the canopy and understory sampling boxes from the 180 ft. flight varied both with the orientation of the face and the elevation of the sampling box within the canopy (Table 6). In most instances the horizontal or top face of the box collected the greatest mass.

Mass deposition from the 50 ft. flight was even more variable than the 180 ft. flight, possibly due to the lower altitude (less space for droplets to disperse in). Analysis of variance indicated that mass deposition for this flight not only varied with the orientation of the sides and elevation of the box, but with replicate trees as well. Actual deposition values were within the same range as the 180 ft. flight (Table 7).

Droplet sizes for the 180 ft. flight varied from 132 μ volumetric mean diameter (VMD) to 2971 μ VMD (Table 8). Larger droplet sizes may be attributable to the single leaking nozzle discovered after the flight was terminated. The large droplet sizes were efficient in maximizing deposition, but were too large for best coverage. Droplet density varied within a range of 0.01 to 0.64 droplets per square centimeter, far below the 2.5 to 15 required for good coverage (2).

The droplet size distribution for the 50 ft. flight was very similar to the 180 ft. flight (Table 9) with the absence of the few very large droplets attributed to the leaking nozzle. These were eliminated during the 50 ft. flight when the nozzles were

Table 6. Mass deposition ($\mu g/cm^2$) of carbaryl in the canopy for flight 1 (180 ft)

Canopy Location	Top	Side East	South	West	North
Tree[a/]					
Upper	1.66	0.10	0.02	0.12	0.05
Middle	0.56	0.01	0.00	0.03	0.02
Lower	0.48	0.01	0.00	0.06	0.05
Understory	0.23	0.00	0.26	0.03	0.00
Brush[b/]	0.84	0.00	0.26	0.03	0.00

a/ Means of 3 replicates.
b/ Means of 2 replicates.

Table 7. Mass deposition ($\mu g/cm^2$) of carbaryl in the canopy for flight 2 (50 ft)

Canopy Location	Top	Side East	South	West	North
Tree[a/]					
Upper	0.27	0.01	0.18	0.01	0.01
Middle	0.32	0.01	0.04	0.30	0.07
Lower	0.42	0.05	0.05	0.09	0.00
Understory	0.86	0.00	0.19	0.05	0.00
Brush[b/]	0.67	0.02	0.01	0.02	0.00

a/ Means of 3 replicates.
b/ Means of 2 replicates.

Table 8. Droplet size characteristics from canopy sampling sites for flight 1 (180 ft)

Canopy Location	Side of Box	Total[a] Number Droplets	Droplet Density (No./cm)	75[b] / 94[c]	108 / 132	150 / 187	213 / 264	300 / 372	424 / 527	600 / 745	849 / 1052	1197 / 1486	1692 / 2102	2394 / 2971	3384
Tree															
Upper	Top	245	0.64	0	1.21[d]	7.3	15.1	23.7	26.5	11.8	6.5	6.5	0.8	0.4	
	Vertical[a]	97	0.06	0	0	1.0	8.8	24.7	38.1	19.6	6.2	2.1	0	0	
Middle	Top	127	0.33	0	0	1.7	5.1	8.6	27.4	39.3	16.2	0	0	1.7	
	Vertical	20	0.01	0	0	0	10.0	30.0	45.0	15.0	0	0	0	0	
Lower	Top	58	0.15	0	0	8.5	6.8	22.0	20.3	23.7	15.3	0	3.4	0	
	Vertical	33	0.02	0	0	6.1	15.2	21.2	21.2	33.3	3.0	0	0	0	
Under-story	Top	42	0.11	0	0	4.8	11.9	31.0	28.6	2.4	16.8	0	0	4.8	
	Vertical	56	0.04	0	1.8	7.1	17.9	23.2	25.0	3.6	25.0	3.6	0	0	
Brush	Top	68	0.18	0	0	2.9	11.8	13.2	17.7	27.9	13.2	10.3	1.6	1.6	
	Vertical	22	0.01	0	0	0	18.2	4.6	18.2	22.7	13.6	4.6	4.6	13.6	

a/ Top is the population from 1 card; vertical is the population from 4 cards.
b/ Size range limits (microns) for each category.
c/ Volumetric mean diameter (microns) for each size range. Calculation made by converting size range limit to volumes and obtaining the mean volumetric diameter.
d/ Percent droplets within size categories.

Table 9. Droplet size characteristics in the canopy for flight 2 (50 ft)

Canopy Location	Side of Box	Total[a/] Number Droplets	Droplet Density ($\mu g/cm^2$)	75–94	108–132	150–187	213–264	300–372	424–527	600–745	849–1052	1197–1486	1692–2102	2394–2971	3384
Tree															
Upper	Top	56	0.15	0	1.8[d/]	10.7	8.9	17.9	28.6	30.4	1.8	0	0	0	
	Vertical	49	0.03	0	0	4.1	0	14.3	63.3	10.2	6.1	2.0	0	0	
Middle	Top	120	0.34	0.8	0.8	8.3	28.3	2.5	29.2	27.5	2.5	0	0	0	
	Vertical	47	0.03	0	0	2.1	17.0	10.6	49.0	19.2	2.2	0	0	0	
Lower	Top	76	0.20	0	1.3	2.6	13.2	32.9	18.4	21.1	9.2	1.3	0	0	
	Vertical	17	0.01	0	0	0	17.7	23.5	29.4	29.4	0	0	0	0	
Under-story	Top	136	0.35	0.7	0.7	4.4	15.4	31.6	19.9	25.0	2.2	0	0	0	
	Vertical	42	0.03	0	0	7.1	9.5	26.2	11.9	45.2	0	0	0	0	
Brush	Top	118	0.31	0	0	1.7	5.9	21.2	45.2	18.6	1.7	1.7	0	0	
	Vertical	9	0.01	0	0	0	0	0	66.7	33.3	0	0	0	0	

a/ Top is the population from 1 card; vertical is the population from 4 cards.
b/ Size range limits (microns) for each category.
c/ Calculation made by converting size range limits to volumes and obtaining the mean volumetric diameter.
d/ Percent droplets within size categories.

changed. Droplet density ranged between 0.01 and 0.35 droplets per square centimeter, again below the desired levels. Both flights showed that 72% of the drops fell on horizontal surfaces, and the volumetric median diameters for the 180 ft. and 50 ft. flights were 435 μ and 410 μ, respectively. It should be noted that the droplet size characteristics were calculated from a small sample size, in the worst case only a total of 17 droplets were collected on all four vertical sides of the sampling box at the lowest elevation.

Regression analysis of the theoretical mass deposition based on calculations from particle sizes and actual mass deposition produced a significant relationship. Actual mass is 29.7% of the theoretical for flight 1, and for flight 2 it is 36.4%.

Flight	DF	R^2	Equation
180'	25	0.768	$y = 0.010 + 0.297x$
50'	25	0.856	$y = 0.014 + 0.364x$

BRUSH - The brush data is very similar to the tree and understory, showing approximately the same levels and distributions as the mid canopy data (Tables 6,7,8, and 9).

LEAF - Mass deposition on leaves presented in Tables 10 and 11 was comparable to canopy sampling boxes. Although highly variable with respect to elevation, the range of values fell

Table 10. Concentration of carbaryl in leaves for flight 1 (180 ft)

Location[a/] in Tree	Mass Deposition $\mu g/cm^2$	Concentration of Carbaryl ppm (fresh weight)	ppm (dry weight)
Upper	.732	44.90	103.62
Middle	.281	18.25	43.21
Lower	.456	32.88	65.75

a/ Same tree sampled for 50' flight

Table 11. Concentration of carbaryl in leaves for flight 2 (50 ft)

Location[a/] in Tree	Mass[b/] Deposition $\mu g/cm^2$	Concentration of Carbaryl[b/] ppm (fresh weight)	ppm (dry weight)
Upper	.264	10.89	21.67
Middle	.813	55.08	106.39
Lower	.062	6.17	6.33

a/ Same tree sampled for 180' flight
b/ Concentrations determined by subtracting the means of all locations for flight 1 from the levels for flight 2.

within the range of mass deposition collected on all faces of sampling boxes. Mass deposition is converted to ppm leaf weight in Tables 10 and 11 to facilitate comparisons with published insect feeding studies.

VII. CONCLUSIONS

Results of this study indicated that under these conditions (weather, helicopter configuration, formulation, etc.) aerial application of carbaryl would not be effective in eradicating gypsy moth. Neither application produced even a small percentage of droplets within the effective size range of less than 100 microns (1). On open ground none of the 1943 drops measured were less than 100 μ, and in the canopy only two of the 1221 drops were less than 100 μ, both of these from the 50 ft. flight. Additionally, the droplet density produced was too low to be effective. The highest droplet density, 2.17 drops/cm^2, was produced from the 50 ft. flight over open ground, and even this density does not fall within the suggested limits of 2.5 to 15 drops/cm^2(2). Further, droplet density within the canopy did not approach these levels.

The configuration of the spray equipment suggested by Dr. Akesson was to maximize mass deposition. This produced relatively large droplets to keep drift and evaporation to a minimum. The large droplet sizes resulted in a much smaller number of droplets per unit area due to the exponential relationship between diameter and mass. For example, one 600 μ droplet contains the

same mass of carbaryl as one thousand 60 μ droplets. This configuration was contrary to the ones used in eastern states because Akesson had determined that normal spray configurations would not be effective from higher altitudes used in urban environments in California. Eastern sprays were applied at canopy height over a forest where pilots could fly at treetop height. This trial establishes that mass deposition of carbaryl can be obtained at higher flight altitudes, but only by sacrificing effective coverage and droplet size.

Literature Cited

1. Himel, C. M., and A. D. Moore. 1969. Spray Droplet Size in the Control of Spruce Budworm, Boll Weevil, Bollworm, and Cabbage Looper. J. Econ. Entomol. 62(4): 916-918.

2. Smith, D. B., E. C. Burt, and E. P. Lloyd. 1975. Selection of Optimum Spray-Droplet Sizes for Boll Weevil and Drift Control. J. Econ. Entomol. 68(3): 415-417.

3. Weaver, D. J., W. C. Johnson, and R. J. Oshima. 1982. Helicopter Spray Trials with Carbaryl (XLR). California Department of Food and Agriculture.

APPENDIX A

Protocol for Carbaryl Spray Trials

I. Objectives: To establish and characterize aerial application parameters required for a potential Gypsy Moth eradication effort.

II. Monitoring Plan:

The spray trials will be under the overall supervision of Ronald J. Oshima, Environmental Hazards Assessment Program (EHAP). Phone (916) 322-2395 or ATSS 492-2395. Key personnel participating from EHAP CDFA are listed below:

Tom Mischke - Responsible for selection of sampling methodology, field storage and transport of collected samples, and liaison to CDFA Chemistry Laboratory Services for questions concerning all aspects of the chemical analysis of collected samples. Phone (916) 322-2395 or ATSS 492-2395.

Don Weaver - Responsible for the study design, supervision over sample collection and data reduction. Phone (916) 322-2395 or ATSS 492-2395.

Study Design:

A. The spray trials are designed to produce data enabling an estimation, at different elevations, of the following parameters:

- application swath width
- deposition rate
- particle size distribution
- canopy penetration

Later sections of this protocol will address each of these topics.

B. Application:

1. Sevin XLR will be applied at the rate of 1 qt. per acre.

2. Flights will be made at 2 altitudes, 50 ft and 250 ft.

3. The helicopter configuration for 50' will be 46-54 8004 nozzles, 60 psi, and 75 mph.

4. The helicopter configuration for 250' will be selected from 8008 or 8010 nozzles at 30 psi.

5. Rhodamine dye will be added to the formulation to allow automated droplet quantification.

C. Study Timetable

1. Sampling will occur on two separate days. Swath width will be determined on the second day, and all other parameters on the first day.

2. A sampling day will encompass the period from sunrise to 11:00 am and will be terminated if winds are judged to be too severe.

III. Sampling Design

A. Swath Width

1. A sampling line will be established for 1000 ft with 10 ft intervals between sites.

2. For the 50' flight, plastic backed absorbant paper sheets (1 sq.ft.) will be placed at 20' intervals for 400', and analyzed to determine mass/area. Kromekote cards will be placed at 10' intervals for 400', and analyzed to determine particle sizes and numbers.

3. For the 250' flight, the absorbant paper will be placed at 20' intervals for 1000', and the Kromekote cards at 10' intervals for 1000'.

4. All flights will be made directly into the wind.

5. A total of 70 fallout sheets and 140 Kromekote cards will be collected.

B. Deposition Rate

1. A 5 x 5 sampling site matrix will be established in a 14 acre spray area. Specific locations for each of the 25 sites will be determined by the spray area geography.

2. Two additional sites will be established downwind of the spray area.

3. A fallout sheet will be placed at each of the 27 sites just prior to spraying, and collected 30 min. after termination of the spray operation.

4. A total of 54 fallout sheets will be collected, one half analyzed as priority samples.

C. Particle Size Distribution

1. A Kromekote card will be placed at each of the 27 sites just prior to spraying, and collected 30 min. after termination of the spray operation.

2. Five sites will be established for high volume air samplers (40 cfm), three within the spray area and two downwind of the spray area.

3. Each of these five sites will have three air samplers. One sampler will be equipped with a dual stage cascade impactor to quantify % mass and size distribution of airborne particles greater than and less than 3.5 microns. A second Hi-Vol will collect total suspended particulates on an 8 x 10 glass fiber filter. The third Hi-Vol will collect gas phase carbaryl on XAD-2 resin.

4. Background resin samples will be collected prior to the first and second sprays for 40 minutes.

5. All samplers will run during each spray operation and for 30 minutes after each spray.

6. A total of 27 Kromekote cards, 22 resin jars, and 30 glass fiber filters will be collected. The filter will be analyzed for dye content instead of carbaryl.

D. Canopy Penetration

1. A total of 140 fallout sheets, 140 Kromekote cards, and 12 leaf samples will be collected. The top panel of all boxes and the sprayed leaf samples will be analyzed as priority samples.

2. Three "tree" sites with understory and two "brush" sites will be chosen within the spray area to determine the amount of spray penetration for each altitude.

Boxes with plastic backed absorbant paper and Kromekote cards on the top and four sides will be used to collect pesticide spray.

One box will be placed near the top, middle and lower canopy of each mature tree and in the center of a clump of brush representing understory on the ground beneath each tree. A box will also be placed towards the center of two individual smaller trees representing brush sites.

3. Leaf samples (35-40 leaves) will be collected from one site each in the top, middle ad lower canopy of mature trees. Fresh weight of samples will be determined and leaves will be analyzed for the amount of dislodgable pesticide per unit area.

IV. Handling and Storage of Samples

Allsampling media and containers will be prepared and prenumbered at the CDFA laboratories in Sacramento. Each device will be shipped to the sampling sites with an accompanying Chain of Custody Record. The Chain of Custody Record will be filled out by all parties handling or storing the sampling media or sample containers from the time they leave the lab until they are returned for analysis.

All samples will be collected 30 min. after the termination of each flight and stored in the following manner:

On Dry Ice (-70°C)

Fallout samples
Air samples

On Ice (4°C)

Leaf Samples
Water Samples
Tank Samples

STATE OF CALIFORNIA
DEPARTMENT OF FOOD
AND AGRICULTURE

APPENDIX B

CHAIN OF CUSTODY RECORD

Use Ball Point Pen Only

ENVIRONMENTAL MONITORING
ENVIRONMENTAL HAZ. ASSESS. PROG.
1220 N STREET, ROOM A-328
SACRAMENTO, CA. 95814

Study #	Sample #	Sampler Date on (Mo, Day, Yr.)	Time on	Sampler Date off (Mo, Day, Yr.)	Time off	Collector	Cell Location Code	Site	Spray	BSPF Key	* EO Key	Sample Type Key
1 7		8 2		8 2								
1 2 3 4	5 6 7 8	9 10 11 12 13 14	15 16 17 18	19 20 21 22 23 24	25 26 27 28	29 30	31 32	33 34	35	36	37	38 39 40

Companion UCD/CDFA	Bad Sample		Chemist	Priority
41 42 43 44	45	46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77	78 79	80

Remarks, Chemicals, Observations, Type of Biota, etc.

Partner: Rep #

Lab Results *Save Leaves*

Carbaryl

Dimilin

Acephate Monitor

Chemist Date

Relinquished by: *(Signature)*	Date/Time	
Received by: *(Signature)*	Relinquished by: *(Signature)*	Date/Time
Received by: *(Signature)*	Relinquished by: *(Signature)*	Date/Time
Received by *(Signature)*	Relinquished by: *(Signature)*	Date/Time
Received by *(Signature)*	Relinquished by *(Signature)*	Date/Time
Received by: *(Signature)*	Relinquished by: *(Signature)*	Date/Time
Received for Laboratory by: *(Signature)*	Date/Time	Lab #

Key

COL. 36: B= Background
S= Spray
P= 1st Post
F= 2nd Post

COL 37: *= Flagged
E= Extra
O= Outside

Sample type

TAN= Tank
HIV= Hi-Vol
LOV= Lo-Vol
BIO= Biota
FAL= Fallout CDFA
UCD= Fallout UCD
WAT= Water
FLO= Floater
SOI= Soil
LEA= Leaves

Distribution: Original and One Copy Accompanies Shipment, Copy to Coordinator Field Files