Department of Pesticide Regulation

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MEMORANDUM

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

Background

This memorandum describes procedures used to estimate chlorpyrifos off-site horizontal deposition and air concentrations associated with California use scenarios. These estimates are suitable for use in conducting chlorpyrifos human exposure assessments and in developing exposure mitigation measures for the use of chlorpyrifos. 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 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 (http://www.epa.gov/scipoly/sap/meetings/1997/december/spraydrift.htm). 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. The latest "public" version of AgDRIFT 2.1.1 executable file dated 01/2012 was sent to staff following a request for the latest version of the model through the www.agdrift.com webmaster. However, it was discovered that this public version of AgDRIFT 2.1.1 does not have several capabilities that the older version includes. Specifically, for orchard airblast this public version of the model does not allow access to the extended settings for specific orchard types (e.g. dormant apples) and for ground boom the 90th percentile estimates are not available. AgDRIFT 2.0.05 is an older version of the model but produces deposition results identical to the public version accessible scenarios for all application methods (aerial, ground boom, and orchard airblast). In addition, the 90th percentile ground boom results obtained from AgDRIFT 2.0.05 were identical to the deposition results shown in the recent USEPA guidance on spray drift (White et al., 2013) that USEPA produced using the regulatory version of AgDRIFT 2.1.1. After the analyses in this memorandum were completed, staff was able to obtain a copy of the AgDRIFT 2.1.1 regulatory version, executable filed dated 12/2011. As expected, results from this version of the model were identical to AgDrift 2.0.05 and the public version of AgDRIFT 2.1.1.

The AGDISP 8.28 model was used for aerial application deposition 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 has 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). Staff originally had access only to the public version of the most recent release, AgDRIFT 2.1.1. This most recent public version of AgDRIFT does not include a time step improvement recently incorporated into AGDISP 8.28 (M. Teske, pers. comm., 2014). The lack of that time step improvement in the public version of AgDRIFT 2.1.1 will result 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 2.28.

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 ac. A preliminary deposition limit of 0.35% of the application rate was used for initial drift model scenairo scoping (S. Beauvais, pers. comm., 2014).

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 STDF 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, 44º F to 91º 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 deposition. 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 below. 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). Based upon the greatest distance to the preliminary deposition level of 0.35% of application rate, the AT802A fixed wing and the Bell 205 helicopter were chosen for further refinement in the final modeling scenarios.

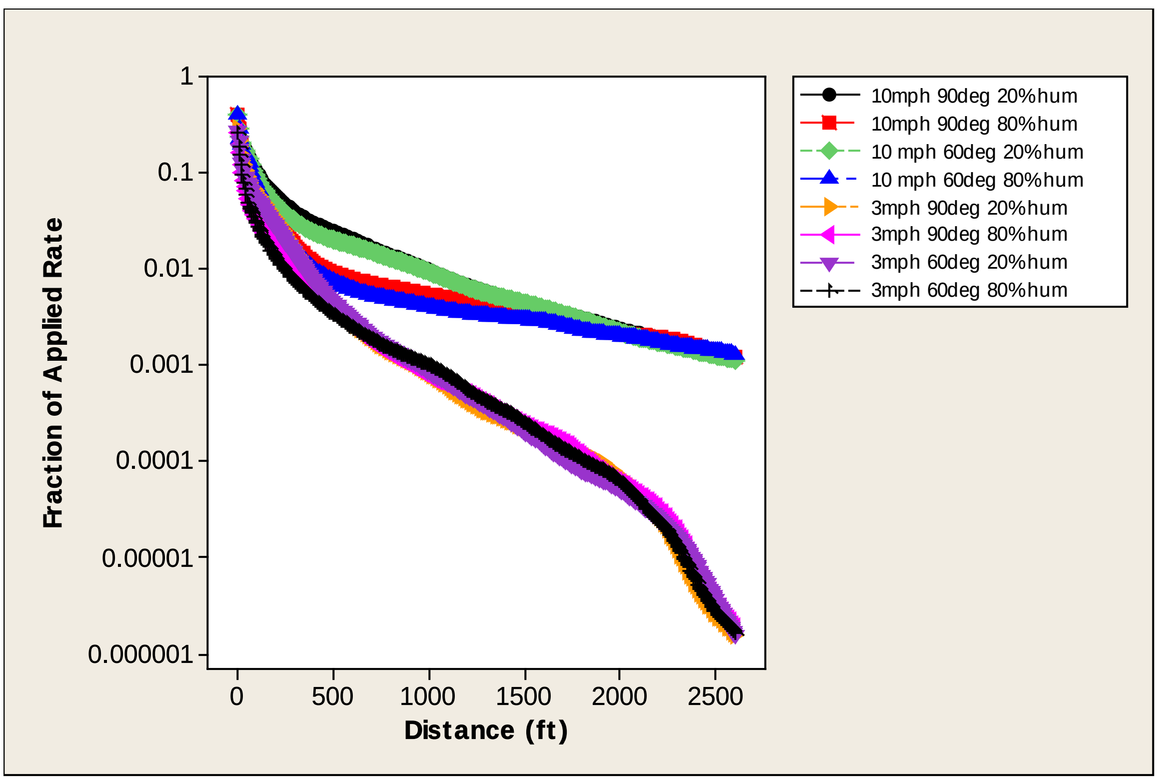
Table 2. Candidate aircraft. All simulations were conducted with a boom length of 76.3% of semi-span or rotor diameter, swath width of 60ft for fixed wing or 1.2xrotor diameter for helicopter, a swath-displacement of 37%, no half-boom effect or swath offset, 2 gal/ac volume, non-volatile active ingredient 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 aircraft. 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 values is the 50^{th} 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 specific California scenario. The AgDRIFT user manual does not state why a 90^{th} percentile is not estimated for orchards. At the 1999 SAP OPP staff did present tolerance bounds for orchard air blast (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 values is the 50^{th} percentile deposition estimate. In addition, the AgDRIFT ground boom empirical model has the choice to output 90^{th} percentile. However, the derivation of the 90^{th} 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 90^{th} percentile at each distance with a 90% or 95% confidence. More likely what is labeled as the 90^{th} percentile is actually the 90% prediction interval on the empirical function. There is no information provided in the AgDRIFT user manual about exactly how 90^{th} 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 50^{th} 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 rows of the orchard are 16 ft apart (16 ft wide), represents an orchard that is 320 ft wide (20 swaths * 16 ft). With the assumption of a square orchard (320 ft x 320 ft) this is 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

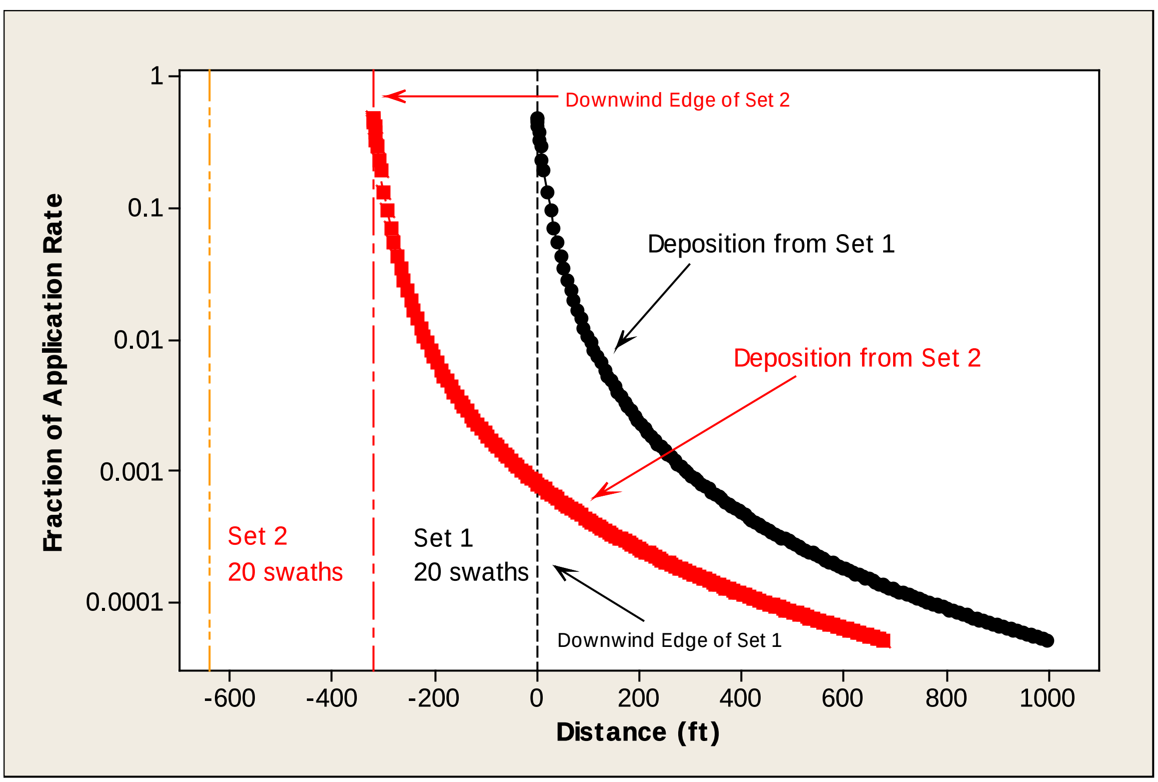
Table 6. Ground boom. Each set of 20 swaths is 900 ft wide. Downwind deposition curves are offset by the appropriate number of feet and then overlaid. When overlaying, upwind deposition curves are allowed to drop to zero at the model domain limit of 997.4 ft.

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.

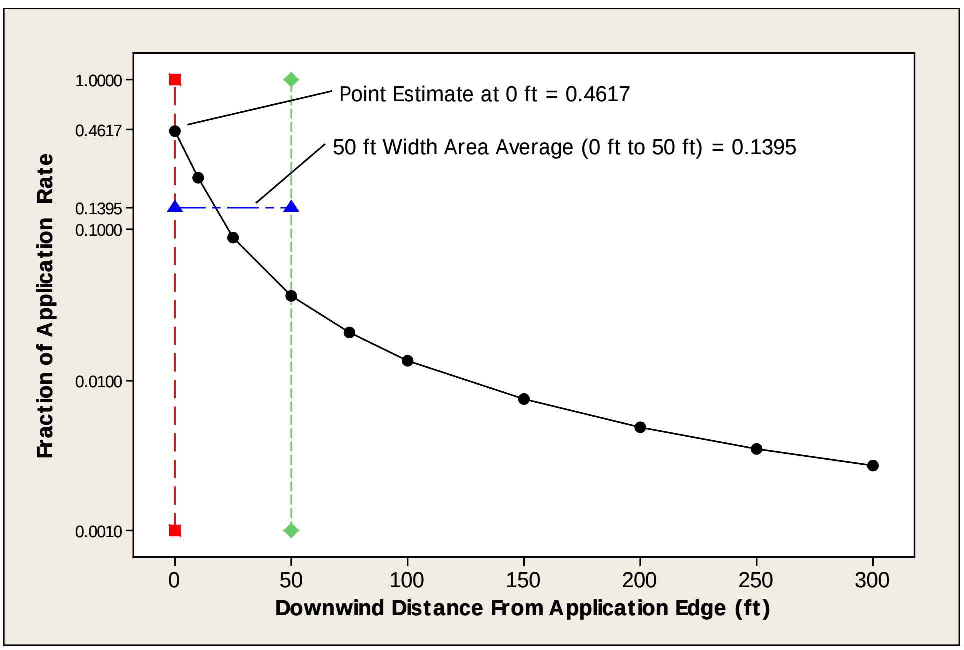


As stated above, this procedure was only implemented if the resulting deposition from the offset upwind swaths was within the prediction domain of the model. The aerial algorithm estimates deposition up to 2605 ft directly downwind of the application (the far field Gaussian handoff was not used in this 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. While these assumed empirical functions may be correct, there is no way 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 those estimates. 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 slowing and more likely over estimate deposition rather than underestimate. See the AgDRIFT manual for 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 µg/cm^2		Start	End	Fraction of App	2 lb/ac µg/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 µg/cm^2		Start	End	Fraction of Rate	2 lb/ac µg/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 µg/cm^2		Start	End	Fraction of Rate	2 lb/ac µg/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 µg/cm^2		Start	End	Fraction of Rate	2 lb/ac µg/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 $\mu g/cm^2$		Start	End	Fraction of Rate	2 lb/ac $\mu g/cm^2$
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 $\mu g/cm^2$		Start	End	Fraction of Rate	2 lb/ac $\mu g/cm^2$
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

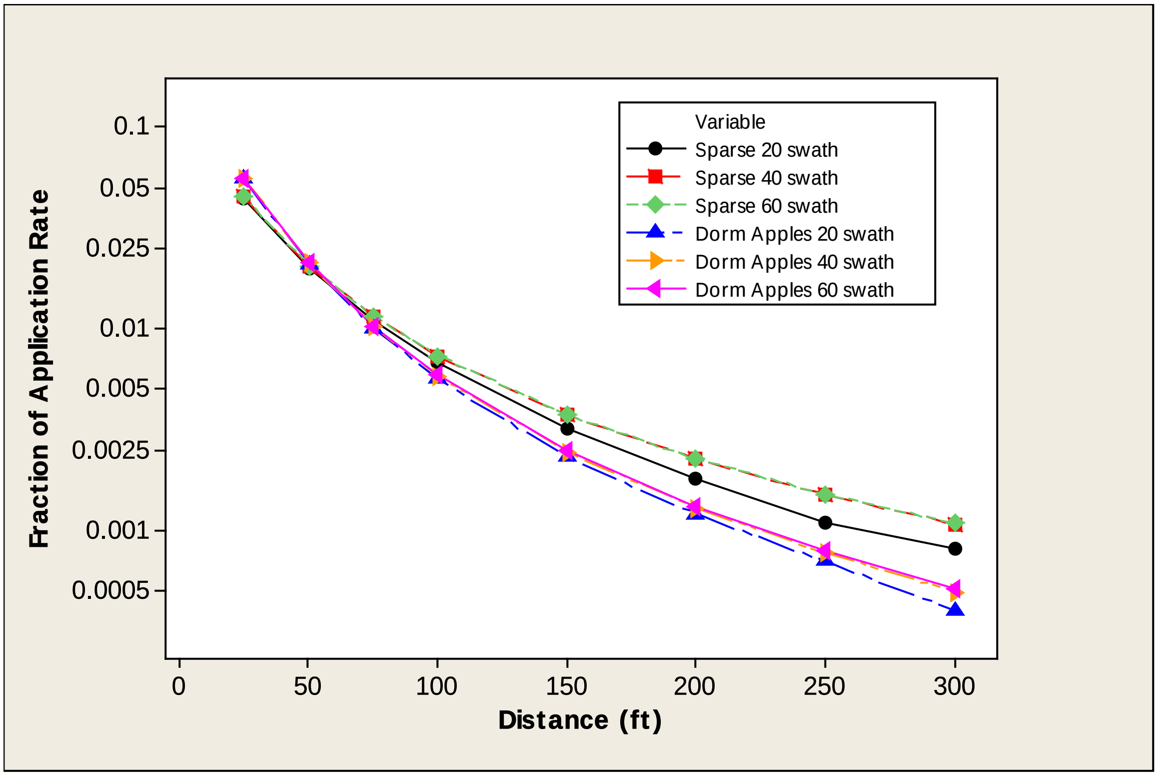
Table 12. Grape vineyard conventional sprayer 20 swath 50th percentile deposition estimates. The development procedure for these deposition estimates is described in the text.

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 $\mu g/cm^2$		Start	End	Fraction of Rate	2 lb/ac $\mu g/cm^2$
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 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 $\mu g/cm^2$		Start	End	Fraction of Rate	2 lb/ac $\mu g/cm^2$
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 µg/cm^2		Start	End	Fraction of Rate	2 lb/ac µg/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 µg/cm^2		Start	End	Fraction of Rate	2 lb/ac µg/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

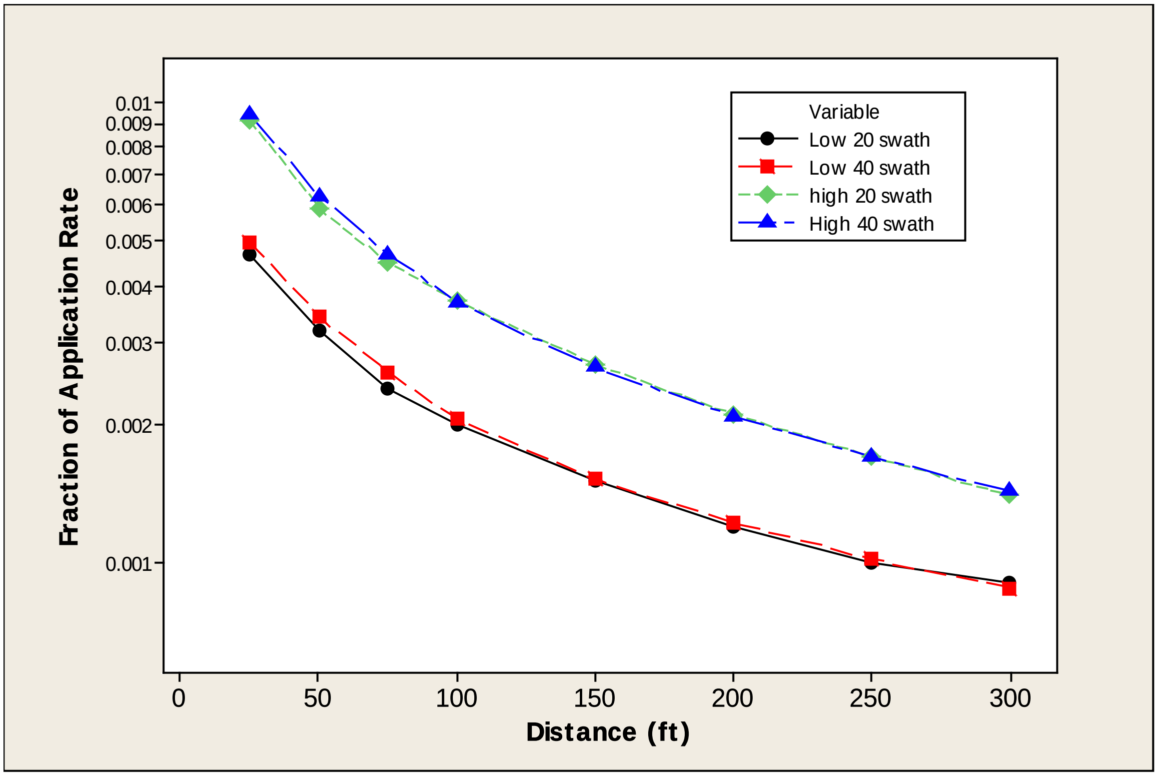
Table 16. Ground boom deposition. High boom and medium/coarse spray quality 20 swath 50th percentile. The development procedure for these deposition estimates is described in the text.

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 $\mu g/cm^2$		Start	End	Fraction of Rate	2 lb/ac $\mu g/cm^2$
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 $\mu g/cm^2$		Start	End	Fraction of Rate	2 lb/ac $\mu g/cm^2$
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.

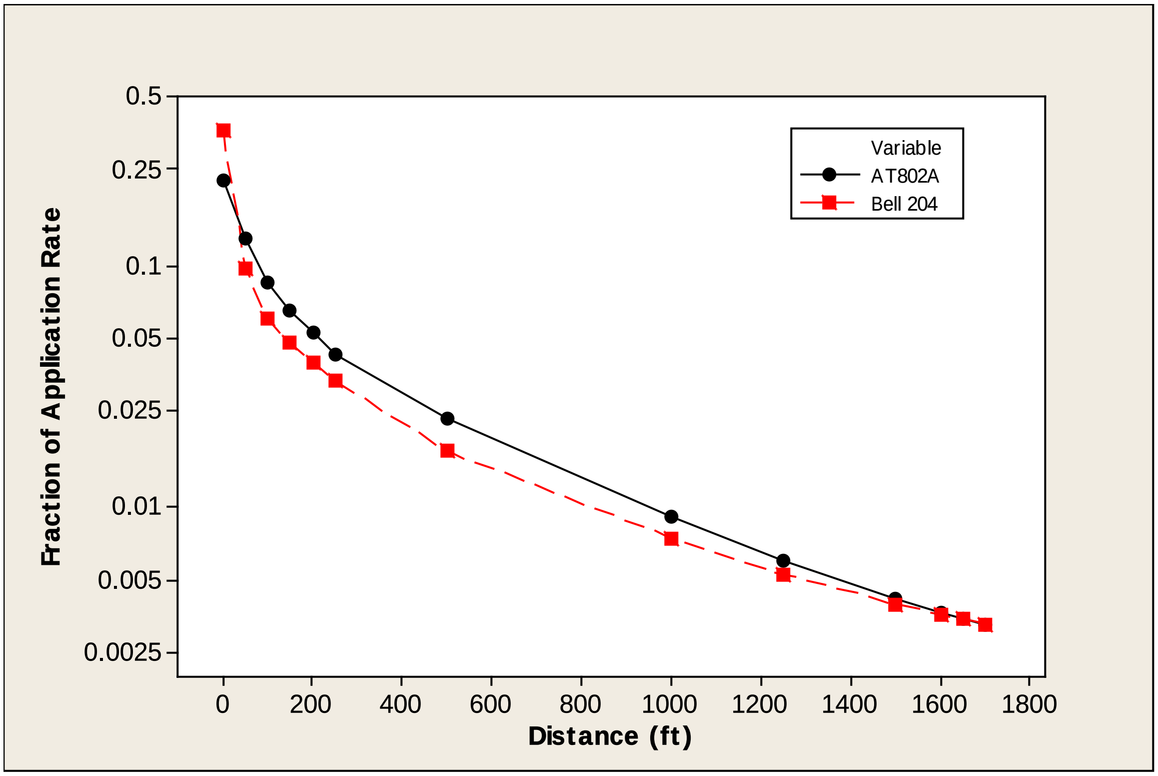
Table 18. Fixed-wing aerial application deposition. AT802A medium spray quality 50 swath 50th percentile. The development procedure for these deposition estimates is described in the text.

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 µg/cm^2		Start	End	Fraction of Rate	2 lb/ac µg/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 $\mu g/cm^2$		Start	End	Fraction of Rate	2 lb/ac $\mu g/cm^2$
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

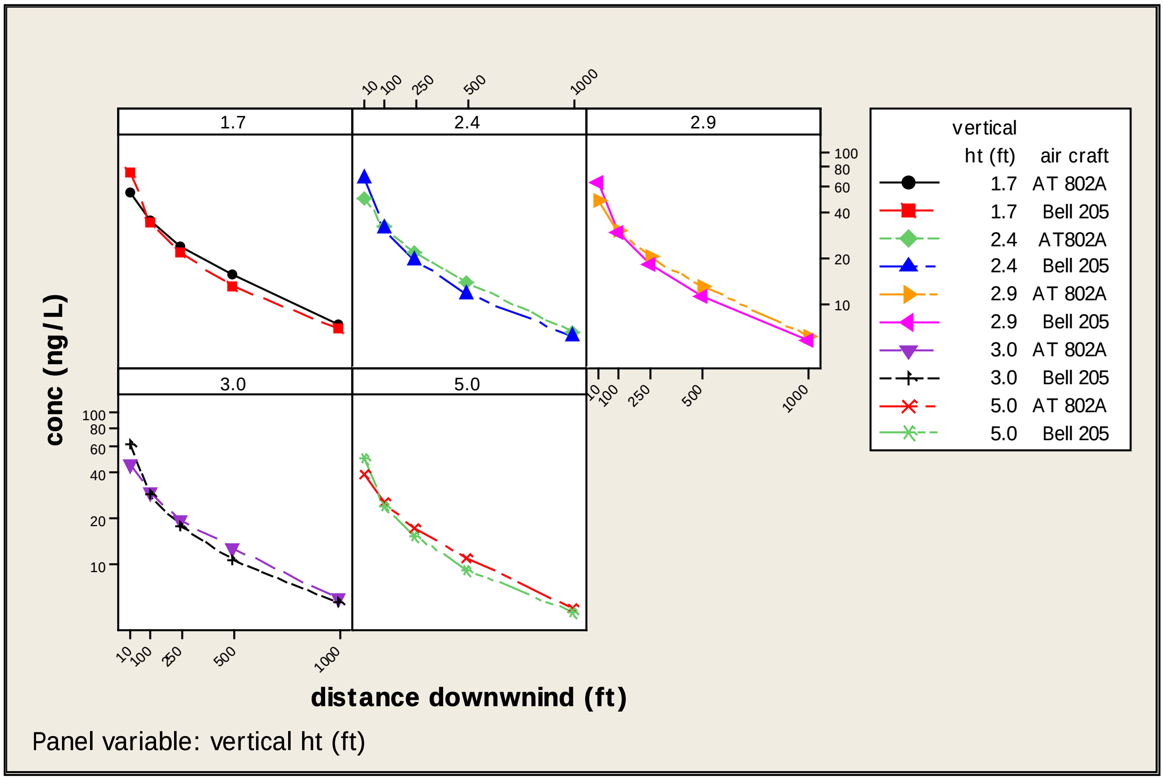
The AGDISP model produces estimated 1-hr time weighted average (TWA) air concentrations in a vertical plane at user specified downwind distances from the application edge. The air concentration estimates for both the AT802A and Bell 205 were obtained from the same model runs that produced the deposition 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.

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 is described in the text.

Height Above Ground		1-Hr TWA Air Concentration (ng/m^3)	
		Aircraft Model	
Inches	Feet	AT802A Fixed Wing	Bell 205 Helicopter
0	0	n/a[1]	n/a[1]
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

[1] The 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 wind air craft 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)

Both fraction of the applied mass that is measured as horizontal deposition (and by extension, the mass measured as horizontal deposition) and air concentrations associate with a particular application are functions of the finished spray volume expressed as gallons per acre (GPA) and the active ingredient (ai) application rate (lb ai/ac). When comparing two scenarios of GPA and application rate, this relationship also changes with the distance downwind. Thus, the designation of a “reasonable worst case” scenario is not simple.

The application tank mix scenarios shown in Table 21 were simulated using AGDISP for both fixed wing (AT802) and rotary (Bell 205) aircraft. The same aircraft set-ups that have been used throughout the Chlorpyrifos spray drift analysis were used for this analysis. Only the tank mix was changed for each scenario. The base finished spray volume is designated as 2 GPA. This is consistent with 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 application rate is designated as 2 lb ai/ac. Thus, for this analysis the base tank mix is 2 GPA finished spray volume and 2 lb ai/ac. All other tank mix combinations will be compared to this base. The Cheminova NUFOS 4E insecticide chlorpyrifos formulation that has 4 lb ai/gallon (0.5 lb/pint) was used for this simulation. For this formulation the ai is 45% by volume. 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.

2 GPA Finished Spray (16 pints)			
ai[1] rate per acre	formulation volume per acre	Proportion of tank mix that is ai	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%
4 lb	8 pints	8/16*0.45 = 0.225	23%
6 lb	12 pints	12/16*0.45 = 0.338	34%
15 GPA Finished Spray (120 pints)			
ai rate per acre	formulation volume per acre	Proportion of tank mix that is ai	Percent ai in the tank mix volume[3]
1 lb	2 pints	2/120*0.45 = 0.008	1%
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	2%
4 lb	8 pints	8/120*0.45 = 0.030	3%
6 lb	12 pints	12/120*0.45 = 0.045	4.5%

[1]Active ingredient
[2]Rounded up to the nearest 1%
[3]Rounded up to the nearest 0.5% rather than 1% because the ai percentage is much smaller

Figure 8 shows, for the AT802-A fixed-wing aircraft, a comparison of the tank mix scenarios with the base tank mix of 2GPA and 2 lb ai/ac. The curves in Figure 8 depict the result for each scenario normalized to the base tank mix (at each distance the scenario results is divided by the result for 2GPA and 2 lb/ac). All six plots are on the same scale. Thus, a comparison of changes in results with scenario and distance can be assessed. The horizontal deposition results are presented in two ways. First the fraction of application rate deposited for each tank mix scenario is shown. In this presentation format the direct effect of application rate on the horizontal deposition mass is not shown but the relative effects are emphasized. Second, deposition of the actual mass for each scenario is shown. In this presentation format the change in mass deposition with changing application rate is emphasized. The air concentration results use the actual air concentrations (ng/L) only. Thus, the air concentration comparisons shown in Figure 8 incorporate directly the effect of changing application rate.

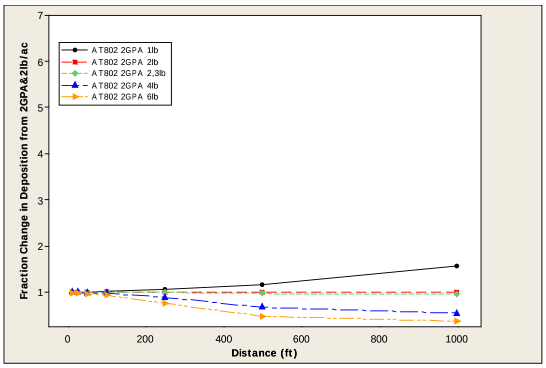
Across all combinations of finished spray volume and application rates, near field (within about 200 ft of the application edge) the horizontal deposition expressed as a fraction is reasonably similar (e.g., the fraction of application rate deposition ratio of base tank mix to scenario tank mix is close to 1.0) (Figure 8a and 8b). However, in the far field the change in fraction of application rate deposition ranges from about half the base rate for 2 gal/ac and 6 lb ai/ac to approximately double the base rate for all the 15 gal/ac scenarios. These results indicate that simple multiplication of a base fraction of application rate deposition curve does not produce the same results as if the AGDISP model (or AgDRIFT model) was run for each tank mix scenario.

Comparison of the mass of horizontal deposition using the 2 gal/ac and 2 lb ai/ac base tank mix shows that the relationship between application rate and deposition for both 2 gal/ac and 15 gal/ac finished spray is as expected between the field edge and about 100 ft downwind (figure 8c and 8d). However, further downwind, beyond 100 ft, the ratio between the base tank mix and the scenarios diverge from the straight multiples of 2 lb ai/ac. For the2 gal/ac scenarios, the ratio of the mass deposited to the base tank mix approaches 1.0 for all the application rates. For the 15 gal/ac scenarios the mass deposited increase in the far field to ratios between 1.0 and 5.3, depending upon the application rate. Air concentration ratios are shown in Figure 8e and 8f. Air concentration ratios for the 2 gal/ac application rates follow a trend similar to the mass deposited. However, the 15 gal/ac application rates show higher ratios with the base tank mix at the application edge and an increasing ratio with the base tank mix with distance downwind.

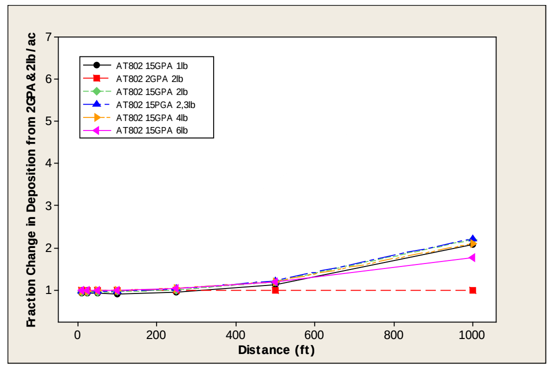
These results imply a tank mix effect that is not considered if the default inputs alone are used to produced horizontal deposition and air concentration estimates. The choice of 2 gal/ac finished spray volume may not be the most health protective scenario. The higher finished spray volume per acre appears to increase both deposition in the far field and increases air concentrations throughout the model domain.

Figure 8. Change in deposition and air concentrations with volume of finished spray (GPA), application rate (lb ai/ac), and distance (ft) for aerial applications with the AT802A fixed wing aircraft. The base scenario is AT802A aircraft 2GPA finished spray and 2 lb ai/ac application rate (AT802 2GPA 2lb).

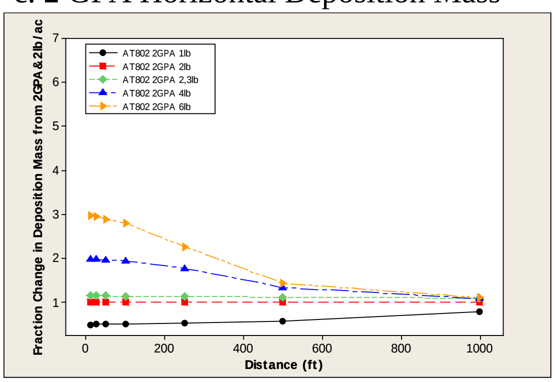
a. 2 GPA Horizontal Deposition Fraction



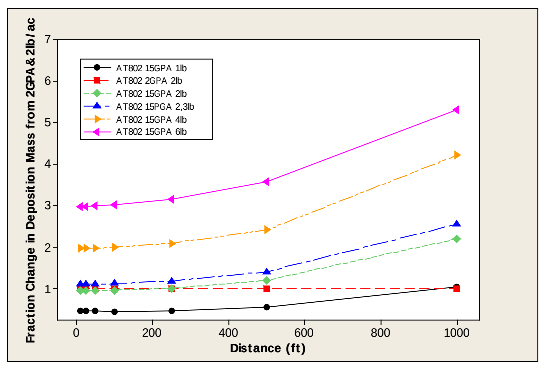
b. 15 GPA Horizontal Deposition Fraction



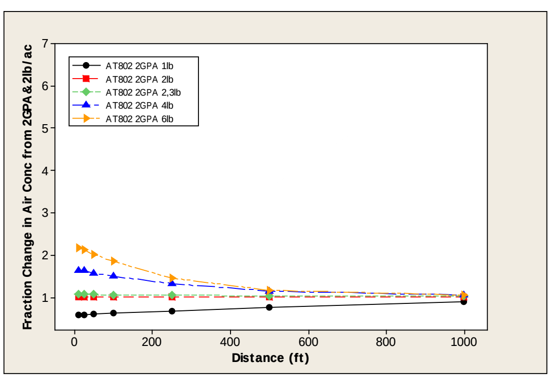
c. 2 GPA Horizontal Deposition Mass



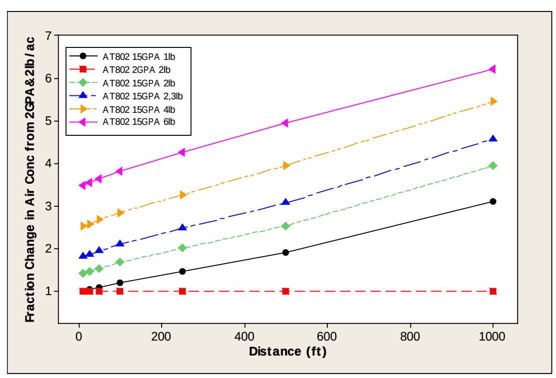
d. 15 GPA Horizontal Deposition Mass



e. 2 GPA Air Concentrations



f. 15 GPA Air Concentrations



Comparison with U.S. EPA Results

Both this analysis and the United States Environmental Protection Agency (USEPA) 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 were able to obtain 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

[1]This 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.
[2]The 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] 50th Percentile	USEPA Low Boom 90th Percentile	This Analysis High Boom[2] 50th Percentile	USEPA High Boom 90th 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

[1]Low boom height is 20 inches above the target.
[2]High boom is 50 inches above the target.
[3]This 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.
[4]USEPA field edge deposition estimates are in error (Per. Comm. Charles Peck, USEPA. 2014).

Aerial. Differences between this analysis and USEPA for aerial simulation inputs produces differences in the horizontal deposition and air concentration estimates. The most important difference is that this analysis used AGDISP 8.28 (Teske, 2013) to simulate the aerial application scenarios while USEPA used AgDRIFT 2.1.1 regulatory version. For this comparison the USEPA Tier II modeling inputs will be compared. Table 24 follows the format of the AgDRIFT 2.0.05 user's manual (Teske, 2002). and shows the input comparisons for the fixed wing aircraft scenario. 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. AgDRIFT Tier I default inputs are shown in Table 24 for the AgDRIFT inputs that were not changed by USEPA from the defaults for the 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 and 15 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

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

[2]Application rates of 1, 2, 2.3, 4, and 6 lb/ac were simulated both 2 gal/ac and 15 gal/ac spray volume.
[3]USEPA 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). AgDRIFT horizontal deposition is higher than AGDISP for the same scenario (AT401 aircraft) due to the lack of the refined evaporation time-step. Thus, for the same inputs, the AgDRIFT model will produce higher horizontal deposition estimates than AGDISP. This effect is apparent in Figure 9. The horizontal deposition estimates reported in this analysis are higher relative to USEPA estimates for several additional 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 swaths) 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. In addition, USEPA used simple multiplication of results from a single AgDRIFT run that produced horizontal deposition for a base application rate and finished spray of 2 GPA. This analysis indicates that simple multiplication of the horizontal deposition from a base application rate to adjust for desired application rates will not yield the same results as model runs for each of the desired application rates (Figure 10).The difference is small in the near field but increases in the far field. Because of this effect, this analysis did not use the simple multiplication method for the application rate adjustments. Instead, each application rate scenario was simulated. There is also a nonlinear effect of spray volume (gal/ac) on deposition at the same application rate. Figure 10 illustrates the effect on horizontal deposition for a spray volume of 2 gal/ac versus a spray volume of 15 gal/ac. As with application rate, the effect is largest in the far field (greater than 300 ft). This analysis included the spray volume analysis as part of the higher application rates scenarios, however, spray volume has an effect at all application rates.

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	This Analysis AGDISP 15 gal/ac 50 swath AT802A
10	0.20	0.1800	0.1374	0.1929	0.1859
25	0.17	0.1500	0.1170	0.1640	0.1580
50	0.13	0.1100	0.0914	0.1286	0.1240
75	0.10	0.0800	0.0742	0.1034	0.0955
100	0.08	0.0700	0.0627	0.0859	0.0833
125	0.06	0.0500	0.0546	0.0739	0.0717
150	0.05	0.0500	0.0483	0.0652	0.0634
200	0.04	0.0400	0.0394	0.0524	0.0515
250	0.03	0.0300	0.0327	0.0430	0.0435
300	0.03	0.0300	0.0275	0.0365	0.0387
500	0.02	0.0154	0.0155	0.0234	0.0286
1000	*[1]	0.0048	0.0054	0.0092	0.0203

[1]AgDRIFT 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 5 different AgDRIFT and AGDISP scenarios.

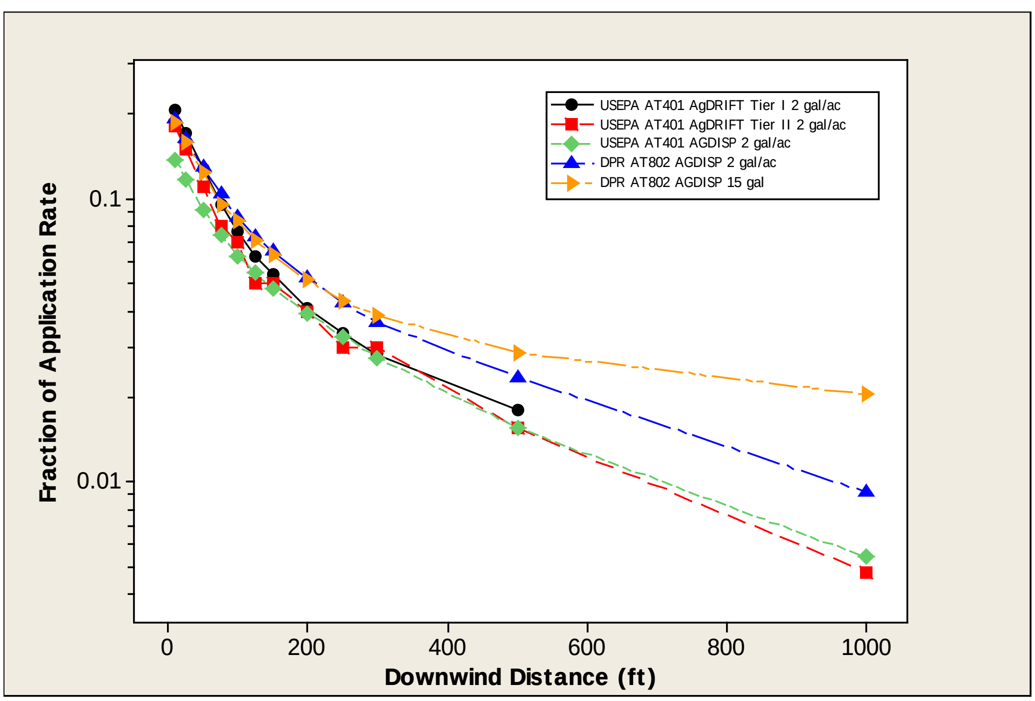
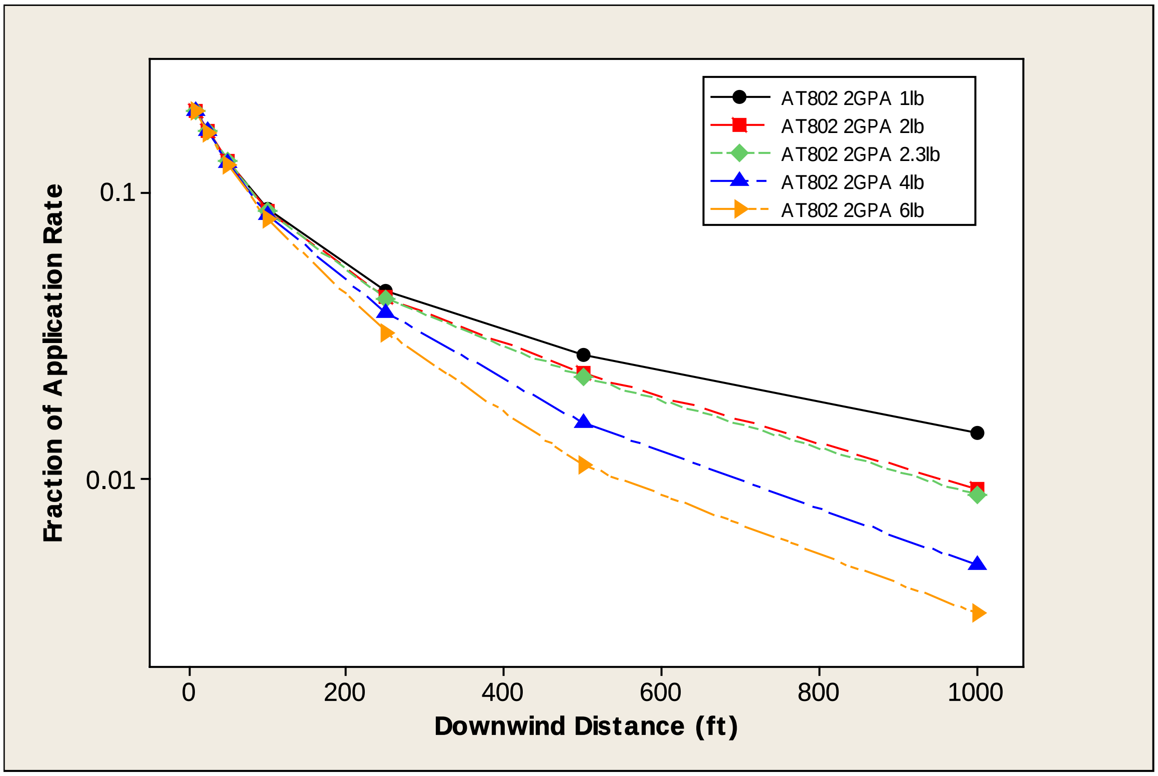


Figure 10. Effect of application rate on aerial application downwind horizontal deposition expresses as a fraction of application rate. The AT802A aircraft was used for these simulations. The simulation inputs are shown in Table 3.



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