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PLUME RISE ASSESSMENT ENERGY FROM WASTE FACILITY

ENERGY FROM WASTE FACILITY

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Completed Form 1247	

1. INTRODUCTION

The Next Generation (NSW) Pty Ltd lodged an Environmental Impact Statement (EIS) for a proposed Energy from Waste (EfW) facility at Eastern Creek, NSW (Urbis, 2015). During the exhibition period for the EIS, submissions were received from Government Agencies and the public. The Department of Infrastructure and Regional Development (DIRD) provided a submission as the responsible agency for the Western Sydney Airport, proposed at Badgerys Creek, approximately 14km southwest of the EfW site. The submission raised the issue of aviation safety, both in terms of physical obstacles to aircraft and the potential for plume rise from the exhaust stacks to cause hazards to aircraft operations. Further assessment was recommended to determine if proposed structures might intrude into declared airspace and whether plume rise from the exhaust stacks might pose a hazard to aircraft approaching from the northeast.

To response to this submission, the proponent has commissioned an aviation assessment, which has determined the likely future airspace requirements for the proposed Western Sydney Airport.

Ramboll Environ Australia Pty Ltd (Ramboll Environ) has been commissioned to complete a plume rise assessment, to assess the critical plume height associated with the operation of the EfW facility, in accordance with the Civil Aviation Safety Authority (CASA) requirements.

The plume rise assessment has been revised in 2017 (this report) to reflect development for Stage 1 only, which would treat a maximum of 552,500 tonnes. The main update for the Stage 1 development, relevant to this plume rise assessment, is the change from two stack locations to a single stack location.

1.1 Background to assessment requirements

In November 2012, the Civil Aviation Safety Authority (CASA) issued a revised Advisory Circular (AC 139-5(1)) for plume rise assessment. The revised AC updates AC 139-5(0) and introduces a new procedure for plume rise assessment, as follows:

- Completion of Form 1247 by the proponent.
- Assessment of the critical plume velocity (CPV).
- Assessment of the critical plume height (CPH).
- Assessment of the impact of the plume.
- Implementation of mitigation.

Following completion of Form 1247, CASA use a screening tool to determine the critical plume height (CPH) and critical plume velocity (CPV) for a proposed facility. However during consultation completed as part of the EIS, CASA were unable to obtain information from DIRD on the Western Sydney Airport and therefore unable to assess plume rise using their screening tool. A completed Form 1247 is provided in **Appendix 1**, however, a plume rise assessment is also presented in this report, following the requirements outlined in AC 139-5(1) and the accompanying "Plume Rise Assessments - Technical Brief".

The Technical Brief contains less detail on the requirements for plume rise assessment than what was outlined in Attachment A of the previous AC 139-5(0). The requirements in the Technical Brief are summarised below:

- A detailed plume rise assessment should determine the Critical Plume Height (CPH) for a facility.
- The modelling must include meteorological conditions representing every hour of a five year period.
- The frequency of the CPH should be analysed to calculate the 0.1% exceedence level for each year.
- The maximum lateral extent of the plume should also be calculated for each year.
- TAPM (The Air Pollution Model) Version 4 (or later) is a suitable model.
- Buoyancy enhancement due to multiple plumes should be considered using the methodology described by Manins et al (1992)

It is noted that guidance in the previous AC 139-5(0) required that plume analysis should consider average plume velocities. This is important when considering the interpretation of results presented in **Section 4**.

2. OVERVIEW OF ASSESSMENT

2.1 Critical plume velocity

The critical plume velocity (CPV) is the vertical velocity of the plume that may affect the handling characteristics of an aircraft in flight, potentially causing a momentary loss of control.

The CPV is either 4.3 m/s or 10.6 m/s, determined by CASA based on the type of operations at a location and potential risk. For the purposes of this assessment, it is assumed that the CPV would be 4.3 m/s.

2.2 Modelled stack parameters

The revised Stage 1 development will have a single stack location, with two adjacent stack ducts separated by a few meters. The location and configuration of the modelled stack are presented in **Table 2-1**.

Table 2-1: Stack parameters for plume rise modelling		
Parameter	Stack Location 1	
	Duct 1	Duct 2
Easting, Northing (m MGA)	298633 6257734	
Latitude, Longitude (decimal degrees)	-33.801426083 150.824722167	
Height above ground (m)	100	100
Stack diameter (m)	2.2	2.2
Stack exit Velocity	21.7	21.7
Stack exit temperature (degC)	120	120
Ground elevation (m AHD)	~62.5	
Stack heights (m AHD)	~162.5	
Note: Ducts are separated by a few metres		

2.3 Modelling approach

The Air Pollution Model, or TAPM, is a three-dimensional meteorological and air pollution model developed by the CSIRO Division of Atmospheric Research. A detailed description of TAPM and its performance can be found in Hurley (2008) and Hurley et al. (2009). TAPM uses fundamental fluid dynamics and scalar transport equations to predict meteorology and pollutant concentrations. It consists of coupled prognostic meteorological and air pollution concentration components. The model predicts airflows that are important to local-scale air pollution, such as sea breezes and terrain induced flows, against a background of larger scale meteorology provided by synoptic analyses.

TAPM was used to predict plume rise from the proposed facility. In accordance with the technical brief, five years of hourly meteorology were modelled and results are presented for each year. The most recent five years (2010 – 2014) were modelled¹. TAPM allows for surface level observation data from nearby meteorological stations to be included in the modelling, referred to as data assimilation. In generating observation files for data assimilation, TAPM requires the used to indicate the number of vertical model levels to assimilate each side of the nearest model level to the observation. It would be unusual to 'nudge' the model with observations beyond the first few vertical model levels, say beyond 50m. Surface measurements of wind speed at 10m would not influence wind speeds at stack height (100m) and therefore were not included for this assessment. There is no requirement from CASA to include data assimilation for plume rise modelling. The TAPM model settings are listed in **Table 2**.

Table 2: TAPM settings	
Parameter	Setting
Model Version	TAPM v.4.0.4
Number of grids (spacing)	4 (30km, 10km, 3km, 1km)
Number of grid points (nx,ny)	25 x 25
Vertical grids / vertical extent	25 / 8000m (~400mb)
Centre of analysis (local coordinates)	298633, 6257734
Year of analysis	2010 - 2014
Terrain and landuse	Default TAPM values based on land-use and soils data sets from Geoscience Australia and the US Geological Survey, Earth Resources Observation Systems (EROS) Data Center Distributed Active Archive Center (EDC DAAC).

¹ The most recent 5 year period at the time of the original plume rise assessment (September 2015)

2.4 Buoyancy enhancement

The assessment of plume rise from multiple stacks is assessed by applying a buoyancy enhancement factor to account for the merging of the plumes. The procedure for deriving a buoyancy enhancement factor is described in Manins et al (1992) and has been adopted for this assessment, described as follows.

A single stack duct was modelled using TAPM without buoyancy enhancement. The final plume rise heights were analysed for each of the five years to obtain the highest average final plume rise height for a single plume. The average final plume rise was applied to the procedure described in Manins et al (1992) to obtain a buoyancy enhancement factor, which is then used in a second model run to simulate the enhanced plume rise. The procedure is outlined in equations 1 – 3 below.

Step 1 – derive a dimensionless separation factor (S) where:	$S = 6 \times \left[\frac{(N - 1)\Delta s}{N^{1/3} \times \Delta z} \right]^{3/2}$ <i>N = number of stacks</i> <i>Δs = spacing between stacks</i> <i>Δz = rise of an individual plume</i>	Eq.1
Step 2 – derive the effective number of stacks (N_E)	$N_E = \left[\frac{N + S}{1 + S} \right]$	Eq.2
Step 3 - derive the rise enhancement factor (E_N) ²	$E_N = N_E^{1/3} < N^{1/3}$	Eq.3

The buoyancy enhancement procedure described in Manins et al (1992) is valid for identical and evenly spaced stacks and is used to derive a buoyancy enhancement factor of 1.3 for the adjacent stack ducts. It is noted that Hibberd et al (2005) describes how the merging of buoyant plumes from each flue in a multi flue stack can be taken into account in modelling either by using buoyancy enhancement factors, or equivalently, by treating them as a combined source.

² Manins et al (1992) clearly defines N_E as the effective number of stacks. Rise enhancement is defined in Manins et al (1992) as the ratio of the rise of the combined plume to the rise of a single plume and the rise enhancement factor (E_N) is then taken as the lesser of $N_E^{1/3}$ or $N^{1/3}$ (where N is the number of stacks). Manins et al (1992) also notes that the maximum rise enhancement factor for N stacks would be $N^{1/3}$, if all the emitted buoyancy were to be completely combined.

3. OVERVIEW OF PRESCRIBED AIRSPACE

The prescribed airspace for the Western Sydney Airport has yet to be prescribed, therefore Airspace Design Solutions has been commissioned to determine the likely future airspace requirements for the proposed Western Sydney Airport (ADC, 2015). Prescribed airspace is defined by the Obstacle Limitation Surface (OLS) and PAN-OPS protection surfaces. For the purpose of this assessment, plume rise is assessed against the OLS.

The aviation assessment indicates that due to the positioning of the proposed EfW facility on the proposed runways extended centreline, penetrations of the OLS would generally not be tolerated, and plume rise is generally considered in the same manner as physical obstacles for aviation safety (ADC, 2015).

Based on a desktop review of the information available for the Western Sydney Airport, the aviation assessment has determined the most critical surface in relation to the OLS would be the Outer Horizontal Surface, estimated to be approximately 223 m AHD. This OLS of 223 m AHD is used for the assessment of plume rise.

4. PLUME RISE RESULTS

4.1 Analysis of all critical plume heights

The gradual plume rise output file from TAPM has been analysed to obtain the critical plume heights (CPH) for the proposed facility. The CPH are defined as the heights where the plume vertical velocity is greater than 4.3 m/s and therefore may impact handling characteristics of aircraft in flight.

For each year of modelling, all heights where the vertical velocity is ≥ 4.3 m/s were extracted and the minimum, maximum and average CPH are presented in **Table 4-1**. TAPM outputs are given in height above ground level (AGL), therefore the heights in AGL are converted to AHD by adding a ground elevation of 62.5 m. For all years, the average CPH is below the OLS, however the maximum is above the OLS for each year.

The CASA technical brief requires “the frequency of the CPH should be analysed to calculate the 0.1% exceedence level for each year”. Therefore, the 99.9th percentile of all CPH model results is presented in **Table 4-1**, representing in 2010, for example, the 14th highest critical plume height. Also presented is the 99th and 95th percentiles of all CPH. A frequency distribution of the critical plume heights is presented in **Figure 1**. The plot shows that less than 5% of all critical plume heights are greater than the OLS.

Table 4-1: Critical plume heights where plume vertical velocity is greater than 4.3 m/s						
Statistic	CPH (m AHD)					OLS (m AHD)
	2010	2011	2012	2013	2014	
Minimum	172	172	172	172	172	223
Maximum	319	296	291	311	302	
Average	179	178	179	180	179	
Median	174	173	174	174	173	
99.9 th ile	297	265	270	285	240	
99 th ile	249	234	238	242	240	
95 th ile	206	203	208	209	205	

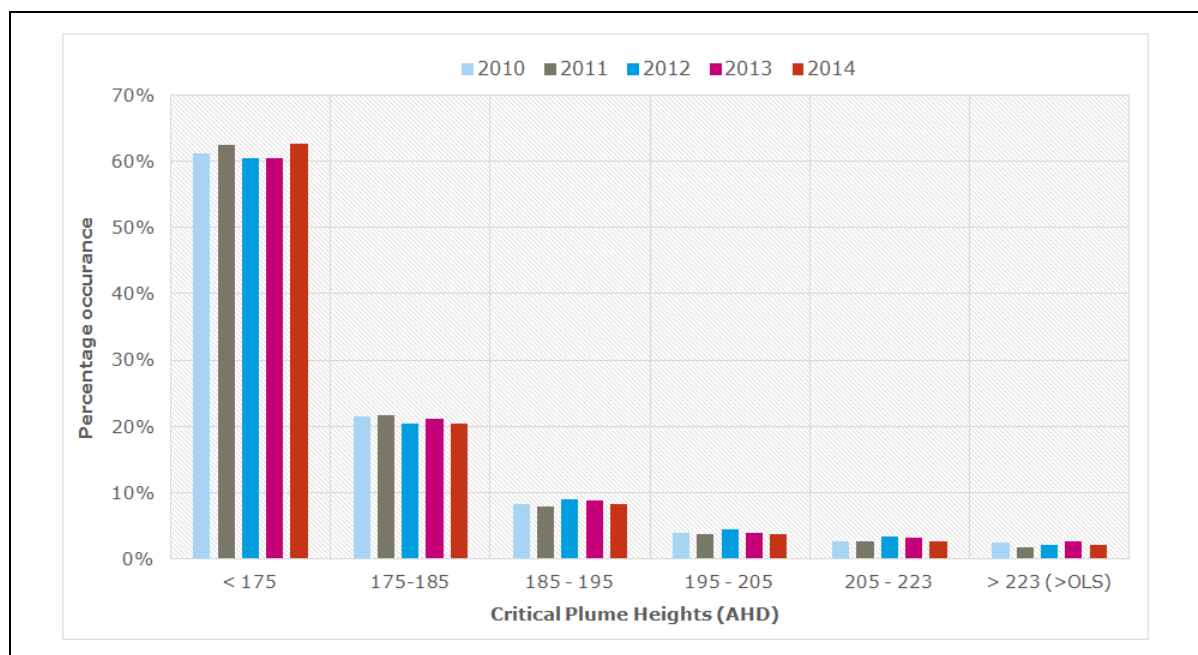


Figure 1: Frequency distribution of all CPH model results

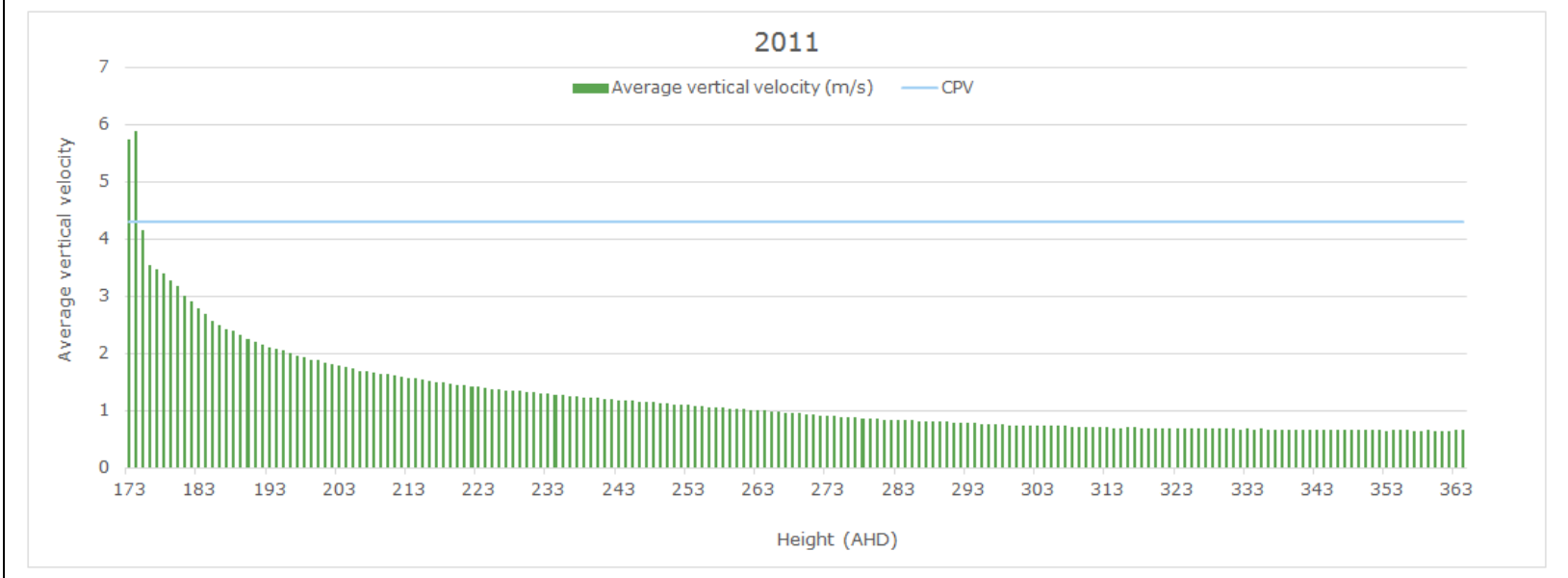
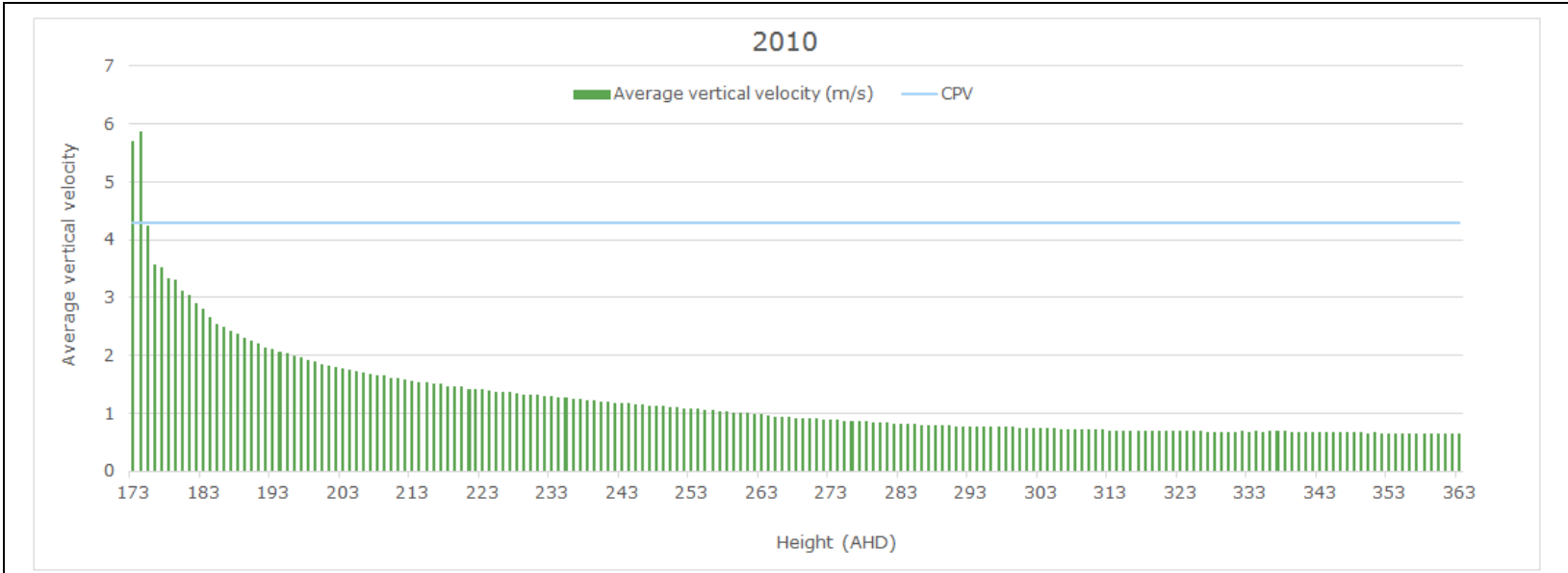
4.2 Analysis of average plume velocity and frequency of occurrence of CPV

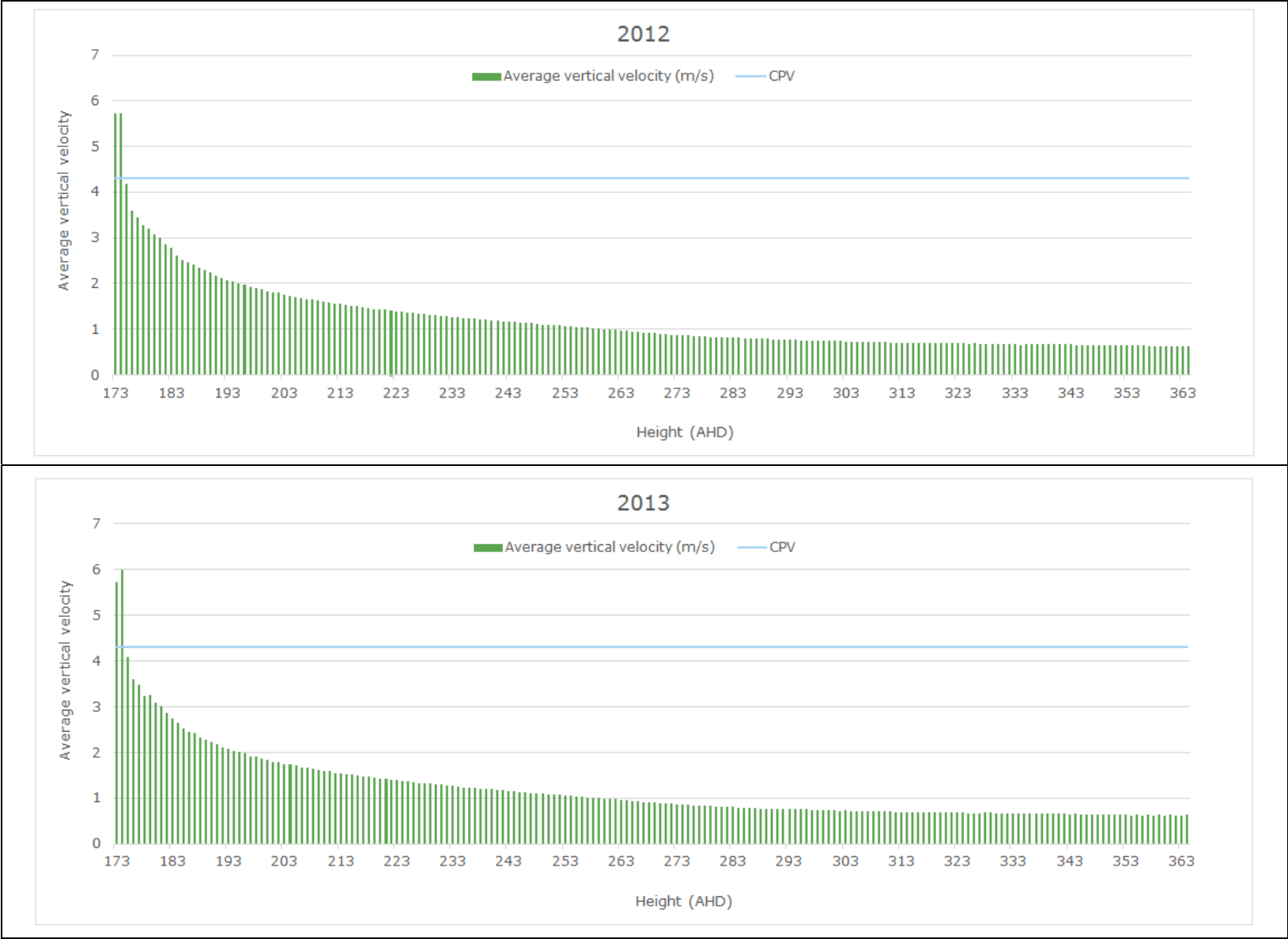
It is noted that previous CASA guidance used different wording for plume analysis, requiring heights above the ground where the average vertical velocity exceeds 4.3 m/s for various percentages of the time (i.e. 100%, 50%, 0.1%). The analysis in **Section 4.1** is presented for all critical plume heights and vertical velocities ≥ 4.3 m/s, i.e. plume velocity is not averaged by height or presented as a frequency of occurrence by height.

Additional analysis is presented in **Figure 2**, showing the plume velocity averaged by height. The plots clearly show that average plume velocity is well below the OLS of 223 m AHD for all years of analysis.

The frequency of occurrence of the critical plume velocity is presented in **Figure 3** for various selected heights. The plots show that the percentage occurrence of critical plume velocities above 4.3 m/s at the OLS of 223 m AHD is very small and difficult to see in the plots. Therefore the percentage occurrence of critical plume velocities above 4.3 m/s at the OLS also presented in **Table 4-2**.

Table 4-2: Percentage occurrence of plume vertical velocity greater than 4.3 m/s at OLS (223m AHD)				
2010	2011	2012	2013	2014
0.21%	0.1%	0.13%	0.13%	0.18%
Percentage value represents the critical plume velocities as the proportion of all plume velocities at each height				





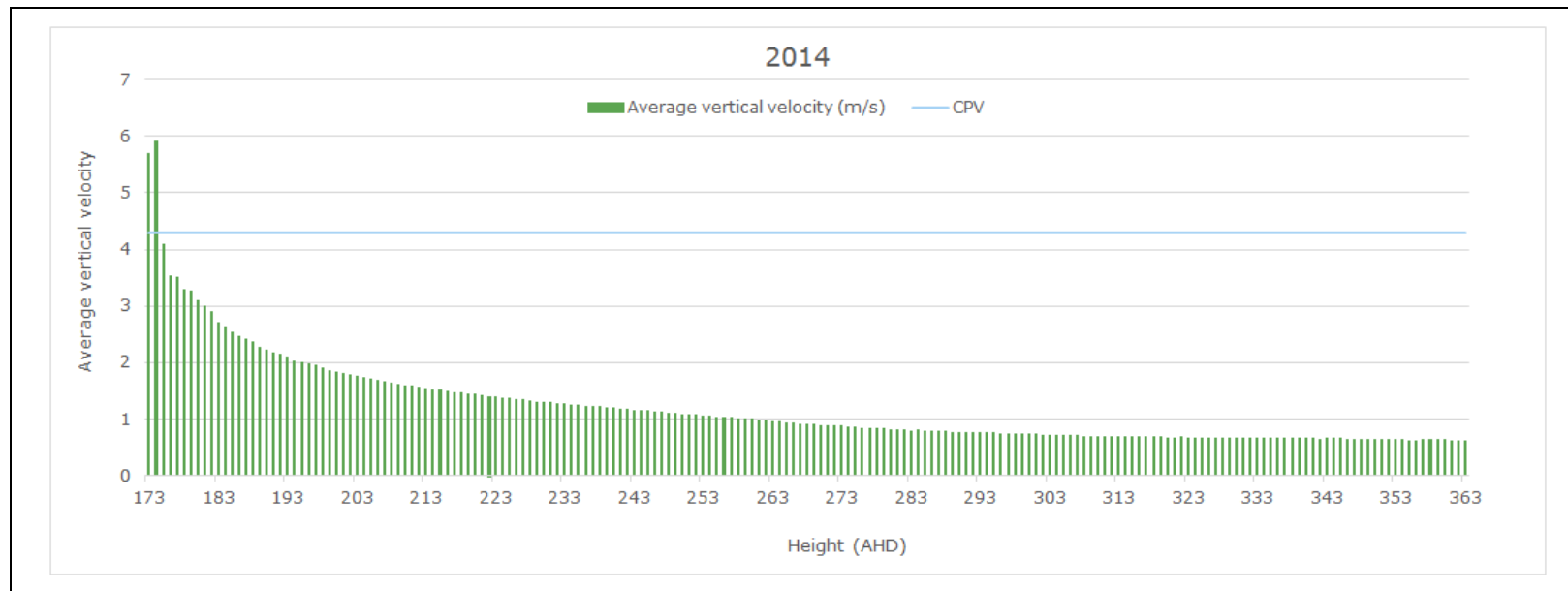
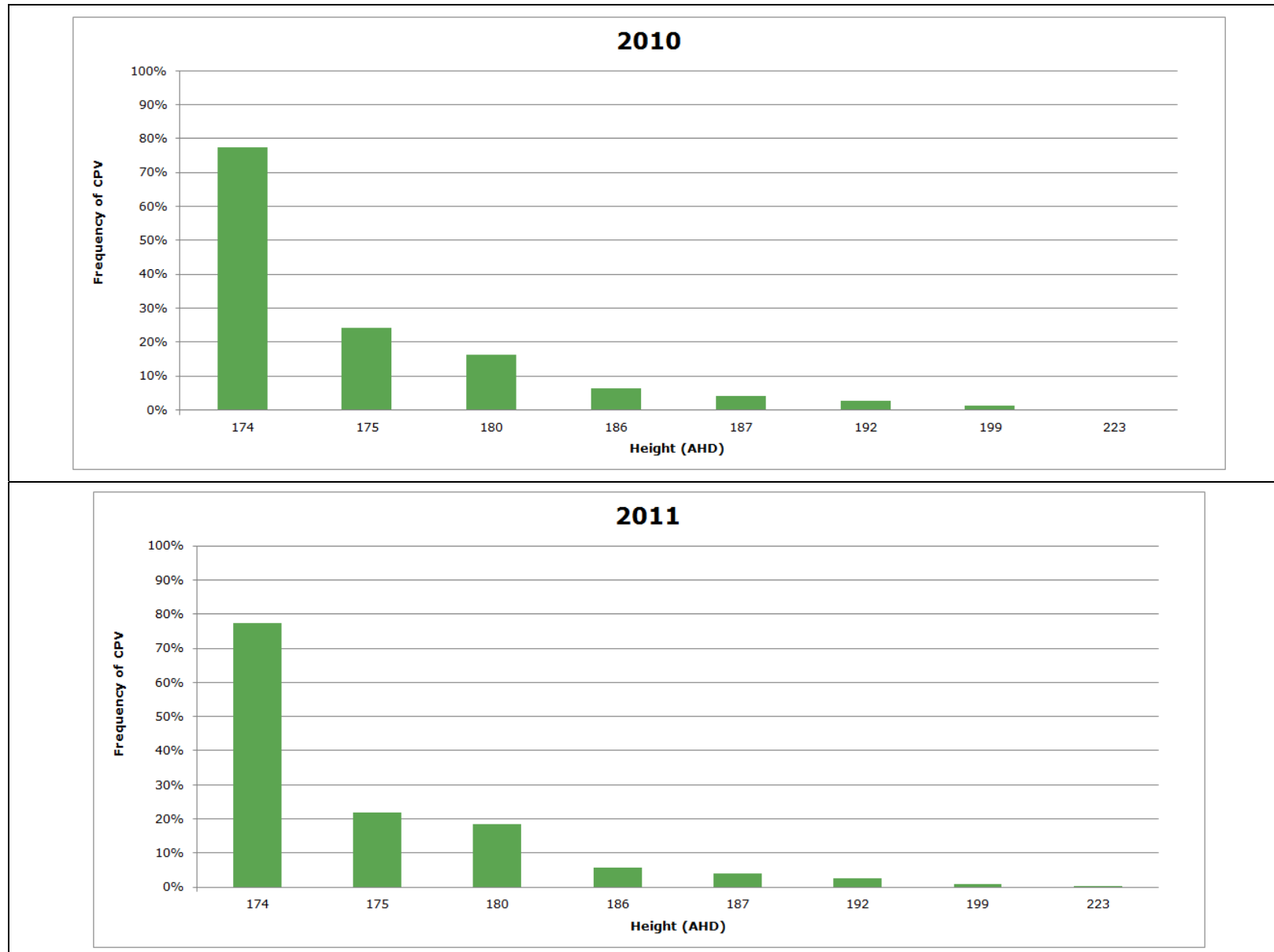
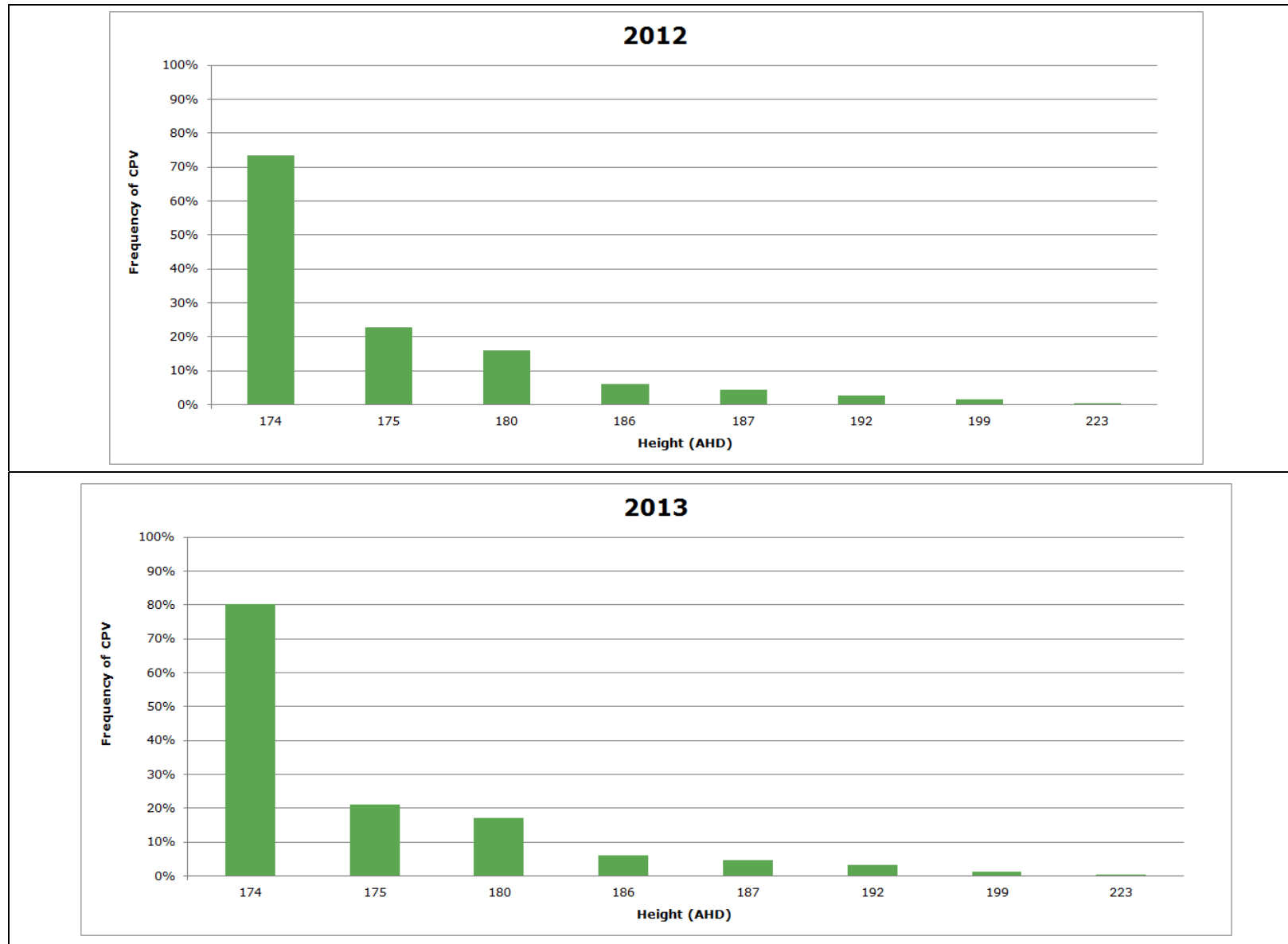


Figure 2: Plume velocity averaged by height





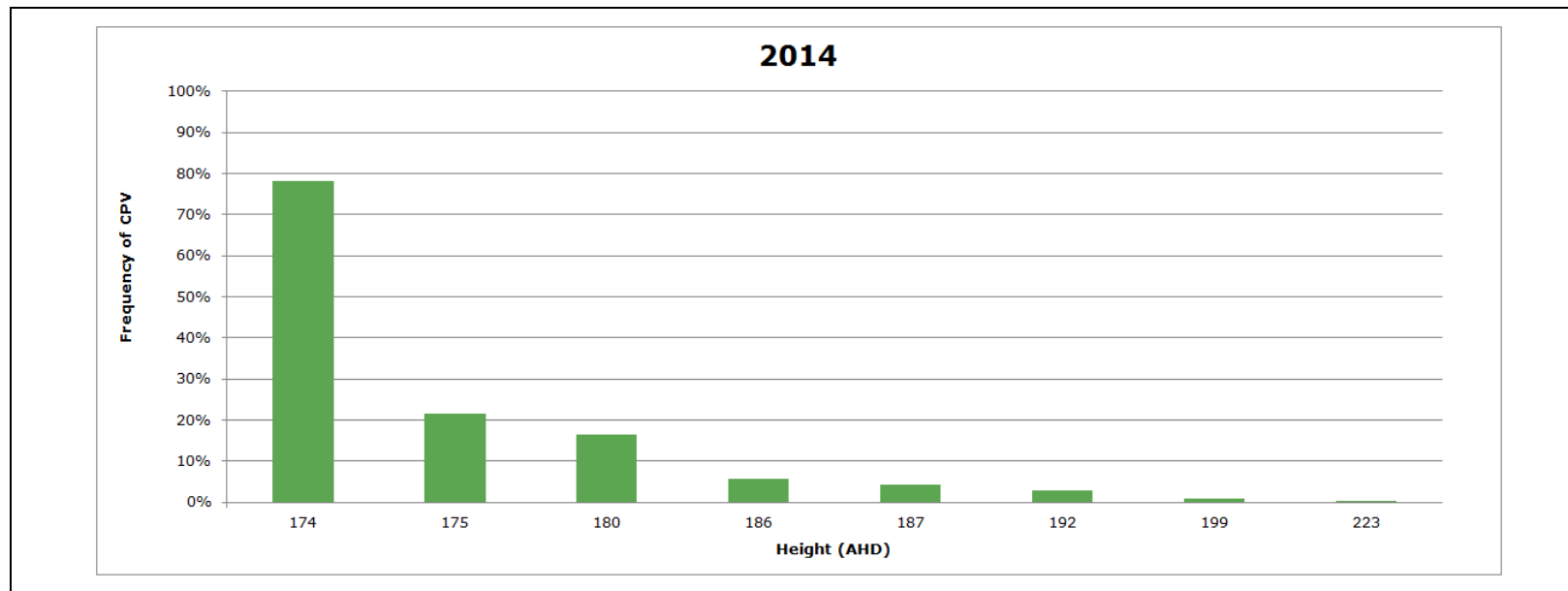


Figure 3: Frequency of CPV at various heights

4.3 Plume displacement

The gradual plume rise output file provides information on the lateral plume radius (R_y) and the west-east and south-north plume distance from source (D_x and D_y). These data can be interpreted to derive the maximum plume displacement for all CPH (the maximum plume displacement for heights where the vertical velocities are greater than 4.3 m/s). D_x and D_y are combined to derive the distance that the plume travels and added to the plume radius to get the maximum plume displacement.

The results are presented in **Table 4-3**. The penetration of the OLS by a vertical velocity in excess of 4.3 m/s occurs for only a very small area in the immediate vicinity of the stacks. The maximum plume displacement of 26m in any direction is presented visually in **Figure 4**.

Table 4-3: Maximum plume displacement where plume vertical velocity is greater than 4.3 m/s					
Statistic	Plume displacement (m)				
	2010	2011	2012	2013	2014
Maximum	26	26	25	26	26

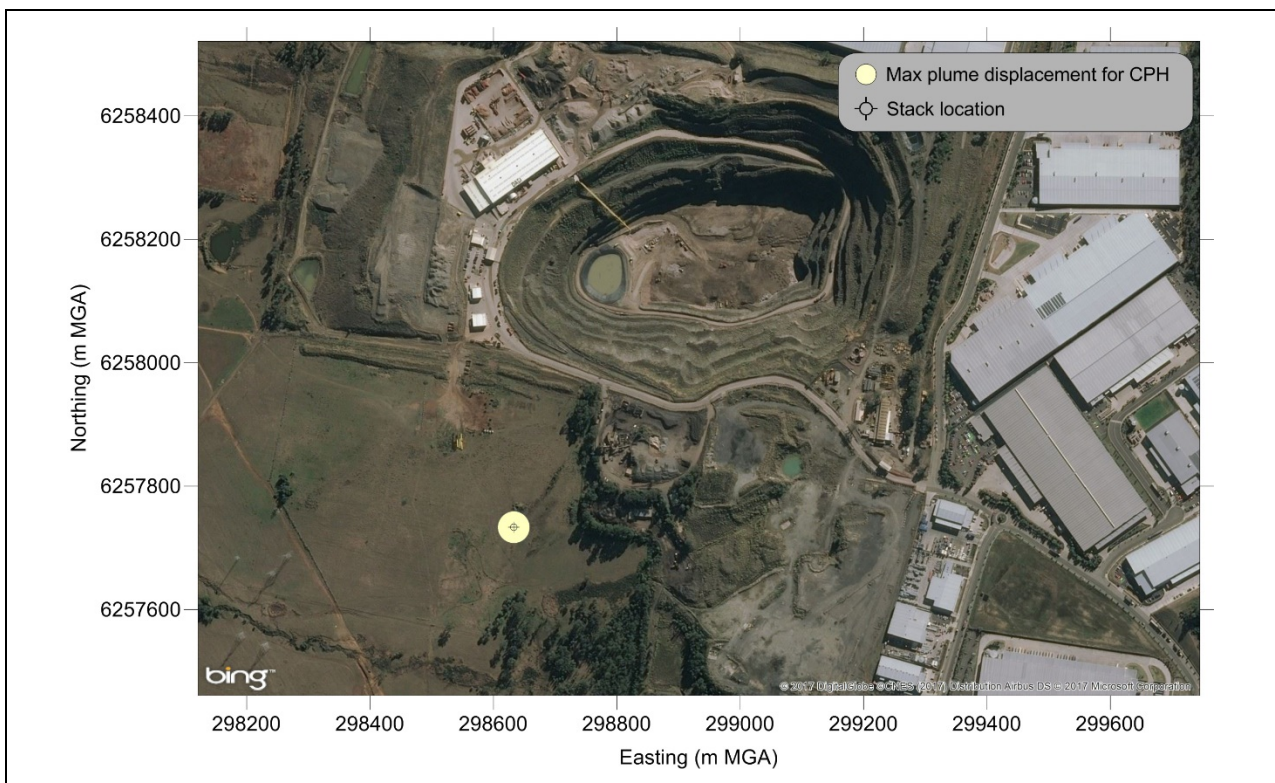


Figure 4: Maximum plume displacement for CPH

5. CONCLUSION

In the absence of prescribed airspace for the proposed Western Sydney Airport, an aviation assessment was commissioned to determine the likely future airspace requirements. Based on a desktop review an obstacle limitation surface (OLS) of approximately 223 m AHD has been derived. The OLS is compared against the critical plume heights, defined as the heights where the plume vertical velocity is greater than 4.3 m/s (the critical plume velocity).

Plume rise modelling indicates that the average critical plume height is below the OLS for each year modelled. The maximum critical plume height is above the OLS, however less than 5% of all critical plume heights are greater than the OLS.

Plots of the plume velocity averaged by height clearly show that average plume velocity is well below the OLS for all years of analysis. Also, the percentage occurrence of critical plume velocities above 4.3 m/s, at the OLS is very small (0.1%-0.2% for all years). Finally, the penetration of the OLS by critical plume heights occurs for only a very small area in the immediate vicinity of the stacks.

Where plume rise from a new facility has the potential to exceed the critical plume velocity, the CASA Advisory Circular lists mitigation measures that might include inserting a symbol of aviation charts to enhance awareness of plume rise or designation of a danger area or restricted area.

6. REFERENCES

ADS (2015). Aviation Assessment of Proposed Energy from Waste Facility, Eastern Creek. 11 September 2015.

Fichtner (2015). The Next Generation (TNG EFW) Energy from Waste Facility, Eastern Creek. Concept Design Report. 11/03/2015.

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Hurley, P., M. Edwards. (2009) "Evaluation of TAPM V4 for Several Meteorological and Air Pollution Datasets." *Air Quality and Climate Change* 43(3): 19.

Manins, P.C., Carras, J.N., Williams, D.L. (CSIRO) (1992). Plume rise from multiple stacks. *Clean Air Australia* May 1992. Vol 26 Part 2 pp 65-68.

Urbis (2015). Environmental Impact Statement. The Next Generation NSW Energy From Waste Facility, Eastern Creek. April 2015.

APPENDIX 1
COMPLETED FORM 1247



Proponent Details

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Date Submitted	
File Reference: (CASA use only)	

Details of the Proposed Facility and Prior Consultation

Type of facility	Energy from Waste Facility
Location of the nearest town (direction and distance)	Minchinbury, 1.2 km north
Location of the facility in latitude and longitude (degrees, minutes, seconds)	Lat: 33 48 05.1339 Long: 150 49 28.9998
Proximity to any other existing or planned facility that generates a plume rise (if known)	N/A
Distance to the nearest aerodrome or landing area including helicopter landing sites	Sydney Airport - > 15km Bankstown Airport- > 15km Proposed Western Sydney Airport - ~14km
Height of the stack or tallest structure at the site above ground level (AGL)	100 m
Elevation of the location of the facility above mean sea level (AMSL)	64m
Date the facility will commence operation	
For single stacks: Stack exit velocity (metres per second) Stack exit temperature (degrees celsius) Stack radius (metres) Stack height (metres above ground level)	

<p>For multiple stacks please give median, mean and range for each parameter:</p> <p>Stack separation distance (metres) Stack exit velocity (metres per second) Stack exit temperature (degrees celsius) Stack radius (metres) Stack height (metres above ground level)</p>	<p>1 stack locations each having 2 adjacent stack ducts with same parameters.</p> <p>Stack ducts separated by a few meters.</p> <p>Exit velocity = 21.7 m/s Temperature = 120 degC Stack radius = 2.2 m Stack Height = 100m</p>
<p>For facilities with multiple configurations please give the parameters for the worst case scenario:</p> <p>Stack separation distance (metres) Stack exit velocity (metres per second) Stack exit temperature (degrees celsius) Stack radius (metres) Stack height (metres above ground level)</p>	N/A
<p>For facilities with multiple configurations please give the parameters for the normal operating scenario:</p> <p>Stack separation distance (metres) Stack exit velocity (metres per second) Stack exit temperature (degrees celsius) Stack radius (metres) Stack height (metres above ground level)</p>	N/A
<p>Details of any prior consultation with:</p> <ol style="list-style-type: none"> CASA Dept of Defence Aerodrome Operator Other relevant party 	<p>Consultation with CASA and Department of Infrastructure and Development during EIS submission regarding potential impacts on Western Sydney Airport.</p> <p>Consultant with Sydney Airport who indicated that they are not concerned with the development</p>

Submitted By:

Name:	Signature:
Contact Phone:	
Email Address:	
Date:	