



Department of Pesticide Regulation



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MEMORANDUM

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FROM: Terrell Barry, Ph.D. *[original signed by T.Barry]*
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DATE: August 15, 2017

SUBJECT: Revised: Estimation of Chlorpyrifos Horizontal Deposition and Air Concentrations
for California Use Scenarios

Background

This memorandum describes modeling procedures used to estimate off-site horizontal deposition and air concentrations associated with California chlorpyrifos use scenarios. The estimates produced with these modeling procedures are suitable for use in conducting pesticide spray drift human exposure assessments. Horizontal deposition and air concentration estimates associated with primary spray drift from orchard airblast, ground boom, and aerial applications are provided.

Modeling Methods

Two computer simulation models were used in this analysis: AgDRIFT (Teske et al., 2002) and AGDISP (Teske and Curbishley, 2013). United States Environmental Protection Agency (USEPA) Office of Pesticide Programs (OPP) uses AgDRIFT for all agricultural deposition analysis and uses AGDISP for mosquito adulticide application scenarios (U.S.EPA, 2014 and 2013a). For the analysis presented in this document, the AgDRIFT 2.0.05 model was used to produce the ground boom and orchard air blast deposition estimates only and AGDISP 8.28 was used to produce all aerial application deposition and air concentration estimates.

For this analysis, the AgDRIFT model was chosen for orchard airblast and ground boom because it is the only accepted model available for these two application scenarios. The AGDISP 8.28

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model includes a ground boom algorithm, but that algorithm is still under development. AgDRIFT estimates horizontal deposition for orchard airblast and ground boom applications using empirical models. The data on which the AgDRIFT empirical models are based were produced by the Spray Drift Task Force (SDTF) and were reviewed in a formal peer review (https://archive.epa.gov/scipoly/sap/meetings/web/html/121097_mtg.html). That peer review led to the current grouping of orchard types and ground boom scenarios. AgDRIFT version 2.0.05 executable file dated 8/2002 was used for all orchard airblast and ground boom simulations in this memorandum. AgDRIFT 2.0.05 is an older version of the model but produces ground boom and orchard air blast deposition results identical to the current regulatory version AgDRIFT 2.1.1. In addition, the 90th percentile ground boom results obtained from AgDRIFT 2.0.05 were identical to deposition results shown in the USEPA guidance on spray drift (White et al., 2013) that USEPA produced using the regulatory version of AgDRIFT 2.1.1. The regulatory version of AgDRIFT 2.1.1 was not available when the analysis presented in this memorandum was conducted.

The AGDISP 8.28 model was used for aerial application deposition and air concentration estimates reported in this memorandum. AGDISP is a well vetted model developed through the work of NASA, USDA Forest Service, and the US Army (Bird, et al., 2002). It is a Lagrangian first principles model that is in the public domain and has a Gaussian handoff module to estimate spray drift beyond 2605 ft. The AGDISP model has ongoing support from partnerships between various government agencies and private sector entities and is under continual improvement to bring the model behavior more accurately into line with field measured data. The AgDRIFT model contains an older version of the AGDISP aerial algorithms incorporated to estimate aerial application spray drift. However, the AgDRIFT model is limited to 2605 ft. In addition, AgDRIFT is a proprietary model developed by the SDTF in cooperation with USEPA Office of Research and Development (ORD) under a Cooperative Research Agreement (CRADA). AgDRIFT 2.1.1 does not include a time step improvement incorporated into AGDISP 8.28 (M. Teske, pers. comm., 2014). The lack of that time step improvement in AgDRIFT 2.1.1 results in higher off-site deposition relative to AGDISP 8.28. Analysis later in this memorandum shows that the regulatory version of AgDRIFT 2.1.1 does produce deposition results greater than AGDISP 8.28.

Development of Exposure Scenarios

The deposition and air concentration estimates presented in this document were developed to reflect off-site movement expected under California chlorpyrifos use patterns. Key California use scenario patterns were selected for this analysis (Table 1). A range of application sizes were produced for each of the use scenarios was chosen based upon USEPA default (U.S.EPA, 2013a) and/or analysis of the Pesticide Use Report (PUR) (Tuli, 2013). For orchard airblast the largest application is 40 acres, for ground boom the largest application is 300 acres, for aerial the largest

acreage for tree fruit and nuts is 350 acres and for high acreage field crops the highest acreage is 900 acres. A preliminary screening deposition of 0.35% of the application rate was used for initial drift model scenario scoping (S. Beauvais, pers. comm., 2014). This preliminary screening deposition was used only to rank aircraft according to the distance downwind to the deposition fraction of 0.35%. The fixed wing and rotary aircraft showing the longest distance to 0.35% were then chosen to estimate exposures due to horizontal deposition and air concentrations. This process is described in more detail below.

Table 1. Application type scenarios for chlorpyrifos deposition estimates (all application methods) and chlorpyrifos air concentration estimates (aerial application methods only).

Application type	Sub-Type
Orchard Airblast	Sparse/Young
	Dormant Apple
	Vineyard
Ground Boom Medium/Coarse	Low Boom (20 in above the canopy)
	High Boom (50 in above the canopy)
Aerial	Fixed Wing
	Helicopter

The SDTF orchard airblast data is categorized into 5 composite orchard types. The sparse/young orchard airblast is the average of small grapefruit and dormant apple orchards field data. Small grapefruit trees are young, short trees. Dormant apple consists of field data only for apple orchards without leaves. The dormant apple orchard type is based only on the field data for dormant apples. The orchard airblast and ground boom scenarios models are empirical fits to the SDTF field trial data. There are no input variables beyond the orchard type for orchard airblast or spray quality (droplet spectra) and boom height for ground boom. For example, weather conditions cannot be changed. The empirical model outputs reflect the weather conditions at the time of the field trials. For orchard airblast, the only orchard type affected by wind speed was dormant apples where the wind speeds for the field trials varied between 4 mph and 12 mph (SDTF, 1997a). The ground boom field trials were conducted near Plainview, Texas. The weather during the field trials covered a wide range of conditions. The ground boom medium/coarse field trials showed environmental conditions spanning 5 mph to 20 mph wind speeds, 44° F to 91° F air temperatures, and 8% to 82% relative humidity (SDTF, 1997b).

The aerial application model algorithm in both AgDRIFT and AGDISP is a Lagrangian model that tracks droplets released from the nozzles during the simulated application. This type of model is called a first principles model because the deposition and air concentration estimates are obtained using the laws of physics rather than through statistical fit to observed data. Thus, the aerial model allows input of a wide range of important aspects of an aerial application. Choice of aircraft, how that aircraft is configured, and the specifications of how an aerial application is conducted can make a significant difference in the degree of off-site movement. It is important that the aerial application scenarios simulated are representative of the expected use patterns and that the inputs are clearly stated. For this analysis aerial application information obtained by the Enforcement Branch was used to select candidate aircraft and meteorological conditions (R. Sarracino, pers. comm., 2014). The AGDISP model has a large aircraft library that can be accessed to insure that each aircraft is correctly specified in the model runs. The aircraft list obtained from the Enforcement Branch was examined to match with aircraft that were in the AGDISP aircraft library. All aircraft on the Enforcement Branch aircraft list that were in the AGDISP aircraft library were used for the exploratory analysis and are shown in Table 2. For the exploratory analysis, the meteorological inputs were chosen to reflect an early summer morning application in the San Joaquin Valley. The specific meteorological inputs were the mean wind speed, temperature, and humidity for the time of 0600 hrs over 5 years of weather data (2009-2013) for the dates June 1 to August 31 from the Fresno State CIMIS weather station (station #80). Table 2 shows, for each of the candidate aircraft, the distance to 0.35% horizontal deposition of application rate. Based upon the greatest distance to the preliminary screening deposition level of 0.35% of application rate (S. Beauvais, personal communication, January 29, 2014) the AT802A fixed wing and the Bell 205 helicopter were chosen for further refinement in the final modeling scenarios.

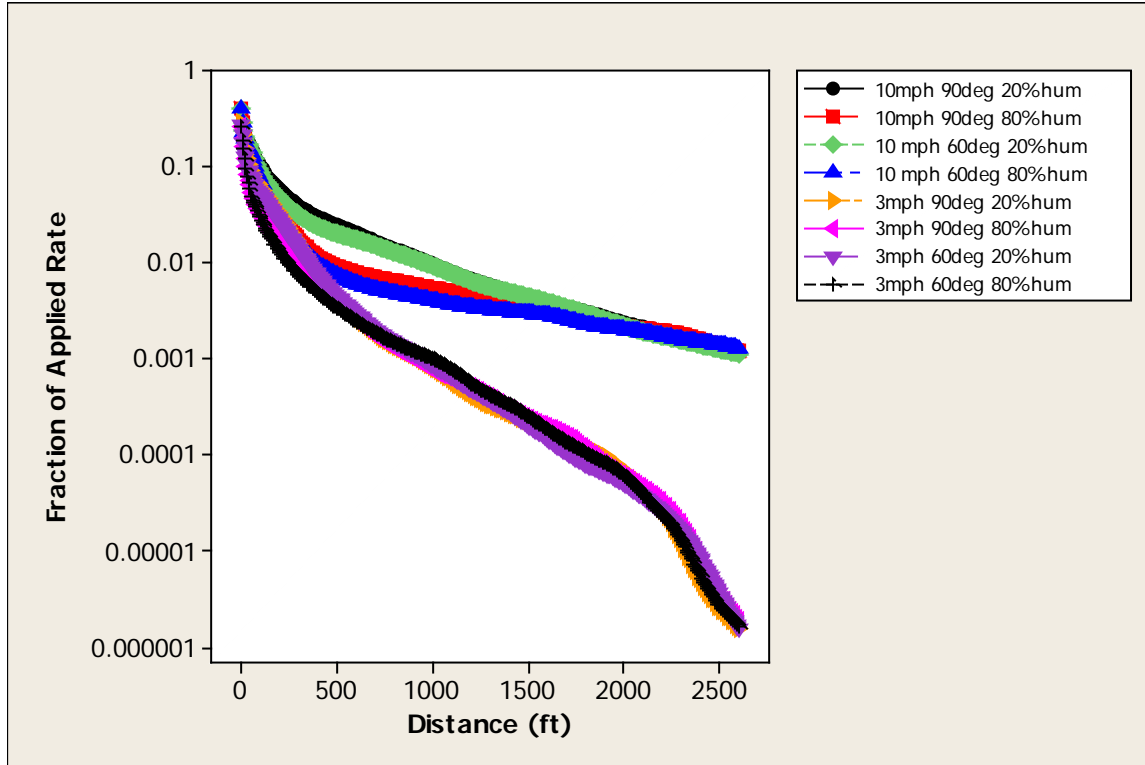
Table 2. Candidate aircraft. All simulations were conducted with a boom length of 76.3% of semi-span or rotor diameter, swath width of 60ft for fixed wing or 1.2x rotor diameter for helicopter, a swath-displacement of 37%, no half-boom effect or swath offset, 2 gal/ac volume, non-volatile active ingredient application rate of 2 lb/ac, 10 mph wind, air temperature 65 deg F, and humidity of 50%. Number of nozzles for each aircraft is the default in the AGDISP library.

Aircraft	Distance to 0.35% of application rate (ft)	Air Speed (mph)	Aircraft Weight (lbs)	Semi-span or Rotor Radius (ft)	Number of Nozzles
Fixed Wing					
AT802A	1174	145	11160	29	39
AT401	1122	120	6000	24.5	42
Trush	1102	140	7665	23.75	32
AT502	1096	155	6660	25	34
AT301	1037	120	5600	22.6	30
AgCat*	1437	150	5022	21.25	29
Helicopter					
Bell 205	1122	92	7697	24	32
Bell 47G-3B-2	1056	58	2422	18.6	25
Hiller UH-12E3	1056	58	2430	17.7	24
Hiller UH-12E3T	1056	58	2370	17.7	24
Aerodyne Wasp	1050	62	2090	17.4	24
Bell 206 Jet Ranger II	1037	69	2053	16.7	23
Bell 206 Jet Ranger III	1037	69	2398	16.7	23
Robinson R-44 Raven	1037	130	1829	16.5	22

*Biplane

Once the AT802A and the Bell 205 aircraft were chosen, the weather conditions were refined for potential worst case conditions. The information gathered by the Enforcement Branch indicated that late afternoon summer applications were expected (R. Sarracino, pers. comm., 2014). Thus, range of weather conditions were chosen to span the possible conditions from sunrise to late afternoon. AGDISP model runs were conducted using all combinations of weather conditions as follows: winds speed 3 mph and 10 mph, temperature 60 deg F and 90 deg F, humidity 20% and 80%. A total of 8 combinations of the chosen wind speed, temperature, and humidity values were simulated for the AT802A aircraft to determine the reasonable worst case weather scenario. The reasonable worst case weather scenario was then used to produce both the deposition and air concentration estimates for the AT802A and the Bell 205 aircrafts. Figure 1 shows the deposition results from those 8 model runs. The 10 mph/20% humidity model runs show the overall highest deposition. The 10 mph/20% humidity/90 deg F scenario shows generally the higher deposition than the 10mph/20% humidity/60 deg F scenario. Thus, the 10 mph/20% humidity/90 deg F meteorology combination was used to produce the deposition and the accompanying air concentrations for the AT802A and the Bell 205 application method scenarios.

Figure 1. AGDISP estimated deposition for the AT802A aircraft under 8 combinations of wind speed, temperature, and humidity.



Uncertainty

No uncertainty factors were added to the modeled deposition or the air concentration estimates. Reasoning for the three application methods of aerial, orchard air blast and ground will be considered separately.

Orchard Airblast. The AgDRIFT orchard air blast empirical model outputs the value of the empirical function. In the case of the least squares fit empirical function this value is the 50th percentile deposition estimate for three orchard types: normal, dense, and sparse. Sparse orchard type was used for this analysis to generally represent California orchards during the dormant spray season, which is reasonable worst case for near field deposition. A refined estimate for specific orchard types is also available. The dormant apples orchard type was simulated as a California specific scenario. The AgDRIFT user manual does not state why a 90th percentile is not estimated for the orchard airblast empirical equations. At the 1999 SAP OPP staff did present tolerance bounds for orchard airblast (U.S. EPA, 1999) but these bounds were not implemented.

Ground Boom. The AgDRIFT ground boom empirical model outputs the value of the empirical function. In the case of the least squares fit empirical function this value is the 50th percentile deposition estimate. In addition, the AgDRIFT ground boom empirical model has the choice to output 90th percentile. However, the derivation of the 90th percentile is not clear. This estimated deposition value does not appear to be large enough, compared to the mean at each distance, to be a tolerance interval capturing the 90th percentile at each distance with a 90% or 95% confidence. More likely what is labeled as the 90th percentile is actually the 90% prediction interval on the empirical function. There is no information provided in the AgDRIFT user manual about exactly how 90th percentile was derived. In the absence of the details of this estimate, and to maintain uniformity in approach between orchard airblast and ground boom, it is preferable to use the 50th percentile estimate (the value on the deposition curve).

Aerial. The AGDISP model produces an ensemble average deposition at a particular distance. For aerial applications all input variables were reasonable worst case. Thus, with all inputs selected for reasonable worst case, the results can be argued to represent a reasonable upper bound on the mean deposition. The AGDISP model algorithm has been compared to numerous field studies and found to produce estimates that are within a factor of two to six of field measured deposition (Bird et al., 2002; Teske and Thistle, 2003; Teske et al., 2003). The AGDISP model algorithm has been found to over-predict deposition in the far field (Bird, et al., 2002). The AGDISP air concentrations estimates have not been compared to field data. However, as mentioned earlier, AGDISP is a first principles model. In addition, mass balance is a feature of the model (Teske and Curbishley, 2013). The air concentration estimated at a particular location includes all the mass in the vertical plane at that location that is present after deposition. Thus, it is likely that the air concentrations will not be sustainably underestimated.

Deposition Estimate Development

Number of swaths. The AgDRIFT and AGDISP models have a maximum number of swaths for each application type. Application sizes are not specified. Instead, the downwind deposition reflects the number of upwind swaths. For these simulations it is assumed that the wind direction is perpendicular to the swath direction and that the deposition estimated is the deposition expected directly downwind from the middle of the swath. Thus, application size was modeled based upon the width in feet of a particular number of swaths. It was further assumed that the field to which the application was made is square. So, the width of the field and the length of the field are assumed to be equal (for aerial applications swath displacement is not considered). The acreage is calculated as the length times the width. For all three application types (orchard airblast, ground boom, and aerial), the width of the desired maximum acreage exceeded the width of the maximum number of swaths the model can simulate. For orchard airblast and

ground boom a maximum of 20 swaths can be simulated. For aerial applications a maximum of 50 swaths can be simulated. Table 3 shows a summary of swath width, maximum number of swaths and the resulting maximum acreage the model will directly produce for each application type.

Table 3. Swath parameter and limits in the AgDRIFT and AGDISP models.

Application Type	Swath Width	Max Number of Swaths	Width of Max Number of Swaths	Equivalent Square Acreage
Orchard Airblast	16 ft	20	320 ft	2.35 ac
Ground Boom	45 ft	20	900 ft	18.6 ac
Aerial Fixed-wing AT802A	60 ft	50	3000 ft	206.6 ac
Aerial Helicopter Bell 205	57.6 ft	50	2880 ft	190.4 ac

The PUR analysis indicates that use patterns in California for orchard airblast and ground boom are commonly much larger than the maximum 20 swath simulations available out of the AgDRIFT model. In order to obtain deposition estimates for applications larger than the maximum single model run limit of 20 swaths the deposition curves from one or more single 20 swath applications were overlaid after being offset upwind by the appropriate distance. Table 4 and Figure 1 show the process for orchard airblast. For orchard airblast, the AgDRIFT model estimates deposition to a maximum downwind distance of 997.4 ft (the prediction domain of the model). A model run of the maximum number of 20 swaths, assuming that rows of the orchard are 16 ft apart (16 ft wide), represents an orchard that is 320 ft wide (20 swaths \times 16 ft). With the assumption of a square orchard (320 ft \times 320 ft) this results in an orchard that is 2.35 ac. If a second set of 20 swaths is added to the upwind side of this initial orchard then the resulting orchard is 40 swaths, or 640 ft, wide. A square 640 ft by 640 ft orchard is 9.4 ac. Although assuming the next size up orchard is twice as wide and twice as long may seem arbitrary, for the purposes of estimating drift that assumption is not critical because only the width in the upwind direction is most important in determining the downwind deposition. The square orchard is a simplifying assumption. The grape vineyard scenario did not require extension beyond one set of 20 swaths (Table 5). The same extension procedure is used to increase the ground boom application size. Details of the ground boom process are shown in Table 6.

Table 4. Orchard airblast swath extension details. Each set of 20 swaths is 320 ft wide. Downwind deposition curves are offset by the appropriate number of feet and then overlaid. When overlaying, upwind deposition curves are allowed to drop to zero at the model domain limit of 997.4 ft.

Swath Set	Swath Width (ft)	Number of Swaths	Total Application Area Width (Sum of Set Widths)	Upwind Offset (ft)	Total Number of Swaths	Resulting Application Size (acres)	Deposition Curve Distance at Set 1 Downwind Edge (ft)	Section of Deposition Curve added to Set 1 Deposition Curve (ft)
1	16 ft	20	320 ft	0 ft	20	2.35 ac	0 ft	0 ft to 997.4 ft
2	16 ft	20	640 ft	320 ft	40	9.4 ac	320 ft	320 ft to 997.4 ft
3	16 ft	20	960 ft	640 ft	60	21.2 ac	640 ft	640 ft to 997.4 ft
4*	16 ft	20	1280 ft	960 ft	80	37.6 ac	960 ft	960 ft to 997.4 ft

*Set 4 is too far up wind to reliably estimate residue contributions to the downwind deposition curve.

Table 5. Grape Vineyard. Conventional and wrap-around sprayers. Each set of 20 swaths is 240 ft wide. Downwind deposition curves for these scenarios are not overlaid with additional upwind blocks because the deposition is so low that overlays are not necessary.

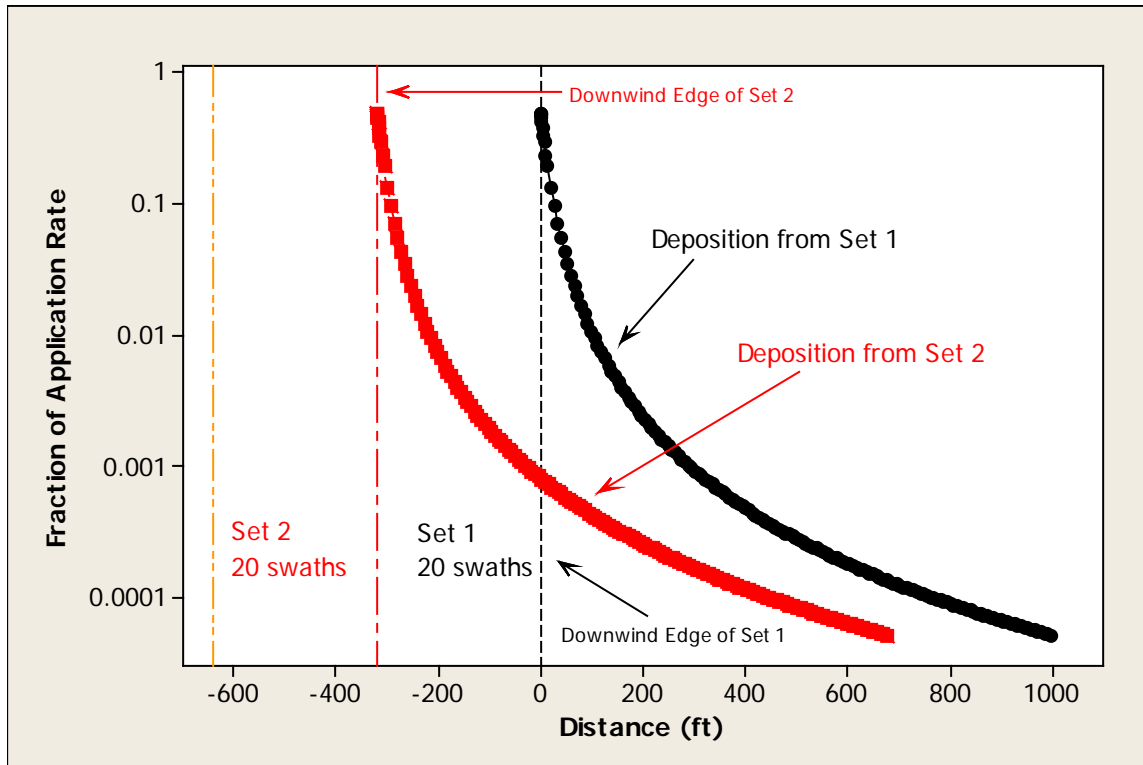
Set	Swath Width (ft)	Number of Swaths	Total Application Area Width (Sum of Set Widths)	Upwind Offset (ft)	Total Number of Swaths	Resulting Application Size (acres)	Deposition Curve Distance at Set 1 Downwind Edge (ft)	Section of Deposition Curve added to Set 1 Deposition Curve (ft)
1	12 ft	20	240 ft	0 ft	20	1.32 ac	0 ft	0 ft to 997.4 ft

Table 6. Ground boom. Each set of 20 swaths is 900 ft wide. Downwind deposition curves are offset by the appropriate number of feet and then overlaid. When overlaying, upwind deposition curves are allowed to drop to zero at the model domain limit of 997.4 ft.

Set	Swath Width (ft)	Number of Swaths	Total Application Area Width (Sum of Set Widths)	Upwind Offset (ft)	Total Number of Swaths	Resulting Application Size (acres)	Deposition Curve Distance at Set 1 Downwind Edge (ft)	Section of Deposition Curve added to Set 1 Deposition Curve (ft)
1	45 ft	20	900 ft	0 ft	20	18.6 ac	0 ft	0 ft to 997.4 ft
2	45 ft	20	1800 ft	900 ft	40	74.4 ac	900 ft	900 ft to 997.4 ft

As an example, the deposition curves from two sets of 20 swaths (Set 1 and Set 2) are overlaid to estimate the composite deposition from the 40 swaths (the total deposition resulting from joining two sets of 20 swaths). The deposition curve from Set 2 is constrained to be used only to 997.4 ft relative to the downwind edge of set 2 (Figure 2). Thus, residues from the Set 2 set of 20 swaths contribute to the downwind deposition from the orchard (Set 1 + Set 2) as a whole only between 0 ft and 677.4 ft on the deposition curve of the Set 1 set of 20 swaths. This process can be repeated for multiple sets of 20 swaths until the upwind setback is so large that the farthest upwind deposition curve extending beyond the downwind edge of the initial set of 20 swaths has a portion too small to sufficiently estimate the residues from the upwind set of swaths. For example, Set 4 in the orchard airblast scenario is too far up wind to reliably estimate residues from Set 4 that might be deposited downwind of Set 1.

Figure 2. Illustration of the deposition curve overlay process to obtain a composite deposition curve for a 40 swath orchard. Two separate 20 swath deposition curves are overlaid as shown below. The Set 2 (red deposition curve) residues only contribute to the total downwind deposition beyond the downwind edge of Set 1. The Set 2 deposition curve is not extended beyond 997.4 ft relative to the downwind edge of Set 2. So, the portion of the composite deposition curve between 667.4 ft and 997.4 ft the Set 1 downwind edge does not receive any deposition from Set 2. This is illustrated by the end of the red deposition curve.



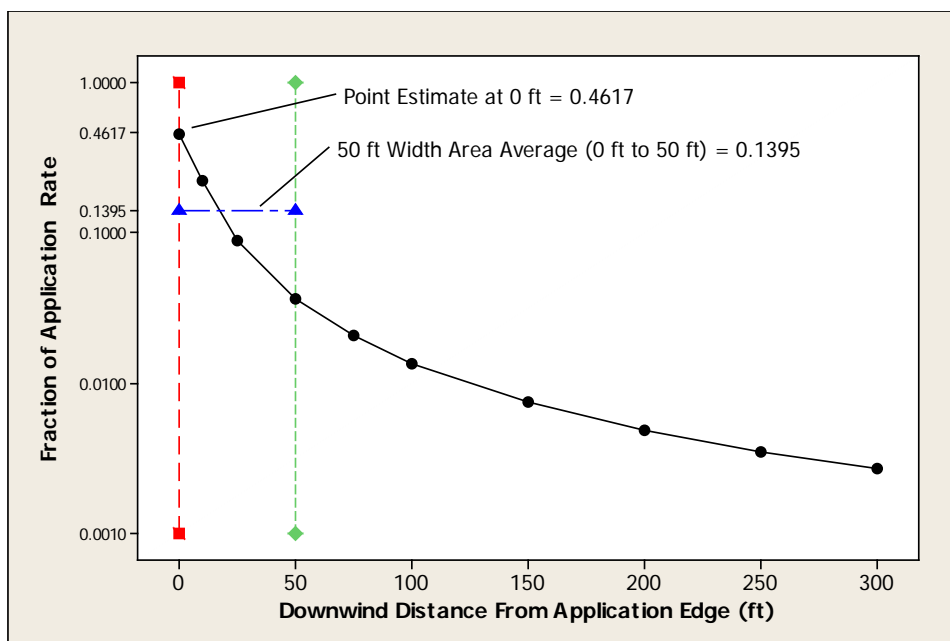
As stated above, this procedure was only implemented if the resulting deposition from the offset upwind swaths was within the prediction domain of the model. The aerial algorithm estimates deposition up to 2605 ft directly downwind of the application (the far field Gaussian handoff was not used in this analysis). The width of the first 50 swaths is 3000 ft for the fixed-wing and 2880 ft for the helicopter. So, the deposition curve from a second set of 50 swaths would fully land on the area of the application comprised by the first 50 swaths. Essentially, all of the deposition from the second set of 50 swaths lands on target. Thus, no new residue would be added to the downwind deposition curve of the first 50 swaths. For this reason the deposition curve overlay procedure was not used for aerial applications. The aerial results were obtained directly out of the AGDISP model.

Once the appropriate composite deposition curves were assembled for 40 swaths and 60 swaths, the point estimates and 50 ft width average deposition at desired distances were produced by fitting an empirical function using TableCurve 2D (AISN, 2000). The purpose of this curve fit was strictly to faithfully reproduce the modelled deposition curve, not as an explanatory analysis. This provided a convenient way to find the deposition at any desired downwind distance. All composite deposition curves were fit in TableCurve2D. Deposition estimates for orchard airblast and ground boom start at 25 ft from the downwind application edge. The SDTF field studies on which the empirical models are based did not include any sampling closer than 25 ft. Thus, the AgDRIFT empirical equations between the field edge and 25 feet are an estimation based on the assumed empirical functions for each of the application methods. These assumed empirical functions may be correct, however, with the data currently available it is impossible to verify that they reflect the actual pattern of deposition very close to the field edge. The deposition fraction likely changes rapidly close to the field. Thus, without measurements it is difficult to place confidence in the empirical estimates between 0 ft and 25 ft. For the ground boom model, the AgDRIFT manual (Teske et al., 2002) shows that a segmented approach is used to produce deposition estimates with two separate functions for 0ft to 25 ft and greater than 25 ft. The orchard airblast does not include a segmented function but the same concerns apply. Reliability of the empirical fit in the downwind direction is also a concern but the empirical functions in the far field decrease slowly and more likely over estimate deposition rather than underestimate. The AgDRIFT manual includes a detailed discussion of far field deposition distances (Teske, et al., 2002). The aerial algorithm is a first principles physics based model so estimates closer than 25 ft are provided.

Two types of estimates were provided, point estimate and an average estimate over a 50 ft width. The 50 ft width is the USEPA standard lawn scenario (USEPA, 2013b). Figure 3 compares the point estimates to the 50ft width area average. This is a generic example not related to chlorpyrifos specifically. The Average Area Deposition is calculated by integrating the area under the deposition curve between a starting downwind distance and a desired width and then dividing by the width. For example, as shown in Figure 3, integrating between 0 ft and 50 ft and

then dividing by 50 ft. In essence this spreads the area under the curve evenly between 0 ft and 50 ft. The difference between the point estimate and the area average is greatest near the application edge because the deposition curve is steep near the application edge (the slope of the curve is steeply negative).

Figure 3. Illustration of the 50 ft Width Average Deposition calculation. The 50 ft width is a moving 50 ft wide segment that depends on the starting downwind distance. In this illustration the starting downwind distance is 0 ft (the application edge) and the segment extends to 50 ft downwind. However, the process is the same regardless of the start and end point of the interval or the width of the interval. See the text for calculation details.



Deposition Estimates

Deposition estimates at selected distances for each scenario are shown in this section. The 20 swath estimates are output directly from either the AgDRIFT or AGDISP model. As described above, all 40 swath and 60 swath estimates are obtained by fitting a function to closely replicate the overlaid deposition curves ($R^2 > 99.9\%$). The 40 swath and 60 swath point and 50ft width average deposition at the selected distances was then evaluated in TableCurve 2D.

Orchard Airblast. Sparse orchard (Tables 6 to 8), dormant apples (Tables 9 to 11), and grapevines (Tables 12 and 13) were simulated. The AgDrift sparse orchard scenario combines

the deposition results from young grapefruit and dormant apples. Dormant apples show higher deposition than sparse orchards near field but lower deposition in the far field (Figure 4).

Table 6. Sparse orchard 20 swath 50th percentile deposition estimates. The development procedure for these deposition estimates is described in the text.

Point Estimates			50 ft Wide Lawn Estimates				
			Location of 50 ft wide Lawn		50 ft Width Average Deposition		
Dist (ft)	Fraction of App	2 lb/ac $\mu\text{g}/\text{cm}^2$	Start	End	Fraction of App	2 lb/ac $\mu\text{g}/\text{cm}^2$	
25	0.10070	2.2574	25	75	0.04430	0.9931	
50	0.03730	0.8362	50	100	0.02000	0.4483	
75	0.01810	0.4057	75	125	0.01100	0.2466	
100	0.01030	0.2309	100	150	0.00680	0.1524	
150	0.00440	0.0986	150	200	0.00320	0.0717	
200	0.00230	0.0516	200	250	0.00180	0.0404	
250	0.00140	0.0314	250	300	0.00110	0.0247	
300	0.00090	0.0202	300	350	0.00080	0.0179	

Table 7. Sparse orchard 40 swath 50th percentile deposition estimates. The development procedure for these deposition estimates is described in the text.

Point Estimates			50 ft Wide Lawn Estimates				
			Location of 50 ft wide Lawn		50 ft Width Average Deposition		
Dist (ft)	Fraction of Rate	2 lb/ac $\mu\text{g}/\text{cm}^2$	Start	End	Fraction of Rate	2 lb/ac $\mu\text{g}/\text{cm}^2$	
25	0.10138	2.2726	25	75	0.04472	1.0025	
50	0.03783	0.8480	50	100	0.02033	0.4558	
75	0.01850	0.4147	75	125	0.01142	0.2560	
100	0.01078	0.2418	100	150	0.00729	0.1635	
150	0.00492	0.1103	150	200	0.00371	0.0831	
200	0.00279	0.0626	200	250	0.00224	0.0502	
250	0.00180	0.0403	250	300	0.00150	0.0336	
300	0.00125	0.0280	300	350	0.00107	0.0240	

Table 8. Sparse orchard 60 swath 50th percentile deposition estimates. The development procedure for these deposition estimates is described in the text.

Point Estimates			50 ft Wide Lawn Estimates				
			Location of 50 ft wide Lawn		50 ft Width Average Deposition		
Dist (ft)	Fraction of Rate	2 lb/ac $\mu\text{g}/\text{cm}^2$	Start	End	Fraction of Rate	2 lb/ac $\mu\text{g}/\text{cm}^2$	
25	0.10151	2.2756	25	75	0.04488	1.0060	
50	0.03799	0.8517	50	100	0.02044	0.4581	
75	0.01860	0.4169	75	125	0.01148	0.2574	
100	0.01085	0.2431	100	150	0.00733	0.1644	
150	0.00495	0.1110	150	200	0.00373	0.0836	
200	0.00281	0.0630	200	250	0.00225	0.0505	
250	0.00181	0.0405	250	300	0.00151	0.0338	
300	0.00126	0.0282	300	350	0.00108	0.0242	

Table 9. Dormant apples 20 swath 50th percentile deposition estimates. The development procedure for these deposition estimates is described in the text.

Point Estimates			50 ft Wide Lawn Estimates				
			Location of 50 ft wide Lawn		50 ft Width Average Deposition		
Dist (ft)	Fraction of Rate	2 lb/ac $\mu\text{g}/\text{cm}^2$	Start	End	Fraction of Rate	2 lb/ac $\mu\text{g}/\text{cm}^2$	
25	0.14380	3.2236	25	75	0.05520	1.2374	
50	0.04350	0.9751	50	100	0.02090	0.4685	
75	0.01820	0.4080	75	125	0.01010	0.2264	
100	0.00930	0.2085	100	150	0.00560	0.1255	
150	0.00330	0.0740	150	200	0.00230	0.0516	
200	0.00160	0.0359	200	250	0.00120	0.0269	
250	0.00090	0.0202	250	300	0.00070	0.0157	
300	0.00050	0.0112	300	350	0.00040	0.0090	

Table 10. Dormant apples 40 swath 50th percentile deposition estimates. The development procedure for these deposition estimates is described in the text.

Point Estimates			50 ft Wide Lawn Estimates				
			Location of 50 ft wide Lawn		50 ft Width Average Deposition		
Dist (ft)	Fraction of Rate	2 lb/ac $\mu\text{g}/\text{cm}^2$	Start	End	Fraction of Rate	2 lb/ac $\mu\text{g}/\text{cm}^2$	
25	0.14416	3.2317	25	75	0.05530	1.2397	
50	0.04380	0.9818	50	100	0.02101	0.4711	
75	0.01846	0.4139	75	125	0.01028	0.2305	
100	0.00948	0.2125	100	150	0.00583	0.1306	
150	0.00350	0.0784	150	200	0.00244	0.0548	
200	0.00169	0.0379	200	250	0.00128	0.0288	
250	0.00097	0.0217	250	300	0.00077	0.0173	
300	0.00061	0.0136	300	350	0.00049	0.0111	

Table 11. Dormant apples 60 swath 50th percentile deposition estimates. The development procedure for these deposition estimates is described in the text.

Point Estimates			50 ft Wide Lawn Estimates				
			Location of 50 ft wide Lawn		50 ft Width Average Deposition		
Dist (ft)	Fraction of Rate	2 lb/ac $\mu\text{g}/\text{cm}^2$	Start	End	Fraction of Rate	2 lb/ac $\mu\text{g}/\text{cm}^2$	
25	0.14422	3.2330	25	75	0.05535	1.2409	
50	0.04385	0.9830	50	100	0.02106	0.4721	
75	0.01851	0.4150	75	125	0.01033	0.2315	
100	0.00952	0.2135	100	150	0.00587	0.1315	
150	0.00353	0.0792	150	200	0.00248	0.0555	
200	0.00172	0.0386	200	250	0.00131	0.0294	
250	0.00099	0.0223	250	300	0.00079	0.0178	
300	0.00063	0.0141	300	350	0.00051	0.0115	

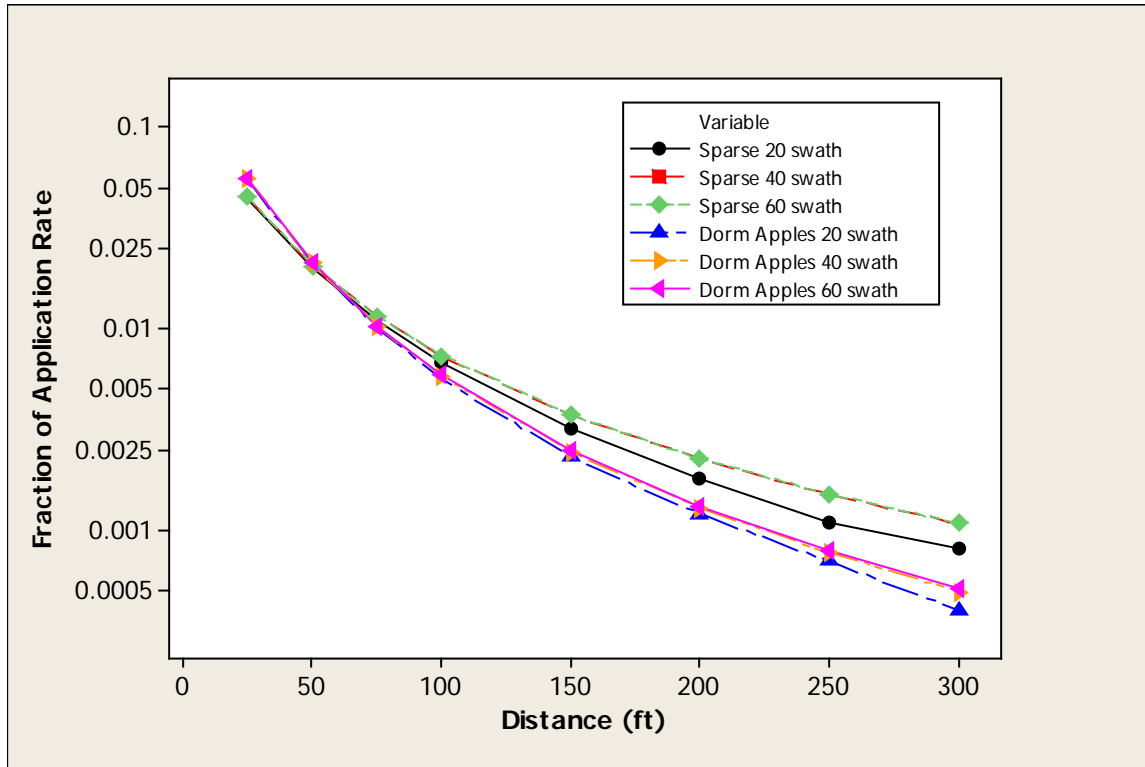
Table 12. Grape vineyard conventional sprayer 20 swath 50th percentile deposition estimates. The development procedure for these deposition estimates is described in the text.

Point Estimates			50 ft Wide Lawn Estimates				
			Location of 50 ft wide Lawn		50 ft Width Average Deposition		
Dist (ft)	Fraction of Rate	2 lb/ac $\mu\text{g}/\text{cm}^2$	Start	End	Fraction of Rate	2 lb/ac $\mu\text{g}/\text{cm}^2$	
25	0.0047	0.10000	25	75	0.0022	0.04960	
50	0.0019	0.04290	50	100	0.0012	0.02660	
75	0.0011	0.02500	75	125	0.0008	0.01770	
100	0.0008	0.01710	100	150	0.0006	0.01300	
150	0.0004	0.01000	150	200	0.0004	0.00828	
200	0.0003	0.00687	200	250	0.0003	0.00592	
250	0.0002	0.00511	250	300	0.0002	0.00451	
300	0.0002	0.00399	300	350	0.0002	0.00359	

Table 13. Grape vineyard wrap-around sprayer 20 swath 50th percentile deposition estimates. The development procedure for these deposition estimates is described in the text.

Point Estimates			50 ft Wide Lawn Estimates				
			Location of 50 ft wide Lawn		50 ft Width Average Deposition		
Dist (ft)	Fraction of Rate	2 lb/ac $\mu\text{g}/\text{cm}^2$	Start	End	Fraction of Rate	2 lb/ac $\mu\text{g}/\text{cm}^2$	
25	0.0007	0.01620	25	75	0.0004	0.00971	
50	0.0004	0.00902	50	100	0.0003	0.00646	
75	0.0003	0.00624	75	125	0.0002	0.00487	
100	0.0002	0.00478	100	150	0.0002	0.00392	
150	0.0001	0.00325	150	200	0.0001	0.00283	
200	0.0001	0.00247	200	250	0.0000	0.00221	
250	0.00009	0.00199	250	300	0.0000	0.00182	
300	0.00007	0.00166	300	350	0.0000	0.00154	

Figure 4. Orchard airblast application 50 ft width average deposition. Comparison between sparse orchard and dormant apples. The development procedure for these deposition estimates is described in the text.



Ground Boom. Low boom (Tables 14 and 15) and high boom (Tables 16 and 17) applications were simulated. A comparison of all deposition estimates is shown in Figure 5. As expected, high boom shows higher deposition than low boom both in the near field and the far field. The 40 swath applications show only slightly higher deposition than the 20 swath applications. This is expected because the 20 swath application is 900 feet wide, only 97 feet less than the domain of the Set 2 deposition curve.

Table 14. Ground boom deposition. Low boom and medium/coarse spray quality 20 swath 50th percentile. The development procedure for these deposition estimates is described in the text.

Point Estimates			50 ft Wide Lawn Estimates				
			Location of 50 ft wide Lawn		50 ft Width Average Deposition		
Dist (ft)	Fraction of Rate	2 lb/ac $\mu\text{g}/\text{cm}^2$	Start	End	Fraction of Rate	2 lb/ac $\mu\text{g}/\text{cm}^2$	
25	0.0083	0.1861	25	75	0.0047	0.1054	
50	0.0043	0.0964	50	100	0.0032	0.0717	
75	0.0031	0.0695	75	125	0.0024	0.0538	
100	0.0024	0.0538	100	150	0.0020	0.0448	
150	0.0017	0.0381	150	200	0.0015	0.0336	
200	0.0013	0.0291	200	250	0.0012	0.0269	
250	0.0011	0.0247	250	300	0.0010	0.0224	
300	0.0009	0.0202	300	350	0.0009	0.0202	

Table 15. Ground boom deposition. Low boom and medium/coarse spray quality 40 swath 50th percentile. The development procedure for these deposition estimates is described in the text.

Point Estimates			50 ft Wide Lawn Estimates				
			Location of 50 ft wide Lawn		50 ft Width Average Deposition		
Dist (ft)	Fraction of Rate	2 lb/ac $\mu\text{g}/\text{cm}^2$	Start	End	Fraction of Rate	2 lb/ac $\mu\text{g}/\text{cm}^2$	
25	0.0085	0.1898	25	75	0.0050	0.1119	
50	0.0046	0.1029	50	100	0.0034	0.0767	
75	0.0034	0.0753	75	125	0.0026	0.0582	
100	0.0026	0.0573	100	150	0.0020	0.0459	
150	0.0017	0.0381	150	200	0.0015	0.0340	
200	0.0014	0.0304	200	250	0.0012	0.0274	
250	0.0011	0.0247	250	300	0.0010	0.0228	
300	0.0009	0.0212	300	350	0.0009	0.0197	

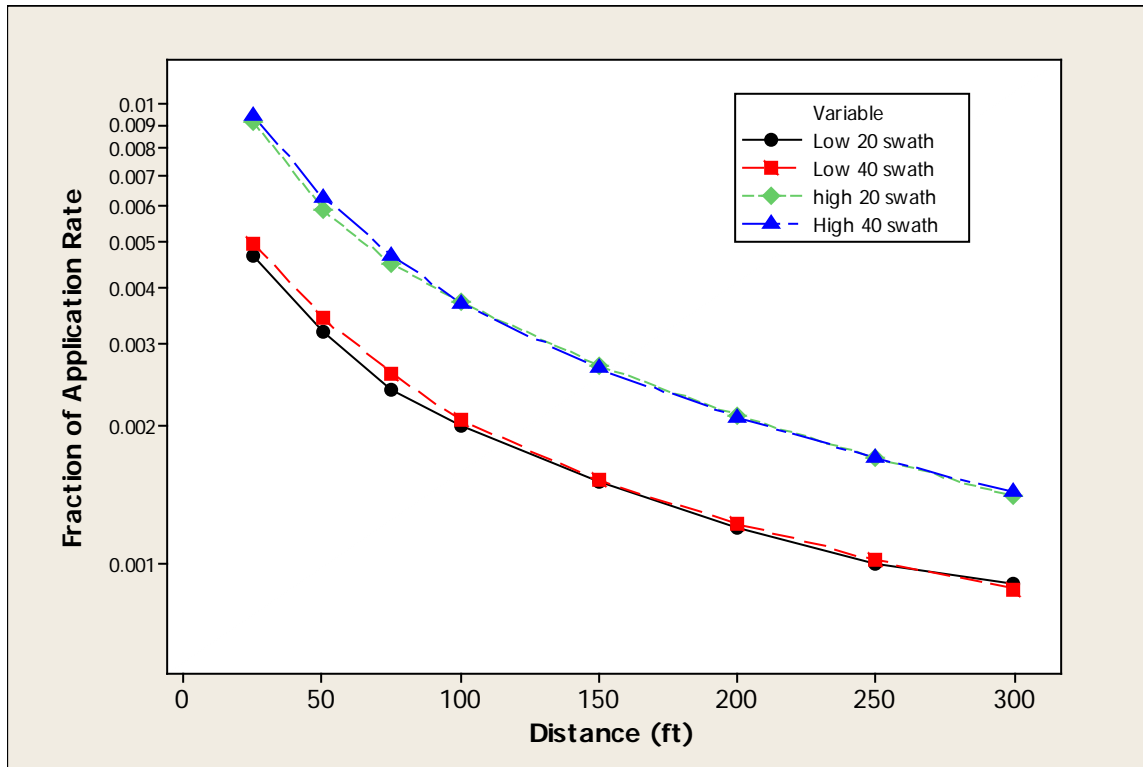
Table 16. Ground boom deposition. High boom and medium/coarse spray quality 20 swath 50th percentile. The development procedure for these deposition estimates is described in the text.

Point Estimates			50 ft Wide Lawn Estimates				
			Location of 50 ft wide Lawn		50 ft Width Average Deposition		
Dist (ft)	Fraction of Rate	2 lb/ac $\mu\text{g}/\text{cm}^2$	Start	End	Fraction of Rate	2 lb/ac $\mu\text{g}/\text{cm}^2$	
25	0.0165	0.3699	25	75	0.0092	0.2062	
50	0.0083	0.1861	50	100	0.0059	0.1323	
75	0.0057	0.1278	75	125	0.0045	0.1009	
100	0.0044	0.0986	100	150	0.0037	0.0829	
150	0.0031	0.0695	150	200	0.0027	0.0605	
200	0.0023	0.0516	200	250	0.0021	0.0471	
250	0.0019	0.0426	250	300	0.0017	0.0381	
300	0.0015	0.0336	300	350	0.0014	0.0314	

Table 17. Ground boom deposition. High boom and medium/coarse spray quality 40 swath 50th percentile. The development procedure for these deposition estimates is described in the text.

Point Estimates			50 ft Wide Lawn Estimates				
			Location of 50 ft wide Lawn		50 ft Width Average Deposition		
Dist (ft)	Fraction of Rate	2 lb/ac $\mu\text{g}/\text{cm}^2$	Start	End	Fraction of Rate	2 lb/ac $\mu\text{g}/\text{cm}^2$	
25	0.0166	0.3716	25	75	0.0095	0.2121	
50	0.0086	0.1937	50	100	0.0063	0.1408	
75	0.0061	0.1375	75	125	0.0047	0.1054	
100	0.0046	0.1034	100	150	0.0037	0.0827	
150	0.0030	0.0679	150	200	0.0027	0.0596	
200	0.0023	0.0524	200	250	0.0021	0.0467	
250	0.0019	0.0417	250	300	0.0017	0.0380	
300	0.0016	0.0348	300	350	0.0014	0.0321	

Figure 5. Ground boom 50 foot width average deposition. Medium/coarse spray quality. Comparison between low boom and high boom. The development procedure for these deposition estimates is described in the text.



Aerial. Deposition estimates for the fixed wing and helicopter scenarios are shown in Tables 18 and 19. A comparison between the AT802A fixed wing aircraft and the Bell 205 helicopter is shown in Figure 6. With the exception of the field edge, the Bell 205 helicopter generally shows less deposition than AT802A fixed wing. The application efficiency is approximately 98% for both the AT802A fixed wing aircraft and the Bell 205 helicopter. This means approximately 98% of the active ingredient released during the application is deposited on-site and 2% is lost by spray drift. The aerial application scenario is 50 swaths, so the application efficiency is higher than a smaller application. For example, a 20 swath application of the same aircraft scenario shows an application efficiency of approximately 95%. However, due to the higher total number of swaths, the downwind horizontal deposition is higher at all distances for the 50 swath application. Therefore, the 50 swath application is the reasonable worst case scenario.

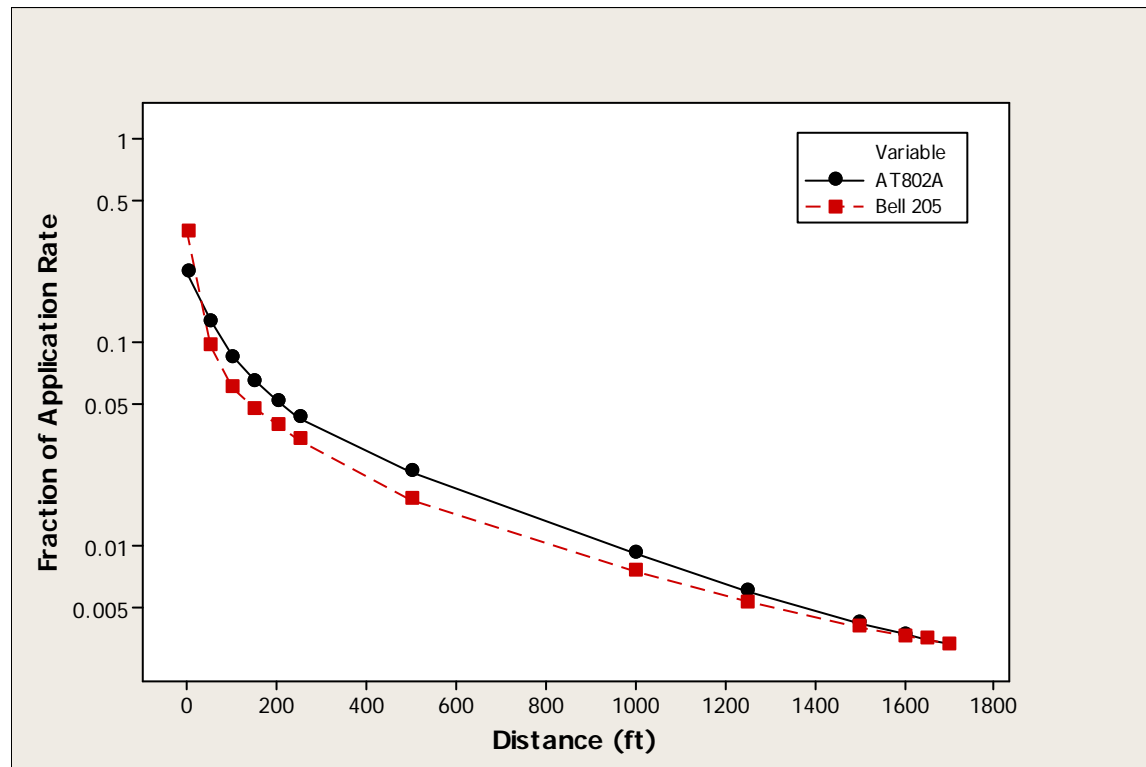
Table 18. Fixed wing aerial application deposition - AT802A medium spray quality 50 swath 50th percentile. The development procedure for these deposition estimates is described in the text.

Point Estimates			50 ft Wide Lawn Estimates			
			Location of 50 ft wide Lawn		50 ft Width Average Deposition	
Dist (ft)	Fraction of Rate	2 lb/ac $\mu\text{g}/\text{cm}^2$	Start	End	Fraction of Rate	2 lb/ac $\mu\text{g}/\text{cm}^2$
0	0.3945	8.8435	0	50	0.2259	5.0640
50	0.1644	3.6854	50	100	0.1286	2.8828
100	0.1026	2.3000	100	150	0.0859	1.9256
150	0.0733	1.6432	150	200	0.0652	1.4616
200	0.0577	1.2935	200	250	0.0524	1.1747
250	0.047	1.0536	250	300	0.043	0.9639
500	0.0245	0.5492	500	550	0.0234	0.5246
1000	0.0096	0.2152	1000	1050	0.0092	0.2062
1250	0.0062	0.1390	1250	1300	0.006	0.1345
1500	0.0043	0.0964	1500	1550	0.0042	0.0942
1600	0.0038	0.0852	1600	1650	0.037	0.8294
1650	0.0036	0.0807	1650	1700	0.0035	0.0785
1700	0.0034	0.0762	1700	1750	0.033	0.0740

Table 19. Helicopter aerial application deposition. Bell 205 medium spray quality 50 swath 50th percentile. The development procedure for these deposition estimates is described in the text.

Point Estimates			50 ft Wide Lawn Estimates			
			Location of 50 ft wide Lawn		50 ft Width Average Deposition	
Dist (ft)	Fraction of Rate	2 lb/ac $\mu\text{g}/\text{cm}^2$	Start	End	Fraction of Rate	2 lb/ac $\mu\text{g}/\text{cm}^2$
0	0.8698	19.4983	0	50	0.3584	8.0343
50	0.1427	3.1989	50	100	0.0969	2.1722
100	0.0683	1.5311	100	150	0.0603	1.3517
150	0.0535	1.1993	150	200	0.0479	1.0738
200	0.0434	0.9729	200	250	0.0396	0.8877
250	0.0363	0.8137	250	300	0.0334	0.7487
500	0.018	0.4035	500	550	0.0171	0.3833
1000	0.0077	0.1726	1000	1050	0.0075	0.1681
1250	0.0055	0.1233	1250	1300	0.0053	0.1188
1500	0.0041	0.0919	1500	1550	0.004	0.0897
1600	0.0037	0.0829	1600	1650	0.0036	0.0807
1650	0.0035	0.0785	1650	1700	0.0035	0.0785
1700	0.0034	0.0762	1700	1750	0.0033	0.0740

Figure 6. Aerial application 50 foot width average deposition. Comparison between fixed wing (AT802A) and helicopter (Bell 205). The development procedure for these deposition estimates is described in the text.



Air Concentration Estimates

The AGDISP model produces estimated 1-hr time weighted average (TWA) air concentrations in a vertical plane at user specified downwind distances from the application edge. The air concentration estimates for both the AT802A and Bell 205 were obtained from the same model runs that produced the deposition estimates. Thus, air concentrations were estimated for both the AT802A and Bell 205 aircraft using the 10 mph, 90 deg F, and 20% humidity weather scenario. The vertical plane was set at selected downwind distances, starting with the minimum federal label buffer zone of 10 ft from the application area edge. The 1-hr TWA air concentrations for the vertical plane at the minimum federal buffer zones of 10 ft and at selected heights above ground level are shown in Table 20. Figure 7 shows the change in 1-hr TWA air concentration with height for the vertical planes between 10 ft and 1000 ft downwind of the application edge. At the minimum federal label buffer zone of 10 ft, for the breathing heights of toddlers to adults (1.7 ft and 5 ft, respectively) the Bell 205 helicopter shows the highest 1-hr TWA air

concentration in the vertical plane. As the elevation above ground level increases, however, the 1-hr TWA air concentrations for the AT802A become higher than the Bell 205. The switch occurs at approximately 10 ft above ground level. The AGDISP user manual defines the 1-hr TWA air concentration as: “average concentration of active spray material through a vertical plane at the Transport Distance.” Not all the mass in the cloud passing through the vertical plan at a particular distances will be contained is droplets that are in the inhalable size range. The AGDISP model can output the droplet spectra present and the air concentration vertical plan. Therefore, if desired, a respirable fraction adjustment can be made to the concentration passing through a vertical plan. Complete AGDISP aerial application results are shown in Appendix A.

Table 20. Selected 1-hr time weighted average (TWA) air concentrations (ng/m^3) in a vertical plane at the federal label minimum buffer zone distance of 10 feet downwind of a 206.6 acres application (20 swaths) with the AT802A fixed wind air craft and a 190.4 acre (20 swaths) application with the Bell 205 helicopter. Development procedures for these air concentration estimates are described in the text.

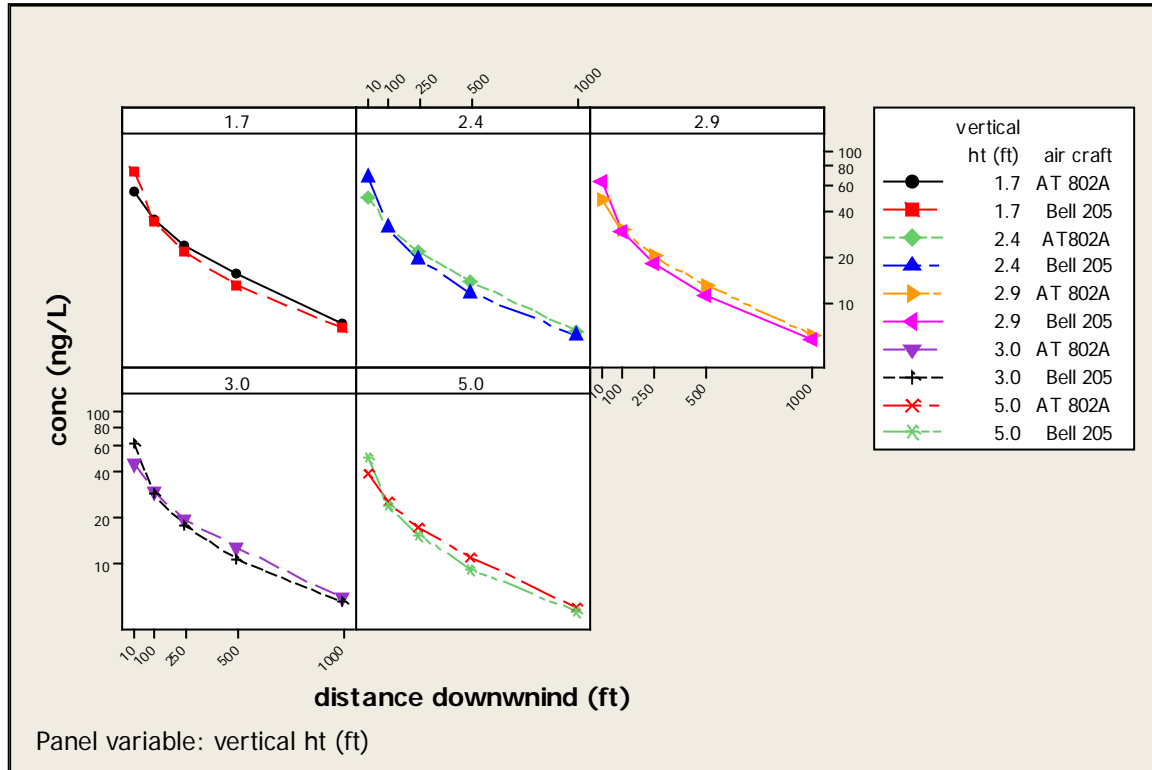
Height Above Ground		1-Hr TWA Air Concentration (ng/m^3)	
		Aircraft Model	
Inches	Feet	AT802A Fixed Wing ¹	Bell 205 Helicopter ²
0	0	n/a ³	n/a ³
20	1.7	54.6	72.8
29	2.4	49.6	66.4
35	2.9	47.0	62.5
36	3.0	46.5	61.8
60	5.0	39.9	50.0

¹Fraction of droplets $10\mu\text{m}$ or less = 0.0285

²Fraction of droplets $10\mu\text{m}$ or less = 0.0366

³The AGDISP model does not estimate air concentrations at ground level.

Figure 7. One hour time weighted air concentrations (ng/m^3) in a vertical plane at distances between 10 ft and 1000 ft downwind of a 206.6 acres application (20 swaths) with the AT802A fixed wing aircraft and a 190.4 acre (20 swaths) application with the Bell 205 helicopter. The development procedure for these air concentration estimates is described in the text.



Comparison of Deposition and Air Concentrations as a function of Finished Spray Volume (GPA) and Application Rate (lb/ac)

The effects of finished spray expressed as gallons per acre (GPA) and the active ingredient (ai) application rate (lb ai/ac) within the same aircraft type and meteorological conditions are examined in this section. There is at least one chlorpyrifos label that requires a minimum of 15 GPA finished spray for certain aerial applications (Cheminova NUFOS 4E USEPA Reg. No. 67760- 28-AA). Based on this label, the two levels of finished spray are modeled: 2GPA (U.S. EPA default) and 15 GPA. Three levels of application rate are also modeled: 1 lb ai/ac, 2 lb ai/ac, and 2.3 lb ai/ac.

The application tank mix scenarios shown in Table 21 were simulated using AGDISP for the fixed wing aircraft AT802A and the rotary wing aircraft Bell205. The 2 GPA tank mix scenarios retain the original aircraft set-ups used in sections above for the chlorpyrifos spray drift analysis.

The 15 GPA scenarios used an aircraft set-up with 60 nozzles on the boom to deliver the higher spray volume. This 60 nozzle spray boom set-up is typical of spray booms used for application of products that require a high GPA finished spray. For example, most propanil labels require a minimum of 10 GPA finished spray for aerial applications with 12-15 GPA recommended in low humidity conditions (e.g. SuperWham!CA EPA Reg. No. 71085-5-ZA and Stam 80 EDF-CA EPA Reg. No. 710085-38-AA). Booms on aircraft performing propanil applications are typically equipped with 50 to 70 nozzles (Rice Research Board, 2001; Rice Research Board, 2002).

The CPF 60 nozzle medium ASAE spray quality aerial boom set-up parameters for the 15 GPA scenario were input into the Aircraft Calibration, Droplet Calculator, and USDA Atomization Model Excel files available for download from the Transland/CP Products Droplet Calculation Tools – Aerial Spray Systems website (<http://www.translandllc.com/download/> - Accessed August 8, 2017). The calculators show that several nozzles exist that can deliver a 15 GPA finished spray in the ASAE medium spray quality range using the recommended pressure between 25 and 60 psi. The AGDISP model uses generic inputs of ASAE spray quality, number of nozzles, nozzle spacing, and boom length together with air speed and release height independent of a specific brand of nozzle. Therefore, use of the CP Product calculators is employed simply as a boom system check. It is not required to assume that CP Product nozzles are actually used for this scenario to the exclusion of other nozzle brands.

The base scenario of 2 GPA finished spray volume is the default in both the AGDISP and AgDRIFT models and is the default finished spray volume typically used by USEPA (Dawson et al., 2012). The base scenario application rate is designated as 2 lb ai/ac. Thus, for this analysis the base scenario tank mix is 2 GPA finished spray volume and 2 lb ai/ac. All other tank mix combinations are compared to this base. As stated above, the Cheminova NUFOS 4E insecticide chlorpyrifos formulation (EPA Reg. No. 67760- 28-AA) that has 4 lb ai/gallon (0.5 lb/pint) was used for this simulation because this label requires a minimum of 15 GPA finished spray for some aerial applications. The ai is 45% by volume in this formulation. For all tank mix scenarios the ai is declared non-volatile. The remainder of the product is assumed to be volatile. While other components of the NUFOS 4E formulation may be non-volatile, the exact properties are unknown so the remainder of the formulation is considered volatile. In addition, it is assumed no tank mix additives were used so only the ai is non-volatile.

Table 21. Tank mix calculations for the AGDISP tank mix comparison runs. Cheminova NUFOS 4E insecticide chlorpyrifos formulation (USEPA Registration Number 67760- 28-AA).

2 GPA Finished Spray (16 pints)			
ai ¹ rate per acre	formulation volume per acre	Proportion of ai in the tank mix volume	Percent ai in the tank mix volume ²
1 lb	2 pints	$2/16*0.45 = 0.56$	6%
2 lb	4 pints	$4/16*0.45 = 0.113$	12%
2.3 lb	4.6 pints	$4.6/16*0.45 = 0.129$	13%
15 GPA Finished Spray (120 pints)			
ai rate per acre	formulation volume per acre	Proportion of ai in the tank mix volume	Percent ai in the tank mix volume ³
1 lb	2 pints	$2/120*0.45 = 0.008$	0.8%
2 lb	4 pints	$4/120*0.45 = 0.015$	1.5%
2.3 lb	4.6 pints	$4.6/120*0.45 = 0.017$	1.7%

¹Active ingredient²Rounded up to the nearest 1%³Not rounded up to the nearest 1% because the proportion of ai in the tank mix is small.

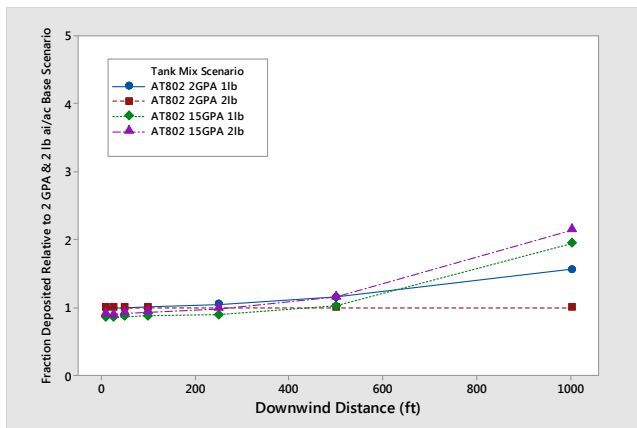
Figure 8 presents results for the AT802A fixed-wing aircraft tank mix scenarios relative to the base tank mix of 2GPA and 2 lb ai/ac (at each distance the scenario result is divided by the result for 2GPA and 2 lb/ac). Comparison of relative changes with scenario and distance can be made between horizontal fraction deposition, horizontal mass deposition, and air concentration in Figure 8 because the results are ratios and the plots are on the same scale. Figure 8a and 8b show the relative deposition of fraction and mass for each scenario, respectively. Figure 8c shows the relative air concentration for each scenario.

Across combinations of finished spray volume and application rates, near field (within about 200 ft of the application edge) the relative horizontal fraction results are reasonably similar (e.g., the fraction of application rate deposition ratio of base tank mix to scenario tank mix is close to 1.0) (Figure 8a). However, the far field results differ between scenarios, ranging from about 1.5 to 2 times the base scenario. Changes in relative fraction deposition are not proportional to differences in tank mix scenarios. Figures 8b and 8c show that changes in relative mass deposition and air concentrations are also not proportional to tank mix scenarios. The 15 gal/ac scenarios show the largest differences regardless of application rate. These results indicate: 1) simple multiplication of a base application rate deposition curve (fraction or mass) to obtain other application rates at the same GPA volume does not produce the same results compared to running the AGDISP model (or AgDRIFT model) separately for each tank mix scenario and 2)

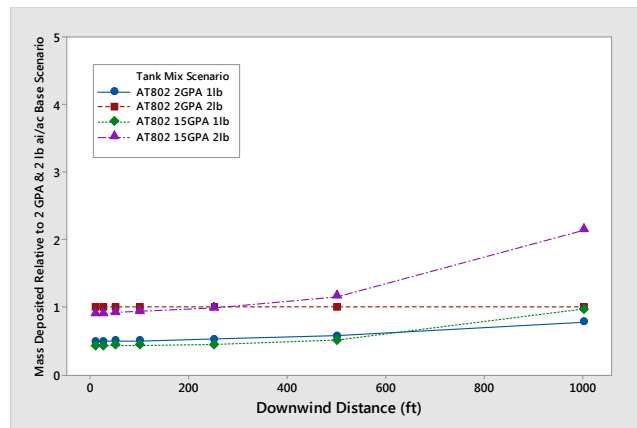
finished spray volume likely affects deposition and air concentration results through differences in the percent of ai in the tank mix. Therefore, these results imply a potential tank mix effect that is not considered if the default inputs alone are used to produce horizontal deposition and air concentration estimates. The higher finished spray volume per acre appears to increase deposition in the far field and increase air concentrations throughout the model domain.

Figure 8. Horizontal deposition (fraction of application rate and mass) and air concentration relative to the base scenario of AT802A aircraft 2GPA finished spray and 2 lb ai/ac application rate (AT802A 2GPA 2lb). Additional scenarios vary combinations of volume of finished spray (GPA) and application rate (lb ai/ac). Results at each distance for each scenario are divided by the result for the base scenario (the vertical axis is dimensionless).

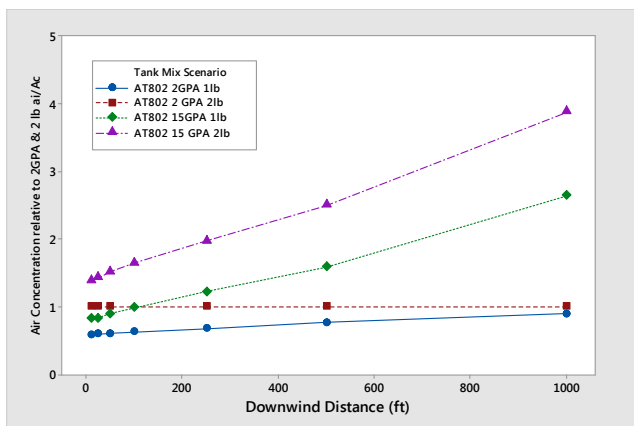
a. Horizontal Fraction Deposition



b. Horizontal Mass Deposition



c. Air Concentration



Comparison with U.S. EPA Results

Both this analysis and the United States Environmental Protection Agency (USEPA) analysis used computer simulation models to produce horizontal deposition and air concentration estimates for chlorpyrifos. Inputs for some scenarios modeled were similar. For other scenarios the inputs were quite different.

For orchard airblast and ground boom this analysis used AgDRIFT 2.0.05 because when this analysis was conducted staff did not have access to AgDRIFT 2.1.1 regulatory version. For orchard airblast and ground boom AgDRIFT 2.0.05 yielded identical results to AgDRIFT 2.1.1 public version. After this analysis was finished staff obtained the regulatory version of AgDRIFT 2.1.1. As expected, results for orchard airblast and ground boom were identical between AgDRIFT 2.0.05 and AgDRIFT 2.1.1 regulatory version. That is because the empirical models that produce the orchard air blast and ground boom results have not changed since the versions of AgDRIFT developed following the expert panel review in the mid-1990's. The user manual supplied with AgDRIFT 2.1.1 is the user manual for AgDRIFT 2.0.07 (Teske et al., 2003).

Orchard Airblast. This analysis and USEPA orchard airblast simulations used consistent inputs. The only differences are due to USEPA rounding up to 2 decimal places for the horizontal deposition. USEPA presented only the sparse orchard scenario. This analysis presents sparse orchard, dormant apples, and grape vineyard (non-wrap-around). A side-by-side comparison for sparse orchard and 2 lb ai/ac application rate is shown in Table 22.

Table 22. Comparison of 50th percentile sparse orchard horizontal deposition (lb ai/ac) across a 50ft wide lawn for 20 rows and 2 lb ai/ac application rate as estimated using the AgDRIFT model.

Distance Downwind (ft)	This Analysis	USEPA
0	* ¹	0.57 ²
10	*	0.16
25	0.0886	0.09
50	0.04	0.04
75	0.022	0.02
100	0.0136	0.01
125	0.009	0.01
150	0.0064	0.01
200	0.0036	0.00
250	0.0022	0.00
300	0.0016	0.00

¹This analysis did not report estimates for empirical model fits between 0 and 25 feet because no field measurements were made within that distance range. The empirical model fit starts at 25 ft downwind of the treated field.

²The USEPA field edge horizontal deposition estimates are in error (Per. Comm. Charles Peck, USEPA, 2014).

Ground Boom. There are no differences between this analysis and USEPA for ground boom simulation inputs. Both used the same scenarios of ASAE Fine to Medium/Coarse droplet spectra for low and high boom applications. However, USEPA reported the 90th percentile estimates. This analysis reported the 50th percentile estimates because the orchard airblast and aerial are both 50th percentile estimates. The use of the 50th percentile estimate puts ground boom on the same estimation basis as orchard airblast and aerial. Table 23 shows a side-by-side comparison of ground boom horizontal deposition (lb ai/ac) across a 50ft wide lawn for 20 swaths and 2 lb ai/ac application rate as estimated using the AgDRIFT model.

Table 23. Comparison of ground boom horizontal deposition (lb ai/ac) across a 50ft wide lawn for 20 swaths and 2 lb ai/ac application rate as estimated using the AgDRIFT model.

Distance Downwind (ft)	This Analysis Low Boom ¹ 50 th Percentile	USEPA Low Boom 90 th Percentile	This Analysis High Boom ² 50 th Percentile	USEPA High Boom 90 th Percentile
0	* ³	0.46 ⁴	*	0.54 ⁴
10	*	0.02	*	0.04
25	0.0094	0.02	0.0184	0.03
50	0.0064	0.01	0.0118	0.02
75	0.0048	0.01	0.009	0.02
100	0.0040	0.01	0.0074	0.01
125	0.0034	0.01	0.0062	0.01
150	0.0030	0.01	0.0054	0.01
200	0.0024	0.00	0.0042	0.01
250	0.0020	0.00	0.0034	0.01
300	0.0018	0.00	0.0028	0.01

¹Low boom height is 20 inches above the target.

²High boom is 50 inches above the target.

³This analysis did not report estimates for empirical model fits between 0 and 25 feet because no field measurements were made within that distance range. The empirical model fit starts at 25 ft downwind of the treated field.

⁴USEPA field edge deposition estimates are in error (Per. Comm. Charles Peck, USEPA. 2014).

Aerial. Differences between aerial simulation inputs for this analysis and USEPA produces differences in the horizontal deposition. One difference is that this analysis used AGDISP 8.28 (Teske and Curbishley, 2013) to simulate the aerial application scenarios while USEPA used AgDRIFT 2.1.1 regulatory version. Table 24 follows the format of the AgDRIFT 2.0.05 user's manual and shows the AgDRIFT and AGDISP model inputs (Teske et al., 2002). The format of the AgDRIFT user's manual does not change with model version and the Tier I default parameter are the same between AgDRIFT 2.0.05 and AgDRIFT 2.1.1. The AgDRIFT Tier I

default inputs shown in Table 24 were not changed by USEPA from those defaults for the AgDRIFT Tier II model runs.

Table 24. Details of Aerial Application inputs for AGDISP and AgDRIFT this analysis and USEPA, respectively.

	This Analysis AGDISP	USEPA AgDRIFT
Aircraft Model	AT802A	AT401
Weight	11160 lbs	6000 lbs
Wing Semispan	29 ft	24.5 ft
Flight Speed	144.99 mph	119.99 mph
Release Height	10 ft	10 ft
Number of Nozzles	39	42
Vertical Offset	-0.6601 ft	-1.51 ft
Horizontal Offset	-0.5 ft	-0.83 ft
Boom Span	76.3%	76.32%
Spacing (even)	14 inches	11 inches
ASABE ¹ Droplet Spectra Classification	Medium	Tier I Fine to Medium Tier II Medium
Wind Speed at 2 m	10 mph	10 mph
Wind Direction	Perpendicular to Flight Path	Perpendicular to Flight Path
Surface Roughness	0.12 ft (low crops)	0.0246 ft (bare soil)
Stability	Overcast (Neutral)	Overcast (Neutral)
Relative Humidity	20%	50%
Temperature	90 deg F	86 deg F
Specific Gravity	1.0	1.0
Spray Volume Rate	2 gal/ac	2 gal/ac
Application Rate	2 lb/ac ²	2 lb/ac
Nonvolatile Rate	2 lb/ac	3 lb/ac ³
Active Solution % of Tank Mix	12%	12%
Additive Solution % of Tank Mix	0%	5%
Nonvolatile Active	12%	12%
Volatile Fraction	0.88	.83
Nonvolatile Fraction	0.12	.17
Swath Width	60 ft	60 ft
Swath Displacement	37%	37%
Number of Flight Lines	50	20

¹American Society of Agricultural and Biological Engineers. Formerly American Society of Agricultural Engineers (ASAE). The organization change names in 2005.

²Application rates of 1, 2, 2.3, 4, and 6 lb/ac were simulated both 2 gal/ac and 15 gal/ac spray volume.

³USEPA indicates in D3399483. AppendixF.CPOSDrift.xlsx "...DAS Error Correction Comments/Meetings" for this tank mix but there is no accompanying documents to explain the "correction." Not all chlorpyrifos products are Dow products so this analysis does not include the 1 lb/ac of non-ai nonvolatile material in the tank mix.

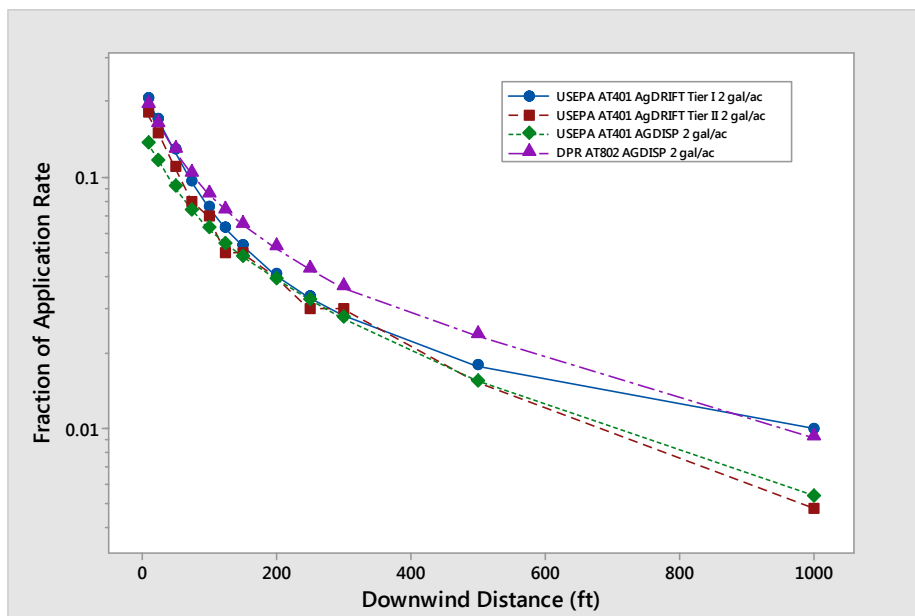
Deposition estimates for 2 lb ai/ac application rate are compared in Table 25 and shown in Figure 9. For this comparison, USEPA AgDRIFT estimates were extended to 1000 ft downwind to match the AGDISP estimates. In addition, the USEPA AgDRIFT inputs were used in AGDISP to provide a comparison of AgDRIFT and AGDISP horizontal deposition estimate for the AT401 aircraft. The AgDRIFT 2.1.1 aerial algorithm does not include an evaporation time-step refinement that was incorporated into AGDISP 8.28 to improve mass accountancy (H. Thistle, pers. comm., 2014). This results in the AgDRIFT horizontal deposition being higher than AGDISP for the same scenario (AT401 aircraft/20 swaths) due to the lack of the refined evaporation time-step. This effect is apparent in Figure 9 because the AGDISP results using the USEPA AT401 inputs show lower horizontal deposition relative to the AgDRIFT AT401 horizontal deposition results. This analysis used AGDISP. However, the horizontal deposition estimates reported in this analysis are higher relative to USEPA horizontal deposition estimates for several reasons: 1) the AT802A was selected as the California aircraft based on common use in California and higher horizontal deposition estimates, 2) this analysis used 50 swathes (USEPA used 20 swathes) to reflect the largest application sizes in California, 3) the meteorological conditions used in this analysis are California specific, and 4) the tank mix fractions used in this analysis are California specific.

Table 25. Comparison of aerial horizontal deposition (fraction of application rate) across a 50ft wide lawn for 2 lb ai/ac application rate as estimated using the AgDRIFT and AGDISP models.

Downwind Distance (ft)	USEPA AgDRIFT 2 gal/ac 20 swath AT401 Tier I	USEPA AgDRIFT 2 gal/ac 20 swath AT401 Tier II	USEPA Inputs AGDISP 2 gal/ac 20 swath AT401	This Analysis AGDISP 2 gal/ac 50 swath AT802A
10	0.20	0.1840	0.1374	0.1929
25	0.17	0.1475	0.1170	0.1640
50	0.13	0.1125	0.0914	0.1286
75	0.10	0.0854	0.0742	0.1034
100	0.08	0.0682	0.0627	0.0859
125	0.06	0.0570	0.0546	0.0739
150	0.05	0.0496	0.0483	0.0652
200	0.04	0.0394	0.0394	0.0524
250	0.03	0.0324	0.0327	0.0430
300	0.03	0.0271	0.0275	0.0365
500	0.02	0.0154	0.0155	0.0234
1000	* ¹	0.0048	0.0054	0.0092

¹AgDRIFT Tier I does not estimate to 1000 ft.

Figure 9. Aerial application horizontal deposition estimates expressed as fraction of 2 lb ai/ac application rate as modeled by 4 different AgDRIFT and AGDISP scenarios.



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Appendix A – AGDISP Full Results for Aerial Application Scenarios

AT802A

2 GPA

1 lb ai/ac

distance downwind (ft)	horizontal deposition (fraction)	Air concentration (ng/L) at 1.7 ft	Air concentration (ng/L) at 5.0 ft	fraction <=10um
10	0.1922	31.8	23.4	0.0341
25	0.1639	29.2	21.8	0.0357
50	0.1290	26.4	19.4	0.0376
100	0.0869	22.0	16.3	0.0406
250	0.0453	16.1	11.8	0.0471
500	0.0270	11.7	8.5	0.0570
1000	0.0144	6.5	4.7	0.0852
1320	0.0094	4.6	3.3	0.1072
2608	0.0017	1.6	1.2	0.2290

Bell205

2 GPA

1 lb ai/ac

distance downwind (ft)	horizontal deposition (fraction)	Air concentration (ng/L) at 1.7 ft	Air concentration (ng/L) at 5.0 ft	fraction <=10um
10	0.2454	40.9	28.8	0.0440
25	0.1553	33.6	24.0	0.0472
50	0.0951	27.4	19.7	0.0510
100	0.0578	21.9	15.8	0.0558
250	0.0369	15.3	11.1	0.0662
500	0.0219	10.2	7.4	0.0831
1000	0.0107	5.8	4.2	0.1178
1320	0.0075	4.5	3.2	0.1410
2608	0.0012	2.0	1.5	0.2500

AT802A
2 GPA
2 lb ai/ac

distance downwind (ft)	horizontal deposition (fraction)	Air concentration (ng/L) at 1.7 ft	Air concentration (ng/L) at 5.0 ft	fraction ≤10um
10	0.1929	54.6	39.9	0.0285
25	0.1640	49.3	36.7	0.0300
50	0.1286	43.7	32.0	0.0321
100	0.0859	35.0	25.9	0.0355
250	0.0430	23.7	17.4	0.0440
500	0.0234	15.3	11.1	0.0589
1000	0.0092	7.2	5.2	0.0999
1320	0.0054	4.9	3.6	0.1300
2608	0.0010	1.6	1.2	0.2800

Bell205
2 GPA
2 lb ai/ac

distance downwind (ft)	horizontal deposition (fraction)	Air concentration (ng/L) at 1.7 ft	Air concentration (ng/L) at 5.0 ft	fraction ≤10um
10	0.2471	72.8	50.0	0.0366
25	0.1574	58.0	40.4	0.0400
50	0.0969	45.8	32.2	0.0445
100	0.0603	34.5	24.6	0.0500
250	0.0334	21.5	15.4	0.0640
500	0.0171	13.0	9.3	0.0867
1000	0.0075	6.8	4.9	0.1329
1320	0.0048	4.99	3.61	0.1600
2608	0.0008	2.19	1.59	0.2887

AT802A
2 GPA
2.3 lb ai/ac

distance downwind (ft)	horizontal deposition (fraction)	Air concentration (ng/L) at 1.7 ft	Air concentration (ng/L) at 5.0 ft	fraction ≤10um
10	0.1929	58.3	42.8	0.0283
25	0.1639	52.6	39.4	0.0302
50	0.1284	46.4	34.1	0.0324
100	0.0856	37.1	27.5	0.0360
250	0.0428	25.0	18.3	0.0451
500	0.0227	15.9	11.5	0.0605
1000	0.0088	7.5	5.4	0.1026
1320	0.0050	5.1	3.7	0.1333
2608	0.0011	1.7	1.2	0.2951

Bell205
2 GPA
2.3 lb ai/ac

distance downwind (ft)	horizontal deposition (fraction)	Air concentration (ng/L) at 1.7 ft	Air concentration (ng/L) at 5.0 ft	fraction ≤10um
10	0.2472	77.1	53.8	0.0376
25	0.1575	61.1	43.5	0.0413
50	0.0970	48.2	34.5	0.0458
100	0.0605	36.2	26.0	0.0521
250	0.0328	22.2	16.0	0.0675
500	0.0165	13.3	9.6	0.0915
1000	0.0071	6.9	5.0	0.1405
1320	0.0045	5.0	3.7	0.1753
2608	0.0009	2.3	1.6	0.3127

AT802A					
15 GPA					
1 lb ai/ac					
distance downwind (ft)	horizontal deposition (fraction)	Air concentration (ng/L) at 1.7 ft	Air concentration (ng/L) at 5.0 ft	fraction <=10um	
10	0.1671	44.3	32.3	0.0737	
25	0.1409	41.3	30.6	0.0749	
50	0.1127	39.1	28.7	0.0765	
100	0.0754	34.8	25.6	0.0788	
250	0.0387	28.9	21.2	0.0826	
500	0.0240	24.3	17.7	0.0863	
1000	0.0179	19.0	13.8	0.0944	
1320	0.0162	16.4	11.9	0.1011	
2608	0.0048	9.0	6.5	0.1468	

Bell205					
15 GPA					
1 lb ai/ac					
distance downwind (ft)	horizontal deposition (fraction)	Air concentration (ng/L) at 1.7 ft	Air concentration (ng/L) at 5.0 ft	fraction <=10um	
10	0.2281	68.5	48.7	0.0920	
25	0.1403	59.2	42.6	0.0958	
50	0.0814	51.7	37.3	0.0994	
100	0.0472	44.8	32.5	0.1026	
250	0.0328	36.7	26.6	0.1102	
500	0.0246	28.8	20.9	0.1200	
1000	0.0161	20.2	14.7	0.1410	
1320	0.0129	15.0	10.8	0.1558	
2608	0.0021	8.0	6.4	0.2140	

AT802A

15 GPA

2 lb ai/ac

distance downwind (ft)	horizontal deposition (fraction)	Air concentration (ng/L) at 1.7 ft	Air concentration (ng/L) at 5.0 ft	fraction ≤10um
10	0.1738	75.8	55.3	0.0565
25	0.1472	70.3	52.2	0.0577
50	0.1186	66.0	48.4	0.0590
100	0.0808	57.9	42.6	0.0615
250	0.0425	46.8	34.2	0.0677
500	0.0271	38.1	27.8	0.0710
1000	0.0197	27.9	20.2	0.0835
1320	0.0171	22.7	16.5	0.0936
2608	0.0041	10.3	7.5	0.1606

Bell205

15 GPA

2 lb ai/ac

distance downwind (ft)	horizontal deposition (fraction)	Air concentration (ng/L) at 1.7 ft	Air concentration (ng/L) at 5.0 ft	fraction ≤10um
10	0.2343	96.7	68.6	0.0708
25	0.1461	82.8	59.6	0.0741
50	0.0870	71.5	51.6	0.0776
100	0.0515	61.2	44.3	0.0814
250	0.0360	48.8	35.3	0.0889
500	0.0256	37.3	27.0	0.1008
1000	0.0155	25.2	18.3	0.1240
1320	0.0118	20.7	15.0	0.1390
2608	0.0021	11.5	8.3	0.2040

AT802A
15 GPA
2.3 lb ai/ac

distance downwind (ft)	horizontal deposition (fraction)	Air concentration (ng/L) at 1.7 ft	Air concentration (ng/L) at 5.0 ft	fraction ≤10um
10	0.1745	84.1	61.4	0.0574
25	0.1480	77.9	57.9	0.0587
50	0.1194	73.0	53.6	0.0602
100	0.0813	63.7	46.9	0.0629
250	0.0429	51.3	37.5	0.0676
500	0.0273	41.5	30.3	0.0735
1000	0.0198	29.9	21.7	0.0875
1320	0.0167	24.1	17.5	0.1001
2608	0.0041	10.6	7.7	0.1740

Bell205
15 GPA
2.3 lb ai/ac

distance downwind (ft)	horizontal deposition (fraction)	Air concentration (ng/L) at 1.7 ft	Air concentration (ng/L) at 5.0 ft	fraction ≤10um
10	0.2355	107.4	76.2	0.0732
25	0.1472	91.7	65.9	0.0759
50	0.0879	78.9	56.9	0.0804
100	0.0522	67.1	48.5	0.0851
250	0.0362	53.2	38.5	0.0926
500	0.0254	40.2	29.1	0.1058
1000	0.0154	26.9	19.5	0.1313
1320	0.0117	22.0	15.9	0.1481
2608	0.0021	12.7	9.2	0.1769