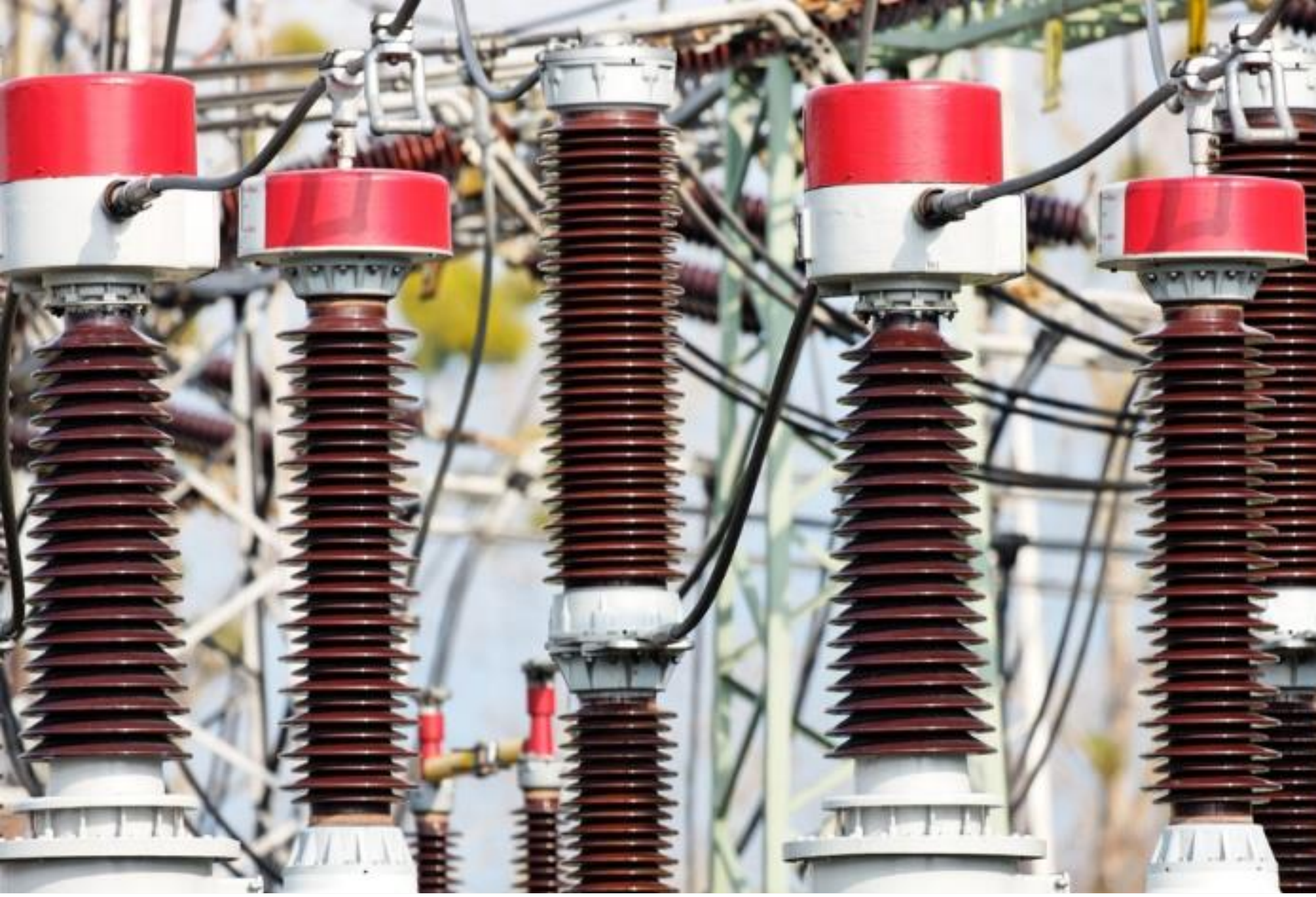
Appendix Q
Plume Rise Assessment



Newcastle Power Station

Plume Rise Assessment

4 September 2019

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The business of sustainability

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4 September 2019

Newcastle Power Station

Plume Rise Assessment

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EXECUTIVE SUMMARY

ERM Australia Pacific Pty Ltd (ERM) was commissioned by Aurecon Australia Pty Ltd (Aurecon) to undertake a Plume Rise Assessment (PRA) for the AGL Newcastle Power Station (the Project).

AGL is seeking to construct and operate peaking power station of approximately 250 MW capacity, comprising either open cycle gas turbine (Gas Turbine) or reciprocating gas engine (Reciprocating Engine) generator technology.

Plume rise modelling was completed using the Commonwealth Scientific and Industrial Research Organisation's (CSIRO's) 'The Air Pollution Model' (TAPM) meteorological and dispersion model, in accordance with the requirements of the Civil Aviation Safety Authority's (CASA's) *Advisory Circular – Plume Rise Assessments* (CASA, 2019), and associated *Technical Brief* (CASA, 2013). Model results (in the form of plume rise profiles) were then interpolated, in order to delineate the critical spatial extent of Project exhaust plumes in airspace.

The analysis was conducted for a Capacity Case, representing a continuous operation of all proposed generation units at full load throughout all hours within the five year (43,824 hour) modelling period. The analysis considered the following cases:

- Two technology alternatives: Gas Turbine and Reciprocating Engine options.
- Three Critical Plume Velocities (CPVs): 4.3m/s, 6.1m/s and 10.6m/s as addressed in CASA (2019).

For both technology alternatives, the modelling predicts incursions of the Obstacle Limitation Surface (OLS) for CPVs of 4.3 m/s and 6.1 m/s. For a CPV of 6.1 m/s:

- the peak Gas Turbine option prediction extends to 410 mAHD, at a height of approximately 250 m above the OLS, whilst the corresponding 99.9th percentile prediction extends up to 285m, approximately 120 m above the OLS. Predictions were within the OLS for greater than 98% of the modelled period.
- the peak Reciprocating Engine option prediction extends to 183 mAHD, at a height of approximately 30 m above the OLS, whilst 99.9th percentile predictions are within the OLS.
- An analysis of diurnal and seasonal variability in model predictions (Appendix A) indicates that critical plume height are typically higher during daylight hours, with a varied distribution of peak impacts between seasons.

AGL propose that the Project will operate on an intermittent basis during times of high network demand or fluctuating supply conditions, which is anticipated to be roughly an order of magnitude lower than the frequency modelled in the Capacity Case. The conservatism in this approach should be recognised when considering the resultant critical plume heights and frequency distributions in the context of potential aviation safety constraints.

Refinement of the assessment approach would involve modelling of anticipated operations (i.e. an Expected Case as opposed to the Capacity Case), thus providing frequency distributions that more closely reflect proposed operation, whilst also testing whether worst case meteorological conditions are encountered during expected operations, as relevant to peak critical plume height predictions.

1. INTRODUCTION

ERM Australia Pacific Pty Ltd (ERM) has been commissioned by Aurecon Australia Pty Ltd (Aurecon) to undertake a plume rise assessment for the AGL Newcastle Power Station (the Project). The Project is proposed to be constructed on a greenfield site at Tomago, on a parcel of land within the bounds of Old Punt Road and the Pacific Highway.

Given the potential for exhaust emissions to rise in the atmosphere at velocities of interest to aviation operations, potential plume rise extent has been investigated in accordance with methods prescribed by the Civil Aviation Safety Authority (CASA). This report provides information to evaluate the potential aviation impacts of the Project, using methodologies prescribed by CASA, including the following:

- Project description
- Assessment framework
- Assessment methodology
- Results and Conclusions.

2. PROJECT DESCRIPTION

2.1 Overview

The Project involves the construction and operation of a power station with a nominal capacity of about 250 MW. The Project would supply electricity to the grid at short notice during periods of high electricity demand, particularly during low supply periods from intermittent renewable sources or during supply outages.

The Project would also involve the construction and operation of a gas pipeline(s) and an electricity transmission line. The pipeline(s) would supply the proposed power station with gas from the eastern Australia gas transmission pipelines via the Jemena network and the Newcastle Gas Storage Facility (NGSF). A new electricity transmission line would transfer the electricity produced by the proposed power station to the national electricity network via connection to the existing 132kV Transgrid switchyard.

The Project has a capital investment value of approximately $400 million and is anticipated to be operational in the year 2022.

The main elements of the Project are as follows:

- Power station comprising of either large reciprocating engine generators or aeroderivative gas turbine generators, necessary supporting ancillary equipment and supporting infrastructure. The power station would be capable of operating with diesel fuel, as necessary.
- 132kV electricity transmission line to the existing Tomago switching yard, operated by TransGrid.
- Gas transmission/storage pipeline(s) and receiving station, compressor units, and ancillary infrastructure.
- Storage tanks and laydown areas.
- Water management infrastructure including pond(s), a connection to existing reticulated potable water infrastructure
- Diesel storage and truck unloading facilities.
- Site access road.
- Office / administration, amenities, workshop / storage areas and car parking.

2.2 Power station

The power station would be a dual fuel power plant, capable of generating about 250 MW of electricity. The proposed power station would either consist of large reciprocating engine generators or aero-derivate gas turbine generators. Generation units would be dual fuel capable, meaning they would be able to be supplied by natural gas and/or liquid fuel.

The decision to install gas turbines or reciprocating technology will be made based on a range of environmental, social, engineering and economic factors that will be considered as the power station design progresses.

2.2.1 Gas Turbine Technology

Electricity would be generated by gas turbine technology through the combustion of natural gas and/or liquid fuel in turbines. With its heritage in the airline industry, aero derivative gas turbine units consist of a compressor, combustion chamber, turbine and generator. Air is compressed to a high pressure before being admitted into the combustion chamber. Fuel (natural gas or diesel as required) is injected into the combustion chamber where combustion occurs at very high temperatures and the gases expand. The resulting mixture of hot gas is admitted into the turbine causing the turbine to turn, generating power. In an open cycle configuration, hot exhaust gas is vented to the atmosphere through an exhaust stack, without heat recovery.

2.2.2 Reciprocating Engine Technology

With its heritage in the shipping industry and a form of internal combustion engine, reciprocating engines used for power generation harness the controlled ignition of gas and/or diesel to drive a piston within a cylinder. A number of pistons move sequentially to rotate a crank shaft which turns the generator.

2.2.3 Ancillary Facilities

The power station, regardless of chosen technology, would require supporting ancillary facilities. These would include:

- Natural gas reception yard potentially including gas metering, pressure regulation, compression, heating stations, pigging facilities and provision for flaring.
- Generator circuit breakers, generator step-up transformers and switchyard including overhead line support gantry.
- Water collection and treatment facilities.
- Water storage tanks and ponds.
- Truck loading/unloading facilities.
- Liquid fuel storage tanks.
- Emergency diesel generators with associated fuel storage.
- Closed circuit cooling systems.
- Control room.
- Offices and messing facilities.
- Electrical switch rooms.
- Occupational health and safety systems including an emergency warning and evacuation system.
- Workshop and warehouse.
- Firefighting system.
- Communication systems.
- Security fence, security lighting, stack aviation warning lights (if required) and surveillance system.
- Landscaped areas and staff parking areas.
- Concrete foundations, bitumen roadways, concrete pads in liquid fuel unloading station and gas turbine or engine unit maintenance areas.
- Concrete bund areas with drains for liquid fuel tanks, liquid chemicals store, oil filled transformers (if installed) and other facilities where contaminated liquids could leak.
- Level construction and laydown area.
- Engineered batters to support and protect the power plant platform.
- Sedimentation pond and associated diversion drain and earth bund.

3. ASSESSMENT FRAMEWORK

Aviation authorities have established that exhaust plumes with vertical velocities exceeding 4.3 m/s have the potential to cause damage to an aircraft airframe, or upset an aircraft flying at low altitudes. Light aircraft, including helicopters, are more likely to be affected by a plume than a heavier aircraft at the same altitude. Part 139.370 of the Civil Aviation Safety Regulations (1998) provides that CASA may determine that a plume is a hazardous object if the vertical velocity of the exhaust exceeds 4.3 m/s. In addition, vertical wind gusts in excess of 10.6 m/s are noted as potentially resulting in severe turbulence and may cause momentary loss of aircraft control.

3.1 CASA Advisory Circular

Guidance for plume rise assessments is provided in *Advisory Circular AC 139-05 v3.0, Guidelines for Conducting Plume Rise Assessments* (CASA, 2019). Plume rise assessment includes the assessment of the critical plume velocity (CPV) and critical plume height (CPH) and the subsequent assessment of potential plume impacts.

Released in January 2019, CASA (2019) introduced a CPV of 6.1 m/s as a default value for analysis of these impacts. Within this report, performance against CPVs of 4.3, 6.1 and 10.6 m/s has been presented. These CPVs are provided in CASA (2019) as thresholds against which potential plume rise impacts may be assessed in accordance with the following classifications:

1. **Light** (1.5 - 6.1 m/s) which can cause momentary changes in altitude and attitude.
2. **Moderate** (> 6.1 - 10.6 m/s) which can cause appreciable changes in altitude and attitude.
3. **Severe** (>10.6 m/s - 15.2 m/s) which can cause large abrupt changes in altitude and attitude and momentary loss of control
4. **Extreme** (> 15.2 m/s) where it can be practically impossible to control the aircraft, and which can cause structural damage.

CASA (2019) considers an exhaust plume of moderate or higher turbulence intensity has the potential to affect the safety of aircraft operations, such as aircraft in critical stages of flight (periods of high pilot workload) and low-level flying operations.A generalised outline of the default plume rise assessment process is outlined in Figure 3.1.

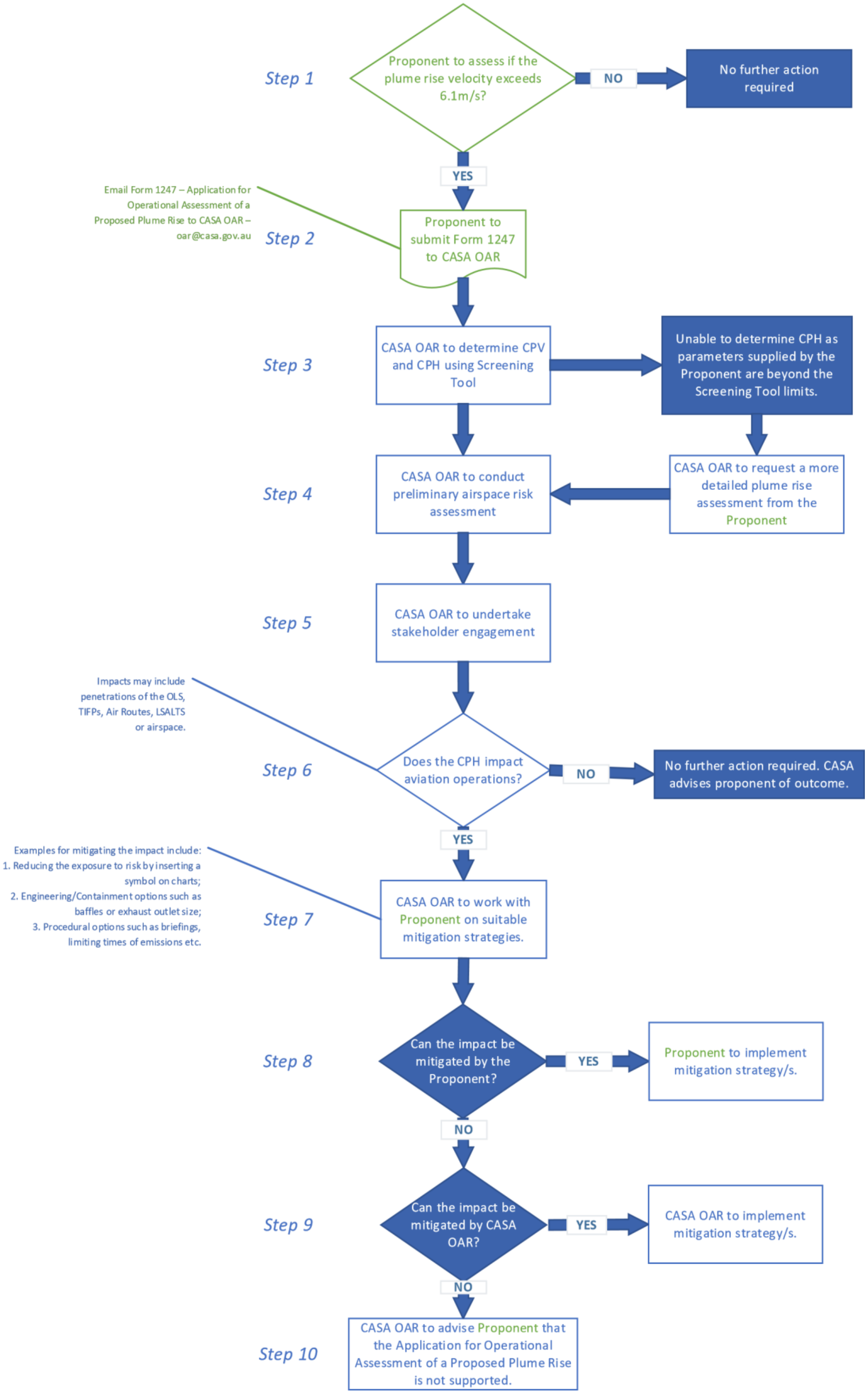


Figure 3.1: Overview of plume rise assessment process (CASA, 2019)

3.2 CASA Technical Brief

The requirements for a detailed plume rise assessment are provided in CASA's *Plume Rise Assessment – Technical Brief* (Technical Brief) (CASA, 2013).

A summary of the requirements to determine the relevant CPH is as follows:

- Site-specific meteorology is to be used.
- A five-year period is to be assessed.
- CASA also specifies that TAPM Version 4 (or later) or CALPUFF Version 6.267 (or later) should be used.
- The methodology described in (Manins P, 1992) should be used to account for the merging of multiple plumes.
- The 0.1% exceedance level for each year should be determined.
- The maximum extent of the plume for each year should be determined.

3.3 Proximity to RAAF Williamtown Airport Airspace

The Project is located approximately 12 km to the west-southwest (WSW) of Williamtown airport. Figure 3.2 shows the location of the facility relative to RAAF Williamtown Airport.

Image source: Google Earth Pro

Figure 3.2: Location of AGL Project Site relative to RAAF Williamtown Airport and surrounds.

Table 3.1: Plume rise analysis spatial information

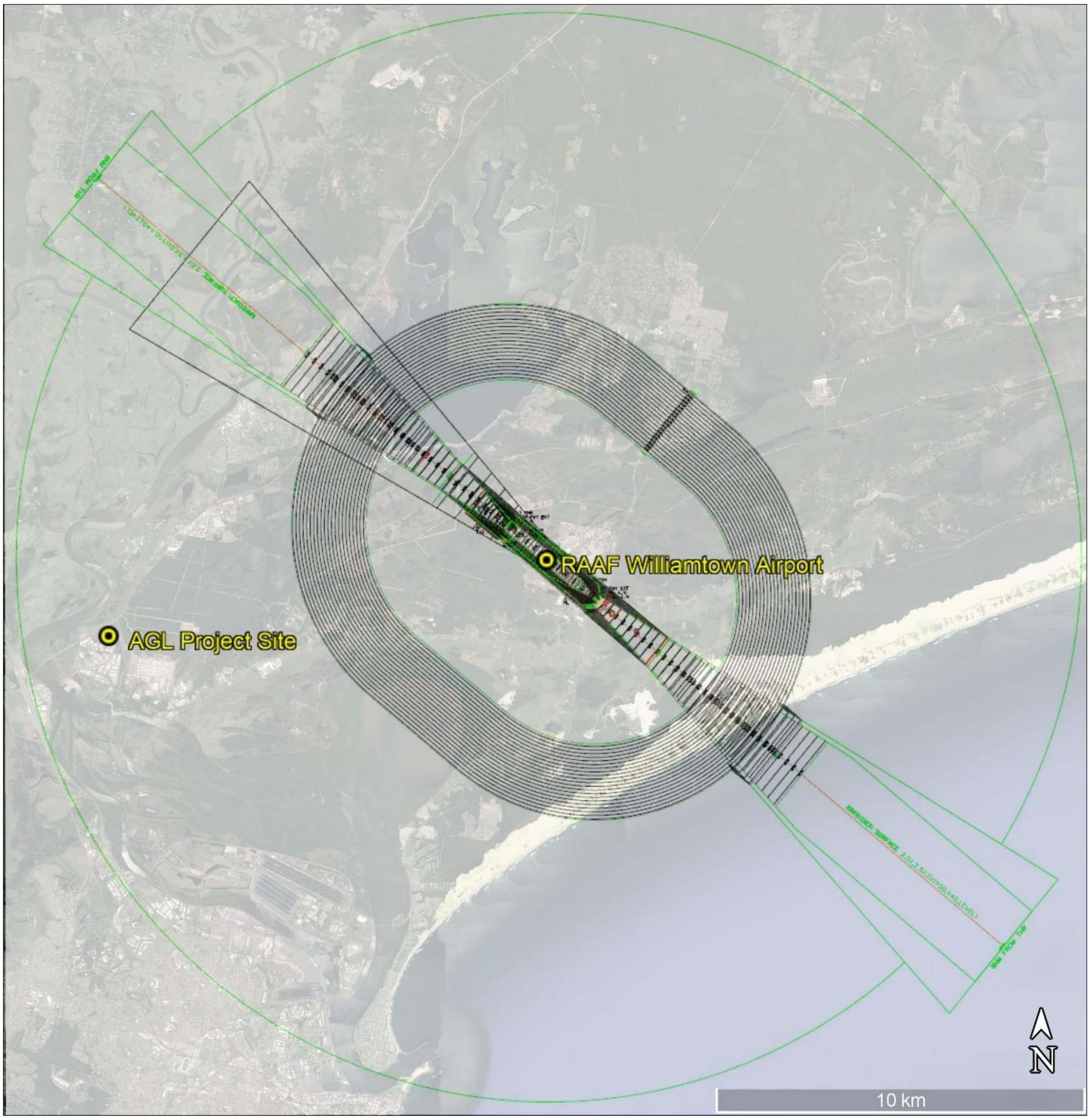
Parameter	Value		Units
Plant easting*	378 986		m MGA94 Zone 56 H
Plant northing*	6368 609		
Base elevation**	15**		mAHD
OLS height	156.5		
PANS-OPS height	-		
	Gas Turbine Option	Reciprocating Engine Option	
Height of exhaust stack**	20	30	mAGL
Top of exhaust stack**	35	45	mAHD

Note:
- *Values represent approximate centre of generator yard (based on preliminary design).
- **Approximate values provided (based on preliminary design).
- mAGL (metres elevation – Above Ground Level).
- mAHD (metres elevation – Australian Height Datum).

ERM has been provided with a non-spatially referenced schematic of the Williamtown OLS (DoD, 2019). For indicative purposes, this image has been aligned with aerial imagery on the basis of the runway alignment, and the annotated distance between the outer approach surface and existing runway extent (threshold)[1], as shown below in Figure 3.3. ERM is not aware of whether this geometry reflects the current runway, hence this figure is provided as indicative.

With an annotated runway ramp length of 8 Nautical Miles (NM), this schematic is estimated to place the Project within the south-western extent of the 156.5 mAHD outer horizontal surface (outer green ring of Figure 3.3), the Project being located approximately 6 NM WSW of the western runway extent.

Procedure for Air Navigation Services – Aircraft Operations (PANS-OPS) information was not available for incorporation into the assessment.



Base image source: Google Earth Pro

Figure 3.3: Indicative outline of the RAAF Williamtown OLS Scheme relative to the Project Site. OLS scheme based on (Department of Defence, 2019)

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[1] Department of Defence (2019), OLS scheme file “WLM_Draft_Rwy_ Ext.pdf”

4. ASSESSMENT METHODOLOGY

4.1 Process Overview

Plume rise modelling has been carried out using the CSIRO's TAPM model (V4.05) in accordance with CASA guidance (CASA 2019; 2013). This has been performed using an iterative process, as required to incorporate the influences of ambient temperature, and plume rise enhancement into the modelling process:

- The TAPM model was run in meteorological mode to provide five years of hourly surface temperature estimates at the Site (2014 to 2018 inclusive).
- Variable emission files were generated for each exhaust option.
- Time-varying exhaust temperatures were estimated using TAPM surface temperatures in conjunction with the design data (which provide exhaust temperature as a function of ambient temperature).
- Maximum exit velocities were applied as representative of the design capacity.
- The CSIRO's TAPM model was run to provide five years (43, 824 hours) of hourly plume rise profiles for a single stack. These profiles were then processed to estimate the extent of plume buoyancy enhancement associated with the merging of plumes produced from the Project's multiple stacks.
- The CSIRO's TAPM model was re-run to provide hourly plume rise profiles incorporating buoyancy enhancement.
- The plume rise profiles were processed to provide a spatial representation of the regions of airspace in which the plume exceeds the CASA defined critical plume velocities (CPVs). Model results were reviewed against the OLS.

A summary of this process is outlined in Figure 4.1:

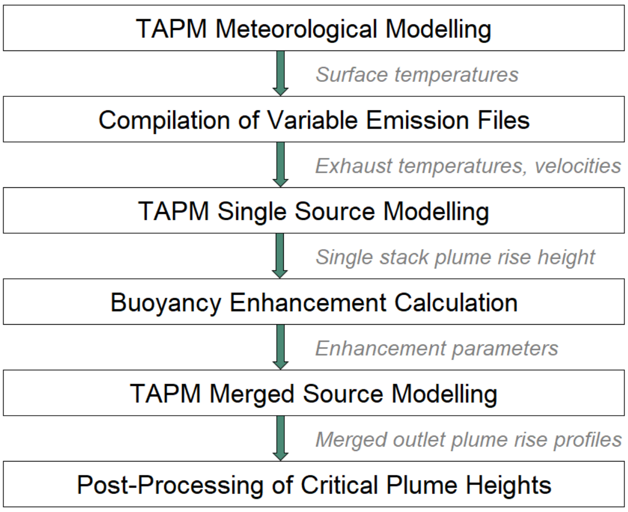


Figure 4.1: Flow chart providing overview of plume rise modelling process

4.2 TAPM Model Configuration

The Air Pollution Model, (TAPM) has been applied in this assessment as nominated for use within CASA (2013). TAPM is a three dimensional meteorological and air pollution model produced by the CSIRO Division of Atmospheric Research (Hurley, 2002a, 2002b; Hurley et al., 2002a, 2002b; Hibberd et al., 2003; Luhar & Hurley, 2003). TAPM solves the fundamental fluid dynamics and scalar transport equations to predict meteorology and pollutant concentrations. It consists of coupled prognostic meteorological and air pollution dispersion components, eliminating the need to have site-specific meteorological observations. The model predicts airflow important to local scale air pollution, such as sea breezes and terrain induced flows, against a background of larger scale meteorology provided by synoptic analyses.

TAPM incorporates the following databases for input to its computations:

- Gridded database of terrain heights on a latitude/longitude grid of 30 second grid spacing, (around one kilometre). This default dataset is supplemented by a finer resolution dataset at nine second spacing (around 270 metres) for this assessment.
- Australian vegetation and soil type data at three minute grid spacing, (around five kilometres).
- Rand's global long term monthly mean sea-surface temperatures on a longitude/latitude grid at one degree grid spacing (around 100 kilometres).
- Six-hourly synoptic scale analyses on a latitude/longitude grid at 0.75-degree grid spacing, (around 75 kilometres), derived from the local analysis and prediction system (LAPS) data from the Bureau of Meteorology.

TAPM (V4.0.5) was run for a five year modelling period as per the configuration outlined in Table 4.1.

Table 4.1: Summary of TAPM model configuration

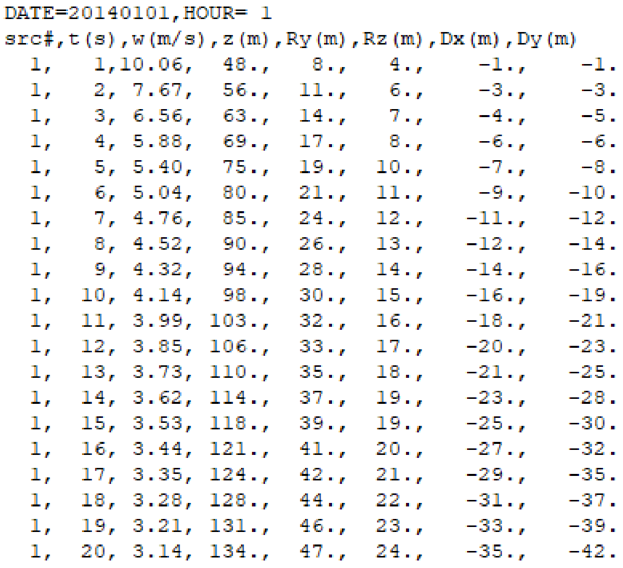
Parameter	Value
Centre of TAPM Analysis	151.7083 °E, 32.8167 °S
	379 085 mE, 6368 298 mN (MGA94, Zone 56H)
Number of grids	4
Grid spacing	30 km, 10 km, 3 km, 1km
Number of grid points	25 x 25 x 25
Years of analysis	2014 to 2018 (inclusive)
Terrain information	AUSLIG 9 second DEM data
Mode	Meteorology and Pollution - Lagrangian Particle Mode (Inner Grid)

4.3 Plume Rise Model

TAPM incorporates a detailed treatment of plume rise, based on a numerical implementation of Glendening (1984). This comprises the solution of a system of coupled differential equations for changes in bulk plume buoyancy, momentum and volume fluxes on a time step basis, with resolution of plume velocity and radius at each time step. For a given hour of the model run, these equations allow the estimation of the plume rise profile corresponding to the meteorological conditions predicted for that hour.

The TAPM outputs from the five year simulation period include a file containing gradual plume rise data for every hour and from each emission source. This output includes data for plume averaged vertical velocity, plume height and plume dimensions from one second after release to the time that the final plume height is reached.

A sample gradual plume rise output file from TAPM is presented in Figure 4-2. This file shows plume rise parameters for the first 20 seconds (t(s)) after release, for the first hour of a model run. The outputs show the vertical velocity (w), height (z) and plume spread statistics (Ry, Rz, Dx and Dy).



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  1,    4, 5.88,  69.,   17.,    8.,    -6.,    -6.
  1,    5, 5.40,  75.,   19.,   10.,    -7.,    -8.
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  1,    8, 4.52,  90.,   26.,   13.,   -12.,   -14.
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  1,   12, 3.85, 106.,   33.,   17.,   -20.,   -23.
  1,   13, 3.73, 110.,   35.,   18.,   -21.,   -25.
  1,   14, 3.62, 114.,   37.,   19.,   -23.,   -28.
  1,   15, 3.53, 118.,   39.,   19.,   -25.,   -30.
  1,   16, 3.44, 121.,   41.,   20.,   -27.,   -32.
  1,   17, 3.35, 124.,   42.,   21.,   -29.,   -35.
  1,   18, 3.28, 128.,   44.,   22.,   -31.,   -37.
  1,   19, 3.21, 131.,   46.,   23.,   -33.,   -39.
  1,   20, 3.14, 134.,   47.,   24.,   -35.,   -42.
```

Figure 4.2: Excerpt from TAPM gradual plume rise file

The TAPM plume rise profiles are provided in regular time intervals from the point of release. Therefore plume rise statistics for specific heights need to be generated via interpolation of the TAPM outputs. Each hourly prediction is then collated into statistical representations of plume rise extent across each 43,824 hour model run.

4.4 Model Scenarios

The assessment has been undertaken using conservatively constructed modelling scenarios for the following technology options:

- Gas Turbine
- Reciprocating Engine.

Further detail of scenario assumptions is provided in the following.

4.4.1 Operating Condition

Modelling has been undertaken for a plant capacity case. This scenario reflects the plant operating at continuous full load across all hours of the model run. This approach provides an estimate of the extent and distribution of potential critical plume height as a function of variability in the local meteorology alone.

AGL propose that the Project will operate on an intermittent basis during times of high network demand or fluctuating supply conditions, which is anticipated to be roughly an order of magnitude lower than the frequency modelled in the capacity case. The conservatism in this approach should be taken into account when considering the resultant critical plume heights and frequency distributions. The power station would operate with a capacity factor in the order of 14% during its initial years of operation with annual starts ranging from 50 to 200 and varying across seasons.

4.4.2 Generator Technologies

AGL is proposing to employ either Gas Turbine or Reciprocating Engine technology for the Project. ERM has been provided with vendor specifications for a range of gas turbine and reciprocating engine options being considered by AGL.

ERM have screened potential plume rise impacts from these options, and progressed detailed modelling of one Gas Turbine and one Reciprocating Engine option as representative of the scale of potential critical plume heights.

4.5 Plume Merging

When multiple emission sources are situated within reasonable proximity to one another, the plumes can overlap and interact, reducing the ratio of entrainment to buoyant acceleration, thus resulting in enhanced plume rise. This process is referred to as plume rise enhancement. When sources are operating concurrently, each plume may be subject to the effects of buoyancy enhancement.

Figure 4.3 provides a schematic of the plume merging process.

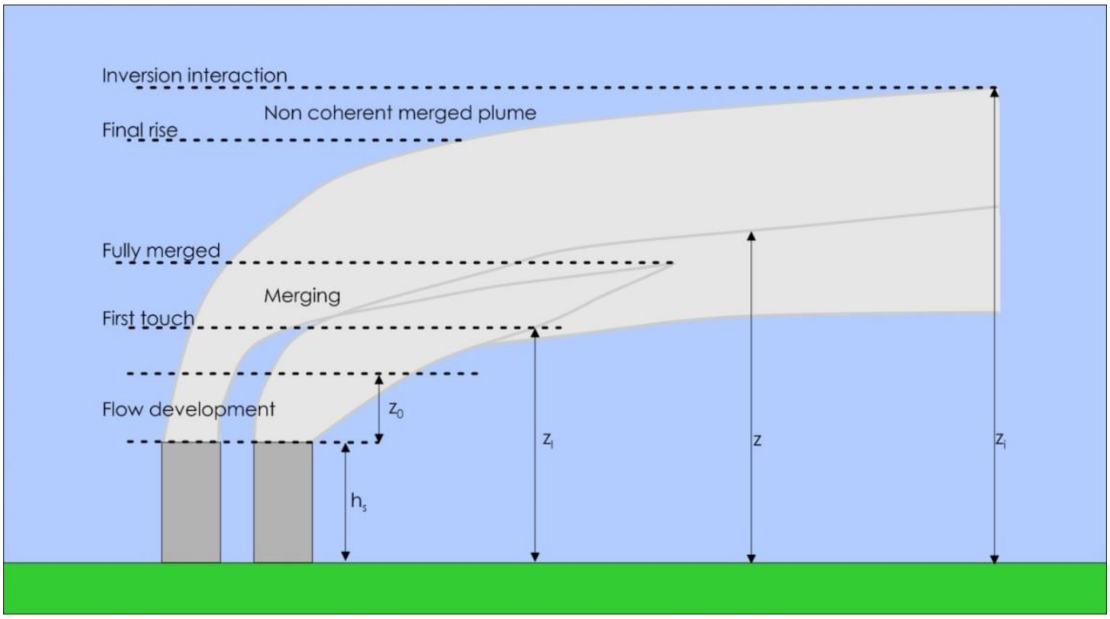

Figure 4.3: Schematic of plume merging process.

As specified in the CASA's Technical Brief (CASA, 2013), the most appropriate approach to estimating the buoyancy enhancement is described in and is based on work previously undertaken by Briggs (Briggs, 1975; 1984). The approach defines a buoyancy enhancement factor (N_E) as follows:

$$N_E = \left[\frac{n+S}{1+S}\right] \qquad \text{Equation 1}$$

Where *n* is the number of stacks and S is the dimensionless separation factor, defined as:

$$S = 6 \times \left[\frac{(n-1)\Delta s}{n^{\frac{1}{3}}.\Delta z}\right]^{\frac{3}{2}} \qquad \text{Equation 2}$$

Where Δs is the stack separation and Δz is the rise of an individual plume above the top of the stack (i.e. for a single stack in isolation).

4.5.1 Gas Turbine Option

For the Gas Turbine option, the relevant Δz was estimated for a single stack in isolation, whilst Δs was based on the stack separation. The separation factor and buoyancy enhancement factor were then estimated in accordance with Equation 1 and Equation 2.

4.5.2 Reciprocating Engine Option

The Reciprocating Engine design features a grouped stack configuration, comprising 15 individual stacks as 3 x 3 stack groups and an additional 6 stack group. Each group comprises adjacent stacks with a separation distance in the order of 2 m. Given the small separation distance, emissions from stacks within each group will merge almost immediately, hence each group can be treated as a single emission source, possessing an effective diameter that provides a cross sectional area equivalent to that of the sum of the stacks within each group.

Given the presence of dissimilar stacks (i.e.differing effective diameters and separation distances), the treatment of plume merging for the Reciprocating Engine option requires a modified implementation of Manins (1992) as per the guidance provided in Briggs (1975). In development of the equations referred to by Manins, Briggs rationalises the bracketed component of the separation factor (Equation 2) as the ratio of the total source line width to the total possible plume rise of all of the plumes were combined at the source:

- Briggs states "*to adapt [Equation 2] to clustered sources, one can simply replace (N-1) with the greatest distance across the cluster*". Accordingly, the Reciprocating Engine plant dimension (131 m) has been maintained in place of the numerator expression of Equation 2.
- The total combined plume rise has been calculated by modelling a single stack possessing an effective diameter that provides a cross sectional area equivalent to the 15 stacks combined. This combined plume rise has been applied in place of the denominator expression of Equation 2.
- The calculated separation factor has then been resolved to provide the number of effective groups, assuming each group possesses 3 individual stacks – as representative of the base quantity within the design.

4.5.3 Summary of Plume Merging Parameters

Table 4.2 provides a summary of the merging parameters applied within the analysis.

Table 4.2: Summary of merging parameters

Enhancement Parameter	Gas Turbine Option	Reciprocating Engine Option	Units
n	4	5[1]	-
Δs	22	32.8	m
Δz	279.9	-	m
$n^{1/3}.\Delta z$	444.3	359[2]	m
S	0.3	1.325	-
Buoyancy Enhancement N_E	3.23	2.72	-

Note: 1: 3 stacks per group across n grouped stacks.
2: Derived from whole of plant plume modelling.

4.6 Emission Parameters

Table 4.3 provides a summary of modelled emission parameters

Table 4.3: Summary of emission parameters

Parameter	Gas Turbine Option		Reciprocating Engine Option		Units
Base elevation	15				mAHD
Location	All sources located at plant centre[1]: 378 986 mE 368 609 mN				MGA94
Height	20		30		mAGL
Exit temperature	413 – 448[2]		385		°C
Exit velocity	60		27.2		m/s
Stack diameter	2.782		1.6		m
Total number of stacks	4		15		-
	Single Stack Run	Plume Merging Run	Whole Plant Run	Plume Merging Run	
Effective diameter	2.782	2.782	6.197[3]	2.771[3]	m
Buoyancy Enhancement (N_E)	1	3.23	1	2.72	-

Note: 1: Stack separation included as per generic manufacturer site layouts. Meteorology included based on location defined in this table.

2: Time varying temperature incorporated (as a function of ambient conditions).

3: Equivalent cross sectional area of 15 and 3 stacks for Whole Plant and Plume Merging runs (respectively).

5. RESULTS

This section presents the plume rise modelling results. Hourly plume rise profiles have been processed to identify the vertical and horizontal regions of the atmosphere in which the plume possesses a velocity greater than or equal to the subject critical plume velocity (CPV)

For each modelling scenario the following results have been produced:

- Tabulated data showing (by year and across all years):
  - Maximum vertical velocity at OLS.
  - Maximum critical plume height.
  - 99.9th percentile critical plume height
- Probability density plots outlining the variation in critical plume extents by frequency of occurrence.

Modelling results have been produced for CPVs of 4.3 m/s, 6.1 m/s and 10.6 m/s, for both Gas Turbine and Reciprocating Engine plant options.

The shaded region of each probability density plot represents the region of space above the Project for which the exhaust plume was predicted to possess a velocity greater than or equal to the CPV at any time during the model run. Within this region, the incremental contour values indicate the regions of space for which velocities greater than or equal the CPV are achieved with increasing frequency. E.g. a 0.1 increment contour indicates the region of space below which a velocity equal to or greater than CPV is attained for 10 per cent or more of modelled hours.

In addition, a summary of the diurnal and seasonal variability in CPH predictions has been provided in Appendix A.

5.1 Gas Turbine Option

A summary of modelling results for the Gas Turbine Option is presented in Table 5.1, whilst corresponding probability density plots of critical plume extent are shown in Figure 5.1. Incursions of the OLS are marked with an asterix.

Table 5.1: Summary of plume rise modelling results – Gas Turbine Option, Capacity Case

Statistic	2014	2015	2016	2017	2018	All Years	Units
Maximum vertical velocity at OLS	8.1	8.2	8.3	8.5	8.4	8.5	m/s
CPV: 4.3 m/s							
Maximum critical plume height	592*	647*	757*	616*	882*	882*	mAHD
99.9th percentile critical plume height	509*	538*	551*	474*	567*	533*	
Percentage of hours within OLS	92.5%	90.9%	90.5%	91.7%	91.4%	91.4%	
CPV: 6.1 m/s							
Maximum critical plume height	374*	377*	387*	361*	410*	410*	mAHD
99.9th percentile critical plume height	257*	309*	280*	272*	290*	285*	
Percentage of hours within OLS	98.6%	98.2%	98.0%	98.4%	98.0%	98.2%	
CPV: 10.6 m/s							
Maximum critical plume height	61	61	60	61	61	61	mAHD
99.9th percentile critical plume height	60	60	60	60	60	60	
Percentage of hours within OLS	100%	100%	100%	100%	100%	100%	

Note: Incursions of the OLS marked with an asterix.

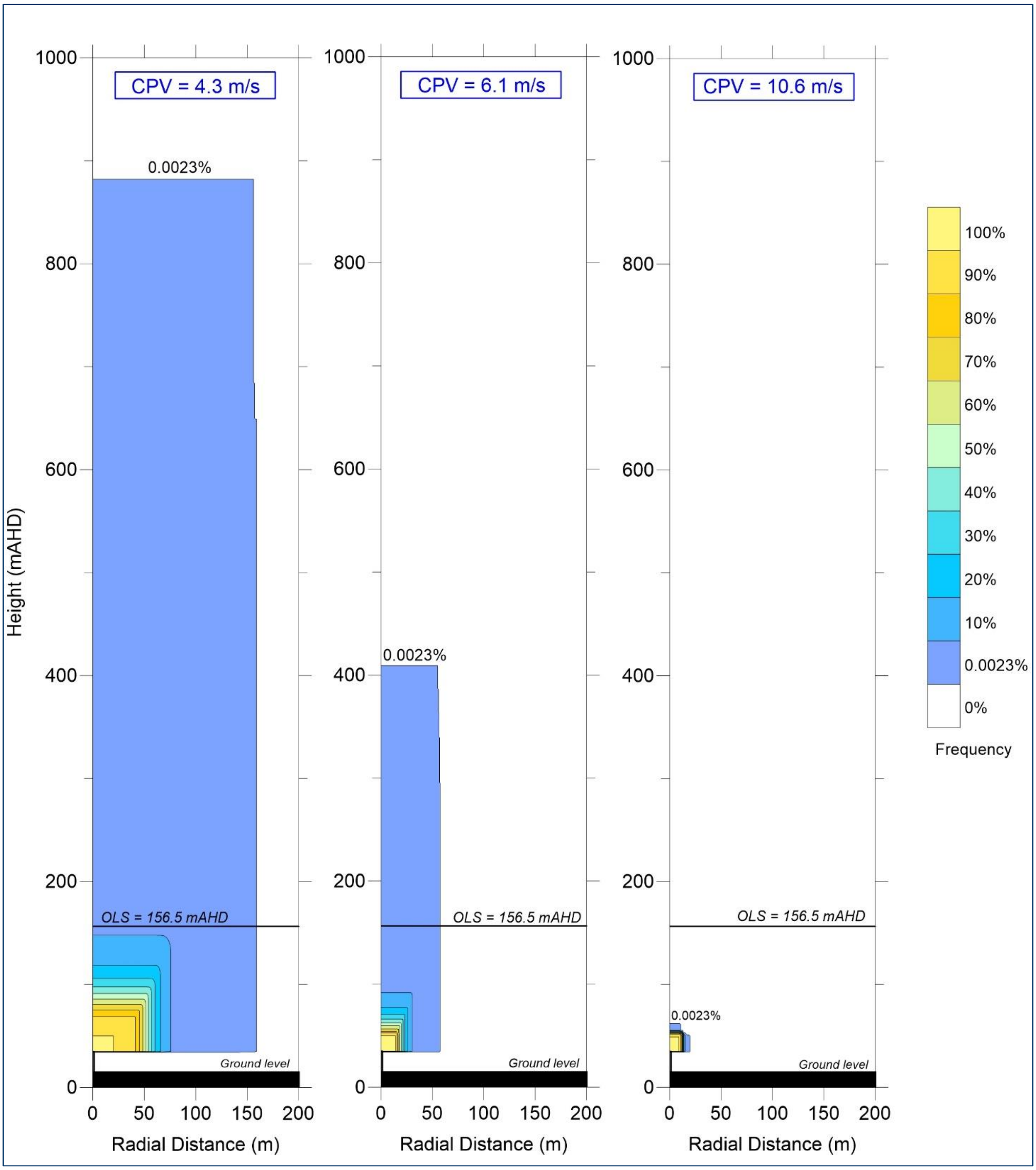

Figure 5.1: Critical plume extent probability density plots - Gas Turbine Option, Capacity Case

As shown in Table 5.1 and Figure 5.1, for a CPV of 6.1 m/s, the peak Gas Turbine option prediction extends up to 410 mAHD, at a height of approximately 250 m above the OLS, whilst the corresponding 99.9th percentile prediction extends up to 285 m, approximately 120 m above the OLS.

5.2 Reciprocating Engine Option

A summary of modelling results for the Reciprocating Engine Option is presented in Table 5.2, whilst corresponding probability density plots of critical plume extent are shown in Figure 5.2. Incursions of the OLS are marked with an asterix.

Table 5.2: Summary of plume rise modelling results – Reciprocating Engine Option, Capacity Case

Statistic	2014	2015	2016	2017	2018	All Years	Units
Maximum vertical velocity at OLS	6.0	6.1	6.2	6.5	6.4	6.5	m/s
CPV: 4.3 m/s							
Maximum critical plume height	375*	376*	390*	358*	417*	417*	mAHD
99.9th percentile critical plume height	247*	300*	268*	260*	281*	272*	
Percentage of hours within OLS	98.9%	98.8%	98.5%	98.9%	98.4%	98.7%	
CPV: 6.1 m/s							
Maximum critical plume height	151	155	168*	183*	176*	183*	mAHD
99.9th percentile critical plume height	123	139	140	128	143	135	
Percentage of hours within OLS	100%	100%	99.98%	99.98%	99.95%	99.98%	
CPV: 10.6 m/s							
Maximum critical plume height	58	57	58	58	58	58	mAHD
99.9th percentile critical plume height	57	57	57	57	57	57	
Percentage of hours within OLS	100%	100%	100%	100%	100%	100%	

Note: Incursions of the OLS marked with an asterix.

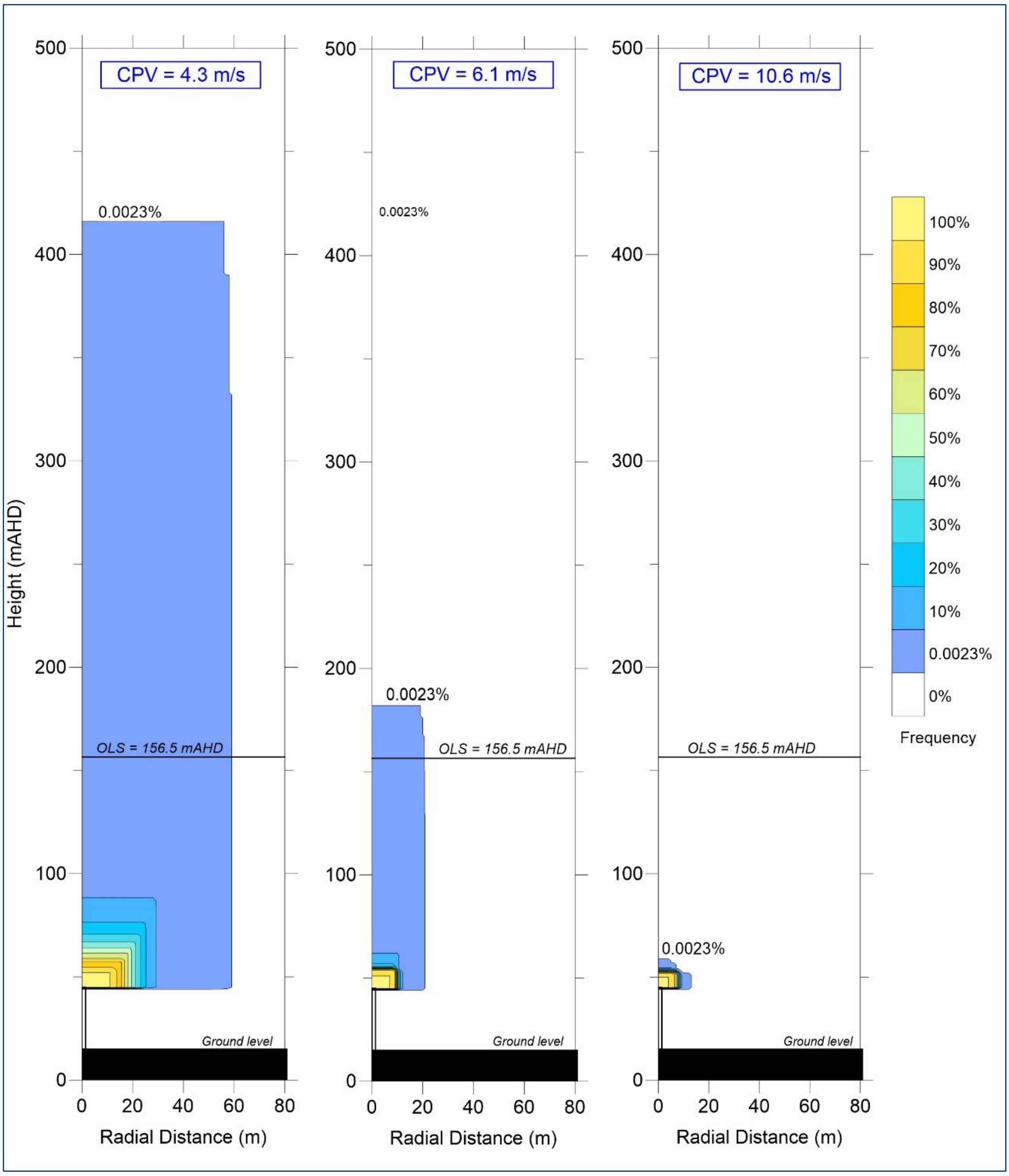

Figure 5.2: Critical plume extent probability density plots - Reciprocating Option, Capacity Case

As shown in Table 5.2 and Figure 5.2, for a CPV of 6.1 m/s, the peak Reciprocating Engine option prediction extends up to 183 mAHD, at a height of approximately 30 m above the OLS, whilst 99.9th percentile predictions are within the OLS.

6. CONCLUSIONS

This report has assessed the potential plume rise extent of exhaust emissions from the Project. Plume rise modelling has been completed using the CSIRO's TAPM meteorological and dispersion model in accordance with the requirements of CASA (2013; 2019). Results have then been processed in order to delineate the critical spatial extent of Project exhaust plumes in airspace.

The analysis has been conducted for a Capacity Case, representing a continuous operation of all proposed generation units at full load throughout all hours within the five year (43,824 hour) modelling period. The analysis has considered the following cases:

- Two technology alternatives: Gas Turbine and Reciprocating Engine options.
- Three Critical Plume Velocities (CPVs): 4.3m/s, 6.1m/s and 10.6m/s

For both technology alternatives, the modelling predicts incursions of the OLS for CPVs of 4.3 m/s and 6.1 m/s. For a CPV of 6.1 m/s:

- The peak Gas Turbine option critical plume height prediction extends to 410 mAHD, at a height of approximately 250 m above the OLS The corresponding 99.9th percentile prediction extends up to 285m, approximately 120 m above the OLS. Critical plume height predictions were within the OLS for greater than 98% of the modelled period, i.e. the critical plume height for the gas turbine option is predicted to exceed the OLS for less than 2% of the hours in which the plant is operational.
- The peak Reciprocating Engine option prediction extends to 183 mAHD, at a height of approximately 30 m above the OLS, whilst 99.9th percentile predictions are within the OLS In summary, the critical plume height for the reciprocating engine option is predicted to exceed the OLS for less than 0.1% of the hours in which the plant is operational.
- An analysis of diurnal and seasonal variability in model predictions (Appendix A) indicates that critical plume heights are typically higher during daylight hours, with a varied distribution of peak impacts between seasons.

AGL propose that the Project will operate on an intermittent basis during times of high network demand or fluctuating supply conditions, which is anticipated to be roughly an order of magnitude lower than the frequency modelled in the capacity case. The conservatism in this approach should be recognised when considering the resultant critical plume heights and frequency distributions in the context of potential aviation safety constraints.

Refinement of this approach would involve modelling of anticipated operating frequencies (i.e. Expected Case rather than Capacity Case), thus providing frequency distributions that more closely reflect proposed operation, whilst also testing whether worst case meteorological conditions are encountered during expected operations.

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APPENDIX A SEASONAL AND DIURNAL CRITICAL PLUME HEIGHT VARIATION

The model has been run to provide 43,824 (hourly) critical plume height (CPH) predictions across a five year period. This section presents a summary of diurnal variation of these predictions for a critical plume velocity (CPV) of 6.1 m/s.

Statistics are presented as box and whisker plots, which show the distribution of predictions by hour of the day for the following CPH statistics:

- Maximum
- 99th percentile (value exceeded 1% of the time)
- Mean
- 1st percentile (value exceeded 99% of the time).

A1.1 Gas Turbine Option – Capacity Case

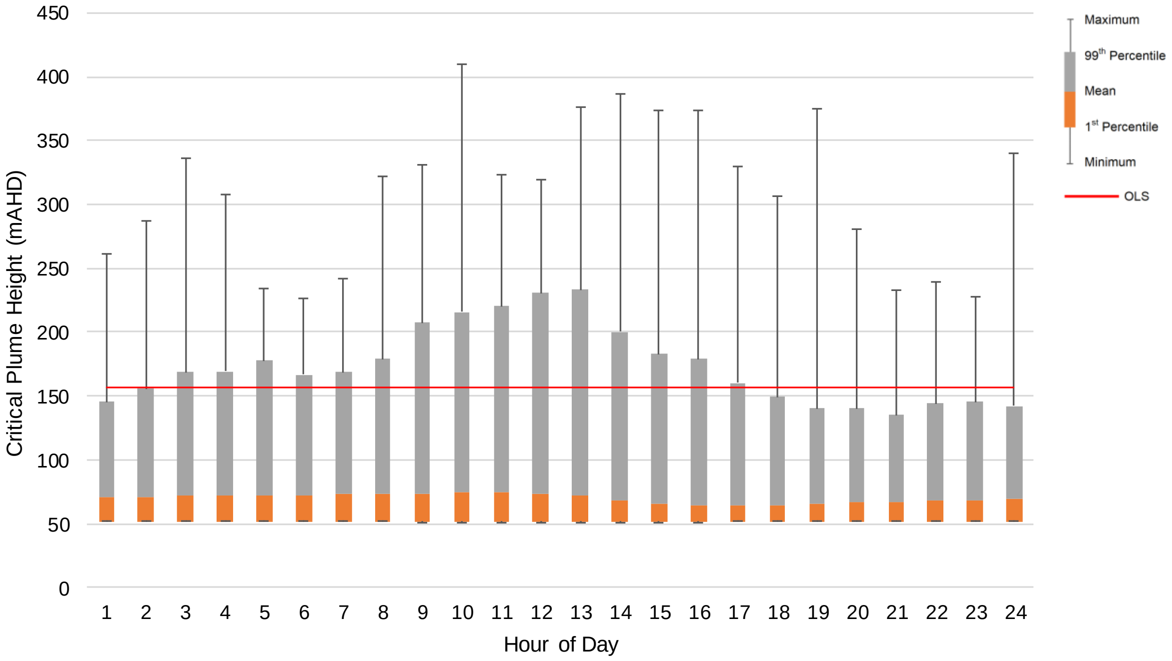

Figure A.1: Box whisker plot showing diurnal variation in CPH – Gas Turbine Option, All Seasons, Capacity Case

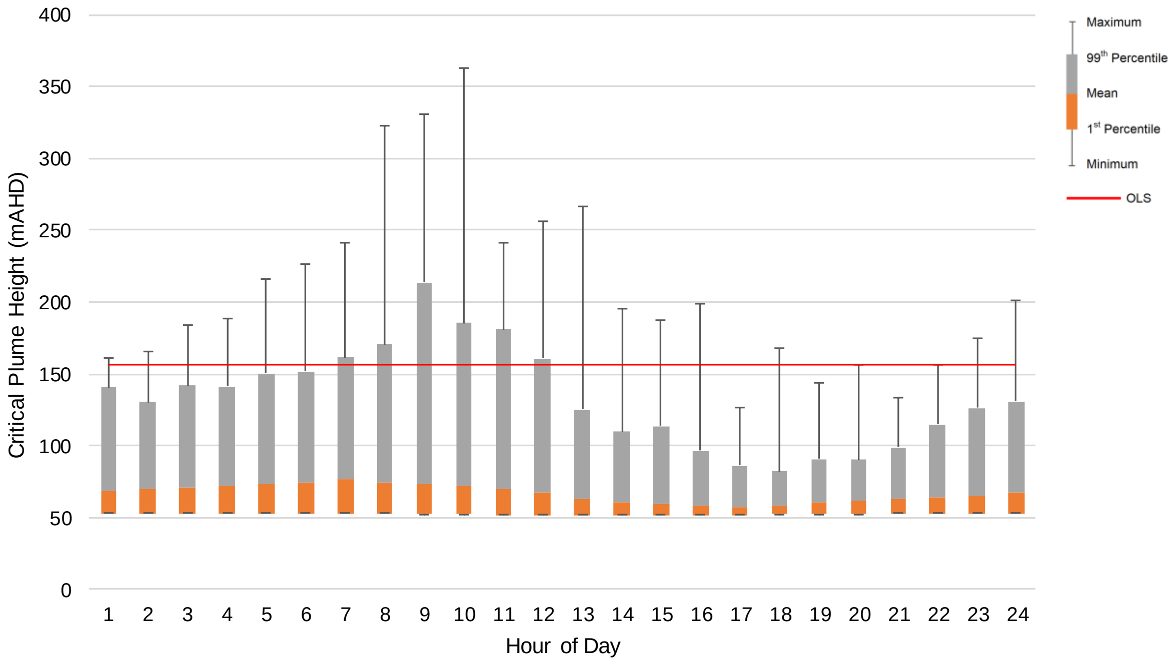

Figure A.2: Box whisker plot showing diurnal variation in critical plume height – Gas Turbine Option, Summer, Capacity Case

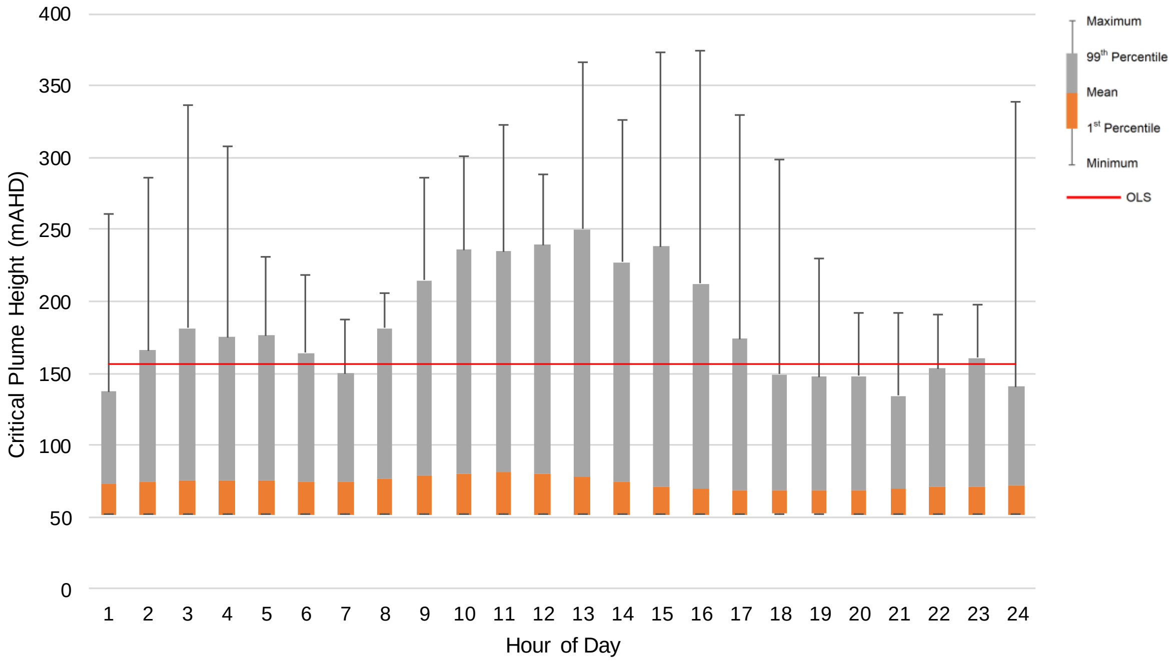

Figure A.3: Box whisker plot showing diurnal variation in critical plume height – Gas Turbine Option, Autumn, Capacity Case

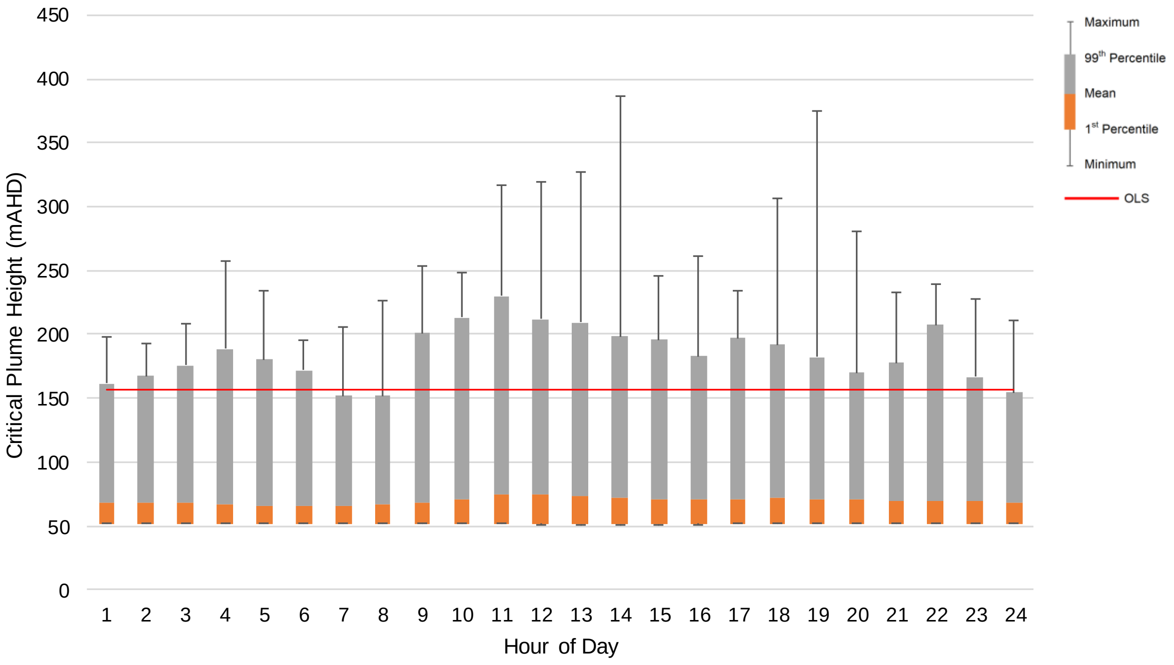

Figure A.4: Box whisker plot showing diurnal variation in critical plume height – Gas Turbine Option, Winter, Capacity Case

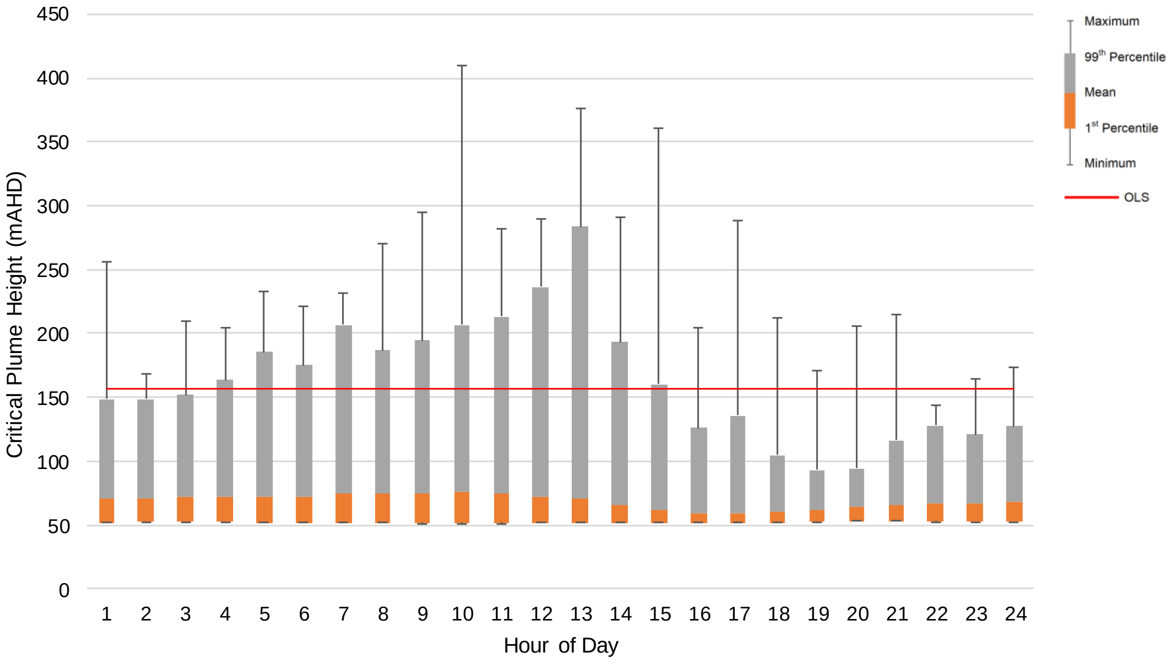

Figure A.5: Box whisker plot showing diurnal variation in critical plume height – Gas Turbine Option, Spring, Capacity Case

A2.1 Reciprocating Engine Option – Capacity Case

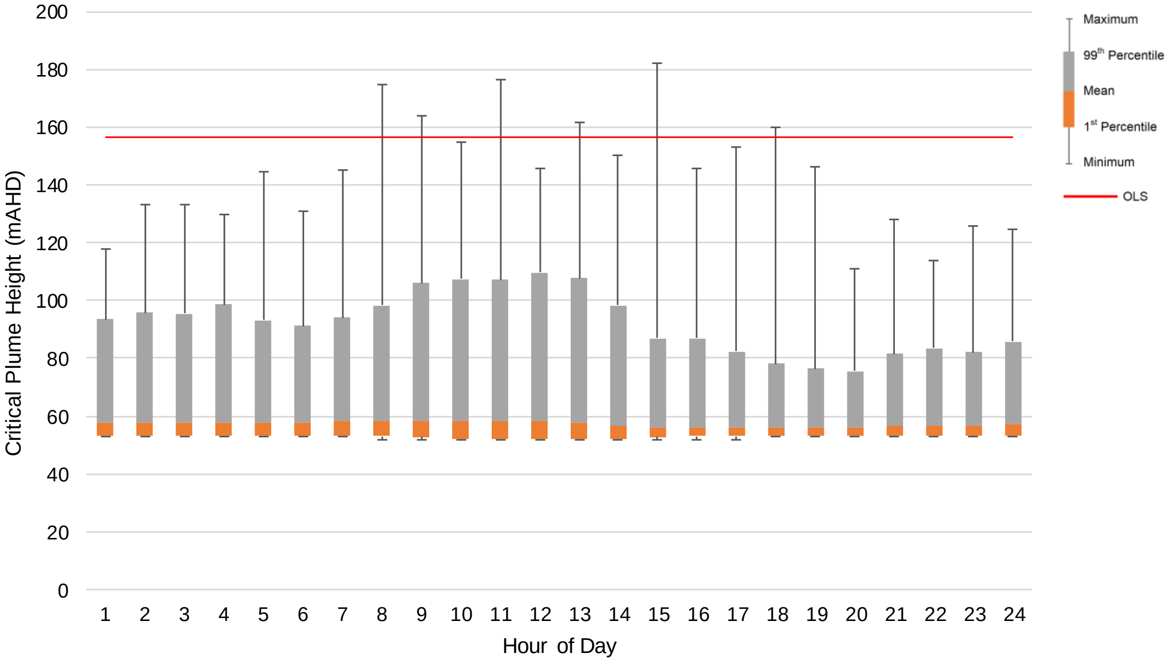

Figure A.6: Box whisker plot showing diurnal variation in CPH – Reciprocating Engine Option, All Seasons, Capacity Case

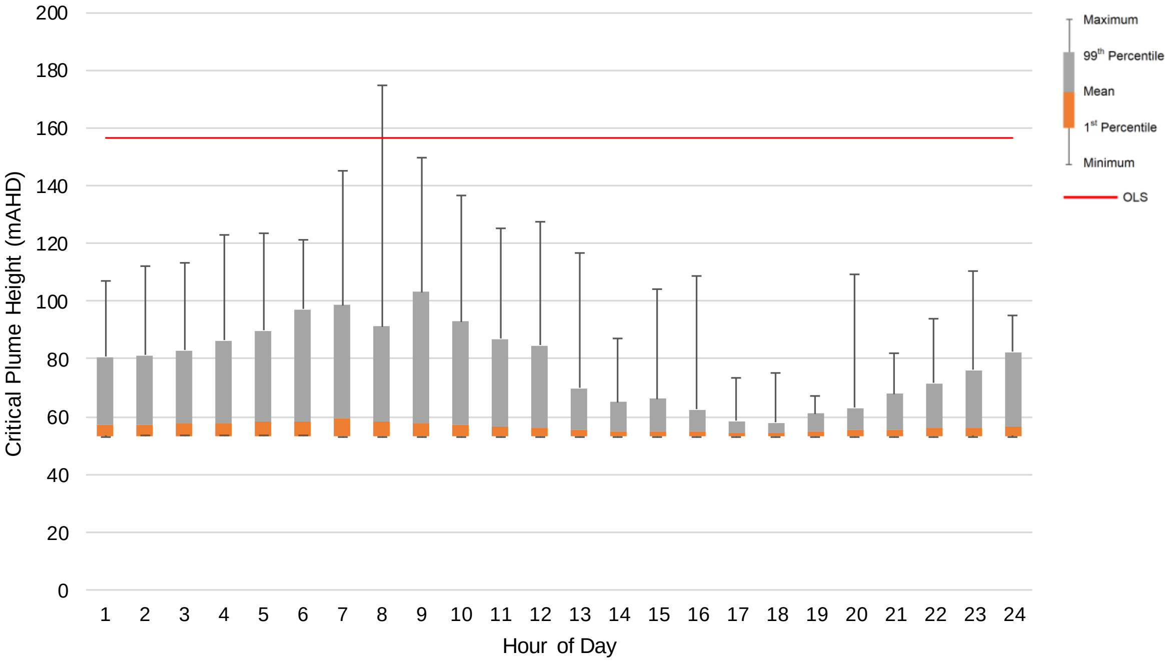

Figure A.7: Box whisker plot showing diurnal variation in critical plume height – Reciprocating Engine Option, Summer, Capacity Case

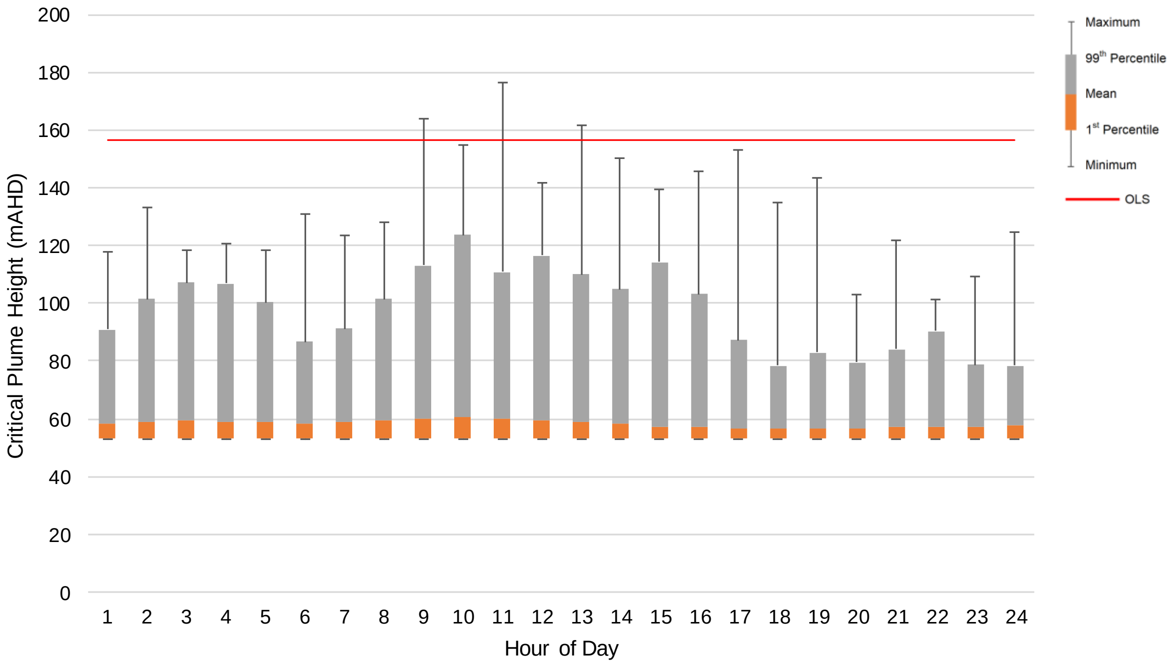

Figure A.8: Box whisker plot showing diurnal variation in critical plume height – Reciprocating Engine Option, Autumn, Capacity Case

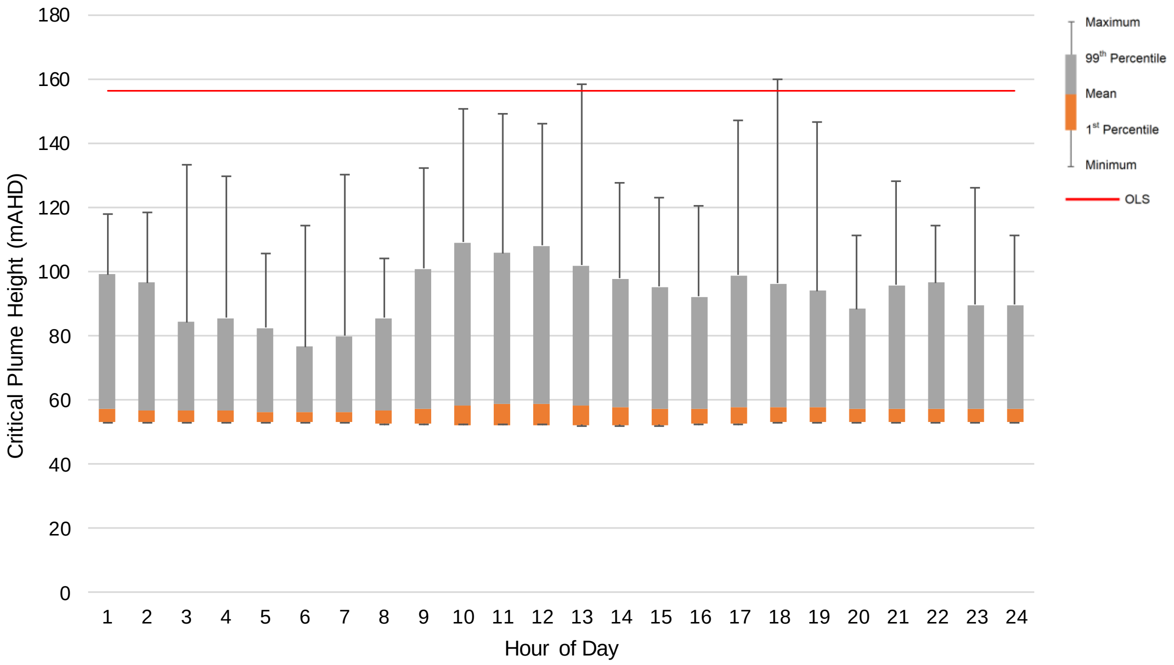

Figure A.9: Box whisker plot showing diurnal variation in critical plume height – Reciprocating Engine Option, Winter, Capacity Case

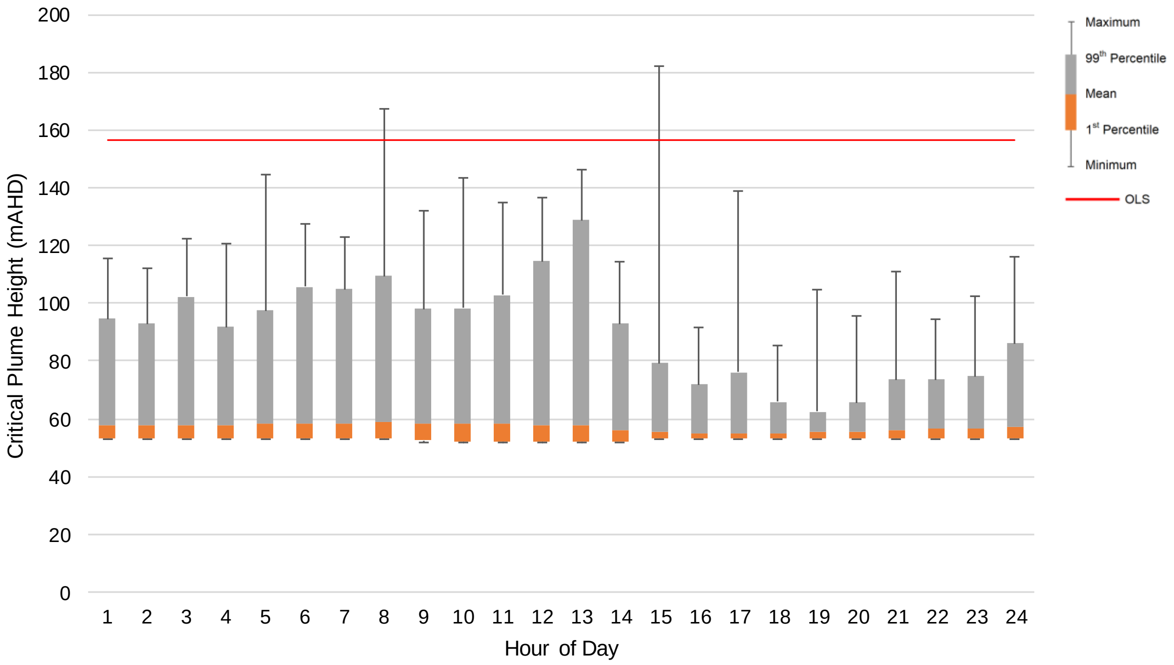

Figure A.10: Box whisker plot showing diurnal variation in critical plume height – Reciprocating Engine Option, Spring, Capacity Case

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