Australian Government
Civil Aviation Safety Authority

ADVISORY CIRCULAR
AC 139.E-02 v1.0

Plume rise assessments

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Advisory circulars are intended to provide advice and guidance to illustrate a means, but not necessarily the only means, of complying with the Regulations, or to explain certain regulatory requirements by providing informative, interpretative and explanatory material.

Advisory circulars should always be read in conjunction with the relevant regulations.

Audience

This advisory circular (AC) is for proponents of facilities generating exhaust plumes, land use planning authorities and aircraft/ airport operators.

Purpose

The AC provides:

- guidance to proponents and stakeholders on the plume rise assessment process
- an explanation of CASA's method of determining the critical plume height of a vertical exhaust plume so that impacts of a plume, near aerodromes and away from aerodromes, can be assessed in a consistent and reliable way.

For further information

For further information, contact CASA’s Air Navigation, Airspace and Aerodromes Branch (telephone 131 757 or email airspace.protection@casa.gov.au)

Unless specified otherwise, all sub regulations, regulations, divisions, subparts and parts referenced in this AC are references to the *Civil Aviation Safety Regulations 1998 (CASR)*.

Status

This version of the AC is approved by the Manager, Flight Standards Branch.

Note: Changes made in the current version are not annotated. The document should be read in full.

Version	Date	Details
v1.0	May 2022	The third revision incorporates the use of the MITRE Exhaust Plume Analyzer (EPA) which was originally developed on behalf of the United States Federal Aviation Administration. This AC replaces AC 139-05 v3.0.
AC 139-05 v3.0	January 2019	This second revision of the AC amends the original 4.3 m/s benchmark velocity parameter to 6.1 m/s in line with the Manual of Aviation Meteorology. Content and flowchart updates have been made to further clarify the process steps and roles.
(1)	November 2012	This is the first revision of the AC relating to conducting plume rise assessments and replaces AC 139-5(0) issued in June 2004. It has been simplified due to the introduction of computer-based modelling (referred to as the “Screening Tool”, see paragraph 5.1) to assist in the assessment process. The plume rise assessment process has also been clarified.
(0)	June 2004	This is the first AC on the subject of plume rise assessments.

Contents

1 Reference material

1.1 Acronyms

The acronyms and abbreviations used in this AC are listed in the table below.

Acronym	Description
AC	advisory circular
AGL	above ground level
CASA	Civil Aviation Safety Authority
CASR	*Civil Aviation Safety Regulations 1998*
CPH	critical plume height
EPA	Exhaust Plume Analyser
FIFO	fly-in fly-out
FT	feet
LSALT	lowest safe altitude
LUPA	Land Use Planning Authority
m/s	metres per second
NM	nautical miles
NOTAM	notice to airmen
OLS	obstacle limitation surface
RPT	regular public transport
TAPM	The Air Pollution Model
US FAA	United States' Federal Aviation Administration

1.2 Definitions

Terms that have specific meaning within this AC are defined in the table below. Where definitions from the civil aviation legislation have been reproduced for ease of reference, these are identified by 'grey shading'. Should there be a discrepancy between a definition given in this AC and the civil aviation legislation, the definition in the legislation prevails.

Term	Definition
critical plume height	The height up to which there is an unacceptable probability of the plume affecting the handling characteristics of an aircraft in flight such that there is an undesirable risk to aircraft safety.
obstacle limitation surfaces	A series of planes associated with each runway at an aerodrome that defines the desirable limits to which objects may project into the airspace around the aerodrome so that aircraft operations may be conducted safely.

Term	Definition
PANS/OPS and Doc 9905/9613 surfaces	Surfaces which protect instrument flight procedures designed on the principles of ICAO PANS-OPS document and Documents 9905/9613
regulated aerodromes	Regulated aerodromes to which the Part 139 of CASR 1998 - Aerodromes applies. At these aerodromes, the aerodrome operator must establish the obstacle limitation surfaces in accordance with the standards set out in these regulations.
screening tool	The computer-generated method of plume rise analysis used by CASA to derive the height at which the average plume rise velocity is 4.3 m/s. The Screening Tool is based on The Air Pollution Model (TAPM) methodology
TAPM	The Air Pollution Model developed by CSIRO.

1.3 References

Legislation

Legislation is available on the Federal Register of Legislation website https://www.legislation.gov.au/

Document	Title
Regulation 6 of the Airspace Regulations 2007	Airspace Regulations 2007
Regulation 139.370	Hazardous objects etc
Part 173	Instrument flight procedure design
Part 139 MOS	Aerodromes Manual of Standards

1.4 Forms

CASA's forms are available at http://www.casa.gov.au/forms

Form number	Title
Form 1247	Application for Operational Assessment of Proposed Plume Rise

2 Background

2.1 Assessing potential impacts of plume rises on aircraft safety

2.1.1 Exhaust plumes can originate from any number of sources. These can include:

- industrial facilities that release process emissions through stacks or vents
- industrial flares that create an instantaneous release of hot gases during the depressurisation of gas systems
- cooling towers that produce large volumes of buoyant gases that can rise a significant distance into the atmosphere
- exhaust gases from power generation facilities that can produce plumes of varying velocities during different operating scenarios.

2.1.2 Aircraft operations in various stages of flight may be affected by a plume rise. A light aircraft in approach configuration is more likely to be affected by a plume rise than a heavy aircraft cruising at altitude. In addition, helicopters and light recreational aircraft may be severely affected by a high temperature plume and the altered air mixture above an exhaust plume.

2.1.3 Regulation 139.180 of the *Civil Aviation Safety Regulations 1988* (CASR) provides that CASA may determine that a gaseous efflux having a velocity in excess of 4.3 m per second (m/s) is, or will be, a hazard to aircraft operations because of the velocity or location of the efflux.

2.1.4 In addition to regulation 139.180, Regulation 6A of the Airports (Protection of Airspace) Regulations 1996 defines 4.3m/s as the level of turbulence that may be capable of affecting normal flight. This piece of legislation applies around leased federal airports and is administered by the Australian Department of Infrastructure, Transport, Regional Development and Communications (DITRDC).

2.1.5 When necessary, CASA will refer proposals to other relevant authorities including the Department of Defence, Airservices Australia and DITRDC.

2.1.6 Previous ACs on this topic were predicated on the use of The Air Pollution Model (TAPM) for the detailed assessment of plume rises. This AC is based on the adoption of the Exhaust Plume Analyzer (EPA)[1] model to predict plume size and severity of flight impact created by a plume rise.

2.1.7 Turbulence is classified as shown in Table 1 and was developed by the Bureau of Meteorology which defines limits for light, moderate and severe turbulence relative to the vertical acceleration of the aircraft.

[1] The EPA was created by the MITRE corporation on behalf of the United States Federal Aviation Administration (FAA). CASA engaged MITRE to update the model for consistency with Australian legislation.
The EPA is a sophisticated model which assesses the risk of encountering light, moderate and severe turbulence caused by plumes for generic aircraft types. It can also model specific aircraft types provided aerodynamic data is provided.

Table 1: Turbulence intensity specifications (Bureau of Meteorology 2014)

Intensity	G load	Aircraft reaction	Reaction inside aircraft
Light	0.15-0.49	Momentary slight and erratic changes in attitude and/or altitude. Rhythmic bumpiness.	Little effect on loose objects.
Moderate	0.50-0.99	Appreciable changes in attitude and/or altitude. Pilot remains in control at all times. Rapid bumps or jolts.	Unsecured objects move. Appreciable strain on seatbelts.
Severe	1,.00-1.99	Large abrupt changes in attitude and/or altitude. Momentary loss of control	Unsecured objects are tossed about. Occupants violently forced against seatbelts.

2.1.8 CASA will use the EPA to conduct plume rise assessments when approached for advice by Land Use Planning Authorities (LUPA) or airport operators.

2.1.9 The EPA uses the Spillane model to compute the mean plume trajectory; in addition, it then applies a turbulence model to account for turbulent gusts associated with the plume. MITRE found the Spillane model to be the plume rise model which had the best correlation with empirical evidence. MITRE found that TAPM underpredicted the height of plume rises in the immediate vicinity of the stack.

2.1.10 The use of the EPA will therefore result in more accurate and more targeted risk assessments than was previously available.

2.1.11 For example, a LUPA may advise that it wishes to implement land use zoning which will ensure that the airport can cater to light sport aircraft. Alternatively, there may be cases where the airport operator may advise that it considers the airport is only available to high-capacity regular public transport (RPT) aircraft and the CASA assessment should be based on the assumption that no light general aviation (GA) and light sport aircraft types operate at the airport.

2.1.12 Another advantage of this approach is that proponents will no longer need to engage specialist consultants to conduct plume rise assessments. This will reduce the regulatory burden for proponents in terms of both cost and time.

2.1.13 LUPAs should ensure that the requisite information in Form 1247 - Operational Assessment of a proposed plume rise is submitted accurately. Plume rise assessment process

2.2 Process steps

2.2.1 The plume rise assessment process involves participation from the proponent and CASA. A flowchart identifying the plume rise assessment process is provided at Appendix A to this AC.

Step 1 and Step 2: Proponent assessment of plume velocity and form submission

2.2.2 The proponent should make an initial assessment of the plume exit velocity. If the exit vertical velocity is less than 4.3 m/s, no further action is required by the proponent.

2.2.3 If the exit vertical velocity exceeds 4.3 m/s, a Form 1247 should be submitted to CASA: (airspace.protection@casa.gov.au)

Step 3: Preliminary assessment of the plume rise proposal - application of the CASA screening tool

2.2.4 CASA will use the information provided into conduct a preliminary assessment. This will be conducted using the CASA screener tool.

2.2.5 If the outputs of the screener tool indicate that the plume velocity will not infringe a flight protection surface at a velocity exceeding 4.3 m/s, no further assessment is required. Flight protection surfaces include OLS/PANS-OPS surfaces, restricted/danger areas and established flight paths.

2.2.6 If the outputs of the screener tool indicate that the plume velocity will infringe a flight protection surface at a vertical velocity exceeding 4.3 m/s, CASA will use the information provided to conduct a detailed assessment of the impact of the plume rise proposal using the EPA.

2.2.7 If the proposal is located outside the OLS of the nearest regulated airport, CASA will conduct a detailed assessment using the EPA only if the plume velocity exceeds 4.3 m/s at 150 m above ground level (AGL).

Step 4: Detailed assessment of the impact of the plume rise proposal- application of the EPA

2.2.8 As explained in 3.1.6, CASA will use the information provided to conduct a detailed assessment of the impact of the plume rise proposal using the EPA.

2.2.9 CASA's position on the risk to aviation safety from a plume will be dependent on the location of the plume, the risk of the relevant turbulence risk thresholds being exceeded and the turbulence level that would be unacceptable (moderate in the case of locations below critical flight protection surfaces and established flight paths (severe in the case of locations below non-critical flight protection surfaces and not below established flightpaths).

2.2.10 The basis for application of EPA output to the assessment of risk from plume rises is detailed at Table 2.

Table 2: Risk and turbulence threshold levels for assessment of risk

Location of plume/ protection surface	Risk threshold levels	Turbulence threshold levels
PANS-OPS/Doc 9905/9613 surface	1 x 10 -5 per operation	Moderate
Approach surface/ take off climb surface/inner horizontal, conical	1 x 10 -5 per operation	Moderate

Location of plume/ protection surface	Risk threshold levels	Turbulence threshold levels
and outer horizontal surfaces (below established flight paths)		
Inner horizontal, conical and outer horizontal surfaces (not below established flight paths)	1 x 10 -5 per operation	Severe
Outside the OLS (flight protection surface set at 1000m /3050 FT AGL)	1 x 10 -4 per operation	Severe

2.3 Assessment of plume rises using the EPA

2.3.1 Infringement of PANS-OPS/Doc 9905/9613 surfaces

2.3.1.1 If there is an infringement of the above surfaces creating a risk of moderate turbulence greater than 1 x 10 $^{-5}$ per operation, CASA will take the position that the proposal will create an unacceptable risk to the safety of aircraft operations.

2.3.1.2 As a practical matter, any infringement of one of these surfaces creating a risk greater than 1 x 10 $^{-5}$ per operation will also involve an infringement of the overlying Obstacle Limitation Surface (OLS.)

2.3.1.3 If the proposal cannot be altered to avoid this impact, changes to Terminal Instrument Flight Procedures (TIFP) maybe an option. However, stakeholders such as LUPA, aircraft operators and airport operators must accept that any changes to TIFP will affect the regularity and efficiency of operations at the airport.

2.3.2 Infringement of approach/take-off climb/transitional surfaces

2.3.2.1 If there is an infringement of the above surfaces creating a risk of moderate turbulence greater than 1 x 10 $^{-5}$ per operation, CASA will take the position that the proposal will create an unacceptable risk to the safety of aircraft operations.

2.3.2.2 These surfaces protect the most critical phases of flying operations.

2.3.2.3 CASA's position is that an unacceptable risk in this location cannot be mitigated through means such as AIP/ chart or introduction of danger/restricted areas.

2.3.3 Infringement of inner horizontal surface- sites below established or potential flight paths

2.3.3.1 If there is an infringement of the above surface creating a risk of moderate turbulence greater than 1 x 10 $^{-5}$ per operation, CASA will take the position that the proposal will create an unacceptable risk to the safety of aircraft operations.

2.3.3.2 This surface protects critical phases of flying operations as aircraft may be in the circuit, departing the airport, or conducting a circling approach above the site.

2.3.3.3 CASA's position is that an unacceptable risk in this location cannot be mitigated through means such as AIP/chart or introduction of danger/ restricted areas.

2.3.4 Infringement of inner horizontal surface- sites not below established or potential flight paths

2.3.4.1 CASA's assessment of infringements in these cases will be based on the risk of creating severe turbulence.

2.3.4.2 The rationale for the higher risk threshold is that the proponent will have demonstrated in an aeronautical study that it is highly unlikely that aircraft will overfly the site.

2.3.4.3 If there is an infringement of the above surface creating a risk of severe turbulence greater than 1 x 10^{-5} per operation, CASA will take the position that the proposal will create an unacceptable risk to the safety of future aircraft operations.

2.3.4.4 CASA may require publication of the plume in by AIP/charts.

2.3.5 Infringement of conical/outer horizontal surface - sites below established or potential flight paths

2.3.5.1 If there is an infringement of the above surfaces creating a risk of moderate turbulence greater than 1 x 10^{-5} per operation, CASA will take the position that the proposal will create an unacceptable risk to the safety of aircraft operations.

2.3.5.2 This surface protects critical phases of flying operations as aircraft may be in the circuit, departing the airport, arriving at the airport, or conducting a circling approach above the site.

2.3.6 Infringement of conical/outer horizontal surface - sites not below established or potential flight paths

2.3.6.1 CASA's assessment of infringements in these cases will be based on the risk of creating severe turbulence.

2.3.6.2 The rationale for the higher risk threshold is that the proponent will have demonstrated in an aeronautical study that it is highly unlikely that aircraft will overfly the site.

2.3.6.3 If there is an infringement of the above surfaces creating a risk of severe turbulence greater than 1 x 10^{-5} per operation, CASA will take the position that the proposal will create an unacceptable risk to the safety of aircraft operations.

2.3.7 Areas outside the vicinity of a regulated airport (site is not below OLS /PANS-OPS/Doc 9905/9613 surfaces for the airport)

2.3.7.1 CASA's assessment of infringements in these cases will be based on the risk of creating severe turbulence above 1000 m/3050 ft AGL and on a threshold of 1 x 10^{-4} per operation.

2.3.7.2 The rationale for the higher risk threshold is that CASA will be satisfied that it is extremely unlikely that aircraft will overfly the site at an altitude where the plume rise will affect the safety of aircraft operations.

2.3.7.3 If there is an infringement of the above surfaces creating a risk of severe turbulence greater than 1 x 10^{-4} per operation, CASA will take the position that the proposal will create an unacceptable risk to the safety of aircraft operations.

2.3.7.4 If the plume rise affects air routes and lowest safe altitudes (LSALTs), changes to these may be an option subject to the agreement of stakeholders engaged through the aviation safety engagement forum (AvSEF) industry consultation process. Any changes made by the Part 173 authority (Airservices Australia) are likely to have cost implications for proponents.

2.4 Mitigation of the impact of the plume rise proposal

2.4.1 Outside the vicinity of an aerodrome, mitigation options for a plume rise may include the following:

a. insertion of a symbol and a height on aviation charts to enhance awareness of the plume rise
b. designation of a danger area in accordance with Regulation 6 of the Airspace Regulations 2007 to alert pilots to the potential danger to aircraft overflying the area.

Designation of a restricted area in accordance with Regulation 6 of the Airspace Regulations 2007 to restrict the flight of aircraft over the area.

2.5 Assessment of stacks with engineering modifications/non-aligned/non-uniform spacing

2.5.1 If the proponent presents a stack design involving engineering modifications aimed to reduce the impact of the plume rise, the EPA cannot be used to assess risk levels directly. There will be a need for Computational Fluid Dynamics (CFD) modelling or scaled, physical modelling before the EPA can be used.

2.5.2 Similarly, the EPA cannot be used to assess multiple stacks which are not aligned and/or at non-uniform distances from each other.

2.5.3 CASA is prepared to engage an independent engineering consultant on a full cost recovery basis to provide specialist advice that will underpin our position on risk to aircraft operations from the proposed plume rise.

3 Examples of the outcomes of a plume rise assessment

3.1 Assessing plume rise information for potential impact on aircraft safety

3.1.1 To illustrate how CASA would base its advice to LUPAs on the assessment of plume rises, the following hypothetical examples demonstrate how the risk to aircraft operations vary with aircraft type.

3.1.2 In this example, a power plant has a single stack and is located 3 nautical miles (NM) from the runway threshold along the extended centreline. The runway has no published instrument procedures. The terrain is flat, so the stack base has the same elevation as the aerodrome.

3.1.3 CASA will initially use Form 1247 from the proponent to obtain information on the plume such as exit velocity, exit temperature, stack diameter and stack height.

3.1.4 In this hypothetical example, the information on the proposed facility from the proponent is:

- exit velocity: 40m/s
- exit temperature: 400 degrees C
- stack diameter: 4.0 m
- stack height: 20 m.

3.1.5 CASA will initially use the screener tool to determine if the plume would have a velocity above 4.3 m/s at the height of an airspace protection surface.

3.1.6 In this example, the screener tool indicates that the CPH is 804.4 m (2 639 ft) above ground level (AGL) and at this height the plume rise would infringe the approach and take off surfaces. The Screener tool is conservative, and CASA will then refine the assessment using the MITRE EPA model.

3.1.7 CASA will then use the following inputs to run the MITRE EPA model:

- Information from the proposed facility detailed in Para 4.1.4 above
- environmental data from the meteorological module of TAPM
- aircraft specific parameters if the LUPA requests advice tailored to the operations at the aerodrome. This approach would be useful at aerodromes where there is a limited range of aircraft types e.g., a mining aerodrome restricted to charter Boeing 737 fly-in fly-out (FIFO) operations.

3.1.8 The MITRE EPA model will calculate the probability of the defined aircraft types experiencing moderate turbulence across the vertical and horizontal envelope.

3.1.9 Figures 1, 2 and 3 present the outputs depicting the probability of moderate turbulence for three different aircraft types.

3.1.10 The figures show that there can be significant differences in the plume's impact on aircraft operations depending on the size of the aircraft.

3.1.11 Depending on the type of operations at an airport, a plume rise may be assessed as acceptable or that it would have presented unacceptable risk to the safety of aircraft operations.

3.1.12 Example 1 - Light General Aviation (GA) aircraft [equivalent to a Cessna 172] overflying plume rise 3 NM along the extended centre-line from runway threshold

3.1.12.1 In the example below, the EPA output shows the probability of a light GA aircraft similar to a Cessna 172 experiencing moderate turbulence.

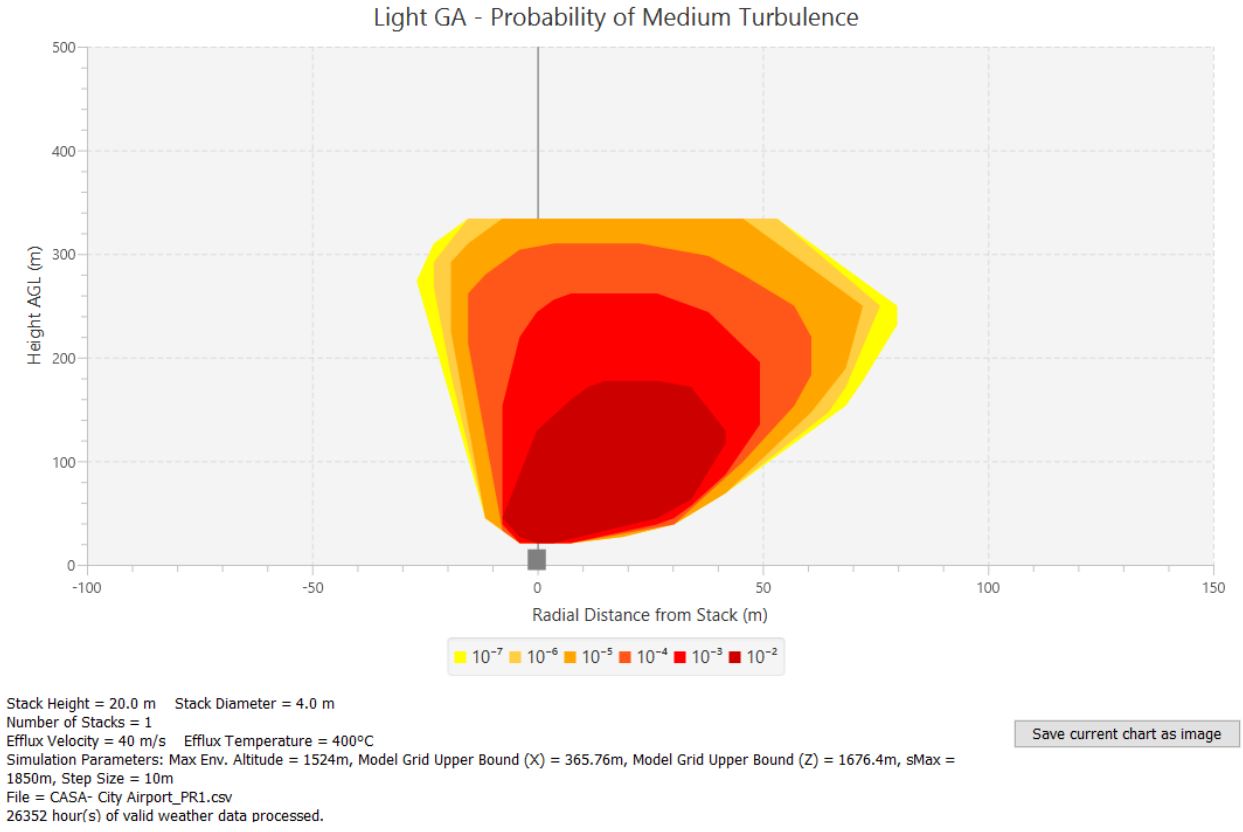

Figure 1 Probability of a light GA aircraft encountering moderate turbulence in the vicinity of the plume rise based on the information in Para 3.1.4

3.1.12.2 The plume is located 3 NM (5.56 km) from a non-precision Code 1 runway in flat terrain.

3.1.12.3 At this site for the proposed plume, CASA will conclude that the risk to aircraft operations is unacceptable.

3.1.12.4 This is because at this stack location (3 NM from the runway threshold), the aircraft would be at 1 000 ft AGL and the probability of Cessna 172 equivalent aircraft experiencing moderate turbulence of 1 X 10-5 extends to a height of 1 115 ft (339.23 m) AGL.

3.1.13 Example 2 - Business jet aircraft [equivalent to Bombardier Dash 8 - 300] overflying plume rise 3 NM from runway threshold

3.1.13.1 In the example below, the EPA output shows the probability of a business jet aircraft similar to a RPT Dash 8-300 experiencing moderate turbulence.

3.1.13.2 The plume is located 3 NM (5.56 km) from a precision Code 3 runway in flat terrain.

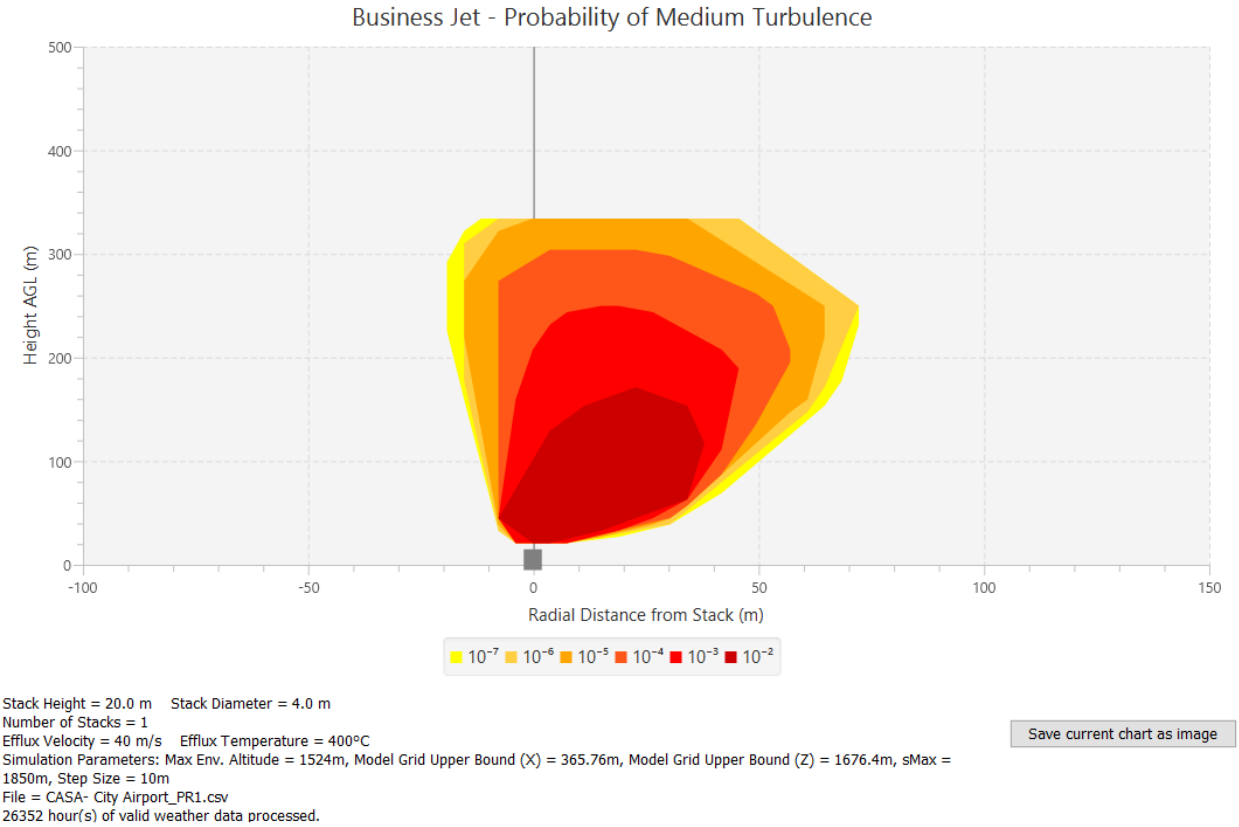

Figure 2 - Probability of a business jet aircraft similar to Dash 8-300 encountering moderate turbulence in the vicinity of the plume rise based on the information in Para 3.1.4

3.1.13.3 At this site for the proposed plume, CASA will conclude that the risk to aircraft operations is unacceptable.

3.1.13.4 This is because at this stack location (3 NM from the runway threshold), the aircraft would be at 1 000 ft AGL. The probability of Dash 8-300 equivalent aircraft experiencing moderate turbulence of 1 X 10 -5 is up to a height of 1 115 ft (339.23 m) AGL.

3.1.13.5 Importantly, the approach surface is at a height of 406 ft (123.75 m) AGL and the 1 X 10-5 probability contour of the plume creating moderate turbulence will infringe it.

3.1.14 Example 3- high capacity RPT aircraft [equivalent to Boeing 737-800] overflying plume rise 3.5 NM from runway threshold

3.1.14.1 In the example below, the EPA output shows the probability of a high capacity RPT jet aircraft similar to a Boeing 737-800 experiencing moderate turbulence.

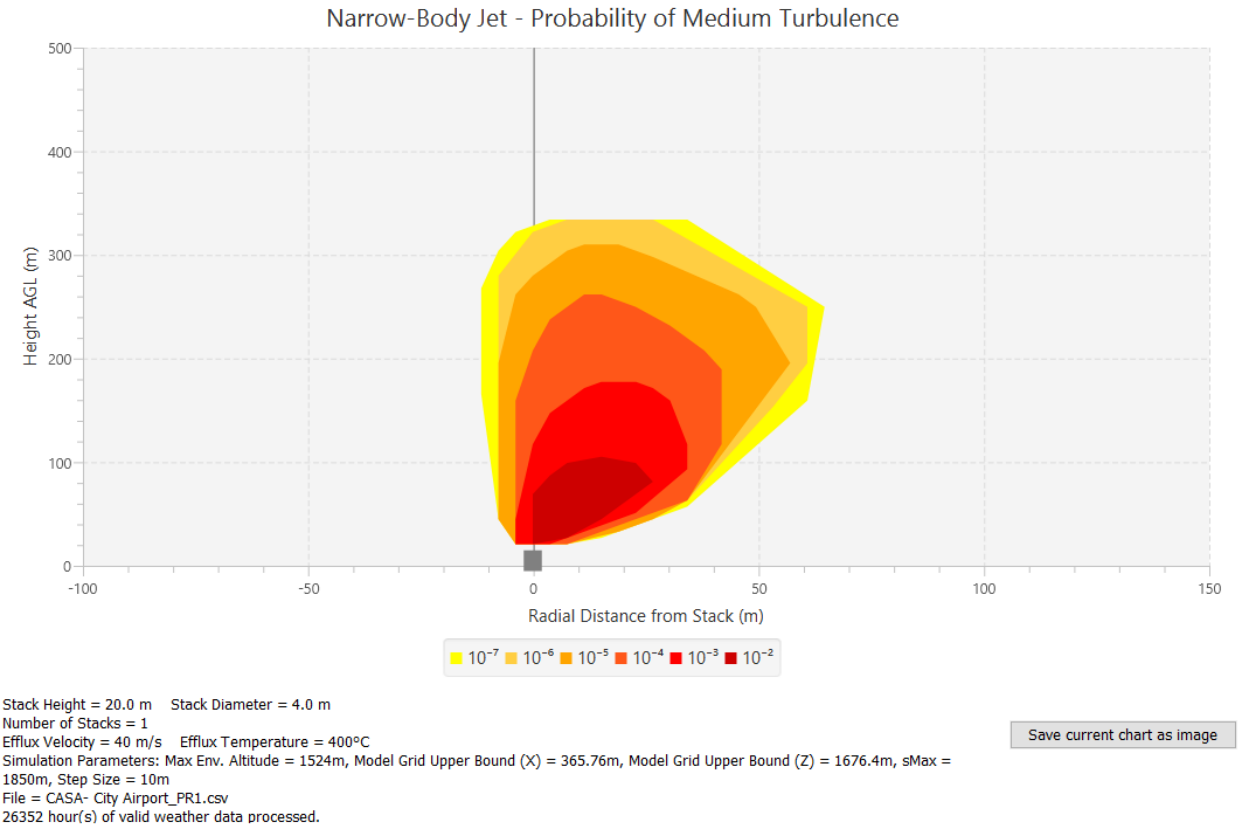

Figure 3 - Probability of a high capacity RPT jet aircraft similar to Boeing 737-800 encountering moderate turbulence in the vicinity of the plume rise based on the information in Para 3.1.4

3.1.14.2 The plume is located 3.5 NM (6.5 km) from a non-instrument Code 4 runway in flat terrain. The aerodrome is a domestic aerodrome restricted to Boeing 737-800 operations (such as a mine site aerodrome with FIFO operations). Aircraft will be flying over the plume at approximately 1115 ft AGL.

3.1.14.3 At this site for the proposed plume, CASA will conclude that the risk to aircraft operations is acceptable.

3.1.14.4 This is because the probability of moderate turbulence for this aircraft type is less than 1 X 10-5 per operation above 1033 ft (315.14 m) AGL.

Appendix A

Plume rise assessment process

A.1 Plume rise assessment process

A.1.1 The flowchart is an overview of the assessment process.

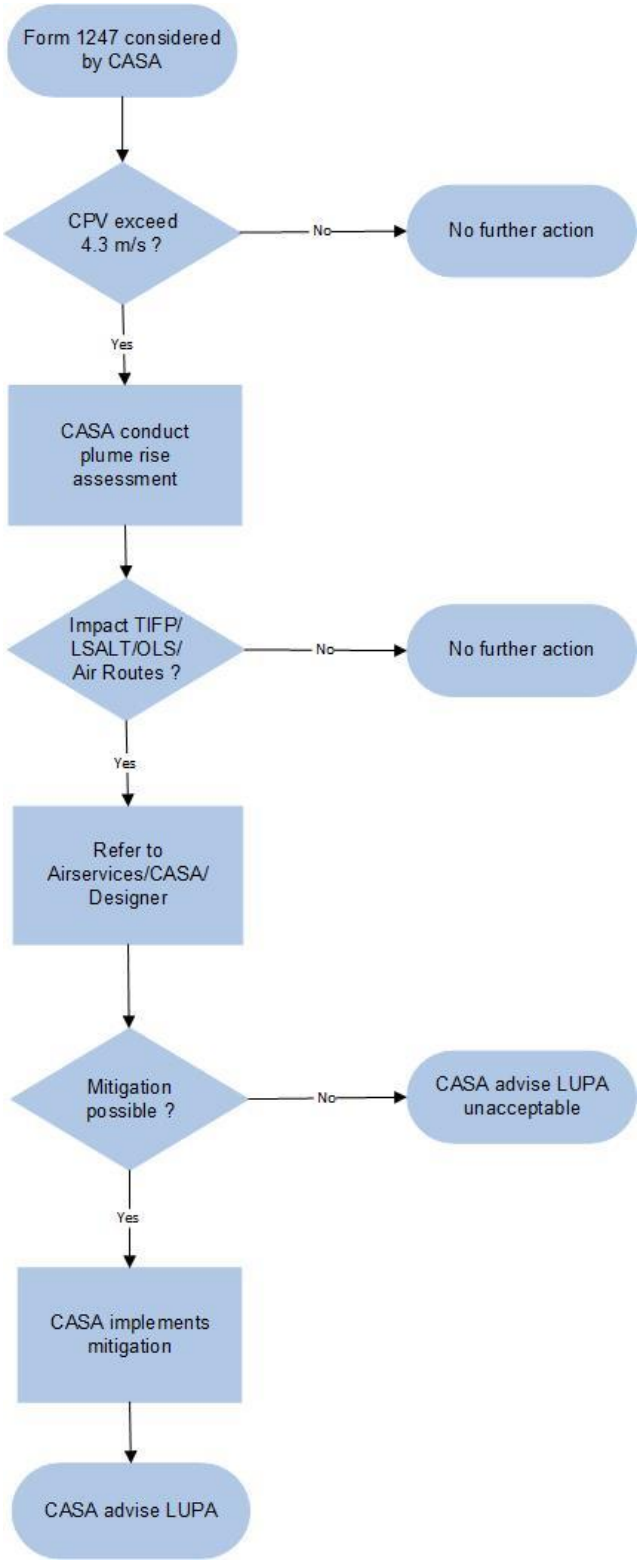

Figure 1 Plume rise assessment process