

Methyl Bromide Concentrations in Air Downwind During Aeration of Fumigated Single-Family Houses

March 20, 1996

HS-1713

by

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Abstract

Concentrations of methyl bromide in air downwind were measured during the aeration periods after each of seven tarped fumigations of the same single-family house. The effects of distance from the house (10, 50, or 100 ft), and method of tarpaulin removal (Standard or PCOC Aeration Methods) on 1- and 24-hr time-weighted-average downwind concentrations were investigated. Concentrations inside 4 houses at approximately 50 and 100 ft from the fumigated house were also measured for 1 and 24 hrs. Compared to the Standard Method, the PCOC Aeration Method was associated with lower concentrations at the 10-ft distance. This difference was statistically significant for the 1-hr, but not the 24-hr concentrations. At greater distances, the methods were indistinguishable. Maximum 1-hr concentrations were 13.6 and 7.5 ppm at 10 feet for the Standard and PCOC Methods, respectively, and 1.8 and 0.65 ppm at 50 and 100 ft, respectively, for the combined Methods. Maximum 24-hr concentrations for the combined Methods were 0.61, 0.10 and 0.037 ppm at 10, 50 and 100 ft, respectively. Concentrations inside neighboring houses were unaffected by Aeration Method and ranged from below 0.012 ppm (ND) to 0.18 ppm for 1 hr, and from ND to 0.098 ppm for 24 hrs.

Introduction

The single-family dwelling house is the most typical site of fumigations of non-commercial structures. Little information is available on offsite migration of fumigant gas during the fumigation and aeration phases of the treatment of single-family houses with methyl bromide (bromomethane, CAS #74-83-9) or other fumigants. Unpublished data from the Department of Pesticide Regulation (DPR), Worker Health and Safety Branch, indicated that there were measurable levels of fumigant gas up to 15 feet away from structures both during fumigation and aeration. DPR is concerned about the magnitude of airborne methyl bromide levels in the vicinity of fumigated single-family dwellings during the aeration phase, in light of new toxicology data received for this fumigant. DPR is now recommending (target exposure value) airborne exposure not exceed 210 parts per billion (ppb) averaged over 24 hours (State of California Memorandum, Nelson to Wells, 1992). This study was designed to determine the downwind concentration versus distance relationship for aeration of single-family dwellings following current aeration work-practices. The concentration versus distance relationship will be compared to DPR's target exposure value. Results of this study may be used to determine if there is presently adequate control over aeration to prevent exposure to persons in the vicinity above the DPR target exposure value. Additional impetus for this study came from the listing of methyl bromide as a Proposition 65 chemical when used for structural fumigation. This listing imposes additional restrictions on the fumigant when used in California. For reference, methyl bromide product labels require the use of respiratory protection if workplace levels exceed 5 parts per million (ppm) and the current occupational exposure limit value of Cal/OSHA for methyl bromide is 5 ppm, averaged over an 8 hour workday. To investigate whether aeration procedures could have an effect on offsite concentrations, fumigated houses were aerated following either a standard method or a method recommended by a structural pest control industry organization (Pest Control Operators of California, PCOC). The purpose of this monitoring was to characterize air levels of methyl bromide near structures during aeration using two methods of tarpaulin removal following structural fumigation. This study also measured air levels inside neighboring structures during aeration.

Methods and Materials

Test Site

The study was conducted in decommissioned base housing at the former Mather Air Force Base in Sacramento, California. All housing in this area was vacant and the grounds were secured by a security service furnished by the base, providing ideal conditions for extensive monitoring of methyl bromide offsite movement. One house was selected as the test house. The same house was fumigated in every test. The test house had approximately 2,590 ft² of floor area (including attached garage), and an inside volume of approximately 20,700 ft³. Five surrounding houses (one on each side, two behind, and one across the street from the test house) were selected for indoor monitoring. The two houses in back (the north side) were on a slight elevation (approximately 1 meter) relative to the fumigated test house. All the houses were one-story three-bedroom two-bathroom buildings constructed on concrete slabs. All had attached garages that were not accessible from within the house. All had been vacant for less than a year and were in good repair, unfurnished, and had no obvious structural defects. The same semi-permanent monitoring stations, set up around the test house and inside the neighboring houses, were used in each test. The open spaces surrounding the houses were not divided by any fences. This common area was covered with grass and shrubs with some trees present. The site is diagrammed in Appendix A.

Fumigation Procedure

A commercial fumigation company in Sacramento was contracted to perform the fumigations. Each fumigation was performed by a two- or three-man crew. The crew deployed industry-standard tarpaulins to enclose the structure, using sand-filled canvas tubes ("sand snakes") to form a seal against the soil. Tarpaulins were joined by rolling the edges together, then clamping the rolls with steel clips. After sealing the tarps, the crew would set up the injection system, consisting of a 150 pound methyl bromide tank (Meth-O-Gas, 99.5% methyl bromide, 0.5% chloropicrin as a warning agent), a high-pressure hose connected to a propane-powered water heater (to warm the gas), and an injector hose into the house. The fumigant was applied at a rate of 3 lb./1000 ft³, which is the upper limit of the label rate and typical of treatments in Northern California. It usually took about 25 minutes to inject the 62 pounds of methyl bromide (20,700 ft³ x 3 lb/1,000 ft³). After injection, the crew would post the required warning signs, dismantle the injection equipment and leave.

All fumigations were conducted in the morning. The series of fumigations began in winter, with the seventh and final fumigation occurring in early spring.

Aeration Procedure

The morning after the fumigation (between 22 and 24 hours post-application), the fumigation crew would return and begin aeration. A Fumiscope[®] was used to measure interior methyl bromide concentrations prior to tarpaulin removal and the start of aeration. This established the magnitude of the remaining concentration of methyl bromide within the structure. There were two different aeration methods under investigation in this study: the PCOC (see Appendix B) and the Standard (see Appendix C) methods. In both methods, the crew ultimately removes the steel clips and sand snakes, removes the tarpaulins from the house and turns on fans previously left in the house, with exhausts directed by large diameter plastic tubing (referred to as “convection tubing”) to the outside. The fans are left on for at least three days. The difference between the methods is that the PCOC Method requires that before the tarpaulins are removed, a fan be used to exhaust the fumigant-containing air upward from the space between the tarpaulin and the house (referred to as the “innerspace”). This fan is installed by opening a seam and clipping the edges of the tarpaulin to the outer housing of the fan. This is done by a worker wearing self-contained breathing apparatus (SCBA). The exhausted air is directed up to roof level by plastic convection tubing. At the same time, a seam is partially opened on the opposite side of the house to allow for make-up air to enter this space. The PCOC Aeration Method was developed to minimize exposure to workers by removing the volume of fumigant-containing air trapped in the innerspace. This procedure lasts 15 minutes, after which the tarpaulins were removed in the same manner as in the Standard Method.

Exterior Monitoring

Exterior monitoring sites were located on all sides of the structure in concentric circles. Samplers were placed at 10, 50, and 100+ feet from the outer surface of the tarpaulin. The air intake for the sampling tubes was elevated between 4 and 5 feet from the ground. Each long-term sampling site consisted of one metal stake (to elevate the sampling media to 4 to 5 feet above the ground), one sampling pump (SKC 224-PCXR7 Universal Constant Flow Sampler), and the sampling train (media and necessary tubing). In addition, during the first hour of aeration, short-term air sampling was also conducted, using an MSA Model C-210 Portable Pump running concurrently with the SKC sampler. Because of equipment allocation restraints, only a limited number of locations had concurrent short-term samplers, primarily the 10 foot sites. Because the length of sampling time required more power than the internal batteries could provide, supplemental battery packs were designed for both the MSA and SKC units. The added power supply allowed sampling to continue beyond the normal 6 to 8 hours provided by the internal batteries.

Each sampling site was assigned a unique location identification site number between 1 and 29. Site locations are shown in Appendix A.

Sampling Schedule

Following each overnight fumigation period, the sampling sites were readied by placing the necessary air samplers and sampling media on the stakes/tripods. The fumigation clearing crew was notified as soon as all sampling stations were ready. Just prior to the crew removing the first clip or sandsnake, all sampling stations were activated. Each research personnel member was responsible for activating multiple sampling stations. The lag period (time between first air sampler in a group turned on to last sampler in a group turned on) for any group of pumps being switched on was about five minutes. Short-term (1 hour) samplers were activated simultaneously with long-term (12 hours) samplers. After 1 hour, the short-term air samplers and their media were collected and processed for storage. The long-term samplers were allowed to run between 10 and 12 hours, at which point the sampling medium was exchanged for fresh charcoal tubes and the battery packs replaced to ensure continued power. Any unusual conditions (sampler failure, battery failure, tube dislodgment, etc.) were noted and reported to the sample processing manager (see Sample Storage and Analysis). The samplers continued to run for another 10 to 12 hours, after which all samplers and media were collected and processed, again noting any unusual or non-conforming conditions. Tests 1, 3, 5, and 7 were conducted using the Standard Aeration Method, while tests 2, 4 and 6 were conducted following the PCOC Method. Between tests, samples were collected from within the treated house and the neighboring houses to ensure the fumigant had dissipated.

Sampling Media

To monitor methyl bromide down to the low level which may be encountered near tarpaulin-covered structural fumigation, sampling followed the method of the National Institute for Occupational Safety and Health (NIOSH method #2520) and used petroleum-based charcoal tubes (SKC-West, Inc., Fullerton, CA 92634, catalog # 226-38-02). This sampling medium consists of adsorbent contained in two sections, a primary tube containing 400 mg of charcoal and a secondary (backup) tube containing 200 mg of charcoal. During sampling, these two sections were connected with a short piece of plastic tubing (TYGON[®] or equivalent). To avoid breakthrough associated with collection of methyl bromide on charcoal, all samplers were calibrated to draw no more than a total of 10 to 12 liters of air through the sampling tubes in a sampling period. This flow rate varied for the two sampling periods (1 hour and 12 hour). Actual volumes were calculated from the sampling characteristics of each pump.

Indoor Monitoring

Each of the five houses neighboring the fumigated test house was assigned an identification number equivalent to its address number (see diagram in Appendix A). Within each house, the room closest to the test house was selected as the sampling room. In Houses 138 and 107, these were bedrooms; in 109 it was the living room; in 135 it was the master bedroom and in 141 it was the dining area. All samplers were situated next to a closed window (single pane, aluminum frame). Each long-term sampling site consisted of one tripod (to elevate the sampling media to 4 to 5 feet above the floor), one sampling pump (MSA Model C-210 Portable Pump [No.468200]), one charger unit for long-term powering of the pump (MSA Model 463679) and the sampling train (media and necessary tubing). These samplers were operated with house power. Additionally, during the first hour of aeration, short-term air sampling was also conducted. This was accomplished in the same room as the long-term sampling, using an SKC 224-PCXR7 Universal Constant Flow Sampler running concurrently with the MSA sampler. The short-term samplers were operated on battery power. All doors and windows were kept closed, with only intermittent front door opening to replace sampling media. Just before each study, background air samples were also collected in each house, including the fumigated structure.

Weather Monitoring

Ambient temperature and the magnitude and direction of the wind were recorded using a portable weather station (Met-1). Because of environmental requirements of the weather station (no large obstructions such as trees nearby), it was not located near the sampled houses, but 300 meters southwest of the treated house. Temperature and relative humidity within the houses and at the 10 foot sampling site were measured using a hand-held meter (HANNA Instruments, Model HI 8564).

Sample Storage and Analysis

After completion of the appropriate air sampling period, the charcoal sampling tubes were returned to the base station (garage of House 138) and given to the sample processing manager for check-in and preparation for storage. After logging in the sample number, tubes were separated (primary "A" tube from secondary backup "B" tube) and capped. Capped tubes were then placed on dry ice and were either stored on the dry ice for the duration of each test period or were transported to a freezer (temperature: -20°C). After all tubes from a test period were collected, the tubes were taken to Chemistry Laboratory Services of the California Department of Food and Agriculture (CLS/CDFA) for analysis of methyl bromide. The methodology used in analysis is given in Appendix D. Results were reported in micrograms per sampling tube. In cases where there were detectable amounts of methyl bromide on the secondary tube, the amount quantified on the secondary tube was combined with the amount determined on the primary tube. If the backup value exceeded 25%, the sample was considered void. In a few cases, there was evidence that the tubes had been incorrectly attached to the pumps, i.e., reverse order. In such cases, it was fairly obvious (detectable levels in the "B" tube, non-detectable levels in the "A" tube) and these tubes were not considered void.

Quality Control

Quality control (QC) tests were conducted by the analytical laboratory (CLS/CDFA) to ensure accurate analytical results. The field samples were analyzed at the lab in 12 batches. A set of three QC spikes, prepared in the laboratory, were analyzed with each batch. Each QC set consisted of a high- (8.52 ug), medium- (4.26 ug) and low-level (0.85 ug) spike. Spike levels were chosen to bracket expected field levels. Four additional sets were analyzed independently. In these sets the high, medium and low spike levels were 8.52, 2.26, and 1.13 ug,

respectively. All 16 sets were combined for statistical analysis. Analytical recovery in these sets averaged 71.4 % (range 49-102 %). Percent recovery was significantly lower in high level spikes than in low level spikes.

To examine storage stability, twenty high- (14.2 ug) and twenty low-level (1.12 ug) spikes were prepared and five of each level were analyzed after 1, 2, 3 and 4 weeks of storage. There was evidence of loss of methyl bromide from low level spikes after one week of storage following spiking, but not from the high level spikes. There appeared to be no further loss at 2, 3 or 4 weeks of storage at either level.

Both the QC spikes and the storage stability spikes showed cyclical trends in recovery. This may indicate a need for tighter control over the analytical process.

Statistical analysis of the QC data is described in Appendix E-I.

Statistical Analysis

The data are presented as 1-hr and 24-hr time-weighted average concentrations. The 24-hr concentrations were obtained by averaging concentrations for the first and second 12-hr periods at each sampler location. All concentrations below the limit of analytical detection were assigned the approximate value of the limit, 0.012 ppm. No correction for recovery or storage loss has been applied to the data in this report.

Only the concentrations measured at samplers downwind of the fumigated house were used because it was expected that the greatest potential for exposure would be in that direction. The downwind sampler locations for each fumigation were identified using wind direction measured during the first hour of aeration. The same set of samplers was used for the 24-hr concentrations in order to make the 1- and 24-hr datasets comparable. The figures in Appendix G identify the downwind samplers in each test.

Nonparametric statistical methods were used to characterize concentration distributions and to compare the two aeration methods, because the form of the treatment population distributions is unknown. (A treatment population may be thought of as a theoretical set of all the concentrations that would be measured if an unlimited number of fumigations were conducted, under conditions like those of the current study, with an unlimited number of air samplers at each time period and distance.) The results of tests of normality were inconclusive; Shapiro-Wilks tests rejected normality for most, and lognormality for some of the treatment groups. More importantly, because dissipation of a gas under field conditions is subject to many uncontrollable influences, there was no *a priori* expectation that the distributions *could* be described by any particular statistical distribution.

The data for each combination of sampling period (1- and 24-hr) and distance (10, 50 and 100 ft) were analyzed separately since sample variances and sizes were different. Within sampling periods and distances, measurements from replicate fumigations ("tests") were pooled and treated as if they were independent. This seemed justified by the apparent absence of differences among tests, and was done in order to simplify the analysis. (No statistical analysis for differences among tests was done because the sample sizes were too small to provide meaningful tests.)

To characterize the statistical relationship between methyl bromide concentration in air and distance from the fumigated structure, the data was treated in a similar fashion to the model of H.D. Goodfellow, K.S. Georgakis and J.W. Smith (Experimental and theoretical studies of dilution and recirculation of fume hood exhaust gases. p.575-587. In R.T. Hughes, H.D. Goodfellow and G.S. Rajhans (eds.) *Ventilation '91: 3rd International Symposium on Ventilation for Contaminant Control*, Sept. 16-20, 1991, Cincinnati, Ohio. ACGIH, Inc., Cincinnati, Ohio).

Statistical analyses were implemented using Base SAS ® software (SAS Institute Inc., *SAS® Procedures Guide, Version 6, Third Edition*, Cary, NC: SAS Institute Inc., 1990) and SAS/STAT ® software (SAS Institute Inc., *SAS/STAT® User's Guide, Version 6, Fourth Edition, Volume 2*, Cary, NC: SAS Institute Inc., 1989).

GLP Compliance

This study was not conducted under compliance with the Good Laboratory Practice standards (40 CFR 160) of the US Environmental Protection Agency. Deviations and/or amendments to the protocol were documented and are available in the raw data archives.

Retention of Raw Data

The testing agency (DPR/WH&S) will retain copies of all raw data for a minimum of 5 years. All raw data will be maintained in a file-folder and the analysis request/chain of custody for handling samples will be maintained.

Results

Methyl bromide concentration in air inside the fumigated house just prior to the start of aeration averaged 42% of the theoretical application rate of 48 ounces per 1,000 cubic feet. Concentration ranged from 3600 to 7460 ppm in 6 tests (mean 5190 ppm). Throughout the study, temperatures within the houses ranged from the low 50's to the low 70's. Relative humidity varied between 40 and 65%. All pre-application, background samples indicated non-detectable methyl bromide levels in all structures.

The sample distribution of methyl bromide concentration in outdoor air, by aeration method, distance, and sample duration is summarized in Table I. This table also gives the percentage of the 24-hr concentration represented by the first-hour concentration. This percentage was calculated by averaging over tests:

$$\frac{\text{mean 1-hr concentration for test} / 24}{\text{mean 24-hr conc'n for test}} \times 100.$$

Statistical comparisons of both 1- and 24-hr concentrations under the two aeration methods were made at each distance. The Wilcoxon rank-sums test was used to compare average concentrations under the two methods. The Kolmogorov-Smirnov test was used to test for overall differences between the two sample frequency distributions. The only statistically significant difference was at the closest (10 ft) distance during the first hour of aeration, with the PCOC Method associated with lower concentrations (Wilcoxon test, $p=0.018$; Kolmogorov-Smirnov test, $p=0.054$). The difference between 24-hr concentrations at 10 ft was close to significance (Wilcoxon test, $p=0.068$; Kolmogorov-Smirnov test, $p=0.159$). Both nonparametric tests were implemented using the SAS NPAR1WAY Procedure. Complete test results are reported in Appendix E-II.

Ninety-fifth percentiles were used for plotting the concentration-distance relationship because we were interested in establishing distances at which most of the concentrations that could be measured during an aeration would be less than the plotted value. Further, the uncertainties associated with the measured concentrations, including the uncertainty of having captured with discrete sampling locations the full range of levels in the 3-dimensional space surrounding the aerating house, and that of having captured in a finite number of tests all the variations of microclimate possible, as well as the variability inherent in sample processing and chemical analysis, make it reasonable to use an upper percentile of the observed concentrations for this purpose.

Nonparametric confidence intervals for the 95th percentile of each treatment population are given in Table II. The familiar parametric confidence intervals cannot be used here since they require assumptions about the distribution of the measured quantity. Unlike the parametric procedure, where the confidence level is chosen first and an interval found having that confidence, here the interval is given and the confidence associated with it must be found. The intervals in Table II include the range from 0 to the highest observed concentration. The confidence, or probability that the population 95th percentile falls in that interval, was computed using the method described by R.V. Hogg and A.T. Craig (*Introduction to Mathematical Statistics, Fourth Edition*, New York, Macmillan Publishing Co., Inc., 1978; p. 304-6). Calculations were done using the SAS programming language in Base SAS.

A summary of the methyl bromide concentrations measured in air inside four neighboring houses during aeration are presented in Table III. House 135 has been excluded from this table because a nonstandard lateral sewer connection between House 135 and the fumigated structure may have directly introduced methyl bromide from the fumigated house through an empty gas trap into the bathroom adjoining the bedroom in which the sampling equipment was located. After it was discovered that the gas trap in the shower in House 135 was not sealing, all gas traps in the monitored houses were resealed with the glycol-based liquid used when the houses were abandoned. The results from the final test (Test 7) showed levels in House 135 in accordance with those found in

the other houses, indicating that the empty traps were indeed the route of the unexpected methyl bromide levels associated with that structure.

To compare indoor and outdoor concentrations (Table IV), the monitored neighboring houses downwind of the fumigated house were identified for each test. As before, 24-hr samples were identified as downwind on the basis of wind direction during the first hour of aeration. If outdoor measurements were available from samplers close to, and at approximately the same distance from the fumigated structure as the downwind house, those data were used in the comparison. Table IV shows that during the first hour of aeration, the ratio of indoor to outdoor concentration was uniformly small in the closer houses (50 feet from the fumigated house). At 100+ feet during the first hour, indoor and outdoor concentrations were similar on average, but the ratio per test varied from 0.08 to 2.5. The same was somewhat true of 24-hr concentrations at 50 feet, with ratios ranging from 0.37 to 2.0. Twenty-four-hour indoor and outdoor concentrations at 100+ feet were similar, both being low.

All of the raw data for each test are displayed on maps of the study site in Appendix G. These figures indicate the range of downwind directions during the first hour of aeration and identify the samplers selected as downwind of the house.

Table I

Methyl Bromide Concentration in Outdoor Air Downwind of Fumigated House, during Aeration, by Aeration Method, Distance from House, and Sample Duration.

Aeration Method	Distance	1 hour						24 hours						Mean percent of 24-hr conc. due to Hr 1‡
		n	Min	Mdn	Mean	95th %ile†	Max	n	Min	Mdn	Mean	95th %ile	Max	
<i>Standard</i>														
	10 ft	17	0.096	2.947	4.857	13.594	13.594	16§	0.020	0.141	0.211	0.611	0.611	96
	50 ft	9	0.067	0.299	0.545	1.488	1.488	9	ND	0.032	0.040	0.092	0.092	59
	100 ft	9	ND¶	0.087	0.201	0.646	0.646	9	ND	ND	0.018	0.033	0.033	49
<i>PCOC</i>														
	10 ft	19	ND	0.638	2.239	7.515	7.515	19	ND	0.055	0.148	0.532	0.532	65
	50 ft	10	ND	0.401	0.667	1.784	1.784	10	ND	0.028	0.040	0.104	0.104	73
	100 ft	9	ND	0.055	0.177	0.496	0.496	9	ND	0.018	0.020	0.037	0.037	40
<i>Combined methods</i>														
	10 ft	36	ND	1.898	3.475	11.826	13.594	35§	ND	0.123	0.177	0.532	0.611	81
	50 ft	19	ND	0.330	0.609	1.784	1.784	19	ND	0.030	0.040	0.104	0.104	66
	100 ft	18	ND	0.071	0.189	0.646	0.646	18	ND	0.015	0.019	0.037	0.037	44

† In most cases, the 95th percentile is the same as the maximum observed value because the small sample sizes do not allow more precise calculation of the percentile.

‡ Calculated by averaging per test percentages. See Results section of text for details.

§ One sampler location used during Hour 1 was missing the 24-hr measurement.

¶ ND: below the detection limit of approximately 0.012 ppm.

Table II
Confidence Intervals for Population 95th Percentiles†

Treatment Population	Sample Size	Interval	Confidence‡ Level
<i>1-hour</i>			
10-ft distance		-----ppm-----	-----percent-----
Standard Method	17	0 - 13.594	0.58
PCOC Method	19	0 - 7.515	0.62
50-ft distance	19	0 - 1.784	0.62
100-ft distance	18	0 - 0.646	0.60
<i>24-hour</i>			
10-ft distance	35	0 - 0.611	0.83
50-ft distance	19	0 - 0.104	0.62
100-ft distance	18	0 - 0.037	0.60

† Based on method of calculating nonparametric confidence intervals in R.V. Hogg and A.T. Craig, *Introduction to Mathematical Statistics, Fourth Edition*, New York, Macmillan Publishing Co., Inc., 1978; p. 304-6.

‡ Probability that population 95th percentile is in interval

Table III
Methyl Bromide Concentrations in Air Inside Neighboring Houses†
with Standard and PCOC Aeration Methods.

<i>Aeration Method</i>			-----ppm-----			
Time	n‡	Minimum	Median	Mean	Maximum	
<i>Standard</i>						
1-hr	12	ND§	0.016	0.038	0.117	
24-hr	12	ND	0.016	0.028	0.098	
<i>PCOC</i>						
1-hr	8	ND	0.032	0.042	0.096	
24-hr	12	ND	0.020	0.030	0.084	
<i>Combined Methods</i>						
1-hr	20	ND	0.025	0.040	0.117	
24-hr	24	ND	0.016	0.030	0.098	

† Data from the house with a faulty sewer connection are not included.

‡ Each group n includes either 2 or 3 tests on each of 4 houses.

§ ND: Below the analytical detection limit of approximately 0.012 ppm.

Table IV

Mean Methyl Bromide Concentrations in Air Inside and Outside Houses Downwind of Fumigated Structure, by Sample Duration and Distance of House from the Fumigated Structure (Combined Aeration Methods)

Distance	Test	Sample Duration			Sample Duration		
		1-hour			24-hour		
		Indoor	Outdoor	Ratio I:O	Indoor	Outdoor	Ratio I:O
		-ppm (number samplers)-			-ppm (number samplers)-		
50 ft	3	0.117 (1)	0.778 (2)	0.15	0.062 (2)	0.039 (3)	1.67
	4	0.096 (1)	0.550 (2)	0.18	0.078 (1)	0.040 (2)	2.00
	5	0.094 (1)	0.731 (2)	0.13	0.075 (1)	0.050 (2)	1.43
	7	0.090 (1)	0.458 (2)	0.20	ND† (1)	0.032 (2)	0.37
	Mean				0.163		
	Std Dev			0.029			0.704
3 100 ft	1	0.044 (2)	0.575 (2)	0.08	0.036 (2)	0.029 (3)	1.25
	3	0.022 (2)	0.027 (2)	0.83	ND (2)	ND (3)	1.00
	4	0.030 (2)	ND (2)	2.50	0.014 (2)	0.016 (2)	0.91
	6	0.058 (2)	0.034 (2)	1.69	0.017 (2)	0.013 (3)	1.25
	Mean				1.276		
	Std Dev			1.050			0.174

† In forming the ratio, ND was treated as 0.012, the approximate value of the detection limit.

One of the objectives of this study was to characterize the statistical relationship between methyl bromide concentration in air and distance from the fumigated structure. The number of air samplers available did not permit sampling at a sufficient number of distances to determine empirically the form of the concentration-distance curve. Instead, a theoretical model for the dilution of exhaust gases was used. The model used is given as Equation 7 in the 1993 paper by H.D. Goodfellow, K.S. Georgakis and J.W. Smith (Experimental and theoretical studies of dilution and recirculation of fume hood exhaust gases. p.575-587. In R.T. Hughes, H.D. Goodfellow and G.S. Rajhans (eds.) *Ventilation '91: 3rd International Symposium on Ventilation for Contaminant Control*, Sept. 16-20, 1991, Cincinnati, Ohio. ACGIH, Inc., Cincinnati, Ohio). This model

specifies that dilution is proportional to distance-squared times wind speed divided by exhaust rate. Wind speed and exhaust rate were not available, and were treated as if they were constant and thus subsumed by the unknown constant in the equation. The model used was thus

$$C^{-1} = a + b \cdot D^2$$

where C is concentration in air and D is distance from the structure. The unknown parameters were determined by fitting this model to the sample 95th percentile at each distance. The resulting concentration-distance curves are shown in Figures One to Three. The equations for the curves are:

First hour, PCOC aeration: $C_{.95}^{-1} = 0.1150 + 0.00018 \cdot D^2$
First hour, Standard aeration: $C_{.95}^{-1} = 0.0500 + 0.00024 \cdot D^2$
First 24 hours, either method: $C_{.95}^{-1} = 1.5812 + 0.00306 \cdot D^2$

The distance at which the 95th percentile of 24-hr concentration theoretically goes below 210 ppb is 32.2 ft.

Figure 1
Theoretical Dissipation Curve Fit to 95th Percentile Methyl Bromide in Air
During First Hour of Aeration by PCOC Method

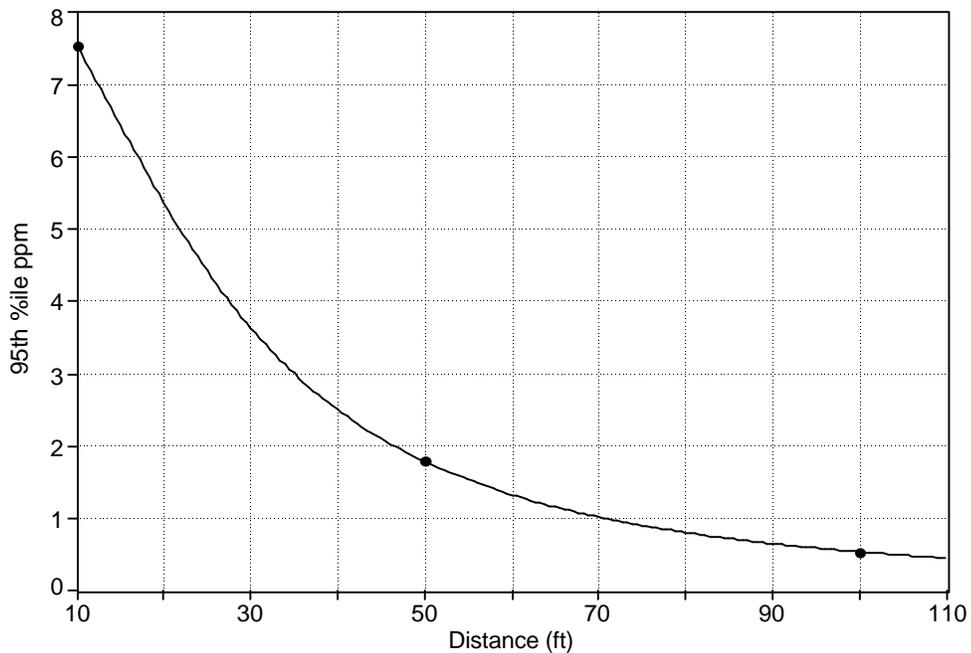


Figure 2
Theoretical Dissipation Curve Fit to 95th Percentile Methyl Bromide in Air
During First Hour of Aeration by Standard Method

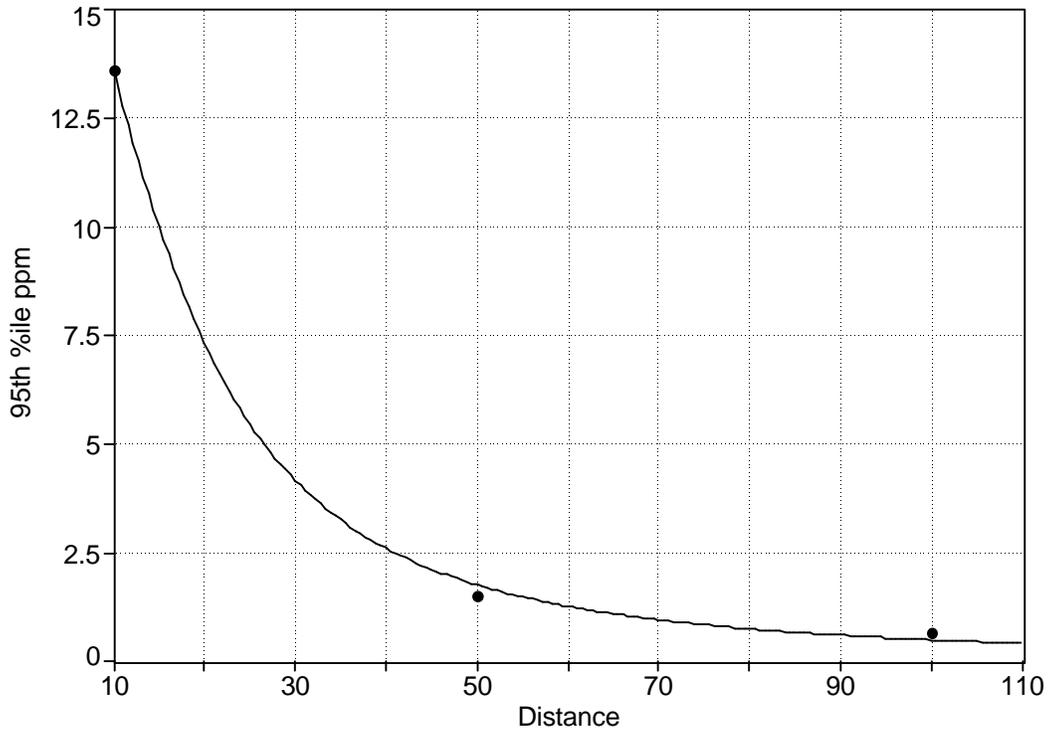
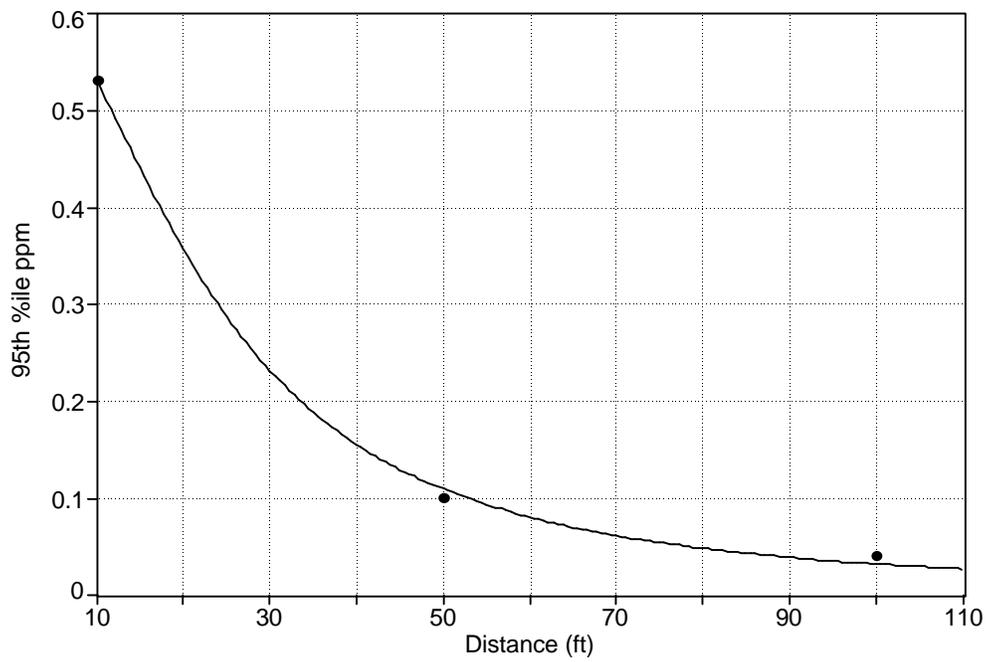


Figure 3
Theoretical Dissipation Curve Fit to 95th Percentile Methyl Bromide in Air
During First 24 Hours of Aeration (Combined Methods)



Discussion

All measured concentrations greater than 5 ppm occurred at the 10-foot sampling sites, during the first hour of aeration (with both methods). The 5 ppm level is the Cal/OSHA Permissible Exposure Limit and the label mandated level beyond which respiratory protection is required. The highest levels were found when using the Standard Aeration Method. It would appear that the initial dropping of the tarpaulins, without pre-exhausting the innerspace, results in an extra parcel of methyl-bromide-laden air that rapidly distributes into the surrounding environment resulting in greater concentrations of fumigant. After the tarpaulins are removed, the methyl bromide within the house is also actively exhausted. This is accomplished by opening doors and windows and using fans to move the inside house air out into the open environment. All this activity usually occurs during the first hour of the aeration procedure and this is reflected in the first hour measurements.

The theoretical concentration versus distance relationship for the first hour of aeration by the PCOC Method (Figure 1) suggests that 95th-percentile outdoor methyl bromide concentrations of up to 5 ppm may be found within 22 feet downwind of an aerating single-family structure. The current DPR target exposure value would allow exposure to 5 ppm for an hour. Methyl bromide labeling requires the use of respiratory protection (SCBA) if levels exceed 5 ppm.

The theoretical concentration versus distance relationship for the first hour of aeration by the Standard Method (Figure 2) suggests that methyl bromide concentrations up to 5 ppm may be found within 27 feet downwind of the structure.

The theoretical concentration versus distance relationship for the first 24 hours of aeration (Figure 3) indicates that methyl bromide concentrations up to 0.21 ppm may be found within 32 feet downwind of single-family structures, with both methods. The current DPR target exposure value would allow exposure to 0.210 ppm (210 ppb) for 24 hours.

All 24-hour air levels measured inside neighboring houses during aeration (excluding the house with the faulty sewer connection) were less than the DPR target value of 210 ppb.

Conclusions

The analysis of these data supports the following conclusions regarding aeration and resulting environmental levels of airborne methyl bromide:

- I. The PCOC Aeration Method is superior to the Standard Aeration Method in reducing downwind offsite airborne levels only at the 10-ft distance and during the first hour of aeration.
- II. During the first hour of aeration by either method, airborne levels of methyl bromide are highest and may exceed 5 ppm within about 30 feet downwind of a fumigated structure.

- III. During the first 24 hours of aeration, airborne levels of methyl bromide may exceed DPR's target value of 210 ppb within about 35 feet downwind of fumigated single-family structures. (The greater part of the 24-hr concentration is due to the high first-hour concentration.)
- IV. Measurable amounts of methyl bromide can be found in the air inside neighboring houses at distances of 50 to 100 feet from the fumigated structure during aeration. All measured concentrations (both 1- and 24-hr) were less than the DPR target level of 210 ppb.
- V. For persons in the vicinity of the aerating house, being indoors provides protection from the high concentrations during the first hour of aeration. No 1-hr indoor concentration measured was greater than 0.117 ppm. Over the 24-hour period, when all concentrations are lower, there is essentially no difference between indoor and outdoor methyl bromide concentrations.
- VI. It is possible for fumigant to travel through the sewer system and into neighboring houses if the drain traps are not filled with liquid.

Acknowledgments

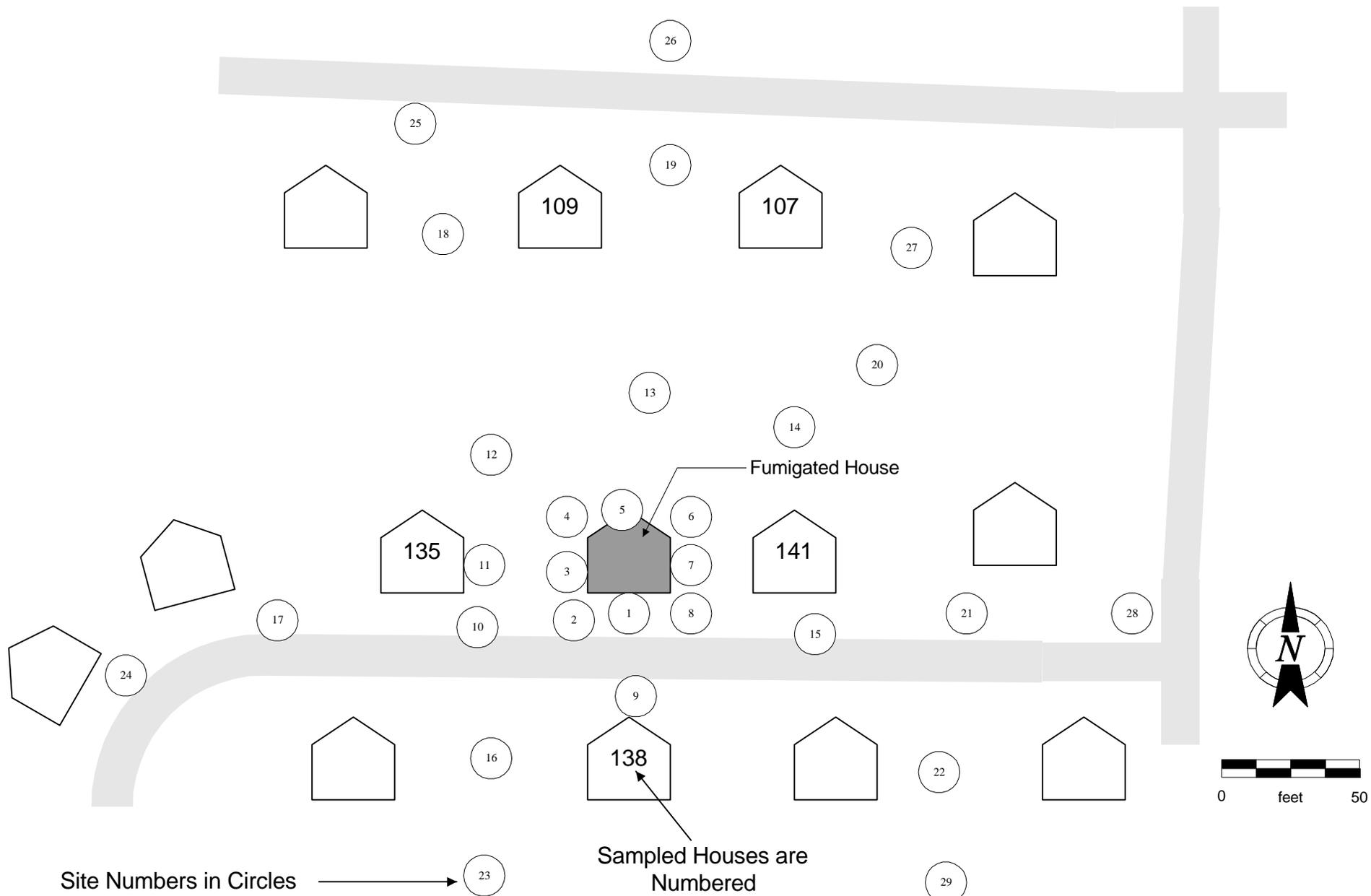
The authors wish to thank the following organizations/individuals for their assistance in the execution of this study: From DPR: Frank Schneider, Bernardo X. Hernandez, Dana Meinders, David Haskell, Dave Kim, Adrian Bradley, Clarice Ando, and Carissa Gana; from Mather: Anthony Wong, Randy Dennis, Roy Murray, and Charles Smith; from CDFA: David Conrad and Vincent Quan; from Norcal Pest Control: Larry Ruthven, Danny Sherven, Robert Litsch, Craig Alexander, and Billy Swafford.

Disclaimer

Use or mention of specific products or trade-names in this report is in no way an endorsement of such products or trade-names by Cal/EPA, Department of Pesticide Regulation or the State of California, nor is criticism implied of similar products not mentioned.

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Appendix A
Map of Mather Test Site

Appendix B

Traditional Tarpaulin Removal Aeration Plan

This tarpaulin removal plan was written for the purposes of this DPR fumigation study. The following procedure describes a method of removing tarpaulins that can be considered a “standard aeration method” and represents a customary method that was used in the past.

1. Starting on the ground, carefully remove sand snakes. Do not break seal with ground.
2. On the roof, carefully remove clamps from seams. If possible, do not disturb tarpaulin when removing clamps. Leave tarpaulin in place as much as possible. Do not open seams. Carefully remove sufficient clamps to allow Step 3.
3. On the roof, carefully peel back the edges of each tarpaulin onto itself to expose as much as possible of the roof area without exposing the worker to untarped area. This may only uncover less than half the roof area. Exit the roof.
4. Wearing self-contained breathing apparatus (SCBA), remove any remaining clamps and separate and peel back the edges of the tarpaulins. The crew should withdraw from the immediate area to allow the gas to dissipate out of the innerspace. Wait 10 minutes.
5. After 10 minutes, with SCBA, test with halide torch to determine rough idea of residual amounts under or near tarpaulins. Wait until there is no halide torch visible methyl bromide before proceeding. After no visible amount remains, test with a detector tube between the house and the tarpaulin. If less than 5 ppm, continue with the tarpaulin removal.
6. While still wearing SCBA, enter structure and open windows and doors.
7. Fold tarpaulins away from the structure.

Appendix C

California Structural Fumigation Pest Control Industry Standard*

Tarpaulin Removal Aeration Plan

Scope

This plan can be used as a general guideline to minimize worker exposure during the clearing operations following fumigation of a typical single family residential structure. It was developed during limited testing of single family residences not over two stories in height. For other types of structures, the basic principle of exhausting the air space between the structure and the tarpaulin utilized in this plan may be applicable. This plan is in addition and designed to compliment existing fumigant label requirements and provide additional safety during clearing operations of structural fumigation by establishing an industry standard method of performing this activity. This plan is applicable to structural pest control fumigations using methyl bromide or sulfuryl fluoride.

Purpose

The purpose of this procedure is to reduce the fumigant concentration between the tarpaulin covering and the structure (site) and thereby minimize exposure to clearing crew and should allow tarpaulin removal without exceeding the 5 ppm label exposure value limit for either fumigant. Additionally, the interior concentration of fumigant within the structure is also reduced simultaneously.

Equipment Necessary

- A. Electricity - generator, or alternate power to operate aeration fan(s)
- B. Extension cord(s)
- C. Aeration fan(s) capable of moving 3,000 to 5,000 cfm (3 to 5 amp)
- D. Convection tubing or ducting to fit over fan housing to direct exhausting fumigant away from work area, sensitive plantings or neighboring property.

Procedure

Initial Steps

1. Prior to commencing fumigation, establish power cords and source of electricity to operate exhaust fan(s). Windows shall be closed, or opened to a maximum of six inches (approximate) so the fumigant from the interior of the site does not influence the innerspace between the tarpaulin and the structure.
2. The exhaust fan location(s) should be selected carefully and engineered in a fashion to protect workers, property and neighboring structures. The fans may also be installed during the tarping period. If fan(s) are installed just prior to aeration, respiratory protection (SCBA) must be worn.

Start of Clearing

3. Utilize convection tubing or ducting to divert fan exhaust away from the workspace and other sensitive items such as plants and neighboring property. This allows for freedom of movement by employees in this area. Selection of fan site(s) to exhaust fumigant is critical to avoid exhausting fumigant into sensitive areas. Extend tubing from fan up the side of the structure to approximately 10 feet or to the first story roof line.
4. Start the fan to draw the tarpaulin down and around the site and exhaust the fumigant from the innerspace between the tarpaulin and the structure.

5. As the tarpaulin contracts, open a seam opposite the fan location to facilitate the draw of the fumigant. Open this seam a few feet.

Bottom Seal Removal

6. As the tarpaulin contracts, sandbag or sand snake removal may take place. Workers should be aware of the position of the exhaust tubing and the exhausting fumigant. When possible, work in both directions away from the location of the exhaust fan and tubing when removing bottom seal.

Clamp Removal

7. During this phase of the procedure, it is important to remove clamps and leave the tarpaulin in place as much as possible. Open seams farthest from a designated "safe area" and work your way back to this area. Typically, the fumigation truck will be positioned in the "safe area". Remember that "enclosed areas" between site and walls, fencing, or other nearby structures may trap fumigant after clamp removal and removal of the tarpaulin. Avoid these areas as much as possible. Lower clamps should be removed before roof clamps so that tarpaulins do not drop unexpectedly.

Tarpaulin Removal

8. When commencing tarpaulin removal, the exhaust fan system may be turned off. When removing the tarpaulins, the roof area creates little hazard (providing worker's breathing zone is not violated). It is safer to pull up tarpaulins and "peel" tarpaulins than to drop them with ground crew below. Peeling the tarpaulins is a procedure whereby the tarpaulin is removed by pulling it off the structure inside out. While working around shrubs, ground crew may lift tarpaulins over shrubs below the waist level (approximate). When encountering shrubs above waist level, the rooftop crew can pull tarpaulins up and over the shrub. It is important that the ground crew are not immediately adjacent to the tarpaulin during this activity. When "peeling back" tarpaulins, the tarpaulin shall be a barrier between the ground crew and the innerspace. The breathing zone of the ground crew is critical in this phase of the procedure to avoid excessive exposure. Caution should be exercised when encountering roof valleys, covered patios, or other areas (dead air spaces) where fumigant may be confined and aeration hindered.

Tarpaulin Folding

9. After the tarpaulins are removed, do not walk into area where fumigant may be trapped unless wearing respiratory protection. Test for airborne fumigant levels above 5 ppm. Wait for fumigant to dissipate to the acceptable level. If entry is necessary, wear SCBA whenever fumigant concentration exceeds 5 ppm or is unknown. These areas may include patios, atriums, breezeways, etc. Allow time for these areas to fully ventilate. Fold tarpaulins away from the site as far as possible.

Conclusion

This plan has been tested to enhance worker safety. However, each single family structure may present unique aeration problems that can only be assessed at the site. Common sense and good practice dictate that when atypical sites are aerated, personnel must rely on additional monitoring and respiratory protection to ensure exposure remains below 5 ppm to either methyl bromide or sulfuryl fluoride.

Footnotes

*Developed in cooperation with the Pest Control Operators of California (PCOC), Sub-Committee on Fumigation, and the Worker Health and Safety Branch (WH&S) of the Department of Pesticide Regulation (DPR). Copies are available from the PCOC, 3031 Beacon Boulevard, West Sacramento, CA 95691 ([916] 372-4363), or from Cal/EPA, DPR, Worker Health and Safety Branch, 1020 N Street, Room 200, Sacramento, CA 95814 ([916] 445-4222). Ask for HS Report 1574.

Procedure based on employee exposure reduction data contained in reports HS-1352 and HS-1538, available from the WH&S Branch of DPR.

This plan has been accepted by the California Department of Pesticide Regulation as provided for in Title 3, California Code of Regulations (CCR), Section 6780 (c).

Revised April 18, 1990

Second Revision August 2, 1994

Appendix D

Laboratory Analytical Method for Methyl Bromide

Scope

This method is for the determination of methyl bromide in charcoal tubes.

Principle

Methyl bromide is extracted from the charcoal tube with ethyl acetate. Analysis is by gas chromatography equipped with electron capture detector.

Reagent and Equipment

Ethyl acetate, Reagent grade, purity checked prior to use.

Vial, 5 ml, white cap

Miscellaneous glassware

Standard Preparation

Ethyl acetate is added to a calibrated 100 ml volumetric flask to the calibration line and the weight taken. Then about 3 ml of solvent is taken from the flask. This is connected by a Luer lock needle to a cylinder containing 99.5% methyl bromide, calibrated to a flow rate of about 50 ml/min. The gas is allowed to bubble into the solvent for about 1 minute. The needle is then removed from the ethyl acetate and the gas turned off, in that order. The volumetric flask is stoppered and allowed to equilibrate at ambient temperature. It is then filled to the calibration line. The weight difference between the flask filled with solvent and the flask after gas bubbling is the amount of the methyl bromide. This is the primary stock solution. It is kept in sealed 2 ml ampoules in a freezer for storage. From this solution the following working standard solutions are prepared: 0.28, 0.56, 1.01, 1.98 and 3.96 ng/ μ l.

Spike Preparation

The charcoal tube is broken in the middle. Spiking solutions, which are made from the primary stock solution, are introduced into the tube by a 10 μ l syringe. Levels of spike are 0.85, 4.26 and 8.52 μ g per sample.

Analysis

The charcoal in the tube is put into a white cap vial containing 4 ml of ethyl acetate. The vial is shaken gently and allowed to settle for two hours. The extract is ready for analysis.

Equipment Conditions

Gas chromatograph: Hewlett-Packard 5880A with Hewlett-Packard 7672A Automatic sampler

Injection volume: 2 μ l

Column: J & W DB-625 30 m \times 0.53 mm \times 0.2 μ m

Temperature profile:

Initial value: 40 $^{\circ}$ C

Initial time: 2.5 minutes

Program rate: 30 $^{\circ}$ C/min

Final value: 200 $^{\circ}$ C

Final time: 3 minutes

Injector temperature: 250 $^{\circ}$ C

Detector temperature: 350 $^{\circ}$ C

Gas flow:

Helium (carrier): 28 ml/min

Argon-Methane: 42 ml/min

Retention Time: 0.64 min

Calculation

μ g methyl bromide/sample = [(std, ng/ μ l)(pk ht sample)(μ l std)(vol of solvent, ml)]/(pk ht std)(μ l sample)

Recovery

60% to 90%

Detection Limit

0.5 μ g/samples

Appendix E

Statistical Analysis

I. Quality Control Data

Analytical Recovery

A set of three QC spikes was included with each batch of field samples analyzed. Each set consisted of a high- (8.52 µg), medium- (4.26 µg) and low-level (0.85 µg) spike. In addition to the 12 spike sets analyzed with the field samples, four sets were analyzed independently. In these sets the high, medium and low spike levels were 8.52, 2.26, and 1.13 µg, respectively. Recovery at each spike level is shown in Table E-I-1.

Table E-I-One
Percent Analytical Recovery in QC Spikes

Type	<i>Spike Level</i>	n	Mean	Coefficient of variation
With field samples	<i>High</i>	12	61	11
	<i>Medium</i>	12	72	16
	<i>Low</i>	12	80	10
Independent	<i>High</i>	4	82	20
	<i>Medium</i>	4	69	19
	<i>Low</i>	4	67	7
Combined	<i>High</i>	16	66	19
	<i>Medium</i>	16	71	16
	<i>Low</i>	16	77	12

The 16 sets of spikes were combined for statistical analysis. Analysis of variance (randomized blocks model using sets as the blocks) indicated there were significant differences among spike levels in mean recovery ($F=4.15$; $df=2,30$; $p=0.0257$). Recovery was significantly greater at the low level than at the high level, while the medium level did not differ significantly from either of the others (Bonferroni t-tests with overall $\alpha=0.05$). Differences among the sets did not reach statistical significance ($F=1.81$; $df=15,30$; $p=0.0805$).

Storage Stability

Twenty high- (14.2 µg) and twenty low-level (1.12 µg) spikes were prepared and five of each level were analyzed after 1, 2, 3 and 4 weeks of storage. Recovery at each time is shown in Table E-I-2.

Table E-I-Two
Mean Percent Recovery in Storage Stability Spikes

Spike Level	Weeks of Storage			
	1	2	3	4
High				
Low				

High	70† (7)‡	66 (5)	62 (5)	67 (8)
Low	61 (9)	53 (9)	52 (4)	56 (6)
Combined	65 (10)	59 (14)	57 (10)	62 (12)

† For each mean n=5.

‡ Coefficient of variation

Analysis of variance (Week x Spike Level complete factorial model) showed significant differences among weeks ($F=7.16$; $df=3,32$; $p=0.0008$) and among spike levels ($F=72.39$; $df=1,32$; $p=0.0001$). The interaction was not statistically significant ($F=0.61$; $df=3,32$; $p=0.6151$), which means that while overall recovery was significantly higher in the high level spikes, the change in recovery from 1 to 4 weeks did not differ for high and low level spikes. Means comparisons (Bonferroni t-tests with overall $\alpha=0.05$) indicated that recovery for the combined spike levels was significantly lower after 2 weeks of storage than after 1 week. Week 3 recovery was not significantly lower than Week 2 (and was significantly lower than Week 1). Mean recovery after 4 weeks was higher than after 2 or 3 weeks, and did not differ significantly from any of the other weeks. However, this apparent decreasing then increasing trend probably represents variability inherent in recovery rather than a real effect of storage time. If recoveries were plotted chronologically for all of the QC spike sets, it would be seen that the week-to-week variation in storage stability samples is well within the range of set-to-set variation in the QC spikes. Moreover, the QC spike sets exhibit cyclical trends in recovery, even though they were all analyzed with no storage interval. (These cycles may indicate a need for better control over the analytical process.)

Although there appears to be no real loss of material between 1 and 4 weeks in storage, it does appear that there is loss between 0 and 1 week in the low-level spikes. Recoveries for high-level spikes were similar in QC and storage spikes, but with low-level spikes the recoveries were lower in the storage spikes, suggesting loss between Week 0 (when the QC spikes were analyzed) and the subsequent weeks. Mean recovery in the pooled storage stability spikes was compared to the mean of the pooled QC spikes at each level using t-tests for independent samples with unequal variances. For the low level spikes, recovery was significantly lower in the stored samples ($t=8.18$, $df=22.2$, $p=.0001$). These comparisons are shown in Table E-I-3.

Table E-I-Three
Mean Percent Recovery in Storage Stability vs. QC Spikes

Spike Level	Type	n	Mean	Standard Deviation
High	QC	16	66	13
	Storage	20	66	5
Low	QC	16	77 ^{***}	9
	Storage	20	55 ^{***}	5

^{***} Significantly different; $p<0.001$.

II. Comparison of Aeration Methods

Nonparametric statistical tests were used to compare outdoor concentrations under the two aeration methods. These tests can be used as alternatives to parametric methods such as the t- and F-tests, when the required assumptions about the form of the population distribution are untenable. The Wilcoxon Rank-Sums test is used to test the hypothesis that the experimental treatment increases (or decreases) the response relative to the control response, against the null hypothesis of no treatment effect. Specifically, it tests for a shift offsetting the treatment distribution from the control distribution. The Kolmogorov-Smirnov test is sensitive to any kind of difference between the treatment and control distributions. As an “omnibus” test, it is necessarily less powerful to detect any specific difference than is the Wilcoxon test to detect a shift. Both tests are described in E.L. Lehmann’s *Nonparametrics: Statistical Methods Based on Ranks* (Holden-Day, Inc., Oakland, California, 1975).

The Wilcoxon test was used to test the 1-sided hypothesis that higher concentrations are associated with the Standard Aeration Method. The p-values were obtained using the normal approximation (with continuity correction) to the distribution of the rank-sum statistic. The test results are given in Table E-II-1.

Table E-II-One
Comparison of Methyl Bromide Concentrations in Outdoor Air with
Standard vs. PCOC Aeration Method: Wilcoxon Rank-Sums Test.

<i>Sample Duration</i> Distance	Z statistic	p (1-sided)
<i>1-hour</i>	10 ft	2.09
	50 ft	-0.12
	100 ft	0.53
<i>24-hour</i>	10 ft	0.068
	50 ft	0.357
	100 ft	0.345

The Kolmogorov-Smirnov test was used to test the inherently 2-sided hypothesis that there is any difference between the distributions for the two methods. The results are shown in Table E-II-2.

Table E-II-Two

Comparison of Methyl Bromide Concentrations in Outdoor Air with Standard vs. PCOC
 Aeration Method: Kolmogorov-Smirnov Test.

<i>Sample Duration</i>	Distance	D statistic	p
<i>1-hour</i>	10 ft	0.449	0.054
	50 ft	0.200	0.991
	100 ft	0.222	0.979
<i>24-hour</i>	10 ft	0.382	0.159
	50 ft	0.200	0.991
	100 ft	0.222	0.979

Appendix F Raw Data Tables

Table F-One
First Hour of Aeration
Methyl Bromide Levels in Air (in ppm)

Site #	Test One	Test Two	Test Three	Test Four	Test Five	Test Six	Test Seven
1	0.050	<u><i>0.011</i></u>		0.489	4.154	0.012	2.870
2		<u><i>0.012</i></u>	0.096	0.018	0.706	<u><i>0.011</i></u>	1.360
3		0.845	2.231	0.269	4.883	<u><i>0.011</i></u>	7.425
4		0.448	2.974	1.119	0.062	0.074	0.228
5		6.547	13.594	6.486	0.225	4.550	0.708
6		5.995	10.904	5.952	8.055	1.001	1.566
7			6.429	7.515	11.285	0.638	11.826
8	0.021	0.015	0.443	0.561	2.270	0.040	2.947
9	0.015					0.072	0.030
10	0.020			<u><i>0.011</i></u>			
11	0.165	0.035	0.076	<u><i>0.012</i></u>	0.015		
12	1.814	0.188	0.170	0.171	<u><i>0.012</i></u>	<u><i>0.012</i></u>	<u><i>0.011</i></u>
13	3.182	1.707	0.723	0.472	<u><i>0.011</i></u>	0.330	<u><i>0.012</i></u>
14	1.321	1.784	1.488	0.978	0.299	1.042	0.211
15	0.014		0.067	0.122	1.163	<u><i>0.011</i></u>	0.705
16	<u><i>0.012</i></u>						
17	<u><i>0.012</i></u>	<u><i>0.012</i></u>	0.013				
18	0.398	0.040	<u><i>0.012</i></u>	<u><i>0.012</i></u>	<u><i>0.011</i></u>	<u><i>0.012</i></u>	<u><i>0.012</i></u>
19	0.752	0.342	0.042	<u><i>0.012</i></u>	<u><i>0.012</i></u>	0.055	<u><i>0.012</i></u>
20	0.277	0.366	0.496	0.496	0.108	0.259	0.023
21	<u><i>0.012</i></u>		0.087		0.646	<u><i>0.011</i></u>	0.380

Note: Numbers in underlined italics are derived from minimum detectable value of 0.5 $\mu\text{g}/\text{sample}$.
Blank cells are from samples which failed or otherwise met voiding criteria (see Sample Storage and Analysis section).

Table F-Two
First 12 Hours of Aeration
Methyl Bromide Levels in Air (in ppm)

Site #	Test One	Test Two	Test Three	Test Four	Test Five	Test Six	Test Seven
1	0.035	0.019	0.046	0.070	0.326	<u>0.011</u>	0.293
2	0.042	0.030	0.026	0.016	0.111	<u>0.013</u>	0.123
3	0.143	0.256	0.249	0.112	0.488	<u>0.013</u>	0.444
4	0.376	0.164	0.157	0.095	0.049	0.015	0.023
5	1.122	1.046	1.210	0.495	0.162	0.488	0.097
6	0.790	0.714	0.819	0.498	0.722	0.066	0.234
7	0.304	0.217		0.919	0.990	0.078	0.688
8	0.045	0.016	0.027	0.062	0.241	<u>0.012</u>	0.259
9	<u>0.011</u>	<u>0.013</u>	<u>0.011</u>	<u>0.011</u>	0.016	<u>0.011</u>	<u>0.013</u>
10	<u>0.013</u>	0.015	0.012	<u>0.012</u>	<u>0.012</u>	<u>0.012</u>	<u>0.012</u>
11	0.020	0.038	0.024	<u>0.011</u>	<u>0.012</u>	<u>0.012</u>	<u>0.011</u>
12	0.141	0.036	0.046		<u>0.012</u>	<u>0.011</u>	<u>0.012</u>
13	0.264	0.196	0.072	0.049	0.013	<u>0.011</u>	<u>0.012</u>
14	0.147	0.128	0.171	0.119	0.052	0.068	0.027
15	<u>0.012</u>	<u>0.013</u>	<u>0.012</u>	0.016	0.124	<u>0.013</u>	0.074
16	<u>0.012</u>	<u>0.012</u>	<u>0.012</u>	<u>0.011</u>	<u>0.011</u>	<u>0.012</u>	<u>0.012</u>
17	<u>0.011</u>	0.016	<u>0.011</u>	<u>0.011</u>	<u>0.012</u>	<u>0.012</u>	<u>0.012</u>
18	0.046	0.024	<u>0.012</u>		<u>0.012</u>	<u>0.012</u>	<u>0.013</u>
19	0.064	0.050	<u>0.011</u>	<u>0.011</u>	<u>0.012</u>	<u>0.012</u>	<u>0.013</u>
20	0.048	0.062	0.049	0.038	0.021	0.028	0.013
21	<u>0.011</u>		<u>0.012</u>	0.015	0.054	<u>0.011</u>	0.033
22	<u>0.012</u>	<u>0.011</u>	<u>0.013</u>	<u>0.012</u>	<u>0.012</u>	<u>0.012</u>	<u>0.011</u>
23	<u>0.010</u>	<u>0.012</u>	<u>0.012</u>	<u>0.011</u>	<u>0.011</u>	<u>0.012</u>	<u>0.012</u>
24	<u>0.011</u>	<u>0.012</u>	<u>0.013</u>	<u>0.012</u>	<u>0.013</u>	<u>0.013</u>	<u>0.012</u>
25	0.016	<u>0.012</u>	<u>0.012</u>	<u>0.012</u>	<u>0.012</u>	<u>0.012</u>	<u>0.011</u>
26	0.031	0.021	<u>0.012</u>	<u>0.012</u>	<u>0.012</u>	<u>0.012</u>	<u>0.013</u>
27	0.025	0.021	<u>0.012</u>	0.025	<u>0.013</u>	0.019	<u>0.008</u>
28	<u>0.011</u>		<u>0.012</u>	<u>0.012</u>	0.012	<u>0.012</u>	<u>0.012</u>
29	<u>0.012</u>	<u>0.013</u>	<u>0.013</u>	<u>0.012</u>	<u>0.011</u>	<u>0.012</u>	<u>0.012</u>

Table F-Three
Second 12 Hours of Aeration
Methyl Bromide Levels in Air (in ppm)

Site #	Test One	Test Two	Test Three	Test Four	Test Five	Test Six	Test Seven
1	<u>0.012</u>	0.020	0.025	0.015	<u>0.012</u>	<u>0.011</u>	<u>0.011</u>
2	<u>0.011</u>	0.033	0.032	0.016	<u>0.017</u>	<u>0.013</u>	<u>0.011</u>
3	0.038	0.132	0.045	0.063	0.037	0.024	0.037
4	<u>0.011</u>	0.021	0.033	0.015	0.017	0.013	<u>0.012</u>
5	<u>0.012</u>	0.017	0.012	<u>0.012</u>	<u>0.012</u>	0.011	<u>0.011</u>
6	<u>0.011</u>	0.013	<u>0.012</u>	<u>0.012</u>	<u>0.011</u>	<u>0.013</u>	<u>0.013</u>
7	<u>0.011</u>	0.019	0.013	<u>0.012</u>	<u>0.012</u>	<u>0.012</u>	<u>0.012</u>
8	<u>0.011</u>		<u>0.018</u>	<u>0.013</u>	<u>0.011</u>	<u>0.012</u>	<u>0.012</u>
9	<u>0.011</u>	<u>0.012</u>	<u>0.011</u>	<u>0.012</u>	<u>0.011</u>	<u>0.011</u>	<u>0.012</u>
10	<u>0.013</u>	0.013	<u>0.011</u>	<u>0.012</u>	<u>0.012</u>	<u>0.012</u>	<u>0.012</u>
11	<u>0.015</u>	<u>0.023</u>	0.018		<u>0.012</u>	<u>0.012</u>	0.012
12	<u>0.011</u>	<u>0.013</u>	<u>0.011</u>		<u>0.012</u>	<u>0.011</u>	<u>0.012</u>
13	<u>0.011</u>	<u>0.013</u>	<u>0.011</u>	<u>0.012</u>	<u>0.013</u>	<u>0.011</u>	<u>0.012</u>
14	<u>0.011</u>	<u>0.011</u>	<u>0.012</u>	<u>0.011</u>	<u>0.013</u>	<u>0.012</u>	<u>0.012</u>
15	<u>0.013</u>	<u>0.012</u>	<u>0.012</u>	<u>0.011</u>	<u>0.011</u>	<u>0.013</u>	<u>0.013</u>
16	<u>0.013</u>	<u>0.011</u>	<u>0.021</u>	<u>0.011</u>	<u>0.011</u>	<u>0.011</u>	<u>0.012</u>
17	<u>0.011</u>	<u>0.012</u>	0.014	<u>0.011</u>	<u>0.012</u>	<u>0.011</u>	<u>0.012</u>
18	<u>0.011</u>	<u>0.012</u>	<u>0.012</u>	<u>0.011</u>	<u>0.012</u>	<u>0.012</u>	<u>0.013</u>
19	<u>0.011</u>	<u>0.012</u>		<u>0.011</u>	<u>0.012</u>	<u>0.012</u>	<u>0.013</u>
20	<u>0.011</u>		<u>0.012</u>	<u>0.011</u>	<u>0.012</u>	<u>0.011</u>	<u>0.011</u>
21	<u>0.011</u>	<u>0.015</u>	<u>0.012</u>	<u>0.012</u>	<u>0.013</u>	<u>0.011</u>	<u>0.012</u>
22	<u>0.012</u>		<u>0.013</u>	<u>0.012</u>	<u>0.011</u>	<u>0.012</u>	<u>0.011</u>
23	<u>0.011</u>	<u>0.011</u>	<u>0.011</u>	<u>0.011</u>	<u>0.021</u>	<u>0.011</u>	<u>0.012</u>
24	<u>0.011</u>	<u>0.012</u>	<u>0.012</u>	<u>0.012</u>	<u>0.013</u>	<u>0.012</u>	<u>0.012</u>
25	<u>0.011</u>	<u>0.011</u>	<u>0.012</u>	<u>0.013</u>	<u>0.012</u>	<u>0.011</u>	<u>0.011</u>
26	<u>0.011</u>	<u>0.012</u>	<u>0.012</u>	<u>0.012</u>	<u>0.012</u>	<u>0.011</u>	<u>0.013</u>
27	<u>0.011</u>	<u>0.011</u>	<u>0.012</u>	<u>0.013</u>	<u>0.013</u>	<u>0.012</u>	<u>0.013</u>
28	<u>0.012</u>						
29	<u>0.012</u>	<u>0.013</u>	<u>0.012</u>	<u>0.012</u>	<u>0.011</u>	<u>0.012</u>	<u>0.012</u>

*Note: Numbers in underlined italics are derived from minimum detectable value of 0.5mg/sample.
Blank cells are from samples which failed or otherwise met voiding criteria (see Sample Storage and Analysis section).*

Table F-Four
 Neighboring House Methyl Bromide Levels During Aeration
Methyl Bromide Levels in Air (in ppm)

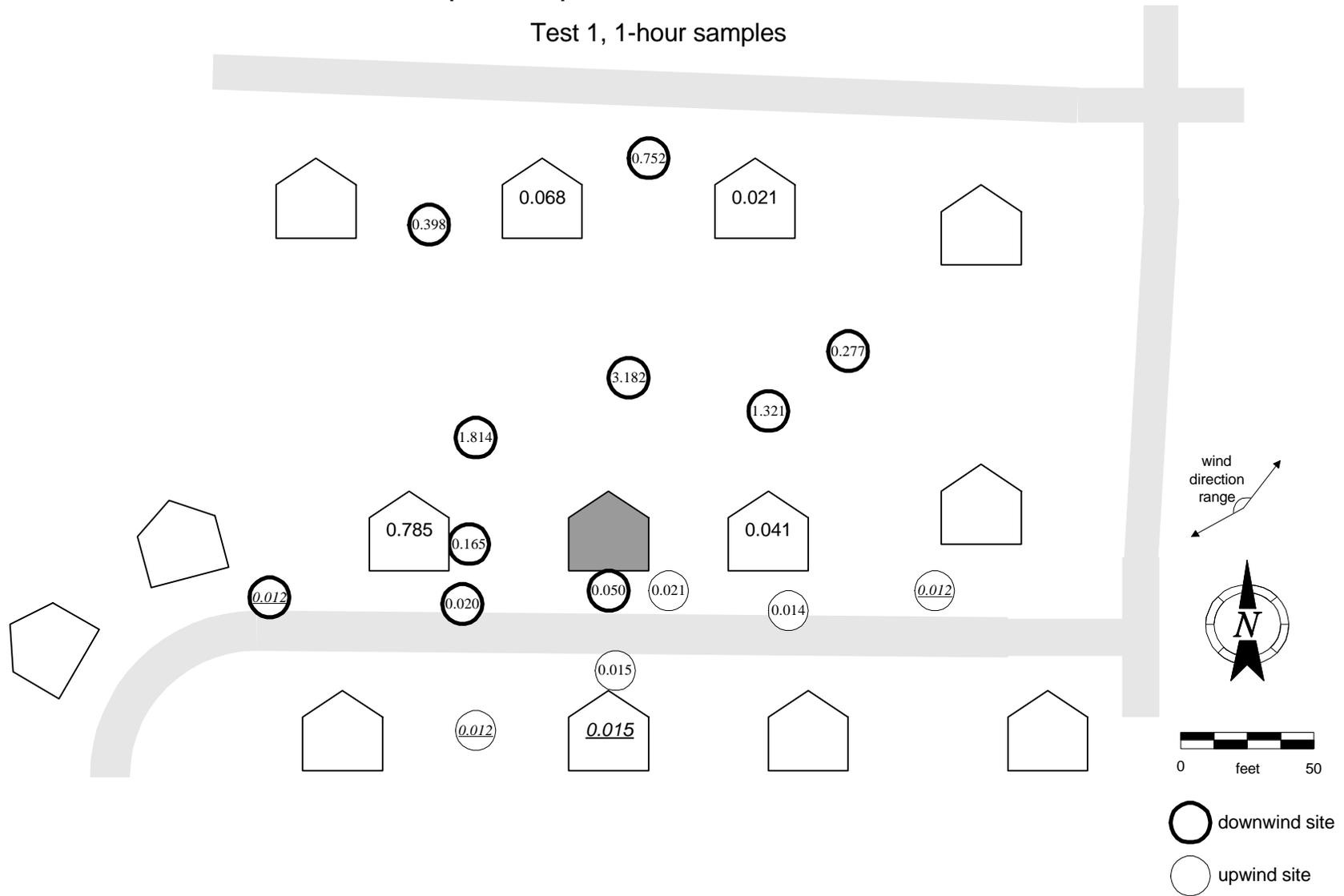
Time Period	Address	Test One	Test Two	Test Three	Test Four	Test Five	Test Six	Test Seven
First Hour	107	0.021	NS	0.020	0.020	<u>0.011</u>	0.033	<u>0.011</u>
	109	0.068	NS	0.025	0.039	0.013	0.083	<u>0.011</u>
	135	0.785	NS	0.229	0.105	1.139	0.210	0.078
	138	<u>0.015</u>	NS	0.041	0.025	0.013	<u>0.011</u>	<u>0.012</u>
	141	0.041	NS	0.117	0.096	0.094	0.031	0.090
First 12 Hours	107	0.033	0.045	<u>0.031</u>	0.016	<u>0.014</u>	0.026	<u>0.012</u>
	109	0.077	0.123	<u>0.014</u>	<u>0.011</u>	<u>0.013</u>	<u>0.014</u>	<u>0.016</u>
	135	0.378	0.085	<u>0.017</u>	<u>0.014</u>	0.031	<u>0.017</u>	0.040
	138	<u>0.012</u>	0.020	0.035	0.021	0.016	<u>0.014</u>	<u>0.015</u>
	141	0.064	0.029	0.154	0.121	0.107	0.037	<u>0.016</u>
Second 12 Hours	107	<u>0.015</u>	0.021	<u>0.020</u>	<u>0.016</u>	<u>0.017</u>	<u>0.017</u>	<u>0.012</u>
	109	0.018	0.045	<u>0.013</u>	<u>0.011</u>	<u>0.013</u>	<u>0.013</u>	<u>0.016</u>
	135	0.044	0.029	<u>0.016</u>	<u>0.014</u>	<u>0.016</u>	<u>0.016</u>	<u>0.016</u>
	138	<u>0.012</u>	<u>0.018</u>	<u>0.016</u>	<u>0.013</u>	<u>0.015</u>	<u>0.014</u>	<u>0.016</u>
	141	0.021	0.021	0.042	0.034	0.042	<u>0.016</u>	<u>0.015</u>

Note: Numbers in underlined italics are derived from minimum detectable value of 0.5 $\mu\text{g}/\text{sample}$.
 NS: No Sample taken during this test.

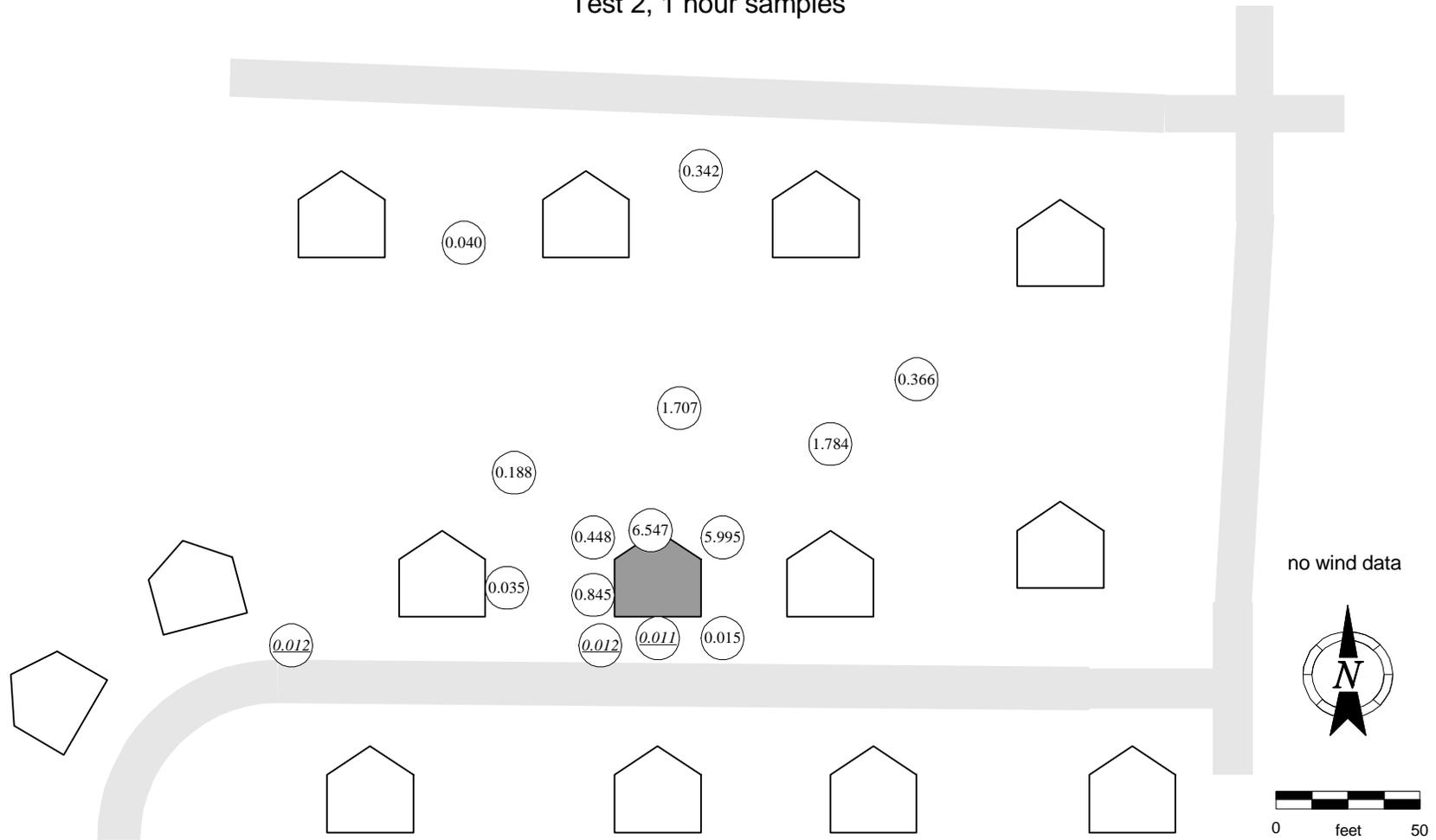
Appendix G

Graphic Representation of Site Values

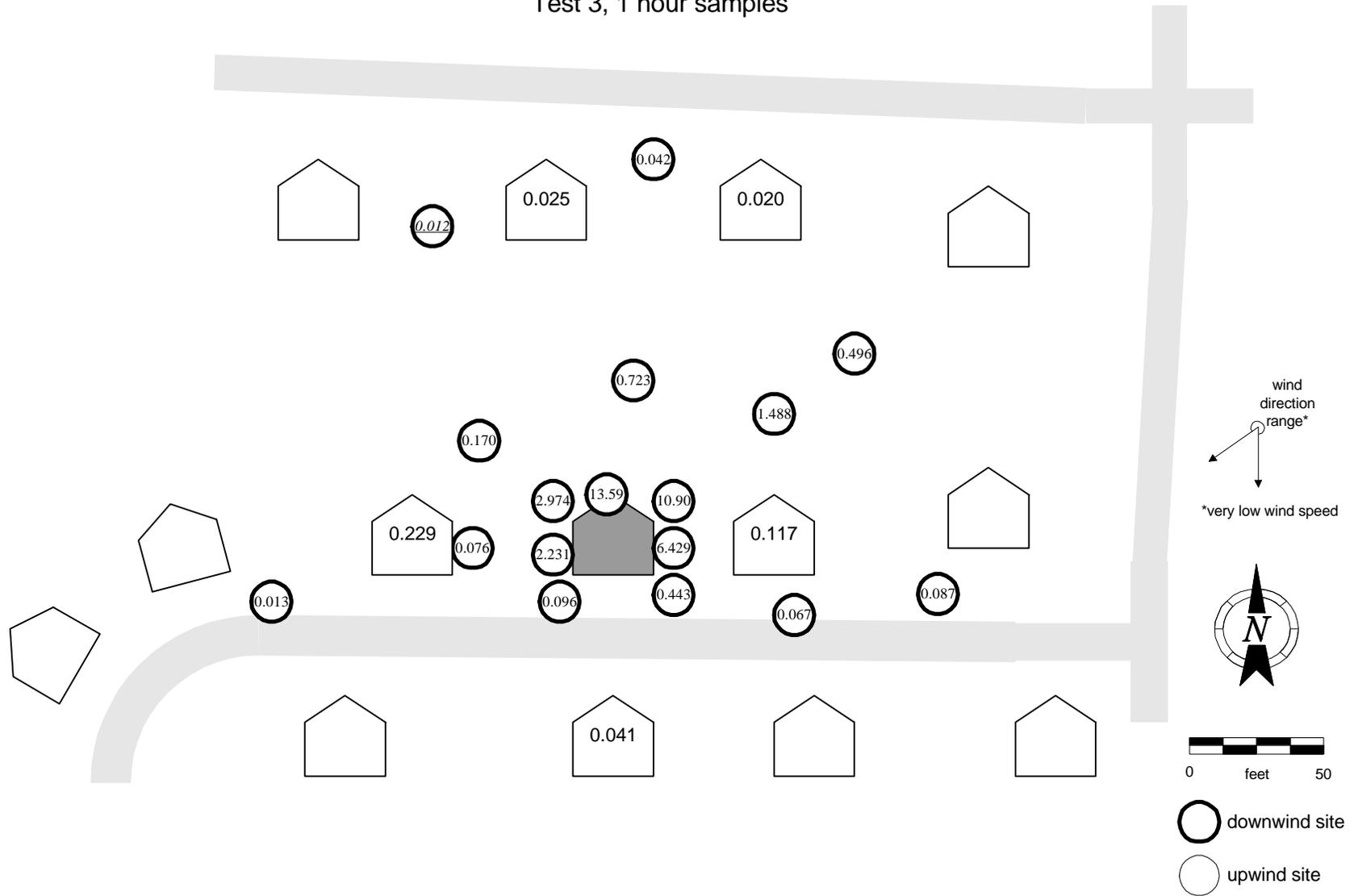
Test 1, 1-hour samples



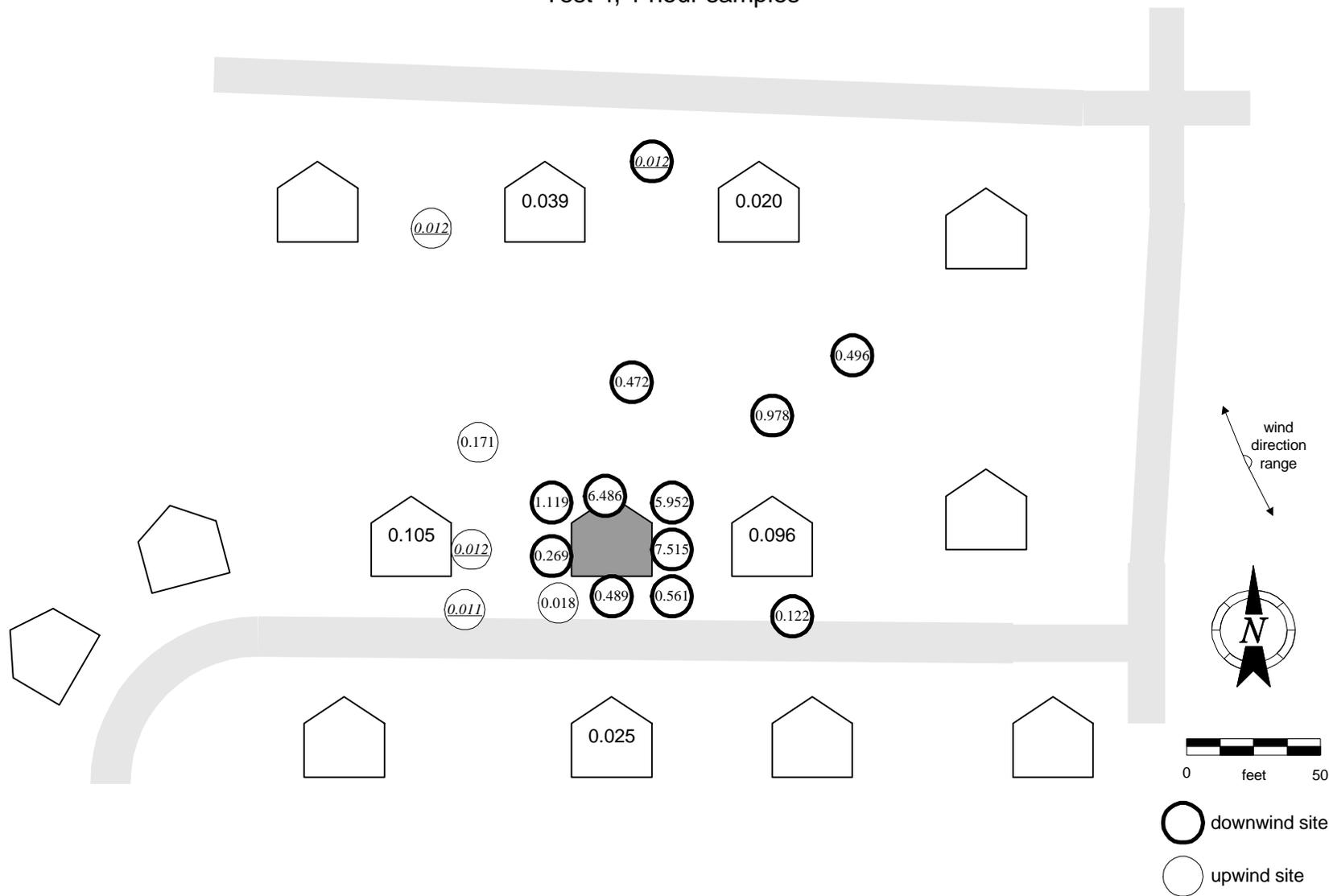
Test 2, 1 hour samples



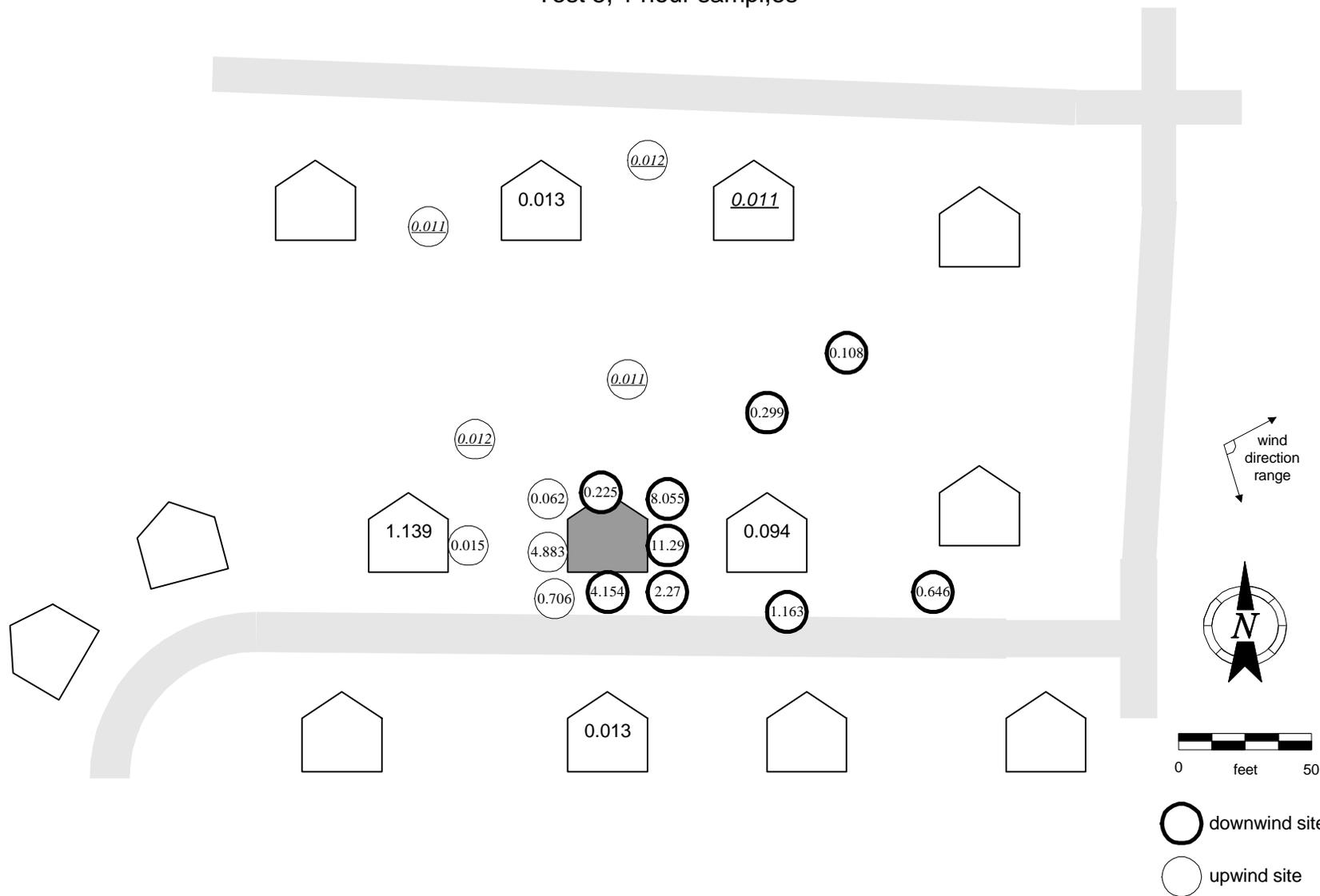
Test 3, 1 hour samples



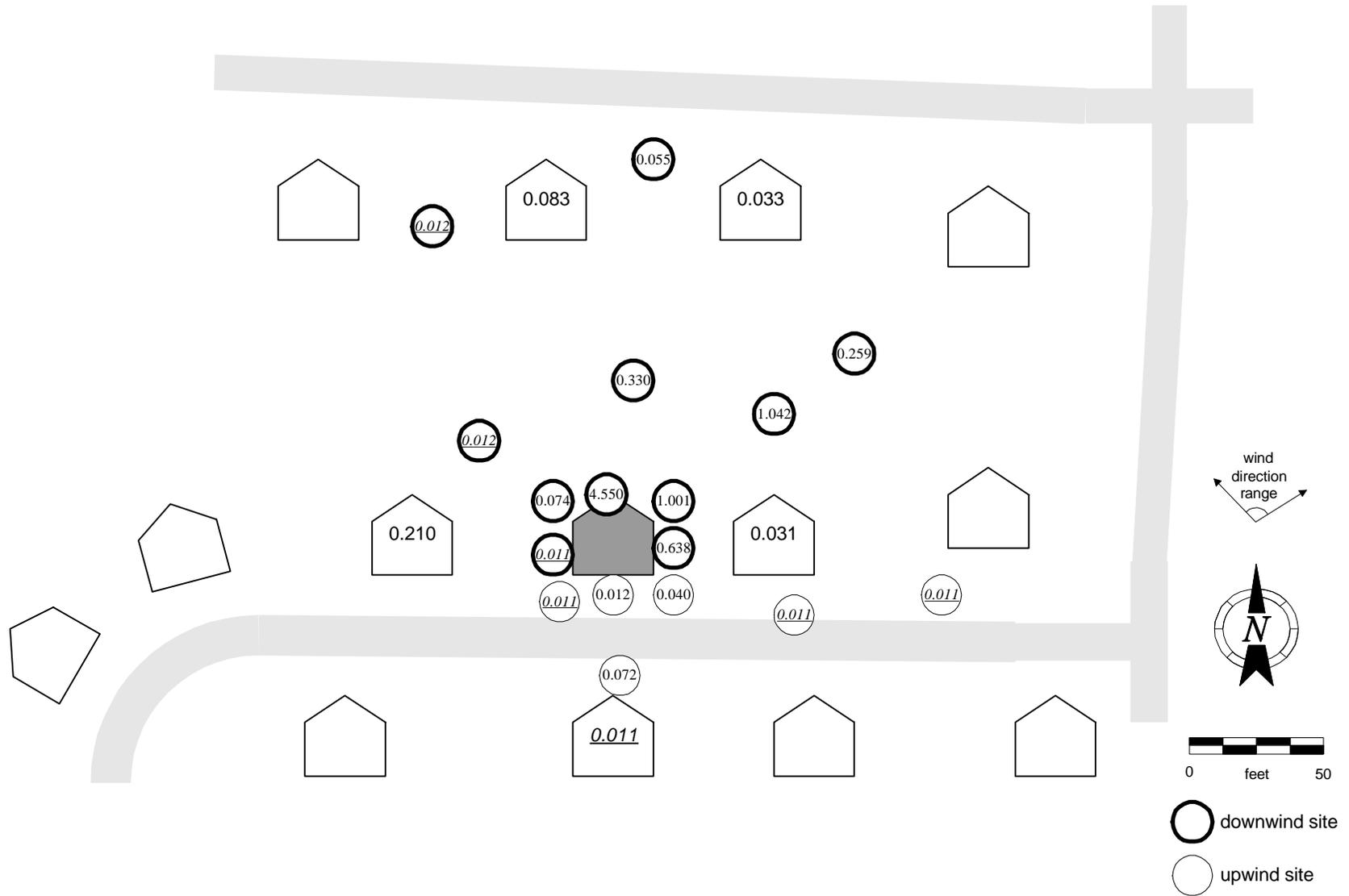
Test 4, 1 hour samples



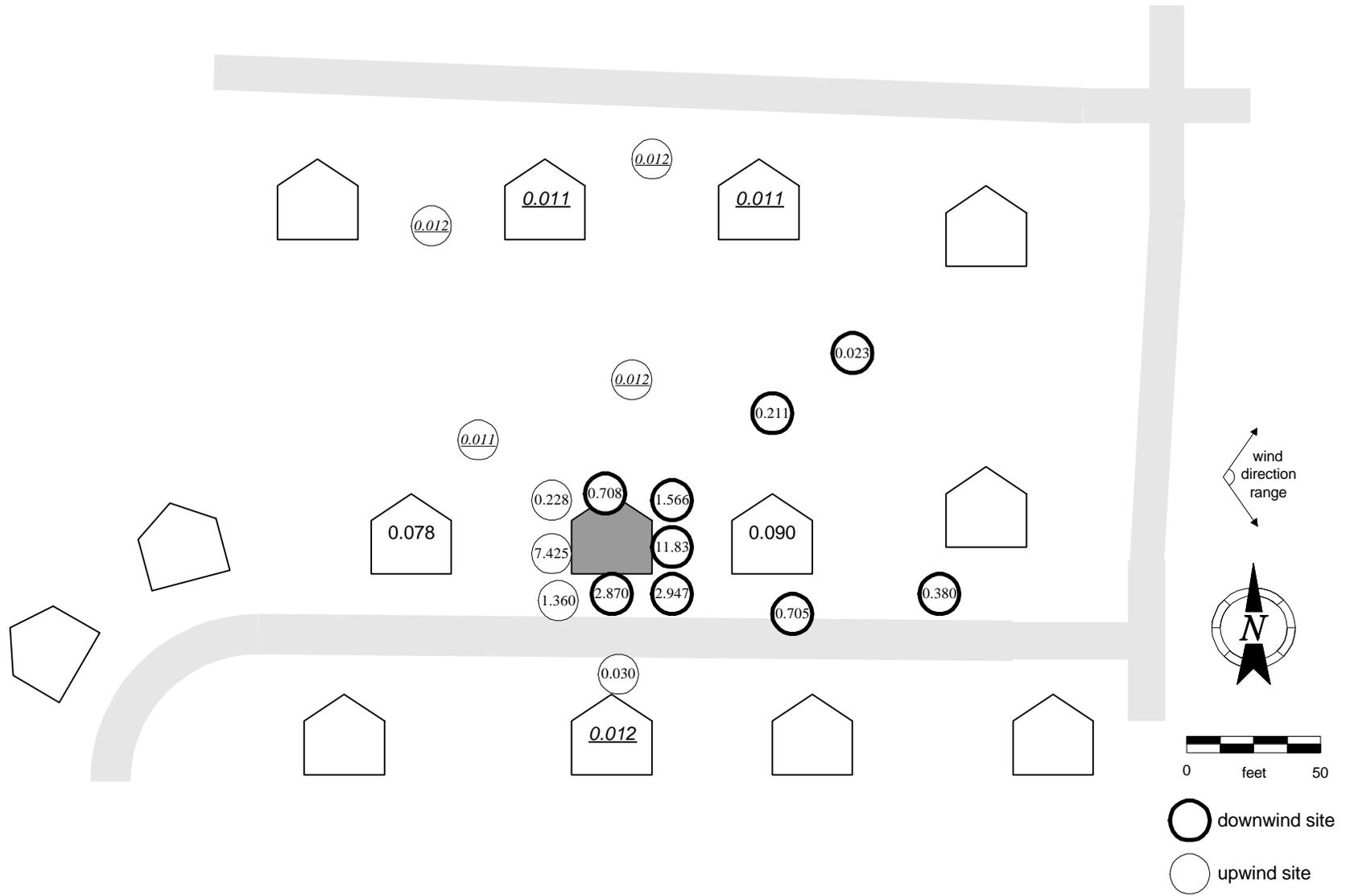
Test 5, 1 hour samples



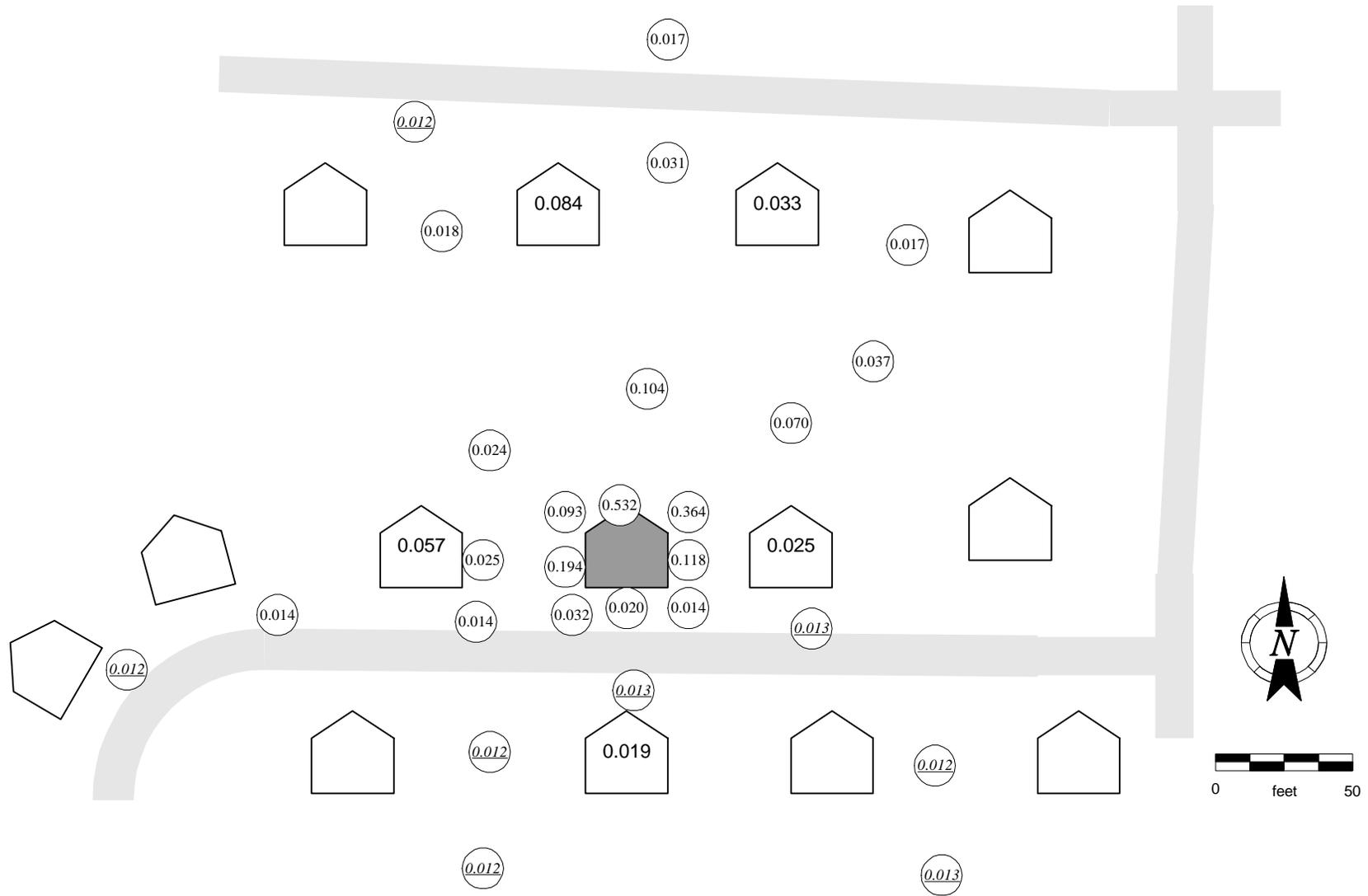
Test 6, 1 hour samples



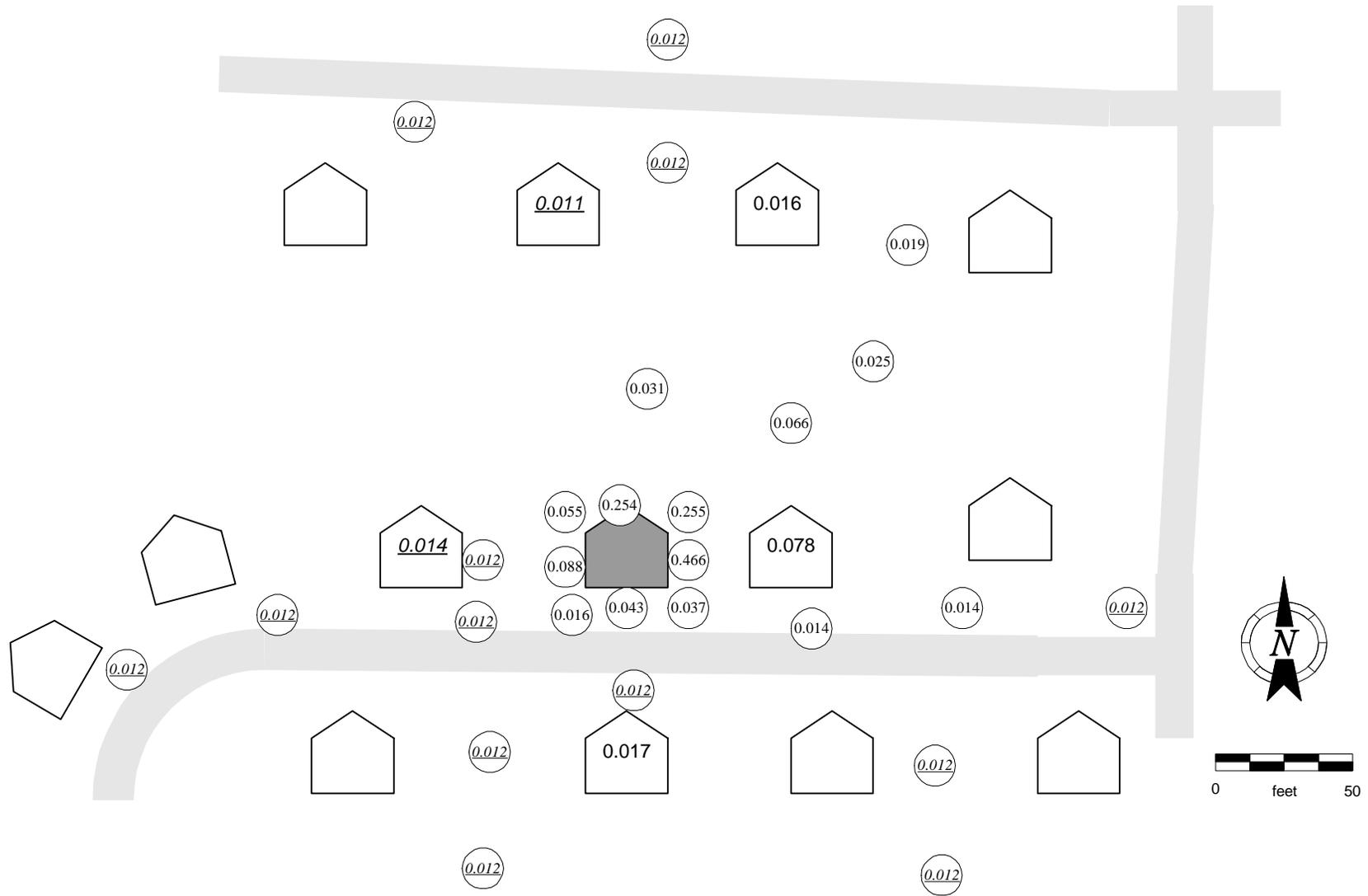
Test 7, 1 hour samples



Test 2, 24 hour samples



Test 4, 24 hour samples



Test 5, 24 hour samples

