Department of Pesticide Regulation

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M E M O R A N D U M
APPENDIX 4

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SUBJECT: DEVELOPMENT OF CHLOROPICRIN BUFFER ZONES - REVISED

I. Background

The Department of Pesticide Regulation (DPR) completed a Risk Characterization Document (RCD) for chloropicrin as a toxic air contaminant (TAC) in February 2010. Focusing on residents and bystander exposure, the RCD assessed the health risk of chloropicrin based on evaluations of toxicology studies, and exposure estimates from air monitoring, computer modeling, and other data. In December 2010, DPR issued a Risk Management Directive that identified some unacceptable exposures in the RCD, and directed staff to develop use restrictions. Consistent with the U.S. Environmental Protection Agency (U.S. EPA), DPR's Risk Management Directive determined that the primary effect observed with acute exposure to chloropicrin is sensory irritation, and the appropriate regulatory target level to restrict acute exposure to chloropicrin is 73 ppb or 0.073 ppm averaged over an eight-hour period. As with other fumigants, a key element in mitigating exposure is establishing a buffer zone between a fumigated area and residents and bystanders.

Label revisions for chloropicrin products developed by registrants and U.S. EPA went into effect in December 2012 (Phase 2 labels). One of the main mitigation measures employed on the new labels is buffer zones. The Phase 2 labels present for each particular use scenario a main buffer zone table containing buffer zones of maximum length, then gives buffer zone credits of up to 80% to reduce the size of a buffer zone. Those credits are applied directly to the buffer zone distance. Labels allow the credits for the following factors: tarp type, organic matter, clay content, soil temperature, Symmetry System, potassium thiosulfate (KTS), and water seal applied over the tarp. The DPR mitigation measures may differ from the labels.

This revised memorandum presents chloropicrin field data analysis performed to provide a basis for California buffer zone development. The original memorandum (Barry, 2013a) was submitted for external peer review through the California Environmental Protection Agency External Peer Review Program administered by the Office or Research, Planning and Performance at the State Water Resources Control Board. Peer review comments were received

in March 2014 (Bowes, 2014). In addition to the peer review, the original memorandum was made available for public comment. Response to peer review comments are presented in Barry (2014). The revisions contained in this memorandum are in response to peer reviewers and public comments. Revised buffer zones are presented. Supporting information for the approach used to develop the chloropicrin buffer zones is also presented. The supporting information is drawn from analysis and modeling performed to develop other fumigant mitigation measures. These fumigants include methyl bromide, metam sodium, and methyl iodide. The supporting topics included in this memorandum are the choice of air dispersion model and an analysis of the protection level of whole field versus maximum direction buffer zones.

II. Field Data Analysis and Results

A. Database and Analysis

An EXCEL (Microsoft EXCEL, 2010) database of 47 chloropicrin applications is shown in Appendix 1. These are the same studies submitted to U.S. EPA, with the addition of two newer studies. One study with 2 applications submitted to U.S. EPA was rejected at DPR (Gillis and Smith, 2002). One study containing one application was submitted to U.S. EPA but not to DPR (Coloma, WA bed/untarp, MIRD 48011601). The four Arizona applications in Beard et al. (1996) were removed from the analysis because, although the study in which the applications were made met acceptance criteria, the applications did not meet the current Good Agricultural Practices (GAPs) required on the federal label (Reardon, 2013). This left 40 chloropicrin applications in the initial analysis. MINITAB (2010) statistical software was used for all the data summaries, statistical analysis. Graphs were composed in MINITAB (2010) or TableCurve2D (AISN software, 2000).

A key factor in determining the size of a buffer zone is the magnitude of the fumigant flux (emissions) to air. This revised document corrects several errors in the original chloropicrin flux database. These corrections are reflected in Appendix 1 and Appendix 2. The first correction is to the application rate for applications 07 and 08, the corrected application rates and resulting flux estimates are shown in Appendices 1 and 2. The second correction is related to the timing of the sampling intervals in the flux studies. The Chloropicrin Manufacturers Task Force (CMTF) noted that the timing of the maximum flux for some of the applications was incorrect (Whilhelm, 2013). The studies with applications that had incorrect maximum flux timing in Barry (2013a) had reported the sampling intervals in summary tables as either the midpoint or the end of a sampling interval rather than the beginning time of the sampling intervals. This was not apparent from descriptions in the reports. Standard practice is to report the beginning of sampling intervals in summary tables. The CMTF submitted additional information to clarify the sampling interval times. The times of the sampling intervals for the studies in question have been verified and corrected. Appendix 2 shows those corrected maximum flux times.

Table 1 shows a summary of the maximum 6-hour chloropicrin flux for the 40 applications in the chloropicrin flux database. Statistical analysis of the full database (40 applications) is problematic due to empty cells. So, Table 1 is a summary table to be used for informational purposes only. Most chloropicrin fumigation applications in the monitoring studies show peak air concentrations and peak fluxes occurring sometime during the first two days following the start of application. During the first two days, air concentrations and flux were generally measured in 6-hour intervals, with sample duration increasing to 12-hour intervals after the first two days. To determine buffer zones, DPR used the 6-hour flux values as a surrogate for 8-hour values (averaging time of the target concentration) with no adjustment. Using the measured 6-hour flux directly as an 8-hour flux is a more conservative approach. A longer averaging period, all other factors held constant, would yield a lower flux. A peak-to-mean adjustment to estimate an 8-hour flux based on the 6-hour flux could have been made and would have resulted in a smaller flux. However, the peak-to-mean adjustment would introduce additional uncertainty. Thus, to be conservative, the 6-hour flux was extended uniformly for 2 additional hours as a surrogate 8-hour flux.

In order to proceed with the analysis, the following flux estimates were removed: 1) the Symmetry Method, 2) metallized (20% Credit tarp), 3)VIF (40% Credit), and 4) strip and deep injection applications. Symmetry Method is not practiced in California and use of metallized tarps is discouraged in California due to disposal issues. The VIF (40% Credit) tarp, strip, and deep injection applications were not conducted in enough combinations of application type and tarp type to allow inclusion in the statistical analysis. Grouping those applications with the other methods in the initial analysis is inappropriate due to differences in application type. A separate evaluation for strip and deep injection applications to determine if partial (strip) tarping or injection depth influences maximum flux (ug/m^2sec). So, only untarp, poly, and TIF (60% Credit tarp) will be included as tarp types. Finally, two outliers were removed: 1) the Ventura drip application from data volume 0199-0142 (Sullivan and Ajwa, 2010) because that application was significantly affected by a large drip application nearby, and 2) the Wasco broadcast/TIF Tarp + KTS application from data volume 0123-0220 (Ajwa and Sullivan, 2010a) because the maximum flux estimate was not acceptable due to estimation difficulties.

Table 1. Summary of the maximum flux (ug/m^{2}sec) in the chloropicrin database. Flux values are normalized to a 200lb/ac broadcast application rate. Most averaging times are 6 hours. See Appendix 1 for full details. (n = sample size)

Application Type		Tarp Type					
		Untarp	Poly[1] (No Credit Tarp)	Metallized (20% Credit Tarp)	VIF (40% Credit Tarp)	TIF (60% Credit Tarp)	All
Bed	Mean	19.1	40.7	45.0	7.7	13.3	
	Median	19.1	40.7	45.0	7.7	13.3	
	n	2	2	2	1	2	7
Broadcast	Mean	61.4	29.6	-	-	15.7	25.3
	Median	61.4	33.4	-	-	5.9	17.5
	n	1	7	-	-	7	15
Broadcast/Deep	Mean	46.6	-	-	-	6.6	26.6
	Median	46.6	-	-	-	6.6	26.6
	n	1	-	-	-	1	2
Strip	Mean	-	46.2	-	-	-	46.2
	Median	-	46.2	-	-	-	46.2
	n	-	1	-	-	-	1
Strip/Deep	Mean	-	-	-	-	5.6	5.6
	Median	-	-	-	-	5.6	5.6
	n	-	-	-	-	1	1
Symmetry	Mean	-	-	46.7	2.9	1.1	17.9
	Median	-	-	49.7	2.9	1.1	2.9
	n	-	-	1	1	1	3
Drip	Mean	111.0	49.1	-	-	10.2	47.4
	Median	111.0	46.4	-	-	10.2	42.3
	n	1	6	-	-	2	9
All	Mean	51.43	39.3	46.6	5.3	12.2	30.2
	Median	46.6	40.1	49.7	5.3	5.7	21.1
	n	5	16	3	2	14	40

[1] The Poly tarp group includes both Low Density Polyethylene (LDPE) and High Density Polyethylene (HDPE) tarps that receive no buffer zone reduction credit on the current labels. See Appendix 1 for details.

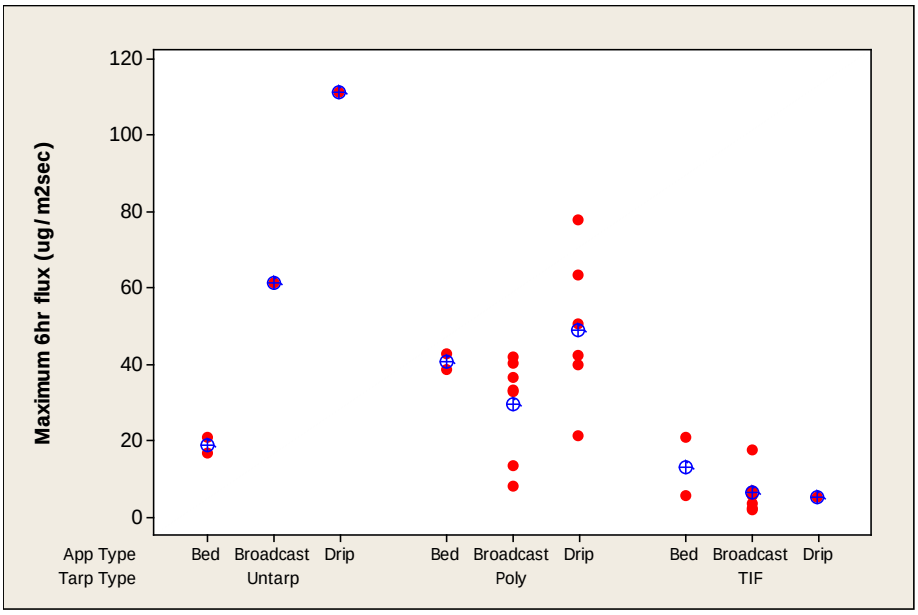
The reduced dataset includes 28 applications and does not have any empty application by tarp type combination cells. The Kolmogorov-Smirnov to test for normality of the maximum flux showed that the flux estimates can be assumed to be normally distributed ($p = 0.126$). Thus, an unbalanced two way analysis of variance (ANOVA) was performed directly on the maximum flux. The ANOVA model used to evaluate effects for application type, tarp type, and the interaction between application type and tarp type. Residual patterns were acceptable. The R^2 value of the model fit was 81.7%. There was a significant interaction effect between application type and tarp type ($p = 0.002$). Table 2 and Figure 1 illustrate the significant interaction effect between application type and tarp type on the maximum flux. The significant interaction means the pattern of difference in the mean maximum flux between application types within tarp type differs between tarp types. Thus, the tarp types were separated for further analysis of application method differences. There are not enough untarp applications to perform further statistical analysis on application methods. For the poly tarp group, the drip applications have a significantly higher flux than the broadcast applications ($p = 0.05$). The bed application mean maximum flux is not significantly different from either broadcast ($p = 0.09$) or drip ($p = 0.4$). This is because the mean maximum flux value for bed is in between the mean maximum flux value for drip and poly. The TIF mean maximum flux for bed and broadcast were not statistically significant ($p = 0.5$). There was only one drip application so statistical analysis was not possible. However, the maximum flux for TIF drip of 5.5 ug/m^2sec was numerically similar to the mean maximum flux of 6.4 ug/m^2sec for the TIF broadcast method. The statistical analysis to further explore differences between applications within tarp type was either impossible or the results were variable between tarp types. Thus, to be similar to the labels and previous DPR regulatory requirements, each application type will be separated within tarp type for buffer zone development.

Table 2. Mean maximum 6-hour flux (ug/m^{2}sec) for the reduced set of chloropicrin applications. Flux values are normalized to a 200lb/ac broadcast application rate. See text for description of records removed. Most averaging times are 6 hours. (n = sample size).

Application Type		Tarp Type			
		Untarp	Poly[1] (No Credit Tarp)	TIF (60% Credit Tarp)	All
Bed	Mean	19.1	40.7	13.3	24.3
	Median	19.1	40.7	13.3	21.0
	N	2	2	2	6
Broadcast	Mean	61.4	29.6	6.4	21.9
	Median	61.4	33.4	4.8	15.6
	N	1	7	6	14
Drip	Mean	111.0	49.1	5.5	51.4
	Median	111.0	46.4	5.5	46.4
	n	1	6	1	8
All	Mean	52.6	38.9	7.8	33.6
	Median	41.3	39.8	5.5	35.1
	n	4	15	9	28

[1] The Poly tarp group includes both Low Density Polyethylene (LDPE) and High Density Polyethylene (HDPE) tarps that receive no buffer zone reduction credit on the current labels. See Appendix 1 for details.

Figure 1. Maximum 6-hour flux (ug/m^{2}sec) versus application type grouped by tarp type. Flux values are normalized to a 200 lb/ac broadcast application rate. Red circles are individual application flux values, blue circle with center cross is the mean maximum 6-hour flux (ug/m^{2}sec) for each group.



Further examination of the mean maximum flux estimates in Figure 1 shows that the untarp bed flux estimates are much smaller than expected for an untarp method. Both untarp bed applications are from data volume 0199-013 (Appendix 1). The mean untarp bed flux estimate is 19.1 ug/m^{2}sec, only slightly larger than the 13.3 ug/m^{2}sec mean maximum flux estimate for TIF bed and it is roughly half the Poly tarp bed flux estimate of 40.7 ug/m^{2}sec. The untarp bed study was conducted in Florida and employed a specialized bed application method for potato production. This application method forms the beds, injects the chloropicrin, and compacts the soil simultaneously. Initial review of this study noted that soil samples taken prior to the application were lost in shipment (Barry, 2012). Thus, soil conditions at the time of application are unknown. Only post-application soil samples were analyzed. The extremely small flux estimates required a more detailed evaluation of the soil conditions and the application method before they were used for buffer zone development. Additional evaluation by Clayton (2014) found that the bulk density of the post application samples was lower than expected and atypical of undisturbed sandy soil. In addition, the soil moisture values were unusually high for Field #1 and unusually low for Field #2. Yet, the flux estimates were very similar at 21.1 ug/m^{2}sec and 17.0 ug/m^{2}sec for Field #1 and Field #2 respectively. The lack of pre-application soil data, unusual soil conditions, and the unusually low flux estimates for this untarp method precludes the use of these two flux estimates in buffer zone development. Thus, they were removed from

further consideration and untarp shallow broadcast method is used as a surrogate for the untarp shallow bed method for buffer zone development.

Increasing injection depth has been presented as a potential mitigation measure. Deeper injection is thought to decrease flux. However, there are only three deep injection applications in the chloropicrin data base, one deep injection application was untarped and two of the deep injection applications used TIF tarps. Of the TIF tarps, one is broadcast and the second is a strip tarp application. The strip tarp application was previously removed from this analysis because it is not directly comparable to bed or broadcast applications. Figure 2 shows the deep application maximum 6-hour flux values relative to the shallow application maximum 6-hour flux values. The deep untarp application is from the Wasco study conducted in 2008 (Ajwa and Sullivan, 2008; 0199-0130). The untarp deep estimated flux is lower than the untarp shallow injection and untarp drip but the untarp application method is not well characterized due to the small number of applications. In addition, variability of deep untarp maximum 6-hour flux is unknown. However, a separate evaluation for deep injection applications using the HYDRUS model supports the assumption that injection depth is an important determinant in the magnitude of chloropicrin flux, with increasing depth associated with decreasing flux (Spurlock, 2013). Thus, to be consistent with the U.S. EPA federal labels an untarp deep broadcast buffer zone table will be developed using the maximum flux estimate from the untarp deep application from data volume 0199-0130. In the case of the TIF tarp, the estimated maximum flux for the deep injection is nearly identical to the mean maximum flux for the shallow TIF tarp applications. It is more likely that the TIF tarp is the factor leading to the low maximum 6-hour flux than the injection depth. The deep TIF tarp applications are from the 2010 MBIP study (Ajwa and Sullivan, 2010a; 0123-0220). No statistical analysis can be performed on these data due to the small sample size of the deep applications relative to the shallow applications. However, the individual flux estimates for the deep TIF tarp applications will be used directly to develop TIF tarp deep broadcast and TIF deep strip buffer zones.

Application of the chemical potassium thiosulfate (KTS) has been presented as a mitigation measure and is assigned a buffer zone reducing credit by U.S. EPA. There are only two applications with KTS applied as a mitigation measure that are acceptable in the chloropicrin data base. One application used a Poly Tarp and one used a TIF Tarp. Figure 3 shows that the two KTS applications have maximum 6-hour flux values that are similar to other applications in the same tarp grouping. The variability of the maximum 6-hour flux associated with the use of KTS being completely unknown. The Poly Tarp application is from the Salinas drip study conducted in 2010 (Ajwa, 2010; 0199-0136). The TIF tarp application is from the Lost Hills study in 2012 (Ajwa and Sullivan, 2012; 50046-0198). The sample size of KTS application was too small to perform statistical analysis on these data. Thus, at this time it is impossible to make a distinction between maximum 6-hour flux for applications that employ KTS as a mitigation measure and applications without KTS.Figure 2. Maximum 6-hour flux (ug/m^{2}sec) versus depth grouped by tarp type. Flux values are normalized to a 200 lb/ac broadcast application rate. Red

circles are individual application flux values, blue circle with center cross is the mean maximum 6-hour flux (ug/m^{2}sec) for each group.

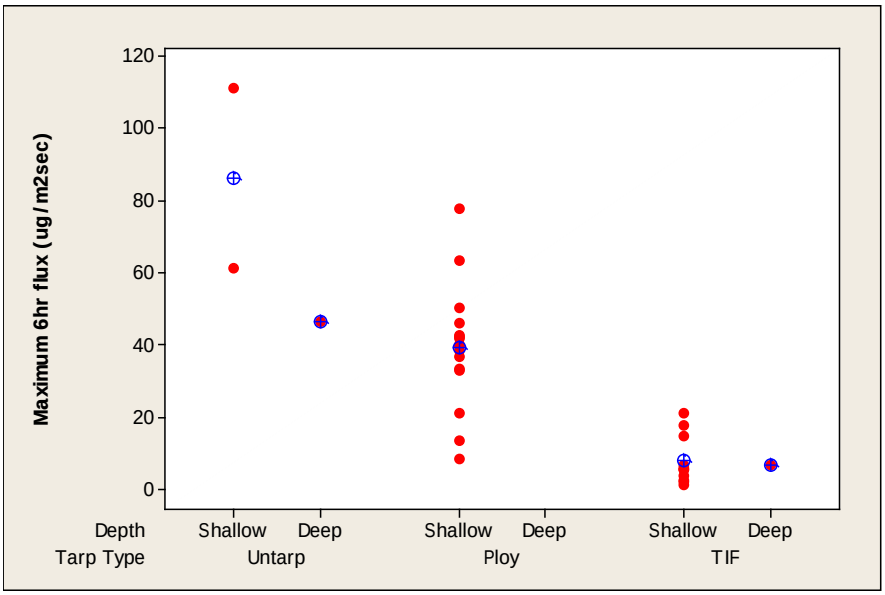
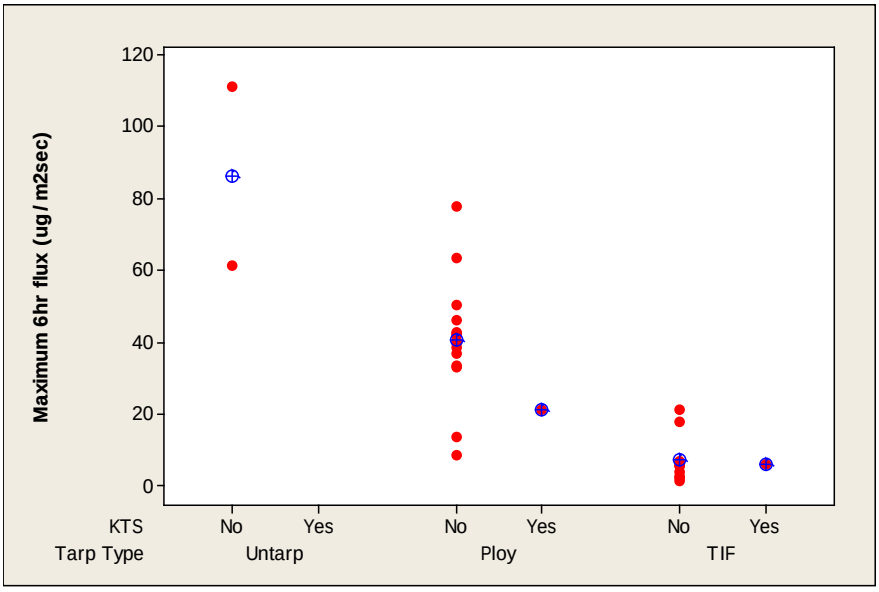


Figure 3. Maximum 6-hour flux (ug/m^{2}sec) versus KTS use grouped by tarp type. Flux values are normalized to a 200 lb/ac broadcast application rate. Red circles are individual application flux values, blue circle with center cross is the mean maximum 6-hour flux (ug/m^{2}sec) for each group.



Application of a “water seal” over the tarp has also been assigned a buffer zone reducing credit by U.S. EPA. Only one application in the chloropicrin database used a post application “water seal.” This was a drip/Poly tarp application in the Salinas study (Ajwa, 2010; 0199-0136). The maximum flux from this application was 50.4 ug/m^{2}sec, which is almost identical to the mean maximum 6-hour flux of 49.1 ug/m^{2}sec for the drip/Poly Tarp group. The Poly/Tarp group includes 6 applications that did not have a water seal applied following application. So, based on the currently available data that shows virtually no difference in the magnitude of the maximum 6-hour flux when a water seal is applied, a post application water seal cannot be justified as an additional mitigation at this time.

As discussed above, DPR buffer zone development used the maximum 6-hour flux from each application as a surrogate for an 8-hour flux matching the target concentration averaging time. Only the 8 hours following the start of the period in which the maximum 6-hour flux occurred was simulated. It is not necessary to use the remainder of the flux profile because the maximum flux interval will determine the size of the buffer zone. This method of simulation also maintains the correct and exact relationship between the time the maximum flux occurred, the sample duration of the maximum flux estimate, averaging interval of the PERFUM2 model runs, and the target concentration averaging time.

Examination of the chloropicrin database shows that 23 of the 26 applications (88%) showed a maximum 6-hour flux during day hours and 3 of 26 applications (12.0%%) showed a maximum 6-hour flux during night hours (Table 3 and Appendix 2). A full statistical analysis cannot be conducted on whether the day and night maximum flux are different because of the small sample size and missing tarp type/application method combinations. However, the poly tarp group of 15 applications indicates there is little difference in the magnitude of the maximum 6-hour flux between day and night (Figure 4). Night occurrence of the maximum flux is still important to consider because night meteorological conditions are more stable relative to day conditions. The same flux value will produce higher air concentrations at night. Thus, buffer zone development must take into account whether the maximum 6-hour flux occurred at night or day. Preserving the timing of the maximum flux as it was measured incorporates the effect of day and night occurrence of the maximum flux in the buffer zone development.

Table 3. Maximum 6-hour flux (ug/m^{2}sec) grouped by tarp type and whether the maximum 6-hour flux occurred during the day or at night. Flux values are normalized to a 200lb/ac broadcast application rate. (n=sample size)

Day/Night		Tarp Type			
		Untarp	Poly[1] (No Credit Tarp)	TIF (60% Credit Tarp)	All
Day Maximum Flux	Mean	111.0	38.6	7.8	29.7
	Median	111.0	39.8	5.5	21.2
	n	1	13	9	23
Night Maximum Flux	Mean	61.4	40.7	*	47.6
	Median	61.4	40.7	*	42.9
	n	1	2	0	3
All	Mean	86.2	38.9	7.8	31.8
	Median	86.2	39.8	5.5	33.1

Figure 4. Maximum 6-hr flux (ug/m2sec) grouped by tarp type and whether the maximum flux occurred during the day or at night. Flux values are normalized to a 200 lb/ac broadcast application rate. Red circles are individual application flux values, blue circle with center cross is the mean maximum 6-hour flux (ug/m^{2}sec) for each group.

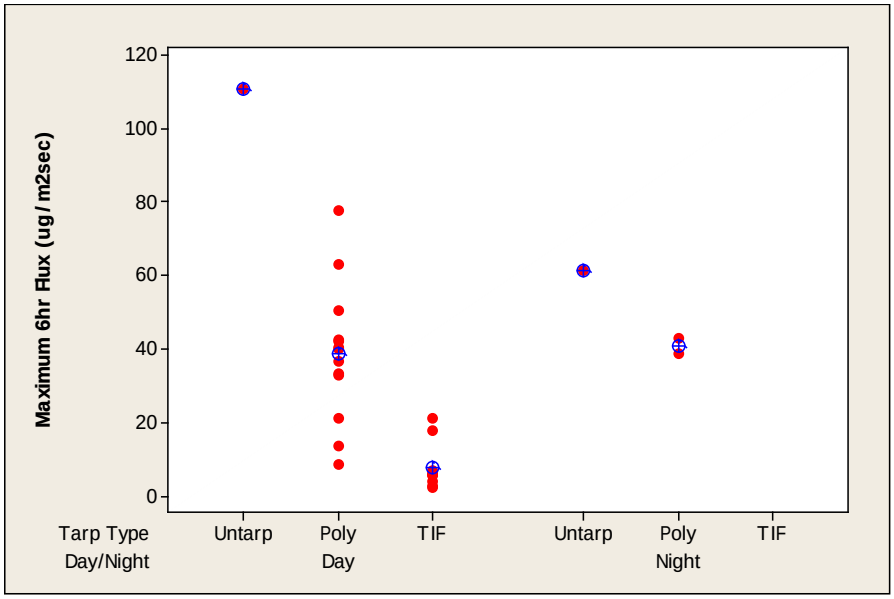


Figure 5 shows a plot of hours after application the maximum 6-hour flux occurs versus the application start time. In addition, whether the maximum flux occurred during the day or at night is indicated. There is no correlation ($r = 0.33$, $p = 0.08$) between hours after application the maximum flux occurs and the application start time. However, there is a clear break in the hours after application that the maximum flux occurs. The break is at approximately 18 hours after application. A code separating the applications by that break was generated. Results are shown in Table 4. More than half the 26 applications showed the maximum flux occurring greater than 18 hours following application.

Figure 5. Number of hours post application that the maximum 6-hour flux occurs versus application time. Whether the maximum flux occurred at day or at night is also indicated.

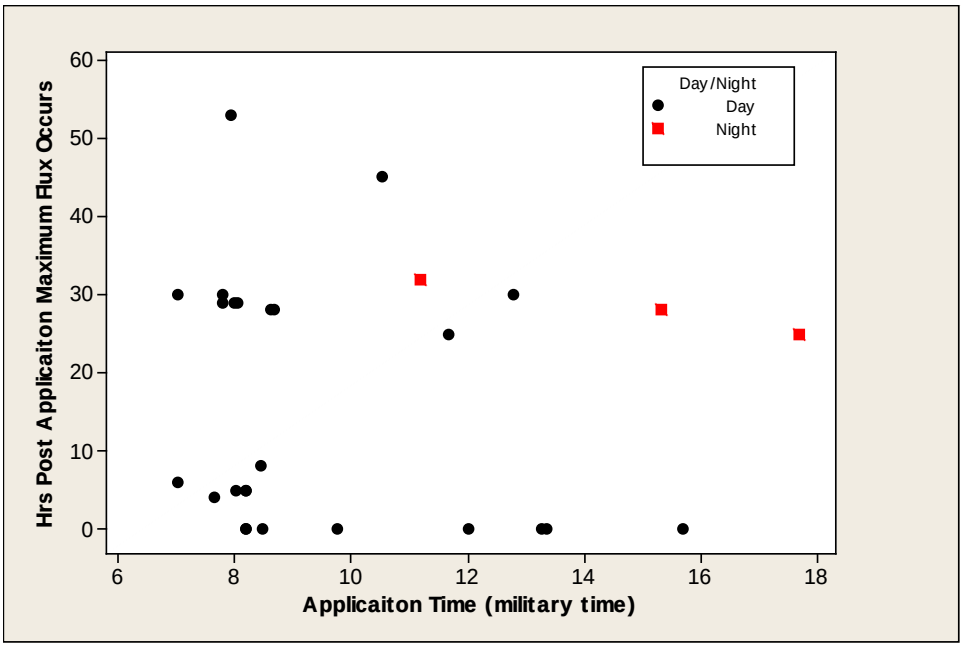


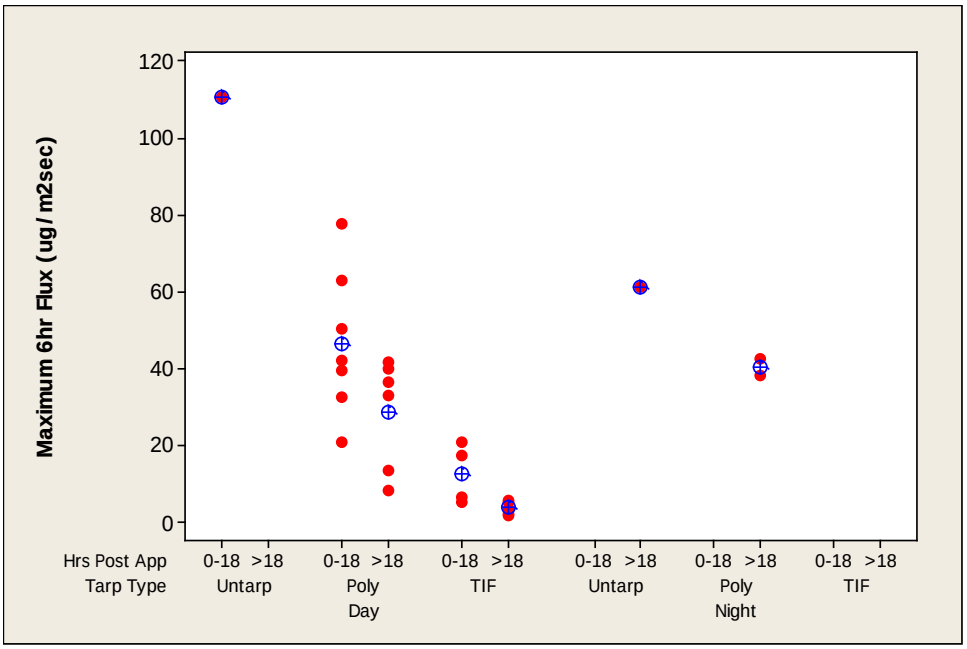
Table 4. Maximum 6-hour flux (ug/m^{2}sec) grouped by tarp type and hours after application start that the maximum 6-hour flux occurred. Flux values are normalized to a 200lb/ac broadcast application rate. (n = sample size)

Time After App		Tarp Type			
		Untarp	Poly[1] (No Credit Tarp)	TIF (60% Credit Tarp)	All
0-18hours	Mean	111.0	46.8	12.7	40.8
	Median	111.0	42.3	12.2	36.3
	n	1	7	4	12
>18hours	Mean	61.4	32.0	3.9	24.1
	Median	61.4	37.7	3.7	23.5
	n	1	8	5	14
All	Mean	86.2	38.9	7.8	31.8
	Median	86.2	39.8	5.5	33.1
	n	2	15	5	26

[1] The Poly tarp group includes both Low Density Polyethylene (LDPE) and High Density Polyethylene (HDPE) tarps that receive no buffer zone reduction credit on the current labels. See Appendix 1 for details.

Figure 6 shows the three layer breakdown of maximum flux at day versus night, tarp type, and hours post application that the maximum flux occurred. Due to the small sample size of the untarp applications no firm conclusions can be drawn. The 15 Poly Tarp applications are comprised of 7 with maximum flux early in the flux profile and 8 with maximum flux late in the flux profile. All 6 poly tarp drip applications showed the maximum flux earlier than 18 hours following application. Of the remaining ploy tarp applications, only one broadcast application showed the maximum flux early. The 9 TIF Tarp applications are approximately equally divided with 4 early and 5 late. The maximum 6-hour flux occurs between 0 hours (max 6-hour flux occurring during application) to 53 hours after the start of application (Appendix 2). Thus, the longest 8-hour interval after the start of application that a maximum 6-hour flux would occur is from the period 53 hours to 59 hours. The current label sets buffer zone duration at 48 hours after application is completed. Most applications take hours to complete so based on the data in Appendix 2 the 48-hour buffer zone duration following completion of the application should be sufficient.

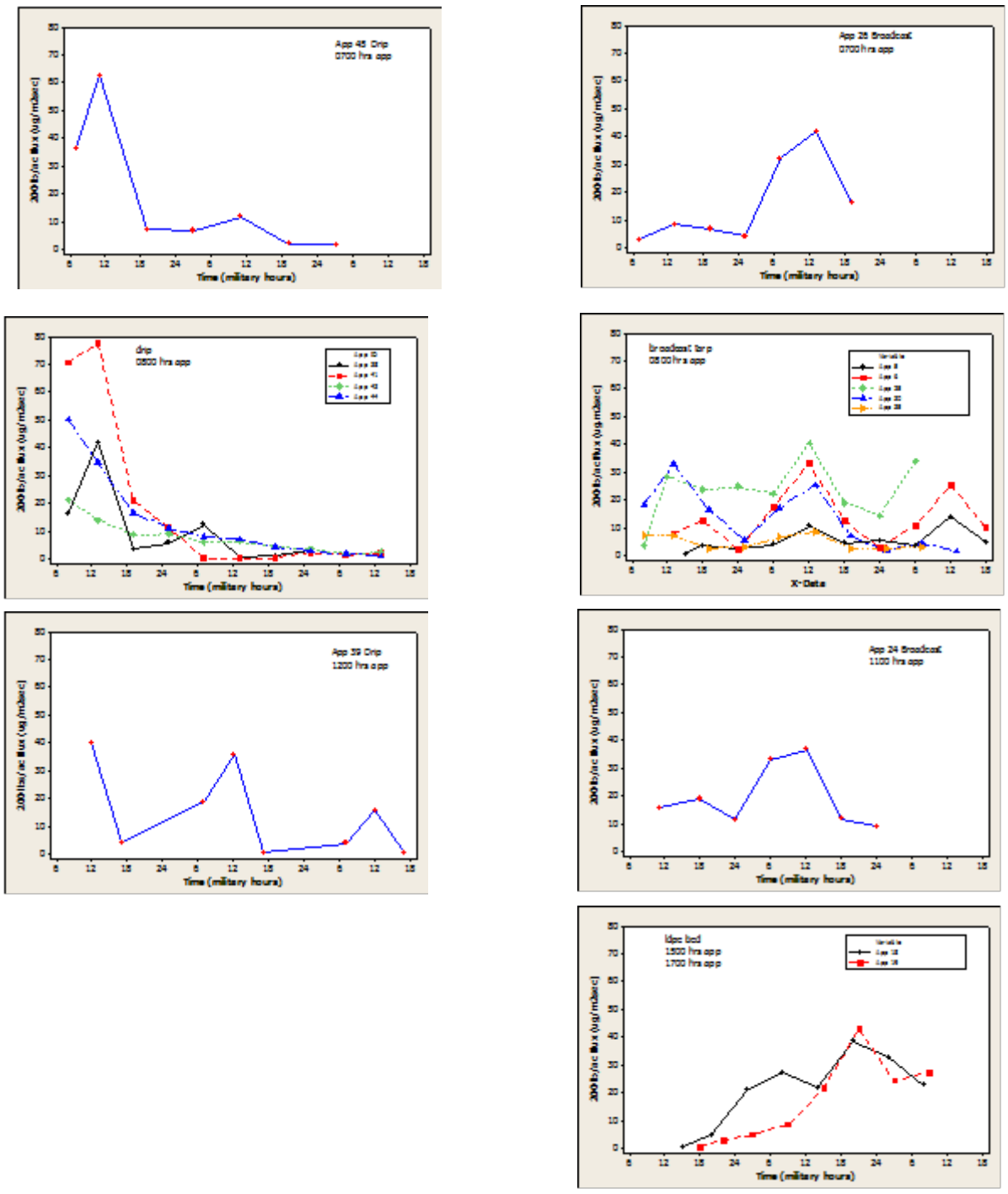
Figure 6. The 6-hour maximum flux (ug/m^{2}sec) grouped by whether the maximum flux occurred at day or at night, tarp type, and number of hours post application that the maximum flux occurred. Flux values are normalized to a 200 lb/ac broadcast application rate. Red circles are individual application flux values, blue circle with center cross is the mean maximum 6-hour flux (ug/m^{2}sec) for each group.



One mitigation suggestion submitted in the public comments was to limit all applications to a start a time of 0600 hrs and to then develop the buffer zones based on that limitation. This would

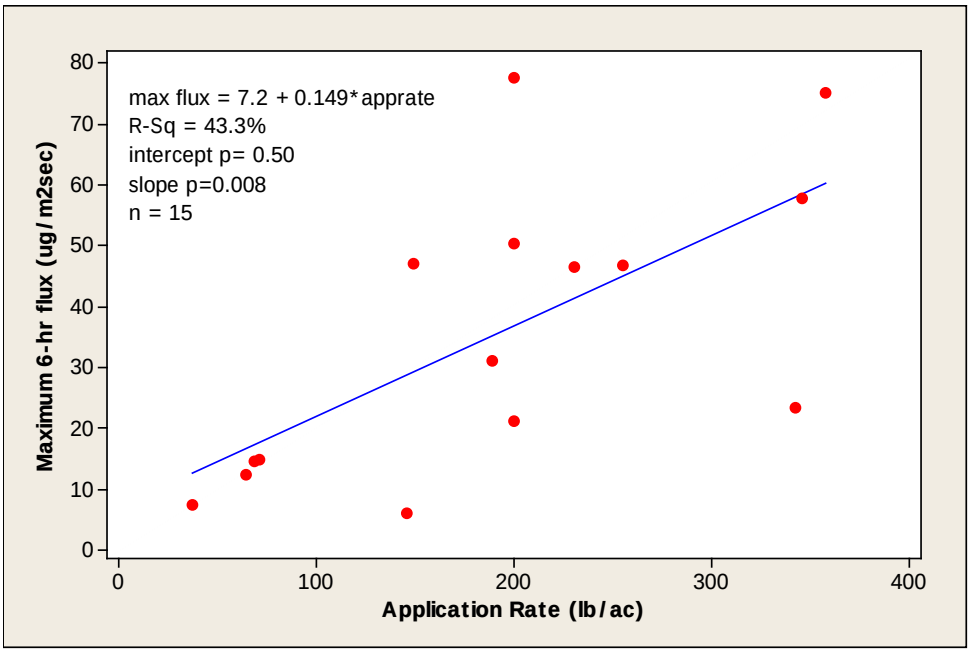
mean shifting all of the 26 flux profiles to start at 0600 hrs and then use the maximum 6 hour flux where it occurred in the timeline based upon that shift of starting time. The start time of the maximum 6 hour flux would shift between 1 hour and 9 hours depending upon the application. The major effect this shift would eliminate night maximum flux entirely from the buffer zone development. A second effect is that all maximum 6 hour flux periods would shift to occurring before noon. Shifting all the flux profiles in the chloropicrin database to a start time of 0600 hrs can only be justified if it is clearly verified that within a tarp/application type group the flux profiles are consistent in pattern from the start of each application without regard to the time of day the application was started. This would mean that the flux profiles would show the maximum 6 hour flux occurring a consistent number of hours following the start of a particular combination of tarp type and application method. It is critical that this consistent pattern of independence be demonstrated with the field data in the chloropicrin database that is used to develop the DPR buffer zones because shifting the timing of the maximum flux has a large effect on the size of required buffer zones. Figure 7 shows the flux profiles for all 15 Poly tarp applications. The plots are all on exactly the same scale. The profile for each application is started on the timeline where the application started in the study. Each separate graph represents a different start time and the start time is indicated in each plot, along with the listing of the applications included in the plot. The left hand plots are drip applications, the right hand plots are broadcast and bed applications. Appendix 2 can be consulted for more information on each application, found by App ID number. These plots illustrate that the flux profiles are not consistent from the start of application without regard to the time of day the application is made. On the contrary, no matter what time the application was started, the maximum flux most often occurs at or near 1200 hrs. Eleven of the 15 Poly tarp applications have a maximum flux occurring at or near 1200 hrs. Yet, the start times of those 11 applications span 5 hours between 0700 hrs to 1200 hrs. This pattern does not support the assumption that flux profile pattern is consistent, with the maximum flux occurring a consistent number of hours following start time, regardless of application start time. Instead, these studies indicate the maximum flux tends to occur most often at or near 1200 hrs. This is true even when the maximum flux occurs the day after the application (more than 18 hours following application). It is not understood why the maximum flux occurs at or near 1200 hrs for most of these applications but also occurs during night hours for others, especially in the context of the maximum flux occurring a day or even two days after an application is made. Thus, for buffer zone development, the maximum 6 hour flux will be used as it occurred in the timeline of the measured flux profile.

Figure 7. Poly tarp flux profiles, 6-hour flux (ug/m^{s}sec) standardized to 200 lb/ac broadcast application rate. The profile for each of the 15 applications is started on the timeline where it started in the study. Each graph represents a different start time, indicated in each plot. Applications included in the plot are listed. Left hand plots are drip applications, right hand plots are broadcast and bed applications. Appendix 2 contains information on each application, cross-referenced by App ID number.



From the earliest use of air dispersion modeling to develop fumigant buffer zones, DPR has assumed that flux is proportional to application rate (Segawa, 1997, Segawa et al, 2000). U.S. EPA has also employed this assumption in their fumigant buffer zone development (USEPA, 2009). Simple linear regression was used to analyze the relationship between the measured maximum flux for the 15 poly tarp applications and application rate in each of the studies (Figure 8). The slope of this linear function is significant (p=0.008), indicating that the slope increases significantly at the rate of 0.149 ug/m^{2}sec with each pound increase of application rate. The intercept is not significant (p = 0.50), indicating, correctly, that when there is an application rate of zero there will be no flux. These results support that the assumption that the maximum flux is proportional to the application rate.

Figure 8. Simple linear regression of maximum 6-hour flux (ug/m^{2}sec) as a function of application rate (lb/ac). The 15 applications in the poly tarp group from the chloropicrin flux data base (Appendix 1) are shown here.



B. Discussion

This analysis examined the flux for various fumigation methods and mitigation measures that are assigned label buffer zone factor credits. Label buffer credits are based primarily on computer modeling with a modified version of CHAIN 2D to identify and quantify field conditions or application practices that reduce flux. In contrast, the DPR analysis relies on flux estimated using field monitoring data to evaluate the buffer zone factor credits. Consequently, DPR's conclusions about the buffer zone factor credits differ from those specified on labels. DPR is also in the

process of evaluating the buffer zone factor credits using a modification of HYDRUS, a state of the art computer model based on the original CHAIN 2D model.

The buffer factor credits include: tarp type (high barrier tarp), organic matter, clay content, soil temperature, Symmetry System, KTS, and water seal applied over the tarp. Additional data is needed to determine if organic matter, clay content, or soil temperature effect chloropicrin flux. Symmetry System is not currently used in California and any effect of the Symmetry System would be reflected in the application rate used to set the buffer zone. Soil moisture is frequently discussed as a factor with potential to reduce flux. However, soil moisture is not a label buffer zone credit. Furthermore, the effect of soil moisture on chloropicrin flux was examined in a separate memorandum (Barry, 2013b; Appendix 3) and found to be inconclusive. Labels include buffer zone tables for various application methods, including untarp and tarp tables for bed, broadcast, drip and strip applications. For tarped application methods the poly tarp (no credit tarp) is the base tarp and then the tarp credit is applied directly to those base buffer zones to obtain the final buffer zone for TIF tarp applications. The other factor credits can also be applied to reduce the original buffer zone by up to 80% in length. Among the label buffer credits listed above, the only factor supported by this analysis is the TIF Tarp.

Application of factor credits directly to the buffer zone length, rather than the flux used to generate buffer zones, is not supported because if the credit factors indeed show measurable effects, those effects are on the flux, not the buffer zone. There is not a proportional transfer of changes to buffer zone length when the flux changes. Thus, DPR does not apply any kind of factor credits to buffer zones. Instead, buffer zones were developed separately for untarp, Poly Tarp, and TIF Tarp applications. In addition, due to the variable results in the ANOVA between application methods within each tarp type, and to be consistent with the buffer zone tables on the current federal labels, DPR developed buffer zones for each tarp type/application method combination. This requires the use of single flux estimates or smaller sample size sets of flux estimates for some tarp type/application rate combinations.

III. Chloropicrin Buffer Zone Development

The Probabilistic Exposure and Risk Model for Fumigants Version 2 (PERFUM2) modeling system (Reiss and Griffin, 2005: Reiss and Griffin, 2006) was used to develop the buffer zones presented in this memorandum. This model uses the Industrial Source Complex Short Term Version 3 (ISCST3) Gaussian dispersion model to estimate air concentrations. Front end and back end processing code allows multi-year simulations using historical weather data and construction of buffer zone distributions generated from the multi-year runs. PERFUM2 has previously been used by DPR to develop buffer zones for methyl isothiocyanate (Barry, 2006).

Based upon analysis and results shown in the previous sections, buffer zone development proceeded by using the PERFUM2 model to simulate 5 years of buffer zones for the 10 tarp type/application method combinations shown below. In addition, the three tarp type/application method combinations that use surrogate buffer zone tables based upon one of the 10 combinations are shown.

1. TIF tarp broadcast shank (6 applications)
2. TIF tarp bed (2 applications)
3. TIF tarp drip (1 application)
4. TIF tarp strip deep (1 application)
5. Poly tarp broadcast shank (7 applications)
    - TIF strip shallow (surrogate)
6. Poly tarp bed (2 applications)
    - Poly tarp strip (surrogate)
7. Poly tarp drip (6 applications)
8. Untarped broadcast shallow shank (1 application)
    - Untarp bed shallow (surrogate)
9. Untarped broadcast deep shank (1 application)
10. Untarped drip (1 application)

Each individual application within the 10 groups above was simulated separately using the PERFUM2 model and five years of meteorological data from five California Irrigation Management Information System (CIMIS) locations:

Ventura County – Piru (Station 101)
Monterey County – Salinas (Station 89)
San Joaquin County – Manteca (Station 70)
Kern County – Belridge (Station 146)
Siskiyou County – Tule Lake (Station 91)

The Ventura County station of Piru is the original station used in the PERFUM2 model at U.S.EPA. DPR also used this weather data in the original chloropicrin buffer zone development (Barry, 2013a). All CIMIS weather (including the Ventura County station of Piru contained in the PERFUM2 model) was processed by the DPR in house programs (Vidrio and Johnson, 2011). An error in the stability class assignment in the Ventura weather was discovered after the buffer zones in the original chloropicrin memorandum (Barry, 2013a) were developed. The error was related to missing solar radiation in the CIMIS data. The missing data value for solar radiation was interpreted by the DPR weather processing program as night hours. This caused the program to assign nighttime stability classes for day hours. Night stability classes occurring during the day generate buffer zones that are larger than if the stability classes were correctly assigned. Those errors in stability class assignment have been corrected and the Ventura County

buffer zones presented in this revised analysis were developed with the corrected weather data. The additional 4 weather data set were also processed with the corrected DPR weather processing program

The PERFUM2 model was modified by DPR staff to output the daily maximum direction buffer zone. The rationale for selecting the maximum direction approach is described in section VI. As discussed earlier, the full flux profile was not used in the simulations. Instead, the maximum 6-hour flux from a study application was input as an 8-hour flux beginning at the first hour it occurred in the flux profile for each application. For example, if the maximum 6-hour flux occurred from 0800 hours to 1400 hours then that 6-hour flux value was input for each of the 8 hours in the interval from 0800 hours to 1600 hours and the buffer zone was calculated only for those 8 hours. To ensure that the maximum 8-hour flux in the flux profile produces the largest buffer zone, the flux value for each monitoring period was modeled with worst-case (screening level) meteorology. Analysis of these screening level buffer zones for each monitoring period found that the maximum 8-hour flux in the profile produced the largest buffer zones for each application. Thus, maximum 8-hour flux results in the largest buffer zones for a specific application flux profile and it is not necessary to simulate the remainder of the flux profile.

The maximum direction buffer zone approach was used so, for each application one 8-hour buffer zone was produced for each day of the five year weather record for all five meteorological data sets. The maximum direction approach results in an individual application having a buffer zone distribution composed of a potential set of 1825 buffers zones (5 years x 365 days), one buffer zone for each day over 5 years (ignoring leap years). However, the total number of buffer zones for each application is usually smaller than 1825 buffer zones because missing data in the meteorological file. After the sets of PERFUM2 simulations for a tarp type/application method set were completed, a composite distribution of buffer zones was constructed by combining the buffer zone results from all the applications within each tarp type/application method set. For example, the Ventura Poly Tarp/broadcast composite distribution contained buffer zones from 7 applications for a total of 12533 buffer zones. The buffer zone sets were sorted and the 95th percentile was located directly using the standard equation $p_i = 100*[(i – 0.5)/n]$ where the buffer zones are sorted and assigned a position, i. The composite buffer zone distribution accounts for variation in the magnitude of the maximum 6-hour flux observed in the database and for night and day differences in maximum 6-hour flux occurrences (provided the set of flux estimates includes applications that showed maximum flux at night). The resulting buffer zones for all five locations are shown in Appendix 4. In some cases, the *calculated* buffer zones shown in Appendix 4 are smaller than the *required* buffer zones specified by labels. Table 5 shows example buffer zones for Ventura and San Joaquin meteorological data and the poly tarp/broadcast application method. The Tri-Clor current label buffer zones are shown in Table 6 for comparison.

Figures 9 to 12 give a visual step by step guide to how the DPR buffer zones shown in Table 5 were developed. The Poly Tarp/Broadcast method, 40 acres, and 350 pounds (lbs) per acre scenario is used because it gives nonzero buffers zones for most applications and days within applications. This result makes it easier to explain the process. The same steps were used for all ten tarp type/application method combinations. This approach gives each application in the tarp type/application method scenario direct representation in the buffer zone distribution used to select the final buffer zones. Thus, a composite distribution was used in buffer zone development.

Figure 9. Example flux profile from Volume 0199-0130 Wasco, California Broadcast/Poly Tarp 350 lb/ac. Sampling intervals are typically 6 or 12 hours. Application ID 26 in Appendix 2.

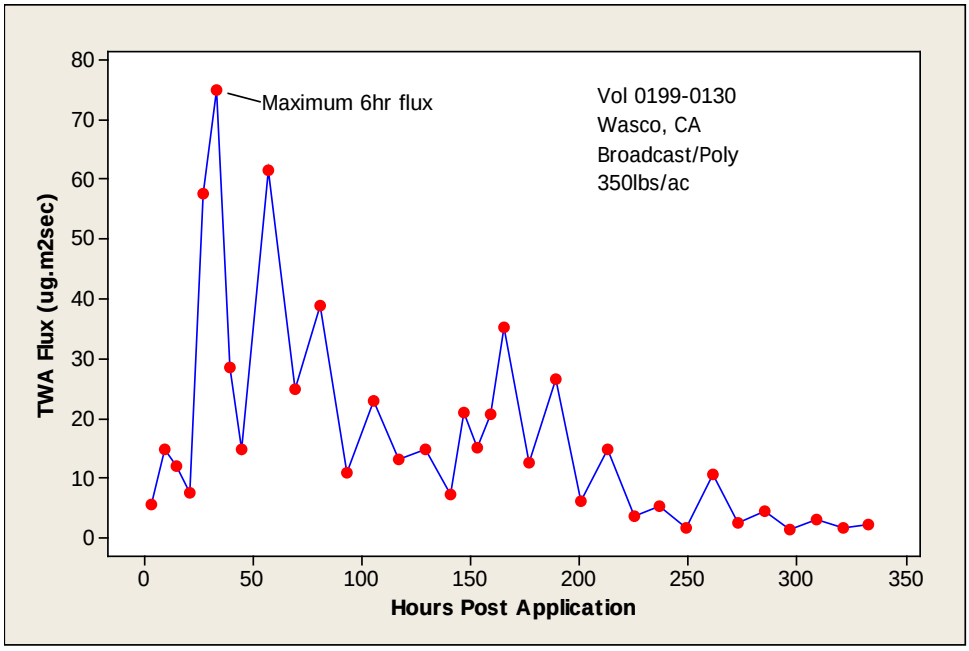


Figure 10. Resulting single application buffer zone distribution using Ventura CIMIS weather for Volume 0199-0130 Wasco, California Broadcast/Poly Tarp 350 lb/ac and 40 acres using the maximum 6-hour flux shown in Figure 8 as an 8-hour flux (See text for details). Application ID 26 in Appendix 2.

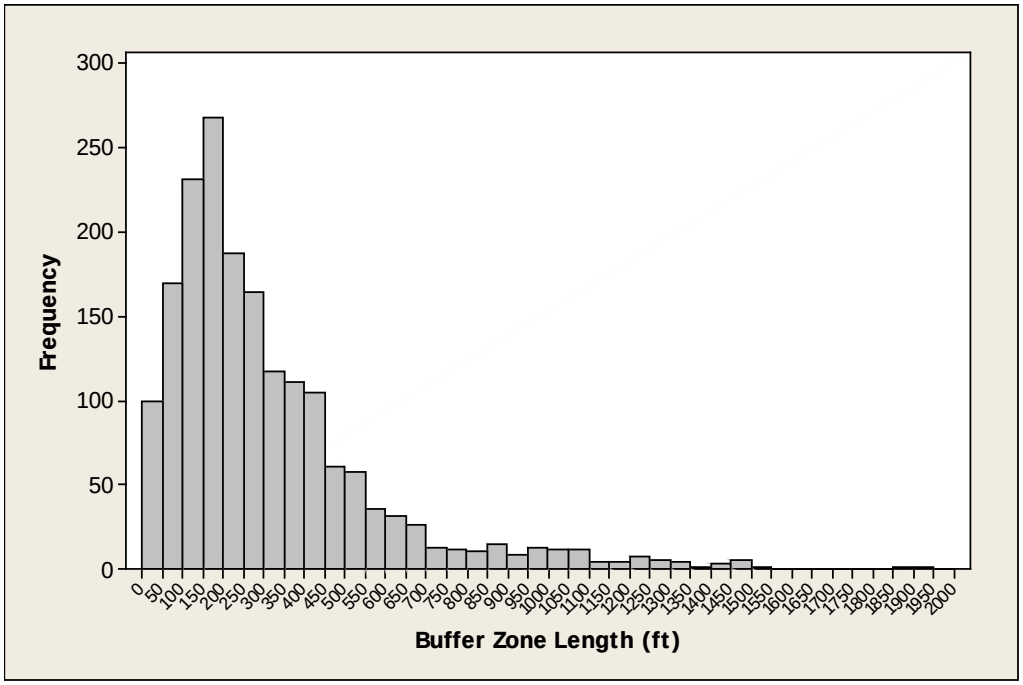


Figure 11. Distributions of buffer zone lengths (ft) for the 7 Poly Tarp/Broadcast Method Applications using Ventura CIMIS weather. Scenario = 40 acres and 350 lbs/ac. Each application name is coded by application ID (e.g. 05), state (e.g. WA), and application method (all application in this figure are broadcast: Broad) as shown in Appendix 2. The time the maximum flux occurred is shown and the maximum 8-hour flux is noted (e.g., 24ug/m2sec). Frequency is raw frequency (maximum frequency = 1825, excluding leap years).

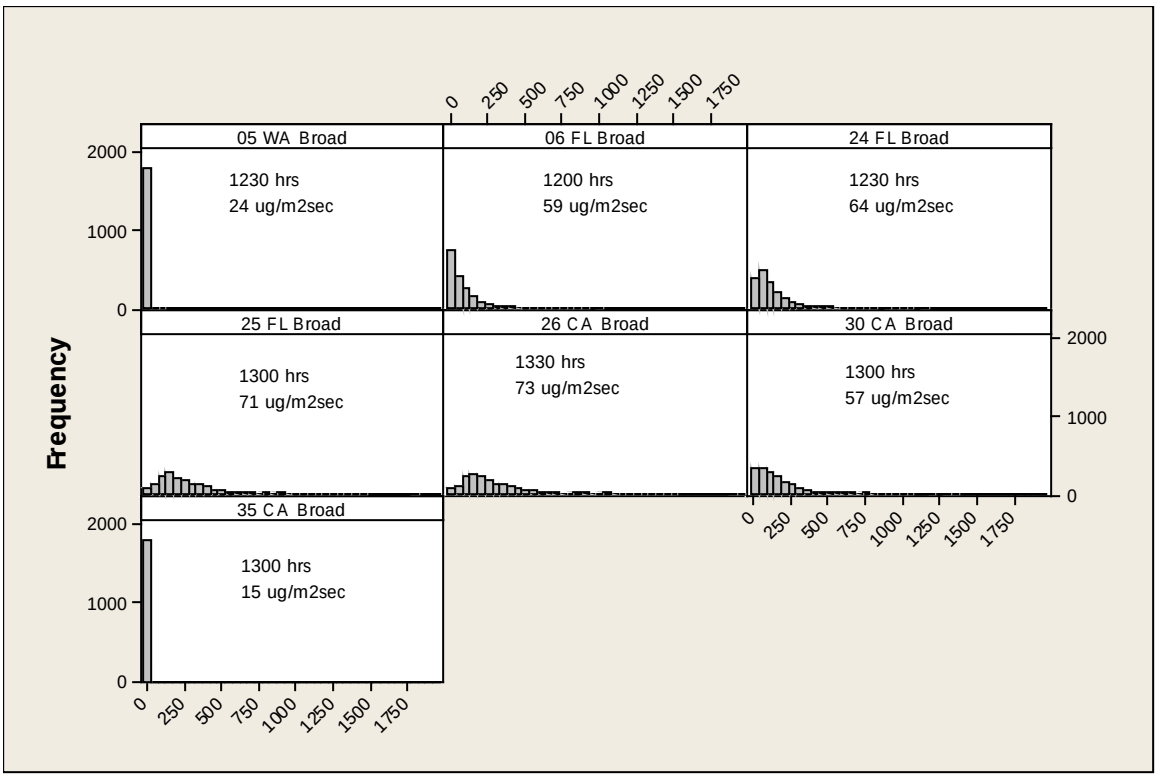


Figure 12. Composite distribution of buffer zone lengths (ft) from the 7 Poly Tarp/Broadcast Method applications using Ventura CIMIS weather as shown in Figure 11 above. This distribution contains a total of 12,533 buffer zones.

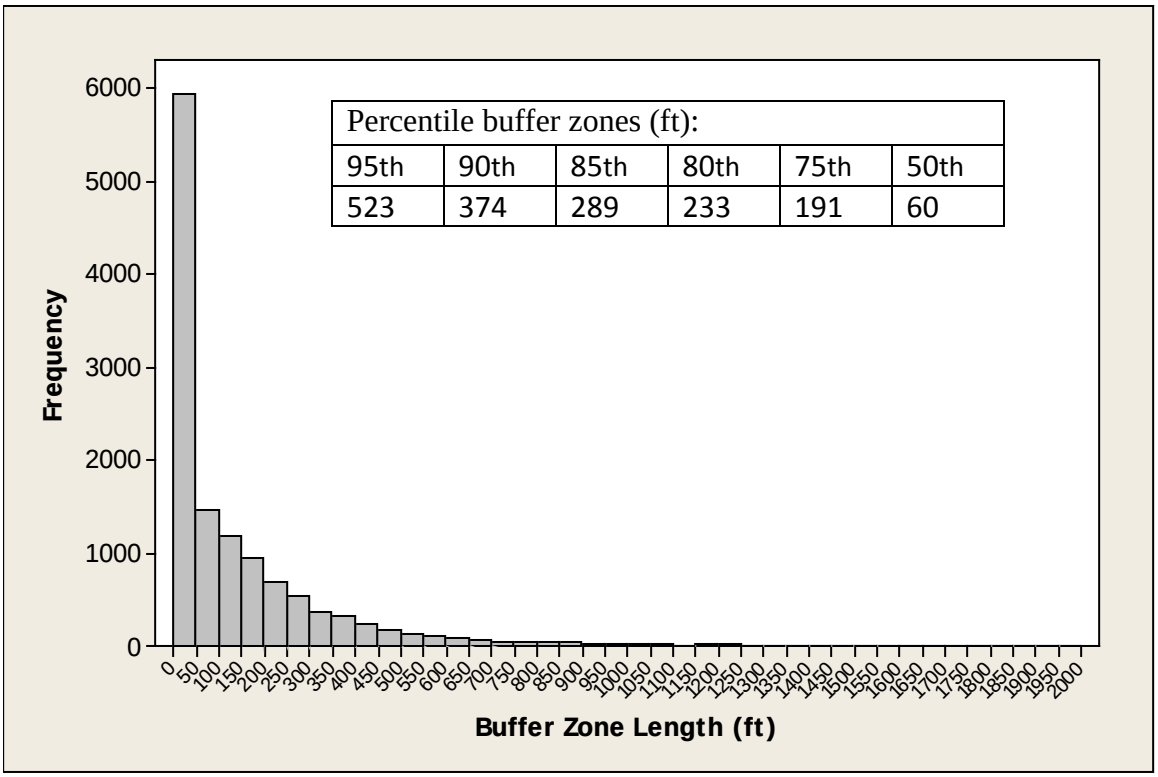


Table 5. The Ventura and San Joaquin 95th percentile composite distribution maximum direction Poly Tarp/Broadcast application method buffer zones (ft) developed using 7 Poly Tarp/Broadcast application method applications.

Ventura

App Rate (lb/ac)	App Size (AC)					
	1	5	10	20	30	40
100	0	0	0	16	16	16
150	0	16	16	16	16	16
200	0	16	16	36	81	116
250	16	16	56	134	191	243
300	16	49	127	227	322	377
350	16	104	193	323	429	523

San Joaquin

App Rate (lb/ac)	App Size (AC)					
	1	5	10	20	30	40
100	0	0	0	16	16	16
150	0	16	16	16	16	16
200	0	16	16	40	69	92
250	16	16	59	116	157	193
300	16	59	117	191	259	301
350	16	100	169	267	344	413

Table 6. Tri-Clor Label Table 5 No Credit Buffer Zones (ft). No factor credits applied.

App Rate (lb/ac)	App Size (AC)					
	1	5	10	20	30	40
100	25	25	25	25	25	33
150	25	25	42	104	144	179
200	25	61	139	207	272	354
250	25	125	204	303	407	499
300	25	165	265	395	495	625
350	50	215	315	475	610	725

Conditions requiring a 25 ft chloropicrin buffer zone for tree hole applications were developed using the untarp deep injection buffer zone results. Table 7 shows the number of tree holes allowed within various field sizes when each tree hole is treated with 1 lb (1.0 lb/tree hole = 1 lb/100 sq ft).

Table 7. Chloropicrin tree hole limitations in order to maintain a 25 ft buffer zone. Tree hole limitations are based upon the untarp deep broadcast injection application method.

Application Size (ac)	Maximum Number of Tree Holes/acre
40	50
10	75
5	100
1	200

IV. Choice of Air Dispersion Model

This buffer zone development used the PERFUM2 model. Barry (2007a) presents and discusses three methods to develop buffer zones that are based on the ISCST3 model: screening meteorological conditions used directly in the ISCST3 model, the Fumigant Emissions Modeling System v5.074 (FEMS) modeling system (Sullivan et al., 2006) and the PERFUM2 model. Screening meteorological conditions are "…worst-case meteorological conditions to provide conservative estimates of the air quality impacts of a specific source…" (U.S. EPA, 2003) to develop buffer zones in the absence of fully developed input data. This is the least refined method to develop buffer zones. Similar to PERFUM, the FEMS model performs multi-year simulations using historical weather data to generate buffer zones. However, there are features of the FEMS model that make it difficult to use to generate chloropicrin buffer zones. The difference between FEMS and PERFUM2 are discussed in detail in Barry (2007a). Briefly, rather than inputting specific flux data, FEMS has a set of default flux profiles. Inputting other flux profiles is difficult and would be time consuming for the 28 applications in the chloropicrin database, but could be accomplished. The most important drawback of the FEMS model is the manner in which it develops buffer zones. FEMS does not construct distributions of buffer zone lengths. Instead it counts exceedances of a target threshold at each receptor around a source. This method is problematic when attempting to account for the observed properties present in the chloropicrin maximum 6-hour flux database such as whether or not the maximum 6-hour flux occurred during the day or at night.

The chloropicrin buffer zones were developed using the PERFUM2 model, which employs the ISCST3 Gaussian air dispersion model to estimate air concentrations. The PERFUM model was reviewed in 2004 by the U.S. EPA Scientific Advisory Panel and found to be scientifically sound (U.S. EPA, 2004). The PERFUM model was used to develop the federal chloropicrin label buffer zones and is a currently posted model on the U.S. EPA Pesticides; Science and Policy page (http://www.epa.gov/pesticides/science/models_pg.htm).

The ISCST3 model was originally a U.S. EPA Office of Air and Radiation and Office of Air Quality Planning "preferred model" but it is currently classified as an "alternative model." The current candidate preferred models are AERMOD (Cimorelli et al. 2004) or CALPUFF (Scire et al., 2000). DPR has used ISCST3 extensively since the 1990's and has established that its performance is acceptable with regard to estimating air concentrations associated with fumigant applications (Johnson et al, 1999; Barry, 2000a, O'Malley et al, 2002, O'Malley et al, 2004, Johnson and Barry, 2005, Barry et al., 2010). Use of an "alternative model" is allowed on a case-by-case basis, after review by the reviewing authority, as long as the use is not for programs that are a State Implementation Plan (SIP) revision or for a New Source Review and Prevention of Significant Deterioration (PSD) programs (Section 3.2, Appendix W, 40 CFR 51, Federal Register 2005). In this case, DPR is the reviewing authority and the use of ISCST3 does not fall under SIP or PSD programs. At this time, for fumigant area sources such as chloropicrin applications modeled in this memorandum, neither AERMOD nor CALPUFF contain features that would significantly improve the mitigation measures developed using PERFUM2/ISCST3 model. The availability of the PERFUM2 model coupled with the long term proven performance of the ISCST3 model supports the approach used to develop the chloropicrin buffer zones. However, it is likely going forward that the AERMOD and CALPUFF models will eventually be incorporated into the air dispersion modeling at DPR.

V. TIF Tarp Cutting Interval

Use of TIF Tarps has raised the concern that off-site air concentrations immediately following tarp cutting may exceed target concentration. The chloropicrin database contains five broadcast/shallow shank injection/TIF Tarp applications appropriate for determining a Tarp Cutting Interval (TCI). Three applications are from the Lost Hills study (Ajwa and Sullivan, 2012; 50046-0198), one from Wasco (Ajwa and Sullivan, 2010a; 0123-0220), and one from Ventura (Sullivan and Ajwa, 2010; 0199-0142). Chloropicrin 6-hour flux for a 350 lb/ac application following tarp cutting is shown in Table 8.

Table 8. Chloropicrin 6-hour flux at various TIF Tarp cutting intervals

CDPR Data Volume	Location	Tarp Cutting Interval (days)	350 lb/ac 6-hour flux (ug/m^{2}sec)
50046-0198	Lost Hills, CA	5	42.0
		10	3.7
		16	0.9
0123-0220	Wasco, CA	6	5.9
0199-0142	Ventura, CA	6	6.5

Figure 13 shows data from the Lost Hills study only (Ajwa and Sullivan, 2012; 50046-0198). The measured flux values are shown as circles. It can be argued that the Lost Hills data only should be used because these three applications were done in the same location and in close proximity. In that case the recommendation would be to require a 10 day TCI. However, while the fit of the function in this graph is very good, the true function of change in maximum 6-hour flux following tarp cutting versus TCI is not well quantified with these data alone. In addition, the variability of flux between locations should be considered.

Figure 13. Lost Hills, California study (CDPR data volume 50046-0198) chloropicrin 6-hour flux (ug/m^{2}sec) for a 350 lb/ac application at TIF Tarp cutting.

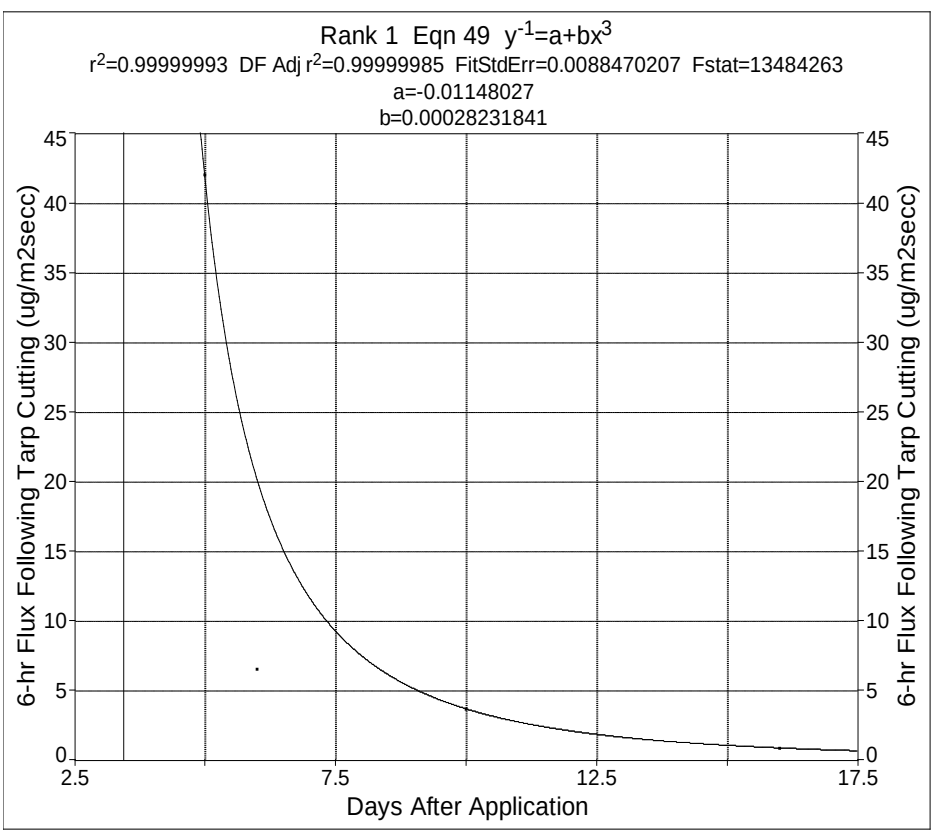
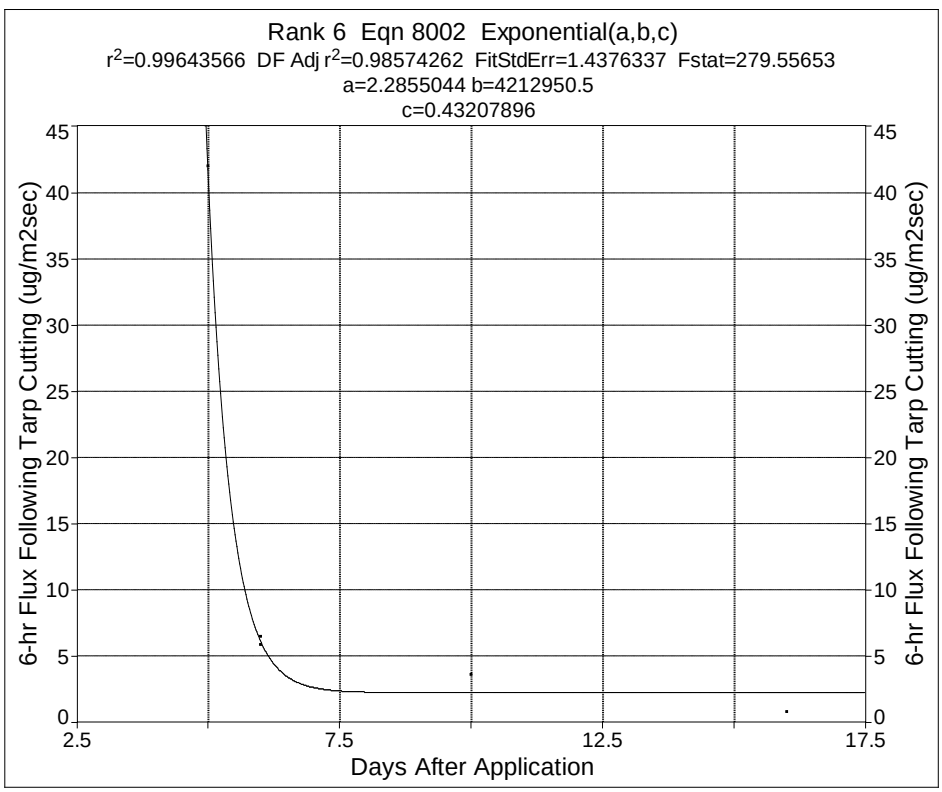


Figure 14 shows all of the tarp cutting data from Table 8. When the two flux values for tarp cutting at 6 days are included there is a much steeper decline in flux as a function of days. Since tarp cutting intervals are set in one day time steps, 6 days would be the minimum tarp cutting interval that could be recommended based upon the full data set. These data indicate that a 10 Day Tarp Cutting Interval may not be necessary. However, the difference between the 5 Day Tarp Cutting flux (42.0 ug/m^{2}sec) versus the average of the two 6 Day Tarp Cutting flux (6.2 ug/m^{2}sec) is substantial. An alternative mitigation measure would be to choose a Tarp Cutting Interval between 6 and 10 days, e.g. 8 or 9 Days. By Day 6 following the start of the application, the buffer zone required by label or permit condition will no longer be in force. Thus, it is important that the tarp cutting interval be long enough so when the tarp is cut the flux is low enough to avoid the tarp cutting producing chloropicrin air concentrations so high that a buffer zone would be required. No buffer zones are required at tarp cutting for either of the 6 Day Tarp Cutting Interval applications. So, any TCI 6 days or larger would not require buffer zones at tarp cutting.

Figure 14. Chloropicrin 6-hour flux (ug/m^{2}sec) for a 350 lb/ac application at TIF Tarp cutting for the three studies shown in Table 8.



VI. Whole Field versus Maximum Direction Buffer Zones

The PERFUM model includes two methods for constructing buffer zone distributions: whole field and maximum direction. The two different distributions are constructed during the same model run. Barry and Johnson (2007) described and analyzed the difference between whole field and maximum direction buffer zone distributions.

Briefly, both methods use "spokes" of receptors that surround a source (the fumigated field). However the difference between the two methods is how those receptors are used to generate the buffer zone distributions. The target concentration is the air concentration reference level set by DPR. For each day during an averaging period (e.g. 8 hours), the maximum direction method finds along each spoke the distance away from the source edge where the target concentration occurs. Then for each day, the maximum direction method selects the one distance amongst all of the spokes that is the largest for that day. A 5-year simulation would provide (1 buffer zone X 365 days x 5 years) = 1825 maximum direction buffer zones which would be compiled into a buffer zone distribution.

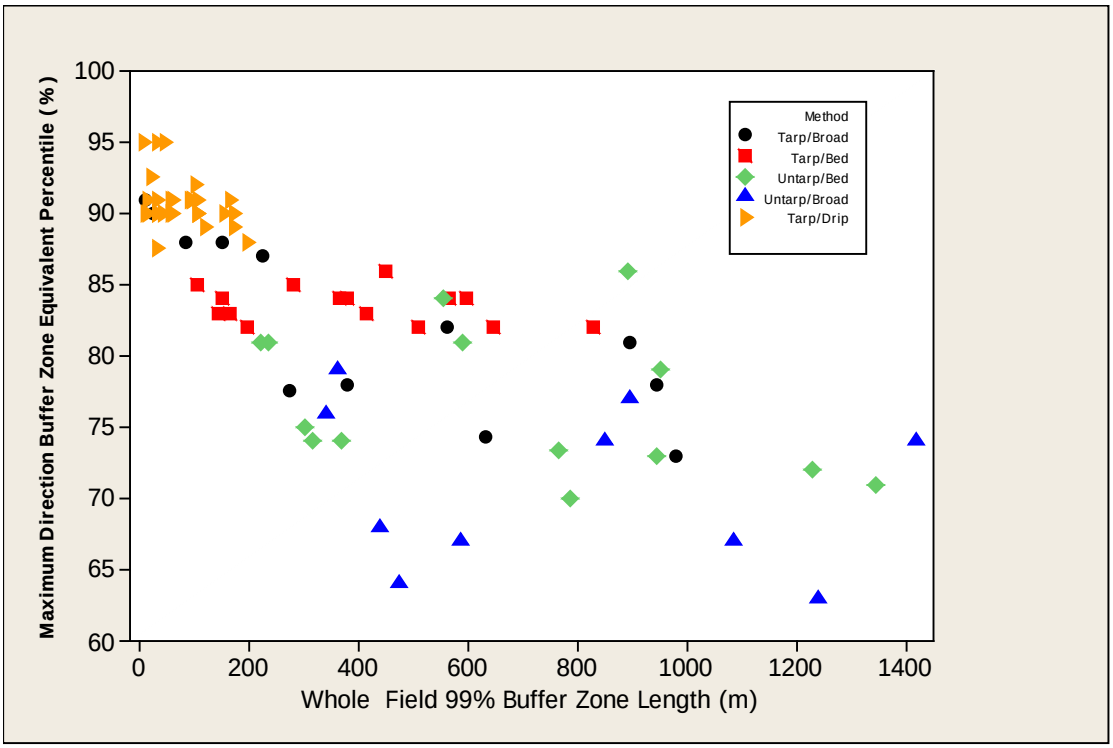
The whole field approach finds the distance to the target concentration along each spoke of receptors and adds that distance to the buffer zone distribution. Thus, the number of distances recorded for each day is equal to the number of spokes. For example, if the simulated application had 200 spokes of receptors surrounding the application then each day of the simulation would yield 200 buffer zones. These distances include distances along spokes that are in both the predominately upwind as well as the predominately downwind directions during that day. The maximum buffer zone distance among all the whole field spokes for a particular day is also the single maximum direction buffer zone. For the example of 200 spokes around the application, the completed whole field buffer zone buffer zone distribution will have (200 buffer zones x 365 days x 5 years) = 365,000 buffer zones. This distribution of 356,000 buffer zones will include distributional values heavily weighted to small buffer zone lengths because the distances to the target concentration on the predominately upwind spokes will be zeros or small.

DPR has generally controlled buffer zone protection level probabilities at the individual application level (Segawa et al., 2000; Johnson, 2001; Barry, 2006). The maximum direction buffer zone approach provides buffer zones that achieve this probability. The whole field approach provides a buffer zone that gives the probability that the target concentration is exceeded at any random location along the edge of the buffer zone of a random application. The whole field buffer zone percentiles do not correspond to a specific level of protection for an individual application (Barry and Johnson 2007). It, instead, relies on a low probability of bystanders being at the specific spot that the target concentration occurs. However, it cannot be assumed that this probability is low. Barry (2005) found homes or schools within 50 feet of buffer zone distances for 20% of methyl bromide applications in several coastal counties.

Figure 15 (Originally shown in Barry and Johnson, 2007) shows the equivalent chloropicrin maximum direction buffer zone percentile compared to the 99% whole field buffer zone length. The buffer zones in Figure 15 are for a 4-hour averaging time rather than the current 8-hour averaging time for chloropicrin. However, the relationship between the maximum direction and whole field percentiles does not change with the increase to an 8-hour averaging time as demonstrated by the metam sodium analysis conducted in Barry and Johnson (2007). The critical conclusions are: (1) regardless of averaging time, a buffer zone distance based on the 99th percentile whole field approach will be at a lower percentile protection level when evaluated under the maximum direction/individual application protection level methodology, (2) the individual field level protection is lower than for whole field for all averaging time. However, the difference is largest for averaging times less than 24 hours, (3) as whole field buffer zone length increases the maximum direction/individual level protection drops, and (4) the whole field buffer zones with the lowest maximum direction equivalent percentiles occurred at night. As stated in Barry and Johnson (2007): “Thus, shorter threshold averaging time coupled with a flux profile that caused whole field buffer zone size to be driven by nighttime averaging periods was associated with the lowest maximum buffer zone equivalent percentiles.”

Table 3 showed that 3 of the 26 applications used to develop the chloropicrin buffer zones show maximum flux occurring at night. The lack of ability to quantify the failure rate of a whole field developed buffer zone at the individual field level is the most compelling reason to consider maintaining the DPR practice of controlling buffer zone protection level probabilities at the individual application level.

Figure 15. Relationship between the chloropicrin 99% whole field buffer zone length (m) and the equivalent maximum direction buffer zone percentile. Equivalent maximum direction percentile = individual application level protection probability = (1 – individual application buffer zone failure rate). From Barry and Johnson (2007).



VII. Seasonal Buffer Zones

The 15 application Poly tarp applications were assembled into a single composite distribution for each of the Ventura and San Joaquin weather data. The composite distributions were examined for seasonal patterns in buffer zone length. The 40 acre and 350 lb/acre application rate scenario was used because the difference between seasons would likely be largest for that scenario.

The Ventura composite distribution contained 26,839 simulated buffer zone distances, and the San Joaquin composite distribution contained 26,699 simulated buffer zone distances (15 applications x 5 years x 365 days/year, and accounting for missing weather data). For Ventura, the 95th percentile includes 1342 (5% of 26,839) buffer zone distances, and the San Joaquin 95th percentile includes 1334 (5% of 26,699) buffer zone distances. Figure 16 shows the percent of the 1342 or 1335 95th percentile buffer zones that occur in each month for Ventura and San Joaquin. Figure 17 shows the median buffer zone length for Ventura and San Joaquin. The

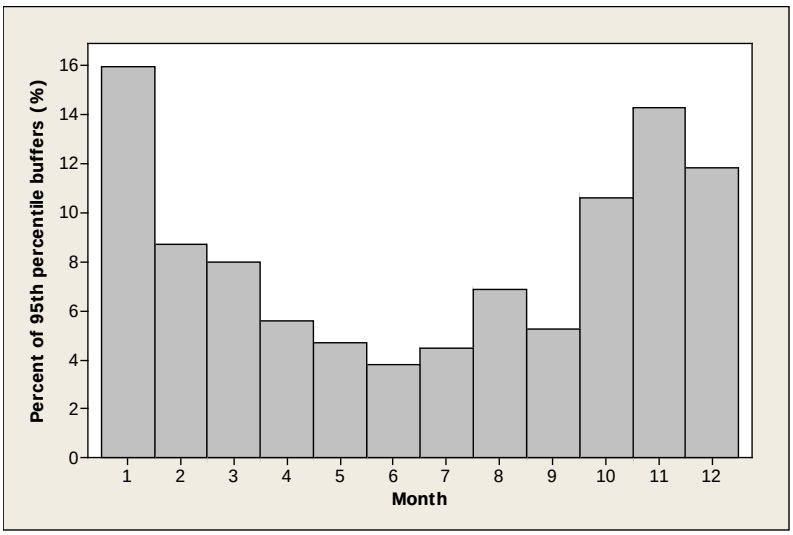
percent of the 95th percentile buffer zones is of interest because this variable will most clearly show if certain months have meteorological conditions that cause longer buffer zones. Figure 16 indicates general patterns with the summer months containing less of the 95th percentile buffer zones and winter months containing more. However, there is no clear cutoff to allow grouping of months together for seasonal buffer zones. Furthermore, the patterns in spring and fall between Ventura and San Joaquin are different. The same is true of the median buffer zone length (Figure 17). A general trend of the shortest buffer zones on average in summer is evident at Ventura but not at San Joaquin. In addition, any cut points based on the median would be different from those based on the percent of 95th percentile buffer zones. A final consideration is that seasonal differences may vary between tarp type and there is not enough data to evaluate seasonal trends in untarp and TIF buffer zones. For these reasons developing seasonal buffer zones is problematic.

VIII. Fumigation Time Limits

The fumigation time limits are designed to maintain day to day application conditions that closely reflect the conditions under which the studies in the chloropicrin database were conducted. Most of the applications used to develop these buffer zones were started during daylight hours and also had the maximum flux interval occurring during daylight hours. Thus, these fumigation time limits help to minimize the chance of having the maximum flux for an application occurring during dark hours. For the same magnitude flux, with all other factors such as application size and rate, and wind speed held constant, night air concentrations associated with that flux will be higher than air concentrations if that same flux occurred during the day. Table 3 showed that for the shallow injection and drip applications, 23 applications had day maximum fluxes compared to 3 applications having night maximum fluxes. Thus, the buffer zone distributions characterize predominantly daytime conditions for the occurrence of the maximum flux. To keep flux profiles for actual chloropicrin application similar to those used to develop the buffer zone the fumigations DPR should consider limits to the starting and ending times, such as no earlier than 1 hour after sunrise and finish several hours before sunset.

Figure 16. Distributions of the Poly tarp Ventura and San Joaquin composite 95th percentile buffer zones over months. Each bar is the number of 95th percentile buffer zones in the month divided by the total number of 95th percentile buffer zones (n) multiplied by 100. Total number of buffer zones in the Ventura composite distribution is 26, 839. Total number of buffer zones in the San Joaquin composite distribution is 26,699.

Ventura (n = 1342)



San Joaquin (n = 1334)

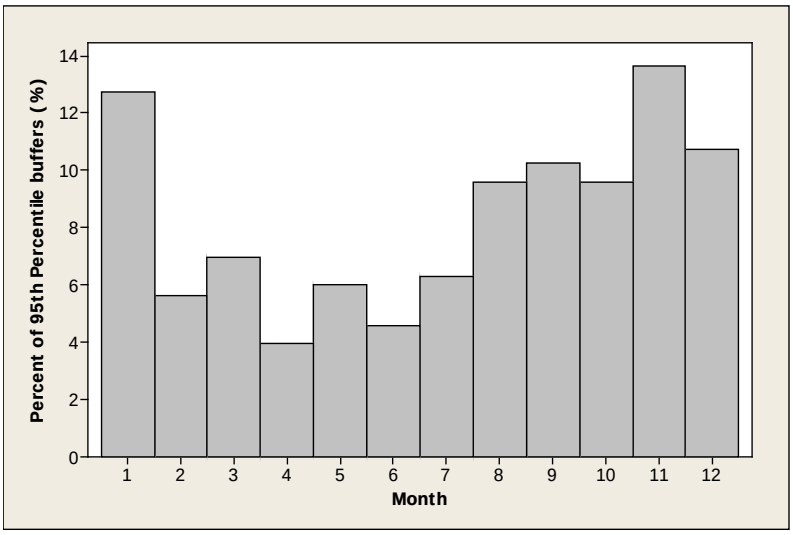
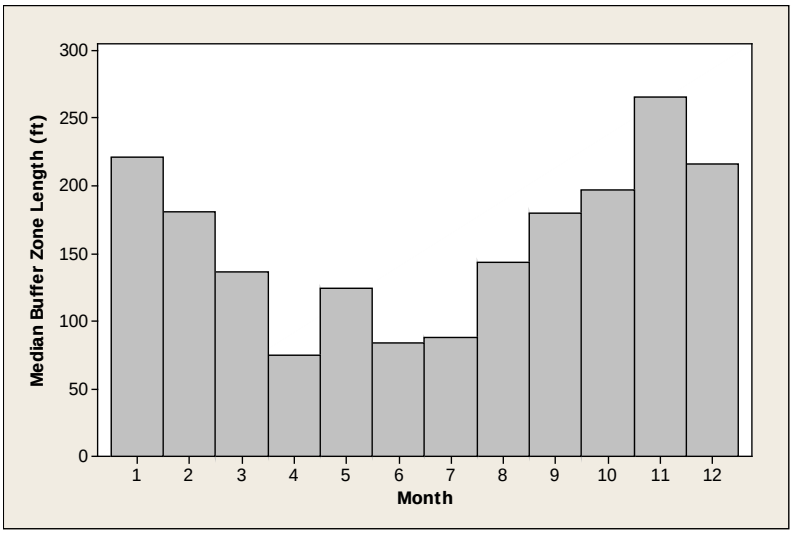
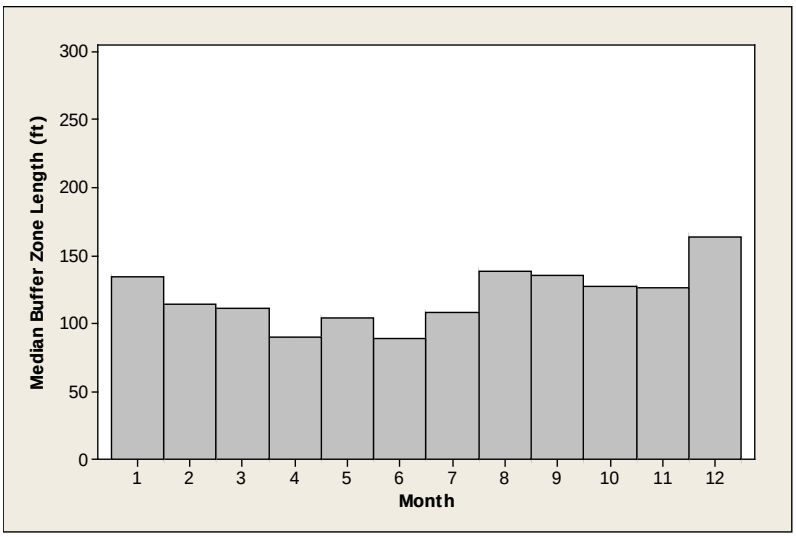


Figure 17. Median buffer zone length (ft) by month for Ventura and San Joaquin Poly tarp composite buffer zone distributions. Total number of buffer zones in the Ventura composite distribution is 26,839. Total number of buffer zones in the San Joaquin composite distribution is 26,699.

Ventura



San Joaquin



IX. Summary and Conclusions

This memorandum presents DPR's chloropicrin flux database (Appendix 1), analyzes that data and develops chloropicrin buffer zones based upon analysis results. The PERFUM2 model (Reiss and Griffin, 2005), modified to output daily maximum direction buffer zone length, was used to generate the buffer zones. Since Barry (2013) DPR has received additional data that resulted in the revised analysis presented in this memorandum. The analysis resulted in 10 tarp type/application method groups that are consistent with the labels. Other factors on the Phase 2 labels that are assigned credits to reduce buffer zone size are not supported by the analysis in this memorandum but are being further evaluated in a separate analysis. In addition, this memorandum discusses two issues related to buffer zone development: tarp cutting interval and the maximum direction versus whole field buffer zone distributions generated by the PERFUM model. DPR has used the maximum direction distribution of buffer zones to develop mitigation measures in the past. The basis for using the maximum direction distribution is explained above. This analysis indicates that the interval for cutting TIF tarps should be 6 – 10 days following application. Five California meteorological stations were use in developing buffer zones:

Ventura County – Piru (Station 101)
Monterey County – Salinas (Station 89)
San Joaquin County – Manteca (Station 70)
Kern County – Belridge (Station 146)
Siskiyou County – Tule Lake (Station 91)

DPR's calculated buffer zones are presented in Appendix 4. In some cases, the *calculated* buffers are smaller than the *required* buffer zones specified by labels. The TIF strip shallow injection buffer zones are the same as the Poly tarp broadcast buffer zones because that data was used a surrogate and considered conservative for estimated buffer zones. For the other TIF tarp application methods (TIF broadcast, TIF bed, TIF drip, TIF strip deep) the buffer zones are the minimum distance of 25 ft so no buffer zone table is included. This analysis, based on the currently available data, can be further refined if new flux data or other relevant studies are submitted in the future.

Greenhouse applications have not been specifically examined in this analysis, although labels include separate buffer zone tables. It is likely that the most appropriate greenhouse buffer zone table will use data from the applications in the database in Appendix 1.

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Appendix 1. Chloropicrin Studies Database

							Appendix 1					
MRID	DPR Volume #	Location	App type (As listed in data volume)	Tarp Type	notes		Industry ID	App rate lb/ac	Flux	ave time (hrs)	200lb/ac Flux	Total Mass loss (%)
44149201	0199-0072	Phoenix, AZ	Bed/untarp	untarp		1996	Beard et al. (1996)	149.0	112.8	6.0	151.4	61.4
		Phoenix, AZ	Bed/LDPE Tarp	Poly				189.0	142.1	6.0	150.4	68.6
		Phoenix,AZ	Broadcast/untarp	untarp				171.0	180.3	6.0	210.9	62.5
		Phoenix, AZ	Broadcast/LDPE tarp	Poly				332.0	211.0	6.0	127.1	62.6
		Yakima, WA	Broadcast/LDPE tarp	Poly				343.0	23.3	6.0	13.6	33.8
		Bradenton, FL	Broadcast/LDPE tarp	Poly				346.0	57.8	6.0	33.4	36.5
48033801	0199-0137	Elkton, FL	Bed/untarp	untarp		2010	CMTF PRS09006	142.0	15.0	5.7	21.1	6.5
		Elkton, FL	Bed/untarp	untarp				155.0	13.2	5.8	17.0	4.9
48011601	not submitted	Coloma, WA	Bed/untarp	untarp								
47295203	52875-0129	Bainbridge, GA	Bed/VIF (hytiblock)	TIF		2007	Arysta PTRL RptNo 1619W-1	71.2	0.4	5.0	1.1	1.6
47295202	52875-0128	Dover, FL	Bed/metallized tarp	Metal		2007	Arysta PTRL RptNo 1595W-1	36.2	9.0	5.5	49.7	13.5
47295204	52875-0130	Hart, MI	Bed/XL Black Blockade VIF tarp	VIF		2007	Arysta PTRL RptNo 1646W-1	41.2	0.6	6.0	2.9	0.35
N/A	50046-0198	Lost Hills, CA	Broadcast/TIF tarp/16Days	TIF	Field 1	2012	USDA-ARS HA2011A	340.5	6.3	6.0	3.7	4.5
			Broadcast/TIF tarp/10Days	TIF	Field 2			326.0	3.2	6.0	2.0	3.6
			Broadcast/TIF tarp/5Days	TIF	Field 3			353.8	4.3	6.0	2.4	10
			Broadcast/TIF tarp/KTS/5Days	TIF	Field 4			355.5	10.6	12.0	5.9	11.8
48200001	52971-0112	Tifton, GA	Bed/Pliant Blockade TIF tarp	TIF	Field 1	2009	USDA 2009B	61.4	1.7	6.0	5.5	2.5
		Tifton, GA	Bed/LDPE Tarp	Poly	Field 2			64.3	12.4	6.0	38.6	8.51
		Tifton, GA	Bed/LDPE Tarp	Poly	Field 3			68.1	14.6	6.0	42.9	7.93
47813901	0199-0138	Duette, FL	Bed/metallized tarp	Metal	Field 1	2009	USDA 2009A	51.1	18.7	6.0	73.2	2.9
		Duette, FL	Bed/Olefinas 1.2mil Guardian VIF tarp	VIF	Field 2			57.3	2.2	6.0	7.7	0.3
		Duette, FL	Bed/metallized tarp w/1,3-D	Metal	Field 3			53.5	4.5	6.0	16.8	0.4
48107601	0199-0140	Ft. Pierce, FL	Bed/TIF tarp	TIF		2010	MBIP HA201001	134.5	14.1	5.0	21.0	3.4
48085701	0199-0143	Ft. Pierce, FL	Broadcast/LDPE tarp/low dist std rig	Poly	Site 1	2010	USDA 2009H	254.8	46.8	6.0	36.8	34.56
		Ft. Pierce, FL	Broadcast/LDPE tarp/std rig	Poly	Site 2			230.4	46.5	6.0	40.3	43.87

MRID	DPR Volume #	Location	App type		notes		Industry ID	App rate lb/ac	Flux	ave time (hrs)	200lb/ac Flux	Total Mass loss (%)
47576901	0199-0130	Wasco, CA	Broadcast/LDPE tarp	Poly	Field 1	2008	Study ID 200801	358.0	75.1	6.0	42.0	47.8
		Wasco, CA	Strip/LDPE tarp	Poly	Field 2			165.0	38.1	6.0	46.2	47.6
		Wasco, CA	Broadcast/untarp	untarp	Field 3			197.0	60.5	6.0	61.4	46.36
		Wasco, CA	Broadcast/Deep/untarp	untarp	Field 4			321.0	74.8	6.0	46.6	46.3
48006001	0123-0220	Wasco, CA	Broadcast/LDPE tarp	Poly	Field 1	2010	MBIP HA20091	189.1	31.0	6.0	32.8	18.29
		Wasco, CA	Broadcast/vaporsafe tarp	TIF	Field 2			180.3	15.8	6.0	17.5	12.68
		Wasco, CA	Broadcast/vaporsafe tarp + KTS	TIF	Field 3			177.9	63.8	6.0	71.7	9.77
		Wasco, CA	Strip/vaporsafe tarp/deep	TIF	Field 4			101.3	2.8	6.0	5.5	17.92
		Wasco, CA	Broadcast/deep/vaporsafe tarp	TIF	Field 5			181.1	5.9	6.0	6.5	9.37
*	0199-0142	Ventura, CA	Broadcast/Polyethylene tarp	Poly	Field 1	2010	HA200902-2	145.8	6.1	6.0	8.3	10.8
		Ventura, CA	Broadcast/TIF tarp	TIF	Field 2			135.2	4.6	6.0	6.8	14.1
		Ventura, CA	Drip/TIF/KTS	TIF	Field 3			177.7	13.3	6.0	15.0	30.4
45112901	50046-0153	Salinas, CA	drip/bed/VIF	Poly		2000	DowAgroSciences Study ID 980070.01	70.5	14.9	6.0	42.3	8.6
45112902	50046-0152	GA	drip/bed/poly tarp	Poly		2000	DowAgroSciences Study ID 990072	36.8	7.3	5.3	39.8	12.3
47456001	0199-0093	Yuma, AZ	buried drip/bed/poly	Poly		1999	TRICAL Project #TC350	*	*	*	*	*
		Yuma, AZ	buried drip/bed/untarp	untarp			study rejected					
47679301	0199-0131	Yuma, AZ	buried drip/bed/untarp	untarp		2008	CMTF PRS08004	70.8	39.3	6.0	111.0	36.6
48087401	0199-0136	Salinas, CA	drip/bed/LDPE tarp	Poly		2010	Study ID 2007-D	200.0	77.7	6.0	77.7	22.3
		Salinas, CA	drip/bed/TIF tarp	TIF				200.0	5.5	6.0	5.5	3
		Salinas, CA	drip/bed/LDPE w/KTS	Poly				200.0	21.2	5.5	21.2	9.2
		Salinas, CA	drip/bed/LDPE w/water seal	Poly				200.0	50.4	5.5	50.4	14.4
46420201	199-0112	Salinas, CA	drip/bed/LDPE	Poly	Site 16	2004	CMTF PRS02004	148.7	47.0	8.0	63.2	15.2

Appendix 2. Summary of Maximum 6 hour flux, application start time, and timing of maximum 6-hour flux

					App		Hrs after	
					Start	Max Flux	app Max	flux (ug/m2sec)
DPR Volume #	Location	App type	Application ID	notes	Time (hrs)	Time (hrs)	Flux occurs	350lb/ac
0199-0072	Yakima, WA	Broadcast/LDPE tarp	05		755	1230	53	23.8
	Bradenton, FL	Broadcast/LDPE tarp	06		747	1200	29	58.5
50046-0198	Lost Hills, CA	Broadcast/TIF tarp/16Days	13	Field 1	701	1230	30	6.5
		Broadcast/TIF tarp/10Days	14	Field 2	802	1230	29	3.5
		Broadcast/TIF tarp/5Days	15	Field 3	759	1230	29	4.2
		Broadcast/TiF tarp/KTS/5Days	16	Field 4	1032	700	45	10.4
52971-0112	Tifton, GA	Bed/Pliant Blockade TIF tarp	17	Field 1	1247	630	31	9.7
	Tifton, GA	Bed/LDPE Tarp	18	Field 2	1519	1900	28	67.5
	Tifton, GA	Bed/LDPE Tarp	19	Field 3	1740	1930	26	75.0
0199-0140	Ft. Pierce, FL	Bed/TiF tarp	23		945	945	0	36.7
0199-0143	Ft. Pierce, FL	Broadcast/LDPE tarp/low dist std rig	24	Site 1	1139	1230	25	64.3
	Ft. Pierce, FL	Broadcast/LDPE tarp/std rig	25	Site 2	836	13	29	70.6
0199-0130	Wasco, CA	Broadcast/LDPE tarp	26	Field 1	747	1330	30	73.4
	Wasco, CA	Broadcast/untarp	28	Field 3	1110	1930	32	107.5
0123-0220	Wasco, CA	Broadcast/LDPE tarp	30	Field 1	826	13	5	57.4
	Wasco, CA	Broadcast/vaporsafe tarp	31	Field 2	828	830	0	30.7
0199-0142	Ventura, CA	Broadcast/Polyethylene tarp	35	Field 1	840	1300	29	14.6
	Ventura, CA	Broadcast/TIF tarp	36	Field 2	1315	1300	0	12.0
50046-0153	Salinas, CA	drip/bed/VIF	38		700	1300	6	74.0
50046-0152	GA	drip/bed/poly tarp	39		1200	1200	0	69.7
0199-0131	Yuma, AZ	buried drip/bed/untarp	40		800	1300	5	194.3
0199-0136	Salinas, CA	drip/bed/LDPE tarp	41		810	1300	5	136.0
	Salinas, CA	drip/bed/TIF tarp	42		810	1300	5	9.6
	Salinas, CA	drip/bed/LDPE w/KTS	43		810	810	0	37.1
	Salinas, CA	drip/bed/LDPE w/water seal	44		810	810	0	88.3
199-0112	Salinas, CA	drip/bed/LDPE	45	Site 16	739	1130	4	110.6

Department of Pesticide Regulation

Brian R. Leahy
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M E M O R A N D U M

APPENDIX 3

TO: Randy Segawa
Environmental Program Manager I
Environmental Monitoring Branch

FROM: Terrell Barry, Ph.D.
Research Scientist III
Environmental Monitoring Branch
916-324-4140

Original signed by

DATE: February 12, 2013

SUBJECT: AVAILABLE SOIL MOISTURE EFFECT ON MAXIMUM SIX HOUR FLUX

The Chloropicrin Manufacturers Task Force (CMTF) submitted a proposal to the Department of Pesticide Regulation dated October 27, 2011 (CMTF, 2011) which included four sections: regulatory exposure levels, appropriate field data, buffer zones development for mitigation, and conclusions. A key element in this proposal was the argument by the CMTF that certain field study applications should be eliminated from use in analysis because the CMTF contends that the applications in question do not meet new federal label language related to soil moisture. The question of appropriate field data and the basis used by CMTF to argue for removal of certain applications is related to Good Agricultural Practices (GAPs). GAPs were developed with the intent to aid in mitigation of off-site exposure. However, there is no comprehensive data analysis supporting GAPs. Instead, both the CMTF the U.S. Environmental Protection Agency (EPA) use single study observations to conclude that the GAPs are effective. This amounts to GAPs being supported only by expert opinion. The U.S. EPA Phase II labels require that for shank applications soil moisture at 9 inches below the surface must be equal to or greater than 50% of Available Water Capacity (AWC).

This memorandum presents analysis of the relationship between AWC and the magnitude of the maximum 6 hour (6hr) flux. The studies and applications within the studies used for this analysis are shown in Table 1. In order to perform the analysis the AWC has to be estimated using soil moisture measurements in the reports for each application. AWC is soil-specific and may be estimated with considerable uncertainty for a particular soil. Soil moisture information from the studies is presented in the form of soil characteristics (clay/silt/sand, bulk density) and soil moisture by weight. Soil moisture calculators can be used to estimate AWC. U.S. EPA label language does not require the use of a specific method or Soil Water Calculator to determine if post application soil moisture at 9 inch below the surface met the GAP criteria. Three Soil Water Calculators were used in this analysis: Saxton et al. (1986) and Saxton and Rawls (2006) from the Soil-Plant-Air-Water Model version 6.02.75, and Nelson (1997). Soil moisture was calculated for the 15 applications from the 3 studies shown in Table 10. Soil cores were taken to various depths at each of the applications. This analysis closely followed the U.S. EPA labels specification to calculate to soil moisture. Thus, only the soil core sections that provided the closest bracketing of the 9 inch depth were used in this analysis. The soil moisture parameters

were estimated by the three methods: Saxton et al. (1986), Saxton and Rawls (2006) and Nelson (1997). Results are shown in Figure 1. Each study is separated and the applications listed in order within study. The depth for soil moisture calculation is shown under each study. Application #11 in Beard et al. (1996) had to be excluded because the percent sand was outside of the range for Saxton et al. (1986) and Saxton and Rawls (2006). AWC is shown on the y-axis with the 50% - 75% range bracketed by the red horizontal lines.

There are large differences between the AWC estimates obtained using the three different models. The largest differences occur for applications with low Organic Matter Content. Of particular interest for this analysis is whether any of the bars for a particular application exceed the 50% AWC line. For estimated AWC calculated with Nelson (1997) and Saxton et al. (1986) most do not exceed 50% AWC. Three of the four applications in the CMTF (2008) study do not achieve the 50% AWC line with any of the estimate models, yet these applications were performed under conditions argued to be GAP-compliant. Soil cores in the CMTF (Ajwa and Sullivan, 2008; volume 0199-0130) study were taken to a depth of 30in. The soil moisture reported in the text of this study was averaged over the entire soil core. Averaging over the entire 30 in soil core does not follow the U.S. EPA label language. When only the soil core section bracketing 9 inch (6-12 inches core section) is used, it is clear that the soil was very dry at the measurement depth specified by the U.S. EPA label language. The deeper sections of the core were moist and must be included to achieve the 50% AWC. However, this does not meet the label language. Application #9 the Beard et al (1996) study also does not achieve the 50% AWC line.

The effect of soil moisture on the maximum 6 hr flux is shown in Figure 2. The maximum 6 hr flux is important because it is the driving factor in determining the size of acute buffer zones for the mitigation of off-site exposure to chloropicrin. There is not a discernible pattern and no statistical correlation between AWC and the magnitude of the maximum 6 hr flux. Thus, there does not appear to be a detectable relationship between AWC and maximum 6hr flux. The flux values do generally separate out according to study, thus the studies actually appear to be a surrogate for tarp type. The highest maximum 6hr flux values are the Arizona applications from the Beard (1996) study. All but one of the Vaporsafe tarp applications from the MBIP (Ajwa and Sullivan, 2010; 0123-0220) show the lowest flux values.

This analysis does not support the exclusion of the Arizona applications in Beard et al. (1996) due to soil moisture.

References

Ajwa, H. and D. Sullivan. 2010a. Monitoring of methyl bromide and chloropicrin field emissions from shank applications at shallow and deep injection depth. Sullivan Environmental Consulting, Inc. 1900 Elkin Stree, Suite 200, Alexandra, Virginia 22308. Laboratory Study ID HA200901. MRID 48006001. CDPR data volume 0123-0220.

Ajwa, H. and D. Sullivan. 2008. Monitoring of chloropicrin field emissions from shank applications at shallow and deep injection depths. Sullivan Environmental Consulting, Inc. 1900 Elkin Street, Suite 200, Alexandra, Virginia 22308. Laboratory Study ID HA200801. MRID 47576901. CDPR data volume 0199-0130.

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Nelson, R. 1997. Soil Hydraulic Properties Calculator. Available at: <http://www.afrc.uamont.edu/ficklinr/soils/soiltexture.htm>. Web site last accessed December 31, 2012.

Saxton, K. E., W. J. Rawls, J. S. Romberger, and R. I. Papendick. 1986. Estimating generalized soil water characteristics from texture. Soil Sci. Soc. Amer. J. 50(4):1031-1036.

Saxton, K.E. and Rawls, W.J. (2006). Soil water characteristic estimates by texture and organic matter for hydrologic solutions. Soil Science Society of America Journal, 70, 1569-1578.

Table 1. Studies used to examine the relationship between soil AWC and maximum 6hr flux.

MRID	DPR Volume #	Location	App type	Year	Figure ID
48006001	0123-0220	Wasco, CA	Broadcast/LDPE tarp	2010	MBIP 2010
		Wasco, CA	Broadcast/vaporsafe tarp		
		Wasco, CA	Broadcast/vaporsafe tarp+KTS		
		Wasco, CA	Broadcast/vaporsafe tarp/deep		
44149201	0199-0072	Phoenix, AZ	Bed/untarp	1996	Beard et al 1996
		Phoenix, AZ	Bed/LDPE Tarp		
		Phoenix, AZ	Broadcast/untarp		
		Phoenix, AZ	Broadcast/LDPE tarp		
		Yakima, WA	Broadcast/LDPE tarp		
		Bradenton, FL	Broadcast/LDPE tarp		
47576901	0199-0130	Wasco, CA	Broadcast/LDPE tarp	2008	CMTF 2008
		Wasco, CA	Strip/LDPE tarp		
		Wasco, CA	Broadcast/untarp		
		Wasco, CA	Broadcast/Deep/untarp		

Figure 1. AWC (% of Available Water) for each of 15 applications from 3 studies as shown in Table 1. Note: Application #11 soil was 242% AWC by the Nelson (1997) method and was outside the bounds of Saxton et al. (1986) and Saxton and Rawls (2006).

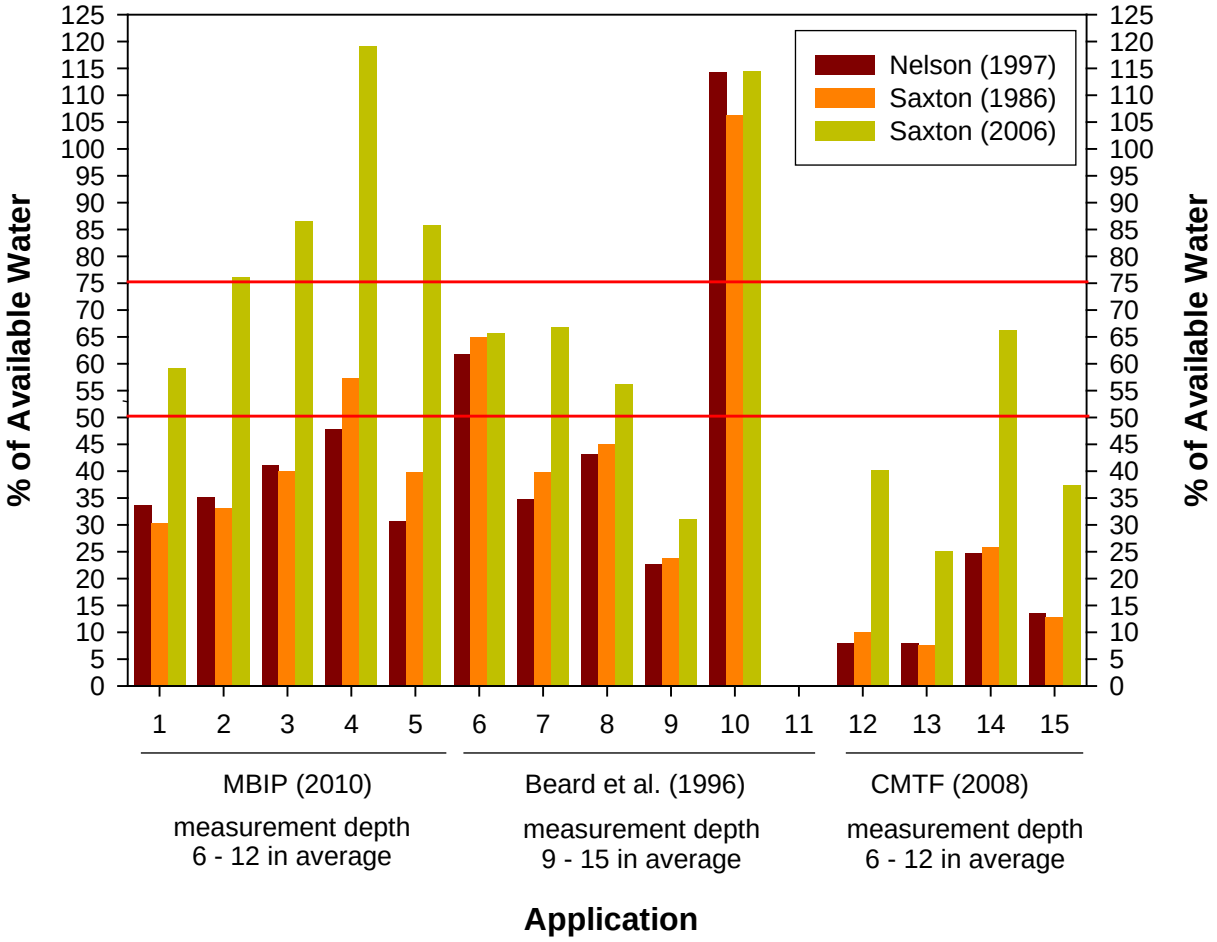
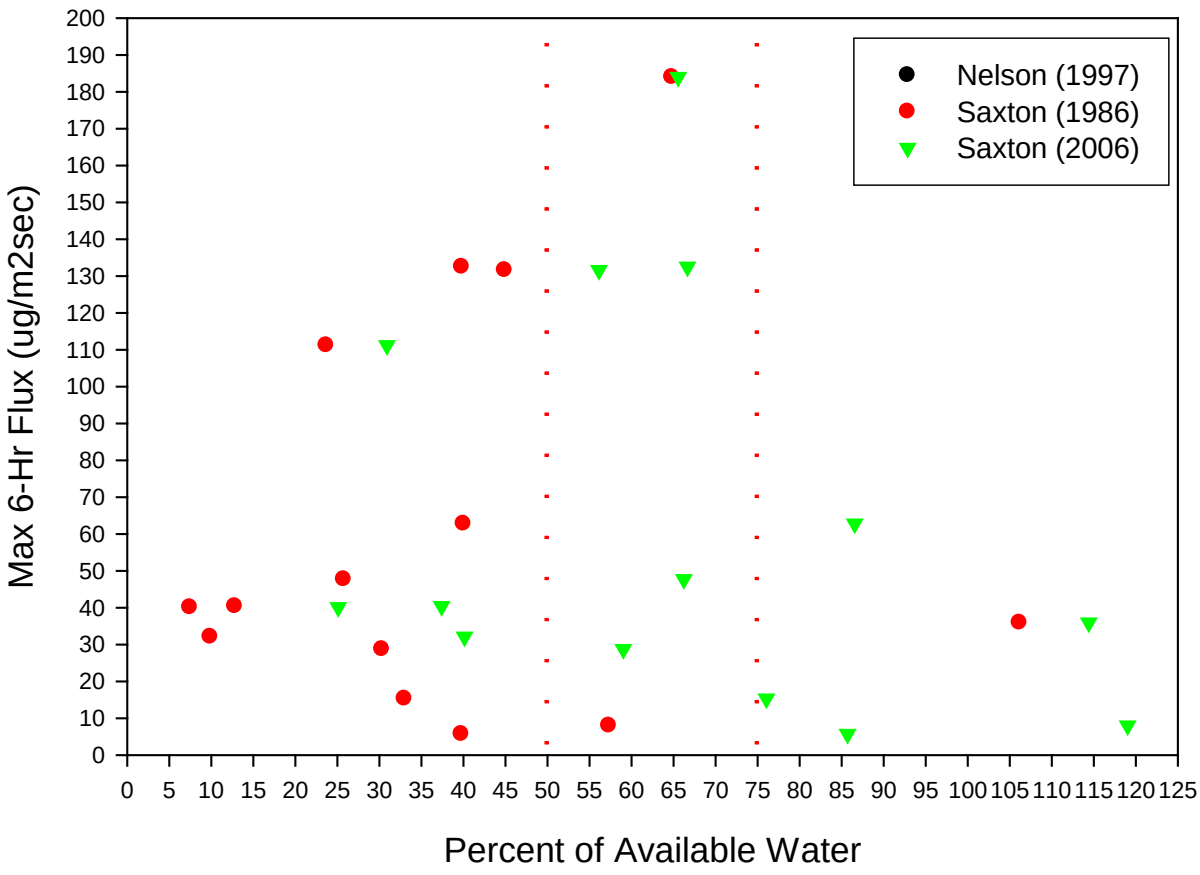


Figure 2. The effect of soil moisture level on maximum 6hr flux (ug/m2sec). The AWC (Percent of Available Water) estimates from the three models for each of the 15 applications listed in Table 1 are shown. The legend shows each model. The 50% - 75% AWC bracket is shown as the red vertical dashed lines.



Appendix 4. 95th Percentile Buffer Zone Tables

95th Percentile Poly Drip Regional Buffer Zones (ft)

Ventura - Ventura County

	app size (ac)					
app rate (lb/ac)	**1**	**5**	**10**	**20**	**30**	**40**
100	0	16	16	16	16	16
150	16	16	59	130	184	231
200	16	90	168	282	373	455
250	16	164	273	436	534	693
300	50	237	379	598	774	936
350	87	307	483	758	976	1179

Belridge - Kern County

	app size (ac)					
app rate (lb/ac)	**1**	**5**	**10**	**20**	**30**	**40**
100	0	16	16	16	16	16
150	16	16	18	50	71	89
200	16	42	78	129	171	206
250	16	85	121	219	282	338
300	31	126	200	311	398	477
350	52	170	264	402	518	627

Salinas - Monterey County

	app size (ac)					
app rate (lb/ac)	**1**	**5**	**10**	**20**	**30**	**40**
100	0	16	16	16	16	16
150	0	16	37	108	158	200
200	16	63	137	238	319	391
250	16	133	299	367	485	589
300	16	197	320	506	697	802
350	56	258	411	649	841	1021

Tule Lake - Siskiyou County

	app size (ac)					
app rate (lb/ac)	**1**	**5**	**10**	**20**	**30**	**40**
100	0	16	16	16	16	31
150	16	16	62	120	169	210
200	16	85	154	252	332	400
250	16	150	245	386	501	603
300	51	212	335	522	674	811
350	80	273	426	660	849	1018

Manteca - San Joaquin County

	app size (ac)					
app rate (lb/ac)	**1**	**5**	**10**	**20**	**30**	**40**
100	0	16	16	16	16	20
150	16	16	57	113	154	189
200	16	85	149	238	309	373
250	24	150	240	372	476	562
300	57	212	329	502	636	752
350	86	271	416	432	795	946

95th Percentile Poly Broadcast Regional Buffer Zones (ft)

Ventura - Ventura County

	app size (ac)					
app rate (lb/ac)	**1**	**5**	**10**	**20**	**30**	**40**
100	0	0	0	16	16	16
150	0	16	16	16	16	16
200	0	16	16	36	81	116
250	16	16	56	134	191	243
300	16	49	127	227	322	377
350	16	104	193	323	429	523

Belridge - Kern County

	app size (ac)					
app rate (lb/ac)	**1**	**5**	**10**	**20**	**30**	**40**
100	0	0	0	0	0	16
150	0	0	16	16	16	16
200	0	16	16	16	16	18
250	16	16	16	40	65	87
300	16	16	48	93	135	159
350	16	44	86	145	192	233

Salinas - Monterey County

	app size (ac)					
app rate (lb/ac)	**1**	**5**	**10**	**20**	**30**	**40**
100	0	0	0	0	16	16
150	0	16	16	16	16	16
200	0	16	16	16	49	76
250	0	16	25	93	139	176
300	16	16	87	166	238	281
350	16	69	141	224	320	388

Tule Lake - Siskiyou County

	app size (ac)					
app rate (lb/ac)	**1**	**5**	**10**	**20**	**30**	**40**
100	0	0	0	16	16	16
150	0	16	16	16	16	16
200	0	16	16	56	93	121
250	16	16	73	141	193	240
300	16	64	134	226	317	367
350	16	112	194	313	412	499

Manteca - San Joaquin County

	app size (ac)					
app rate (lb/ac)	**1**	**5**	**10**	**20**	**30**	**40**
100	0	0	0	16	16	16
150	0	16	16	16	16	16
200	0	16	16	40	69	92
250	16	16	59	116	157	193
300	16	59	117	191	259	301
350	16	100	169	267	344	413

95th Percentile Poly Bed Regional Buffer Zones (ft)

Ventura - Ventura County

	app size (ac)					
app rate (lb/ac)	**1**	**5**	**10**	**20**	**30**	**40**
100	0	16	16	218	322	417
150	0	159	332	571	774	951
200	16	337	573	916	1197	1464
250	16	479	777	1237	1616	1956
300	119	622	981	1540	2014	2464
350	220	746	1179	1840	2413	2958

Belridge - Kern County

	app size (ac)					
app rate (lb/ac)	**1**	**5**	**10**	**20**	**30**	**40**
100	0	16	16	127	200	262
150	16	109	230	405	547	677
200	16	244	412	672	892	1088
250	16	365	589	939	1232	1496
300	130	478	760	1204	1559	1885
350	183	591	924	1449	1878	2281

Salinas - Monterey County

	app size (ac)					
app rate (lb/ac)	**1**	**5**	**10**	**20**	**30**	**40**
100	0	16	16	144	226	296
150	16	91	227	403	545	670
200	16	226	395	637	836	1015
250	16	331	543	873	1130	1356
300	46	429	688	1081	1415	1716
350	130	524	835	1319	1708	2099

Tule Lake - Siskiyou County

	app size (ac)					
app rate (lb/ac)	**1**	**5**	**10**	**20**	**30**	**40**
100	0	16	16	134	212	277
150	16	102	230	401	540	665
200	16	235	403	652	861	1049
250	16	348	566	904	1176	1419
300	109	455	722	1135	1478	1785
350	163	551	875	1362	1770	2158

Manteca - San Joaquin County

	app size (ac)					
app rate (lb/ac)	**1**	**5**	**10**	**20**	**30**	**40**
100	0	16	16	150	223	287
150	16	120	246	421	566	697
200	16	251	423	682	893	1086
250	16	366	588	934	1227	1485
300	128	474	753	1185	1545	1876
350	180	578	911	1428	1857	2264

95th Percentile Poly Strip Regional Buffer Zones (ft)

Ventura - Ventura County

	app size (ac)					
app rate (lb/ac)	**1**	**5**	**10**	**20**	**30**	**40**
100	0	16	16	218	322	417
150	0	159	332	571	774	951
200	16	337	573	916	1197	1464
250	16	479	777	1237	1616	1956
~~300~~	119	622	981	1540	2014	2464
~~350~~	220	746	1179	1840	2413	2958

Belridge - Kern County

	app size (ac)					
app rate (lb/ac)	**1**	**5**	**10**	**20**	**30**	**40**
100	0	16	16	127	200	262
150	16	109	230	405	547	677
200	16	244	412	672	892	1088
250	16	365	589	939	1232	1496
300	130	478	760	1204	1559	1885
350	183	591	924	1449	1878	2281

Salinas - Monterey County

	app size (ac)					
app rate (lb/ac)	**1**	**5**	**10**	**20**	**30**	**40**
100	0	16	16	144	226	296
150	16	91	227	403	545	670
200	16	226	395	637	836	1015
250	16	331	543	873	1130	1356
300	46	429	688	1081	1415	1716
350	130	524	835	1319	1708	2099

Tule Lake - Siskiyou County

	app size (ac)					
app rate (lb/ac)	**1**	**5**	**10**	**20**	**30**	**40**
100	0	16	16	134	212	277
150	16	102	230	401	540	665
200	16	235	403	652	861	1049
250	16	348	566	904	1176	1419
300	109	455	722	1135	1478	1785
350	163	551	875	1362	1770	2158

Manteca - San Joaquin County

	app size (ac)					
app rate (lb/ac)	**1**	**5**	**10**	**20**	**30**	**40**
100	0	16	16	150	223	287
150	16	120	246	421	566	697
200	16	251	423	682	893	1086
250	16	366	588	934	1227	1485
~~300~~	128	474	753	1185	1545	1876
~~350~~	180	578	911	1428	1857	2264

95th Percentile Untarp Drip Regional Buffer Zones (ft)

Ventura - Ventura County

	app size (ac)					
app rate (lb/ac)	**1**	**5**	**10**	**20**	**30**	**40**
100	16	75	177	309	418	518
150	16	242	415	661	863	1057
200	102	397	643	1007	1298	1567
250	170	544	852	1324	1715	2067
300	227	683	1053	1623	2105	2588
350	288	808	1243	1949	2538	3171

Belridge - Kern County

	app size (ac)					
app rate (lb/ac)	**1**	**5**	**10**	**20**	**30**	**40**
100	16	21	75	141	199	249
150	16	128	218	357	466	565
200	57	229	367	572	733	890
250	101	330	517	791	1024	1225
300	142	427	660	1023	1317	1576
350	181	526	810	1251	1642	1998

Manteca - San Joaquin County

	app size (ac)					
app rate (lb/ac)	**1**	**5**	**10**	**20**	**30**	**40**
100	16	83	157	255	398	398
150	47	215	337	519	662	784
200	108	335	521	786	1004	1193
250	159	459	695	1038	1324	1581
300	206	562	845	1297	1660	1976
350	249	662	1016	1530	1947	2332

Salinas - Monterey County

	app size (ac)					
app rate (lb/ac)	**1**	**5**	**10**	**20**	**30**	**40**
100	16	43	118	222	304	387
150	16	181	303	483	639	771
200	78	305	481	755	978	1195
250	129	420	662	1051	1373	1642
300	179	546	855	1341	1727	2080
350	232	663	1022	1581	2052	2285

Tule Lake - Siskiyou County

	app size (ac)					
app rate (lb/ac)	**1**	**5**	**10**	**20**	**30**	**40**
100	16	94	183	302	397	487
150	47	240	377	601	764	917
200	118	365	564	880	1134	1358
250	170	491	755	1165	1508	1820
300	222	607	945	1473	1886	2292
350	270	738	1137	1741	2244	2756

95th Percentile Untarp Broadcast Shallow Regional Buffer Zones (ft)

Ventura - Ventura County

	app size (ac)					
app rate (lb/ac)	**1**	**5**	**10**	**20**	**30**	**40**
100	16	227	420	703	928	1130
150	16	480	768	1231	1615	1974
200	180	704	1109	1730	2283	2792
250	299	916	1438	2257	2916	3573
300	383	1118	1703	2662	3536	4350
350	464	1281	1972	3151	4203	4724

Belridge - Kern County

	app size (ac)					
app rate (lb/ac)	**1**	**5**	**10**	**20**	**30**	**40**
100	16	161	295	498	667	817
150	16	364	585	932	1223	1485
200	164	545	854	1342	1740	2109
250	240	711	1105	1725	2254	2749
300	309	869	1358	2097	2750	3412
350	373	1027	1593	2487	3269	4015

Manteca - San Joaquin County

	app size (ac)					
app rate (lb/ac)	**1**	**5**	**10**	**20**	**30**	**40**
100	16	150	283	476	636	782
150	16	344	561	900	1184	1433
200	150	524	823	1301	1701	2065
250	226	696	1100	1709	2214	2700
300	293	890	1325	2087	2723	3346
350	358	1010	1568	2440	3267	4025

Salinas - Monterey County

	app size (ac)					
app rate (lb/ac)	**1**	**5**	**10**	**20**	**30**	**40**
100	16	151	228	483	645	793
150	16	328	537	865	1133	1365
200	107	492	788	1230	1603	1945
250	196	649	1024	1616	2093	2566
300	263	810	1260	1967	2579	3160
350	326	959	1486	2316	3065	3782

Tule Lake - Siskiyou County

	app size (ac)					
app rate (lb/ac)	**1**	**5**	**10**	**20**	**30**	**40**
100	16	130	264	451	603	738
150	16	316	521	822	1075	1305
200	121	475	759	1196	1555	1891
250	197	633	1003	1576	2078	2529
300	264	795	1249	1946	2556	3111
350	326	950	1477	2289	3009	3720

95th Percentile Untarp Bed Shallow Regional Buffer Zones (ft)

Ventura - Ventura County

	app size (ac)					
app rate (lb/ac)	**1**	**5**	**10**	**20**	**30**	**40**
100	16	227	420	703	928	1130
150	16	480	768	1231	1615	1974
200	180	704	1109	1730	2283	2792
250	299	916	1438	2257	2916	3573
300	383	1118	1703	2662	3536	4350
350	464	1281	1972	3151	4203	4724

Belridge - Kern County

	app size (ac)					
app rate (lb/ac)	**1**	**5**	**10**	**20**	**30**	**40**
100	16	161	295	498	667	817
150	16	364	585	932	1223	1485
200	164	545	854	1342	1740	2109
250	240	711	1105	1725	2254	2749
300	309	869	1358	2097	2750	3412
350	373	1027	1593	2487	3269	4015

Manteca - San Joaquin County

	app size (ac)					
app rate (lb/ac)	**1**	**5**	**10**	**20**	**30**	**40**
100	16	150	283	476	636	782
150	16	344	561	900	1184	1433
200	150	524	823	1301	1701	2065
250	226	696	1100	1709	2214	2700
300	293	890	1325	2087	2723	3346
350	358	1010	1568	2440	3267	4025

Salinas - Monterey County

	app size (ac)					
app rate (lb/ac)	**1**	**5**	**10**	**20**	**30**	**40**
100	16	151	228	483	645	793
150	16	328	537	865	1133	1365
200	107	492	788	1230	1603	1945
250	196	649	1024	1616	2093	2566
300	263	810	1260	1967	2579	3160
350	326	959	1486	2316	3065	3782

Tule Lake - Siskiyou County

	app size (ac)					
app rate (lb/ac)	**1**	**5**	**10**	**20**	**30**	**40**
100	16	130	264	451	603	738
150	16	316	521	822	1075	1305
200	121	475	759	1196	1555	1891
250	197	633	1003	1576	2078	2529
300	264	795	1249	1946	2556	3111
350	326	950	1477	2289	3009	3720

95th Percentile Untarp Deep Regional Buffer Zones (ft)

Ventura - Ventura County

	app size (ac)					
app rate (lb/ac)	**1**	**5**	**10**	**20**	**30**	**40**
100	0	16	215	404	563	702
150	16	305	518	850	1120	1363
200	16	488	780	1254	1640	2032
250	136	662	1049	1629	2136	2633
300	247	817	1291	2025	2682	3255
350	328	976	1536	2367	3108	3786

Belridge - Kern County

	app size (ac)					
app rate (lb/ac)	**1**	**5**	**10**	**20**	**30**	**40**
100	0	16	139	274	376	472
150	16	217	376	620	823	1004
200	16	370	595	948	1241	1503
250	149	510	803	1264	1638	1985
300	209	636	1001	1552	2010	2440
350	263	761	1188	1853	2404	2928

Manteca - San Joaquin County

	app size (ac)					
app rate (lb/ac)	**1**	**5**	**10**	**20**	**30**	**40**
100	0	16	129	264	367	462
150	16	206	356	587	783	956
200	16	350	572	913	1200	1455
250	129	493	772	1213	1582	1928
300	193	616	976	1540	2012	2417
350	248	749	1182	1811	2362	2910

Salinas - Monterey County

	app size (ac)					
app rate (lb/ac)	**1**	**5**	**10**	**20**	**30**	**40**
100	0	16	144	298	397	492
150	16	201	356	592	782	949
200	16	323	544	877	1145	1384
250	86	459	736	1159	1505	1828
300	161	579	918	1435	1885	2304
350	220	698	1104	1715	2255	2754

Tule Lake - Siskiyou County

	app size (ac)					
app rate (lb/ac)	**1**	**5**	**10**	**20**	**30**	**40**
100	0	16	115	251	351	443
150	16	186	335	554	731	901
200	16	321	532	835	1093	1333
250	102	443	708	1125	1462	1777
300	168	565	894	1404	1841	2251
350	219	684	1082	1707	2233	2736

95th Percentile TIF Strip Shallow Regional Buffer Zones (ft)

Ventura - Ventura County

	app size (ac)					
app rate (lb/ac)	**1**	**5**	**10**	**20**	**30**	**40**
100	0	0	0	16	16	16
150	0	16	16	16	16	16
200	0	16	16	36	81	116
250	16	16	56	134	191	243
300	16	49	127	227	322	377
350	16	104	193	323	429	523

Belridge - Kern County

	app size (ac)					
app rate (lb/ac)	**1**	**5**	**10**	**20**	**30**	**40**
100	0	0	0	0	0	16
150	0	0	16	16	16	16
200	0	16	16	16	16	18
250	16	16	16	40	65	87
300	16	16	48	93	135	159
350	16	44	86	145	192	233

Salinas - Monterey County

	app size (ac)					
app rate (lb/ac)	**1**	**5**	**10**	**20**	**30**	**40**
100	0	0	0	0	16	16
150	0	16	16	16	16	16
200	0	16	16	16	49	76
250	0	16	25	93	139	176
300	16	16	87	166	238	281
350	16	69	141	224	320	388

Tule Lake - Siskiyou County

	app size (ac)					
app rate (lb/ac)	**1**	**5**	**10**	**20**	**30**	**40**
100	0	0	0	16	16	16
150	0	16	16	16	16	16
200	0	16	16	56	93	121
250	16	16	73	141	193	240
300	16	64	134	226	317	367
350	16	112	194	313	412	499

Manteca - San Joaquin County

	app size (ac)					
app rate (lb/ac)	**1**	**5**	**10**	**20**	**30**	**40**
100	0	0	0	16	16	16
150	0	16	16	16	16	16
200	0	16	16	40	69	92
250	16	16	59	116	157	193
300	16	59	117	191	259	301
350	16	100	169	267	344	413