Brian R. Leahy
Director

MEMORANDUM

Edmund G. Brown Jr.
Governor

TO: Pamela Wofford
Environmental Program Manager
Environmental Monitoring Branch

FROM: Jing Tao
Senior Environmental Scientist Specialist
Environmental Monitoring Branch
916-445-6189

Original Signed by

DATE: July 16, 2015

SUBJECT: AERMOD MODELING FOR TWO AIR MONITORING STUDIES OF STRUCTURAL FUMIGATION WITH SULFURYL FLUORIDE

I. BACKGROUND

In 2007, the Department of Pesticide Regulation (DPR) listed sulfuryl fluoride as a toxic air contaminant and issued a risk management directive (Gosselin, 2007). The risk management directive specifies that DPR's "mitigation efforts should ensure that acute exposures to sulfuryl fluoride do not exceed the 24-hour time-weighted average (TWA) reference concentrations of 2.57 ppm (10.7 mg/m^3) for workers and 0.12 ppm (0.51 mg/m^3) for bystanders and residents." Sulfuryl fluoride is primarily used to fumigate residential houses and other structures. Monitoring by the Air Resources Board (ARB) and others indicate that some air concentrations exceed the regulatory target concentrations set by the risk management directive. To assist in developing measures to mitigate these exposures, DPR employed the air dispersion model AERMOD to estimate the distribution of sulfuryl fluoride air concentrations around the fumigated residential structures.

The computer modeling consists of two phases. Phase I is to evaluate the modeling performance of AERMOD for structure fumigation with sulfuryl fluoride by simulating previous monitoring studies, and to develop an appropriate modeling set-up for further simulation. Phase II will apply the developed set-up to assess potential exposure in residential areas of the counties using the most sulfuryl fluoride. This memorandum summarizes the air modeling and data analysis of Phase I.

II. AIR MONITORING STUDIES

Few, if any, studies report quantified sulfuryl fluoride emissions (i.e. flux) from fumigated residential structures. However, this data is crucial to developing mitigation measures for pesticides. In 2004, at the request of DPR, ARB conducted monitoring studies at two houses, one in Loomis and one in Grass Valley (ARB, 2005a; ARB, 2005b). These two studies provided information about the fumigated houses, onsite meteorological records, outdoor sampling procedure and results, and indoor initial and terminal concentrations (Table 1). The data obtained from these two studies is used in Phase I modeling to evaluate AERMOD's performance in modeling residential structure fumigation and to develop modeling set-ups for this sulfuryl fluoride project.

In the 2004 ARB monitoring studies, the tarps were removed following 40 – 50 minutes of mechanical venting after the fumigation treatment was completed. The short period of mechanical venting was conducted to remove the gas between the tarp and the structure. The period after the tarps were completely removed was defined as "aeration" in these two studies (ARB, 2005a; ARB, 2005b). This aeration procedure differed from the current California Aeration Plan (CAP). The CAP requires conducting at least 16 hours of mechanical aeration for initial concentrations between 33 and 48 oz /1000 ft^3 and then removing tarps and seals. Hence, the aeration period of the two 2004 ARB studies do not represent the CAP and are not modeled.

Four sampling intervals at the Loomis site and seven sampling intervals at the Grass Valley site were scheduled during the fumigation treatment period. In both studies, the air monitoring samplers (receptors) were placed in three rings at distances of 5, 10, and 40 feet from the edge of the structure (ARB, 2005a; ARB, 2005b). The sampler locations were shown in the site diagram of the study reports but their coordinates were not reported. In these studies, the onsite meteorological station was set up at a height of 21 feet to measure wind speed and direction, air temperature, barometric pressure, and relative humidity. The station was positioned 845 feet from the Loomis house and 100 feet from the Grass Valley house. The raw meteorological data were not available in electronic format so the 5-minute average data in Appendix VI of the ARB reports (2005a, 2005b) were input to Excel as meteorological data.

III. AERMOD MODELING

AERMOD is a Gaussian plume dispersion model based on planetary boundary layer turbulence structure and scaling concepts. This model was developed by the American Meteorological Society/Environmental Protection Agency Regulatory Model Improvement Committee. AERMOD retains an input /output structure similar to the Industrial Source Complex, version 3 (ISC3) and incorporates new or improved algorithms such as convective and stable boundary layer dispersion, plume rise and buoyance, urban nighttime boundary layer, treatment of building wake effects, and treatment of receptors on all types of terrain (USEPA, 2004). The United States Environmental Protection Agency (USEPA) prefers AERMOD for regulatory air quality modeling. Two pre-processors (AERMET and AERMAP) and the dispersion model forms the AERMOD modeling system. AERMET processes the meteorological data and provides two types of meteorological input files for AERMOD. AERMAP characterizes the terrain information for sources and receptors. AERMOD View, an interface of AERMOD developed by Lakes Environmental, is used for modeling in this memorandum.

1. Meteorological Data Processing

AERMET needs both meteorological data and surface characteristics to calculate boundary layer parameters. The weather information recorded in these two studies was not sufficient for AERMOD input. Therefore, the DPR Environmental Monitoring Branch requested assistance from the ARB Modeling and Meteorology Branch to process the meteorological data for this AERMOD modeling project (Duncan, 2014). ARB staff combined wind speed, wind direction, temperature, and relative humidity data from onsite weather records and solar radiation data from Remote Automated Weather Station (RAWS) to create hourly surface weather data. Thus, parts of the surface weather information for modeling the Loomis study came from the RAWS station at Lincoln, CA and some weather information for the Grass Valley study came from the RAWS station at Reader Ranch, CA. The surface data and the upper air data from Oakland International Airport (Station No. 23230) were then processed by AERMET to output surface and profile weather files. Only one upper air station at Oakland is available in the northern California area so the data from this station were used for both locations. The weather files output by AERMET were sent to DPR for the AERMOD modeling.

2. Modeling Sources, Receptors, and Periods

Residential structures are tarped during the sulfuryl fluoride treatment period. The bottom edges of the tarps are sealed to the ground using soil, sand, or weighted “snakes”. Gas escaping through the bottom seal and soil could be an important source of sulfuryl fluoride emissions. Mass loss through the tarp could also contribute to the emissions. The houses during the treatment period can be represented as multiple area sources with the same location and size but at different sets of heights (Barry et al., 1996). ARB’s monitoring studies (2005a, 2005b) did not record the coordinates of each corner of the tarped houses. For modeling purpose, the area sources are assumed to be a rectangle shape and they are mapped through AERMOD View and Google Earth Pro to represent the source as closely as possible. Receptor coordinates used in the modeling input are also obtained by mapping the site diagrams in the study reports on Google Earth Pro. The Universal Transverse Mercator (UTM) coordinate system is used in the modeling and mapping. Since AERMOD runs hourly data, each modeling period is slightly different from the actual sampling period, which usually did not start on the hour. These time differences are negligible, shorter than 5% of period durations. More details are described below for the individual sites.

Loomis Site

Two scenarios of sulfuryl fluoride mass loss are modeled for the Loomis house, a 3.9 m high structure. Scenario I assumes that 100% mass loss of sulfuryl fluoride escapes from the ground seal. This scenario has one area source placed at 0 m height. Scenario II assumes that 50% mass loss is from the ground seal (one area source at 0 m) and 50% from the tarp at the receptor height (another area source at 1.5 m). The higher source is also close to the middle height of the house. A diagram of the modeling sources and receptors at the Loomis site is shown in Figure 1. As mentioned above, the modeling periods cannot perfectly match the sampling periods. Their different start and end times are compared in Table 2.

Grass Valley Site

Three mass loss scenarios are modeled for the Grass Valley house, a 7.0 m high structure. Scenario I has one area source at ground level (0 m high) and assumes that 100% mass loss of sulfuryl fluoride escapes from the ground seal. Scenario II assumes that 50% mass loss is from the ground seal (0 m) and 50% mass loss from the tarp at the receptor height (1.5 m). Scenario III assumes that 50% mass loss of sulfuryl fluoride escapes from the ground seal (0 m) and 50% from the tarp at the height equal to the middle height of the house (3.5 m). A diagram of the modeling sources and receptors at the Grass Valley site is shown in Figure 2. The start and end times of the monitoring and modeling periods are compared in Table 3.

3. Flux Estimation

DPR developed a procedure to back-calculate flux using air monitoring measurements and ISC modeling results (Ross et al., 1996, Johnson et al., 2010). Sulfuryl fluoride Phase I modeling uses a similar procedure with AERMOD results. Since the flux during the fumigation period is unknown, the modeling starts with a nominal flux of 1 g/s-m^2 for each modeling period. For scenarios with two area sources, each source was assigned with 0.5 g/s-m^2 and the total nominal flux is 1 g/s-m^2. The modeling results are then paired with monitoring measurements and statistical regression analysis is used to estimate the slope between the two sets of data. The slope value brings the modeled air concentration into line with the pattern and magnitude of the measured air concentrations so it can be interpreted as the flux.

The monitoring data reported some air concentrations lower than the method detection limit (MDL) or the estimated quantitation limit (EQL). Before the statistical analysis, the records of samples < MDL were substituted with the value of the MDL and the records of samples < EQL were substituted with the EQL. The monitoring data are paired with the modeling results for each modeling period by their receptor location and by their rank in each period. The classic least squares method is applied to estimate linear regression slope, coefficient of determination (R^2), and p-value of the paired data. P-values and R^2s are used to evaluate the significance and performance of the regression. The regression is statistically significant if p-value is less than 0.05.

For each period, a slope estimated from a significant regression is considered to be the flux estimate. Regression of data paired by receptors (Receptor Pair) intends to match the measured concentrations to the simulated concentrations in both space and time. However, even small variations in measured wind direction can cause significantly different spatial patterns of air concentrations (Zannetti, 1990). Therefore, the matching in space and time is a rigorous expectation and may not be achieved. Regression of data paired by rank (Rank Pair) focuses on matching the magnitude of the measured concentrations to the modeling results during the same sampling interval. The concentration locations do not have to match since the magnitude of the air concentrations is the key to estimate sulfuryl fluoride exposure around a fumigated house.

4. Mass Loss Estimate

With the estimated flux expressed as mass/area-time, the mass loss of each modeling period can be calculated by multiplying the flux with the source area and the duration of the period. The monitoring studies reported the initial and the terminal indoor concentrations of sulfuryl fluoride during the fumigation treatment period (Table 1). The total mass loss of the treatment period can also be calculated from the decrease of the reported indoor concentrations and the known volume of the structure. The mass losses calculated using the decreased indoor concentrations are 78.5 lbs at the Loomis site and 70.8 lbs at the Grass Valley site. The Loomis study introduced additional 45.5 lbs sulfuryl fluoride at the 21st hour of the treatment period; thus the total mass loss of this site is 124.0 lbs, the sum of 78.5 lbs and 45.5 lbs. To evaluate AERMOD performance, the mass loss estimated from the modeling results are compared to 124.0 lbs and to 70.8 lbs measured in the Loomis and the Grass Valley studies, respectively.

5. Distribution of 24-hour TWA Concentrations

For the selected source scenario, an emission file is made to assign the estimated flux to each sampling period. A receptor network with a grid spacing of 5 m is set in a domain of 160 m by 160 m around the area source. With these two new inputs, the 24-hour TWA concentrations during the fumigation are modeled by AERMOD for the receptor network. Contour maps are plotted to show the distributions of sulfuryl fluoride concentrations near the fumigated houses. Google Earth Pro was used to locate the greatest distance from the fumigated houses where each of the following modeled air concentrations occurred on the contour map: (1) the regulatory target concentration of 0.12 ppm (510 $\mu g/m^3$), designated for bystanders and residents in the risk management directive; (2) 3 times the regulatory target concentration (0.36 ppm or 1530 $\mu g/m^3$); and (3) 10 times the regulatory target concentration (1.2 ppm or 5100 $\mu g/m^3$).

IV. RESULTS AND DISCUSSIONS

1. Comparison of Mass Loss Scenarios

As described above, two scenarios of sulfuryl fluoride mass loss are modeled for the Loomis study. Linear regressions are estimated for the monitoring data (respond variable) paired with the modeling results (predictor variable). Regression estimates are listed in Appendix I with the modeled air concentrations. For every modeling period of the two scenarios, the linear regressions of both the Receptor Pair and the Rank Pair are significant (p-value < 0.05). The regression slopes are used as the flux to calculate the mass loss (Table 4). The ratio of the model estimated mass loss and the mass loss calculated from the measured indoor concentrations (124.0 lbs) is close to 1. Scenario II shows a better fit between the measured and the modeled air concentrations with higher R^2.

Besides area source scenarios, the volume source representation was examined to simulate the Loomis study. The results showed that the modeled and measured air concentrations had poor correlation. Receptor Pair had significant regression in only two periods. The estimated mass loss was 348 lbs, about 2.8 times the measured mass loss. This result is consistent with the previous modeling work for warehouse fumigation by Barry et al. (2006).

Three mass loss scenarios are modeled for the Grass Valley study. For most of the modeling periods, the regression of monitoring data and modeling results paired by receptor is not statistically significant (Table 5). Two potential factors could be responsible for these results. First, Google Earth and the study report indicate that the Grass Valley house was surrounded by trees from 10 feet to over 40 feet tall. These trees and the building itself could alter the air flow near the house. The meteorological data collected by the 21 feet tall station at 100 feet from the house may not represent the meteorological conditions at 5 feet from the house. Second, the relative location of the samplers to the house and structure angles could have affected the air concentrations. At this study site, the modeled source and receptors cannot accurately reflect the real house dimensions and sampler locations because their coordinates were not reported. Unlike the Grass Valley site, the Loomis site is located at a much more open space and its shape is closer to a rectangle. The regression of monitoring data and modeling results paired by receptor is significant for all periods of the Loomis study.

Regression of Rank Pair is significant in all the modeling periods of the Grass Valley site. Three periods of Scenario II have significant linear regressions of Receptor Pair, while Scenario I has two significant periods and Scenario III has one. For period 4 and 6 where two or three scenarios have significant regression of Receptor Pair, Scenario II estimated higher R^2. These results suggest that Scenario II provides a better fit between the measured and simulated concentrations. For periods that regression of Receptor Pair is not significant, the slope of Rank Pair is the only option for the flux estimate. The mass loss is computed with the mixed estimates of Receptor Pair and Rank Pair and the estimates of Rank Pair only (Table 5). The ratio of the model estimated mass loss and the measured mass loss is 1.70 – 2.55. In Scenario II, the ratio is closer to 1 than in the other two scenarios.

2. Distribution of 24-hour TWA Air Concentrations

Two standards are used to choose the best modeling scenarios: (1) the modeled mass loss close to the measured mass loss, and (2) high R^2 estimated in the linear regression. The flux estimated with the Rank Pair of Scenario II is used for further modeling of the two ARB monitoring studies because the overall results are closest to the measured air concentration magnitude and total mass loss. Table 4 and 5 show that sulfuryl fluoride flux is greatest immediately after injection is complete and decreases over the span of the holding time. During the 41-hr sulfuryl fluoride treatment period of the Loomis study, 94 lbs mass loss (71% of the estimated total loss) occurs in the first 24-hour. For the 71-hr treatment period of the Grass Valley study, 73.5 lbs sulfuryl fluoride mass loss is estimated in the first 24-hour, 42.5 lbs in the second 24-hour, and 20.8 lbs in the last 23-hour. Therefore, off-site air concentrations for the first 24-hour following injection are modeled to assess the highest 24-hour TWA concentrations near the fumigated houses. Figure 3 and 4 present the isopleths with the labeled 24-hour TWA air concentrations. For the Loomis site, the greatest distance to the DPR regulatory target air concentration (510 $\mu g/m^3$) is approximately 90 feet from the house; the greatest distance to 3 times the target concentration (1530 $\mu g/m^3$) is 33 feet (Figure 3). The highest air concentration near the Loomis site is 3696 $\mu g/m^3$, estimated within 2 feet from the house. Figure 4 shows that the air concentration 510 $\mu g/m^3$ is estimated the farthest at 115 feet from the Grass Valley house. Air concentrations over 1530 $\mu g/m^3$ and 5100 $\mu g/m^3$ are estimated within 35 feet and 5 feet from the house.

V. CONCLUSIONS

Based on this analysis, we recommend using Scenario II in future AERMOD modeling for the residential structure fumigation. Scenario II assumes that (1) 50% sulfuryl fluoride mass loss escapes from the ground seal (area source height = 0 m); and (2) 50% mass loss escapes from the tarp at the height of 1.5 m. In Phase II, we will use AERMOD, with the recommended set-up, to assess potential exposures in the residential areas of five counties with the highest sulfuryl fluoride use in California.

VI. REFERENCE

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Table 1. Fumigation information of two air monitoring studies on residential structure fumigation with sulfuryl fluoride (ARB, 2005a; ARB, 2005b)

City of Structure Location	Loomis	Grass Valley
Size of Structure (ft^3)	45,000	81,000
Product Applied	Vikane®	
Type of Application	Structural, tarped	
Application Amount (lbs)	171.8 (initial 126.3, added 45.5 at 21 hr)	202.0
Duration of Fumigation (hr)	43.5	71.0
Initial Indoor Concentration (oz /1000 ft^3)	44.9	40.0
Terminal Indoor Concentration (oz /1000 ft^3)	17.0	26.0
Mass Loss during Fumigation Period (lbs, %)	124.0, 72.2	70.8, 35.0
Duration of Vent, including tarp removal (hr)	0.8	1.4
Duration of Aeration (hr)	72	72

Table 2. The start and end time of each monitoring and modeling period at the Loomis site

Period	Monitoring		Modeling	
	Recorded Time (mo/dd hhmm)	Duration(hr)	Time (mo/dd hhmm)	Duration(hr)
1	6/30 1305 – 6/30 1845	5.7	6/30 1300 – 6/30 1900	6
2	6/30 1845 – 7/01 0550	11.2	6/30 1900 – 7/01 0600	11
3	7/01 0550 – 7/01 1840	12.7	7/01 0600 – 7/01 1900	13
4	7/01 1840 – 7/02 0605	11.3	7/01 1900 – 7/02 0600	11

Table 3. The start and end time of each monitoring and modeling period at the Grass Valley site

Period	Monitoring		Modeling	
	Recorded Time (mo/dd hhmm)	Duration(hr)	Time (mo/dd hhmm)	Duration(hr)
1	7/19 1240 – 7/19 1830	5.9	7/19 1300 – 7/19 1900	6
2	7/19 1830 – 7/20 0605	11.5	7/19 1900 – 7/20 0600	11
3	7/20 0605 – 7/20 1835	12.5	7/20 0600 – 7/20 1900	13
4	7/20 1835 – 7/21 0605	11.5	7/20 1900 – 7/21 0600	11
5	7/21 0605 – 7/21 1830	12.4	7/21 0600 – 7/21 1900	13
6	7/21 1830 – 7/22 0605	11.5	7/21 1900 – 7/22 0600	11
7	7/22 0605 – 7/22 1200	6	7/22 0600 – 7/22 1200	6

Table 4. Modeled mass loss scenarios during the fumigation period of the Loomis study. The listed flux is the statistically significant linear regression slope (p-value <0.05) of the measured and modeled air concentrations paired by receptor (Receptor Pair) or paired by rank (Rank Pair).

Total mass loss measured at the Loomis Site: 124.0 lbs							
Scenario I: 336 m², 100% mass loss from 0 m height							
		Receptor Pair			Rank Pair		
Modeling Period	Hours	Flux ($g/s\text{-}m^2$)	R^2 (%)	Mass Loss (lbs)	Flux ($g/s\text{-}m^2$)	R^2 (%)	Mass Loss (lbs)
1	6	0.0024	47.8	38.3	0.0031	81.1	49.5
2	11	0.00086	42.3	25.2	0.0011	75.1	32.2
3	13	0.00084	59.9	29.1	0.00092	72.7	31.8
4	11	0.00078	38.1	22.8	0.00083	43.4	24.3
Total	41			115.4			137.8
Modeled/Measured				0.93			1.11
Scenario II: 336 m², 50% mass loss from 0 m height, 50% from 1.5 m height							
		Receptor Pair			Rank Pair		
Modeling Period	Hours	Flux ($g/s\text{-}m^2$)	R^2 (%)	Mass Loss (lbs)	Flux ($g/s\text{-}m^2$)	R^2 (%)	Mass Loss (lbs)
1	6	0.0023	52.8	36.7	0.0029	86.8	46.3
2	11	0.00085	54.3	24.9	0.0011	84.8	32.2
3	13	0.00083	71.8	28.7	0.00083	71.8	28.7
4	11	0.00081	52.1	23.7	0.00085	57.1	24.9
Total	41			114.0			132.1
Modeled/Measured				0.92			1.06

Table 5. Modeled mass loss scenarios during the fumigation period of the Grass Valley study. The listed flux is the statistically significant linear regression slope (p-value <0.05) of the measured and modeled air concentrations paired by receptor (Receptor Pair) or paired by rank (Rank Pair).

Total mass loss measured at the Grass Valley Site: 70.8 lbs

Scenario I: 315 m², 100% mass loss from 0 m height

		Receptor Pair and Rank Pair Mixed			Rank Pair		
Modeling Period	Hours	Flux ($g/s\text{-}m^2$)	R^2 (%)	Mass Loss (lbs)	Flux ($g/s\text{-}m^2$)	R^2 (%)	Mass Loss (lbs)
1	6	0.0027	73.2	40.4	0.0027	73.2	40.4
2	11	0.00037	89.1	10.2	0.00037	89.1	10.2
3	13	0.0014	79.1	45.4	0.0014	79.1	45.4
4	11	0.00025[a]	37.5	6.9	0.00041	97.4	11.3
5	13	0.00071	79.8	23.0	0.00071	79.8	23.0
6	11	0.00028[a]	77.5	7.7	0.00031	95.5	8.5
7	6	0.00022	65.9	3.3	0.00022	65.9	3.3
Total	71			136.9			142.1
Modeled/Measured				1.93			2.01

a. Statistically significant regression slopes estimated with Receptor Pair for period 4 and 6 of Scenario I. All the other periods use slopes estimated with Rank Pair.

Scenario II: 315 m², 50% mass loss from 0 m height, 50% from 1.5 m height

		Receptor Pair and Rank Pair Mixed			Rank Pair		
Modeling Period	Hours	Flux ($g/s\text{-}m^2$)	R^2 (%)	Mass Loss (lbs)	Flux ($g/s\text{-}m^2$)	R^2 (%)	Mass Loss (lbs)
1	6	0.0019[b]	33.9	28.4	0.0027	74.0	40.4
2	11	0.00038	88.2	10.4	0.00038	88.2	10.4
3	13	0.0013	71.7	42.2	0.0013	71.7	42.2
4	11	0.00026[b]	41.4	7.1	0.00040	97.5	11.0
5	13	0.00069	75.4	22.4	0.00069	75.4	22.4
6	11	0.00026[b]	80.3	7.1	0.00028	93.9	7.7
7	6	0.00019	72.4	2.8	0.00019	72.4	2.8
Total	71			120.4			136.9
Modeled/Measured				1.70			1.93

b. Statistically significant regression slopes estimated with Receptor Pair for Period 1, 4, and 6 of Scenario II. All the other periods use slopes estimated with Rank Pair.

Table 5 (Cont.). Modeled mass loss scenarios during the fumigation period of the Grass Valley study. The listed flux is the statistically significant linear regression slope (p-value <0.05) of the measured and modeled air concentrations paired by receptor (Receptor Pair) or paired by rank (Rank Pair).

Total mass loss measured at the Grass Valley Site: 70.8 lbs							
Scenario III: 315 m^2, 50% mass loss from 0 m height, 50% from 3.5 m height							
		Receptor Pair and Rank Pair Mixed			Rank Pair		
Modeling Period	Hours	Flux ($g/s\text{-}m^2$)	R^2 (%)	Mass Loss (lbs)	Flux ($g/s\text{-}m^2$)	R^2 (%)	Mass Loss (lbs)
1	6	0.0033	73.8	49.4	0.0033	73.8	49.4
2	11	0.00048	88.3	13.2	0.00048	88.3	13.2
3	13	0.0018	81.3	58.4	0.0018	81.3	58.4
4	11	0.00053	95.8	14.5	0.00053	95.8	14.5
5	13	0.00091	82.6	29.5	0.00091	82.6	29.5
6	11	0.00035[c]	73.7	9.6	0.00040	96.3	11.0
7	6	0.00029	61.9	4.3	0.00029	61.9	4.3
Total	71			178.9			180.3
Modeled/Measured				2.52			2.55

c. Statistically significant regression slopes estimated with Receptor Pair for period 6 of Scenario III. All the other periods use slopes estimated with Rank Pair.

Figure 1. Diagram of area source and receptor locations for the Loomis site

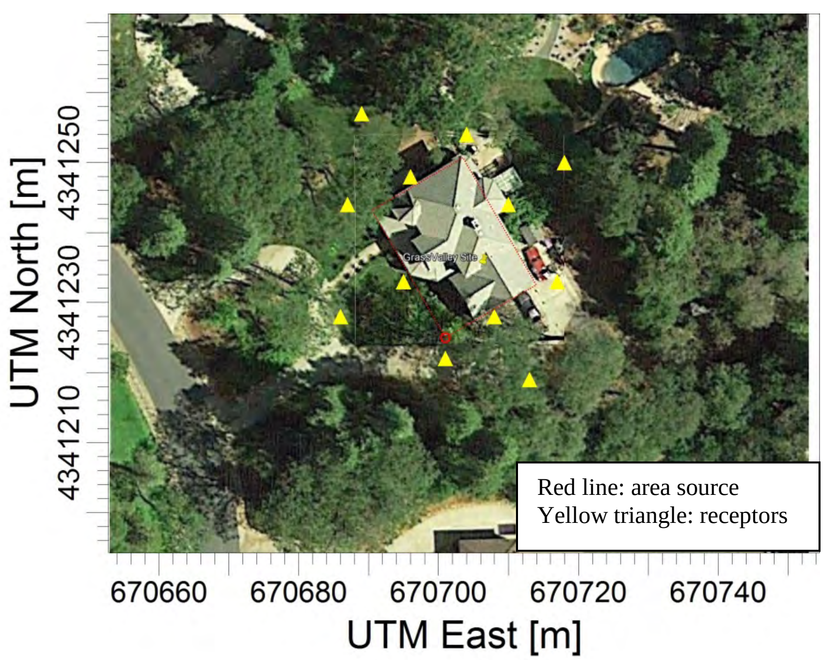

Figure 2. Diagram of area source and receptor locations for the Grass Valley site

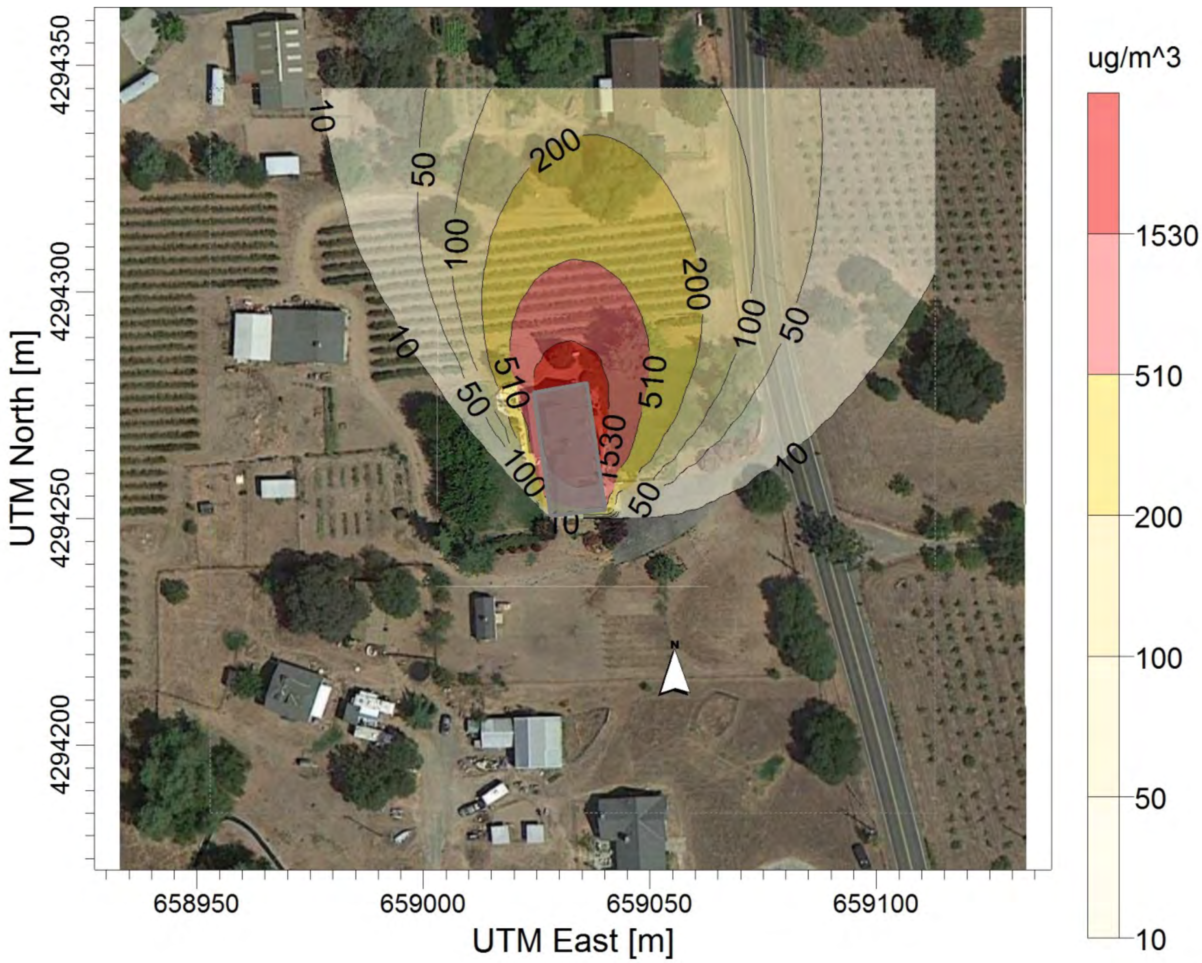

Figure 3. Highest 24-hour time weighted average air concentrations (μg/m^3) of sulfuryl fluoride estimated for the Loomis study site with AERMOD.

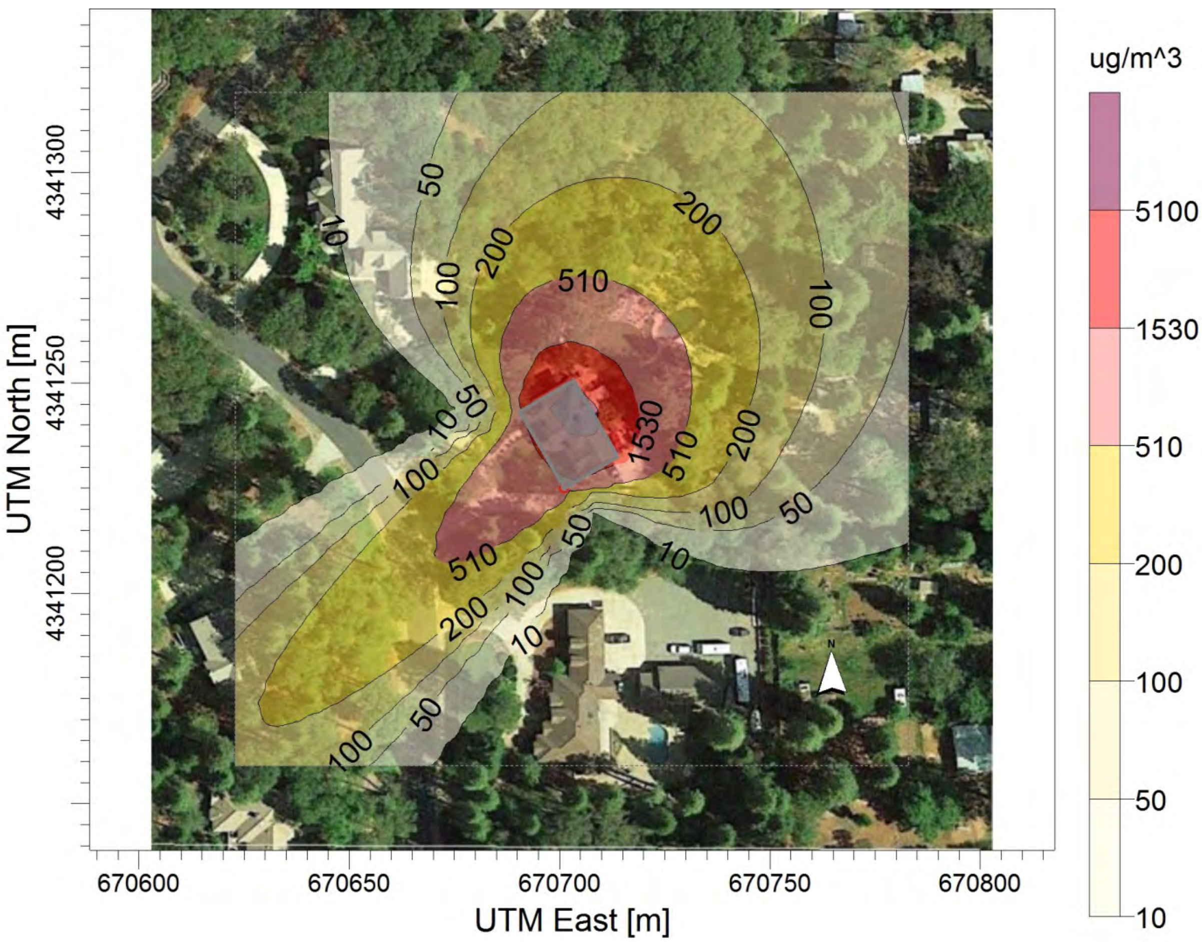

Figure 4. Highest 24-hour time weighted average air concentrations (µg/m^3) of sulfuryl fluoride estimated for the Grass Valley study site with AERMOD.

APPENDIX I

SULFURYL FLUORIDE AIR MONITORING RESULTS AND AERMOD ESTIMATES

LOOMIS STUDY

Receptor ID	UTM Coordinate		Monitored Sulfuryl Fluoride Air Concentrations (µg/m^3, ARB, 2005a)			
	Easting	Northing	Period 1	Period 2	Period 3	Period 4
EI	659039	4294265	6100	700	2100	580
EO	659049	4294273	676	68	400	338
N	659029	4294280	3800	3500	2100	3500
NEI	659037	4294282	1900	338	660	390
NEO	659038	4294291	1000	338	430	338
NWI	659021	4294279	676	1300	303	520
NWO	659013	4294283	676	460	303	338
SE	659043	4294250	676	338	303	338
SI	659034	4294248	676	338	303	338
SO	659036	4294238	676	338	303	338
SWI	659026	4294247	676	338	303	338
SWO	659017	4294243	676	338	303	338
W	659024	4294263	676	660	303	338

Sulfuryl Fluoride Mass Loss Modeling Scenario I: 336 m^2 area source 100% mass loss from 0 m height, 1 g/m^2-s							
Receptor ID	UTM Coordinate		Modeled Air Concentrations ($\mu g/m^3$)				
	Easting	Northing	Period 1	Period 2	Period 3	Period 4	
EI	659039	4294265	814732	840748	1450282	966271	
EO	659049	4294273	218477	90436	555605	136836	
N	659029	4294280	1343644	1972267	1334663	1832799	
NEI	659037	4294282	1228445	1603996	1601653	1760005	
NEO	659038	4294291	614785	991690	737031	1065647	
NWI	659021	4294279	302686	323692	161165	221612	
NWO	659013	4294283	64244	40449	26445	20807	
SE	659043	4294250	0	0	104946	0	
SI	659034	4294248	0	0	15089	0	
SO	659036	4294238	0	0	225	0	
SWI	659026	4294247	0	0	0	0	
SWO	659017	4294243	0	0	0	0	
W	659024	4294263	157092	145041	78937	96074	
Linear Regression Estimate	Receptor Pair	R^2 (%)	47.8	42.3	59.9	38.1	
		p-Value	0.009	0.016	0.002	0.025	
		Slope	0.0024	0.00086	0.00084	0.00078	
	Rank Pair	R^2 (%)	81.1	75.1	72.7	43.4	
		p-Value	0.000	0.000	0.000	0.014	
		Slope	0.0031	0.0011	0.00092	0.00083	

Sulfuryl Fluoride Mass Loss Modeling Scenario II: 336 m^2 area source 50% mass loss from 0 m height, 0.5 g/m^2-s 50% mass loss from 1.5 m height, 0.5 g/m^2-s						
Receptor ID	UTM Coordinate		Modeled Air Concentrations ($\mu g/m^3$)			
	Easting	Northing	Period 1	Period 2	Period 3	Period 4
EI	659039	4294265	906925	942853	1645372	1088505
EO	659049	4294273	220827	96158	546099	142703
N	659029	4294280	1615226	2454692	1664914	2313362
NEI	659037	4294282	1188536	1588430	1556330	1737876
NEO	659038	4294291	582443	935802	707427	999145
NWI	659021	4294279	307132	328302	170195	228807
NWO	659013	4294283	73000	48296	31733	26461
SE	659043	4294250	0	0	105664	0
SI	659034	4294248	0	0	16850	0
SO	659036	4294238	0	0	268	0
SWI	659026	4294247	0	0	0	0
SWO	659017	4294243	0	0	0	0
W	659024	4294263	165250	150680	86628	100943
Linear Regression Estimate	Receptor Pair	R^2 (%)	52.8	54.3	71.8	52.1
		p-Value	0.005	0.004	0.000	0.005
		Slope	0.0023	0.00085	0.00083	0.00081
	Rank Pair	R^2 (%)	86.8	84.8	71.8	57.1
		p-Value	0.000	0.000	0.000	0.003
		Slope	0.0029	0.0011	0.00083	0.00085

GRASS VALLEY STUDY

Receptor ID	UTM Coordinate		Monitored Sulfuryl Fluoride Air Concentrations (μg/m^3, ARB, 2005b)						
	Easting	Northing	Period 1	Period 2	Period 3	Period 4	Period 5	Period 6	Period 7
N	670704	4341254	2300	--	890	329	380	329	639
NEI	670710	4341244	1900	800	311	329	590	329	639
NEO	670718	4341250	676	329	311	66	311	66	128
E	670717	4341233	1600	329	311	329	311	329	639
SEI	670708	4341228	3300	1300	1000	1800	810	1000	850
SEO	670713	4341219	676	329	311	66	311	66	639
S	670701	4341222	676	590	520	660	311	520	639
SWI	670695	4341233	676	2400	1300	2200	1200	1800	1100
SWO	670686	4341228	135	830	330	550	311	590	639
W	670687	4341244	676	1600	510	1600	311	1000	639
NWI	670696	4341248	9900	960	3300	329	1800	329	1200
NWO	670689	4341257	676	329	311	329	311	66	639

Sulfuryl Fluoride Mass Loss Modeling Scenario I: 315 m^2 area source 100% mass loss from 0 m height, 1 g/m^2-s									
Receptor ID	UTM Coordinate		Modeled Air Concentrations ($\mu g/m^3$)						
	Easting	Northing	Period 1	Period 2	Period 3	Period 4	Period 5	Period 6	Period 7
N	670704	4341254	1694879	3786052	1088772	0	1245234	0	139368
NEI	670710	4341244	2567809	4285027	2087736	89324	2247586	0	1111960
NEO	670718	4341250	781132	1533588	605831	0	635976	0	297891
E	670717	4341233	785376	282473	948671	350329	902724	0	1036503
SEI	670708	4341228	384387	64166	1116040	4610810	985065	1576719	2937316
SEO	670713	4341219	1630	0	241732	1633645	156528	58844	861568
S	670701	4341222	0	0	549610	3946410	425043	2402844	2136153
SWI	670695	4341233	62255	14762	799042	3457948	993025	5404856	2311800
SWO	670686	4341228	0	0	805981	754697	852080	2307743	1592160
W	670687	4341244	103132	23402	83647	332	235485	1210080	18242
NWI	670696	4341248	1873674	3216434	1099399	21	1371138	607066	80808
NWO	670689	4341257	420014	592201	217238	0	239781	388	0
Linear Regression Estimate	Receptor Pair	R^2 (%)	30.3	2.2	4.3	37.5	19.4	77.5	7.7
		p-Value	0.064	0.665	0.517	0.034	0.152	0.000	0.382
		Slope	0.0017	-0.000065	0.00033	0.00025	0.00035	0.00028	0.000074
	Rank Pair	R^2 (%)	73.2	89.1	79.1	97.4	79.8	95.5	65.9
		p-Value	0.000	0.000	0.000	0.000	0.000	0.000	0.001
		Slope	0.0027	0.00037	0.0014	0.00041	0.00071	0.00031	0.00022

Sulfuryl Fluoride Mass Loss Modeling Scenario II: 315 m^2 area source 50% mass loss from 0 m height, 0.5 g/m^2-s 50% mass loss from 1.5 m height, 0.5 g/m^2-s									
Receptor ID	UTM Coordinate		Modeled Air Concentrations ($\mu g/m^3$)						
	Easting	Northing	Period 1	Period 2	Period 3	Period 4	Period 5	Period 6	Period 7
N	670704	4341254	1605182	3513042	1041813	0	1200168	0	149333
NEI	670710	4341244	2464050	4173956	2005674	97140	2136482	0	1084197
NEO	670718	4341250	768417	1498352	601755	0	623311	0	309134
E	670717	4341233	787262	309867	929179	379205	895424	0	1008471
SEI	670708	4341228	416121	94943	1354182	5058469	1117515	1801783	3432385
SEO	670713	4341219	1907	0	244924	1588789	163789	69313	846361
S	670701	4341222	0	0	601678	3642537	428611	2352606	2156191
SWI	670695	4341233	71143	19146	1327985	3595346	1450181	5884014	3272839
SWO	670686	4341228	0	0	751160	775689	808290	2165889	1498544
W	670687	4341244	109535	29348	105579	498	285002	1217471	40710
NWI	670696	4341248	1924016	3419559	1145128	66	1440724	674034	107307
NWO	670689	4341257	446458	631506	225624	0	256588	583	0
Linear Regression Estimate	Receptor Pair	R^2 (%)	33.9	2.1	8.7	41.4	32.4	80.3	13.1
		p-Value	0.047	0.672	0.352	0.024	0.054	0.000	0.248
		Slope	0.0019	-0.000063	0.00046	0.00026	0.00045	0.00026	0.00008
	Rank Pair	R^2 (%)	74.0	88.2	71.7	97.5	75.4	93.9	72.4
		p-Value	0.000	0.000	0.001	0.000	0.000	0.000	0.000
		Slope	0.0027	0.00038	0.0013	0.00040	0.00069	0.00028	0.00019

Sulfuryl Fluoride Mass Loss Modeling Scenario III: 315 m^2 area source 50% mass loss from 0 m height, 0.5 g/m^2-s 50% mass loss from 3.5 m height, 0.5 g/m^2-s									
Receptor ID	UTM Coordinate		Modeled Air Concentrations ($\mu g/m^3$)						
	Easting	Northing	Period 1	Period 2	Period 3	Period 4	Period 5	Period 6	Period 7
N	670704	4341254	1467234	3067564	930510	0	1092890	0	122929
NEI	670710	4341244	2050151	3220855	1667035	62898	1825645	0	896087
NEO	670718	4341250	743265	1399590	579783	0	610303	0	286402
E	670717	4341233	649307	224398	817952	322864	774902	0	923740
SEI	670708	4341228	270762	40589	844647	3422074	734657	1091249	2232326
SEO	670713	4341219	1467	0	231741	1474350	151152	58369	800664
S	670701	4341222	0	0	411568	3179499	347940	1942784	1657569
SWI	670695	4341233	43130	10032	532960	2552600	691997	3994332	1621588
SWO	670686	4341228	0	0	555209	706722	616416	2036152	1144721
W	670687	4341244	90670	24483	79578	365	197406	995409	22150
NWI	670696	4341248	1432761	2355961	835222	12	1063820	413219	56573
NWO	670689	4341257	394985	566644	206404	0	233613	460	0
Linear Regression Estimate	Receptor Pair	R^2 (%)	25.9	3.1	2.4	32.7	13.5	73.7	5.5
		p-Value	0.091	0.603	0.633	0.052	0.239	0.000	0.462
		Slope	0.0019	-0.00010	0.00031	0.00031	0.00037	0.00035	0.000084
	Rank Pair	R^2 (%)	73.8	88.3	81.3	95.8	82.6	96.3	61.9
		p-Value	0.000	0.000	0.000	0.000	0.000	0.000	0.002
		Slope	0.0033	0.00048	0.0018	0.00053	0.00091	0.00040	0.00029

APPENDIX II

EXAMPLES OF AERMOD CODE

A. First modeling period in scenario I of the Loomis Site

```
****************************************
** AERMOD Input Produced by:
** AERMOD View Ver. 8.6.0
** Lakes Environmental Software Inc.
** Date: 10/2/2014
** File: D:\StructureFumi\ARB 2004 Studies\AERMOD VIEW\Loomis\Loomis\Loomis.ADI
****************************************
****************************************
** AERMOD Control Pathway
****************************************
CO STARTING
   TITLEONE D:\StructureFumi\ARB 2004 Studies\AERMOD VIEW\Loomis\Loomis\Loomis.i
   MODELOPT CONC FLAT ELEV
   AVERTIME PERIOD
   POLLUTID SF
   FLAGPOLE 1.50
   RUNORNOT RUN
   ERRORFIL Loomis.err
CO FINISHED
****************************************
** AERMOD Source Pathway
****************************************
SO STARTING
** Source Location **
** Source ID - Type - X Coord. - Y Coord. **
   LOCATION AREA1       AREA       659024.000  4294278.000      153.000
** Source Parameters **
   SRCPARAM AREA1            1.0     0.000    28.000    12.000    82.500
   SRCGROUP ALL
SO FINISHED
****************************************
** AERMOD Receptor Pathway
****************************************
RE STARTING
** DESCRREC "" ""
   DISCCART    659039.00   4294265.00  153.00  153.00    1.50
   DISCCART    659049.00   4294273.00  153.00  153.00    1.50
   DISCCART    659029.00   4294280.00  153.00  153.00    1.50
   DISCCART    659037.00   4294282.00  153.00  153.00    1.50
```

```
  DISCCART    659038.00   4294291.00  153.00  153.00    1.50
  DISCCART    659021.00   4294279.00  153.00  153.00    1.50
  DISCCART    659013.00   4294283.00  153.00  153.00    1.50
  DISCCART    659043.00   4294250.00  153.00  153.00    1.50
  DISCCART    659034.00   4294248.00  153.00  153.00    1.50
  DISCCART    659036.00   4294238.00  153.00  153.00    1.50
  DISCCART    659026.00   4294247.00  153.00  153.00    1.50
  DISCCART    659017.00   4294243.00  153.00  153.00    1.50
  DISCCART    659024.00   4294263.00  153.00  153.00    1.50
RE FINISHED
****************************************
** AERMOD Meteorology Pathway
****************************************
ME STARTING
  SURFFILE loomis_onsite_2.SFC
  PROFFILE loomis_onsite_2.PFL
  SURFDATA 0 2004
  UAIRDATA 23230 2004 OAKLAND/WSO_AP
  SITEDATA 1 2004
  PROFBASE 153.0 METERS
  STARTEND 2004 6 30 13 2004 6 30 18
ME FINISHED
****************************************
** AERMOD Output Pathway
****************************************
OU STARTING
** Auto-Generated Plotfiles
  PLOTFILE PERIOD ALL Loomis.AD\PE00GALL.PLT 31
OU FINISHED

 ***********************************
 *** SETUP Finishes Successfully ***
 ***********************************
```

B. First modeling period in scenario II of the Grass Valley site

```
****************************************
** AERMOD Input Produced by:
** AERMOD View Ver. 8.6.0
** Lakes Environmental Software Inc.
** Date: 7/8/2014
** File: D:\StructureFumi\ARB 2004 Studies\AERMOD VIEW\GrassValley\GrassValley.ADI
****************************************
```

```
****************************************
** AERMOD Control Pathway
****************************************
CO STARTING
   TITLEONE D:\StructureFumi\ARB 2004 Studies\AERMOD VIEW\GrassValley\GrassValle
   MODELOPT CONC FLAT ELEV
   AVERTIME PERIOD
   POLLUTID SF
   FLAGPOLE 1.50
   RUNORNOT RUN
   ERRORFIL GrassValley.err
CO FINISHED
****************************************
** AERMOD Source Pathway
****************************************
SO STARTING
** Source Location **
** Source ID - Type - X Coord. - Y Coord. **
   LOCATION AREA1       AREA      670701.000  4341225.000     887.250
   LOCATION AREA2       AREA      670701.000  4341225.000     887.250
** Source Parameters **
   SRCPARAM AREA1           0.5     0.000    15.000    21.000   -30.000
   SRCPARAM AREA2           0.5     1.500    15.000    21.000   -30.000
   SRCGROUP ALL
SO FINISHED
****************************************
** AERMOD Receptor Pathway
****************************************
RE STARTING
** DESCRREC "" ""
   DISCCART    670704.00   4341254.00  887.25  887.25    1.50
   DISCCART    670710.00   4341244.00  887.25  887.25    1.50
   DISCCART    670718.00   4341250.00  887.25  887.25    1.50
   DISCCART    670717.00   4341233.00  887.25  887.25    1.50
   DISCCART    670708.00   4341228.00  887.25  887.25    1.50
   DISCCART    670713.00   4341219.00  887.25  887.25    1.50
   DISCCART    670701.00   4341222.00  887.25  887.25    1.50
   DISCCART    670695.00   4341233.00  887.25  887.25    1.50
   DISCCART    670686.00   4341228.00  887.25  887.25    1.50
   DISCCART    670687.00   4341244.00  887.25  887.25    1.50
   DISCCART    670696.00   4341248.00  887.25  887.25    1.50
   DISCCART    670689.00   4341257.00  887.25  887.25    1.50
RE FINISHED
****************************************
```

```
** AERMOD Meteorology Pathway
****************************************
ME STARTING
   SURFFILE grass_valley_onsite_2.SFC
   PROFFILE grass_valley_onsite_2.PFL
   SURFDATA 0 2004
   UAIRDATA 23230 2004 OAKLAND/WSO_AP
   SITEDATA 1 2004
   PROFBASE 887.25 METERS
   STARTEND 2004 7 19 13 2004 7 19 18
ME FINISHED
****************************************
** AERMOD Output Pathway
****************************************
OU STARTING
** Auto-Generated Plotfiles
   PLOTFILE PERIOD ALL GrassValley.AD\PE00GALL.PLT 31
   SUMMFILE GrassValley.sum
OU FINISHED

 ***********************************
 *** SETUP Finishes Successfully ***
 ***********************************
```