MEMORANDUM

To	Amanda Jones, Amanda.jones@energyaustralia.com.au
From	Simon Welchman Simon.welchman@katestone.com.au
Deliverable No.	D19025-45
Subject	Response to CASA Letter
Date	15 June 2021

Dear Amanda,

Katestone has reviewed the Australian Civil Aviation Safety Authority (CASA) letter to the New South Wales (NSW) Department of Planning, Industry and Environment (DPE) dated 29 March 2021. The letter provides CASA's comments on the GHD Peer Review of the Tallawarra B Power Station Supplementary Plume Rise Assessment.

The Attachment to this memorandum provides Katestone's comments where CASA disagrees with the findings of the GHD peer review.

The main disagreement is that CASA does not consider the meteorological parameters used in the CFD model to be representative of the 99.9th plume rise height. CASA's expectation is that a calm wind scenario should have been used to determine the 99.9th percentile plume rise height.

Katestone disagrees that the 99.9th percentile plume rise height necessarily occurs under calm winds, Katestone has worked with Stacey Agnew to identify calm wind scenarios for further CFD modelling. The method that has been used to determine the calm wind scenarios is detailed in the Attachment.

Stacey Agnew has subsequently completed additional CFD modelling of a calm scenario and a hypothetical worst-case scenario (equivalent to the 99.98th percentile), the results of which are summarised below and in the Attachment. A copy of Stacey Agnew's report (Stacey Agnew, 2021) accompanies this memorandum.

Katestone notes that CASA does not support the "top hat" method of calculating the average plume velocity in the context of CFD modelling that was postulated in the previous CFD modelling (Stacey Agnew, 2020). Rather, CASA prefers GHD's suggested methodology whereby the average plume velocity is calculated by dividing the peak velocity by two. In this regard, CASA makes the following statements in its letter of 29 March 2021:

> *"…GHD states that reporting of the maximum CFD estimated plume velocity and equating half of its value to the critical plume velocity (sic) is a very simple approach that is likely to be conservative and removes the need to define the plume edge.*
>
> *CASA agrees with GHD and will accept half the maximum CFD derived plume velocity as the plume velocity for that altitude."*

The results of Stacey Agnew's previous CFD modelling (Stacey Agnew, 2020) and the results of the calm wind scenarios are summarised in Table 1, which shows peak vertical velocities at 650 ft, 700 ft and 1000 ft. Table 1 compares the previous CFD modelling results (CFD 1) with two calm wind scenarios: CFD 2 and CFD 3 (hypothetical worst-case scenario).

Table 1 **Peak vertical velocities at 650 ft, 700 ft and 1,000 ft for three meteorological scenarios produced by CFD modelling conducted by Stacey Agnew**

Scenario	Case	Average meteorological conditions: 654 ft to 818 ft		Peak vertical plume velocity (m/s)		
		Wind speed (m/s)	Temperature (°C)	650 ft	700 ft	1,000 ft
CFD 1	Previous (Stacey Agnew, 2020)	2	14.6	11.5	11.5	10.7
CFD 2	Calm wind	0.4	20.7	8.4	8.1	7.3
CFD 3	Hypothetical worst-case	0.4	14.6	11.8	11.6	10.4

Average vertical velocities are presented in Table 2, which have been calculated by dividing the peak velocity from the CFD model by 2 as recommended by CASA in its letter of 29 March 2021 and GHD in its peer review of the previous CFD modelling.

Table 2 **Average vertical velocities at 650 ft, 700 ft and 1,000 ft for three meteorological profiles produced from peak vertical velocities obtained by CFD modelling conducted by Stacey Agnew**

Scenario	Case	Average 654 ft to 818 ft		Average plume vertical velocity (m/s)		
		Wind speed (m/s)	Temperature (°C)	650 ft	700 ft	1,000 ft
CFD 1	Previous (Stacey Agnew, 2020)	2	14.6	5.8	5.8	5.4
CFD 2	Calm wind	0.4	20.7	4.2	4.1	3.7
CFD 3	Hypothetical worst-case	0.4	14.6	5.9	5.8	5.2

The results show that for all CFD scenarios, average vertical velocities are predicted to be below CASA's critical plume velocity of 6.1 m/s when calculated using CASA's preferred methodology of dividing the peak velocity by 2. The calm wind scenario (CFD 2) produced significantly lower plume vertical velocities compared with the previous model (CFD 1) that are well below CASA's critical plume velocity of 6.1 m/s. This lower plume vertical velocity occurs in conjunction with higher ambient air temperatures resulting in the horizontal jet from the PDD travelling further away from the stack prior to the plume buoyancy causing the plume to ascend. The greater horizontal displacement of the jets means that the strands of the plume once travelling vertically do not tend to merge until they are cooler and reach a higher elevation.

The hypothetical worst-case CFD model run (CFD 3), which combines calm wind speeds (CFD 2) and a cooler temperature profile (CFD 1), produces vertical velocities that are marginally greater than CFD 1 but are still below CASA's critical plume velocity at 700 ft. CFD 3 shows that average wind speeds below 818 ft do not have a significant effect on the vertical velocity at 700 ft when compared to CFD 1, which has a higher average wind speed. Consequently, the plume velocities for CFD 3 have not been impacted significantly by ambient wind speed compared to the base case (CFD 1).

Please contact the undersigned with any questions or queries.

Yours sincerely,

Simon Welchman - Director

ATTACHMENT

A1 Responses to CASA Letter Comments

Table A1 Responses to CASA Letter Disagreements

Comment	*GHD Key Conclusion*	*CASA Letter Comment*	Katestone Response
1	The selected meteorological condition for the CFD modelling is representative of worst-case plume rise conditions	Table at Page 2 of CASA letter dated 29 March 2021: This is not correct. We advised NSW DPIE worst case plume rise conditions occur in calm winds. The wind speed applied in the CFD modelling is significantly higher than would be expected for worst case conditions. As GHD correctly noted, "the wind speed between 200 and 300 metres (660 to 980 FT) for the CFD model are higher than those in the top ranked conditions." Figure 4 of the GHD report indicates that between 200 and 300 metres in height, the CFD model used wind speed inputs of approximately 2.5 m/sec. Figure 4 also shows the wind speed used in the CFD model for the critical 700 FT altitude is significantly higher than the wind speed that should have been used. The wind speed inputs that should have been used as revealed by Figure 4 are consistent with previous modelling at Tallawarra which indicates that winds of 0.3m/sec and	Whilst Katestone does not agree with CASA's comments and the conclusions reached, further CFD modelling of calm wind conditions has been conducted later in this document. The reasons for Katestone's disagreement are outlined further as follows. CASA's statement that worst case plume rise conditions occur in calm winds appears to follow CASA's statement earlier in its letter that "…*the 99.9th percentile plume rise would be expected to occur under calm conditions*…" This opinion is also referenced to CASA's letter to NSW DPIE dated 4 February 2021. However, CASA's expectation in this regard is not borne out by Katestone's TAPM modelling and data analysis. Katestone selected the meteorological conditions for CFD modelling from the TAPM modelling. The meteorological conditions that were chosen were those that produce the 99.9th percentile plume rise. Katestone's TAPM modelling and data analysis was based on 5 years of hourly meteorological profiles and estimating the corresponding plume vertical velocities. As detailed in Katestone (2020), a limitation of CFD modelling is that only one set of meteorological profile conditions can be considered in each CFD model. CFD models are computationally

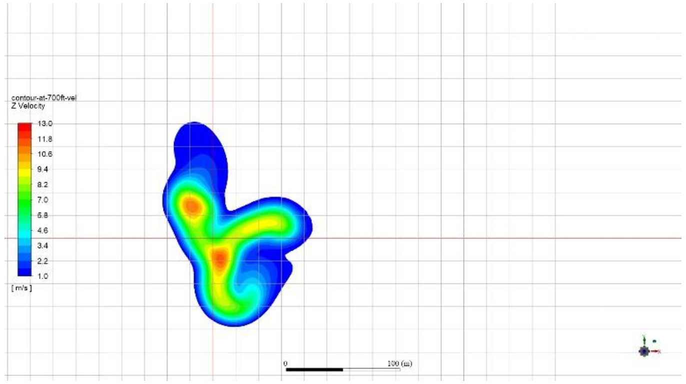
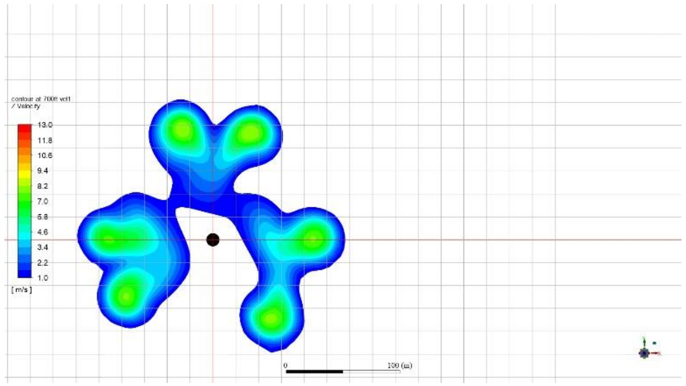
Comment	*GHD Key Conclusion*	*CASA Letter Comment*	Katestone Response
		lower would occur approximately 0.11 % of the time for heights between 656 FT and 984FT. Conclusion at Page 5 of CASA letter dated 29 March 2021: CASA notes that the wind speeds inputs to the CFD model for the critical 700 FT altitude appear to be at least five times higher than in the conditions that would result in the 99.9th percentile plume rise.	intensive and so it is not practical to run 5 years of hourly meteorological profiles in a CFD model. GHD gave particular attention in Section 10 of its peer review to the approach that was taken to determine the meteorological conditions. Katestone provided GHD with all meteorological profiles that were generated by the TAPM modelling for a zero momentum plume rise case. GHD noted that the meteorological data used in the CFD model is "…*equivalent to the 99.85th percentile, for plume rise velocity at 700 ft*". Referring to the potential difference in outcome between the 99.9th percentile and the 99.85th percentile meteorological conditions, GHD states "*This is considered to be an insignificant difference*…". In summary, Section 10.2 of GHD's review states "…*even though the adopted methodology does not comply precisely with the 99.9th percentile requirement, the CFD modelled wind condition, being the 99.85th percentile plume rise condition at 700 ft, will likely have insignificant impact on the outcome of the plume rise study. Re-running the CFD modelling for this reason alone would not be warranted.*" Whilst at Page 1 of GHD's peer review, the finding with respect to the CFD meteorological conditions are summarised as *"…The selected meteorological condition for the CFD modelling is representative of worst-case plume rise conditions"*, this finding must be read in the context of Section 10 of GHD's peer review, which refers to the 99.9th percentile meteorological conditions. Whilst a calm wind profile could be used to test the sensitivity of the outcome, Katestone's meteorological modelling of the

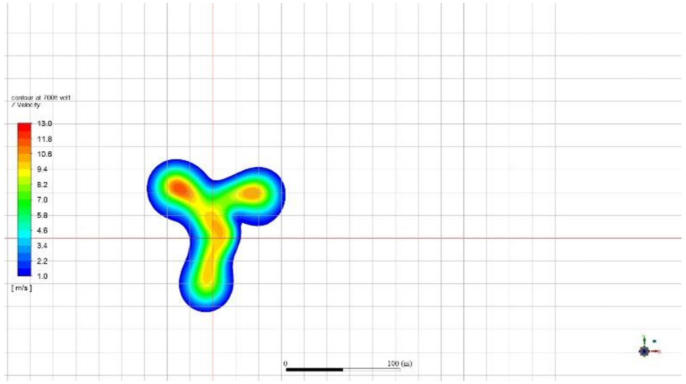
Comment	*GHD Key Conclusion*	*CASA Letter Comment*	Katestone Response
			Tallawarra B Power Station shows that the 99.9th percentile plume rise does not occur under calm wind conditions. Further analysis of the wind profiles associated with the 99.9th percentile (and higher percentiles) plume rise heights is provided below and shows that average wind speed at around 700 ft ranges from 0.05m/s to 1.85m/s with no obvious relationship between wind speed and the rank of vertical velocity (see Table A3 below).
2	Based on the assumptions underlying. the CASA plume rise assessment methodology, compliance with the CASA specified default 6.1 m/s critical plume velocity has been demonstrated.	This is not correct. The outputs of the modelling are based on the use of wind speeds that are at least five times greater than what would be expected at 700 FT to produce the 99.9th percentile plume. When wind speeds of this magnitude are used as inputs in modelling instead of the calm winds that would be expected at this altitude, the outputs would incorrectly produce outputs showing lower plume velocities. Please refer to Attachment A which is an extract from a paper prepared by experts from Katestone Environmental which expands on the above point with examples.	Although Katestone does not agree with CASA's comments, further CFD modelling of calm wind conditions has been conducted later in this document. The reasons for Katestone's disagreement are outlined further as follows. CASA's statement that the outputs are based on wind speeds that are five times greater than would be expected to produce the 99.9th percentile plume rise are incorrect as detailed in response to Comment 1. The outputs of the CFD model were generated using a meteorological profile that resulted in the 99.9th percentile plume height over 5 years of hourly TAPM modelling. The CFD model output shows compliance with the 6.1 m/s critical plume velocity, as stated by GHD in its peer review. The information provided in Attachment A to CASA's letter is a paper prepared by Katestone in 2003, which illustrates amongst other things, the importance of accounting for merging of multiple plumes. To make this point, it presents plume vertical velocities for a single stack and two stacks operating in a simplified atmosphere with uniform winds of varying velocities (calm (0 m/s), 1.5 m/s and 3m/s and unbounded atmosphere. Because

Comment	*GHD Key Conclusion*	*CASA Letter Comment*	Katestone Response
			the results are presented for a simplified atmosphere, they cannot be related to the 99.9th percentile at the subject site. Notwithstanding the comments detailed above, Katestone has worked with Stacey Agnew to identify calm wind scenarios for further CFD modelling, which has been completed by Stacey Agnew. The results of this further CFD modelling are summarised below. Stacey Agnew's detailed report (Stacey Agnew, 2021) accompanies this memorandum.

Table A2 Responses to CASA Letter other matters

Comment	*Other CASA Letter Comment*	Katestone Response
1	CASA had recommended that NSW DPIE should conduct a verification and validation exercise on the CFD methodology in its letter dated 4 Feb 2021. GHD's examination of the CFD model was limited to model parameters such as solver settings, domain size and mesh resolution. CASA therefore advises that the recommendation was not addressed in the manner we envisaged.	Appendix B of Stacey Agnew's revised CFD report (Stacey Agnew, 2021) contains additional details to assist in the verification and validation of the CFD modelling.
2	GHD states that the maximum vertical velocity value of 10.7m/s is not stated but is left to the educated reader to interpret from Figure 8 in Katestone (2020). This statement is incorrect. The Katestone report states that at 1,000 ft, the maximum vertical velocity is 13 m/s.	The velocity range scale in Figure 8 of the Katestone report is from 0 to 13 m/s. However, GHD is correct in saying that the plume profile image shows that the maximum velocity reaches 10.7 m/s.

Comment	*Other CASA Letter Comment*	Katestone Response
3	CASA advised that: • the EA Report did not include a plume cross sectional analysis at 700 ft AMSL.	Appendix C of Stacey Agnew's revised CFD report (Stacey Agnew, 2021) contains plume cross sectional analysis at 700 ft. The cross-sectional analysis is reproduced below. CFD 1  CFD 2 

Comment	*Other CASA Letter Comment*	Katestone Response
		CFD 3 

A2 Meteorological analysis of 99.9th to maximum plume rise heights

To identify potential candidate profiles of meteorological conditions for a calm wind CFD case, Katestone's zero momentum TAPM modelling has been analysed. The TAPM modelling includes five years of hourly average meteorological conditions, which represents 43,824 hours in total. The 99.9th percentile vertical plume velocities equate to the 44 hours with the highest vertical plume velocities. The date, time and wind speeds associated with the top 44 ranked vertical plume velocities are shown in Table A3.

Note that the zero momentum TAPM scenario simulates the effect of the PDD on the plume that eliminates its initial vertical velocity but it does not simulate the breaking up and horizontal distribution of the plume that is also achieved by the PDD. The plume has near zero initial vertical velocity but buoyancy that is equivalent to the proposed Tallawarra B Power Station plume. Consequently, the vertical velocities that have been predicted by the TAPM model are induced entirely by the plume's buoyancy. However, the TAPM model only allows a single plume to be modelled rather than multiple plumes that result from the PDD. Therefore, the zero momentum TAPM modelling will overpredict vertical velocities that would be produced by the PDD.

The TAPM model allows wind speed and temperatures to be extracted at certain elevations from 33 ft to 26,000 ft. This data cannot be extracted at 700 ft so data from the two nearest elevations, 654 ft and 818 ft, has been extracted.

A calm wind is commonly defined as a wind speed that is less than 1 knot, which is equivalent to 0.51 m/s. Consequently, 0.5 m/s has been used as the threshold to identify calm wind profiles.

The following steps have been taken to determine calm wind profiles for use in the CFD modelling:

- The vertical plume velocity at 700ft was determined from the zero-momentum scenario for each hour of five meteorological years – 43,824 predictions.
- The wind profiles for the top 44 ranked vertical plume velocities were analysed for elevations below 818 ft and the average wind speeds across the following elevations were determined:
  - Less than or equal to 654 ft
  - At 700 ft (average of the two adjacent elevations namely: 654 ft and 818 ft).
- Five cases were chosen for further examination that are nearest to the 99.9th percentile and with average wind speed at 654 ft to 818 ft that is less than or equal to 0.5m/s. Those five cases are shown in bold in Table A3. They are:
  - 1 April 2014 at 05:00 – 0.2 m/s
  - 8 March 2015 at 06:00 – 0.4 m/s
  - 15 July 2015 at 12:00 – 0.05 m/s
  - 6 April 2017 at 09:00 – 0.25 m/s
  - 8 April 2018 at 07:00 – 0.5 m/s.

Table A3 Date and time of the 44 top ranked plume velocities at 700ft and the average wind speeds at <=654 ft and at 700 ft (average of 654 ft to 818 ft)

Rank	Date	Time	Average wind speed	
			<=654 ft	654-818ft
1	05-Jun-17	11:00:00	0.55	0.60
2	22-Sep-14	8:00:00	0.47	0.35
3	27-Aug-16	11:00:00	0.35	0.60
4	19-Apr-16	10:00:00	0.67	0.25
5	20-Apr-16	9:00:00	0.35	0.35
6	06-Sep-15	9:00:00	0.68	0.20
7	18-Oct-14	8:00:00	0.93	0.30

Rank	Date	Time	Average wind speed	
			<=654 ft	654-818ft
8	23-Apr-17	9:00:00	0.48	0.15
9	09-Nov-17	8:00:00	0.43	0.35
10	06-Nov-14	23:00:00	0.65	0.40
11	01-Jan-18	6:00:00	0.17	0.35
12	23-Aug-14	9:00:00	0.48	0.50
13	19-Jul-16	19:00:00	0.48	0.60
14	10-Dec-17	7:00:00	0.18	0.40
15	26-Sep-18	9:00:00	0.43	0.30
16	13-Sep-14	9:00:00	0.40	0.25
17	27-Aug-15	11:00:00	0.52	0.60
18	18-Apr-17	9:00:00	0.37	0.70
19	26-Mar-17	6:00:00	0.25	0.35
20	09-Apr-16	6:00:00	0.62	0.55
21	08-Apr-18	8:00:00	0.27	0.50
22	12-Aug-16	10:00:00	1.07	1.55
23	17-May-15	10:00:00	0.78	0.30
24	13-Apr-16	9:00:00	0.50	0.55
25	23-Aug-18	9:00:00	0.98	0.25
26	06-Nov-14	22:00:00	0.53	0.90
27	06-Jun-15	10:00:00	0.92	1.35
28	**08-Mar-15**	**6:00:00**	**0.47**	**0.40**
29	29-Jun-17	16:00:00	0.45	0.65
30	**01-Apr-14**	**5:00:00**	**0.60**	**0.20**
31	27-Aug-15	15:00:00	1.65	0.75
32	21-Aug-16	14:00:00	1.57	1.85
33	**06-Apr-17**	**9:00:00**	**0.73**	**0.25**
34	09-Oct-18	7:00:00	0.38	0.70
35	**08-Apr-18**	**7:00:00**	**0.38**	**0.50**
36	20-Aug-17	20:00:00	0.42	0.75
37	01-Jan-18	5:00:00	0.22	0.70
38	05-Feb-18	8:00:00	0.98	0.60
39	12-Mar-14	10:00:00	0.75	1.45
40	**15-Jul-15**	**12:00:00**	**0.05**	**0.05**
41	19-Nov-15	4:00:00	0.35	0.65
42	09-May-18	8:00:00	0.68	0.60
43	18-Apr-16	21:00:00	0.58	0.80
44	04-Jul-14	11:00:00	0.98	0.75
Previous CFD case			0.92	2.05

The data in Table A3 shows that the top 44 cases include instances with average wind speeds that are less than 0.5 m/s (calm) below 700 ft and instances where the average wind speed is greater than 0.5 m/s.

The wind speed profiles up to 1800 ft for five candidate cases and the previous CFD modelling (CFD 1) are plotted in Figure A1 and the temperature profiles are plotted in Figure A2. Figure A1 shows the following:

- Wind speeds are variable across the profile with lighter winds tending to occur at lower elevations and stronger winds occurring at higher elevations.
- The five candidate cases all have average wind speeds at 654 ft - 818 ft that are less than 0.5 m/s.
- Above about 400ft, the wind speed in the previous CFD modelling is higher than the five candidates.

Katestone provided the five candidate meteorological profiles to Stacey Agnew for consideration from a CFD modelling and stability perspective. Following further discussion with Stacey Agnew, the profile from the 8 March 2015 was chosen. Three candidates were not chosen because they had features that would likely be unstable in the CFD model (e.g. wind speeds that fall to 0 m/s, dramatic changes in wind direction with small change in elevation). Whilst the remaining candidate (1 April 2014), has an average wind speed at 654 ft - 818 ft that is less than 0.5 m/s, at elevations below 654 ft the average wind speed is 0.6 m/s, which is greater than that which would be expected for a calm wind and higher than 8 March 2015 (the candidate profile that was chosen).

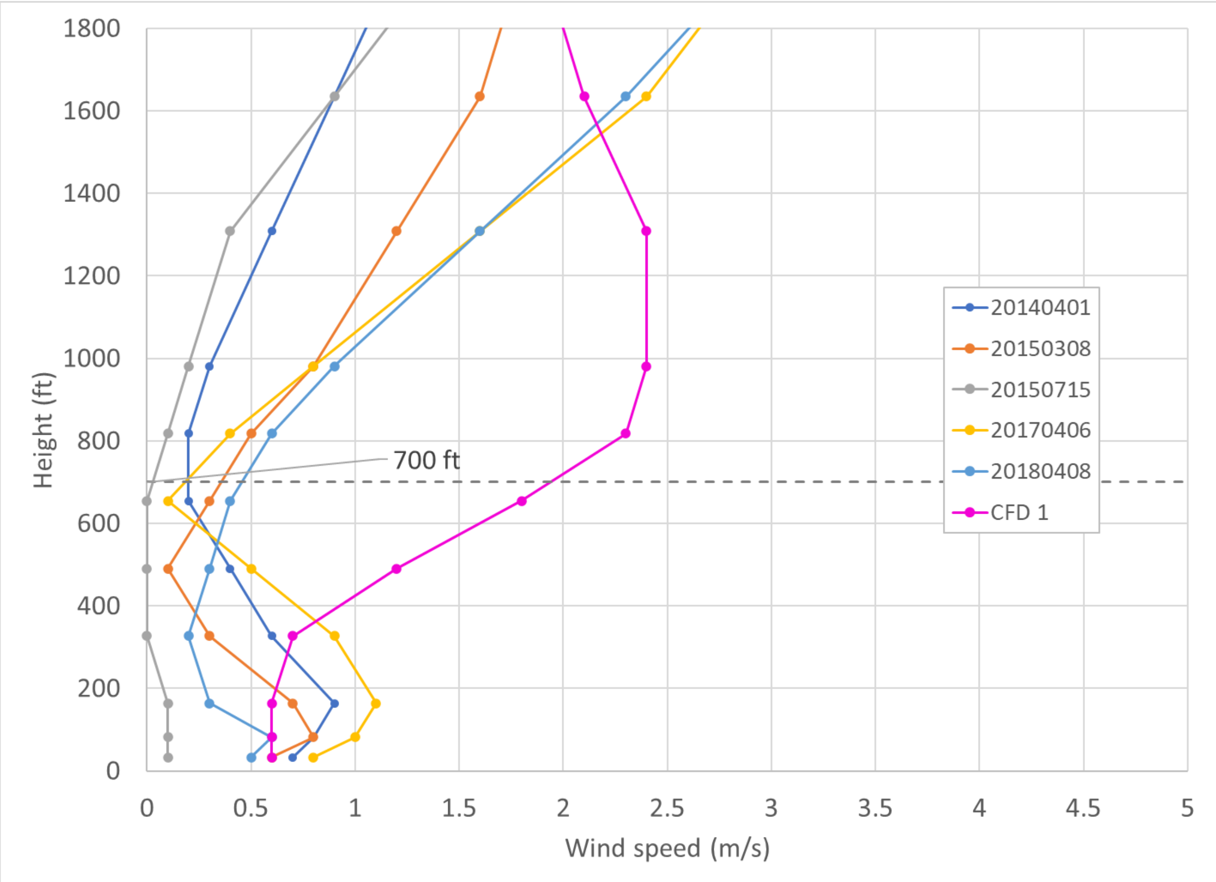


Figure A1 Wind speed profiles for five calm wind CFD candidates compared with previous CFD modelling case (CFD 1)

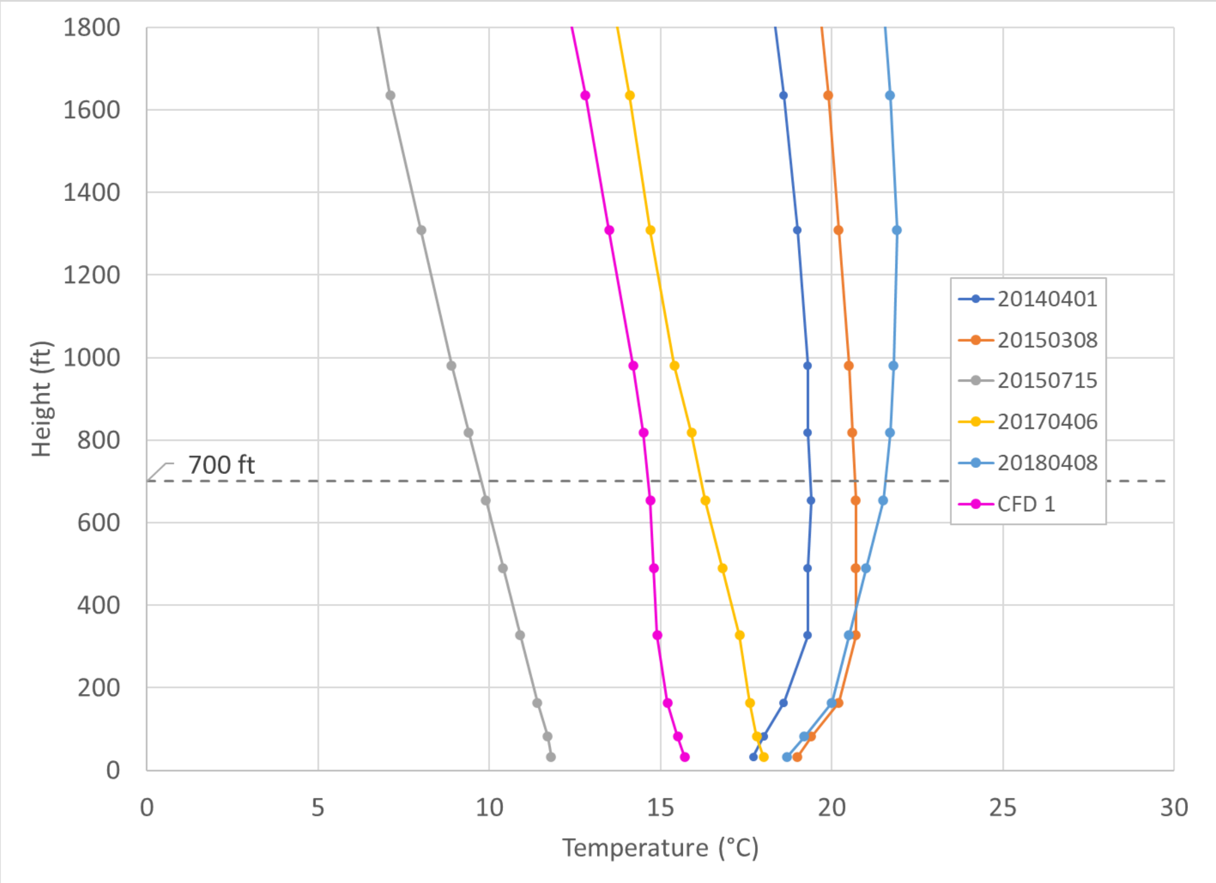


Figure A2 Temperature (°C) profiles for five calm wind CFD candidates compared with previous CFD modelling case (CFD 1)

A third "hypothetical case" (CFD 3) was created by combining the wind speed profile from 8 March 2015 (CFD 2) and the temperature profile from CFD 1. This hypothetical case represents a worst-case scenario. The scenario was constructed to investigate the effect that ambient temperature is likely to have on the plume as it transitions from a horizontal jet into a vertical plume.

Whilst the ambient temperature will also affect the volumetric flowrate of exhaust gases from the PDD, this aspect has not been corrected for in the CFD model. The volumetric flowrate of exhaust gases has been based on the maximum flow rate as per the manufacturer's specification (at 15°C). At lower ambient temperatures, the volumetric flowrate of gases may be reduced.

To provide further context, the average temperature and wind speed from 654 ft to 818 ft from the profiles that have been used for CFD modelling have been compared to the profiles that produce the 44 top ranked plume velocities in the zero momentum TAPM modelling. The comparison shows the following:

- The average temperature for CFD 1 and 3 is the 18th coolest
- The average temperature for CFD 2 is the 40th coolest
- The average wind speed for CFD 1 is stronger than the 44 top ranked cases
- The average wind speed for CFD 2 and 3 is the 17th lightest.

Consequently, CFD 3 represents a combined case of low temperatures and light winds. Of the 44 top ranked plume velocities, there are nine that have both average temperatures and wind speeds that are less than or equal to CFD 3. Consequently, CFD 3 equates to a 99.98th percentile case.

The wind speed and temperature profiles for the 44 top ranked plume velocities in the zero momentum TAPM modelling and the previous CFD case (CFD 1) are shown in Figure A3 and Figure A4.

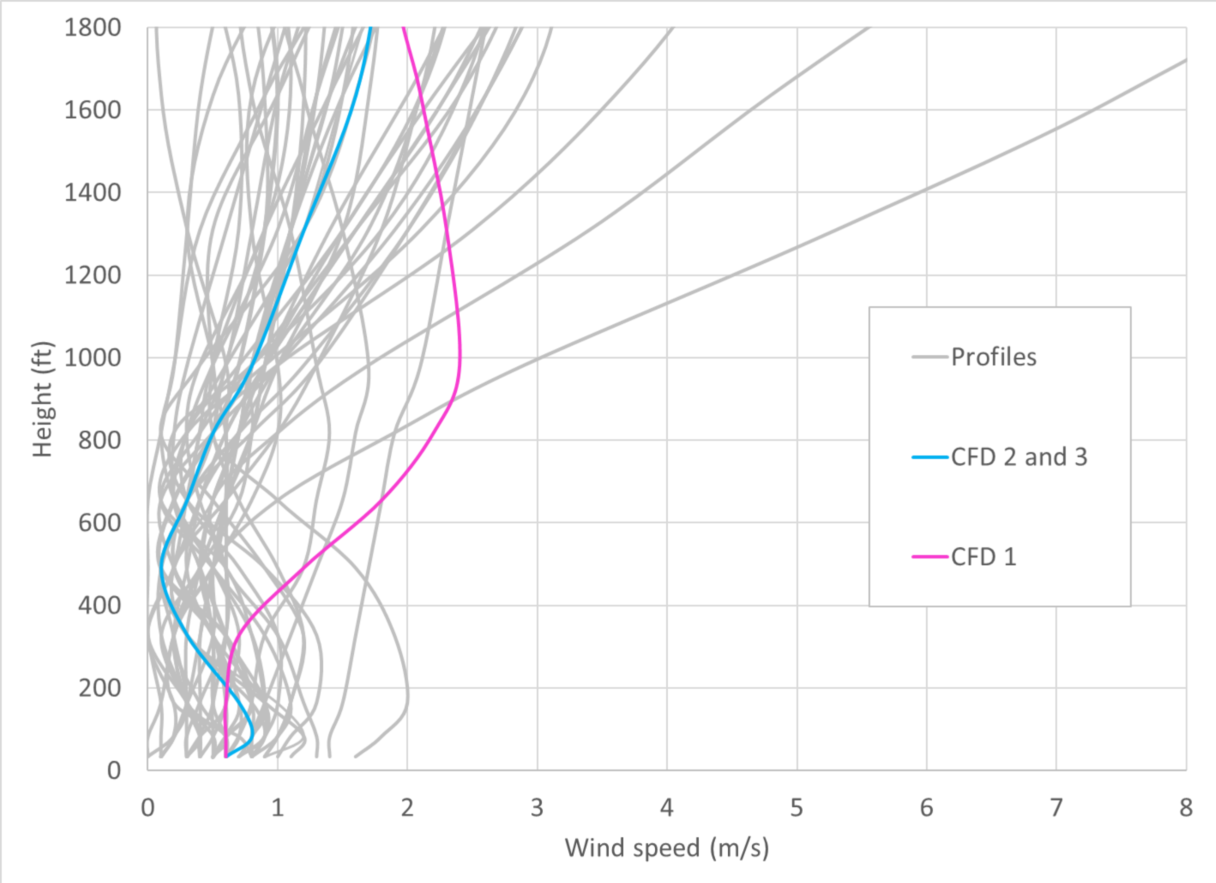


Figure A3 Wind speed profiles that produce the top 44 plume velocities in the zero momentum TAPM model and the previous CFD wind speed profile (CFD 1 – pink line) – the blue line is the CFD 2 and 3 wind speed profile

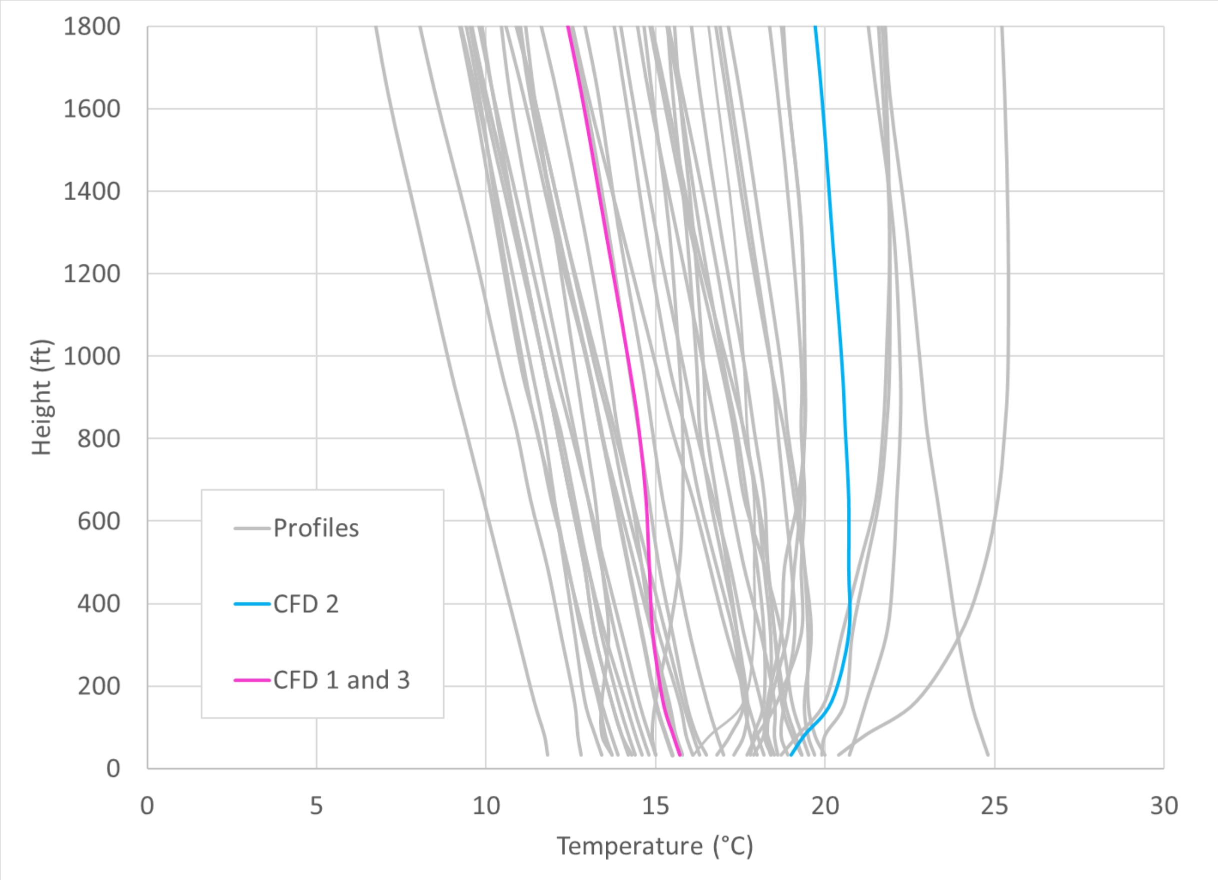


Figure A4 Temperature profiles that produce the top 44 plume velocities in the zero momentum TAPM model and the previous CFD temperature profile (CFD 1 – pink line and also CFD 3 profile) – the blue line is the CFD 2 temperature profile

A3 CFD model results

The peak and average vertical velocities at 650 ft, 700 ft and 1000 ft are presented in Table A4. Average vertical velocities were calculated by dividing the peak velocity from the CFD model by 2 as recommended by GHD in its peer review of the previous CFD modelling.

Table A4 Average and peak vertical velocities at 650 ft, 700 ft and 1,000 ft for three meteorological profiles produced by CFD modelling conducted by Stacey Agnew

Scenario	Date	Average 654 ft to 818 ft		Plume vertical velocity (m/s) Average (peak)		
		Wind speed (m/s)	Temperature (°C)	650 ft	700 ft	1,000 ft
CFD 1	3 July 2014 10:00	2	14.6	5.8 (11.5)	5.8 (11.5)	5.4 (10.7)
CFD 2	8 March 2015 06:00	0.4	20.7	4.2 (8.4)	4.1 (8.1)	3.7 (7.3)
CFD 3	Combined	0.4	14.6	5.9 (11.8)	5.8 (11.6)	5.2 (10.4)

The results show that for all CFD scenarios, average vertical velocities are predicted to be below CASA's critical plume velocity of 6.1 m/s. The calm wind scenario (CFD 2) produced significantly lower plume vertical velocities compared with the previous model (CFD 1) that are well below CASA's critical plume velocity of 6.1 m/s. This lower plume vertical velocity occurs in conjunction with higher ambient air temperatures resulting in the horizontal jet from the PDD travelling further away from the stack prior to the plume buoyancy causing the plume to ascend.

The greater horizontal displacement of the jets means that the strands of the plume once travelling vertically do not tend to merge until they are cooler and reach a higher elevation.

The worst-case CFD model run (CFD 3), which combines calm wind speeds (CFD 2) and a cooler temperature profile (CFD 1), produces vertical velocities that are marginally greater than CFD 1 but are still below CASA's critical plume velocity at 700 ft. CFD 3 shows that average wind speeds below 818 ft of the order of 2 m/s or less does not have a significant effect on the vertical velocity at 700 ft. Consequently, in spite of the worst ambient conditions, the plume velocities for CFD 3 have not been impacted significantly compared to the base case i.e. CFD1.

The results of Stacey Agnew's previous CFD modelling (Stacey Agnew, 2020) and the results of the calm wind scenarios (Stacey Agnew, 2021) are summarised in Table A5, which shows peak vertical velocities at 650 ft, 700 ft and 1000 ft. Table A5 compares the previous CFD modelling results (CFD 1) with two calm wind scenarios: CFD 2 and CFD 3 (hypothetical worst-case scenario).

Table A5 Peak vertical velocities at 650 ft, 700 ft and 1,000 ft for three meteorological scenarios produced by CFD modelling conducted by Stacey Agnew

Scenario	Date	Case	Average meteorological conditions: 654 ft to 818 ft		Peak vertical plume velocity (m/s)		
			Wind speed (m/s)	Temperature (°C)	650 ft	700 ft	1,000 ft
CFD 1	3 July 2014 10:00	Previous (Stacey Agnew, 2020)	2	14.6	11.5	11.5	10.7
CFD 2	8 March 2015 06:00	Calm wind	0.4	20.7	8.4	8.1	7.3
CFD 3	Combined	Hypothetical worst-case	0.4	14.6	11.8	11.6	10.4

Average vertical velocities are presented in Table A6, which have been calculated by dividing the peak velocity from the CFD model by 2 as recommended by CASA in its letter of 29 March 2021 and GHD in its peer review of the previous CFD modelling.

Table A6 Average vertical velocities at 650 ft, 700 ft and 1,000 ft for three meteorological profiles produced from peak vertical velocities obtained by CFD modelling conducted by Stacey Agnew

Scenario	Date	Case	Average 654 ft to 818 ft		Average plume vertical velocity (m/s)		
			Wind speed (m/s)	Temperature (°C)	650 ft	700 ft	1,000 ft
CFD 1	3 July 2014 10:00	Previous (Stacey Agnew, 2020)	2	14.6	5.8	5.8	5.4
CFD 2	8 March 2015 06:00	Calm wind	0.4	20.7	4.2	4.1	3.7
CFD 3	Combined	Hypothetical worst-case	0.4	14.6	5.9	5.8	5.2

The results show that for all CFD scenarios, average vertical velocities are predicted to be below CASA's critical plume velocity of 6.1 m/s when calculated using CASA's preferred methodology. The calm wind scenario (CFD 2) produced significantly lower plume vertical velocities compared with the previous model (CFD 1) that are well below CASA's critical plume velocity of 6.1 m/s. This lower plume vertical velocity occurs in conjunction with higher ambient air temperatures resulting in the horizontal jet from the PDD travelling further away from the stack prior to the plume buoyancy causing the plume to ascend. The greater horizontal displacement of the jets means that the strands of the plume once travelling vertically do not tend to merge until they are cooler and reach a higher elevation.

The hypothetical worst-case CFD model run (CFD 3), which combines calm wind speeds (CFD 2) and a cooler temperature profile (CFD 1), produces vertical velocities that are marginally greater than CFD 1 but are still below CASA's critical plume velocity at 700 ft. CFD 3 shows that average wind speeds below 818 ft of the order of 2 m/s or less do not have a significant effect on the vertical velocity at 700 ft. Consequently, the plume velocities for CFD 3 have not been impacted significantly by ambient wind speed compared to the base case (CFD 1).

A4 References

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