8 July 2021

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Our ref: 12547390
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Your ref:

Attention: NSW Department of Planning, Industry and Environment (DPIE)

Tallawarra B Power Station
Review of CFD Plume Rise Assessment

Summary

Tallawarra B Power Station (TBPS) is a proposed single F-Class open cycle gas turbine (OCGT). TBPS is proposed to be built to the immediate northeast of EnergyAustralia's (EA) existing Tallawarra A Power Station (TAPS) on the western edge of Lake Illawarra, approximately 4.5 km northeast of Shellharbour Airport.

The gas turbine exhaust is to be discharged through a vertical stack with a plume dispersion device (PDD) attached to the top of the stack. The PDD discharges the gas turbine exhaust horizontally. Significant plume rise occurs due to the high temperature of the exhaust, about 630°C. This rising plume of exhaust gas may have the potential to cause a turbulence hazard to aircraft operations above and near the TBPS.

A plume rise assessment, as per CASA guidelines, was undertaken by Katestone Pty Ltd, with computational fluid dynamic (CFD) modelling for the assessment being undertaken by StaceyAgnew Pty Ltd.

The DPIE requested the following scope for the independent review: verify and validate the CFD model methodology, assumptions used and the model outputs for both the initial and calm wind scenarios, including the meteorological conditions considered for both scenarios. This independent review was based on eight supplied documents (Section 4), supplied model files (Section 5) and correspondence with Katestone.

This independent review follows a peer review by GHD (2021)[1]. The Katestone assessment has been modified and updated based on feedback from CASA and to address certain items that particularly pertain to the meteorological conditions.

The independent review and peer review have found the following.

- Using CFD for the modelling of plume rise from the TBPS was reasonable given the complex near field flow physics and model limitations of the standard model, TAPM.

[1] GHD 2021. Tallawarra B Power Station – Review of CFD Plume Rise Assessment. Doc. No.: 12547390-LET-Katestone_review_report. 4 March 2021.

- The selected CFD modelled meteorological conditions are equivalent to (CFD 1) or exceed (CFD 2 and CFD3) the compliance requirements and represent conditions which are conducive to worst-case (>99.9th percentile) plume rise.
- The use of the proposed top hat equivalent velocity calculation methodology is not valid for this plume emission when CFD modelling is used. A simpler approach using half the peak value was recommended by GHD, accepted by CASA and adopted by Katestone.
- There is a lack of assessment guidance information provided by CASA for assessments involving non-standard models such as CFD.
- 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 at 650 ft, 700 ft and 1000 ft.
- The determination of safe aircraft operations near the TBPS is needed to be made by aviation specialists and CASA. Such a determination is beyond the scope of this independent review and any plume rise model output.

1 Introduction

An independent review was requested by DPIE on the modelling undertaken as part of the plume rise study that is required as part of the Tallawarra B Power Station (TBPS) approvals process.

The following independent review of the supplied modelling reports and model files was undertaken by Dr. David Featherston (B.Eng, Ph.D.), working for GHD Pty Ltd. Curriculum Vitae attached. The independent review gave consideration to the NSW Peer Review Guidelines, with compliance to all requirements achieved as best as possible. Additional details are provided in Section 4.2.

2 Glossary and Nomenclature

For convenient reference, a glossary of commonly used terms and jargon is supplied in Table 1.

Table 1 Glossary

Abbreviation or term	Meaning
ABL	Atmospheric boundary layer
CASA	Civil Aviation Safety Authority
CFD	Computational fluid dynamics
CPV	Critical plume velocity, default value of 6.1 m/s
DPIE	NSW Department of Planning, Industry and Environment
EA	EnergyAustralia
GE	General Electric

Abbreviation or term	Meaning
Katestone	Katestone Environmental Pty Ltd.
OCGT	Open cycle gas turbine
PDD	Plume dispersion device
StaceyAgnew	StaceyAgnew Pty Ltd
TAPM	The Air Pollution Model. An atmospheric dispersion modelling package developed by CSIRO, that combines meteorological modelling and pollution dispersion. It is the preferred and stated method of CASA plume rise assessments.
TAPS	Tallawarra A Power Station. Combined cycle gas turbine 435 MW power station.
TBPS	Tallawarra B Power Station. Open cycle peak load gas turbine 400 MW power station.

3 Conflict of Interest Statement

At the time of this review, the following conflict of interest statement is correct.

3.1 EnergyAustralia

David Featherston is not engaged in any work with EnergyAustralia.

David Featherston is not included in any current proposals/bids for work with EA.

No members of David Featherston's immediate family and friends work for or have commercial interests in EA.

3.2 Katestone

David Featherston has never been engaged by Katestone for any work, other than previous work related to this project.

David Featherston is currently involved in a review process for DPIE involving work done by Katestone for the WestConnex road project. This work is being done for DPIE (Client) and involves the review of Katestone work. Refer to Section 3.5.

David Featherston is not included in any current proposals/bids for work with Katestone.

No members of David Featherston's immediate family and friends work for or have commercial interests in Katestone.

Katestone and other areas of the GHD business are pursuing an opportunity in partnership, with Katestone expected to be engaged as a subconsultant by GHD for works if they eventuate. These works are not related to the Tallawarra B Power Station.

3.3 StaceyAgnew

StaceyAgnew is a software distribution supplier to GHD, for the software IDA and IDA-RTV.

GHD is part of a design Joint Venture for the Kidston Pumped Storage Project. StaceyAgnew are a design sub-consultant to one of the JV partners, Mott MacDonald.

David Featherston is not engaged in any direct work with StaceyAgnew, but has been consulted within GHD about parts of the Kidston project relating to tunnel ventilation.

No proposals for work with StaceyAgnew are current.

No members of David Featherston's immediate family and friends work for or have commercial interests in StaceyAgnew.

3.4 CASA

David Featherston is not engaged in any work with CASA.

No proposals for work with CASA are current.

No members of David Featherston's immediate family and friends work for CASA.

3.5 NSW Department of Planning, Industry and Environment (DPIE)

David Featherston is currently engaged in work with DPIE regarding the following projects.

- Pyrmont Place Peninsula pedestrian comfort and safety wind assessment. DPIE contact details can be supplied upon request.
- WestConnex Local Planning Air Quality Assessment Process, WestConnex environmental condition number E42.

David Featherston is not included in any current proposals/bids for work with DPIE.

No members of David Featherston's immediate family and friends work for DPIE.

4 Reviewed Documents

Eight documents were reviewed. These are listed below. Screen shots of the title pages of these documents for confirmation are provided in Section 17.

- Katestone 2020. Supplementary Plume Rise Assessment for the Tallawarra B Power Station Aviation Impact Assessment. Prepared for: EnergyAustralia. Doc. No.: D19025-35, Ver. 1.0 (Final) 18 December 2020.
- StaceyAgnew 2020. Tallawarra B Power Station CFD Plume Modelling – GE-Modified PDD Design. Summary Report. For Katestone. Doc. Ref.: 2001, Ver. No. 2, 20th August 2020.
- CASA 2019. ADVISORY CIRCULAR AC 139-05v3.0. Plume Rise Assessments. Civil Aviation Safety Authority. File ref.: D18/492979. Date: January 2019.
- NSW 2017. Peer Review. Draft Environmental Impact Assessment Guidance Series. Planning & Environment, NSW Government. ISBN 978-0-6480102-0-3. June 2017.

- Katestone 2021a. Response to GHD Draft Peer Review of the Tallawarra B Power Station Supplementary Plume Rise Assessment – version 0.1. Memorandum prepared by Andrew Vernon (Katestone). Deliverable No. D19025-37. Date 1 March 2021.
- Katestone 2021b. Response to CASA Letter. Memorandum from Simon Welchman (Katestone) to Amanda Jones (EnergyAustralia). Deliverable No. D19025-45. Date 15 June 2021.
- StaceyAgnew 2021a. Tallawarra B Power Station CFD Plume Modelling – GE-Modified PDD Design. Summary Report. For Katestone. Doc. Ref.: 2001, Ver. No. 5, 15th June 2021.
- StaceyAgnew 2021b. Letter from Dr Conrad Stacey (Director Stacey Agnew) to Simon Welchman (Katestone), re: Peer Review Correspondence Regarding Intellectual Property. 22 June 2021.

4.1 CASA 2019

The CASA 2019 plume rise assessment document is stamped with "Under review – December 2019"[2]. No other public document has been located that indicates this document has been superseded.

Additionally, the Katestone plume rise assessment has been undertaken using this document as its basis.

4.2 NSW 2017

The NSW 2017 peer review guidance[3] document provides a list of items that are required to be undertaken in an independent review.

All requirements specified in NSW 2017 have been given due consideration and best possible adherence has been undertaken.

4.3 Previous Review

A previous independent review was undertaken on this project. This was based on the initial CFD modelling submission to CASA. This review is referred to in this document as GHD (2021).[4]

5 Model Files

As part of this review, three model files were supplied and inspected with regards to model setting implementation. The three model files consisted of one case and one data file, i.e., six files in total. Refer to Figure 1 for screen shots of the file names, sizes and designations.

[2] Available online at https://www.casa.gov.au/sites/default/files/advisory-circular-ac-139-05-plume-rise-assessments.pdf

[3] Available online at https://www.planning.nsw.gov.au/-/media/Files/DPE/Guidelines/guideline-9-draft-peer-review-2017-06.ashx

[4] GHD 2021. Tallawarra B Power Station – Review of CFD Plume Rise Assessment. Doc. No.: 12547390-LET-Katestone_review_report. 4 March 2021.

Readme.txt	25/06/2021 9:59 AM	Text Document	1 KB
TPM03-GE-ModDesign-Case20140703_10-02-GHD.cas	25/06/2021 7:19 AM	CAS File	3,244,661 KB
TPM03-GE-ModDesign-Case20140703_10-02-GHD.dat	25/06/2021 7:22 AM	DAT File	9,144,687 KB
TPM07-GE-ModDesign-Case20150308_Calm-01-GHD.cas	25/06/2021 7:23 AM	CAS File	3,516,850 KB
TPM07-GE-ModDesign-Case20150308_Calm-01-GHD.dat	25/06/2021 8:09 AM	DAT File	10,042,544 KB
TPM07-GE-ModDesign-CaseW_20150308_Calm_T_2014...	25/06/2021 7:25 AM	CAS File	4,697,146 KB
TPM07-GE-ModDesign-CaseW_20150308_Calm_T_2014...	25/06/2021 8:12 AM	DAT File	10,404,798 KB

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'Initial' wind case: TPM03-GE-ModDesign-Case20140703_10-02-GHD.#

Calm wind case: TPM07-GE-ModDesign-Case20150308_Calm-01-GHD.#

'Combined' wind case: TPM07-GE-ModDesign-CaseW_20150308_Calm_T_20140703_10-01-GHD.#
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Figure 1 Reviewed model files. Supplied by StaceyAgnew.

6 Project Appreciation

6.1 Power Station

Tallawarra B Power Station (TBPS) is a proposed single F-Class open cycle gas turbine (OCGT). TBPS is proposed to be built to the immediate northeast of EnergyAustralia's (EA) existing Tallawarra A Power Station (TAPS) on the western edge of Lake Illawarra, approximately 4.5 km northeast of Shellharbour Airport.

6.2 Approvals

TBPS was granted approval in 2010 following the completion of an Environmental Impact Statement (EIS).

In February 2020, EA submitted an Aviation Impact Assessment (AIA) for the TBPS to the Secretary of NSW Department of Planning, Industry and Environment (DPIE). The AIA included a plume rise assessment, conducted by Katestone Environmental Pty Ltd (Katestone), to address Condition 1.6 of the TBPS approval, which requires an AIA be submitted to the DPIE Secretary to demonstrate that the TBPS plume would not cause an adverse impact on aviation safety.

6.3 AIA Plume Rise Assessment – Initial Assessment

The AIA plume rise modelling assessment was conducted based on Australian Civil Aviation Safety Authority (CASA) guidelines and recommendations in Advisory Circular (AC) 139-05 v3.0 (CASA, 2019). The assessment investigated buoyant exhaust plumes generated by TBPS and their potential impact on aircraft using the nearby Shellharbour Airport through assessment against the plume average vertical velocity criteria of 6.1 m/s stated in AC139-05 v3.0.

The AIA presented indicative plume rise modelling results for TBPS. The results indicated that the TBPS plume average vertical velocity would reduce to below 6.1 m/s below 700 ft AMSL. Overall, the AIA concluded that the level of aviation safety risk associated with TBPS is at an acceptably low level.

6.4 Turbine Design Specification

Since the submission of the AIA, EA has selected a preferred supplier of the TBPS gas turbine, who has now provided a design of an F-Class turbine that is specified in more detail. The turbine stack differs from the design assessed in the original AIA and now includes a Plume Dispersion Device (PDD). Katestone was commissioned by EA to undertake a supplementary plume rise modelling assessment of the latest design of TBPS. EA's requirement to the preferred supplier is for the design of the TBPS and PDD to maintain the same acceptably low level of risk to aviation safety that was determined in the AIA.

6.5 Plume Dispersion Device (PDD)

The exhaust gases from the TBPS gas turbine will be discharged via a stack. The exhaust stack will have a PDD to reduce the plume vertical velocity and consequently minimise the potential impacts to the safety of aircraft using the nearby Shellharbour Airport, as directed by EA.

The indicative design of the PDD considered in the supplementary plume rise assessment is shown in Figure 3. The indicative PDD design has 12 rectangular outlets angled at 90° from the vertical. Exhaust gases from the gas turbine will travel through the stack and discharge via the PDD outlets.

6.6 CFD Plume Rise Assessment

With a PDD, the standard plume rise assessment approach, using TAPM, needs to be modified. A computational fluid dynamics (CFD) model was constructed by StaceyAgnew (2020) to estimate plume rise velocity associated with the identified worst case, plume rise meteorological conditions, representative of the 99.9th percentile condition.

This assessment jointly conducted by Katestone and StaceyAgnew was independently reviewed by GHD. From this review, some modifications to the original CFD modelling assessment were undertaken. The updated assessment and the GHD review were supplied to DPIE and CASA.

CASA have since responded to the updated assessment and GHD review comments. This CASA response has resulted in additional CFD modelling being undertaken by StaceyAgnew (2021a).

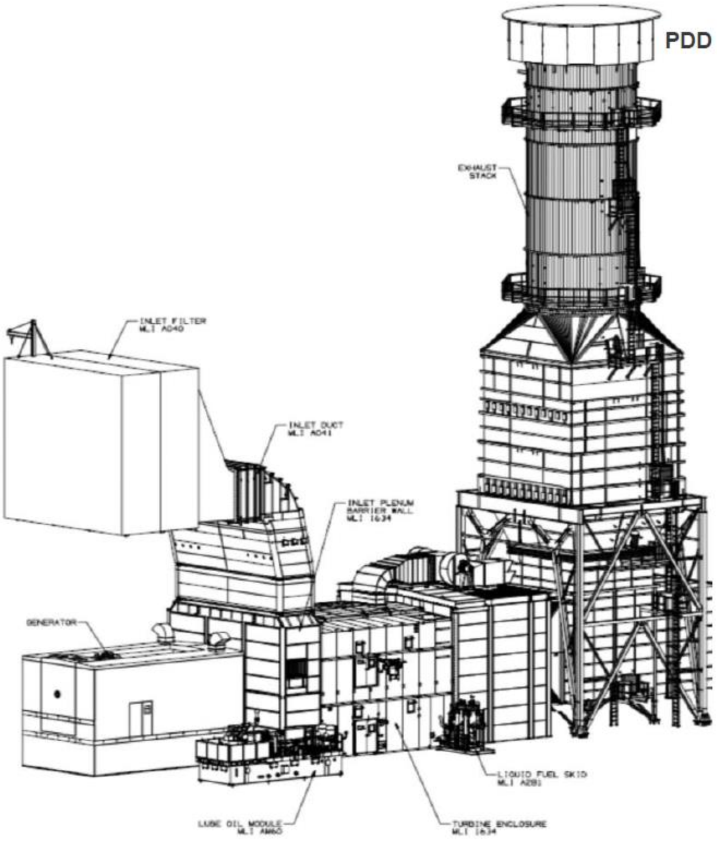


Figure 2 Indicative Design of Tallawarra B Gas Turbine with PDD. Source: Katestone 2020 (Fig.2)

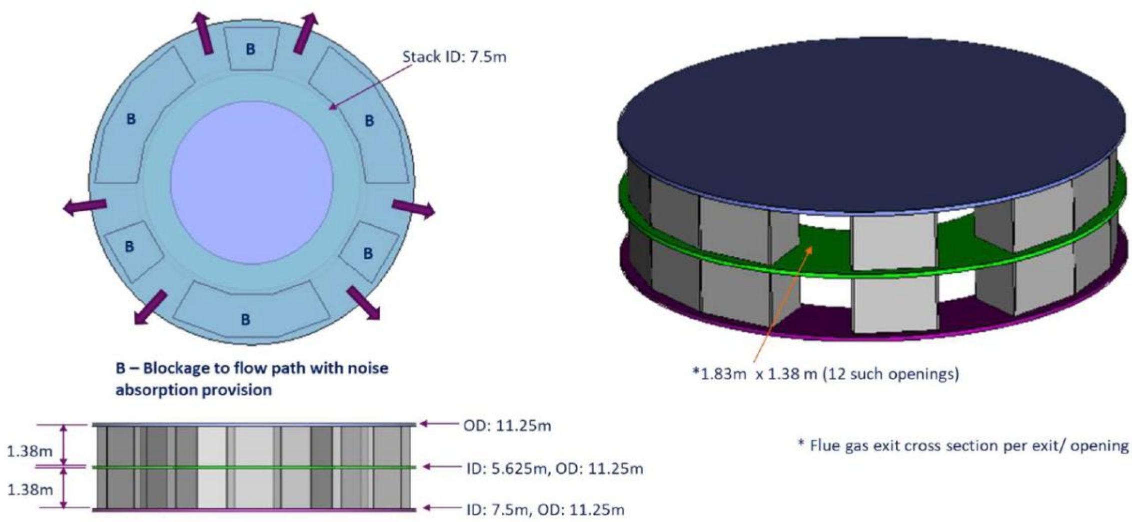


Figure 3 Sketch and dimensions of proposed and assessed PDD design. Source: StaceyAgnew 2020 (Fig.5)

7 Review Scope

7.1 Scope of works

This scope of works builds on the review originally undertaken by GHD (2021). Many issues addressed in this original review will not be re-examined in this additional review.

The agreed review scope of services with Katestone included the following.

- Independent review of Tallawarra B Power Station updated CFD Modelling Assessment, as defined in StaceyAgnew (2021a).
  - Verify and validate the CFD model methodology, assumptions used and the model outputs for both the initial and calm wind scenarios, including the meteorological conditions considered for both scenarios.
- Review of supplied CFD model files.
- Review of reports provided by Katestone Environmental, including:
  - Katestone Environmental - Response to CASA Letter. (15 June 2021)
- Preparation of one version of an independent review report developed with consideration of the DPIE Peer Review guideline. The independent review report will be authored and signed by David Featherston (GHD).

7.2 Qualifications

The following qualifications are applicable to the scope of works.

- GHD has aimed to complete the independent review as best as possible in compliance with DPIE peer review guidelines.
- No independent modelling or calculations have been carried out as part of the scope of works that would allow for quantitative evaluation of any deviation of assessment results from what has been presented by Katestone (and Stacey Agnew).
- CFD model simulations have not been independently re-run. StaceyAgnew (2021b) did not supply sufficient boundary condition information to allow for the model files to be independently run, citing intellectual property.
- This review document should be read in conjunction with the previous review document, GHD (2021)[5].

7.3 Aircraft Safety

The outcome of this independent review does not determine the level of safety for an aircraft operating in the vicinity of the TBPS. The independent review has evaluated the plume rise assessment and CFD modelling against CASA's plume rise guidelines and has considered whether the modelling shows

[5] GHD 2021. Tallawarra B Power Station – Review of CFD Plume Rise Assessment. Doc. No.: 12547390-LET-Katestone_review_report. 4 March 2021.

compliance with CASA's critical plume velocity. Whether potentially hazardous conditions prevail due to the operation of the TBPS as a result of any plume rise is left up to aviation specialists to determine.

7.4 Limitations

This report has been prepared by GHD for Katestone Environment Pty Ltd and may only be used and relied on by Katestone Environment Pty Ltd, EnergyAustralia (proponent) and the NSW Department of Planning, Industry and Environment for the purpose agreed between GHD and the Katestone Environment Pty Ltd as set out in section 7 of this report.

GHD otherwise disclaims responsibility to any person other than Katestone Environment Pty Ltd arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.

The services undertaken by GHD in connection with preparing this report were limited to those specifically detailed in the report and are subject to the scope limitations set out in the report.

The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report, refer to Section 4. GHD has no responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared.

The opinions, conclusions and any recommendations in this report are based on assumptions made by GHD described in this report. GHD disclaims liability arising from any of the assumptions being incorrect.

GHD has prepared this report on the basis of information provided by Katestone Environment Pty Ltd and others who provided information to GHD, which GHD has not independently verified or checked beyond the agreed scope of work. GHD does not accept liability in connection with such unverified information, including errors and omissions in the report which were caused by errors or omissions in that information.

8 CASA Plume Rise Assessment

A detailed analysis of CASA plume rise assessment has been previously undertaken as part of the initial review (GHD 2021). Refer to GHD (2021) for these details.

The critical item is the vertical velocity induced by plume rise cannot exceed 6.1 m/s at the critical plume heights of 700 ft and 1000 ft

A plume rise assessment is intended to be used to inform aviation specialists regarding safe aircraft operations, refer to Section 7.3.

9 CFD Model Details

Information stated in this section has been primarily obtained from StaceyAgnew 2021a.

Note that all model details have not been supplied as part of this review. StaceyAgnew did not supply the boundary functions applied to generate the inlet wind conditions, citing reasons of commercial intellectual property (StaceyAgnew 2021b).

Model details addressed in GHD (2021) have not been re-examined as part of this assessment, unless something of significant relevance has been identified as part of this review.

9.1 General Observations

Some general observations from a review of the CFD supplied model files are provided below.

9.1.1 Solver

Of the three models provided, the numerical solver settings are different for all three. Both segregated and coupled solvers are used. The pressure calculation method changes from 2nd order to body forced weighted. These differences are not necessarily an issue, and it is accepted that these differences will have negligible impact on the predicted results. Such changes can be used to stabilise the numerical solution.

9.1.2 Turbulence discretisation

For all three models, a discretisation scheme of 1st order upwind has been applied to both the turbulence kinetic energy and turbulence dissipation rate transport equations.

For a polyhedral type computational mesh, or a hexahedral mesh with non-aligned flow, a numerical calculation scheme of 1st order is generally not considered acceptable for anything other than commencing a simulation. The StaceyAgnew (2021a, Section 2, Table 2) report does not provide this level of information, only stating "…*with a spatial discretisation method of 2nd order. A second order discretisation method was used in order to avoid numerical diffusion*." First order schemes are more robust and therefore less sensitive to numerical instabilities. As observed in the wind vector plots, discussed in Section 9.2 (Table 3), solution numerical instability is possible, however, no mention is made in the CFD modelling report, nor methods used to overcome or mitigate its effects.

9.1.3 Transient modelling

Steady state models have not been supplied.

The supplied models all have used an unsteady (transient) RANS (URANS) modelling method. URANS modelling tends to smooth out peak velocity fluctuations. A more advanced transient turbulence modelling approach would be to apply a scale resolving eddy model such as SAS, DES or LES.[6] SAS or DES are considered more suited for this application as only flow eddies with time scales in the order of one tenth of a second to one second need to be resolved, therefore, the small-time steps associated with LES models can be avoided.

The ability of CFD modelling to resolve time variation in plume velocity is considered a strength. However, the CASA plume rise guidance is unable to utilise this strength, as no turbulence requirement exits, unlike other aviation guidance documentation, such as NASF Guideline B for wind shear

[6] SAS = Scale-adaptive simulation. DES = Detached Eddy simulation. LES = Large Eddy simulation.

assessments. Based on this, the application of the URANS approach used by StaceyAgnew (2021a) is considered appropriate.

The plume rise results stated in StaceyAgnew (2021a, Tables 7, 8 and 9) are assumed to be those from steady state simulations. However, this is unclear in the report. The time variation at 200 m elevation is only about 6 percent (StaceyAgnew, 2021a, Figure 23).

The CFD models have applied a fixed time step of 0.5 seconds. The supplied information in StaceyAgnew (2021, Figure 23) would indicate that this is sufficiently small enough to resolve the large scale eddies, especially using a URANS approach.

9.1.4 Compressibility effects

A review of the StaceyAgnew (2021a) CFD 1 model velocity fields though the PDD has found that there are areas of very high velocity magnitude. A peak cell velocity of 197 m/s was reported in the model data file (CFD 1). An examination of discharge velocity found large areas where the discharge velocity near the exit plane of the PDD exceeds 150 m/s, as shown in Figure 4 and Figure 5.

As a general rule-of-thumb, if air speeds are less than 30 percent of the speed of sound, or Mach Number of 0.3 (for sonic speed Mach Number = 1), gas compressibility effects can be neglected. The Mach No. at the PDD discharge is estimated to be about 0.25 based on the sonic speed of air at a temperature of 600 °C being about 590 m/s. Given that the flow through the PDD technically complies with this rule-of-thumb guidance, modelling of gas compressibility may not make any substantial difference to the primary purpose of the assessment, that being the atmospheric plume rise. However, as part of the reason for using CFD was to model the near field flow distribution immediately adjacent to the PDD, a sensitive study as to the impact of any compressibility would have been good practice. No evidence has been provided to indicate that such a study has been undertaken.

The stated discharge velocity from the PDD in the StaceyAgnew (2021a, Table 5) as being an average of 63.24 m/s is correct. Although, not strictly relevant for a plume rise assessment, additional information such as discharge velocity range would be useful if this report is also being used for noise attenuation design purposes.

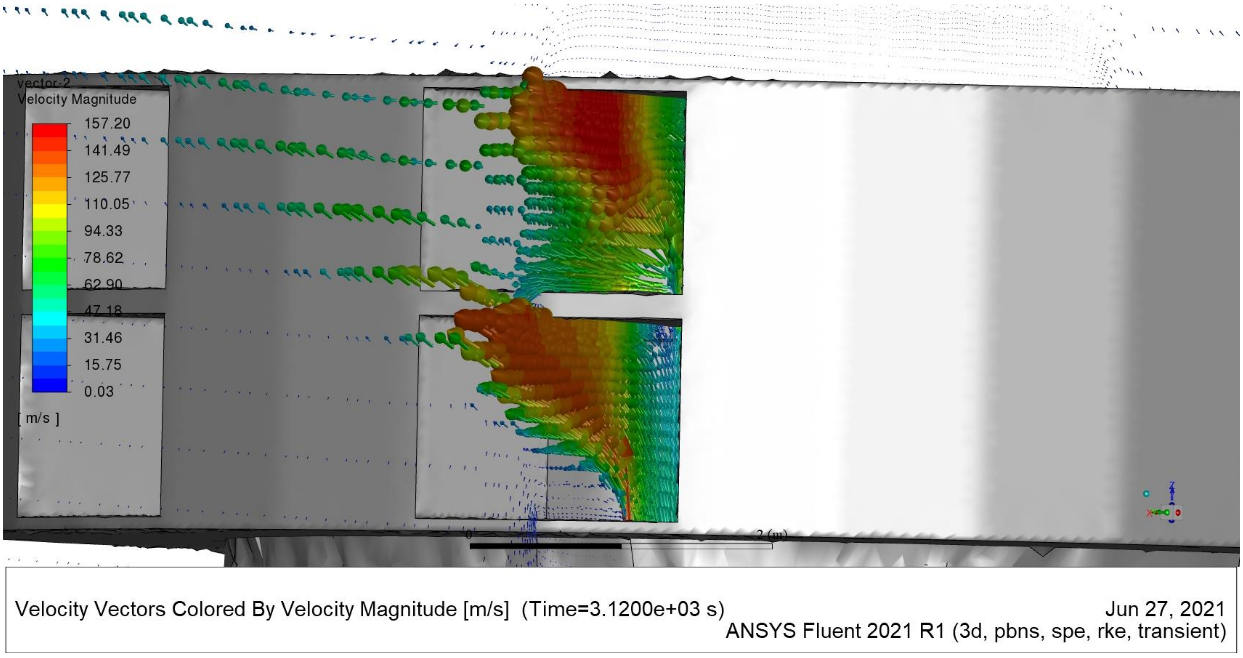


Figure 4 PDD discharge velocity vectors for CFD 1 model.

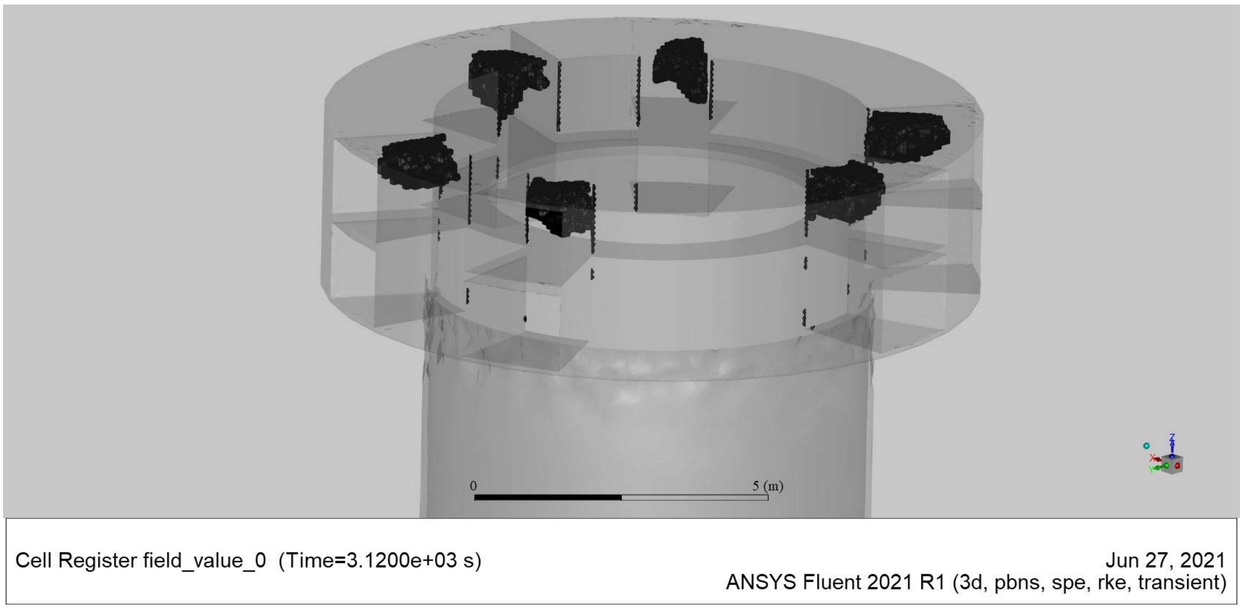


Figure 5 Volumetric zones of PDD where air speed exceeds 150 m/s.

9.1.5 Modelled air viscosity

Air viscosity was set to have a value of 1.72×10^{-5} Pa.s (kg/m.s). This is considered to be a low value and looks to be the default ANSYS/Fluent value used when the species model is activated.

Air viscosity between 15 °C and 600 °C varies between about 1.8 and 3.9×10^{-5} Pa.s.

This is likely to only have a minor effect on the modelling, but should be considered if any future modelling is undertaken.

9.1.6 Turbulence viscosity ratio limit

It is noted that the turbulence viscosity ratio limit has been increased from the default value by four orders of magnitude.

Increasing this value is considered common practice for the modelling of atmospheric flows.

9.1.7 Stack pressure

It is observed from the CFD model files (CFD 1 and CFD 3) that a pressure of just over 3000 Pa is required to discharge modelled mass flow rate of 746 kg/s from the PDD.

9.1.8 Temperature profile

Ambient temperature and CFD modelled potential temperature profiles were examined. It can be confirmed that the ambient temperature profiles identified by Katestone have been correctly implemented by StaceyAgnew, in the form of potential temperature profiles.

9.1.9 Atmospheric turbulence

The applied atmospheric turbulence values are five percent intensity and turbulence viscosity ratio of 10. The applied values are the ANSYS/Fluent defaults. ANSYS/Fluent will use these boundary values to calculate the atmospheric turbulence parameters of turbulent kinetic energy, k (TKE) and turbulent dissipation rate, ε (TDR).

From the reviewed documents and model files and based on the application of the model defaults, it is the considered opinion that TKE and TDR boundary values have not been selected using a recognised methodology.

Richards and Hoxey (1992)[7] detail a simple method for estimating atmospheric TKE and TDR values with respect to altitude, y, based on the atmospheric boundary layer (ABL) friction velocity, u*. The equations used in this method is summarised as:

$$k(y) = \frac{u^{*2}}{\sqrt{C_\mu}}$$

$$\varepsilon(y) = \frac{u^{*3}}{\kappa(y + y_0)}$$

Where $C\mu = 0.09$ and $\kappa = 0.42$ (von Karman constant).

[7] Richards, P.J. and Hoxey, R.P., 1992. Appropriate boundary conditions for computational wind engineering models using the k-ε turbulence model. Proceedings of the 1st International Symposium on Computational Wind Engineering (CWE 92), Tokyo, Japan, August 21–23, 1992.

This methodology for estimating atmospheric TKE and TDR has been applied in other studies such as Collins (2002)[8]. However, there has been a considerable body of work improving on this method, such as the work done by Toparlar et al (2019)[9] and Blocken et al (2007)[10].

Applying the Richards and Hoxey (1992) methodology, assuming a wind speed of 0.5 m/s @ 10 m elevation and a surface roughness length of 0.1 m, the friction velocity is 0.049 m/s, which results in estimates of TKE and TDR at 10 m elevation of 0.008 m^2/s^2 and 2.8×10^{-5} m^2/s^3. This excludes any suppression due to temperature stratification associated with a stable ABL. Extracted data from the supplied model CFD 1, approximately 80 m inside from the "neg-y" velocity inlet, shown in Figure 6, indicates that with the applied boundary conditions the TKE has a value within a range considered representative of the Richards and Hoxey (1992) estimate of 0.008 m^2/s^2, However, note that within 200 m of elevation, the TKE value is six (6) orders of magnitude lower than that at ground level. This is inconsistent with previous published studies by Richards and Hoxey (1992) and Blocken et al (2007), that show the vertical TKE profile remaining near constant. The value of TDR shown in Figure 6 near ground level is similar in magnitude to the Richards and Hoxey derived value, but most significantly, after a fall in TDR, the TDR increases with elevation. This increase is inconsistent with published information (Richards and Hoxey, 1992 and Blocken et al., 2007).

It is recognised that a stable ABL with shear layers will behave different to the published idealised conditions. However, no evidence has been presented that indicates anything other than model defaults have been applied to the ABL turbulence profile.

It just so happens that the applied boundary conditions result in low turbulence parameter values that are consistent with the low values expected during 'calm' stable maximum plume rise conditions.

Shown in Figure 7 are plots of the vertical turbulence parameters at the stack location in comparison with those at the ABL inlet. As atmospheric turbulence levels during 'calm' wind events are low anyway and given that the PDD plume induces turbulent kinetic energy levels numerous orders of magnitude higher than background (Figure 7), the application of the CFD model default boundary definitions will have negligible impact on the outcome of the plume rise assessment.

[8] Collins, D.H., 2002. Fugitive air emissions from heavy industry. PhD thesis, Dept. of Civil and Environmental Engineering, The University of Melbourne.

[9] Toparlar, Y., Blocken, B., Maiheu, B. and van Heijst, G., 2019. CFD simulation of the near-neutral atmospheric boundary layer: New temperature inlet profile consistent with wall functions. Journal of Wind Engineering & Industrial Aerodynamics 191 (2019) 91–102.

[10] Blocken, B., Stathopoulos, T. and Carmeliet, J., 2007. Atmospheric Environment 41 (2007) 238-252.

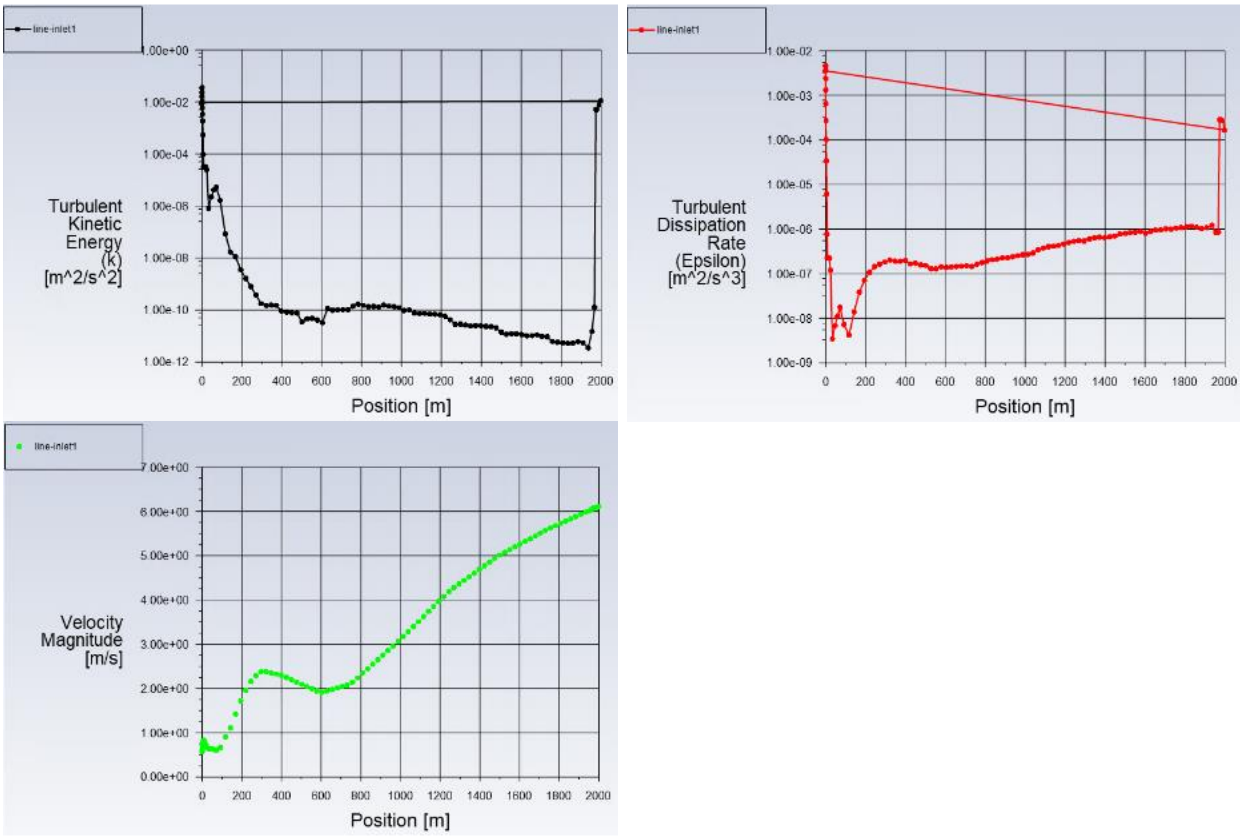


Figure 6 Applied vertical turbulence values of k and ε for model CFD 1 and velocity magnitude. Note the log10 vertical scale for the turbulence parameters.

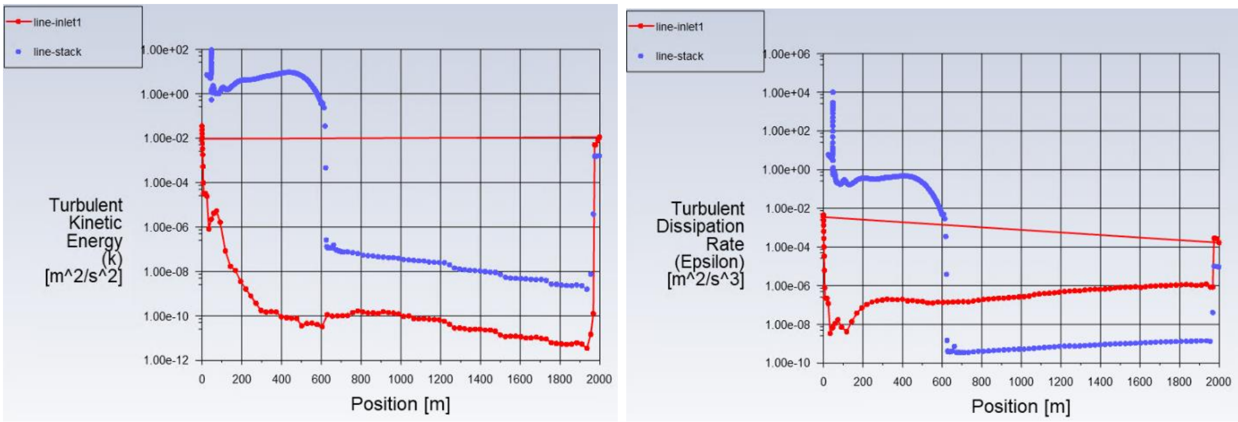


Figure 7 Comparison of vertical turbulence values of k and ε for model CFD 1 at the inlet (red) and stack (blue) locations. Note the log10 vertical scale.

9.1.10 Solution convergence

Solution convergence criteria have been reviewed. Numerous flow solution values have been used to determine convergence. I have some queries regarding how the applied convergence criteria interacts with the flow solution, given that only five iterations per time step are applied.[11] This small number of possible time step iterations is unusual. These queries do not invalidate the results. It is recommended that a time step size be selected so that convergence is achieved within 10 iterations. However, with a fixed time step solution applied, sudden flow solution instability may result in more iterations being required. In the absence of the ability to apply additional iterations, solution divergence may develop. For the flow conditions modelled, no evidence of solution divergence is indicated.

Independently running a portion of the simulations to make a better assessment was not possible as full boundary conditions were not supplied (StaceyAgnew 2021b).

9.2 Wind Condition

StaceyAgnew (2021a) state that the wind conditions were supplied by Katestone.

The initial assessed wind condition, identified as CFD 1 is quite complex, with a stable atmospheric temperature gradient, varying vertical wind speed profile and a vertical wind direction profile that is quite complex. The understood vertical wind direction profile for CFD 1 is shown graphically in Table 2. The wind condition is that which TAPM predicts to have occurred at 10 AM on 3 July 2014.

The assessment of implementation of the wind condition, as occurring at the PDD stack, in StaceyAgnew (2021a, Appendix B) states: "***It is clear that the wind direction is maintained less accurately where the wind speed is very low, and the wind direction changes quickly in elevation*****.**" This has been confirmed by inspection of the wind velocity vector plots in StaceyAgnew (2021a, Appendix B, Table B.1), noting that the local wind direction near ground level appears to be coming from a completely wrong direction.

It is interesting to note that the letter supplied by StaceyAgnew (2021b) in providing reasons for not supplying all input model boundary conditions provides a different statement: "*In order to provide the evidence that the appropriate boundary conditions (including velocity and temperature profile) were applied, a detailed validation section has been incorporated in our latest revised technical report (Appendix B).* ***This section proves that the velocity and temperature profile around the plume is maintained****, and aligns with the wind profiles provided by Katestone*."

9.2.1 Supplied CFD Models

A review of the supplied CFD models in StaceyAgnew (2021a) for the CFD 1 case with regards to wind direction implementation finds that the winds at the stack location are basically as per the specified meteorological conditions. Refer to Table 3 for vector plots of wind at the vertical elevations identified in Table 2.

[11] CFD 1 = 5 iterations per time step. CFD 2 = 8 iterations per time step. CFD 3 = 5 iterations per time step.

It is noted that the supplied model is a transient simulation and therefore the winds are at that modelled point in time. However, as the inlet wind conditions for the transient modelling do not vary with respect to time, the vector plots of the wind field in Table 3 are considered representative of steady state winds.

From the vector plots shown in Table 3 it appears that the pressure outlet boundaries are not resulting in a uniform domain velocity upwind of the stack. The random nature of the velocity vectors along this boundary, for elevation up to 200 m, indicates instability between the flow wanting to enter and leave the modelled domain. Observed internal wind field shearlines at low altitudes point to flow instabilities. When compared to the apparently uniform flow vectors for elevation of above 1000 m, as indicated in Table 3. It would appear that a major reason why the wind is in a representative direction, for near ground level elevations, is due to the distance between the northern most “outlet” boundary.

Even with the identified issues of the boundary modelling, these will not impact on the plume rise assessment result primarily as the low wind speed and vertical temperature profile, irrelevant of direction, is the primary driver of the plume rise.

Table 2 Wind direction vertical profile applied to CFD model for model CFD 1.

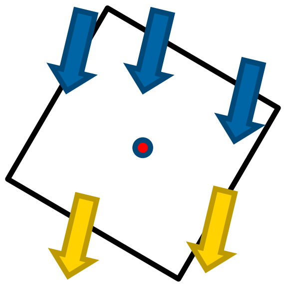
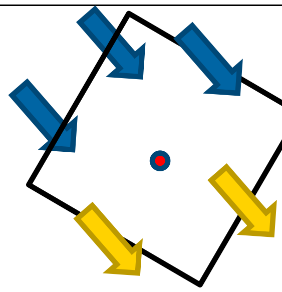
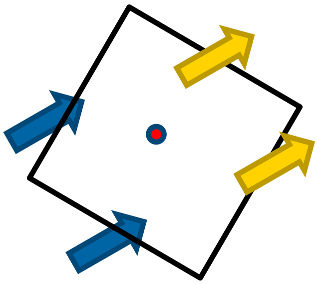
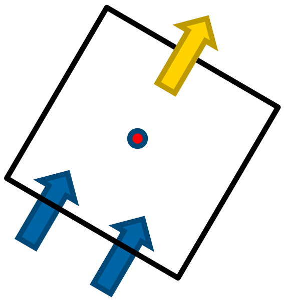
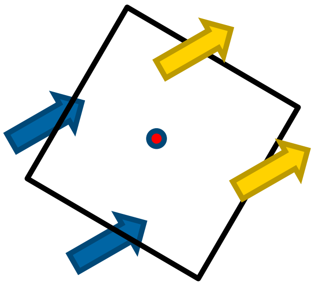
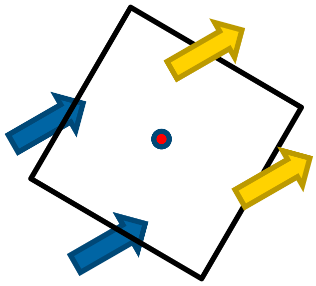
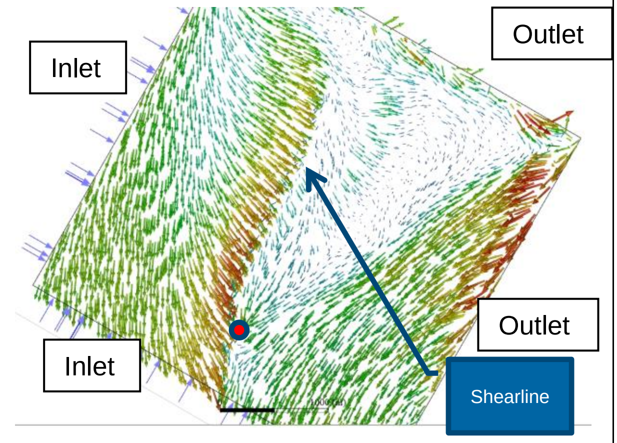
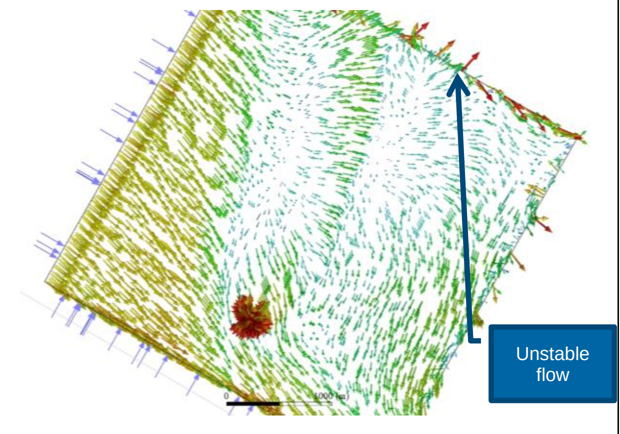
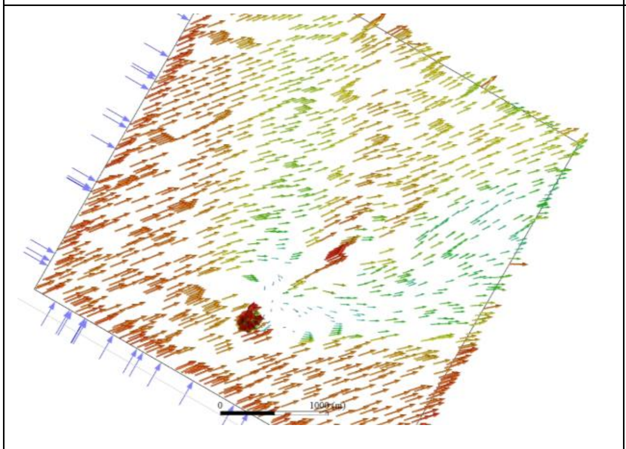
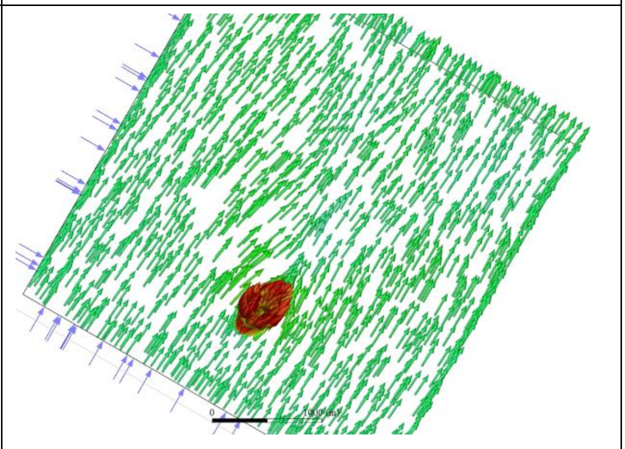
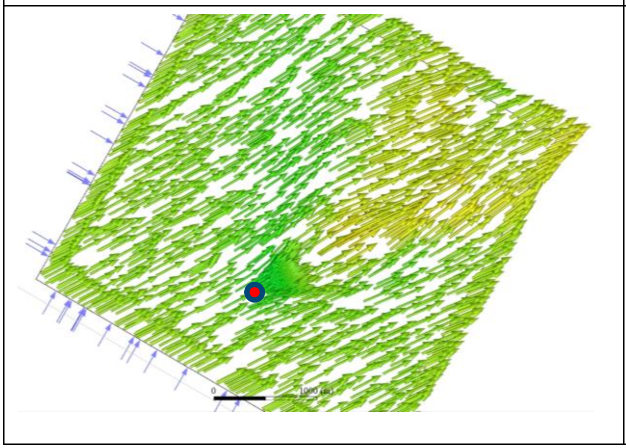
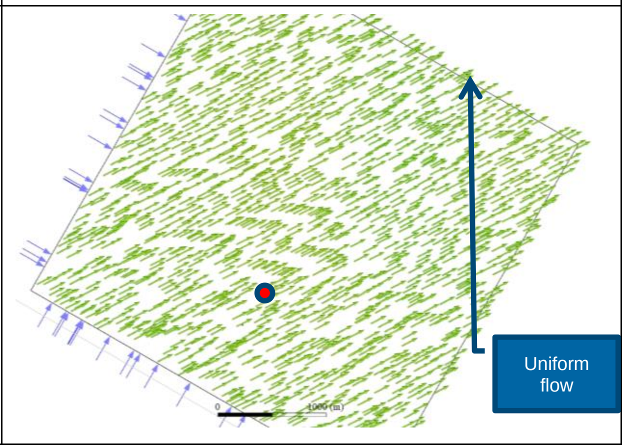
Height = 10 m (7°)	Height = 100 m (320°)
	
Height = 200 m (240°)	Height = 500 m (210°)
	
Height = 1000 m (240°)	Height = 2000 m (240°)
	

Table 3 Implemented wind profile in CFD 1 model. Extracted from supplied StaceyAgnew (2021a) model files. Compare with Table 2.

Height = 10 m (WD = 7°)	Height = 100 m (WD = 320°)
	
Height = 200 m (WD = 240°)	Height = 500 m (WD = 210°)
	
Height = 1000 m (WD = 240°)	Height = 2000 m (WD = 240°)
	

10 CFD Model Wind Condition Selection

Having reviewed the methodology for selection of the CFD modelled wind conditions and CASA guidance, I am of the opinion that the selected meteorological profiles used for the three CFD scenarios are equivalent to the 99.9th percentile condition (CFD 1) or higher percentile conditions (CFD 2 and CFD 3).

Many state regulatory bodies supply detailed guidance information, such as the NSW Approved Methods.[12] These guidance documents have specific details and requirements for determining worst-case conditions for assessments. Demonstration of compliance with these formalised worst-case conditions almost automatically assures approval for these items of a project. CASA does not have any such guidance document that compares to the NSW Approved Methods, for example.

All agree that greatest plume rise is associated with calm wind/meteorological conditions. But, what defines a calm meteorological condition? A wind speed of less than one knot (0.51 m/s) is commonly considered a calm wind speed. But, does this have to occur through the entire depth of the relevant atmosphere, i.e., below 1000 ft ? Katestone (2021b, Section A2) have shown that for the Tallawarra site, there is significant wind velocity variation with altitude.

Other than wind speed, the vertical atmospheric potential temperature[13] profile is important. An unstable atmosphere, where air at ground level is warmer (higher potential temperature) than the air above it, is most conducive to plume rise. However, the analysis by Katestone has found that these atmospheric conditions do not occur at the same time as low wind speeds.

It has been established that the modelled case CFD 3 is representative of plume rise conditions more adverse than any other previously modelled condition. I would not disagree with the Katestone (2021b) assertion that this is equivalent to a 99.98th percentile condition.

11 Top Hat – Gaussian Plume Calculation Methodology

This was discussed in detail in the previous review (GHD, 2021) and therefore will not be re-examined.

It is noted in Katestone (2021b) that CASA consider the proposed simple method of applying half the peak velocity as a reasonable and acceptable method.

12 CASA Comments

I am aware of five (5) comments that CASA have made with regards to the previous GHD (2021) review and modelling. Extracts of these comments, and the responses provided by Katestone (2021b) are shown in Section 18.

[12] Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales. NSW EPA. 2016. https://www.epa.nsw.gov.au/-/media/epa/corporate-site/resources/air/approved-methods-for-modelling-and-assessment-of-air-pollutants-in-nsw-160666.pdf

[13] Potential temperature adjusts for air pressure changes with altitude.

12.1 Comment A1 – Modelled Conditions

CASA's position is that the modelled 99.9th percentile representative conditions by CFD do not represent 99.9th conditions that should be occurring due calm wind meteorology.

After having reviewed all of the supplied information, including CASA's own guidelines, I am of the opinion that the combined Katestone and StaceyAgnew assessment has followed correct process and undertaken all necessary steps to determine and assess worst case 99.9th representative plume rise.

Katestone have assessed the meteorology that is related to the site. Applying idealised meteorology that may not be associated with conditions that could reasonably occur at this site is considered unreasonable based on the current CASA guidance.

Katestone have followed all best practise guidelines and methods in arriving at the selected meteorological conditions.

Additional comments are provided in Section 10.

12.2 Comment A2 – Plume Rise Compliance Demonstration

CASA do not believe that plume rise compliance has been demonstrated in StaceyAgnew's initial CFD modelling (StaceyAgnew, 2020) as the meteorological condition has wind speeds that are too high.

Katestone have addressed this issue by modelling meteorological conditions that are more extreme, in terms of both wind speed and atmospheric vertical temperature profile, than done in the original assessment.

As CASA's guidelines to not specify meteorological conditions that must be modelled, the process undertaken by Katestone and StaceyAgnew to determine 99.9th percentile meteorological conditions is considered reasonable, good practice and within the guidelines.

12.3 Comment B1 – Verification and Validation

CASA does not believe that the original study provided sufficient verification and validation.

The only way to fully verify and validate a numerical model outcome is to compare it to physical experimental results. For the vast majority of situations, this is just not possible. This is the primary reason a model is used to make an assessment instead of creating a physical scale model.

The numerical accuracy of atmospheric dispersion models, such as AUSPLUME, AERMOD and TAPM, are compared to 'standard' experimental data sets from field tests, such as the 1980-81 Kincaid or 1985 Indianapolis plume dispersion studies.

More appropriate is an 'evaluation' of the model instead of 'validating' it.

Model files for the latest assessment have been supplied and reviewed. Refer to previous section of this document for details. Unfortunately, the models cannot be re-run as the full boundary condition information has not been supplied by StaceyAgnew, citing intellectual property (StaceyAgnew, 2021b). There is a very minor concern regarding convergence criteria, as discussed in Section 9.1.10, that cannot be eliminated without independently running the simulations. However, on balance, the likelihood of all three modelled conditions producing inaccurate plume rise estimates is incredibly minute.

12.4 Comment B2 – Interpretation of Results

CASA believe that GHD have mis-interpreted results in the Katestone (2020, Figure 8) report.

Figure 8 of Katestone (2020) has been reviewed, shown in Figure 8.

The colour scale ranges from 1.0 (dark blue) to 13.0 m/s (red). The yellow contour has an upper limit of 9.4 m/s. The peak is three colour scale values higher than the yellow, equating to a range of 10.6 to 11.2 m/s. As the size of this colour contour is not as large as the previous contour level, this would indicate a reducing gradient, meaning the peak value is likely closer to the lower limit value than the upper. Therefore, the estimated value of 10.7 m/s is considered reasonable, however, a value of up to 10.9 m/s would also be considered an acceptable interpretation. A difference of 0.2 m/s, or 2 percent, is not considered to be enough to invalidate the original assessment.

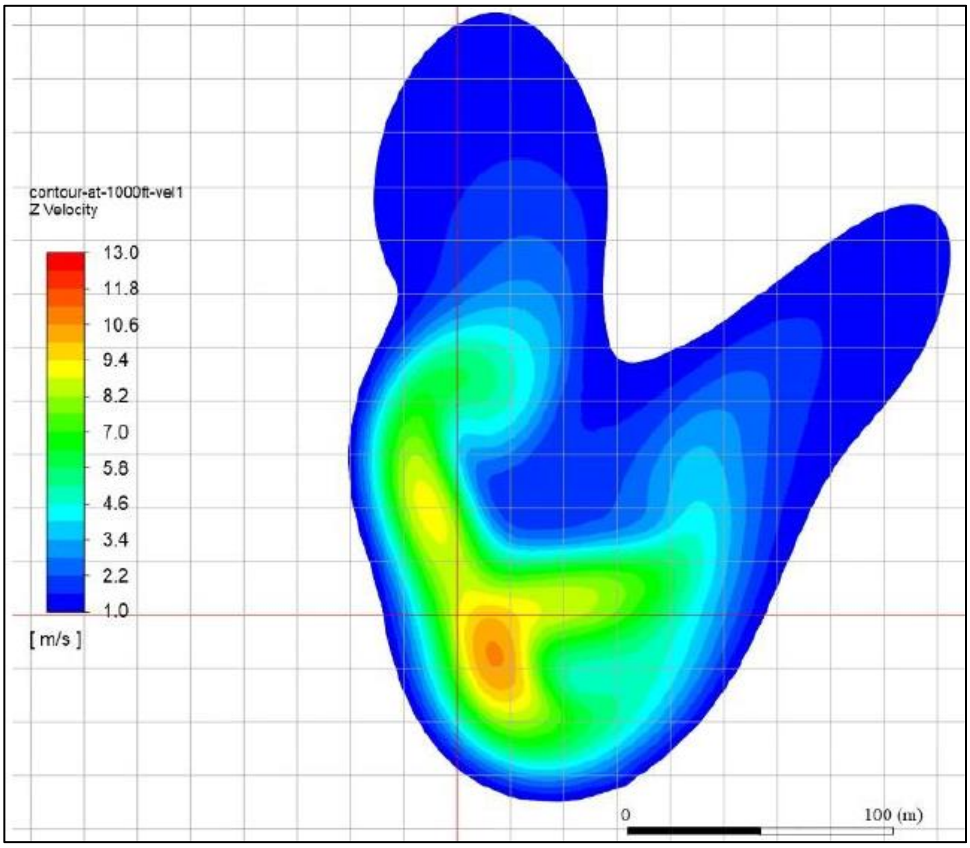


Figure 8 Figure 8 from Katestone (2020) extract.

12.5 Comment B3 – Plume Cross Sections at 700 ft

CASA advised that no plume cross sectional analysis had been supplied for an altitude of 700 ft.

Katestone (2021b) and StaceyAgnew (2021a) have provided these profile images. No detailed analysis has been provided, but this is not considered to be critical given that the peak and average cross sectional velocities are summarised in Katestone (2021b, Tables 1, 2, A5 and A6).

13 Plume Rise Assessment Results

Katestone (2021b) state that the plume rise velocity, using the GHD recommended and CASA agreed estimation method, does not exceed 6.1 m/s.

Based on all the evidence provided as part of this review, including a review of the supplied model files, I am of the opinion that the assessment results presented by Katestone (2021b) are a correct and accurate representation of the results from a properly formed study.

Shown below in Figure 9 and Figure 10 are pathlines of the plume discharge from the PDD, as generated by GHD from the supplied CFD 1 and CFD 3 model files. It is very apparent from these two images that for at least 500 m (1640 ft) the modelled plume is effectively exposed to calm wind conditions, even for the CFD 1 conditions that CASA claim (Section 18) are not representative of 'calm' wind.

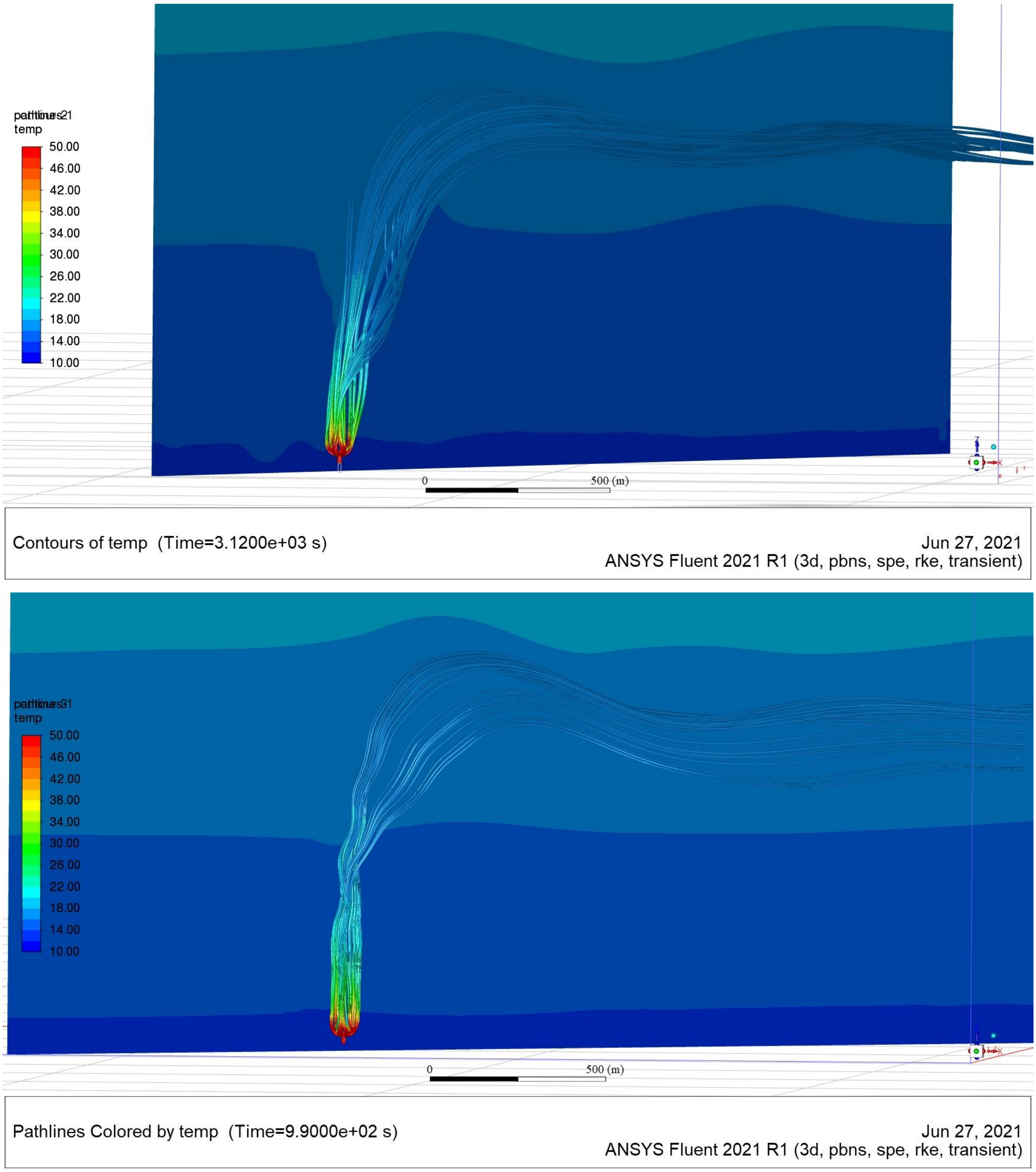


Figure 9 PDD discharge pathlines from model CFD 1 (top) and CFD 3 (bottom). Generated by GHD from supplied model files. Plume and atmosphere coloured by temperature.

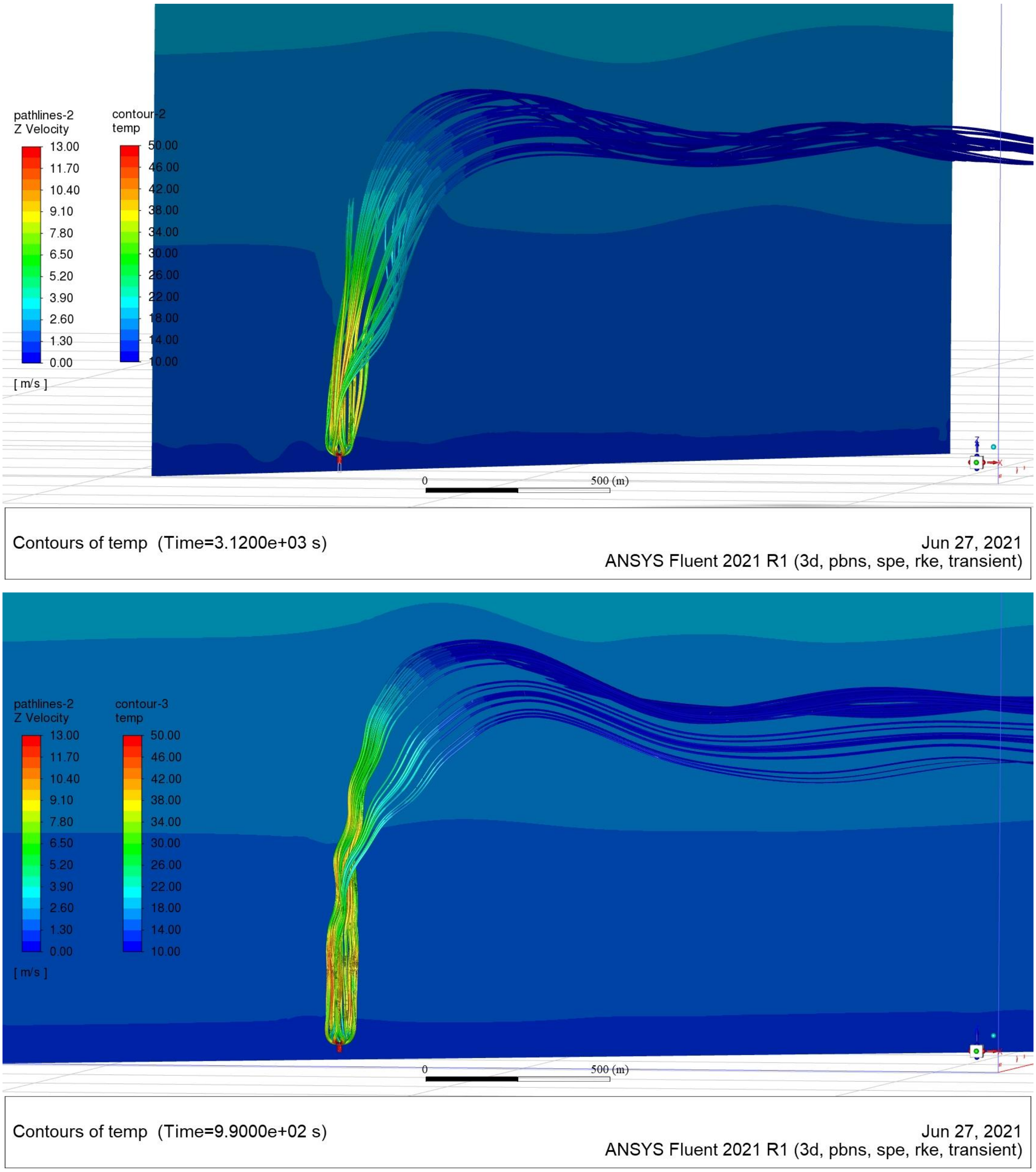


Figure 10 PDD discharge pathlines from model CFD 1 and CFD 3. Generated by GHD from supplied model files. Plume coloured by z-velocity and atmosphere coloured by temperature.

14 Summary of key issues

Based on the supplied documents none of the identified issues would be likely to change the outcome of the plume rise assessment.

The key item is the selection of the meteorological condition representative of worst-case plume rise conditions.

The modelling of atmospheric conditions at relevant altitudes has been demonstrated by Katestone and StaceyAgnew to be representative of calm conditions.

15 Concluding Comments

There are some minor issues surrounding the CFD modelling, but nothing of critical importance that would invalidate the outcome of the assessment.

It should be recognised that EA is applying best practice control and mitigation of plume rise.

Katestone has exceeded the necessary requirements for a CASA guideline compliant plume rise assessment.

It is re-iterated (Section 7.3) that this assessment does not infer a level of aircraft safety, only demonstration of compliance with CASA plume rise assessment criteria and process guidelines.

16 Compliance with NSW Peer Review Guidelines

16.1 Peer Review Practice

The NSW peer review guidelines require an independent review to undertake five specific tasks. Compliance with these tasks for this assessment is described below.

16.1.1 Discussion of Specific Environmental Matter

Discussions between Katestone (Principal consultant) and the independent reviewer were undertaken during the previous review stage of this project (GHD, 2021). Specifically, discussions have taken place on 10, 16 and 26 February 2021.

No discussions with Katestone have taken place regarding this latest review as it was not deemed necessary.

16.1.2 Review of Assessment Reports

For this latest review, two specific reports regarding the plume rise assessment, one letter and three model files, listed in Sections 4 and 5, were reviewed. These items were the only items supplied by Katestone to be reviewed.

16.1.3 Review of Comments

A list of CASA's comments regarding the assessment was supplied in Katestone (2021b), shown in Section 18. These were considered in the review process and have been addressed in Section 12.

16.1.4 Review of Principal Consultant Judgements

Katestone's judgements were reviewed.

Katestone had taken on board and implemented all items that had been raised in the previous review (GHD 2021).

Katestone has also assessed the results based on CASA's preferred velocity estimation method.

I have no concerns regarding Katestone's judgement with regards to this project.

16.1.5 Review of Principal Consultant Conclusions

The conclusions reached by Katestone and StaceyAgnew were evaluated. The information contained in this report provides the summary of the evaluation.

16.2 Peer Review Answers

The NSW peer review guidelines require an assessment report to answer five items. Compliance with these items for this assessment report is described below.

16.2.1 Principal Consultant's Assessment

I am of the opinion that Katestone assessment has been performed in accordance with the relevant standards, ethical requirements, and applicable legal and regulatory requirements.

16.2.2 Significant Matters

I am of the opinion that significant matters with regards to plume rise have been identified by Katestone and StaceyAgnew and extensive analysis of these conditions has been undertaken.

I am of the opinion that:

1. The selected meteorological conditions for the CFD modelling are representative of worst-case plume rise conditions.
2. Katestone have exceeded the requirements for a plume rise assessment, based on guidance material supplied by CASA.

16.2.3 Revision of Assessment

I am of the opinion that no additional assessment should be required based on the supplied documentation and project details. An amended assessment should be undertaken if there was to be a material change to the PDD discharge characteristics

16.2.4 Assessment Evidence

The assessment evidence obtained is sufficient, however, independent simulation of the CFD model files was not possible (StaceyAgnew, 2021b).

16.2.5 Assessment Conclusions

I am of the opinion that it has been demonstrated that the vertical plume rise does not exceed the default CPV value of 6.1 m/s, based on the CASA agreed estimation method. Therefore, compliance with the default critical plume velocity defined by CASA is shown.

I am of the opinion that the CFD modelled meteorological conditions are equivalent to (CFD 1) or exceed (CFD 2 and CFD 3) the 99.9th percentile worst case conditions for a plume dispersed through the PDD.

Sincerely

David Featherston
BEng (Mech.), Ph.D. (RMIT)
Senior Mechanical Engineer
Level 9, 180 Lonsdale Street Melbourne Victoria 3000 Australia
D 61 3 8687 8493 E david.featherston@ghd.com

Attachment 1: CV for David Featherston

17 Title Pages – Review Documents

Document Control

Deliverable #:	D19025-35
Title:	Supplementary Plume Rise Assessment for the Tallawarra B Power Station Aviation Impact Assessment
Version:	1.0 (Final)
Client:	EnergyAustralia
Document reference:	D19025-35 Tallawarra B Power Station - Plume Rise Study_v1.0_Final.docx
Prepared by:	Andrew Vernon
Reviewed by:	Simon Welchman
Approved by:	Simon Welchman 18/12/2020

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Stacey Agnew

TALLAWARRA B POWER STATION CFD PLUME MODELLING – GE-MODIFIED PDD DESIGN

SUMMARY REPORT

for Katestone

20TH AUGUST 2020

Ref 2001

REVISION HISTORY			
No.	**Date**	**Comment**	**Signed**
0	29th May 2020	Draft to Katestone	
1	22nd June 2020	Revised draft in response to comments	
2	20th August 2020	Final version	C Stacey

Guideline
9

Peer Review

Draft
Environmental
Impact Assessment
Guidance Series
June 2017

NSW GOVERNMENT
Planning & Environment

Australian Government
Civil Aviation Safety Authority

ADVISORY CIRCULAR
AC 139-05 v3.0

Plume rise assessments

Date	January 2019
File ref	D18/492979

MEMORANDUM

To	David Featherston, David.Featherston@ghd.com
cc	Danny Craggs, Danny.Craggs@ghd.com
From	Andrew Vernon, Andrew.vernon@katestone.com.au
Deliverable No.	D19025-37
Subject	Response to GHD Draft Peer Review of the Tallawarra B Power Station Supplementary Plume Rise Assessment – version 0.1
Date	1 March 2021

katestone
www.katestone.global

Dear David,

Katestone has reviewed the draft version of your peer review report of the Tallawarra B Power Station Supplementary Plume Rise Assessment (12547390-LET-DRAFT Tallawarra B CFD Modelling Peer Review, 17 February 2021) and has provided a response to the technical comments in the attachment.

katestone
www.katestone.global

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.

Stacey Agnew

TALLAWARRA B POWER STATION CFD PLUME MODELLING – GE-MODIFIED PDD DESIGN

SUMMARY REPORT

for Katestone

15TH JUNE 2021

Ref 2001

REVISION HISTORY			
No.	**Date**	**Comment**	**Signed**
0	29th May 2020	Draft to Katestone	
1	22nd June 2020	Revised draft in response to comments	
2	20th August 2020	Final version	
3	25th March 2021	Inclusion of Fluent version in section 2.1. Detailed information on polyhedral elements in section 2.3. Inclusion of specified turbulence parameter at boundaries in section 2.4 Detail of stack boundary condition in Table 6. Correction of axis description in Figure 9. Inclusion of plume edge definition in Section 4.	
4	1st June 2021	Update to incorporate two additional simulations with calm wind condition	
5	15th June 2021	Revised draft in response to comments	

Stacey Agnew

4/35 Limestone Street
Darra 4076
Australia

22nd June 2021

Simon Welchman
Director
16 Marie Street
Milton QLD 4064

by email: simon.welchman@katestone.com.au

Peer Review Correspondence Regarding Intellectual Property

Dear Simon,

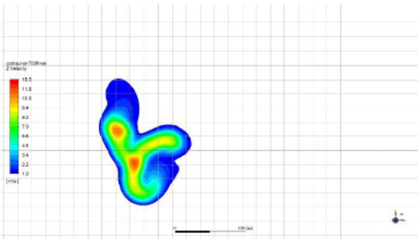
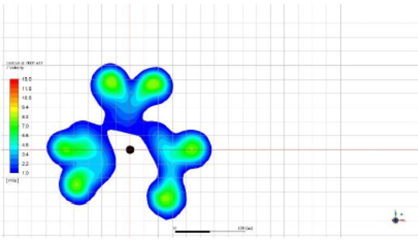
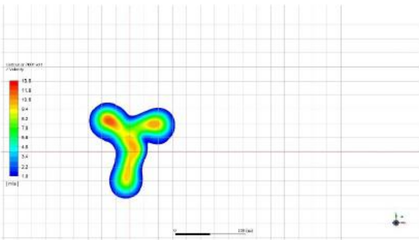
Further to your email of Friday, 18 June 2021, that included GHD's request for CFD model files, Stacey Agnew has prepared the following response.

18 CASA Comments Extract

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 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.	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 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 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 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.
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 
		CFD β 

Attachment 1: Curriculum Vitae for David Featherston

Curriculum Vitae

David Featherston

Senior Mechanical Engineer

Qualified. Bachelor of Engineering (Mech), RMIT, 1997 | Doctor of Philosophy, RMIT, 2002

Relevance to project. David Featherston has had more than 20 years' experience as a mechanical engineer in the area of computational engineering. David has assisted with tunnel and ventilation system design, process improvement and solution optimisation by applying high level numerical analysis and CFD modelling. These aspects include fan and ventilation design, greenhouse gas emission minimisation, pollution emission estimation, product structural reliability improvement and compliance with environmental and OH&S requirements for air quality.

Education

1997 – 2002	**Doctorate of Philosophy (Engineering)** Royal Melbourne Institute of Technology Program Title: Improved Performance of Direct Radiator Loudspeakers through Numerical Structural Optimisation
1993 – 1996	**Bachelor of Engineering (Mechanical) with First Class Honours** Royal Melbourne Institute of Technology Honours thesis in Computation Fluid Dynamics (CFD)
1992	**Victorian Certificate of Education** Bundoora Secondary College

Academic Awards

2000	Student Paper Presentation Citation – EMAC 2000 Conference
1997	Australian Postgraduate Award Scholarship
1996	The Institute of Engineers Award
1996	RS Components Award for Engineering Excellence
1995	Mechanical Engineering Professional Development Program Prize
1994	Mechanical Engineering 2nd Year Prize
1993	John Grant Holmes Memorial Prize

Publications

Featherston, D., Pollock, T. and Power, M. Odour Dispersion Modelling of Meat Chicken Farms. Rural Industries Research & Development Corporation (RIRDC). ISBN: 978-1-74254-719-0. 21 October 2014.

Featherston, D. and Kriznic, P., 'The effect of house model detail and the presence of an acoustic barrier on prediction of pollutant dispersion from a roadway using CFD', Fifth International Symposium on Computational Wind Engineering (CWE2010), Chapel Hill, North Carolina, USA, May 23-27, 2010.

Featherston, D., Tomas, J. and Barabasz, M., 'Finite-Element Modelling and Optimisation of Loudspeaker Suspensions', WAFEC Conference Proceedings, Presented at the WAFEC Conference, Worley FEA, February 22 – 23, Melbourne, Australia, 2001.

Featherston, D. and Barabasz, M., 'Loudspeaker Response Improvement Using Cone Thickness Variation', Journal of the Audio Engineering Society, Vol. 48, No. 12, December, pp. 1216-1220, 2000.

Forrest, J. and Featherston, D. Passenger Vehicle Nitrogen Dioxide Emission Rates – PIARC 2012 vs PIARC 2019 Emission Factors. Poster presentation and extended abstract. CASANZ 2019 Conference. Queenstown, New Zealand. 16 – 18 September 2019.

Wilks, R. and Featherston, D. Odour measurement and management at Australian Paper Maryvale. January 2014, Appita Journal 67(1):31-34.

Previous Employment History

July 2002 – Nov 2010 Senior CAE Engineer

Synergetics Environmental Engineering Pty. Ltd.
Tasks: *CFD Engineer* – Pollutant Dispersion Modelling. Involved in the determination of urban residential exposure of pollutants from road tunnel emissions. This involved the integration of CFD and Gaussian air dispersion models into a unified air quality modelling system. Aluminium Smelter Modelling. Modelled the air flow and temperature within and through an aluminium smelter to determine the heat stress levels on personnel and compliance with EPA regulations.
Industrial Ventilation – Computer modelling and site measurements of an installed acid fume extraction system that was not meeting design criteria. Simple modifications were made which allowed the system to function as designed. On-site measurements confirmed all computer modelling results.
Process Design – Involved in the design specifications for a biomedical and clinical waste incinerator. The project involved combustion, heat transfer and thermodynamic issues within government regulatory specifications.
Weather Forecasting – Issue twice weekly site specific seven day weather forecasts for tropical Queensland.
Product Development – Design, analysis and prototype testing of a new range of industrial ventilation hoods. The hoods are designed to minimise occupational exposure to hazardous industrial process emissions.
Supervisor – Supervision and management of engineering projects involving cross discipline areas of control systems, meteorology, risk analysis and engineering design.

Nov. 2000 – April 2002 CFD Consultant – Melbourne Office Manager

CFD Research Pty. Ltd.
Tasks: CFD Consultant – Analysis of a Furnace Heat Exchanger. Lead to the determination of the optimum operating conditions.
Office Manager – Responsible for the running of day-to-day office activities, maintenance of the computer network, purchase of minor capital investments and co-ordinating training courses.
Instructor – Presenting technical information on a group and individual basis during training courses.

Feb. 1997 – Nov. 2000 Consulting Engineer

Lorantz Audio Services Pty. Ltd.
Tasks: Analysis of a current loudspeaker design. Lead to design changes that improved overall product performance.

Curriculum Vitae

Transport for NSW | Sydney Metro Central Station Ventilation | (2020)
The Sydney Metro Central Station platform ventilation system is designed to maintain comfortable atmospheric conditions for the commuting public. A computational fluid dynamics (CFD) model of the station platform area was constructed to assess the ventilation system performance. All heat loads, including those from people and infiltration/exfiltration of air through the platform screen doors, were modelled. Transient simulations showed that the system performed as designed.

National Grid (UK) | Severn Power Transmission Cable Tunnel Ventilation Refurbishment | (2019)
The Severn-Wye power transmission cable tunnel was built during the early 1970's. The original ventilation system was to be replaced with a new ventilation system. The new system design allowed easier maintenance access, increased reliability and controlled for all likely fire scenarios.

National Grid (UK) | Snowdonia Power Transmission Cable Tunnel Ventilation Tender Design | (2019)
National Grid was replacing overhead high voltage power transmission cables with underground cables. Modern higher voltage (400 kV) power transmission cables are air cooled. To achieve this, a ventilation system was designed to meet all required cooling and smoke control requirements for all design conditions.

North East Link Authority (NELA) | NEL Tunnel Ventilation Reference Design and Tender Evaluation| (2018-2020)
The North East Link (NEL) road tunnel consists of two twin bore tunnels each over 6 km long. The ventilation system for the reference design was designed and assessed for normal and emergency operations. This involved the application of tunnel ventilation software (IDA-RTV), CFD modelling and calculations to determine vehicle emissions and smoke conditions for safe operation. The project also involved the assessment of tender submissions.

Westgate Tunnel | Tunnel Ventilation Technical Advisor | (2017-2020)
The Westgate Tunnel consists of a road, including tunnel, connecting City Link to the West Gate Bridge. Provision of ongoing advice regarding tunnel ventilation and fire safety design provisions to the Victorian Government.

Northerly Group | Pedestrian Wind Comfort and Safety Assessment | (2018)
A pedestrian wind comfort and safety assessment of a proposed six-storey retirement housing development in Scarborough Western Australia using CFD. The CFD modelling provided clear guidance with respect to areas that had the potential to be unsafe or where certain activities, such as outdoor sitting and eating, would be uncomfortable for unacceptable durations. This allowed the external and internal architectural design to be refined.

Transport for NSW | Westconnex Due Diligence | (2017-2018)
The Westconnex Project consists of three individual road tunnel projects in western Sydney, when completed, will form a single underground road network. Review and reporting on the designed ventilation system was undertaken for the purposes on informing potential purchasers of the infrastructure from the NSW government.

Western Sydney Airport | Airport Wind Shear Assessment | (2018)
A wind shear assessment, as prescribed under NASF Guideline B, was undertaken for the proposed new Western Sydney Airport. A three dimensional CFD model was constructed of the airport and its surrounds. Recommended developmental limits were supplied based on the study outcomes.

Level Crossing Removal Authority | Wind Driven Rain Study | (2017)
Qualitative assessments of wind driven rain impacts for the design of three new train stations was undertaken. Best practise, international Standards and current literature information was applied in performing the assessments. Recommended modifications to the station designed were made based on the study outcomes.

Metro Trains Melbourne (MTM) | MURL Draught Relief Shaft Performance | (2017)
A three dimensional CFD model was constructed of the three underground railway stations, Parliament, Flagstaff and Melbourne Central. The performance of the Draught Relief Shafts (DRS) was estimated using the modelling for situations before and after proposed smoke management system equipment, such as fans and smoke dampers, were installed. The estimates determined from the modelling were confirmed using site measurements of air velocity.

Western Sydney Airport | Tunnel Ventilation Feasibility Assessment Review| (2017)
Possible designs for the proposed Western Sydney Airport include a train link with possible underground tunnels and stations. A review of advice regarding the ventilation of the underground facilities at this feasibility stage was provided to the Australian Government.

Westgate Tunnel (DEDJTR) | Tunnel Ventilation Options Assessment and Tender Review| (2016-2017)
The Western Distributor Project (Westgate Tunnel) consists of a road, including tunnel, connecting City Link to the West Gate Bridge. An assessment of different, non-standard ventilation options was undertaken along with a technical review of all tender design and construct submissions. Advice regarding the feasibility of each assessed option was provided to the Victorian Government.

Metro Trains Melbourne (MTM) | MURL Smoke Exhaust Atmospheric Dispersion | (2016)
Smoke dispersion modelling using a computational fluid dynamics (CFD) model was undertaken for the Melbourne Underground Rail Loop (MURL). The modelling was undertaken in the highly built up urban environment for numerous exhaust vent design options that would satisfy stakeholders' requirements.

Metro Trains Melbourne (MTM) | MURL Ventilation Assessment | (2016)
A one dimensional ventilation model was created of the Melbourne Underground Rail Loop (MURL) to evaluate the air flow rates through the entire system as a whole in the event of a fire/incident at one of the many underground station platforms. Numerous combinations of ventilation system operation were examined. Detailed sensitivity testing was undertaken which determined the important parameters to be considered when operating and designing upgrades to the ventilation system.

Sydney Metro North West Rail Link (TfNSW) | Independent Certifier | (2016)
Independent certification role assessing submitted design documentation against specified project design and performance requirements for the Sydney Metro North West underground train system in Sydney. The assessment focussed on the tunnel ventilation requirements of the design and interconnected systems.

Ambleside Tunnel (South Australia) Ventilation Assessment (ARTC) | OH&S Air Quality Assessment | (2015)
Assessment of the ventilation requirements for construction and earthworks inside of the 170 m tunnel to maintain an atmosphere compliant with Occupational Health and Safety regulations in South Australia. The analysis included a review of mitigation options and calculation of an emissions inventory.

Canarail (Canada) | Preliminary Tunnel Ventilation Assessment | (2015)
Assessment of the ventilation requirements for safe operations through three proposed iron ore freight tunnels through Quebec. The assessment included an analysis of the pollutant and heat emissions from a diesel train through two 1 km long tunnels and one 3 km long tunnels. Recommendations were made with regards to a further work required during later stages of the design process.

Christchurch Prison (New Zealand) | Roof Ventilators Performance Analysis | (2015)
A CFD model was constructed of a passive roof ventilator for a prison facility. The pressure loss coefficient was determined via the numerical modelling based on supplied design drawings and evaluated against typical values. The information was used by the fire engineer to determine specific smoke spill fan capacity requirements.

Public Transport Victoria (PTV) | MURL Smoke Exhaust Atmospheric Dispersion | (2015)
Smoke dispersion modelling using a computational fluid dynamics (CFD) model was undertaken for the Melbourne Underground Rail Loop (MURL). The modelling was undertaken in the highly built up urban environment for numerous exhaust vent design options that would satisfy stakeholders' requirements.

Department of Defence | High Voltage Transformer Room Ventilation | (2015)
There were concerns that a high voltage transformer and an auxiliary transformer were not going to be properly ventilated and would therefore overheat. A CFD model of the room configuration and design weather conditions was constructed and used to determine potential room temperatures and ventilation rates.

Toowoomba Regional Council | Aerodrome Wind Shear Assessment | (2015)
A wind shear assessment, as prescribed under NASF Guideline B, was undertaken for a proposed development at the Toowoomba aerodrome. A three dimensional CFD model was constructed of the aerodrome and its surrounds, with and without the development. Recommended developmental limits were supplied based on the study outcomes.

Hobart International Airport | Wind Turbulence Study | (2014)
A study of the effect of landscaping at the end of a runway on local wind vertical velocity and turbulence was undertaken. Estimates of flight path winds and turbulence was made using a constructed CFD model of the area. These estimates were used to inform additional studies with regards to the risk to landing aircraft.

Westconnex Road Tunnel Tender Design | Submission Fire Performance of Rock Bolts | (2014)
A numerical analysis of a rock bolt configuration was examined. The rock bolt and the adjacent tunnel lining had to be able to withstand certain conditions during a design fire event. Numerous numerical transient models were constructed to determine the performance of different design options and minimum design requirements to meet Australian and international standards.

APA – Mains Gas Leak Modelling | (2014)
As part of a risk assessment into the potential impact of increasing gas pressure inside underground pipelines, a series of Computational Fluid Dynamic (CFD) models were constructed. The models consisted of complex physics where rapid gas expansion was immediately followed by combustion reactions of a sonic jet plume within a confined environment. The CFD modelling provided estimates of radiant heat and surface temperatures exposure.

Fortescue Metals Group (FMG) | Conveyor Tunnel Ventilation | (2014)
An assessment of the ventilation conformance of an iron ore conveyor tunnel in regard to the potential exposure of transiting and maintenance personnel to pollutants such as nitrogen dioxide, conveyor dust and diesel particulate matter (DPM) was undertaken. It was found that DPM was the limiting factor that lead to the recommendation that diesel powered generators not be operational inside the short tunnel at the same time as personnel.

East-West Link (Linking Melbourne Authority) | Tender Review | (2014)
Part of a small team responsible for reviewing tender submissions for the design and construction of the East-West Link Stage 1 tunnel between the Eastern Freeway and City Link. The process involved a confidential and critical assessment of each of the submissions with respect to compliance to the project performance requirements for ventilation, fire/life safety and environmental impact – both during operation and construction.

BHP Billiton (Iron Ore) | Newman Mine Train Load-out Tunnel Ventilation | (2012)
Compilation of an emissions inventory and occupational health and safety exposure assessment for iron ore hauling diesel locomotives. Modelling of emissions, using emission specifications and measurements, from locomotives and assessing the impact of tunnel ventilation system design on the exposure of locomotive drivers to nitrogen dioxide emissions. A detailed assessment, complying with regulatory guidelines, of possible design options was

provided to the client. This project involved the application of standard engineering ventilation design principles and CFD modelling.

Maldon-Dombarton Rail Link (Transport for NSW) | Air Quality Assessment | (2013)
Compilation of an emissions inventory for diesel locomotives travelling along a freight corridor. Assessment of the proposed ventilation system performance of the 4 km tunnel for compliance with NSW environmental regulations. A detailed assessment, complying with regulatory guidelines, of the impact of the proposed project and the tunnel ventilation system on the local environment was provided to the client.

Refrigeration Cabinet Design | (2010)
Refrigeration cabinets were re-designed to decrease the amount of cold air spillage into the aisle of a supermarket. The new design led to a reduction in cold air spillage, which significantly decreased the energy consumption of the refrigerator. Moist air was no longer entrained into the evaporator, and therefore, less energy was used in latent heat transfer of condensing water.

Thermal and Energy Performance of a Domestic Ceiling Cavity Ventilation System | (2010)
The thermal performance of a commercially available domestic ceiling cavity ventilation system was examined. For the climate examined, the unit provided limited overall heating/cooling costs savings. However, on very hot days, cooling costs could be reduced by as much as 50 per cent.

Xstrata Mt Isa Mines | Industrial Ventilation and Fume Capture from Copper Smelting | (2009)
The tapping of a copper smelter produces significant gaseous emissions. A CFD model was constructed of the tapping deck of a copper smelter to determine the best way to capture the emissions. The project led to a significant reduction in fugitive emissions from the copper production process.

Rio Tinto | Aluminium Smelter Ventilation | (2009)
Aluminium smelter building ventilation is driven by natural buoyancy. A CFD model of the complete internal structure of an aluminium smelter pot room was constructed. Heat loading was applied to generate the natural ventilation which drives the emissions through the roof vents. These internal models were coupled to a series of external wind fields to determine the total amount of emission from the roof ventilators for environmental regulatory reporting.

NSW RTA | In-tunnel Smokey Vehicle Detection System Analysis | (2008)
A detailed CFD model of various different truck configurations was constructed to assess the performance of a system design to identify smokey trucks travelling through and urban road tunnel. The CFD model involved transient simulations using Moving Dynamics Mesh techniques. The results were used by the client to fine tune the accuracy of the system to identify polluting vehicles.

Rio Tinto | Heat Stress Assessment inside Aluminium Smelters | (2007)
Aluminium smelter building ventilation is driven by natural buoyancy. An increase in aluminium production leads to more heat being generated, and therefore, more induced ventilation. However, workers inside the building can be subject to large surfaces of hot metal covers radiating heat. A heat stress assessment on workers prior to an increase in production was undertaken using a CFD model. The Wet-Bulb-Globe-Temperature (WBGT) was used as the assessment tool. Recommended working practices within the aluminium smelter building were implemented.

Toyota (Australia) | Altona Casting Plant Fume Extraction System | (2006)
Field measurements and construction of a numeric model of the entire fume extraction system for the aluminium casting processes.

Design and Analysis of Fume Capture Systems for Aluminium Casting Processes | (2006)
Aluminium casting is a relatively clean process; nevertheless, fume emissions from the casting process can contain toxic substances that may have adverse effects on operators if exposure becomes too great. The entire casting platform for motor vehicle components was modelled using CFD to allow for improvement in the fume capture system to be assessed. The modelling showed that fans for cooling the operators would circumvent the fume capture systems.

Assessment of Green Building Thermal Performance | (2006)
A CFD model was constructed to determine the thermal and ventilation performance of a first generation “green” office building. The results indicated that large areas a stagnant air were present, which could be confirmed by the client. As the client had a large absentee rate due to illness, the results from the modelling assisted facilitation of the client’s relocation.

Copra Drying | (2005)
Multiple CFD models were constructed to assess the design of a rotary copra (coconut) dryer. A single phase gas model with heat transfer was constructed for the dryer assessment. A Granular-Eulerian multi-phase model was constructed for the design and optimisation of internal paddle placement that maximised airborne copra. The process was improved to eliminate the burning of copra while maintaining product quality.

Heat Exchanger Design | (2005)
A cross flow tube heat exchanger was designed to conform to process requirements for heat transfer and process flow pressure losses. The design had to be robust enough to be constructed in Australia and installed and operated in regional Papua New Guinea. The constructed heat exchanger exceeded the design performance requirements.

NSW RTA | Road Tunnel Vehicle Emissions & Ventilation Modelling | (2004)
A vehicle emissions inventory applicable for the Sydney’s Cross City Tunnel was constructed for the purposes of determining minimum ventilation requirements for the tunnel. The ventilation of the tunnel, with regards to PIARC requirements, including main fans, jet fans and ventilation pressure losses, was examined under various different scenarios including minimum energy consumption. The model was used to assist the client in determining tunnel design specifications and the optimum location of sensors for the tunnel ventilation control system.

Synergetics Environmental Engineering | Product Development of Low Flow Dust Capture Hoods (Patent Pending) | (2004)
Development of dust capture hoods for the purposes of reducing dust emissions from paper mill processes while minimising the energy consumption.

NSW RTA | M5 East Tunnel Ventilation Modelling | (2002)
Construction of an emissions and CFD model of the M5 East tunnel ventilation system for analysis of localised in-tunnel high pollution levels.

Airborne Water Droplet Dispersion for the 2006 Commonwealth Games | 2005
The dispersion of water droplets from the Yarra River during the 2006 Commonwealth Games “Fish” display was modelled. A combination of CFD models and heat and mass transfer analysis was undertaken to determine if an airborne water droplet would evaporate or would travel to the nearby river bank. A probability distribution based on the local wind speed that determined the maximum water fountain height was supplied to the Commonwealth Games organisers.

NSW RTA – Tunnel Ventilation Stack Dispersion Modelling | (2002)
Construction of a CFD model of central Sydney for the atmospheric dispersion modelling of emissions from a proposed ventilation stack of the Cross City Tunnel. Complex urban flow and interaction with multiple high rise buildings were modelled. Short term peak ground level pollution concentrations were determined through transient atmospheric dispersion modelling. A complete assessment against regulatory dispersion models AUSPLUME and CALPUFF was undertaken and provided the client with confidence in their selected ventilation stack design.

Jemena – Gas Pipeline Blowdown Dispersion Modelling | (2012)
A high voltage electricity power line was proposed to cross a natural gas pipeline near a release vent. In order to undertaken pipeline maintenance, the high pressure gas must be vented through the release valve in what is known as a “blowdown”. The extent of a potential explosive mixture of natural gas and air was model using CFD in order to determine a minimum separation distance between the high voltage electrical network and the release vent.

BLEVE Modelling | (2012)
CFD modelling of Boiling Liquid Expanding Vapour Explosion (BLEVE) in an enclosed space. Determination of the primary blast pressure pulse

secondary reflected pressure pulses and expanding flame front from a ruptured flammable gas pressure vessel.

Smelting Lance Performance Assessment | (2007)
The internal design of a copper smelting lance was examined. It was found that superior heat transfer performance could be obtained by creating a swirl in one part of the internal lance flow.

Medical Waste Incineration | (2006)
A rotary furnace medical waste incinerator was designed and analysed for compliance with government regulations. The process consisted of the design of a primary and secondary furnace, with dry air heat exchange and lime dosing to comply with government regulations on dioxin discharges to air. Various spreadsheet and CFD based models were constructed to assess the performance of the system to a level required for a Works Approval Application.

Radiant Heat Exchanger (2001)
The processing of nickel clinker involved heated clinker travelling along a conveyor and exiting the furnace. As the clinker exited, cool hydrogen gas was blown into the furnace to minimise oxidisation of the clinker. To improve energy efficiency, a radiant heat exchanger was designed and optimised using CFD modelling. The heat from the clinker would radiate to a series of panels designed to intercept the radiation and transfer the heat to the hydrogen gas via convection. The design was implemented into the mining process reducing the need to pre-heat the hydrogen before entering the furnace.

Charge Air Cooling Radiator Assessment | (2003)
Combustion air for a diesel train passes through a super charger where it is both compressed and heated. To improve engine performance, this charge air is cooled through a dry air radiator. A CFD model was constructed to determine the performance of the charge air cooling unit under different environmental conditions.

IDRIS (Qatar, USA) – CFD Modelling of Sewer Connections (2016)
A series of differing connections were modelled using CFD analysis. The connections ranged from simple two pipe connections to drop pipe structures of varying heights. The performance of each connection preliminary design was evaluated to provide information for design improvements.

Yonkers County (New York, USA) – Grit Tank CFD Modelling (2016)
A rectangular baffled grit tank at a waste water treatment plant was modelled using CFD analysis. The performance of the tank with regards to numerous different flow and baffle configurations was examined.

City of Barrie (Oro Medonte, Canada) – Sludge Settling Tank Jet Mixer CFD Modelling (2016)
A circular bio-solids sludge settling tank at a waste water treatment plant was modelled using CFD analysis. The performance of a submerged jet mixer system was assessed with regards to re-suspending the settled solids.

Rockland County (New York, USA) – Secondary Settling Tank CFD Modelling (2015)
A rectangular secondary settling tank at a waste water treatment plant was modelled using CFD analysis. The performance of the tank with regards to numerous different flow and influent conditions was examined.

VicRoads – Stormwater Siphon Modelling | (2015)
A CFD model was constructed of a proposed modification to a stormwater system. The existing surface drain was to be replaced with a siphon passing under some buried infrastructure. Numerous models were constructed and assessed of different pipe configurations to determine which was the most optimum with respect to performance, constructability and on-going maintenance.