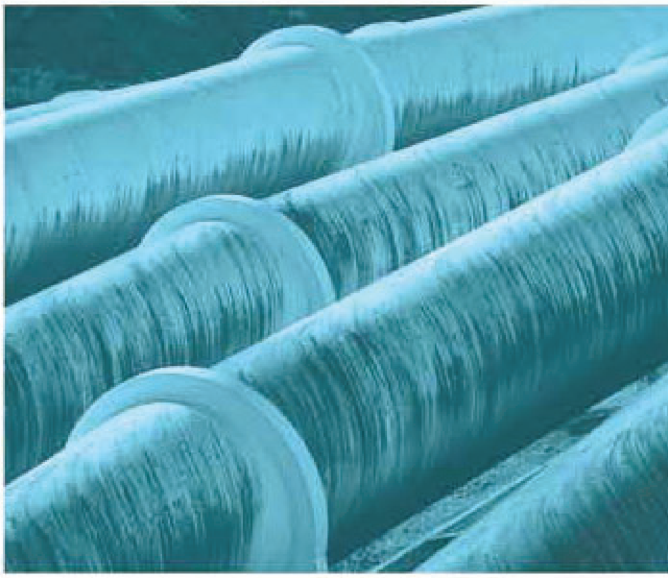
APPENDIX V

AIR QUALITY IMPACT ASSESSMENT


Air Quality Impact Assessment

Snowy 2.0 Main Works

Prepared for Snowy Hydro Limited
September 2019

EMM
creating opportunities

Air Quality Impact Assessment

Snowy 2.0 Main Works

Report Number

J17188 RP#93

Client

Snowy Hydro Limited

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v1 Final

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Executive Summary

This air quality impact assessment (AQIA) supports the Environmental Impact Statement (EIS) for the proposed Snowy 2.0 Main Works located within the Australian Alps, in southern NSW. It documents the existing air quality and meteorological environment, applicable impact assessment criteria, air pollutant emission calculations, dispersion modelling of calculated emissions and assessment of predicted impacts relative to criteria.

The AQIA has been prepared in general accordance with the guidelines specified by the NSW Environment Protection Authority (EPA) in the *Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales*.

Existing environmental conditions were quantified using data from the Bureau of Meteorology's (BoM) Cabramurra SMHEA Automatic Weather Stations (AWS), three Snowy Hydro-owned meteorological stations at Tantangara Dam, Cabramurra Airstrip and Talbingo and the three Australian Capital Territory (ACT) monitoring stations: Civic, Florey and Monash.

Emissions estimation and dispersion modelling was completed for one construction scenario corresponding to peak construction activities at the project. Emissions of total suspended particulates (TSP), particulate matter less than 10 micrometres (µm) in aerodynamic diameter (PM_{10}), particulate matter less than 2.5 µm in aerodynamic diameter ($PM_{2.5}$) and nitrogen dioxide (NO_2) were estimated and modelled.

The atmospheric dispersion of air pollutant emissions from one construction scenario was simulated using the CALPUFF model.

The cumulative results showed that R24 (Wares Yards Campground) was predicted to exceed the maximum 24-hour average PM_{10} criterion on two days in the modelled year. The increment at this location on these days was high compared to the background but it is noted that R24 is located within 500 m of a long unpaved road and may not be used at time of project construction. R24, R27 (Lobs Hole accommodation camp) and R29 (Tantangara accommodation camp) exceeded the 24-hour average $PM_{2.5}$ criterion on two days, two days and one day respectively. Timeseries plots for these locations showed that the background was the dominating source when considering cumulative concentrations. The majority of cumulative concentrations (90%) were also below 15 µg/m^3 at these locations.

The construction of the project will require mitigation measures. These include watering of dozer areas, watering of unpaved project-related roads and paving roads 1 km each side of the Lobs Hole and Tantangara accommodation camps. These measures have been taken into account in the emissions estimation and modelling of the project.

A GHG assessment was also undertaken for the project. Annual average total GHG emissions (Scope 1, 2 and 3) generated by the Snowy 2.0 Main Works construction represent approximately 0.12% of total GHG emissions for NSW and 0.03% of total GHG emissions for Australia, based on the National Greenhouse Gas Inventory for 2017. Annual average total GHG emissions (Scope 1, 2 and 3) generated by the Snowy 2.0 Main Works operations represent approximately 0.40% of total GHG emissions for NSW and 0.10% of total GHG emissions for Australia, based on the National Greenhouse Gas Inventory for 2017.

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1 Introduction

1.1 The project

Snowy Hydro Limited (Snowy Hydro) proposes to develop Snowy 2.0, a large-scale pumped hydro-electric storage and generation project which would increase hydro-electric capacity within the existing Snowy Mountains Hydro-electric Scheme (Snowy Scheme). This would be achieved by establishing a new underground hydro-electric power station that would increase the generation capacity of the Snowy Scheme by almost 50%, providing an additional 2,000 megawatts (MW) generating capacity, and providing approximately 350,000 megawatt hours (MWh) of storage available to the National Electricity Market (NEM) at any one time, which is critical to ensuring system security as Australia transitions to a decarbonised NEM. Snowy 2.0 will link the existing Tantangara and Talbingo reservoirs within the Snowy Scheme through a series of underground tunnels and hydro-electric power station.

Snowy 2.0 has been declared to be State significant infrastructure (SSI) and critical State significant infrastructure (CSSI) by the former NSW Minister for Planning under Part 5 of the NSW *Environmental Planning and Assessment Act 1979* (EP&A Act) and is defined in clause 9 of Schedule 5 of the *State Environmental Planning Policy (State and Regional Development) 2011* (SRD SEPP). CSSI is infrastructure that is deemed by the NSW Minister to be essential for the State for economic, environmental or social reasons. An application for CSSI must be accompanied by an environmental impact statement (EIS).

Separate applications are being submitted by Snowy Hydro for different phases of Snowy 2.0 under Part 5, Division 5.2 of the EP&A Act, including Exploratory Works for Snowy 2.0 (the Exploratory Works) and Main Works for Snowy 2.0 (the Main Works). In addition, an application under Part 5, Division 5.2 of the EP&A Act is also being submitted by Snowy Hydro for a segment factory that will make tunnel segments for both the Exploratory Works and Main Works phases of Snowy 2.0.

The first stage of Snowy 2.0, the Exploratory Works, includes an exploratory tunnel and portal and other exploratory and construction activities primarily in the Lobs Hole area of the Kosciuszko National Park (KNP). The Exploratory Works were approved by the former NSW Minister for Planning on 7 February 2019 as a separate project application to DPIE (SSI 9208).

This air quality impact assessment (AQIA) has been prepared to accompany an application and supporting EIS for the second phase of Snowy 2.0, which is to be known as the Snowy 2.0 Main Works. As the title suggests, this phase of the project covers the major construction elements of Snowy 2.0, including permanent infrastructure (such as the underground power station, power waterways, access tunnels, chambers and shafts), temporary construction infrastructure (such as construction adits, construction compounds and accommodation), management and storage of extracted rock material and establishing supporting infrastructure (such as road upgrades and extensions, water and sewage treatment infrastructure, and the provision of construction power). Snowy 2.0 Main Works also includes the operation of Snowy 2.0.

Snowy 2.0 Main Works is shown in Figure 1.1 and Figure 1.2. If approved, the Snowy 2.0 Main Works would commence before the completion of the Exploratory Works.

The Snowy 2.0 Main Works do not include the main transmission works proposed by TransGrid (TransGrid 2018) that provide connection between the cableyard and the NEM. These transmission works will provide the ability for Snowy 2.0 (and other generators) to efficiently and reliably transmit additional renewable energy to major load centres during periods of peak demand, as well as enable a supply of renewable energy to pump water from Talbingo Reservoir to Tantangara Reservoir during periods of low demand. While the upgrade works to the wider transmission network and connection between the cableyard and the network form part of the CSSI declaration for Snowy 2.0 and Transmission Project, they do not form part of this application and will be subject to separate application and approval processes, managed by TransGrid. This project is known as the HomeLink and is part of AEMO's Integrated System Plan.

With respect to the provisions of the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act), on 30 October 2018 Snowy Hydro referred the Snowy 2.0 Main Works to the Commonwealth Department of the Environment and Energy (DoEE) and, on a precautionary basis, nominated that Snowy 2.0 Main Works has potential to have a significant impact on MNES and the environment generally.

On 5 December 2018, Snowy 2.0 Main Works were deemed a controlled action by the Assistant Secretary of the DoEE. It was also determined that potential impacts of the project will be assessed by accredited assessment under Part 5, Division 5.2 of the EP&A Act. This accredited process will enable the NSW Department of Planning, Industry and Environment (DPIE) to manage the assessment of Snowy 2.0 Main Works, including the issuing of the assessment requirements for the EIS. Once the assessment has been completed, the Commonwealth Minister for the Environment will make a determination under the EPBC Act.

1.2 Location of Snowy 2.0 Main Works

Snowy 2.0 Main Works are within the Australian Alps, in southern NSW, about mid-way between Canberra and Albury. Snowy 2.0 Main Works are within both the Snowy Valleys and Snowy Monaro Regional local government areas (LGAs).

The nearest large towns to Snowy 2.0 Main Works are Cooma and Tumut. Cooma is located about 50 kilometres (km) south-east of the project area (or 70 km by road from Providence Portal at the southern edge of the project area), and Tumut is located about 35 km north-west of the project areas (or 45 km by road from Tumut 3 power station at the northern edge of the project area). Other townships near the project area include Talbingo, Cabramurra, Adaminaby and Tumbarumba. Talbingo and Cabramurra were built for the original Snowy Scheme workers and their families, while Adaminaby was relocated in 1957 to make way for the establishment of Lake Eucumbene.

Figure 1.1 shows the location of the Snowy 2.0 Main Works in a regional context and Figure 1.2 shows the location of the project in a local context.

The pumped hydro-electric scheme elements of Snowy 2.0 Main Works are mostly underground between the southern ends of Tantangara and Talbingo reservoirs, a straight-line distance of 27 km. Surface works will also occur at locations on and between the two reservoirs. Key locations for surface works include:

- **Tantangara Reservoir** - at a full-supply level (FSL) of about 1,229 metres (m) to Australian Height Datum (AHD), Tantangara Reservoir will be the upper reservoir for the pumped hydro project and will include the headrace tunnel and intake structure. The site will also be used for a temporary construction compound, accommodation camp and other temporary ancillary activities;
- **Marica** - this site will be used primarily for construction (including construction of vertical shafts to the underground power station (ventilation shaft) and headrace tunnel (surge shaft), and a temporary accommodation camp);

- **Lobs Hole** - this site will be used primarily for construction but will also become the main entrance to the power station during operation. Lobs Hole will provide access to the Exploratory Works tunnel, which will be refitted to become the main access tunnel (MAT), as well as the location of the emergency egress, cable and ventilation tunnel (ECVT), portal and associated services; and

- **Talbingo Reservoir** - at an FSL of about 546 m AHD, Talbingo Reservoir provides the lower reservoir for the pumped hydro-electric project and will include the tailrace tunnel and water intake structure. The site will also be used for temporary construction compounds and other temporary ancillary activities.

Works will also be required within the two reservoirs for the placement of extracted rock. Supporting infrastructure will include establishing or upgrading access tracks and roads, and electricity connections to construction sites.

Most of the proposed pumped hydro-electric and temporary construction elements and most of the supporting infrastructure for Snowy 2.0 Main Works are located within the boundaries of KNP, although the disturbance footprint for the project during construction is less than 0.25% of the total KNP area. Some of the supporting infrastructure (including sections of road upgrade, power and communications infrastructure) extends beyond the national park boundaries. These sections of infrastructure are primarily located to the east and south of Tantangara Reservoir. One temporary construction site is located beyond the national park along the Snowy Mountains Highway about 3 km east of Providence Portal (referred to as Rock Forest).

The project is described in more detail in Chapter 2.

1.3 Project area

A project area for Snowy 2.0 Main Works has been identified that includes the elements of the project, including all construction and operational elements. The project area is shown in Figure 1.1 and Figure 1.2.

Key features of the project area are:

- the water bodies of Talbingo and Tantangara reservoirs, covering areas of 19.4 square kilometres (km^2) and 21.2 km^2 respectively. The reservoirs provide the water to be utilised in the pumped hydro-electric scheme;

- major watercourses including the Yarrangobilly, Eucumbene and Murrumbidgee rivers and some of their tributaries;

- KNP, within which the majority of the project area is located. Within the project area, KNP is characterised by two key zones: upper slopes and inverted treelines in the west of the project area (referred to as the ‘ravine’) and associated subalpine treeless flats and valleys in the east of the project area (referred to as the ‘plateau’); and

- farmland southeast of KNP at Rock Forest.

The project area is interspersed with built infrastructure including recreational sites and facilities, main roads as well as unsealed access tracks, hiking trails, farmland, electricity infrastructure, and infrastructure associated with the Snowy Scheme.

1.4 Proponent

Snowy Hydro is the proponent for the Exploratory Works. Snowy Hydro is an integrated energy business – generating energy, providing price risk management products for wholesale customers, and delivering energy to homes and businesses. Snowy Hydro is the fourth largest energy retailer in the NEM and is Australia’s leading provider of peak, renewable energy.

1.5 Purpose of this report

This AQIA supports the EIS for the Snowy 2.0 Main Works. It documents the existing air quality and meteorological environment, applicable impact assessment criteria, air pollutant emission calculations, dispersion modelling of calculated emissions and assessment of predicted impacts relative to criteria.

This AQIA consists of the following sections:

- a description of the local setting and surrounds of the project;
- the pollutants which are relevant to the assessment, and the applicable impact assessment criteria;
- a description of the existing environment, specifically:
  - the meteorology and climate; and
  - the existing air quality environment;
- a detailed air pollutant emissions inventory for the Snowy 2.0 Main Works;
- atmospheric dispersion modelling for the quantified emissions, including an analysis of Snowy 2.0 Main Works construction-only and cumulative impacts accounting for baseline air quality;
- an overview of mitigation measures and air quality monitoring requirements; and
- a greenhouse gas assessment.

The AQIA has been prepared in general accordance with the guidelines specified by the NSW Environment Protection Authority (EPA) in the *Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales* (EPA 2016), referred to hereafter as 'the Approved Methods for Modelling'.

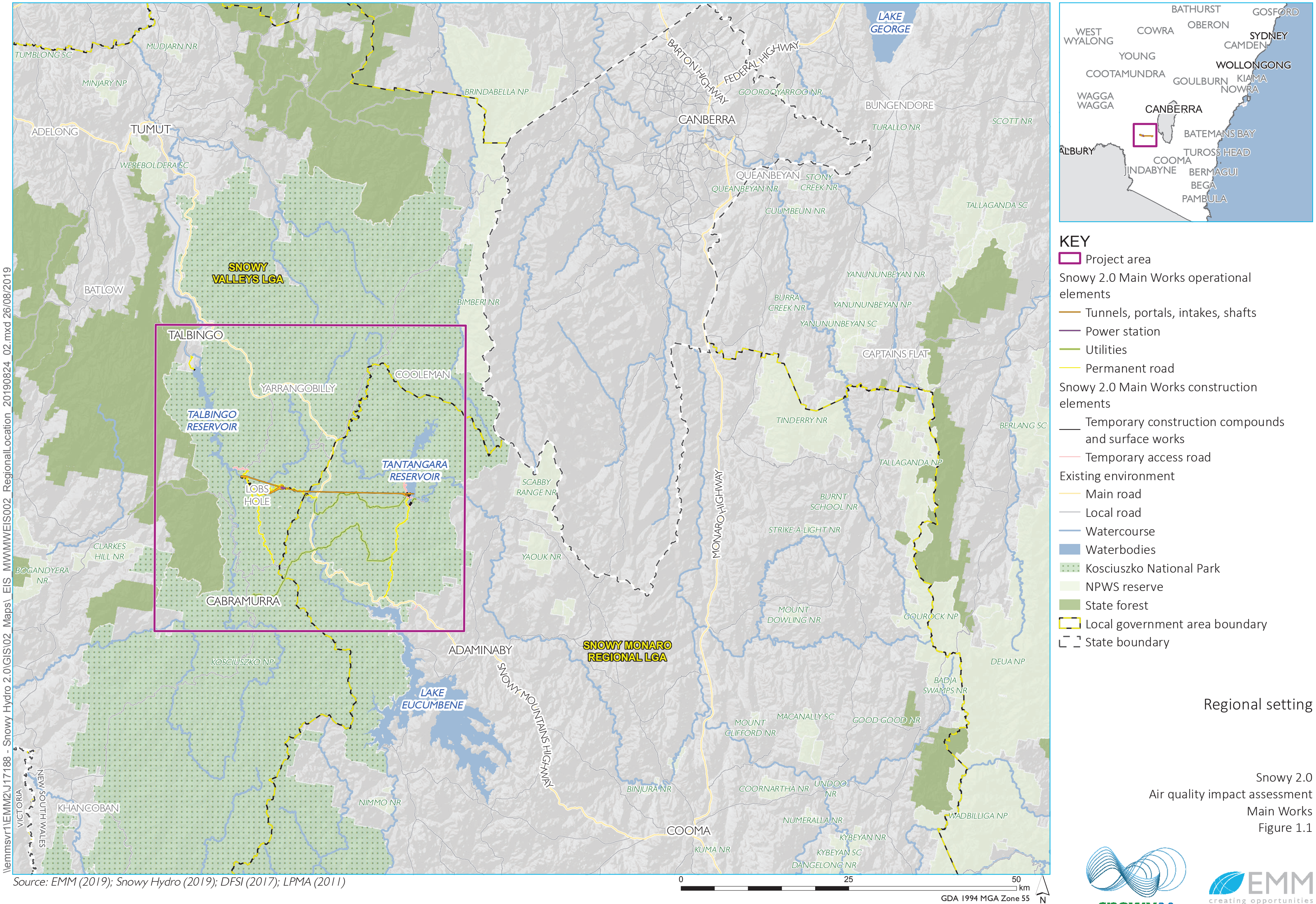
1.6 Assessment guidelines and requirements

This AQIA has been prepared in accordance with the Secretary's Environmental Assessment Requirements (SEARs) for Main Works, issued on 31 July 2019, as well as relevant governmental assessment requirements, guidelines and policies, and in consultation with the relevant government agencies.

The SEARs must be addressed in the EIS. Table 1.1 lists the matters relevant to this assessment and where they are addressed in this report.

Table 1.1 Relevant matters raised in SEARs

Requirement	Section addressed
Air: an assessment of the particulate matter and greenhouse gas emissions of the project	Entire report



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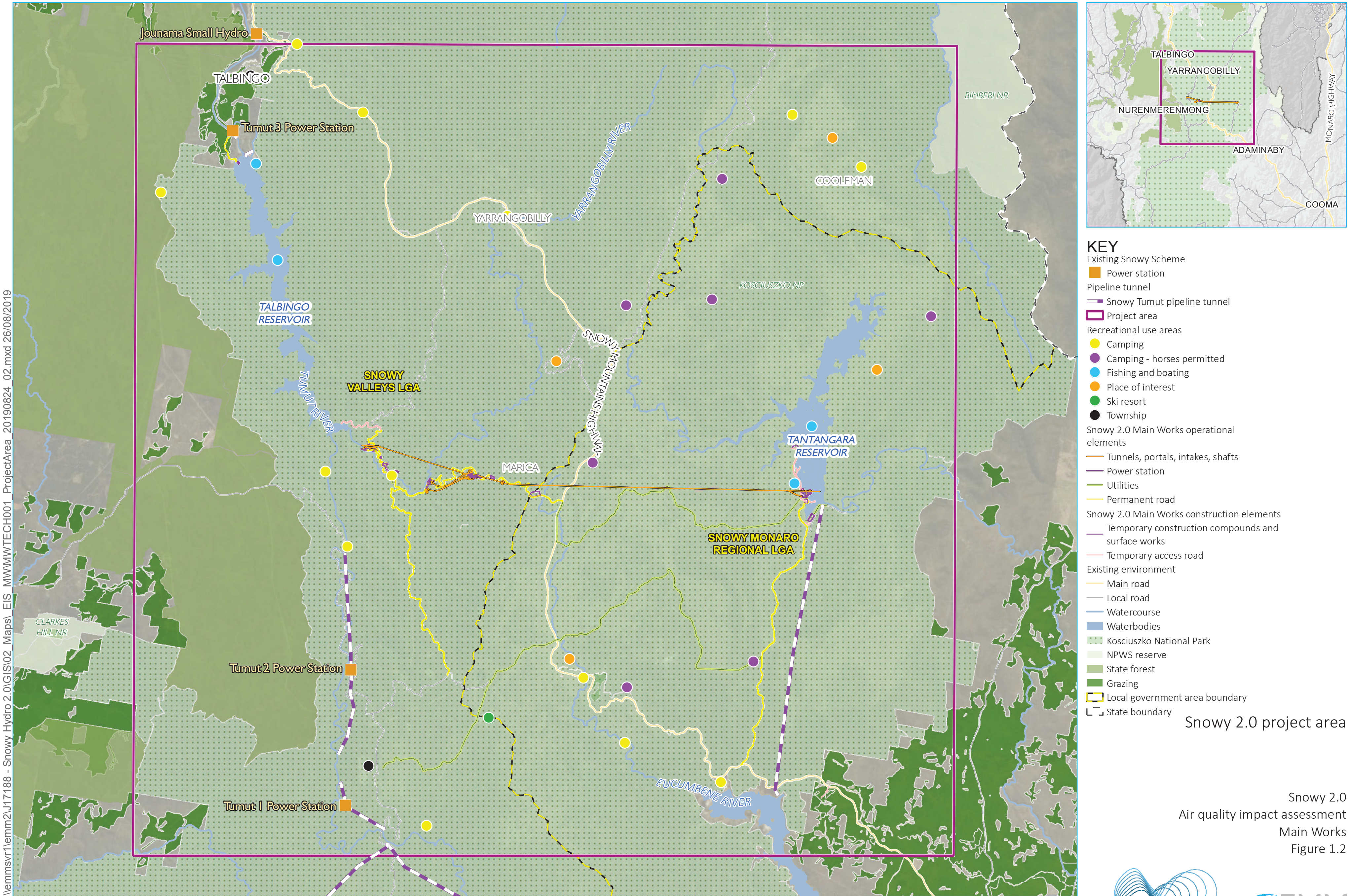
Source: EMM (2019); Snowy Hydro (2019); DFSI (2017); LPMA (2011)

Regional setting

Snowy 2.0
Air quality impact assessment
Main Works
Figure 1.1



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Source: EMM (2019); Snowy Hydro (2019); DFSI (2017); LPMA (2011)

KEY

Existing Snowy Scheme
- Power station

Pipeline tunnel
- Snowy Tumut pipeline tunnel
- Project area

Recreational use areas
- Camping
- Camping - horses permitted
- Fishing and boating
- Place of interest
- Ski resort
- Township

Snowy 2.0 Main Works operational elements
- Tunnels, portals, intakes, shafts
- Power station
- Utilities
- Permanent road

Snowy 2.0 Main Works construction elements
- Temporary construction compounds and surface works
- Temporary access road

Existing environment
- Main road
- Local road
- Watercourse
- Waterbodies
- Kosciuszko National Park
- NPWS reserve
- State forest
- Grazing
- Local government area boundary
- State boundary

Snowy 2.0 project area

Snowy 2.0
Air quality impact assessment
Main Works
Figure 1.2

snowy 2.0
EMM creating opportunities

2 Project and site description

2.1 Project description

2.1.1 Introduction

Snowy 2.0 will link the existing Tantangara and Talbingo Reservoirs within the present Snowy Scheme through a series of new underground tunnels and a hydro-electric power station, to be constructed within a cavern. Most of the project's facilities will be underground. An overview of Snowy 2.0 is shown on Figure 2.1.

2.1.2 Construction

The following main activities would be undertaken for the construction of the project:

Table 2.1 Snowy 2.0 construction elements

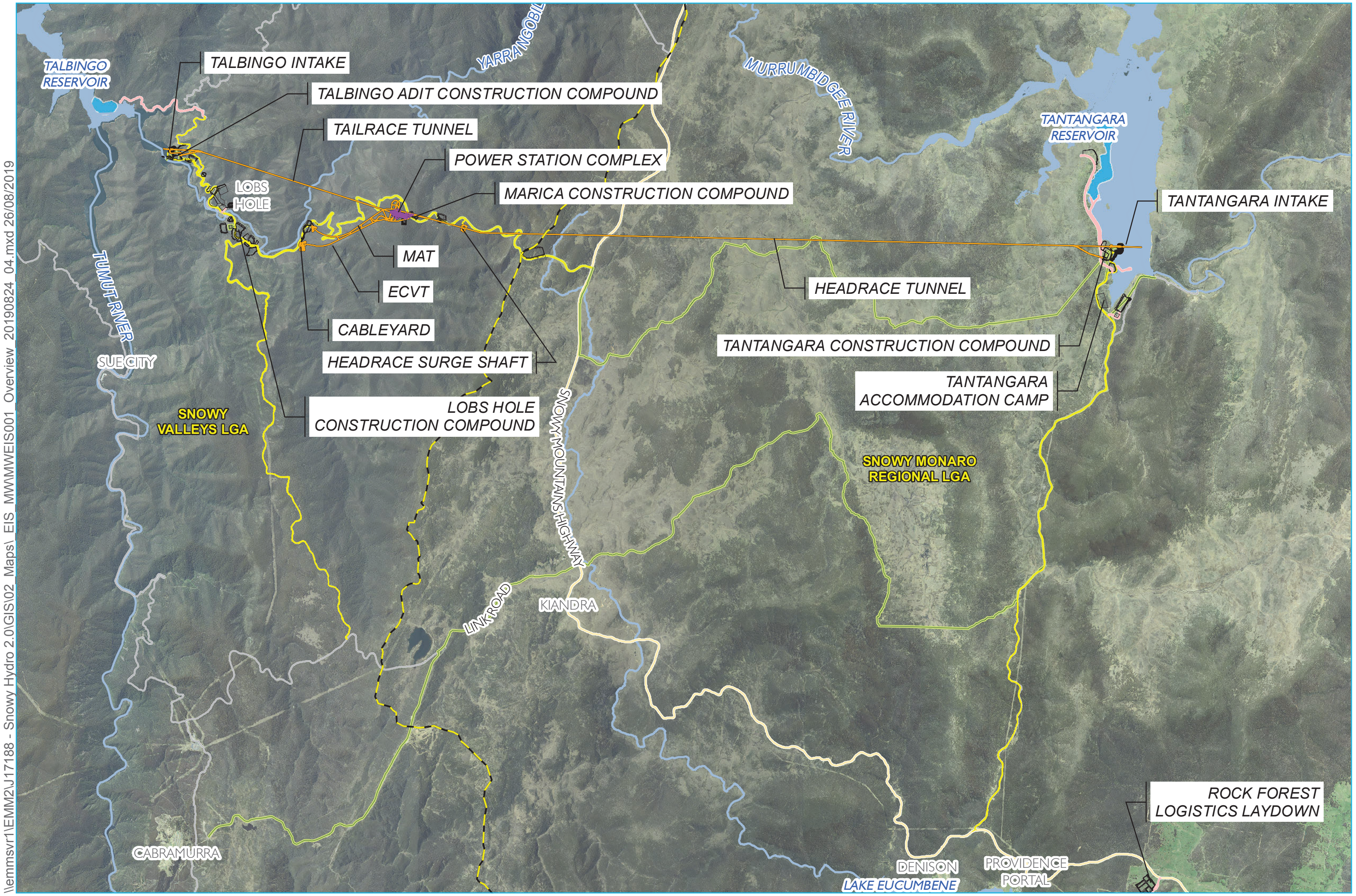
Construction element	Purpose	Location
Construction sites	Due to the remoteness of Snowy 2.0, construction sites are generally needed to: • provide ancillary facilities such as concrete batching plants, mixing plants and on-site manufacturing; • store machinery, equipment and materials to be used in construction; • provide access to underground construction sites; and • provide onsite accommodation for the construction workforce.	Each construction site needed for Snowy 2.0 is shown on Figure 2.1.
Substations and power connection	One substation is required to provide permanent power to Snowy 2.0, at Lobs Hole. This substation is proposed as part of a modification to the Exploratory Works with a capacity of 80 mega volt amp (MVA). It will continue to be used for Main Works, however requires the establishment of further power supply cables to provide power to the work sites and TBM at Tantangara, as well as Talbingo, in particular to power the TBMs via the MAT, ECVT, Talbingo and Tantangara portals.	The supporting high voltage cable route mostly follows access roads to each of the work sites, using a combination of aerial and buried arrangements.
Communications system	Communications infrastructure will connect infrastructure at Tantangara and Talbingo reservoirs to the existing communications system at the Tumut 3 power station (via the submarine communications cable in Talbingo Reservoir established during Exploratory Works) and to Snowy Hydro's existing communications infrastructure at Cabramurra.	The cable will be trenched and buried in conduits within access roads. Crossing of watercourses and other environmentally sensitive areas will be carried out in a manner that minimises environmental impacts where possible, such as bridging or underboring.

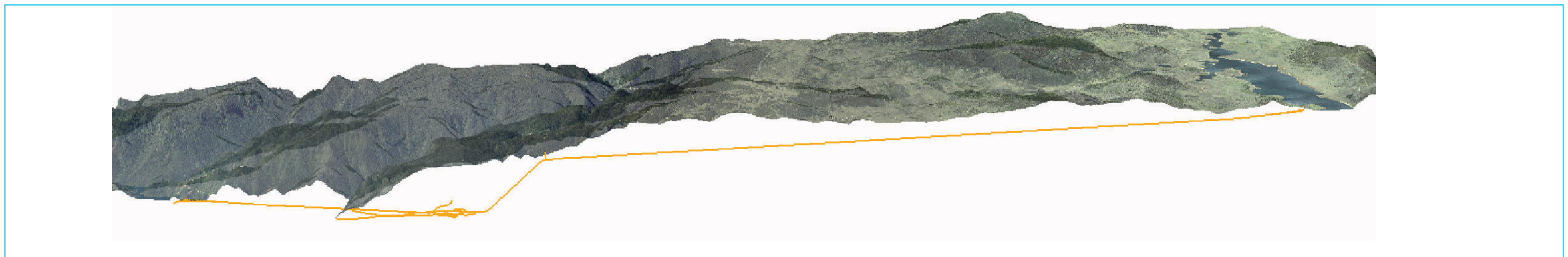
Table 2.1 Snowy 2.0 construction elements

Construction element	Purpose	Location
Water and waste water servicing	Drinking water will be provided via water treatment plants located at accommodation camps. Water for treatment will be sourced from the nearest reservoir. There are three main wastewater streams that require some form of treatment before discharging to the environment, including: • tunnel seepage and construction wastewater (process water); • domestic sewer (wastewater); and • construction site stormwater (stormwater).	Utility pipelines generally follow access roads. Water treatment plants (drinking water) will be needed for the accommodation camps and will be located in proximity. Waste water treatment plants will similarly be located near accommodation camps. Process water treatment plants will be at construction compounds and adits where needed to manage tunnel seepage and water during construction.
Temporary and permanent access roads	Access road works are required to: • provide for the transport of excavated material between the tunnel portals and the excavated rock emplacement areas; • accommodate the transport of oversized loads as required; and • facilitate the safe movement of plant, equipment, materials and construction workers into and out of construction sites. The access road upgrades and establishment requirements are shown on Figure 2.2 to Figure 2.6. These roads will be used throughout construction including use of deliveries to and from site and the external road network. Some additional temporary roads will also be required within the footprint to reach excavation fronts such as various elevations of the intakes excavation or higher benches along the permanent roads.	The access road upgrades and establishment requirements are shown across the project area. Main access and haulage to site will be via Snowy Mountains Highway, Link Road and Lobs Hole Ravine Road (for access to Lobs Hole), and via Snowy Mountains Highway and Tantangara Road (for access to Tantangara Reservoir) (Figure 2.1).
Excavated rock management	Approximately 9 million m^3 (unbulked) of excavated material will be generated by construction and require management. The strategy for management of excavated rock will aim to maximise beneficial reuse of materials for construction activities. Beneficial re-use of excavated material may include use for road base, construction pad establishment, selected fill and tunnel backfill and rock armour as part of site establishment for construction. Excess excavated material that cannot be re-used during construction will be disposed of within Talbingo and Tantangara reservoirs, used in permanent rehabilitation of construction pads to be left in situ in Lobs Hole, or transported for on-land disposal if required.	Placement areas are shown on Figure 2.1.
Barge launch facilities	Barge launch facilities on Talbingo Reservoir will have already been established during Exploratory Works for the placement of the submarine communications cable, and will continued to be used for Main Works for construction works associated with the Talbingo intake structure. The Main Works will require the establishment of barge launch facilities on Tantangara Reservoir to enable these similar works (removal of the intake plug).	Barge launch sites are shown on Figure 2.1.

Table 2.1 Snowy 2.0 construction elements

Construction element	Purpose	Location
Construction workforce	The construction workforce will be accommodated entirely on site, typically with a FIFO/DIDO roster. Private vehicles will generally not be permitted and the workforce bused to and from site.	Access to site will be via Snowy Mountains Highway





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KEY

Existing environment
- Main road
- Local road
- Watercourse
- Waterbodies
- Local government area boundary

Snowy 2.0 Main Works operational elements
- Tunnels, portals, intakes, shafts
- Power station
- Utilities
- Permanent road

Snowy 2.0 Main Works construction elements
- Temporary construction compounds and surface works
- Temporary access road
- Indicative rock emplacement area

Snowy 2.0 project elements

Snowy 2.0
Air quality impact assessment
Main Works
Figure 2.1

Source: EMM (2019); Snowy Hydro (2019); DFSI (2017); LPMA (2011)

0 2.5 5 km
GDA 1994 MGA Zone 55

The key areas of construction can be described across the following locations:

- Talbingo Reservoir – Talbingo Reservoir provides the lower reservoir for the pumped hydro-electric project and will include the tailrace tunnel and water intake structure. The site will also be used for temporary construction compounds and other temporary ancillary activities;
- Lobs Hole – this site will be used primarily for construction (including construction of the MAT and ECVT portals and tunnels to the underground power station and the headrace tunnel (and headrace tunnel surge shaft), underground tailrace surge shaft and a temporary accommodation camp);
- Marica – the site will be used primarily for construction to excavate the ventilation shaft to the underground power station as well as for the excavation and construction of the headrace surge shaft;
- Plateau – the land area between Snowy Mountains Highway and Tantangara Reservoir is referred to as the Plateau. The Plateau will be used to access and construct a utility corridor and construct a fish weir on Tantangara Creek;
- Tantangara Reservoir – Tantangara Reservoir will be the upper reservoir for the pumped hydro project and include the headrace tunnel and intake structure. The site will also be used for a temporary construction compound, accommodation camp and other temporary ancillary activities; and
- Rock Forest – a site to be used temporarily for logistics and staging during construction. It is located beyond the KNP along the Snowy Mountains Highway about 3 km east of Providence Portal.

2.1.3 Operation

Snowy 2.0 would operate within the northern Snowy-Tumut Development, connecting the existing Tantangara and Talbingo reservoirs.

Tantangara Reservoir currently has the following operational functions within the Snowy Scheme:

- collects releases from the Murrumbidgee River and the Goodradigbee River Aqueduct;
- provides a means for storage and diversion of water to Lake Eucumbene via the Murrumbidgee-Eucumbene Tunnel; and
- provides environmental releases through the Tantangara Reservoir river outlet gates to the Murrumbidgee River.

Talbingo Reservoir currently has the following operational functions:

- collects releases from Tumut 2 power station;
- collects releases from the Yarrangobilly and Tumut rivers;
- acts as head storage for water pumped up from Jounama Pondage; and
- acts as head storage for generation at Tumut 3 power station.

Due to its historic relationship to both the upstream Tumut 2 power station and downstream Tumut 3 power station, Talbingo Reservoir has had more operational functions than Tantangara Reservoir in the current Snowy Scheme.

Following the commencement of the operation of Snowy 2.0, both Tantangara and Talbingo reservoirs will have increased operational functions. Tantangara Reservoir will have the additional operational functions of acting as a head storage for generation from the Snowy 2.0 power station and also acting as a storage for water pumped up from Talbingo Reservoir. Talbingo Reservoir will have the additional operational function of acting as a tail storage from Snowy 2.0 generation.

As a result of the operation of Snowy 2.0, the water level in Tantangara Reservoir will be more variable than historically. Notwithstanding this, operations will not affect release obligations under the Snowy Water Licence nor will it involve any change to the currently imposed Full Supply Levels (FSLs). No additional land will be affected by virtue of the inundation of the reservoirs through Snowy 2.0 operations. Water storages will continue to be held wholly within the footprint of the existing FSLs.

2.1.4 Permanent access

Permanent access to Snowy 2.0 infrastructure is required. During operation, a number of service roads established during construction will be used to access surface infrastructure including the power station's ventilation shaft, water intake structures and gates, and the headrace tunnel surge shaft. Permanent access tunnels (the MAT and ECVT) will be used to enter and exit the power station. For some roads, permanent access by Snowy Hydro will require restricted public access arrangements.

2.1.5 Rehabilitation and final land use

A Rehabilitation Strategy has been prepared for Snowy 2.0 Main Works and appended to the EIS.

It is proposed that all areas not retained for permanent infrastructure will be revegetated and rehabilitated. At Lobs Hole, final landform design and planning has been undertaken to identify opportunities for the reuse of excavated material in rehabilitation to provide landforms which complement the surrounding topography in the KNP.

Given that most of Snowy 2.0 Main Works is within the boundaries of the KNP, Snowy Hydro will liaise closely with NPWS to determine the extent of decommissioning of temporary construction facilities and rehabilitation activities to be undertaken following the construction of Snowy 2.0 Main Works.

2.2 Site and surrounding area

The Snowy 2.0 Main Works are located within the Australian Alps, mid-way between Canberra and Albury. The project area consists of valleys and mountainous terrain in the western projects area with elevations ranging between approximately 600 m AHD and 1,510 m AHD. The terrain in the east is dominated by alpine high plains ranging from approximately 1,160 m AHD to 1,609 m AHD. A three-dimensional representation of the local topography is presented in Figure 2.2.

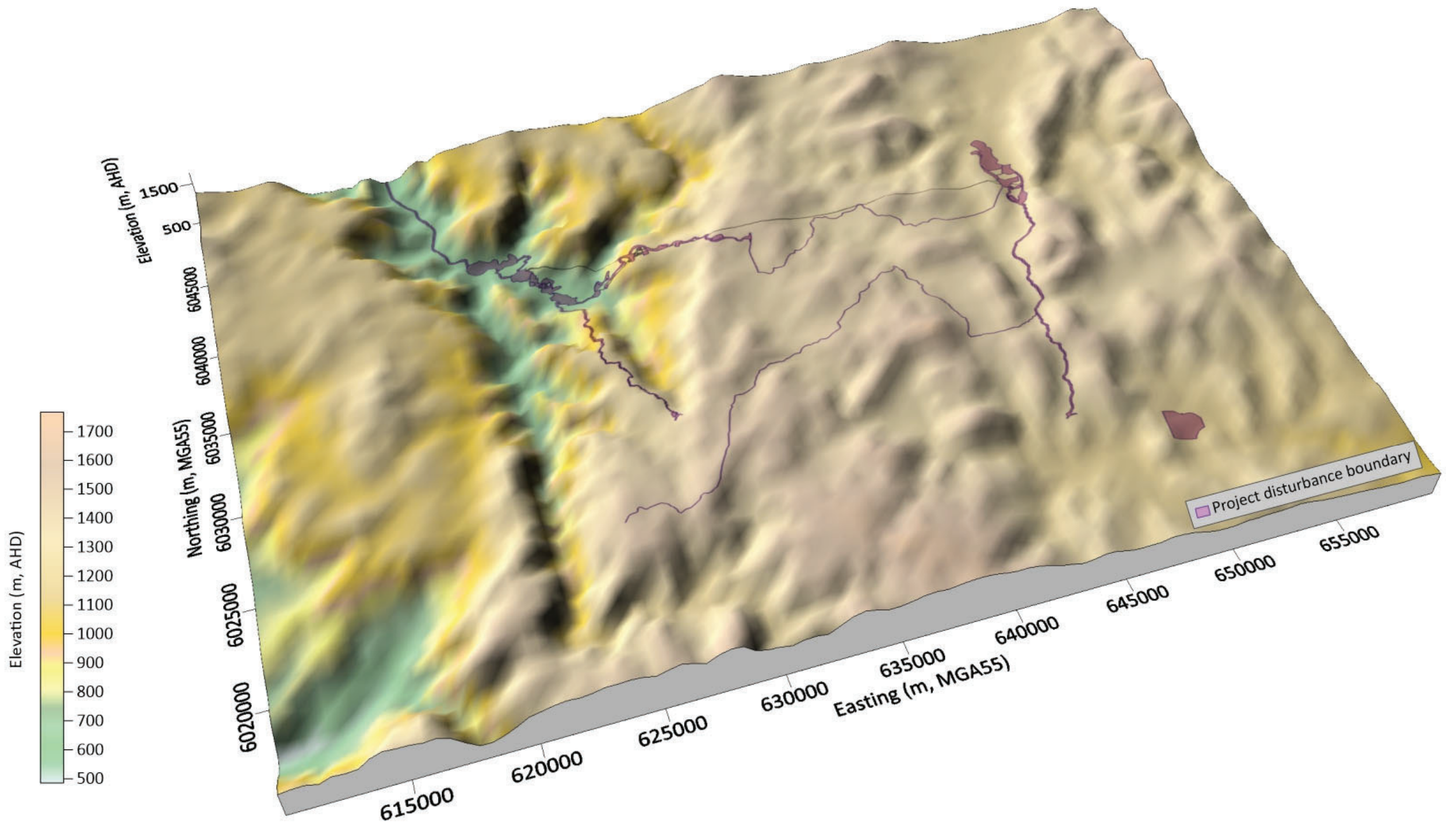

Figure 2.2 3-dimensional topography surrounding the project

Source: NASA Shuttle Radar Topography Mission data

2.3 Assessment locations

The nearest representative air quality sensitive locations to the Main Works have been identified for the purpose of assessing potential air quality impacts. Details are provided in Table 2.2 and their locations are shown in Figure 2.3. They are referred to in this report as assessment locations.

Table 2.2 Air quality assessment locations

ID	Description	Assessment location type	Easting	Northing
R1	Bullocks Hill campground	Passive recreation	637207	6039763
R2	Cabramurra town	Residential	624617	6022721
R3	Old Kiandra	Passive recreation	635905	6028711
R4	Selwyn Snow Resort	Active recreation	631364	6025420
R5	Yarrangobilly Village	Commercial	634825	6045448
R6	6560 Snowy Mountains Highway	Residential	650414	6021793
R7	6065 Snowy Mountains Highway	Residential	653068	6017700
R8	6067 Snowy Mountains Highway	Residential	652785	6018304
R9	6069 Snowy Mountains Highway	Residential	652758	6018605
R10	6074 Snowy Mountains Highway	Residential	653301	6018452
R11	6076 Snowy Mountains Highway	Residential	653413	6018914
R12	6078 Snowy Mountains Highway	Residential	652937	6018962
R13	Rock Forest, 6193 Snowy Mountains Highway	Residential	652289	6019054
R14	4/DP1002302 Snowy Mountains Highway, Adaminaby	Residential	651167	6018200
R15	Lot 3 Snowy Mountains Highway, Adaminaby	Residential	651093	6018384
R16	Lot 2 Snowy Mountains Highway, Adaminaby	Residential	650893	6018404
R17	1/DP100230, Snowy Mountains Highway, Adaminaby	Residential	650879	6018592
R18	6225 Snowy Mountains Highway, Adaminaby	Residential	649917	6018153
R19	10/DP48756 Snowy Mountains Highway, Adaminaby	Residential	650325	6019535
R20	Yarrangobilly Caves	Passive recreation	635163	6045458
R21	Private properties at Nurrenmerenmong	Residential	615307	6040979
R22	Three Mile Dam campground	Passive recreation	630757	6027446
R23	Rocky Plain Campground	Passive Recreation	639142	6027130
R24	Wares Yards Campground	Passive Recreation	646262	6028591
R25	Providence Portal	Residential	646991	6021120

Table 2.2 Air quality assessment locations

ID	Description	Assessment location type	Easting	Northing
R26	Currango Homestead	Commercial	653200	6044983
R27	Snowy 2.0 Lobs Hole Accommodation	Worker accommodation	625947	6039216
R28	Snowy 2.0 Marica Accommodation	Worker accommodation	630540	6038820
R29	Snowy 2.0 Tantangara Accommodation	Worker accommodation	648840	6036903

The majority of assessment locations identified in the region of the Main Works are passive and active recreation areas. These include recreation areas such as Yarrangobilly campground (to the north), Bullocks Hill campground (to the north), Currango Homestead (to the north-east), Wares Yards campground (to the south), Rocky Plain campground (to the south), Old Kiandra Goldfields (to the south), Selwyn Snow Resort (to the south), Three Mile campground (to the south) Coonara Point and O'Hares rest area (to the west) and Talbingo reservoir (to the northwest).

The assessment locations most likely to be affected by Main Works construction activities are residences and campgrounds in the vicinity of the Snowy Mountains Highway between Cooma and Talbingo.

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Source: EMM (2019); Snowy Hydro (2019); DFSI (2017); LPMA (2011)

0 2.5 5 km

GDA 1994 MGA Zone 55

N

KEY

Air quality assessment location

- Active recreation
- Passive recreation
- Residential
- Commercial
- Snowy accommodation camp

Snowy 2.0 Main Works operational elements

- Tunnels, portals, intakes, shafts
- Power station
- Utilities
- Permanent road

Snowy 2.0 Main Works construction elements

- Temporary construction compounds and surface works
- Temporary access road
- Indicative rock emplacement area

Existing environment

- Main road
- Local road
- Watercourse
- Waterbodies

Air quality assessment locations

Snowy 2.0
Air Quality Impact Assessment
Main Works
Figure 2.3

snowy 2.0

EMM creating opportunities

3 Pollutants and assessment criteria

3.1 Introduction

This assessment focuses on the potential air quality emissions and associated impacts from Snowy 2.0 Main Works construction activities only. The construction of Snowy 2.0 Main Works has the potential to generate emissions of various air pollutants to the atmosphere. Air pollution emission sources will comprise of a mixture of the following:

- fugitive sources of particulate matter, such as material handling and processing activities, movement of mobile plant and equipment, and wind erosion of exposed surfaces and storage piles; and
- combustion sources, such as exhaust emissions from the construction equipment fleet and emergency generators.

A detailed description of the emission sources associated with the Snowy 2.0 Main Works is presented in Section 6.

Operational phase emissions would principally consist of emissions from:

- wheel-generated dust emissions from the movement of vehicles along sealed and unpaved traffic routes between Snowy 2.0 Main Works surface infrastructure; and
- fuel combustion (petrol, diesel) from vehicles travelling between Snowy 2.0 Main Works surface infrastructure.

The volume of traffic and fuel combustion associated with the operation of the Snowy 2.0 Main Works will be sustainably lower than the construction phase. Additionally, the construction phase will involve the handling, transfer and emplacement of excavated tunnel spoil. Consequently, air pollution emissions from the operations phase of the Snowy 2.0 Main Works will be negligible relative to the construction phase. The construction phase therefore represents the most significant period of the Snowy 2.0 Main Works for potential air quality impacts and is the focus of this report. The operational phase of the Snowy 2.0 Main Works has not been considered further in this assessment.

3.2 Potential air pollutants

The construction phase of the Snowy 2.0 Main Works will generate emissions of:

- particulate matter, specifically:
  - total suspended particulate matter (TSP);
  - particulate matter less than 10 micrometres (µm) in aerodynamic diameter (PM_{10}); and
  - particulate matter less than 2.5 µm in aerodynamic diameter ($PM_{2.5}$).
- gaseous pollutants, specifically:
  - oxides of nitrogen (NO_x)[1], including nitrogen dioxide (NO_2);

[1] By convention, NOx = nitrous oxide (NO) + NO_2.

- sulfur dioxide (SO_2);
- carbon monoxide (CO); and
- volatile organic compounds (VOCs).

Of the above listed pollutants, this assessment will focus on emissions and impacts from particulate matter (TSP, PM_{10} and $PM_{2.5}$) and NO_2. These pollutants are considered key indicators for potential effects on human health and amenity based on the types and intensity of activities proposed during the construction phase of the Snowy 2.0 Main Works.

Impact assessment criteria applicable to particulate matter and NO_2 is presented in the following sections as defined in the Approved Methods for Modelling (NSW EPA 2016). The impact assessment criteria are designed to maintain ambient air quality that allows for the adequate protection of human health and well-being.

3.3 Applicable air quality assessment criteria

3.3.1 Particulate matter

The NSW EPA's impact assessment criteria for particulate matter, as documented in Section 7 of the Approved Methods for Modelling, are presented in Table 3.1. The assessment criteria for PM_{10} and $PM_{2.5}$ are consistent with the National Environment Protection (Ambient Air Quality) Measure (AAQ NEPM) national reporting standards (Department of the Environment 2016).

TSP, which relates to airborne particles less than around 45 micrometres (µm) in diameter (US EPA 1999), is used as a metric for assessing amenity impacts (reduction in visibility, dust deposition and soiling of buildings and surfaces) rather than health impacts (NSW EPA 2013). Particles less than 10 µm and 2.5 µm in diameter, a subset of TSP, are fine enough to enter the human respiratory system and can lead to adverse human health impacts. The NSW EPA impact assessment criteria for PM_{10} and $PM_{2.5}$ are therefore used to assess the potential impacts on human health of particulate matter concentrations.

The Approved Methods for Modelling classifies TSP, PM_{10}, $PM_{2.5}$ and dust deposition as criteria pollutants. Assessment criteria for criteria pollutants are applied at the nearest existing or likely future off-site sensitive receptor and compared against the 100^{th} percentile (ie the highest) dispersion modelling prediction in the case of 24-hour impacts. Both the incremental (Snowy 2.0 Main Works impacts only) and cumulative (Snowy 2.0 Main Works impacts plus background) impacts need to be presented, the latter requiring consideration of existing ambient background concentrations for the criteria pollutants assessed.

For dust deposition, the NSW EPA (2016) specifies criteria for the project increment and cumulative dust deposition levels. Dust deposition impacts are derived from TSP emission rates and particle deposition calculations in the dispersion modelling process.

Table 3.1 Impact assessment criteria for particulate matter

PM metric	Averaging period	Impact assessment criterion
TSP	Annual	90 µg/m³
PM_{10}	24 hours	50 µg/m³
	Annual	25 µg/m³
$PM_{2.5}$	24 hours	25 µg/m³
	Annual	8 µg/m³
Dust deposition	Annual	2 g/m²/month (project increment only)
		4 g/m²/month (cumulative)

Notes: µg/m³: micrograms per cubic metre; g/m²/month: gram per square metre per month

3.3.2 Gaseous pollutants

The project is anticipated to generate emissions of a range of gaseous pollutants, including NO_x/NO_2, CO, SO_2 and VOCs from fuel combustion. This assessment focuses on NO_2 as the indicator[2] for all gaseous pollutants.

The impact assessment criteria for NO_2, as defined by the NSW EPA (2016), are summarised in Table 3.2.

Table 3.2 Impact assessment criteria for NO_2

Pollutant	Averaging period	Impact assessment criterion
NO_2	1 hour	246 µg/m³
	Annual	62 µg/m³

The impact assessment criteria for NO_2 are applicable at the nearest existing or likely future off-site sensitive receptor. In assessing compliance against the applicable criteria, the maximum cumulative concentration (project increment plus background concentration) at each receptor must be reported as the 100th percentile concentration (i.e. maximum concentration) for 1-hour impacts.

[2] For combustion sources NO_2 is often the critical gaseous pollutant when considering emission rates, existing background concentrations and compliance with ambient air quality standards. This assessment therefore assumes that NO_2 represents a worst-case gaseous pollutant in this assessment.

4 Meteorology and climate

4.1 Monitoring data resources

There are several meteorological stations operated by Snowy Hydro surrounding the Snowy 2.0 Main Works. These stations are located between around 5 km and 50 km of the Snowy 2.0 Main Works construction compounds. One-hour average wind speed, wind direction, humidity, temperature, rainfall and barometric pressure data have been supplied by the client for the following stations for the period 2013 to 2017:

- Tantangara Dam;
- Cabramurra Airstrip;
- Cabramurra Town; and
- Talbingo.

The Bureau of Meteorology (BoM) also operates an Automatic Weather Station (AWS) at Cabramurra (Cabramurra SMHEA AWS – Station Number 072161), which is located between 15 km and 25 km south of the Snowy 2.0 Main Works construction compounds.

Figure 4.1 shows the locations of the meteorological stations in relation to the Snowy 2.0 Main Works.

Source: EMM (2019); Snowy Hydro (2019); DFSI (2017); LPMA (2011)

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KEY

Met station location

- Bureau of Meteorology
- Snowy Hydro

Existing environment

- Main road
- Local road
- Watercourse
- Waterbodies
- Local government area boundary

Snowy 2.0 operational elements

- Tunnels, portals, intakes, shafts
- Power station
- Utilities
- Permanent road

Snowy 2.0 construction elements

- Temporary construction compounds and surface works
- Temporary access road
- Indicative rock emplacement area

Location of meteorological stations surrounding the Snowy 2.0 Main Works

Snowy 2.0
Air Quality Impact Assessment
Main Works
Figure 4.1

snowy 2.0

EMM creating opportunities

4.2 Prevailing winds

Meteorological data located within the assessment domain were analysed. This included the BoM Cabramurra SMHEA AWS and Snowy Hydro meteorological stations at Tantangara Dam and Cabramurra Airstrip. As there were no wind speed data available from the Cabramurra Town station, data from this location were excluded from analysis.

Meteorological data recorded by the BoM Cabramurra SMHEA AWS for the five-year period between 2014 and 2018 were analysed. Data recorded for the five-year period between 2013 and 2017 were analysed for the project-related stations at Tantangara Dam and Cabramurra Airstrip. Data for the project-related stations for 2018 were not available at time of writing this report. Details relating to the selection of meteorological year and the representativeness of the dataset are provided in Annexure A.

The 2017 calendar year was deemed representative of meteorological conditions in the project area and therefore was adopted as the 12-month modelling period for the purpose of this AQIA (see Annexure A). As discussed in Annexure A, given its distance from the Snowy 2.0 Main Works, surface observations from the Talbingo station were included only in The Air Pollution Model (TAPM) run. Data from the Cabramurra Airstrip site were also excluded from the meteorological modelling as it was used for model evaluation purposes. Consequently, the focus of this section is on the BoM Cabramurra SMHEA AWS and the Tantangara Dam station.

Annual wind roses for the BoM Cabramurra SMHEA AWS and the Tantangara Dam station for 2017 are shown in Figure 4.2 and Figure 4.3 respectively. Similar to the inter-annual wind roses presented in Annexure A, the recorded wind patterns for 2017 were dominated by westerlies at the BoM Cabramurra SMHEA AWS and by southerlies at the Tantangara Dam station. There was a high proportion of elevated winds (greater than 5 m/s) at the BoM Cabramurra SMHEA AWS. Wind speeds were much lower at the Tantangara Dam station falling predominantly within the 0 to 2 m/s range. Calm conditions (wind speeds less than 0.5 m/s) at the BoM Cabramurra SMHEA AWS were 4.3% annually and 3.8% annually at the Tantangara Dam station.

Seasonal and diurnal wind roses for the BoM Cabramurra SMHEA AWS and the Tantangara Dam station are provided in Annexure A.

The seasonal variation in wind speed at BoM Cabramurra SMHEA AWS was minor, with the mean ranging from 4.3 m/s in winter to 5.2 m/s in spring. Wind direction was more varied seasonally with a higher percentage of westerlies in the spring and summer months. Diurnal variation in wind speed was minor with a mean of 5 m/s for both night-time and daytime periods. Wind direction was more varied diurnally with a higher percentage of westerlies during the daytime.

The seasonal variation in wind speed and wind direction at Tantangara Dam was minor, with the mean ranging from 1.3 m/s in autumn to 1.7 m/s in spring. Wind speed and wind direction varied on a diurnal basis. The night-time hours featured a higher proportion of southerly winds, while northerly winds were more evident during the daytime. The wind speeds at night were slightly lower on average than during the daytime, with average wind speeds of 1.2 m/s during the day and 1.7 m/s during the night.

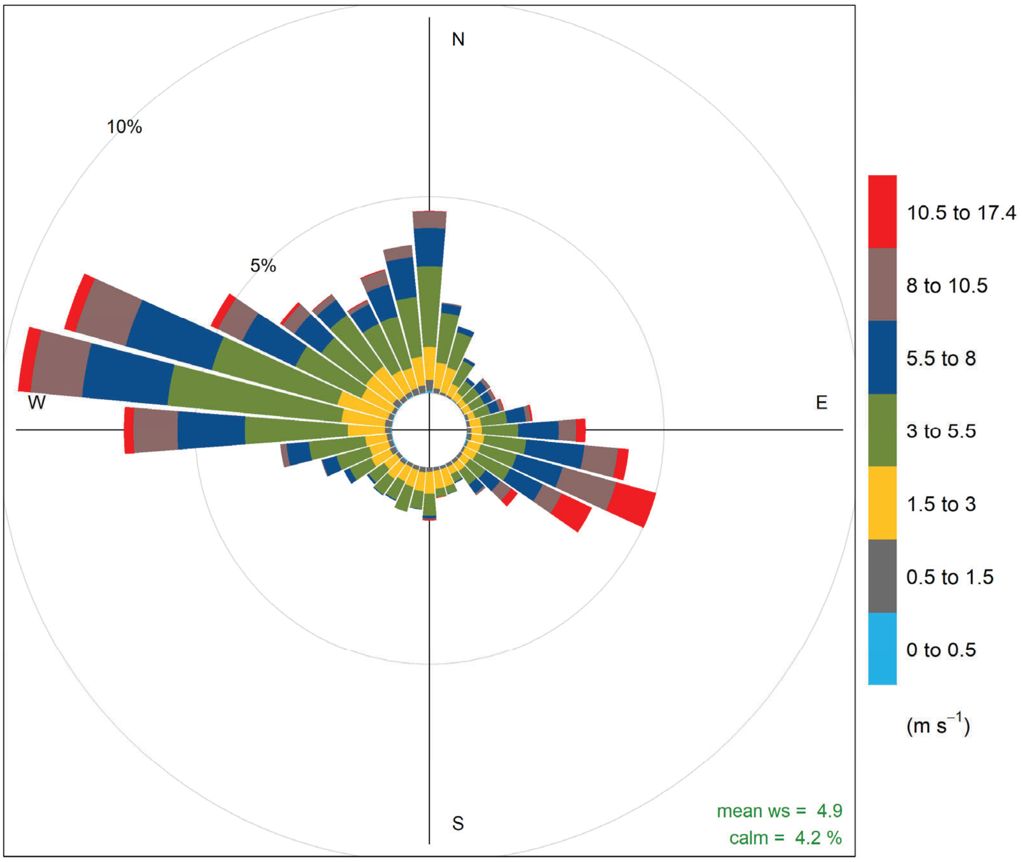


Figure 4.2 Recorded wind speed and direction – BoM Cabramurra SMHEA AWS – 2017

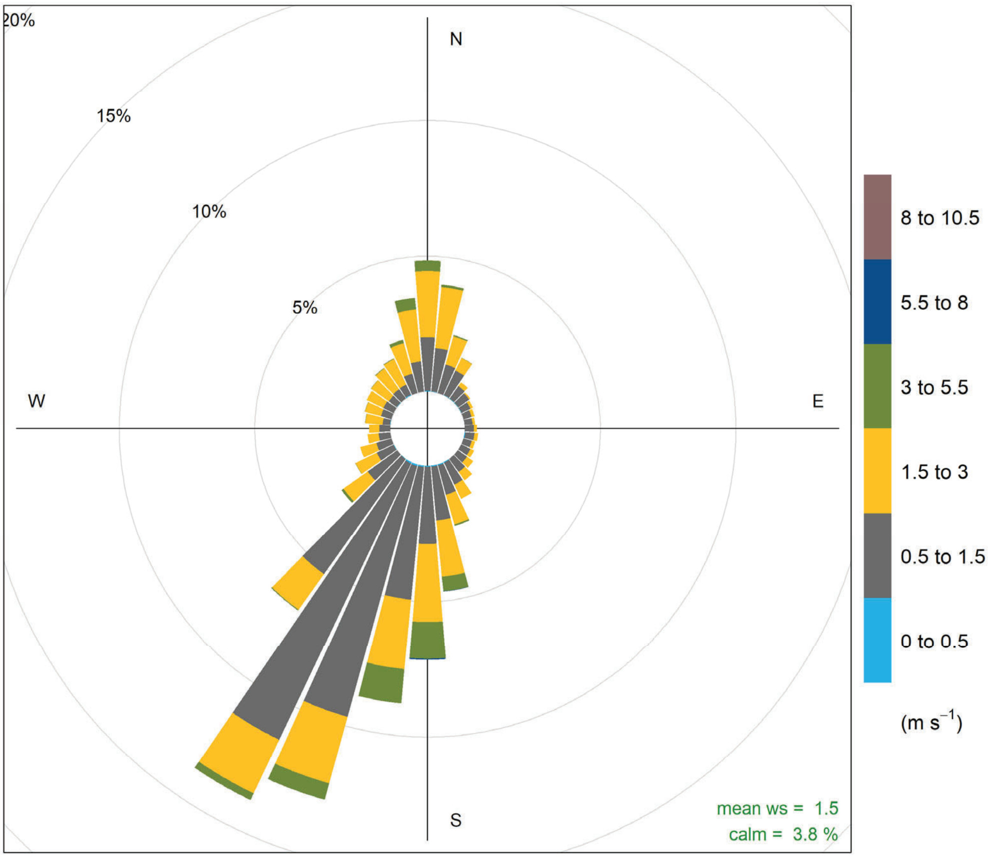


Figure 4.3 Recorded wind speed and direction – Tantangara Dam – 2017

4.3 Meteorological modelling

4.3.1 Overview

Atmospheric dispersion modelling for this assessment has been completed using TAPM and the CALMET/CALPUFF model suite.

Section 4.1 of the Approved Methods for Modelling specifies that meteorological data representative of a site can be used in the absence of suitable on-site observations. The data should cover a period of at least one year with a percentage completeness of at least 90%. Data can be obtained from either a nearby meteorological monitoring station or synthetically generated using the CSIRO prognostic meteorological model TAPM.

Hourly average meteorological data from the BoM Cabramurra SMHEA AWS and project-related stations at Tantangara Dam, Cabramurra Airstrip and Talbingo were used as observations in the TAPM modelling. Data from the BoM Cabramurra SMHEA AWS and Tantangara Dam were used in the CALMET modelling. To supplement these meteorological observation datasets, TAPM was used to generate parameters not routinely measured.

Further details of the TAPM and CALMET meteorological modelling is presented in Annexure B.

4.3.2 CALMET predicted winds

Wind speed and direction data recorded at the Cabramurra Airstrip weather station during 2017, excluded as observations from the CALMET model, were used to verify the performance of CALMET in predicting wind conditions. This analysis is presented in Annexure B.

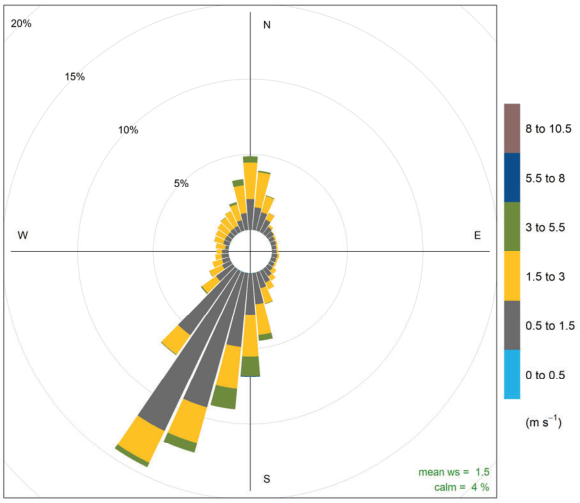
Meteorological data were also extracted from CALMET at the following construction compound locations (as shown on Figure 4.4):

- the Tantangara Reservoir;
- Marica; and
- Lobs Hole.

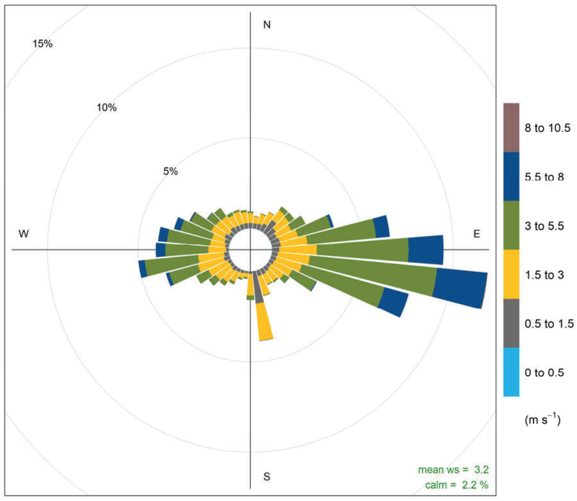
Annual wind roses created from the CALMET data extracts are presented in Figure 4.4.

The annual wind rose for the Tantangara Reservoir construction compound shows the same dominant southerly winds as seen in the observed meteorological data (see Figure 4.3). These southerly winds reflect the terrain at this location which is a low-lying valley surrounded by elevated terrain to the east and west. The annual average wind speed (1.5 m/s) and percentage of calms (4%) is also similar to the observed data.

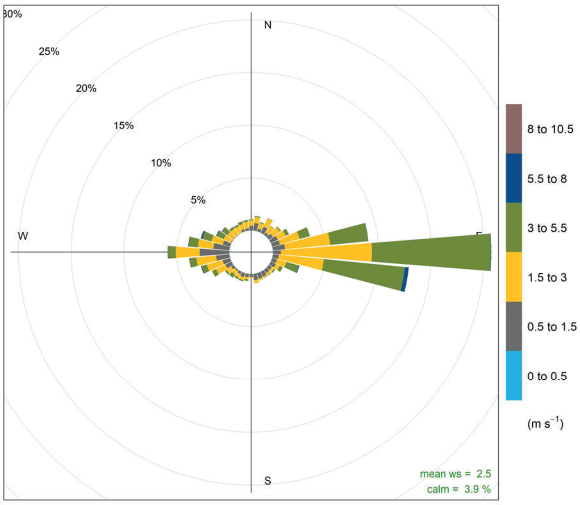
The annual wind roses for Marica and Lobs Hole construction compounds are similar in wind pattern with dominant winds from the east. The annual average wind speeds are 1.5 and 3.2 m/s respectively and the annual percentage of calms is 2.2% and 4.0%. The Marica construction compounds is located in an area of elevated terrain decreasing to the valley to the east towards the location of the Lobs Hole construction compound.



Tantangara Reservoir



Marica



Lobs Hole

Figure 4.4 CALMET-predicted wind speed and direction – Tantangara Reservoir, Marica and Lobs Hole construction compounds – 2017

4.3.3 Atmospheric stability and mixing depth

Atmospheric stability refers to the degree of turbulence or mixing that occurs within the atmosphere and is a controlling factor in the rate of atmospheric dispersion of pollutants.

The Monin-Obukhov length (L) provides a measure of the stability of the surface layer (ie the layer above the ground in which vertical variation of heat and momentum flux is negligible; typically about 10% of the mixing height). Negative L values correspond to unstable atmospheric conditions, while positive L values correspond to stable atmospheric conditions. Very large positive or negative L values correspond to neutral atmospheric conditions.

Figure 4.5 illustrates the diurnal variation of atmospheric stability, derived from the Monin-Obukhov length calculated by CALMET, extracted at the Cabramurra Airstrip station. The diurnal profile shows that atmospheric instability increases during the daylight hours as the sun generated convective energy increases, whereas stable atmospheric conditions prevail during the night-time. This profile indicates that the potential for effective atmospheric dispersion of emissions would be greatest during daytime hours and lowest during evening through to early morning hours.

Mixing depth refers to the height of the atmosphere above ground level within which the dispersion of air pollution can be dispersed. The mixing depth of the atmosphere is influenced by mechanical (associated with wind speed) and thermal (associated with solar radiation) turbulence. Similar to the Monin-Obukhov length analysis above, higher daytime wind speeds and the onset of incoming solar radiation increases the amount of mechanical and convective turbulence in the atmosphere. As turbulence increases, so too does the depth of the boundary layer, generally contributing to higher mixing depths and greater potential for the atmospheric dispersion of pollutants.

Figure 4.6 presents the hourly-varying atmospheric boundary layer depths generated by CALMET. Greater boundary layer depths occur during the daytime hours, peaking in the mid to late afternoon.

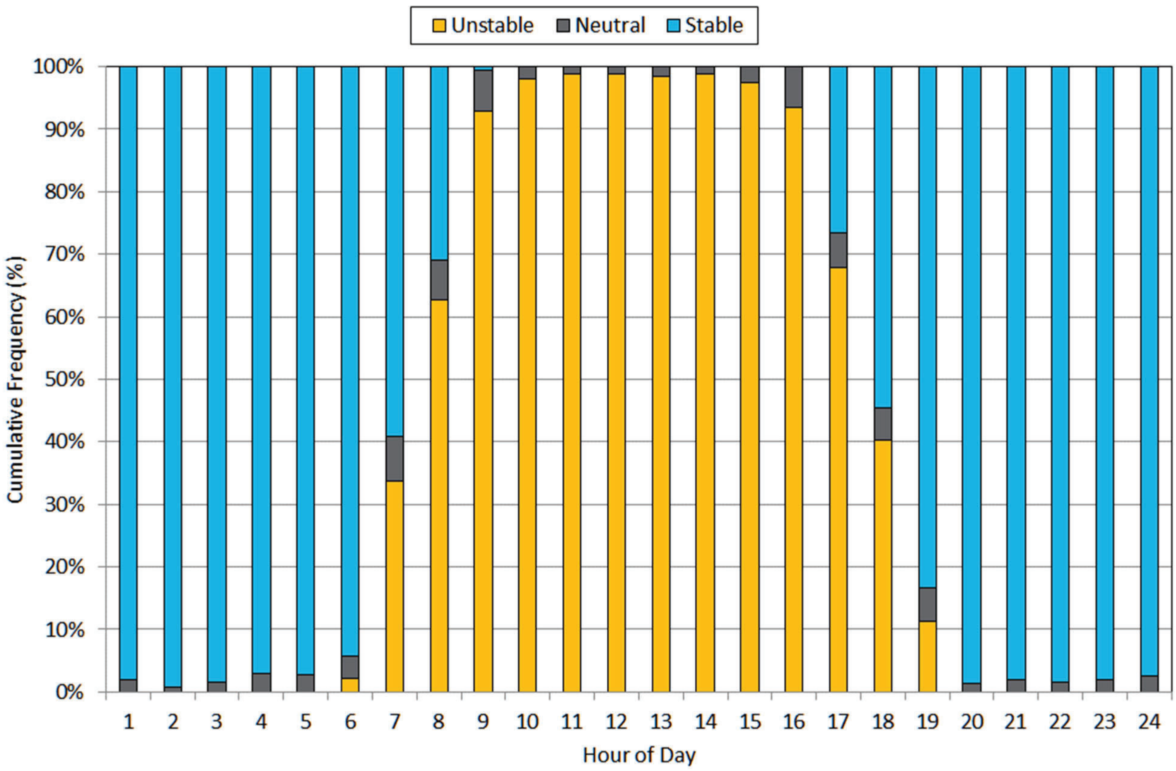


Figure 4.5 CALMET-calculated diurnal variation in atmospheric stability – Cabramurra Airstrip 2017

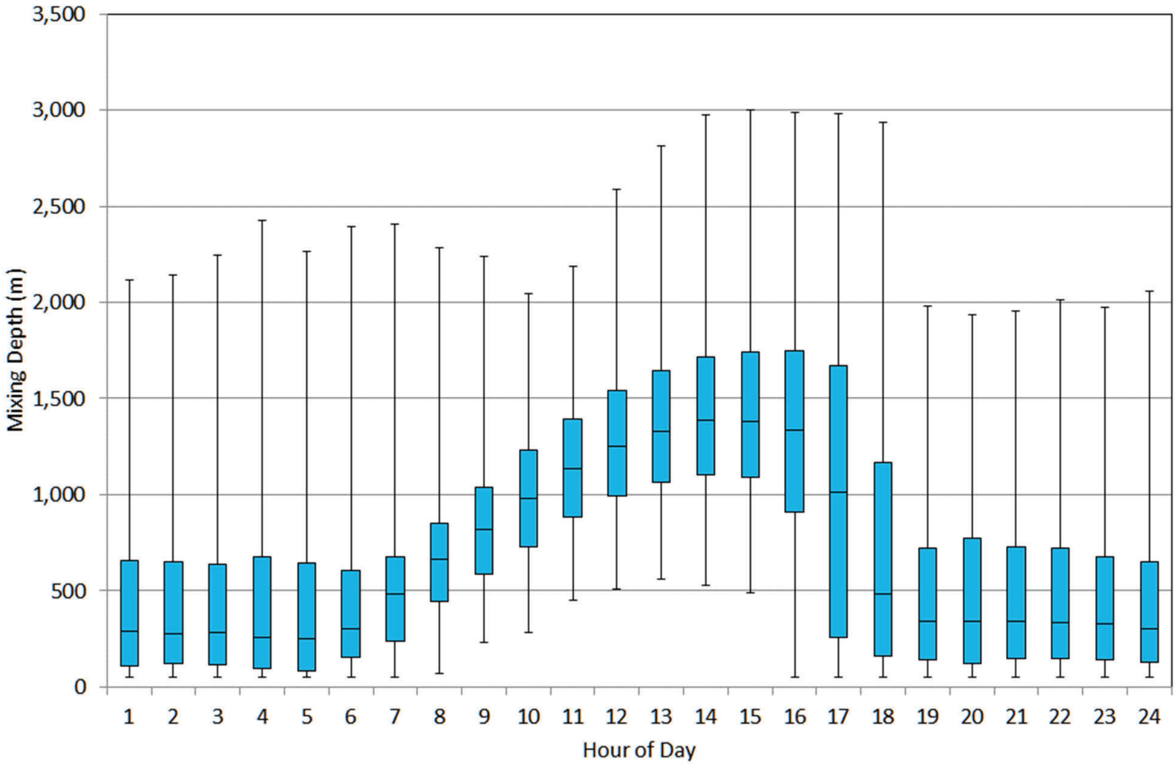


Figure 4.6 CALMET-calculated diurnal variation in atmospheric mixing depth – Cabramurra Airstrip 2017

5 Background air quality

5.1 Overview

When assessing the air quality impacts of a project against the criteria in the NSW Approved Methods for Modelling, the standard approach is to add the project's modelled contribution to the existing 'background' concentration. In theory, the background concentration represents the contribution from all sources other than the modelled project. It typically includes, for example, contributions from natural sources and domestic activity.

The Approved Methods for Modelling states the following:

> 'Including background concentrations of pollutants in the assessment enables the total impact of the proposal (i.e. impact of emissions on existing air quality) to be assessed. The background concentrations of air pollutants are ideally obtained from ambient monitoring data collected at the proposed site. As this is extremely rare, data is typically obtained from a monitoring site as close as possible to the proposed location where the sources of air pollution resemble the existing sources at the proposal site.' (NSW EPA 2016)

The concentrations of some air pollutants, including PM_{10}, $PM_{2.5}$ and NO_2, vary significantly in time. In the case of particulate matter, events such as dust storms, natural bush fires and planned burning activities are often associated with high concentrations. This temporal variation should be captured where possible in the definition of the background.

It is also important that the same year is used for the background air quality data and the meteorological data used in the dispersion modelling, given the strong influence of the latter on the former. For this assessment, the selected year for the meteorological data and modelling was 2017 (see Section 4).

The approaches used to determine long-term and short-term background concentrations for PM_{10}, $PM_{2.5}$ and NO_2 in this assessment are explained below. The implications of the selection of 2017 with respect to background air quality for the Snowy 2.0 Main Works are also discussed.

5.2 Existing sources of emissions

Airborne particulate matter is a complex mixture of substances that are derived from a range of sources and processes. The contributions of these sources and processes, and hence the physical and chemical properties of particulate matter, vary according to many factors including location, season, time of day, and both local and regional weather conditions.

The National Pollutant Inventory (NPI) and NSW EPA environment protection licence databases have been reviewed to identify significant existing sources of air pollutants in the vicinity of the project area. No significant reporting sources were identified.

In the absence of significant industrial sources, the primary contributing sources of air pollutant emissions to baseline air quality in the vicinity of the project area include:

- dust entrainment due to vehicle movements along unpaved and paved town and rural roads with high silt loadings;
- fuel combustion-related emissions from on-road and non-road engines;
- wind generated dust from exposed areas within the surrounding region;

- seasonal emissions from household wood burning; and
- episodic emissions from vegetation fires.

More remote sources which contribute episodically to suspended particulates in the region include dust storms and bushfires. It is considered that all of the above emission sources are accounted for in the monitoring data analysed in the following sections of this report.

5.3 Air quality monitoring data resources

There are no current air quality measurements available for the project area. The closest government monitoring stations to the Snowy 2.0 Main Works are located in the Australian Capital Territory (ACT), between approximately 60 km and 75 km to the northeast of the Tantangara Reservoir compound and 75 km to 95 km east-northeast of the Lobs Hole compound. Three air quality monitoring stations (Civic, Florey and Monash) are operated by ACT Environment Protection Authority for compliance with the AAQ NEPM and are illustrated in in Figure 5.1.

While spatially remote from the project area, it is considered that the ACT monitoring stations are considered to provide the most representative publicly available source of monitoring data to quantify background air quality at the project area. Discussion of recorded concentrations at the ACT monitoring stations is presented in Section 5.4.

Other monitoring datasets considered included a $PM_{2.5}$ monitoring station within the project area at Yarrangobilly and NSW Office of Environment and Heritage (OEH) monitoring stations at Wagga Wagga North and Albury.

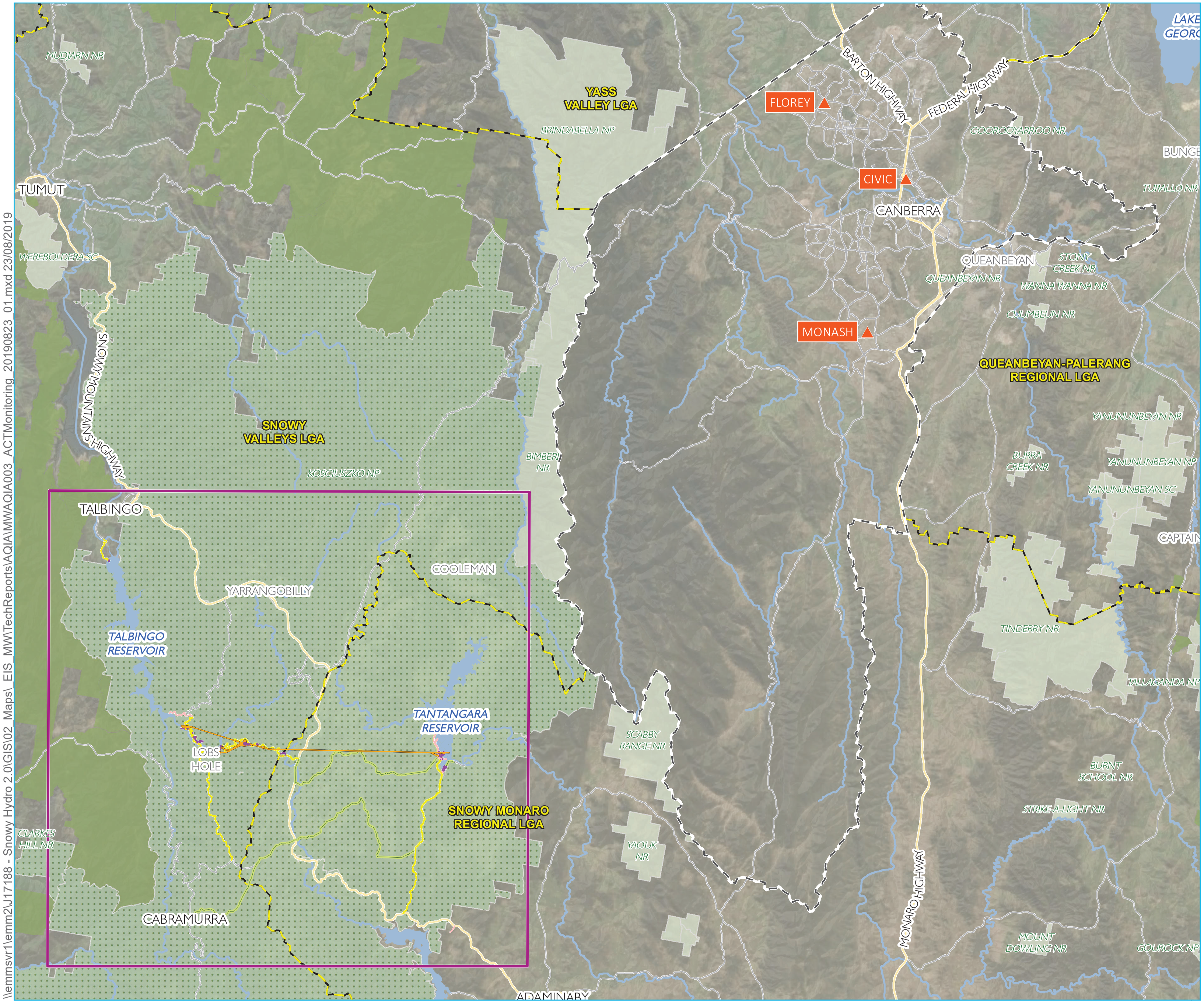
Long term monitoring of $PM_{2.5}$ was conducted by Australian Nuclear Science and Technology Organisation (ANSTO) at a single location in the Snowy Mountains, as reported by Tadros et al. (2018). The monitoring was conducted between 2013 and 2017 at a location above Jillabenan Cave within the Yarrangobilly Caves system in the northern part of KNP, approximately 10 km northeast of Lobs Hole and approximately 15 km west-northwest of Tantangara Reservoir. The sampler was installed at an altitude of 1,059 m above sea level. While this station is located within the project area, 24-hour average $PM_{2.5}$ concentrations were only recorded two days per week, and therefore the dataset does not completely meet the requirements of the Approved Methods for Modelling. Furthermore, PM_{10} concentrations were not measured at the location. Data from this station is referenced for comparison against the ACT monitoring datasets.

The NSW OEH monitoring stations at Wagga Wagga North (approximately 120 km northwest of Lobs Hole) and Albury (approximately 130 km west-southwest of Lobs Hole) were also considered. Both sites are further away from and are located at a much lower altitude (approximately 600 m AHD for the ACT stations compared with approximately 180 m AHD for the OEH stations) than the project area relative to the ACT stations. Based on Köppen climate classification maps provided by the BoM[3], the climate classification of the project area (temperate/no dry season/mild summer) is more comparable to that of the ACT monitoring stations (temperate/no dry season/warm summer) than the NSW OEH stations (temperate/no dry season/hot summer). Finally, the NSW OEH stations are located to the west of the Great Dividing Range, where there can be an influence on air pollution from emission sources that are not relevant to the project area such as extensive agricultural activities. For example, at Wagga Wagga particle levels[4] are impacted by wide-scale agricultural activities (including stubble burning) during the cooler months (NSW OEH 2018).

For these reasons, the NSW OEH monitoring stations at Wagga Wagga North and Albury were not considered further in this AQIA.

3 http://www.bom.gov.au/jsp/ncc/climate_averages/climate-classifications/index.jsp

4 During 2017 the highest daily PM_{10} concentration recorded at Wagga Wagga was 171.6 µg/m^3. This was probably due to widespread agricultural burning (OEH 2017).



Source: EMM (2019); Snowy Hydro (2019); DFSI (2017); LPMA (2011)

Locations of ACT air quality monitoring stations - regional context

Snowy 2.0
Air Quality Impact Assessment
Main Works
Figure 5.1

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5.4 Recorded concentrations

The measurements of PM_{10}, $PM_{2.5}$ and NO_2 at the three ACT stations between 1 January 2014 and 31 December 2018 were considered in the assessment, with the data being obtained from the ACT Government web site[5]. As noted in Section 3.3, the impact assessment criteria for PM_{10} and $PM_{2.5}$ are stated in terms of annual average and 24-hour average concentrations, whereas those for NO_2 are stated in terms of annual average and 1-hour average concentrations.

The time series of 24-hour average PM_{10} and $PM_{2.5}$ concentrations are shown in Figure 5.2 and Figure 5.3 respectively. In the case of PM_{10} the figure contains an inset to show that some particularly elevated concentrations were recorded on 16 December 2018. Figure 5.4 shows the time series for maximum daily 1-hour average NO_2 concentrations. It should be noted that the measurement of NO_2 at the Civic station ceased in February 2014.

The temporal patterns in the PM_{10} and $PM_{2.5}$ monitoring data are shown in Annexure C. Some basic statistics for PM_{10} and $PM_{2.5}$ at the three stations are also presented in Table 5.1, and statistics for NO_2 are given in Table 5.2.

5 https://www.data.act.gov.au/Environment/Air-Quality-Monitoring-Data/94a5-zqnn

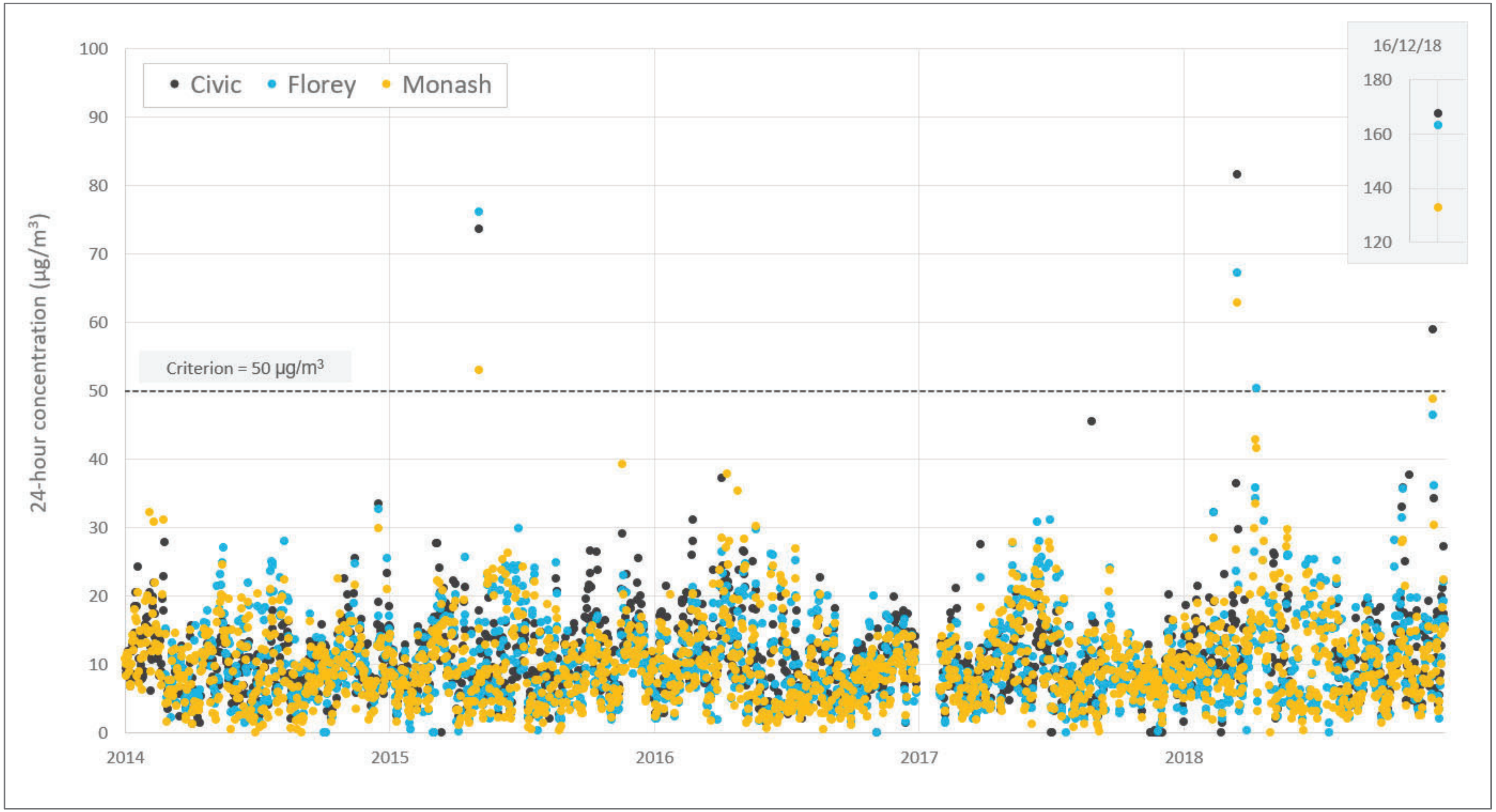


Figure 5.2 Time series of 24-hour average PM_{10} concentrations at ACT stations

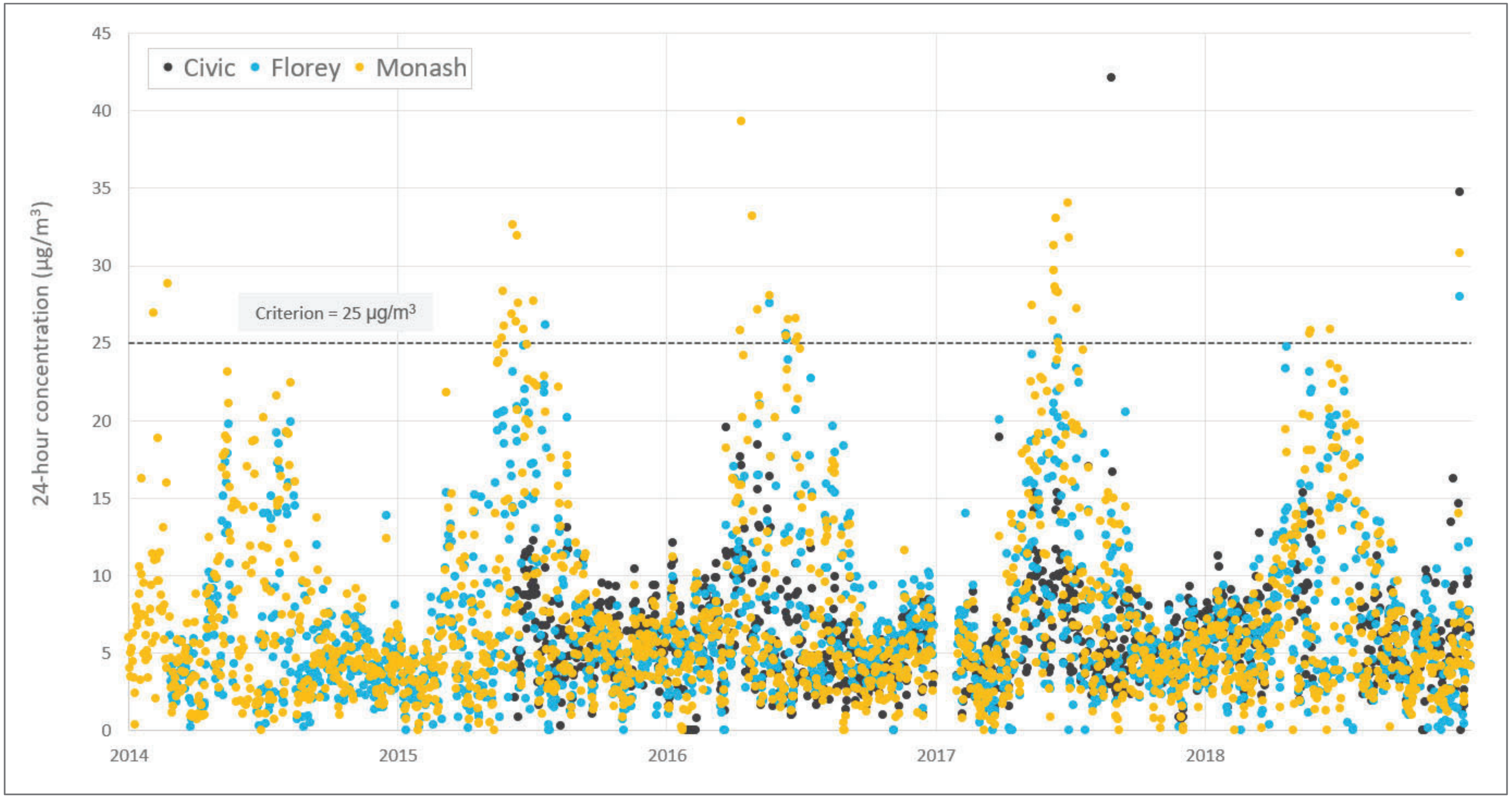


Figure 5.3 Time series of 24-hour average $PM_{2.5}$ concentrations at ACT stations

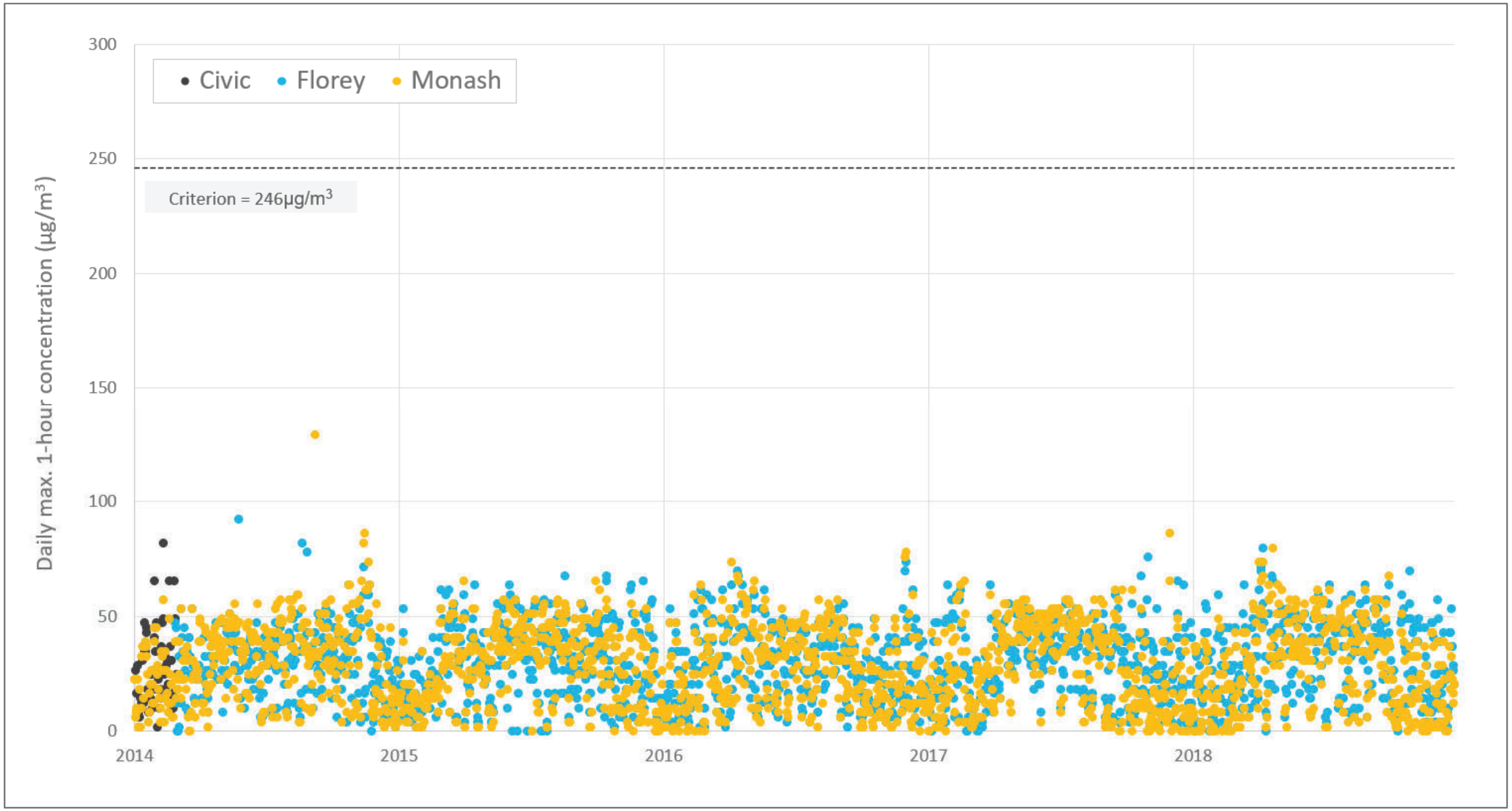


Figure 5.4 **Time series of maximum daily 1-hour average NO_2 concentrations at ACT stations**

Table 5.1 Summary of PM_{10} and $PM_{2.5}$ measurements at ACT stations

Statistic	Year	PM_{10} (µg/m³)			$PM_{2.5}$ (µg/m³)		
		Civic	Florey	Monash	Civic	Florey	Monash
Average	2014	10.0	10.0	9.8	-[(a)]	-	6.5
	2015	11.1	10.3	9.8	-	6.4	7.1
	2016	10.7	10.0	9.8	5.3	7.0	7.0
	2017	9.0	9.8	9.8	5.8	7.0	7.8
	2018	13.0	11.9	11.7	6.0	6.9	6.8
	Average 2014–2017	10.2	10.0	9.8	5.6	6.8	7.1
Max. 24h	2014	33.5	32.6	32.2	-	-	28.8
	2015	73.6	76.2	53.1	-	26.2	32.6
	2016	37.3	29.8	37.9	19.6	27.6	39.3
	2017	45.6	31.2	27.9	42.1	25.3	34.0
	2018	167.3	163.0	132.9	34.7	28.0	30.8
	Average 2014–2017	47.5	42.4	37.8	30.9	26.4	33.7

a) a dash indicates where data availability was less than 75% for the year.

Table 5.2 Summary of NO_2 measurements at ACT stations

Statistic	Year	NO_2 (µg/m³)	
		Florey	Monash
Average	2014	9.7	9.7
	2015	9.9	8.8
	2016	9.6	8.2
	2017	10.2	9.2
	2018	9.5	8.1
	Average 2014–2018	9.8	8.8
Max. 1h	2014	92.4	129.3
	2015	67.7	65.7
	2016	73.9	78.0
	2017	75.9	86.2
	2018	80.0	80.0
	Average 2014–2018	78.0	87.8

The following observations have been made:

- The figures show that, for both PM_{10} and $PM_{2.5}$, there was very little variation in the average concentration by hour of the day, and little variation by day of the week. On the other hand, there was a seasonal influence on concentrations. PM_{10} concentrations were typically highest in autumn, whereas $PM_{2.5}$ generally peaked in winter.

- The Civic station generally had higher PM_{10} concentrations but lower $PM_{2.5}$ concentrations than the Florey and Monash stations. $PM_{2.5}$ at Florey and Monash was especially high compared with Civic during winter. This is attributed to the difference in setting of the Civic station (Canberra CBD) compared with the Florey and Monash stations (residential) and the influence of domestic wood heater emissions. It is noted that ACT Health commissioned a study in 2009 (Bridgman 2009) investigating the air quality of the Tuggeranong Valley (within which the Monash station is located). This report found that domestic wood heating during winter months significantly influenced particulate matter concentrations experienced in the area.

- For PM_{10}, annual mean concentrations in 2018 were markedly higher than, and in some cases significantly[6] different from, those in previous years. Maximum 24-hour concentrations in 2018 were much higher than those in previous years. The increase in PM_{10} concentrations in 2018 is probably linked to the extensive drought conditions across NSW during the year.

- For $PM_{2.5}$, the differences between 2018 and the other years were less pronounced. In terms of annual mean concentrations, the result for Civic in 2018 was higher than, and significantly different from, the results for previous years. However, at Florey the annual mean in 2018 was lower than, but not significantly different from, the means in 2016 and 2017. At Monash the annual mean $PM_{2.5}$ concentration in 2018 was lower than in most other years. For maximum 24-hour $PM_{2.5}$ concentrations, the results for 2018 were broadly representative of those for previous years, notwithstanding that the values for the Civic station were quite variable from year to year.

- For NO_2 the annual mean concentrations at the Florey and Monash stations varied little from year to year and were well below the impact assessment criterion of 30 µg/m^3. Maximum 1-hour concentrations were also well below the impact assessment criterion of 246 µg/m^3.

Based on the analysis undertaken, it was considered that the concentrations in 2017 were representative of concentrations in previous years, and therefore suitable for use in the air quality assessment. Table 5.2 shows average values for the period 2014–2017. PM_{10} concentrations in 2017 were similar to, or lower than, the four-year average, whereas $PM_{2.5}$ concentrations in 2017 were similar to or higher than the four-year average. Annual average and maximum 1-hour concentrations of NO_2 in 2017 were representative of the longer-term average.

Due to the difference in setting between the ACT stations (urbanised area) and the project area (largely untouched natural environment), it is considered that the concentrations measured at the ACT stations are likely to be a conservative representation of existing air quality levels at the project area.

6 A multiple comparison test (Student-Newman-Keuls - SNK) was used to test the differences between the annual mean PM_{10} concentrations in different yeas. For the Monash station the SNK test showed that the mean PM_{10} concentration in 2018 was significantly different from the mean concentrations in all other years. For the Florey station the means in 2015 and 2018 were significantly different from those in the other years. For the Civic station, where PM_{10} was more variable, the annual mean concentrations in all years were significantly different.

For additional context, the measurements in the Snowy Mountains by Tadros et al. (2018) showed a four-year average $PM_{2.5}$ concentration of 3.3 µg/m^3. Although the comparison is not a direct one, this is substantially lower than the long-term average concentration at the ACT station (5.6–7.1 µg/m^3) and reflects the remoteness of the Snowy Mountains station. The highest 24-hour concentration at the Snowy Mountains station was, on the other hand, relatively high (70.2 µg/m^3) compared with the highest value at any of the ACT stations (42.1 µg/m^3). However, it is likely that this was the consequence of an exceptional event (bushfire), and overall the measurements were less variable than at the ACT stations. For example, the standard deviation of the Snowy Mountains $PM_{2.5}$ measurements was 2.5 µg/m^3, compared with 4.8 µg/m^3 at Florey and 5.8 µg/m^3 at Monash.

It is therefore considered, based on the analysis above, that the use of ACT Government air quality monitoring data is appropriate for representing ambient air quality conditions at the project site.

5.5 Assumed background concentrations

5.5.1 PM_{10} and $PM_{2.5}$

As noted in the previous section, the data from the ACT stations in 2017 were used to define background concentrations of PM_{10} and $PM_{2.5}$ for the assessment.

For each pollutant, a 'synthetic profile' of background concentrations was defined using the data from the three ACT stations. This took the form of a time series of 24-hour average concentrations during 2017. For each day of 2017, the value in the synthetic profile was taken to be the *average* value across the three ACT stations. Some gap filling was required for January 2017, as there were no data for the three stations. The values for each day in this month were defined as a mean for the corresponding day between 2014 and 2016.

The synthetic profiles for PM_{10} and $PM_{2.5}$ are shown in

Figure 5.5 and Figure 5.6 respectively. The corresponding 24-hour air quality criterion for each pollutant is also shown in each figure. In addition, some key summary statistics for the two profiles are presented in Table 5.3.

Concentrations of PM_{10} and $PM_{2.5}$ in the synthetic background datasets developed are below the applicable impact assessment criterion throughout the 2017 calendar year. For the $PM_{2.5}$ dataset, concentrations are elevated (greater than 20 µg/m^3) during mid-June and in September. The elevated concentrations in June are associated with the influence of domestic wood heater emissions, while the September peak was coincident with extensive hazard reduction burns across NSW.

5.5.2 NO_2

To convert predicted concentrations of NO_x to NO_2, the ozone limiting method (OLM) prescribed in Section 8.1.2 of the NSW EPA Approved Methods for Modelling (EPA, 2016) has been applied. While further detail relating to this approach is presented in Section 7.2, the OLM requires background concentrations of NO_2 and ozone (O_3).

Similar to the approach undertaken for PM_{10} and $PM_{2.5}$, a 'synthetic profile' of background concentrations was defined using the data from the ACT air quality monitoring stations. For each hour of 2017, the value in the synthetic profile was taken to be the *average* value across the ACT stations (two for NO_2 and three for O_3).

The synthetic profiles for NO_2 and O_3 are shown in Figure 5.7 and Figure 5.8 respectively. The corresponding 1-hour air quality criterion is also shown in each figure. In addition, some key summary statistics for the two profiles are presented in Table 5.4.

It can be seen from these figures that the recorded concentrations of NO_2 and O_3 were well below applicable NSW EPA impact assessment criteria throughout 2017.

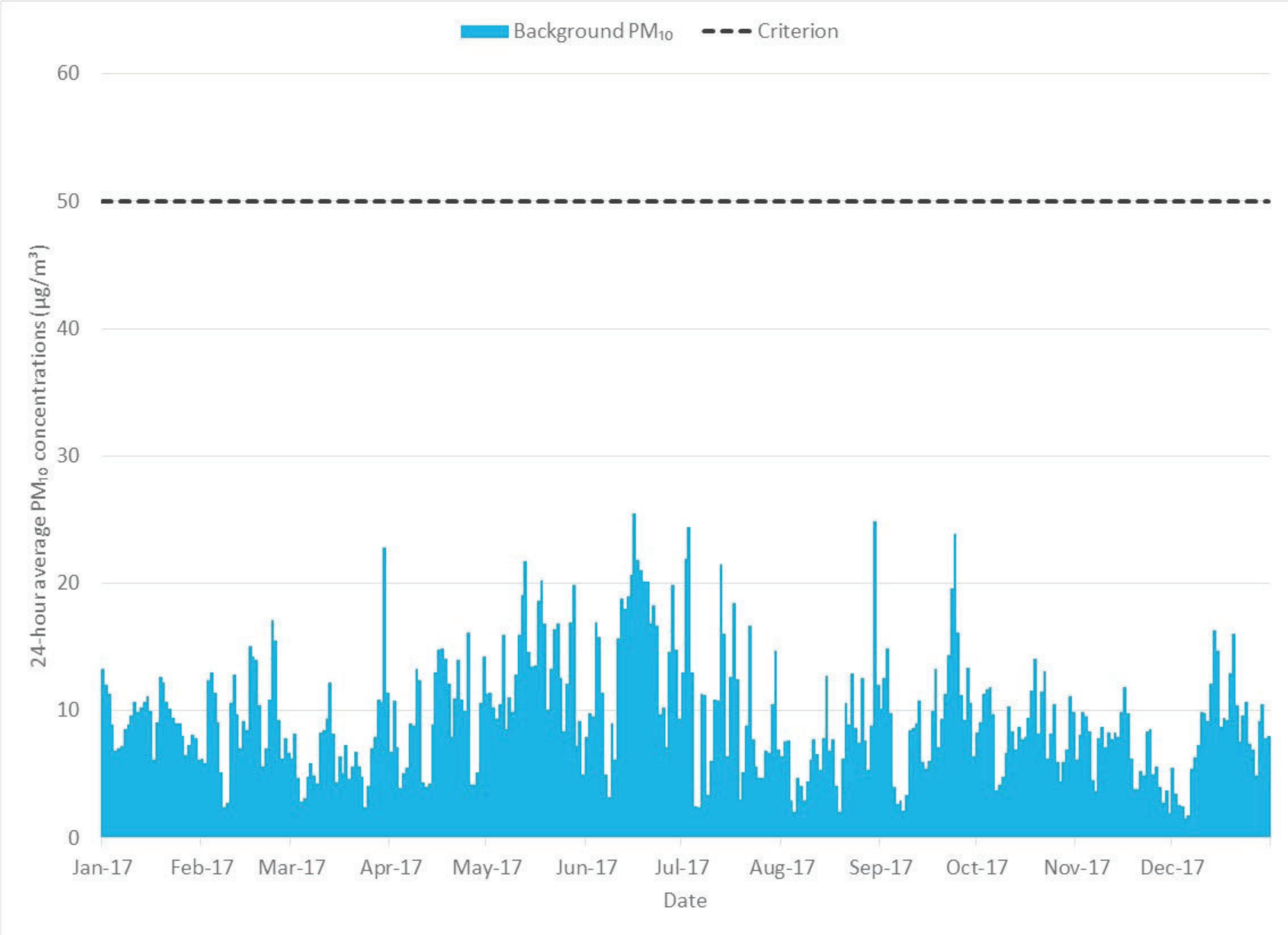


Figure 5.5 Synthetic background profile for PM10

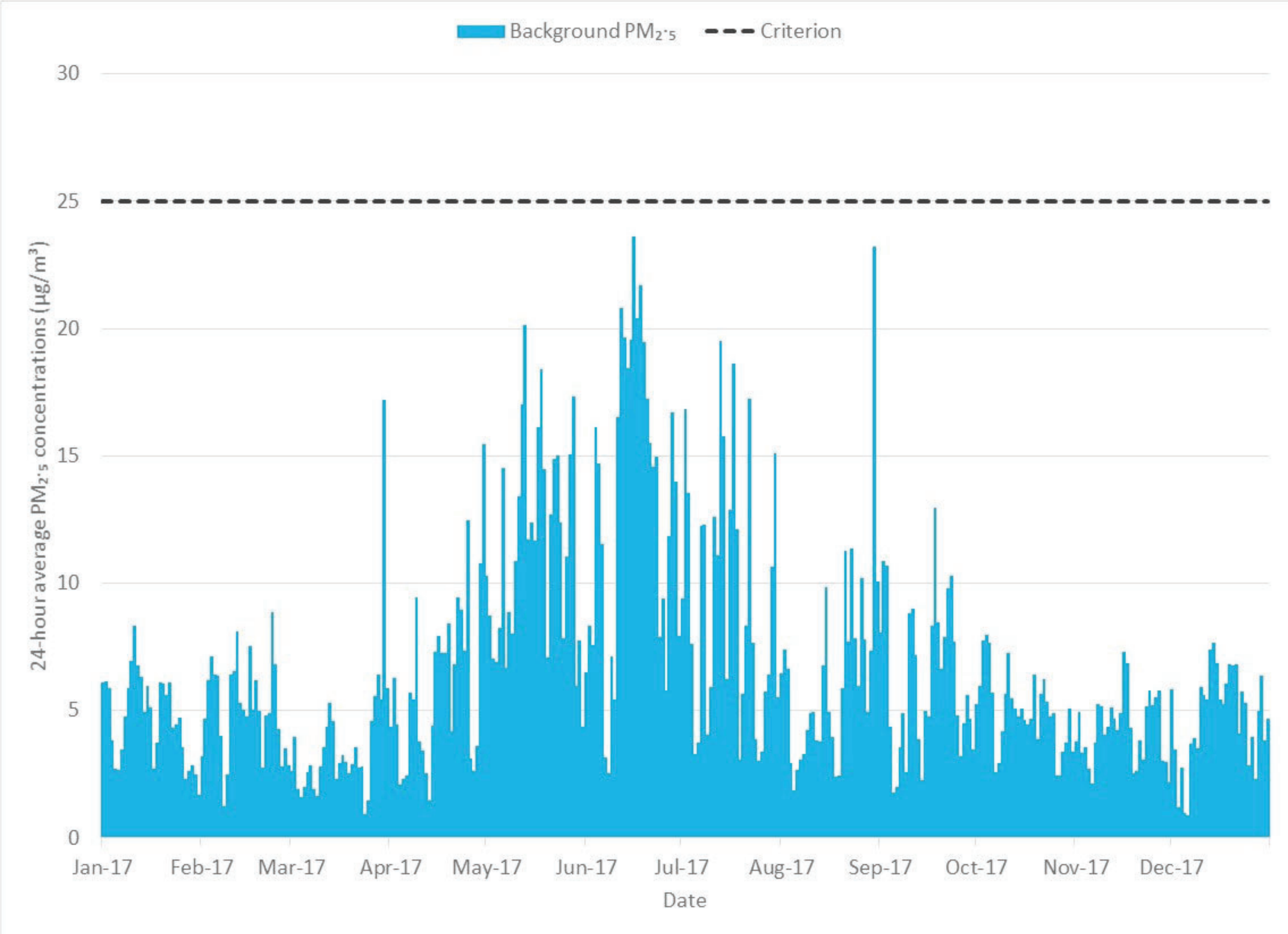


Figure 5.6 Synthetic background profile for $PM_{2.5}$

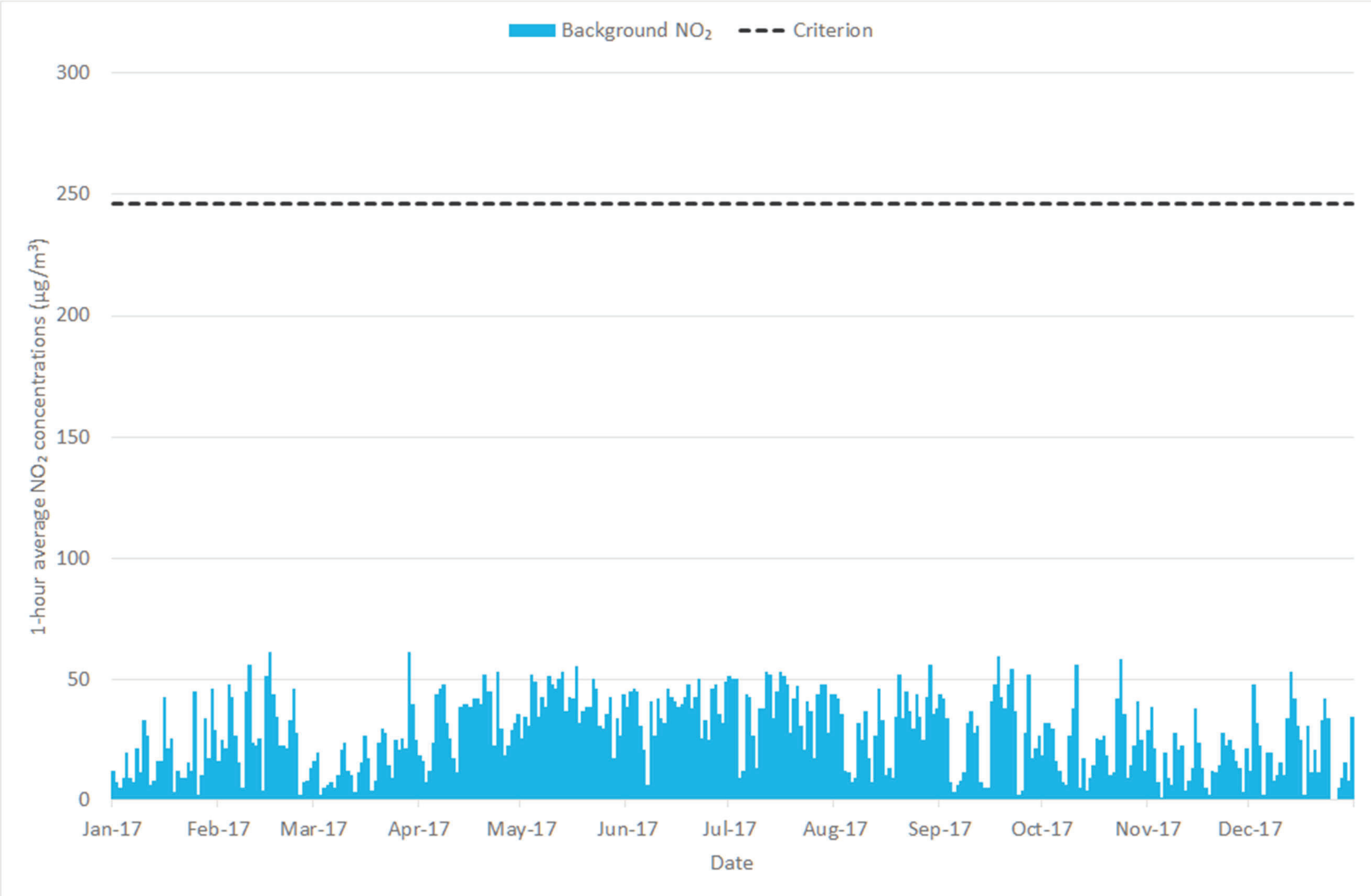


Figure 5.7 Synthetic background profile for NO_2

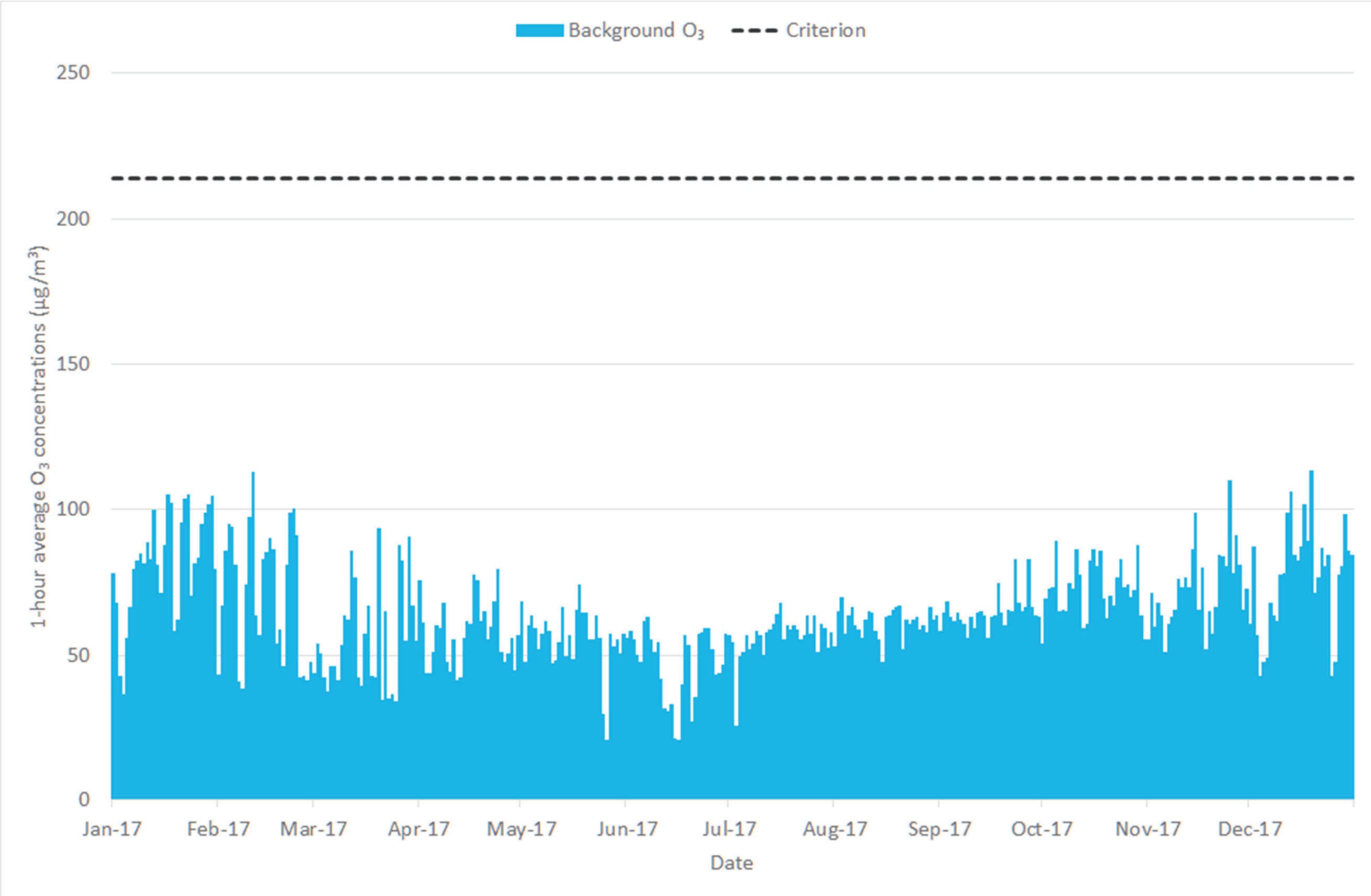


Figure 5.8 Synthetic background profile for O_3

Table 5.3 Summary statistics for synthetic profiles

Statistic	24-hour average concentration (µg/m³)	
	PM_{10}	$PM_{2.5}$
Maximum	25.4	23.6
2nd highest	24.9	23.2
3rd highest	24.4	21.7
99th percentile	23.2	20.5
98th percentile	21.6	19.6
90th percentile	16.0	13.5
75th percentile	11.9	7.9
Median	8.9	5.5
Mean	9.5	6.7
Days with PM_{10} >50 µg/m³	0	-
Days with $PM_{2.5}$ >25 µg/m³	-	0

Table 5.4 Summary statistics for synthetic profiles – NO_2 and O_3

Statistic	1-hour average concentration (µg/m³)	
	NO_2	O_3
Maximum	61.6	113.7
2nd highest	61.6	113.1
3rd highest	59.5	110.2
99th percentile	47.2	92.8
98th percentile	43.1	86.0
90th percentile	27.7	65.9
75th percentile	15.4	54.7
Median	5.1	39.5
Mean	9.9	38.5

6 Emissions inventory

6.1 Sources of emissions

Sources of atmospheric emissions associated with the construction phase of the Snowy 2.0 Main Works include the following:

- vegetation clearing;
- topsoil removal;
- general surface earthworks (road upgrades, construction compound preparation, intakes excavations, etc);
- tunnel excavation (drill and blast, tunnel boring machine);
- conveyors transferring spoil to the surface;
- loading spoil to trucks;
- trucks unloading spoil to spoil disposal areas;
- dozers working on spoil storage piles and storage areas;
- concrete batching plant operations;
- the movement of trucks on unpaved and paved roads;
- wind erosion from spoil storage areas;
- rehabilitation works; and
- diesel combustion from plant equipment, trucks and electricity generators.

These activities are accounted for in the assessment scenario for the Snowy 2.0 Main Works.

6.2 Emissions scenario

In order to quantify peak air pollution emissions and associated impacts in the surrounding environment from the Snowy 2.0 Main Works construction phase, a worst-case construction emissions scenario has been configured. The worst-case construction emissions scenario corresponds to the largest projected 12-month period of truck movements (tunnel spoil transportation, raw material delivery, etc) over the duration of the Snowy 2.0 Main Works construction phase, specially between month 6 and month 17 of the projected traffic movement schedule. The movement of trucks along unpaved road surfaces is the most significant source of emissions, both with respect to magnitude of emissions generated and the spatial extent of emission release.

The emissions sources listed in Section 6 have been incorporated into the worst-case construction emissions scenario with the exception of the following:

- vegetation clearing;
- topsoil removal;

- general surface earthworks (road upgrades, construction compound preparation, intake excavations, etc);
- tunnel excavation (drill and blast, tunnel boring machine), excluding the conveying and handling of tunnel spoil at various portal locations; and
- rehabilitation works.

These emission sources are unlikely to coincide with the peak 12-month period of traffic movements that has been quantified. Furthermore, the emissions from these activities are considered to be either minor (eg vegetation clearing) or a short-term release (eg open air drilling and blasting) relative to the handling and transportation of tunnel spoil. Therefore, it is considered that the emissions scenario quantified is appropriately conservative to account for any impacts from the excluded sources.

6.3 Material movements

Spoil tonnages for a worst-case year of construction activities were estimated based on the projected spoil truck movements during the construction phase of the Snowy 2.0 Main Works. All other heavy and light vehicles, associated with the transportation of raw materials and workers, were also accounted for in the emissions inventory relating to wheel-generated dust and combustion emissions.

The tonnes of spoil moved along each transport route is shown in Figure 6.1. It is estimated that the majority of spoil will be moved along Lobs Hole Road and a large portion along Tantangara Road. It is noted that spoil will also be transported from the HRT portal along the Snowy Mountains Highway, linking onto Tantangara Road. Spoil transported along the Snowy Mountains Highway has not been included in the emissions estimation as this road is an existing paved, public road and is anticipated to have minor wheel-generated dust emissions compared to the other road sources assessed.

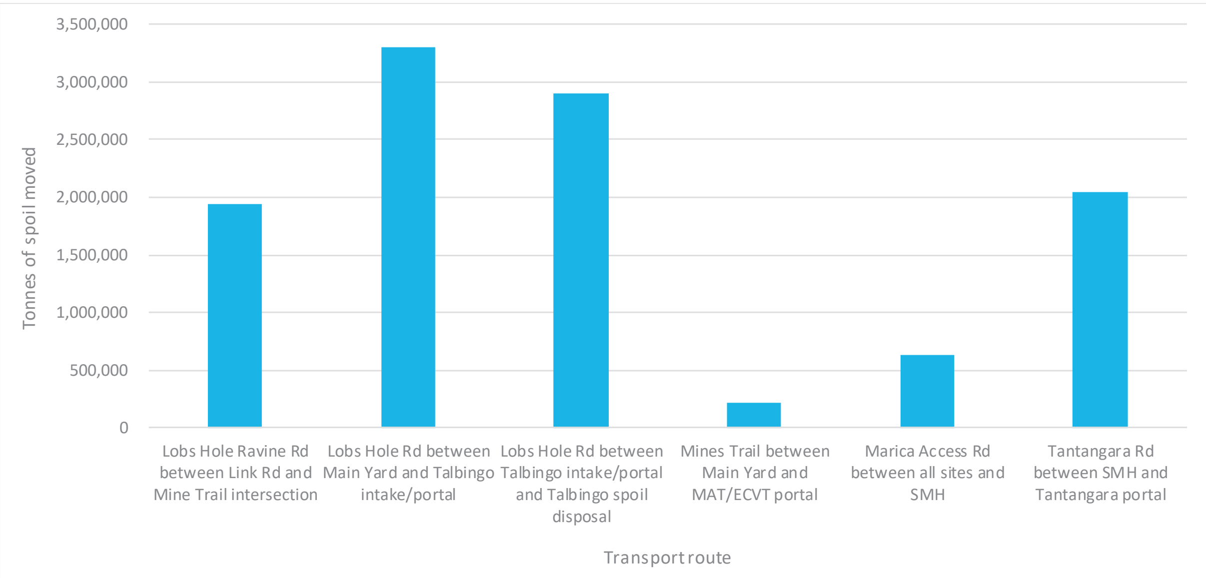


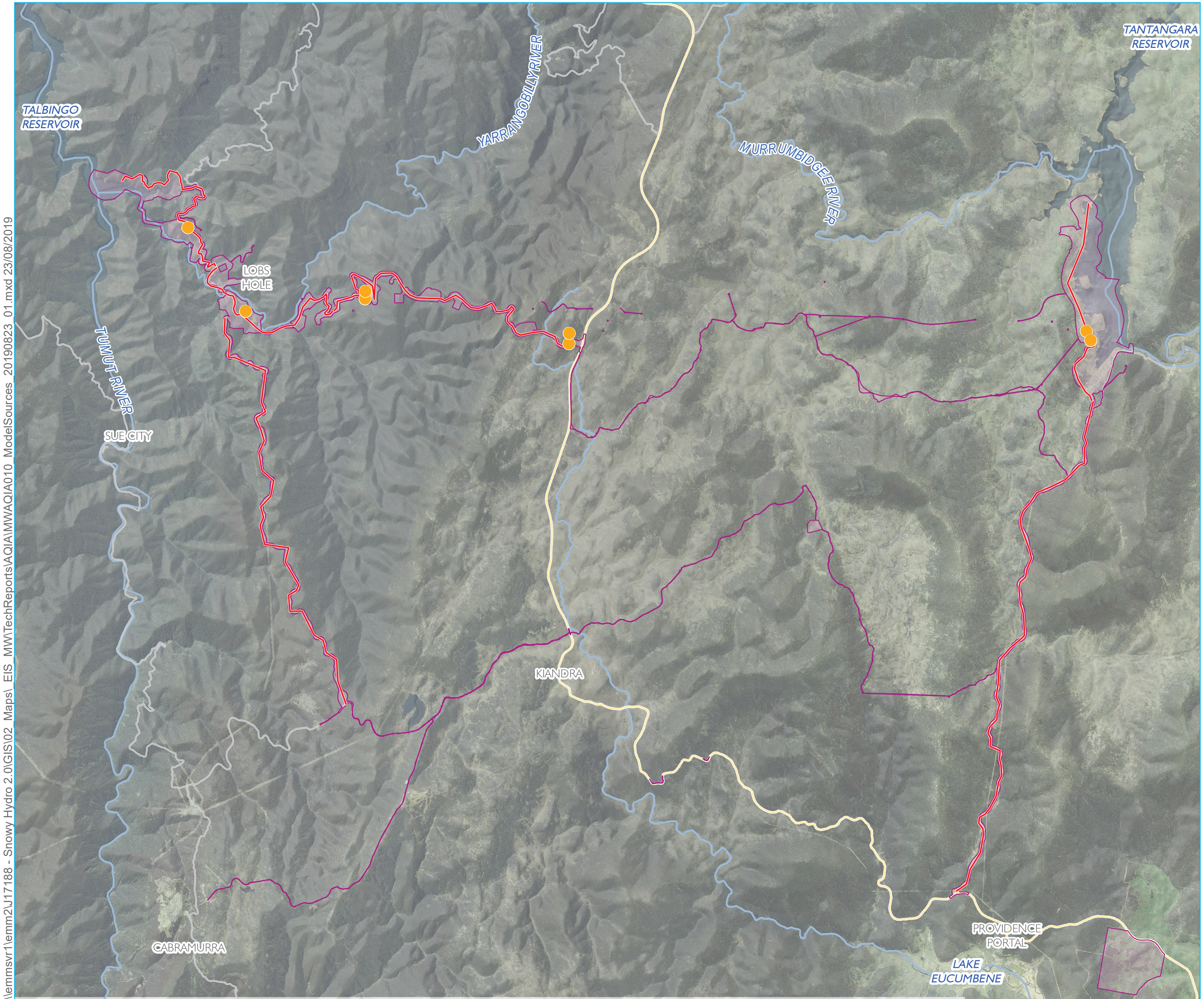
Figure 6.1 Maximum projected spoil moved during construction (t/y)

6.4 Emissions estimates

Fugitive dust sources associated with the Snowy 2.0 Main Works construction were quantified through the application of US-EPA AP-42 emission factor equations. Particulate matter emissions were quantified for the three size fractions identified in Section 3, with the TSP fraction also used to provide an indication of dust deposition rates. Emission rates for coarse particles (PM_{10}) and fine particles ($PM_{2.5}$) were estimated using ratios for the different particle size fractions available in the literature (principally the US-EPA AP-42).

Emissions from fuel combustion (diesel) were estimated using the provided maximum diesel usage and the NPI Emissions Estimation Technique Manual for Combustion Engines (NPI 2008). Emissions for diesel were apportioned across the site according to material handling and transportation activity rates.

A detailed description of the assumptions and emission factors adopted in the development of the construction phase emissions inventory are provided in Annexure D. The modelled source locations are shown in Figure 6.2.



KEY

Model source type

- Volume source
- Line volume source

Existing environment

- Main road
- Local road
- Watercourse

Disturbance area

Source: EMM (2019); Snowy Hydro (2019); DFSI (2017); LPMA (2011)

\\emmsvr1\emm2\J17188 - Snowy Hydro 2.0\GIS\02_Maps_EIS_MW\TechReports\AQIA\MWAQIA010_ModelSources_20190823_01.mxd 23/08/2019

Model source locations

Snowy 2.0
Air Quality Impact Assessment
Main Works
Figure 6.2

6.4.1 Emissions summary

As stated, worst-case annual construction emissions by source type were estimated for the 12-month period corresponding to peak projected traffic movements.

A graphical summary of the contribution to annual construction dust emissions by source type for the worst-case construction year is provided in Figure 6.3. Calculated annual emissions by emissions source is presented in Table 6.1. Particulate matter control measures, as documented in Section 6.5, are accounted for in these emission totals.

From the data presented in Figure 6.3 and Table 6.1, the most significant source of particulate matter emissions from the Snowy 2.0 Main Works construction phase is associated with the movement of vehicles across unpaved road surfaces. The unpaved roads segments with the largest estimated emissions are Lobs Hole Ravine Road and Tantangara Road.

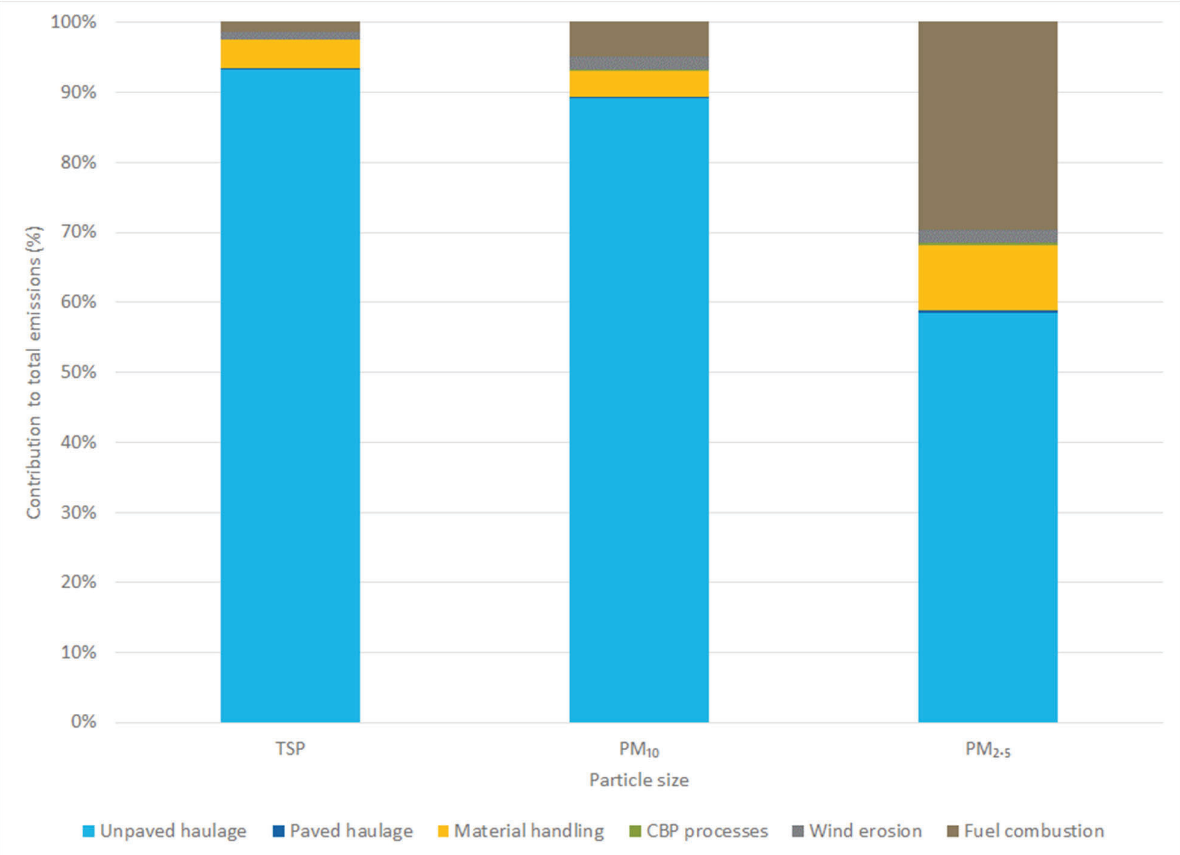


Figure 6.3 Contribution to annual emissions by emissions source type and particle size

A summary of the annual emissions for NO_x, associated with the combustion of diesel by mobile plant, trucks and diesel generators, is presented in Table 6.2.

Further details regarding emission estimation factors and assumptions are provided in Annexure D.

Table 6.1 Calculated annual TSP, PM_{10} and $PM_{2.5}$ emissions – worst-case construction scenario

Emission source	Calculated annual emissions (kg/annum) by source		
	TSP	PM_{10}	$PM_{2.5}$
Tunnel spoil handling			
Conveyer transferring spoil from Talbingo portal to surface	594	281	43
Loading spoil from conveyor to trucks - Talbingo portal	5,652	2,673	405
Unloading spoil from trucks to Talbingo spoil disposal	8,983	4,249	643
Dozer working on spoil - Talbingo disposal	102,621	24,799	10,775
Conveyer transferring spoil from MAT/ECVT portals to surface	5,581	2,640	400
Loading spoil from conveyor to trucks - MAT/ECVT portals	5,581	2,640	400
Dozer working on spoil at MAT/ECVT portals	25,655	6,200	2,694
Conveyer transferring spoil from HRT portal to surface	428	202	31
Loading spoil from conveyor to trucks HRT portal	428	202	31
Unloading spoil from trucks to stockpile at SMH	428	202	31
Loading spoil from SMH stockpile to road trucks	428	202	31
Dozer working on spoil at SMH surge stockpile	25,655	6,200	2,694
Conveyer transferring spoil from Tantangara portal to surface	1,570	743	112
Loading spoil from Tantangara portal to trucks	2,058	973	147
Trucks unloading spoil at Tantangara portal	488	231	35
Trucks unloading spoil to Tantangara spoil disposal	2,058	973	147
Dozer working on spoil - Tantangara spoil disposal	102,621	24,799	10,775
All hauling activities			
Lobs Hole Ravine Road - between Link Road and Mine Trail intersection	3,659,828	987,997	98,800
Lobs Hole Road - between Main Yard and Talbingo intake/portal (paved)	7,761	1,490	360
Lobs Hole Road - between Main Yard and Talbingo intake/portal	141,729	38,261	3,826
Lobs Hole Road - between Talbingo intake/portal and Talbingo spoil disposal	441,956	119,309	11,931
Mines Trail - between Main Yard and MAT/ECVT portal	656,922	177,341	17,734
Marica Access Road - between HRT and SMH	104,703	28,265	2,827
Tantangara Road - between SMH and Tantangara portal (uncontrolled)	1,597,005	431,123	43,112
Tantangara Road - between SMH and Tantangara portal (paved)	1,519	291	71
Tantangara spoil access road	204,577	55,227	5,523

Table 6.1 Calculated annual TSP, PM_{10} and $PM_{2.5}$ emissions – worst-case construction scenario

Emission source	Calculated annual emissions (kg/annum) by source		
	TSP	PM_{10}	$PM_{2.5}$
Concrete batching			
Concrete batching plants – all sites	9,438	3,774	1,197
All wind erosion			
Wind erosion from Talbingo spoil area	18,615	9,308	1,396
Wind erosion from Marica portal spoil stockpile	850	425	64
Wind erosion from SMH spoil stockpile	850	425	64
Wind erosion from Tantangara spoil area	55,505	27,753	4,163
All diesel combustion			
Diesel combustion – all sources (trucks, electricity generation)	101,502	101,502	93,043
Total	**7,293,589**	**2,060,700**	**313,505**

Note: emission totals incorporate particulate matter management measures

Table 6.2 Calculated NO_x emissions – worst-case construction scenario

Emission source	Calculated NO_x annual emissions (kg/annum)
Diesel combustion (total site)	1,268,774

6.5 Management measures

In order to manage particulate matter emissions from the Snowy 2.0 Main Works construction phase, a range of mitigation measures and management practices are required. Proposed dust management measures include the following:

- dozer working areas will be watered;
- wind erosion from spoil disposal areas will be controlled through watering;
- unpaved roads within works areas will be watered using water carts;
- Lobs Hole Road will be sealed 1 km each side of the Lobs Hole accommodation camp; and
- Tantangara Road will be sealed 1 km each side of the Tantangara accommodation camp.

Further discussion relating to the management of wheel-generated dust emissions in the vicinity of the Lobs Hole and Tantangara accommodation camps is provided in Section 6.5.1.

To account for these emission management methods, the following particulate matter emission reduction factors have been applied in the emissions totals presented in Table 6.1:

- dozers - 50% reduction for watering of materials (NPI 2012 and Katestone 2011);
- unpaved roads wheel dust - 75% reduction for watering (NPI 2012); and
- paved roads – paved roads equation applied (US-EPA 2011).

6.5.1 Unpaved road emission management options

The presented emission calculations for the worst-case construction emissions scenario have established that the most significant source of particulate matter emissions is the movement of vehicles across unpaved road surfaces, in particular Lobs Hole Ravine Road and Tantangara Road.

It is noted that the Lobs Hole (R27) and Tantangara (R29) accommodation camps are located immediately adjacent to Lobs Hole Ravine Road and Tantangara Road respectively. Preliminary modelling was conducted assuming uncontrolled emissions from these road sources, with elevated concentrations predicted at the two accommodation camps. Consequently, the following three options for dust emission management in the vicinity of these locations were investigated:

- the application of watering only to the unpaved road surfaces;
- the application of dust polymer to the unpaved road surfaces; and
- sealing the unpaved road surfaces.

To understand the implications for dust emissions from the use of these three dust control methods, particulate matter emissions were quantified for each road extending 1 km either side of the two accommodation camps. The following emission control reduction factors were applied:

- application of watering to unpaved road surfaces - 75% reduction (NPI 2012);
- application of dust polymer to unpaved road surfaces – 84% reduction (Katestone 2011); and
- sealing the unpaved road surfaces - paved roads equation applied (US-EPA 2011).

It is noted that the dust control factors applied in this assessment are adopted from published emission control literature and are generic in nature. Particularly with regards to dust polymers, a higher emission reduction might be achieved depending on the selected product and site conditions. Nevertheless, the use of these generic factors is considered appropriate for the comparative review of unpaved road particulate matter emission management options.

The calculated emissions from each management option is presented in Table 6.3. The table shows that the paved roads option results in notably lower estimated emissions for these sections of road than the application of watering or dust polymers.

On the basis of these calculated results, the paved roads option was selected as the particulate matter mitigation measure to be applied in the vicinity of the Lobs Hole and Tantangara accommodation camps. This management measure is accounted for in the emissions estimates presented in Table 6.1 and the dispersion modelling conducted for the Snowy 2.0 Main Works construction phase (see Section 6.5).

Table 6.3 Estimated PM_{10} emissions using different mitigation options on roads at Lobs Hole and Tantangara accommodation camps

	Emission estimate PM_{10} (kg/year)		
Emission source	**Unpaved roads with watering**	**Unpaved road with dust polymers**	**Paved road**
Lobs Hole Road near Lobs Hole Accommodation Camp	47,826	30,609	1,490
Tantangara Road near Tantangara Accommodation Camp	14,034	8,982	1,166
Total	**61,860**	**39,590**	**2,656**

Note: emissions relate to the 1 km section of road either side of the entrance to the proposed Lobs Hole and Tantangara accommodation camps. Paved roads assume water flushing as required to maintain paved surface silt loading.

7 Air dispersion modelling

7.1 Dispersion model selection and configuration

Dispersion modelling for this assessment uses the CALPUFF modelling system, which is commonly used in NSW for applications where non-steady state conditions may occur (ie complex terrain or coastal locations) or when calm wind conditions are important (ie for odour assessment). In the absence of available upper air measurements, CALMET (the meteorological pre-processor for CALPUFF) can be run using prognostic upper air data (as a three-dimensional '3D.dat' file). Gridded upper air data were derived using TAPM[7] , which is then used in CALMET to derive an initial wind field (known as the Step 1 wind field). CALMET then incorporates mesoscale and local scale effects, including surface observations, to adjust the wind field. This modelling approach is known as the 'hybrid' approach (TRC 2011) and is adopted for this assessment. TAPM and CALMET model settings are described in Annexure B and selected in accordance with recommendations in NSW EPA (2016) and TRC (2011). Surface observations are included in the modelling (referred to as data assimilation), discussed and described in Section 4.

In addition to the 29 individual assessment locations (documented in Section 2.3), air pollutant concentrations were predicted over a 45 km by 33 km domain with 500 m resolution.

Specific activities (listed in Table 6.1) were represented in CALPUFF by line-volume and volume sources, located according to the layout of the Snowy 2.0 Main Works construction areas.

Simulations were undertaken for the 12-month period of 2017.

7.2 Conversion of NO_x to NO_2

NO_x emissions associated with fuel combustion are primarily emitted as NO with some NO_2. The transformation in the atmosphere of NO to NO_2 was accounted for using the US-EPA's Ozone Limiting Method (OLM) which requires ambient ozone data, as per the Approved Methods for Modelling.

Reference has been made to the synthetic hourly-varying NO_2 and O_3 concentration datasets based on concentrations recorded by the ACT Government monitoring network (see Section 5.5.2).

The equation used to calculate NO_2 concentrations from predicted NO_X concentrations is as follows:

$$[NO_2]_{TOTAL} = \{0.1 \times [NO_x]_{PRED}\} + MIN\{(0.9) \times [NO_x]_{PRED} \text{ or } (46/48) \times [O_3]_{BKGD}\} + [NO_2]_{BKGD}$$

Where:

$[NO_2]_{TOTAL}$ = The predicted concentration of NO_2 in µg/m^3.

$[NO_x]_{PRED}$ = The AERMOD prediction of ground level NO_X concentrations in µg/m^3.

MIN = The minimum of the two quantities within the braces.

$[O_3]_{BKGD}$ = The background ambient O_3 concentration – hourly varying concentration in µg/m^3.

46/48 = the molecular weight of NO_2 divided by the molecular weight of O_3.

$[NO_2]_{BKGD}$ = the background ambient NO_2 concentration – hourly varying concentration in µg/m^3.

7 CSIRO's The Air Pollution Model

The US-EPA's OLM assumes that all available O_3 in the atmosphere will react with NO until either all of the O_3, or all of the NO has reacted. A major assumption of this method is that the reaction is instantaneous. In reality, this reaction takes place over a number of hours and over distance. The OLM will therefore tend to overestimate concentrations at near-source locations.

Furthermore, the method assumes that the complete mixing of the emitted NO and ambient ozone, down to the level of molecular contact, will have occurred by the time the emissions reach the receptor having the maximum ground-level NO_X concentration.

Consequently, concentrations of the NO_2 reported within this assessment should be viewed as highly conservative, providing an upper bound estimate of NO_2 concentrations from the Snowy 2.0 Main Works construction phase.

7.3 Incremental (Snowy 2.0 Main Works) results

Predicted incremental TSP, PM_{10}, $PM_{2.5}$, NO_2 and dust deposition levels from the Snowy 2.0 Main Works construction phase are presented in Table 7.1 for each of the assessment locations. It is noted that these results are based on the emissions quantified in Section 6 and account for the particulate matter management measures detailed in Section 6.5.

The predicted concentrations and deposition rates for all pollutants and averaging periods are below the applicable NSW EPA assessment criterion at all assessment locations. Except for dust deposition, the assessment criteria listed are applicable to cumulative concentrations. Analysis of cumulative impact compliance is presented in Section 7.4.

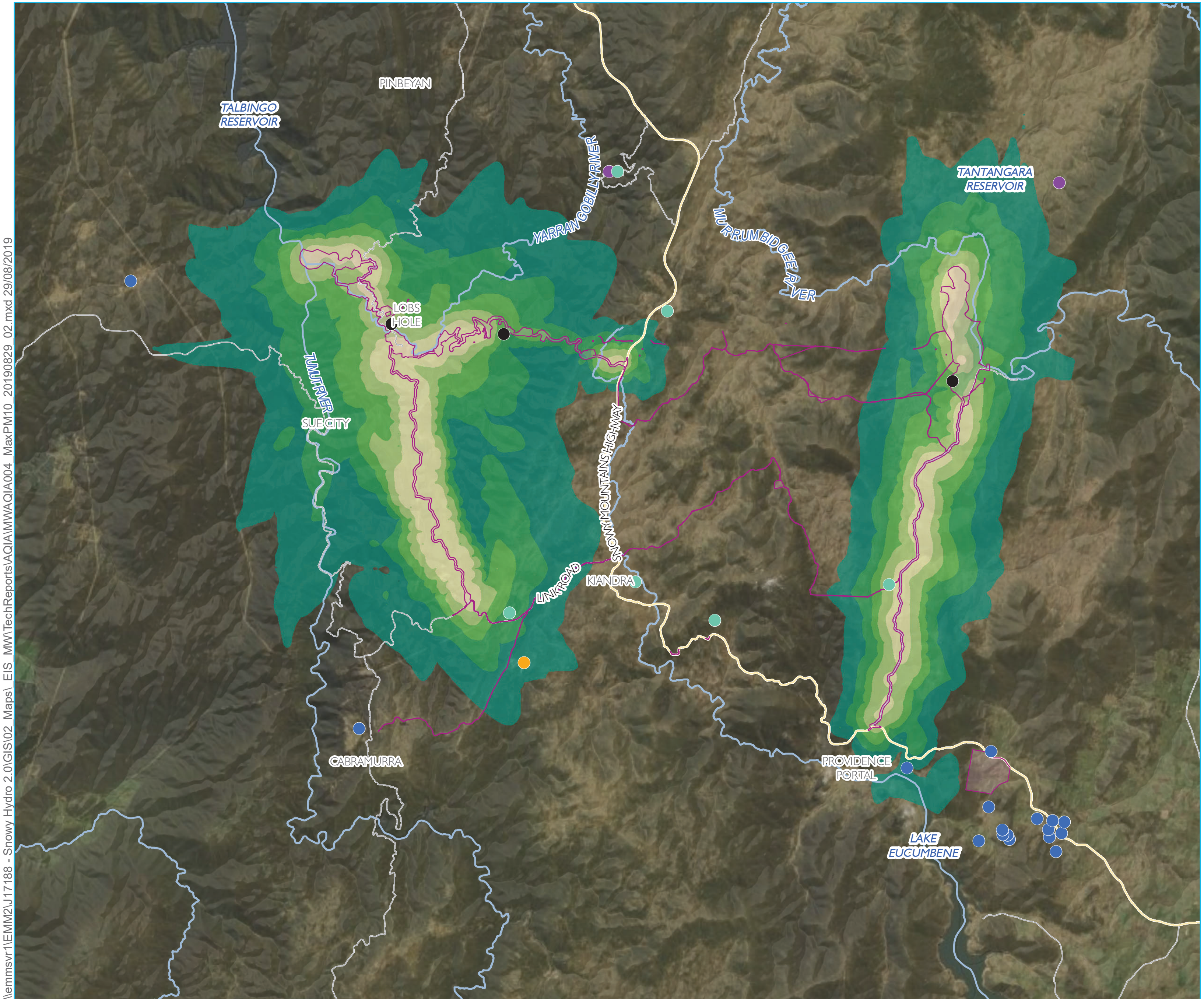
Contour plots, illustrating spatial variations in project-related incremental TSP, PM_{10} and $PM_{2.5}$ concentrations and dust deposition rates are provided in Figure 7.1 to Figure 7.6 below. Contour plots for NO_2 have not been shown. Isopleth plots of the maximum 24-hour average concentrations presented do not represent the dispersion pattern on any individual hour or day, but rather, the maximum hourly or daily concentration that was predicted to occur at each model calculation point given the range of meteorological conditions occurring over the 2017 modelling period.

Table 7.1 Incremental (Snowy 2.0 Main Works construction phase-only) concentration and deposition results

	Predicted incremental concentration (µg/m³) or deposition rate (g/m²/month)							
Assessment location ID	TSP	PM_{10}		$PM_{2.5}$		Dust deposition	NO_2	
	Annual	24-hour maximum	Annual	24-hour maximum	Annual	Annual	1-hour	Annual
Criterion	**90**	**50**	**25**	**25**	**8**	**2**	**246**	**62**
R1	0.3	2.0	0.3	1.3	0.12	0.03	15.0	0.5
R2	0.1	1.0	0.1	0.5	0.04	0.01	10.5	0.2
R3	0.4	1.6	0.3	0.6	0.11	0.05	30.9	1.5
R4	0.4	3.3	0.3	1.2	0.10	0.03	37.9	0.8
R5	0.2	1.5	0.1	0.8	0.06	0.01	9.9	0.4
R6	0.2	0.9	0.1	0.5	0.06	0.02	24.8	0.4
R7	0.1	0.4	0.1	0.2	0.03	0.01	14.5	0.2
R8	0.1	0.5	0.1	0.3	0.03	0.01	5.5	0.2
R9	0.1	0.5	0.1	0.3	0.03	0.01	2.8	0.1

Table 7.1 Incremental (Snowy 2.0 Main Works construction phase-only) concentration and deposition results

Assessment location ID	Predicted incremental concentration (µg/m³) or deposition rate (g/m²/month)							
	TSP	PM_{10}		$PM_{2.5}$		Dust deposition	NO_2	
	Annual	24-hour maximum	Annual	24-hour maximum	Annual	Annual	1-hour	Annual
Criterion	**90**	**50**	**25**	**25**	**8**	**2**	**246**	**62**
R10	0.1	0.5	0.1	0.2	0.03	0.01	3.1	0.1
R11	0.1	0.6	0.1	0.2	0.03	0.01	3.1	0.1
R12	0.1	0.6	0.1	0.3	0.03	0.01	2.6	0.1
R13	0.1	0.5	0.1	0.3	0.03	0.01	3.8	0.1
R14	0.1	0.8	0.1	0.3	0.04	0.01	3.5	0.1
R15	0.1	0.7	0.1	0.3	0.04	0.01	3.5	0.1
R16	0.1	0.8	0.1	0.3	0.04	0.01	6.5	0.2
R17	0.1	0.7	0.1	0.3	0.04	0.01	6.0	0.2
R18	0.1	1.0	0.1	0.4	0.04	0.01	8.4	0.2
R19	0.1	0.8	0.1	0.3	0.04	0.01	6.4	0.2
R20	0.2	1.7	0.1	1.0	0.06	0.01	7.5	0.2
R21	0.2	1.3	0.1	0.5	0.05	0.01	5.0	0.2
R22	1.5	7.1	1.0	2.5	0.28	0.21	21.2	0.2
R23	0.2	0.9	0.2	0.4	0.07	0.05	9.6	0.2
R24	10.7	42.6	5.4	8.8	1.16	1.66	41.7	1.0
R25	0.4	2.5	0.3	0.8	0.09	0.04	5.6	0.3
R26	0.3	1.6	0.2	0.8	0.12	0.02	76.6	3.4
R27	6.4	32.7	4.2	9.9	1.32	0.83	16.7	0.4
R28	3.5	9.5	2.2	3.5	0.77	0.72	14.7	0.4
R29	11.5	15.1	5.2	5.6	1.59	1.84	75.7	4.6



Source: EMM (2019); Snowy Hydro (2019); DFSI (2017); LPMA (2011)

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KEY

Disturbance area

Air quality assessment location

- Active recreation
- Passive recreation
- Residential
- Commercial
- Snowy accommodation camp

Existing environment

- Main road
- Local road
- Watercourse

Maximum predicted 24-hour average PM_{10} (µg/m³)

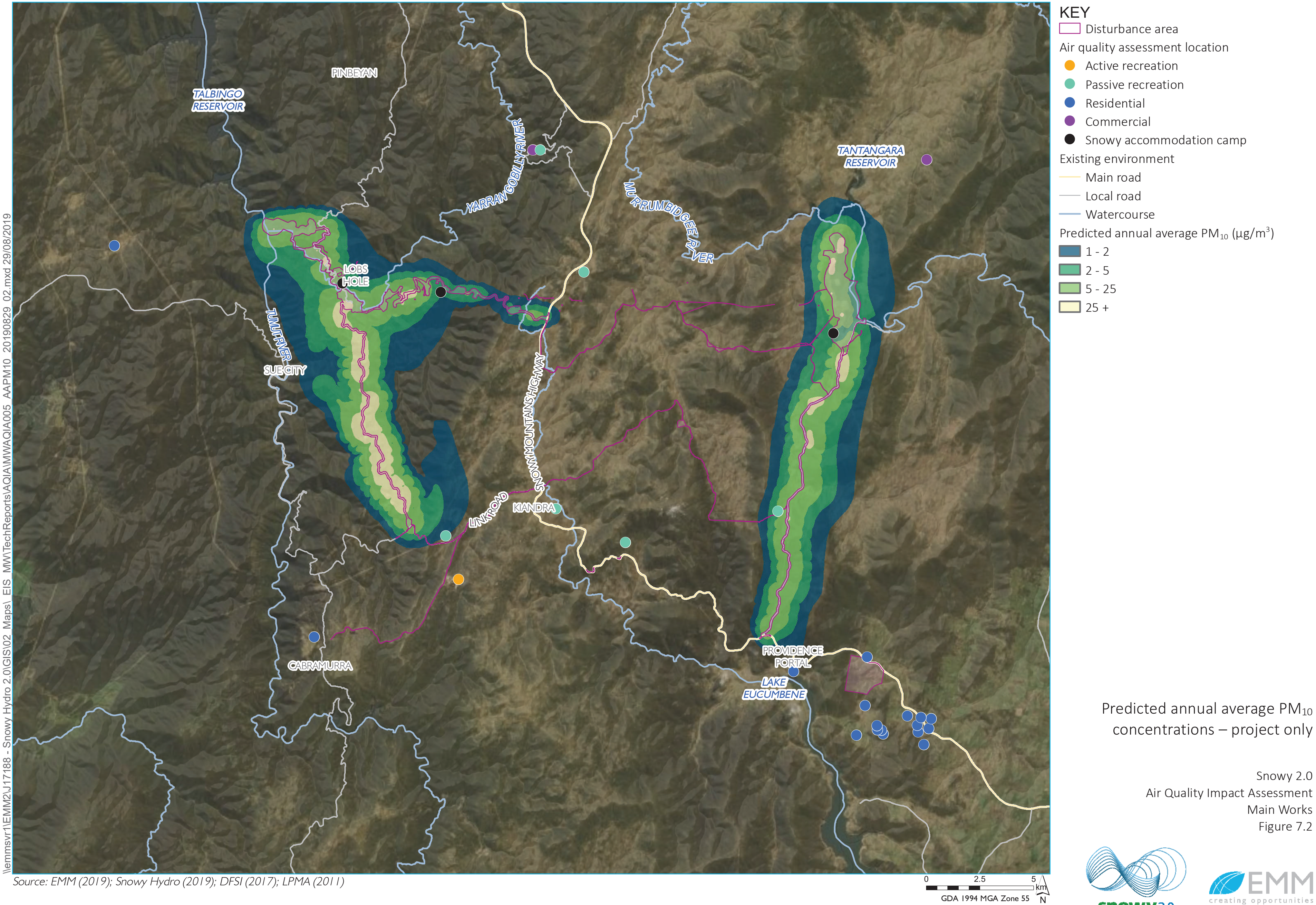
- 2.5 - 5
- 5 - 10
- 10 - 20
- 20 - 50
- 50+

Maximum predicted 24-hour average PM_{10} concentrations – project only

Snowy 2.0
Air Quality Impact Assessment
Main Works
Figure 7.1

snowy 2.0

EMM creating opportunities



Source: EMM (2019); Snowy Hydro (2019); DFSI (2017); LPMA (2011)

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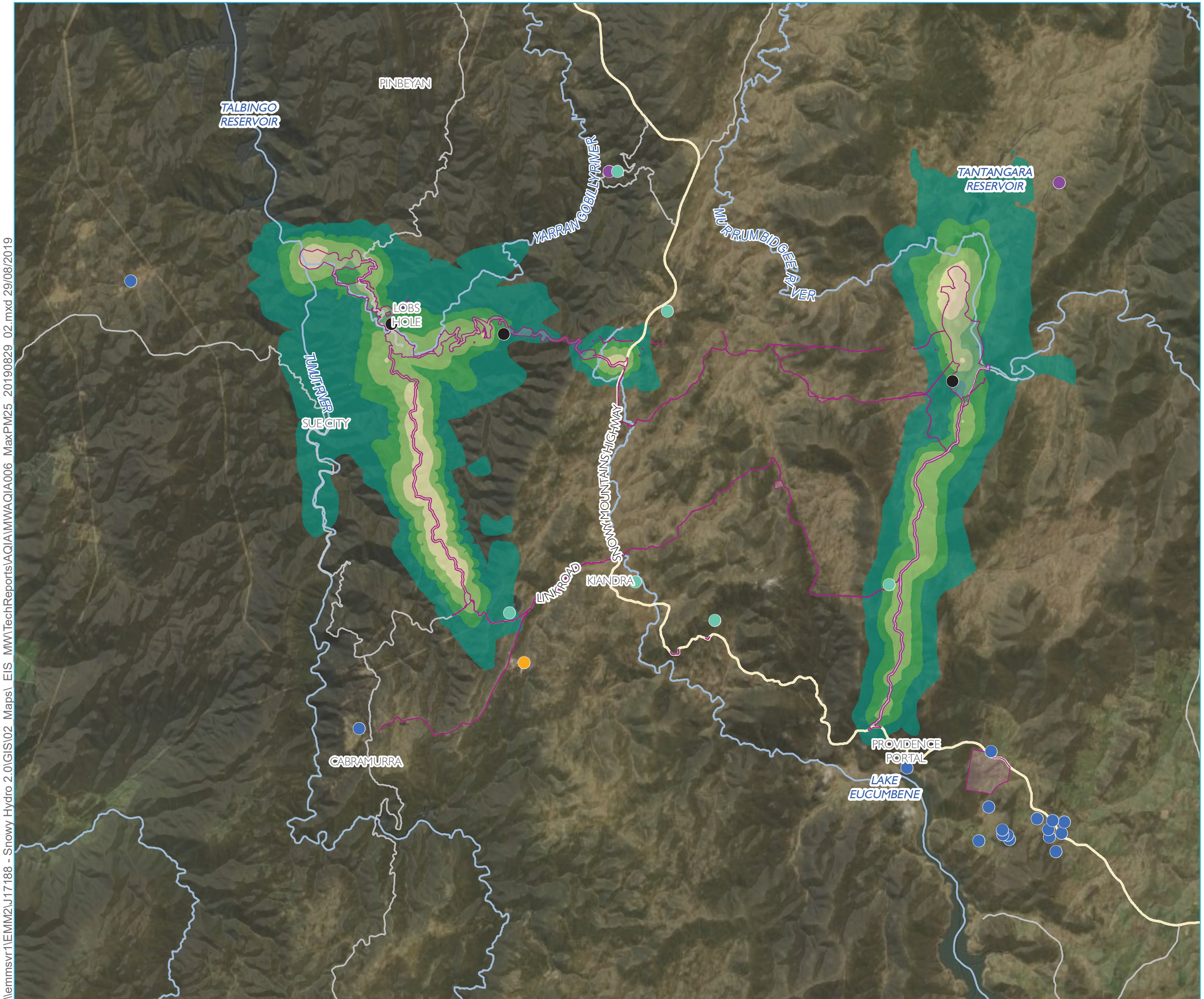
Predicted annual average PM_{10} concentrations – project only

Snowy 2.0
Air Quality Impact Assessment
Main Works
Figure 7.2

snowy 2.0

EMM creating opportunities



Source: *EMM (2019); Snowy Hydro (2019); DFSI (2017); LPMA (2011)*

KEY

- Disturbance area

Air quality assessment location

- Active recreation
- Passive recreation
- Residential
- Commercial
- Snowy accommodation camp

Existing environment

- Main road
- Local road
- Watercourse

Maximum predicted 24-hour average $PM_{2.5}$ ($\mu g/m^3$)

- 2 - 5
- 5 - 10
- 10 - 25
- 25+

Maximum predicted 24-hour average $PM_{2.5}$ concentrations – project only

Snowy 2.0
Air Quality Impact Assessment
Main Works
Figure 7.3

snowy2.0

EMM creating opportunities

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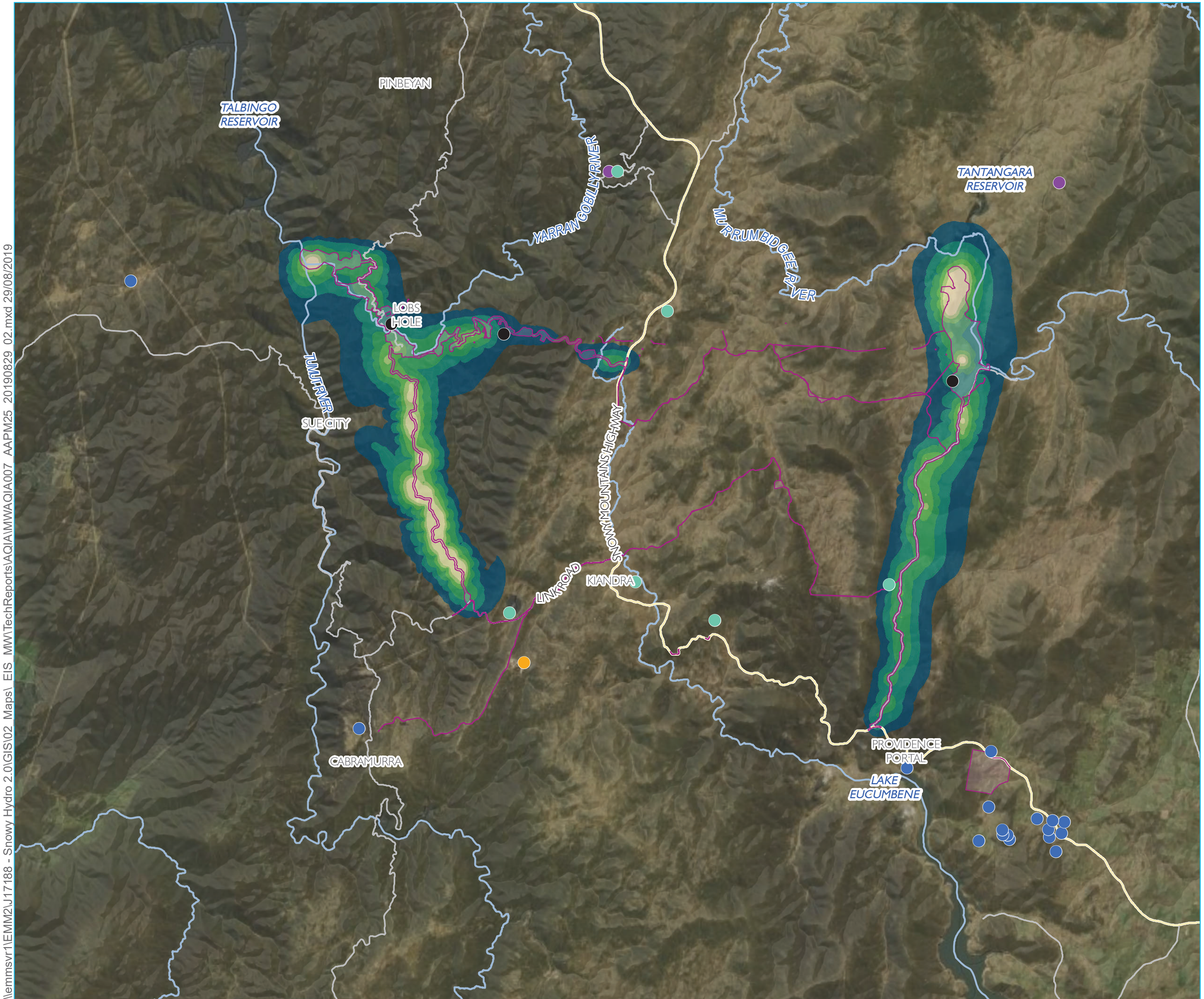

KEY

- Disturbance area

Air quality assessment location

- Active recreation
- Passive recreation
- Residential
- Commercial
- Snowy accommodation camp

Existing environment

- Main road
- Local road
- Watercourse

Predicted annual average $PM_{2.5}$ ($\mu g/m^3$)

- 0.5-1
- 1-2
- 2-4
- 4-6
- 6-8
- 8+

Predicted annual average $PM_{2.5}$ concentrations – project only

Snowy 2.0
Air Quality Impact Assessment
Main Works
Figure 7.4

Source: EMM (2019); Snowy Hydro (2019); DFSI (2017); LPMA (2011)

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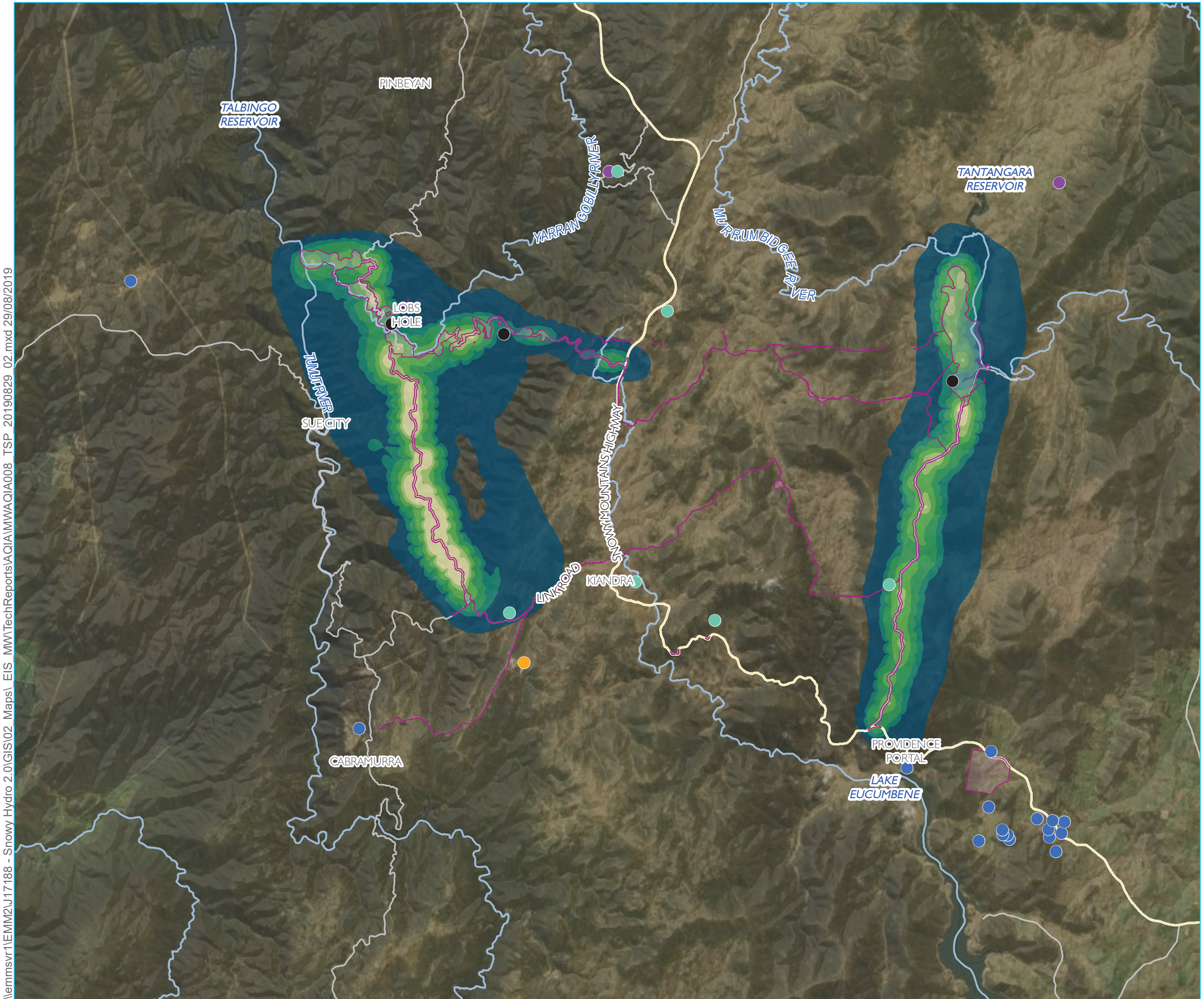

Source: EMM (2019); Snowy Hydro (2019); DFSI (2017); LPMA (2011)

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KEY

Disturbance area

Air quality assessment location

- Active recreation
- Passive recreation
- Residential
- Commercial
- Snowy accommodation camp

Existing environment

- Main road
- Local road
- Watercourse

Predicted annual average TSP (µg/m^3)

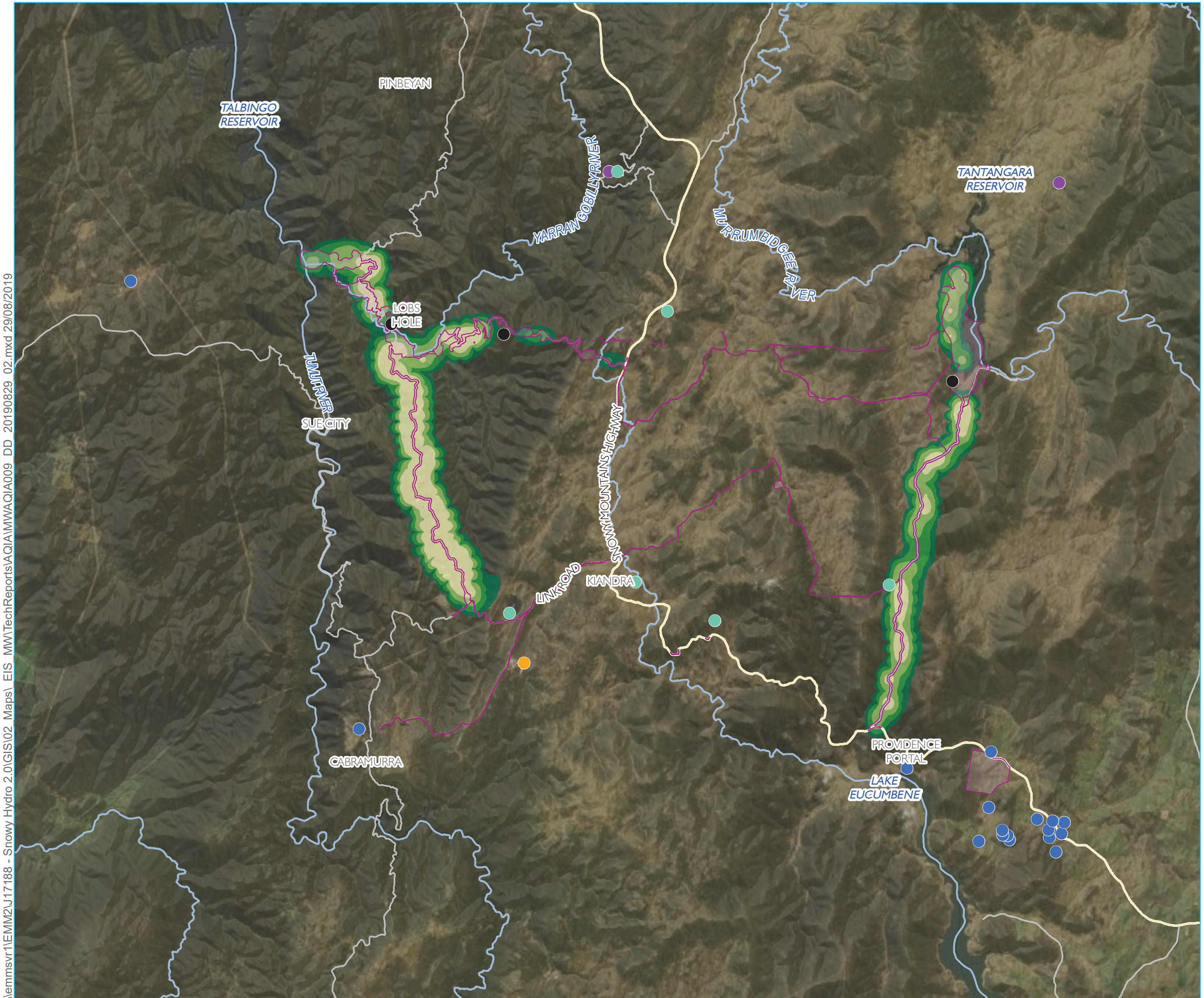
- 1-5
- 5-10
- 10-30
- 30-60
- 60-90
- 90+

Predicted annual average TSP concentrations – project only

Snowy 2.0
Air Quality Impact Assessment
Main Works
Figure 7.5

snowy 2.0

EMM
creating opportunities



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Source: EMM (2019); Snowy Hydro (2019); DFSI (2017); LPMA (2011)

KEY

Disturbance area

Air quality assessment location

- Active recreation
- Passive recreation
- Residential
- Commercial
- Snowy accommodation camp

Existing environment

- Main road
- Local road
- Watercourse

Predicted annual average dust deposition (g/m²/month)

- 0.5-1
- 1-2
- 2-4
- 4+

Predicted annual average dust deposition levels – project only

Snowy 2.0
Air Quality Impact Assessment
Main Works
Figure 7.6

snowy 2.0

EMM creating opportunities

7.4 Cumulative (Snowy 2.0 Main Works plus background) results

Cumulative concentrations (Snowy 2.0 Main Works construction phase impacts plus background) were derived following the contemporaneous assessment approach. For each pollutant and averaging period, the coincident model prediction and corresponding background value were paired together to derive a cumulative concentration at each receptor location. For example, in the case of 24-hour average PM_{10}, at each assessment location the background concentration on the 1st January 2017 was paired with the model prediction on the 1st January 2017 and repeated for the entire modelling period.

A summary of the predicted cumulative TSP, PM_{10} and $PM_{2.5}$ concentrations associated with Snowy 2.0 Main Works construction phase activities are presented in Table 7.3. It is noted that annual dust deposition results are not shown as background data are not available. The incremental results however (see Table 7.1) were well below the impact assessment criterion. Table 7.3 also shows the contribution of the increment and background concentrations on the day of exceedance at each location. Predicted cumulative concentrations for each of the assessment locations are presented in Table 7.3.

Table 7.2 Summary of results above the impact assessment criteria

Assessment location ID	PM_{10}				$PM_{2.5}$			
	24-hour increment	Background	Total	Days over the criterion	24-hour increment	Background	Total	Days over the criterion
Criterion	50 µg/m³				25 µg/m³			
R24	42.6	14.6	57.2	2	8.2	20.4	28.6	2
	35.3	21.8	57.1		2.8	23.6	26.4	
R27	-	-	-	-	6.1	23.2	29.3	2
	-	-	-	-	2.1	23.6	25.7	
R29	-	-	-	-	3.2	23.6	26.8	1

The following points are made in relation to the presented cumulative concentrations:

- R24 (Wares Yards Campground):
  - the daily-varying maximum 24-hour average PM_{10} cumulative concentrations predicted at R24 are presented in Figure 7.7. Although the incremental results are high on the two exceedance days, the majority (90%) of cumulative concentrations are below 30 µg/m³. The campground is located within 500 m of Tantangara Road which was assumed as unpaved for purposes of this assessment. It is unsure at this stage whether the campground will exist during the Snowy 2.0 Main Works construction phase.
  - the daily-varying maximum 24-hour average $PM_{2.5}$ cumulative concentrations predicted at R24 are presented in Figure 7.8. The figure shows that the background is the dominating factor when considering cumulative concentrations. On the two exceedance days, the background was 20.4 µg/m³ and 23.6 µg/m³ compared against a cumulative criterion of 25 µg/m³. 90% of cumulative predictions were below 15 µg/m³.
- R27 (Lobs Hole accommodation camp):

- the daily-varying maximum 24-hour average $PM_{2.5}$ cumulative concentrations predicted at R27 are presented in Figure 7.9. The background is the dominating factor when considering cumulative concentrations. On the two exceedance days, the background was 23.2 µg/m^3 and 23.6 µg/m^3 compared against a cumulative criterion of 25 µg/m^3. 89% of cumulative predictions were below 15 µg/m^3.

- R29 (Tantangara accommodation camp):
  - the daily-varying maximum 24-hour average $PM_{2.5}$ cumulative concentrations predicted at R29 are presented in Figure 7.10. The background is the dominating factor when considering cumulative concentrations. On the exceedance day, the background was 23.6 µg/m^3 compared against a cumulative criterion of 25 µg/m^3. 89% of cumulative predictions were below 15 µg/m^3.

Table 7.3 Cumulative (Snowy 2.0 Main Works construction phase plus background) concentration and deposition results

Assessment location ID	Predicted cumulative concentration (µg/m³)						
	TSP	PM_{10}		$PM_{2.5}$		NO_2	
	Annual	24-hour maximum	Annual	24-hour maximum	Annual	1-hour	Annual
Criterion	**90**	**50**	**25**	**25**	**8**	**246**	**62**
R1	24.1	25.9	9.8	23.9	6.8	61.6	10.2
R2	23.9	25.7	9.6	23.7	6.8	61.6	9.9
R3	24.3	26.2	9.9	24.0	6.8	64.5	11.2
R4	24.2	26.1	9.8	23.9	6.8	63.3	10.5
R5	24.0	25.6	9.7	23.7	6.8	62.0	10.1
R6	24.0	26.1	9.7	23.9	6.8	62.9	10.1
R7	23.9	25.9	9.6	23.8	6.7	62.5	9.9
R8	23.9	26.0	9.6	23.8	6.7	61.9	10.0
R9	23.9	26.0	9.6	23.8	6.7	61.9	9.8
R10	23.9	25.9	9.6	23.8	6.7	61.8	9.8
R11	23.9	26.0	9.6	23.8	6.7	61.8	9.8
R12	23.9	26.0	9.6	23.8	6.7	61.8	9.8
R13	23.9	25.9	9.6	23.8	6.7	61.8	9.8
R14	23.9	26.0	9.6	23.8	6.8	61.8	9.9
R15	23.9	26.1	9.6	23.8	6.8	61.8	9.9
R16	23.9	26.0	9.6	23.8	6.8	62.2	9.9
R17	23.9	26.1	9.6	23.8	6.8	62.1	9.9
R18	23.9	25.7	9.6	23.7	6.8	62.1	9.9
R19	23.9	26.3	9.6	23.9	6.8	62.1	9.9
R20	24.0	25.6	9.7	23.7	6.8	62.1	9.9

Table 7.3 Cumulative (Snowy 2.0 Main Works construction phase plus background) concentration and deposition results

Assessment location ID	Predicted cumulative concentration (µg/m³)						
	TSP	PM_{10}		$PM_{2.5}$		NO_2	
	Annual	24-hour maximum	Annual	24-hour maximum	Annual	1-hour	Annual
Criterion	**90**	**50**	**25**	**25**	**8**	**246**	**62**
R21	24.0	25.6	9.6	23.7	6.8	61.8	9.9
R22	25.3	29.7	10.5	24.7	7.0	67.3	9.9
R23	24.0	25.8	9.7	23.8	6.8	61.6	9.9
R24	34.5	**57.2**	15.0	**28.6**	7.9	62.6	10.7
R25	24.2	26.5	9.8	23.9	6.8	62.0	10.0
R26	24.1	26.3	9.8	24.2	6.8	96.8	13.2
R27	30.2	44.6	13.7	**29.3**	8.0	62.1	10.1
R28	27.3	28.5	11.8	24.8	7.5	66.3	10.1
R29	35.3	34.6	14.7	**26.8**	8.3	79.8	14.3

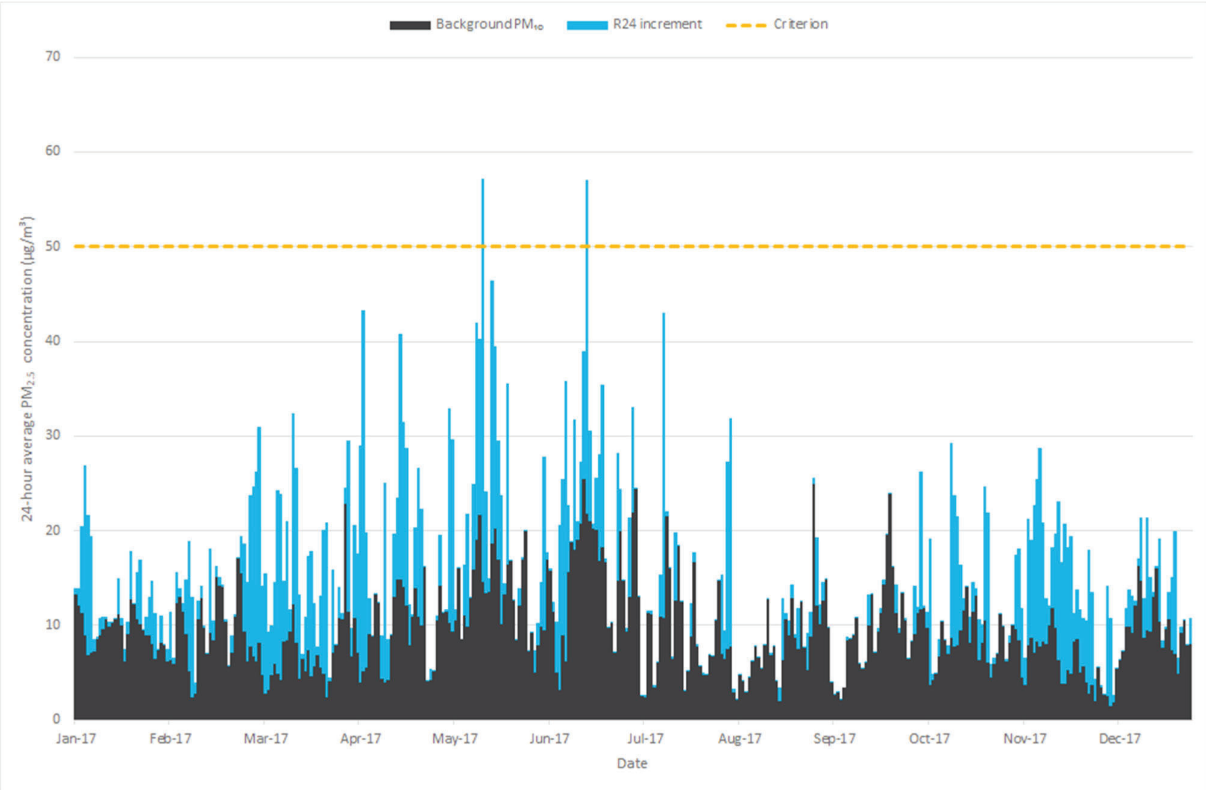

Figure 7.7 Cumulative 24-hour average PM_{10} concentrations – receptor R24

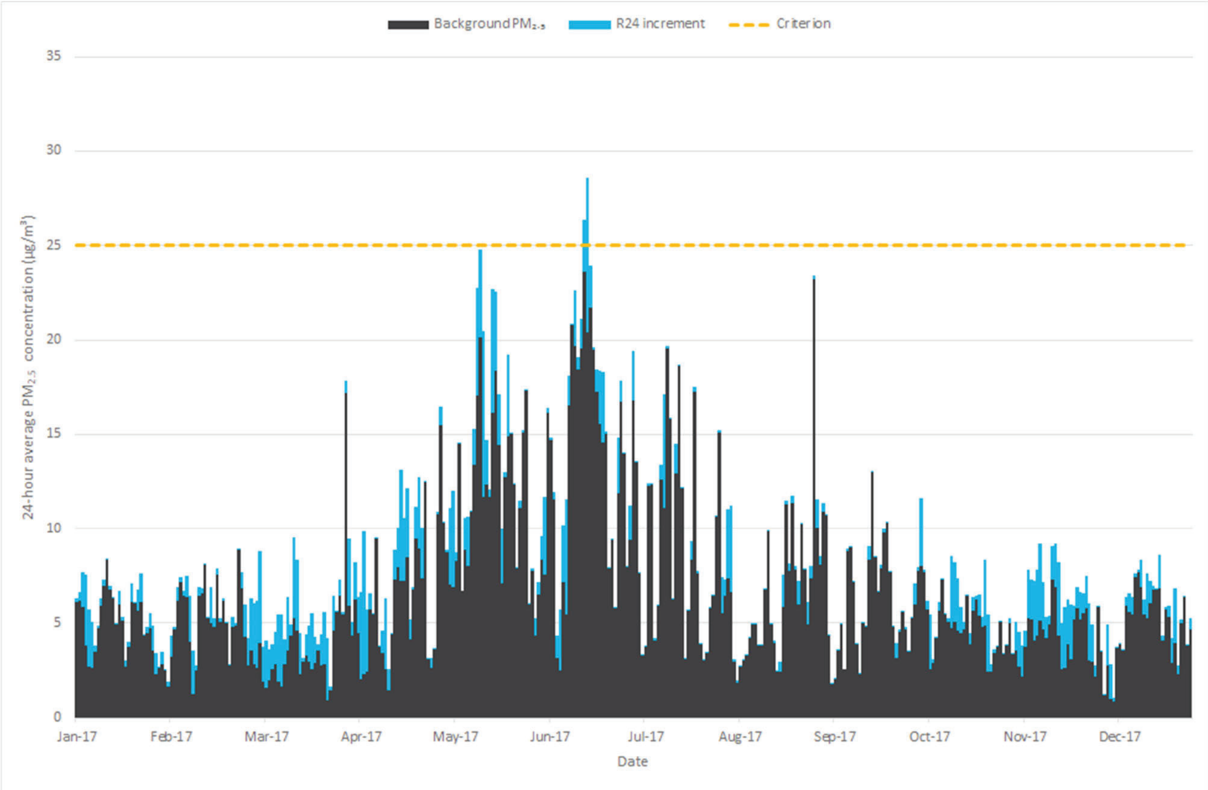

Figure 7.8 Cumulative 24-hour average $PM_{2.5}$ concentrations – receptor R24

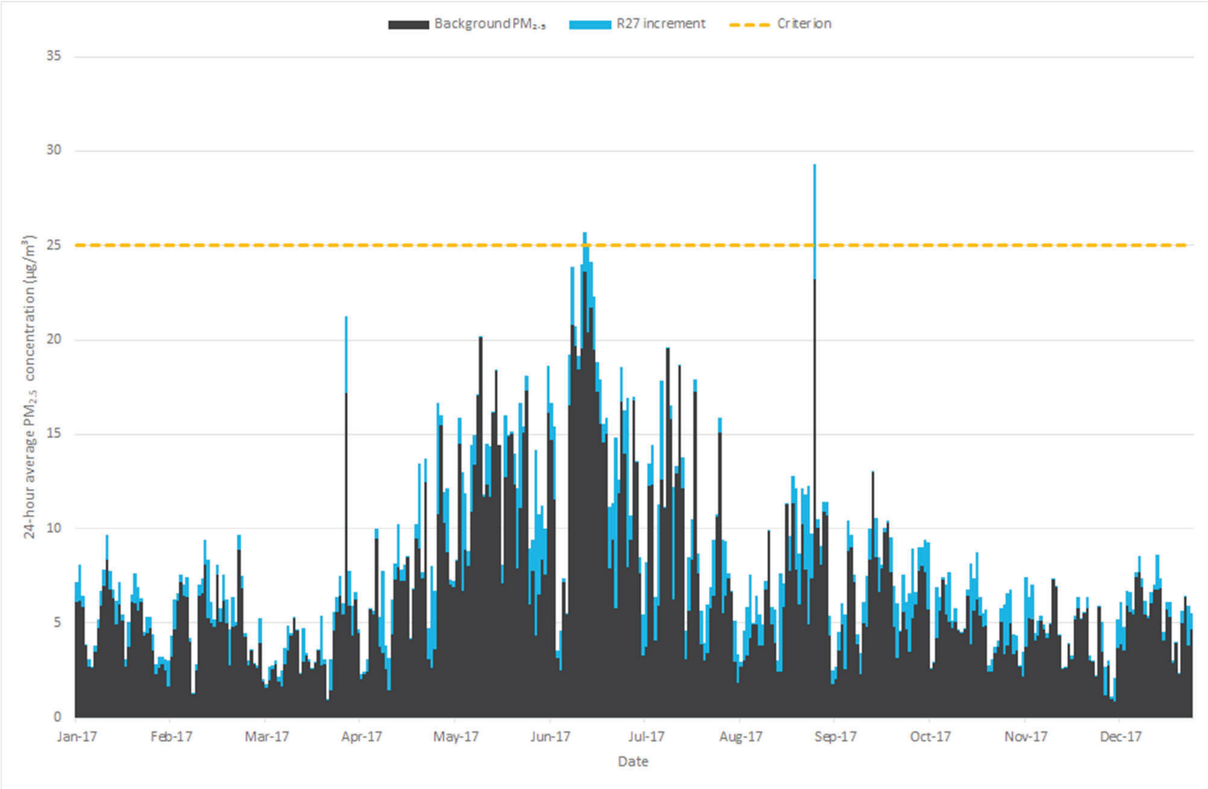

Figure 7.9 Cumulative 24-hour average $PM_{2.5}$ concentrations – receptor R27

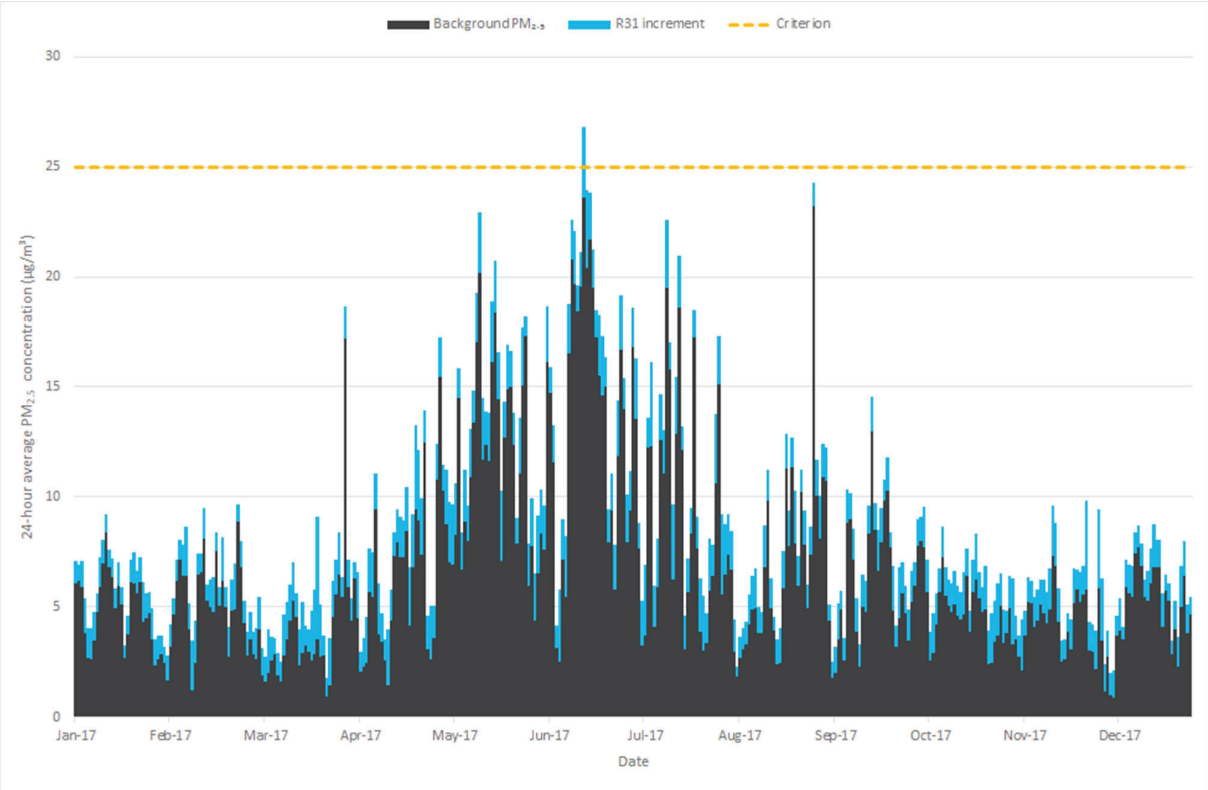

Figure 7.10 Cumulative 24-hour average $PM_{2.5}$ concentrations – receptor R29

8 Mitigation measures

8.1 Fugitive particulate matter emissions

As documented in Section 6.5, a range of mitigation measures and management practices will be implemented during the Snowy 2.0 Main Works construction phase. Proposed dust management measures include the following:

- dozer working areas will be watered;
- wind erosion from spoil disposal areas will be controlled through watering;
- unpaved roads within works areas will be watered using water carts; and
- Lobs Hole Road and Tantangara Road will be sealed 1 km each side of the Lobs Hole and Tantangara accommodation camps.

These particulate matter emission management methods were incorporated into the emissions calculations and dispersion modelling wherever an appropriate emission reduction factor was available.

Regarding the sealing of roads in the vicinity of the Lobs Hole and Tantangara accommodation camps, the exact pavement design and materials to be used will be determined prior to commencement of the Snowy 2.0 Main Works construction phase.

8.2 Diesel combustion emissions

The following management practices will be implemented where feasible to minimise emissions from the combustion of diesel during the Snowy 2.0 Main Works construction phase:

- where feasible, mobile and stationary equipment compliant with a more recent emission standard than USEPA Tier 2 will be sourced;
- unpaved roads will be routinely maintained to reduce truck tyre rolling resistance;
- all equipment will be routinely serviced to maintain manufacturers' emission specifications;
- idling of diesel equipment will be minimised wherever feasible; and
- low-sulphur diesel fuels and lubricants will be used where feasible.

9 Greenhouse gas assessment

9.1 Introduction

The estimation of greenhouse gas (GHG) emissions for the Snowy 2.0 Main Works construction phase was based on the DoEE National Greenhouse Accounts Factors (NGAF) workbook (DoEE 2018). The methodologies in the NGAF workbook follow a simplified approach, equivalent to the 'Method 1' approach outlined in the National Greenhouse and Energy Reporting (Measurement) Technical Guidelines (DoE 2014). The Technical Guidelines are used for the purpose of reporting under the National Greenhouse and Energy Reporting Act 2007 (the NGER Act).

For accounting and reporting purposes, GHG emissions are defined as 'direct' and 'indirect' emissions. Direct emissions (also referred to as Scope 1 emissions) occur within the boundary of an organisation and as a result of that organisation's activities. Indirect emissions are generated as a consequence of an organisation's activities but are physically produced by the activities of another organisation (DoEE 2018). Indirect emissions are further defined as Scope 2 and Scope 3 emissions. Scope 2 emissions occur from the generation of the electricity purchased and consumed by an organisation. Scope 3 emissions occur from all other upstream and downstream activities, for example the downstream extraction and production of raw materials or the upstream use of products and services.

Scope 3 is an optional reporting category (Bhatia et al 2010) and should not be used to make comparisons between organisations, for example in benchmarking GHG intensity of products or services. Typically, only major sources of Scope 3 emissions are accounted and reported by organisations. Specific Scope 3 emission factors are provided in the NGAF workbook for the consumption of fossil fuels and purchased electricity, making it straightforward for these sources to be included in a GHG inventory, even though they are a relatively minor source.

9.2 Emission sources

The GHG emission sources included in this assessment are listed in Table 9.1, and represent the most significant sources associated with the Snowy 2.0 Main Works.

GHG emissions from the project are estimated using the methodologies outlined in the NGAF workbook, using fuel energy contents and Scope 1, 2 and 3 emission factors for diesel, gasoline, and electricity use in NSW. Greenhouse gas emissions from carbon loss associated with the removal of vegetation were estimated using the method outlined in the TAGG Workbook (2013). The calculations require classification of vegetation types which are then assigned to a specific emission factor.

Table 9.1 Scope 1, 2 and 3 emission sources

Scope 1	Scope 2	Scope 3
Direct emissions from fuel combustion (diesel) by onsite plant and equipment	Indirect emissions associated with the consumption of purchased electricity	Indirect upstream emissions from the extraction, production and transport of diesel
Direct emissions from vegetation clearing		Indirect upstream emissions from electricity lost in delivery in the transmission and distribution network
		Transport of construction materials to site

9.3 Excluded emissions

The following GHG emission sources are considered minor relative to the emission sources listed in Table 9.1 and have consequently been excluded from this GHG assessment.

These include:

- fuel combustion by vehicles travelling between operational Snowy 2.0 Main Works surface infrastructure (Scope 1 and 3); and
- travel of employees to and from the project during operations (Scope 3).

9.4 Activity data

Annual energy consumption rates associated with Snowy 2.0 Main Works (construction and operations) have been conservatively estimated based on the following assumptions:

- construction and operating schedule of 365 days per year;
- maximum diesel consumption for machinery, mobile equipment, employee transportation, diesel generators and vehicles of approximately 28 million litres for a worst-case 12-month period during construction;
- construction materials including concrete, segments and road base being transported from distances up to 300 km from the project;
- vehicle movements associated with servicing of accommodation camps transported to site by various heavy-duty vehicles from a maximum distance of 130 km. Trips per year were calculated based on the traffic assessment; and
- a total facility power draw of 80,000 kilovolt-amperes (kVa), converted to kilowatts (kW) through a load factor of 0.8 during operations.

The adopted activity data (fuel and electricity) for the emission estimates is presented in Table 9.2.

Table 9.2 Annual fuel and energy consumption

Process	Fuel consumption (kL) or electricity use (kWh)
Construction	
Diesel used on-site	28,195
Diesel used for transport of construction materials to site and servicing of accommodation camps	3,299
Operation	
Purchased electricity	560,640,000

Table 9.3 presents the amount of land and land types estimated to be cleared as part of the Snowy 2.0 Main Works construction phase. The areas and types of vegetation to be cleared was analysed based on data collated for the Biodiversity Development Assessment Report (EMM 2019) for Snowy 2.0 Main Works. The land area totals of clearing by vegetation type ae presented in Table 9.3.

Table 9.3 Vegetation clearance - Snowy 2.0 Main Works construction phase

Vegetation class	Name	Amount cleared in hectares (ha)
A	Rainforest and vine thicket	-
B	Eucalypt tall open forest	73
C	Open forest	615
D	Open woodlands	195
E	Callitris forest and woodland	8
F	Mallee and Acacia woodland and shrubland	-
G	Open shrubland	-
H	Heathlands	-
I	Grassland	155
Total construction phase (70 months)		**1,047**
Total single year		**179**

9.5 Emission estimates

The following emission factors have been used to estimate GHG emissions from the project:

- diesel consumption on-site (Scope 1) – diesel oil factor from Table 3 of the NGAF workbook (2018);
- vegetation clearing (Scope 1) – emission factors from Table 15 of the *Supporting Document for Greenhouse Gas Assessment Workbook for Road Projects* (TAGG 2013);
- electricity consumption (Scope 2) – NSW Scope 2 emission factor from Table 5 of the NGAF workbook (2018);
- diesel consumption on-site (Scope 3) – diesel oil factor from Table 40 of the NGAF workbook (2018); and
- electricity consumption (Scope 3) - NSW Scope 3 emission factor from Table 41 of the NGAF workbook (2018).

The estimated annual GHG emissions for each emission source are presented in Table 9.4.

The significance of Snowy 2.0 Main Works GHG emissions relative to state and national GHG emissions is made by comparing annual average GHG emissions against the most recent available total GHG emissions inventories (calendar year 2017[8]) for NSW (128,870 kt CO_2-e) and Australia (530,841 kt CO_2-e).

Annual average total GHG emissions (Scope 1, 2 and 3) generated by the Snowy 2.0 Main Works construction represents approximately 0.12% of total GHG emissions for NSW and 0.03% of total GHG emissions for Australia, based on the National Greenhouse Gas Inventory for 2017.

Annual average total GHG emissions (Scope 1, 2 and 3) generated by the Snowy 2.0 Main Works operations represent approximately 0.40% of total GHG emissions for NSW and 0.10% of total GHG emissions for Australia, based on the National Greenhouse Gas Inventory for 2017.

8 http://ageis.climatechange.gov.au/

The contribution of the Snowy 2.0 Main Works to projected climate change, and the associated environmental impacts, would be in proportion with its contribution to global greenhouse gas emissions.

Table 9.4 Estimated annual GHG emissions during construction

Emission source	Annual GHG emissions (t CO_2-e/year)			
	Scope 1	**Scope 2**	**Scope 3**	**Total**
Diesel used on-site	76,401	-	3,918	80,318
Diesel used for transport of construction materials to site and servicing of accommodation camps	-	-	349	349
Vegetation clearing	73,613	-	-	73,613
Total	**150,014**	**0**	**4,267**	**154,281**

Table 9.5 Estimated annual GHG emissions during operations

Emission source	Annual GHG emissions (t CO_2-e/year)			
	Scope 1	**Scope 2**	**Scope 3**	**Total**
Purchased electricity	-	459,725	56,064	515,789
Total	**0**	**459,725**	**56,064**	**515,789**

10 Conclusions

Dispersion modelling was completed for a worst-case construction phase scenario of the Snowy 2.0 Main Works using the CALPUFF model system. Hourly meteorological observations from 2017, collected at Snowy Hydro stations at Talbingo, Tantangara and Cabramurra Airstrip and the BoM Cabramurra SMHEA AWS, were used as inputs into the dispersion model.

Emissions of TSP, PM_{10}, $PM_{2.5}$ and NO_x were estimated and modelled for the peak period of construction activities based on the maximum 12-month period of projected traffic volumes.

In order to manage particulate matter emissions during the construction phase of Snowy 2.0 Main Works, dust mitigation measures are required. These measures include:

- watering of dozer areas;
- watering of unpaved roads within works areas; and
- paving roads 1 km each side of the Lobs Hole and Tantangara accommodation camps.

These measures were taken into account in the emissions estimation and modelling of the worst-case construction phase scenario.

The results of the modelling show that the predicted concentrations and deposition rates for incremental particulate matter (TSP, PM_{10}, $PM_{2.5}$ and dust deposition) and NO_2 are below the applicable impact assessment criteria at all assessment locations.

Cumulative impacts were assessed by combining modelled project impacts with recorded ambient background levels. The cumulative results showed that compliance with applicable NSW EPA impact assessment criteria was predicted at all sensitive receptor locations for all pollutants and averaging periods, with the following exceptions:

- R24 (Wares Yards Campground) was predicted to exceed the maximum 24-hour average PM_{10} criterion on two days in the modelled year. The increment at this location on these days was high compared to the background but it is noted that R24 is located within 500 m of a long unpaved road and may not be used at time of project construction.
- R24, R27 (Lobs Hole accommodation camp) and R29 (Tantangara accommodation camp) exceeded the 24-hour average $PM_{2.5}$ criterion on two days, two days and one day respectively. Timeseries plots for these locations showed that the background was the dominating source when considering cumulative concentrations. The majority of cumulative concentrations (90%) were also below 15 $\mu g/m^3$ at these locations.

A GHG assessment was also undertaken for the Snowy 2.0 Main Works. Annual average total GHG emissions (Scope 1, 2 and 3) generated by the Snowy 2.0 Main Works construction represent approximately 0.12% of total GHG emissions for NSW and 0.03% of total GHG emissions for Australia, based on the National Greenhouse Gas Inventory for 2017. Annual average total GHG emissions (Scope 1, 2 and 3) generated by the Snowy 2.0 Main Works operations represent approximately 0.40% of total GHG emissions for NSW and 0.10% of total GHG emissions for Australia, based on the National Greenhouse Gas Inventory for 2017.

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US-EPA 2006c, AP-42 13.2.5 – *Industrial wind erosion*

US-EPA 2011, AP-42 Chapter 13.2.1 – *Paved roads*

Abbreviations

ACT	Australian Capital Territory
AHD	Australian height datum
ANSTO	Australian Nuclear Science and Technology Organisation
Approved Methods for Modelling *in New South Wales*	*Approved Methods for the Modelling and Assessment of Air Pollutants*
AQIA	Air quality impact assessment
AWS	Automatic weather station
BoM	Bureau of Meteorology
CBP	Concrete batching plant
CO_2-e	Carbon dioxide equivalent
CO	Carbon monoxide
CSIRO	Commonwealth Scientific and Industrial Research Organisation
CSSI	Critical State significant infrastructure
DoEE	Department of the Environment and Energy
EIS	Environmental impact statement
EPA	Environment Protection Authority
EPL	Environment protection licence
FGJV	Future Generation Joint Venture
GHG	Greenhouse gas
KNP	Kosciuszko National Park
kVa	Kilovolt-amperes
kW	Kilowatt
LGA	Local government area
MWh	Megawatt hour
NEM	National Electricity Market
NGAF	National Greenhouse Accounts Factors
NO_x	Oxides of nitrogen
NPI	National Pollution Inventory
O_3	Ozone
OEH	Office of Environment and Heritage

OLM	Ozone limiting method
PM_{10}	Particulate matter less than 10 microns in aerodynamic diameter
$PM_{2.5}$	Particulate matter less than 2.5 microns in aerodynamic diameter
Snowy Hydro	Snowy Hydro Limited
Snowy Scheme	Snowy Mountains Hydro-electric Scheme
SO_2	Sulphur dioxide
SSI	State significant infrastructure
TAPM	The Air Pollution Model
US-EPA	United States Environmental Protection Agency
VOC	Volatile organic compounds

Annexure A

Meteorological modelling and processing

A.1 Meteorological monitoring datasets

As discussed in Section 4.2, meteorological datasets were collated from the following monitoring stations:

- BoM Cabramurra SMHEA AWS; and
- project-related stations at Tantangara Dam, Talbingo and Cabramurra Airstrip.

The BoM Cabramurra SMHEA AWS is the primary resource for meteorological data in this assessment. These data are supplemented by the Tantangara Dam and Cabramurra Airstrip monitoring stations.

Data from the BoM Cabramurra SMHEA AWS has been analysed for the period between 2014 to 2018. Data availability and analysis of inter-annual trends for this five-year period is presented in the following sections.

A.1.1 Data availability

A summary of data availability for the BoM Cabramurra SMHEA AWS dataset for the period between 2014 and 2018 is provided in Figure A.1. The following points are noted:

- data completeness is close to 100% for all parameters for all years between 2014 and 2018. Therefore, all years meet the minimum 90% data completeness requirements for all parameters specified with Section 4.1 of the Approved Methods for Modelling (EPA, 2016); and
- as data for 2013 to 2017 was available for the project-related stations, 2017 was chosen for assessment. It was also deemed representative of meteorological conditions at this location over the five-year period.

Figure A.1 Five-year data completeness analysis plot – BoM Cabramurra SMHEA AWS – 2014 to 2018

A.1.2 Selection of a representative year

While 2017 was the most recent and complete year of monitoring data from the available meteorological datasets, in order to determine the most representative year of data for modelling an analysis of inter-annual trends was conducted.

Inter-annual wind roses for the BoM Cabramurra SMHEA AWS and project-related stations at Cabramurra Airstrip, Tantangara Dam and Talbingo are presented in Figure A.2 to Figure A.5 respectively.

The wind roses for the BoM Cabramurra SMHEA AWS and the project-related Cabramurra Airstrip station show that the general wind directions were similar between the two stations, with dominant westerly and south-easterly flows. The exception to this was 2015 at the BoM Cabramurra SHMEA AWS station, where the dominant wind directions appear to be from the north-west rather than the west. The annual wind speeds at the BoM Cabramurra SMHEA AWS are higher than at the Cabramurra Airstrip station. The annual percentage of calms were significantly lower at the Cabramurra Airstrip station. It is noted that for 2017, the annual calms are 6.6% compared to around 1% for previous years. This is due to the amount of missing data in the 2017 dataset (approximately 40%).

The percentage of annual calms was also consistent between the two data sets, with values ranging between 4.2% and 6.1%. The highest wind speeds were from the west.

At the Talbingo station the annual wind speeds and wind directions were also very consistent between 2013 and 2017, with dominant winds from the south. Annual average calms at this station were much higher than at the other stations, ranging from 9.4% to 12.4% over the five-year period. Given its distance from the project sites, surface observations from this station were included only in the TAPM model run (see Section 4.3).

Diurnal distribution of wind speed, wind direction, temperature and relative humidity for BoM Cabramurra SMHEA AWS recorded between 2014 and 2018 are shown in Figure A.6 to Figure A.9 respectively.

The inter-annual profiles for wind speed and wind direction reflect the annual consistency as shown in the wind roses for the BoM Cabramurra SMHEA AWS in Figure A.2.

The inter-annual profiles for air temperature and relative humidity were also comparable between 2014 and 2018. The 2018 dataset showed slightly higher temperatures towards the end of the day and lower relative humidity which is a potential indicator of drought conditions during the year.

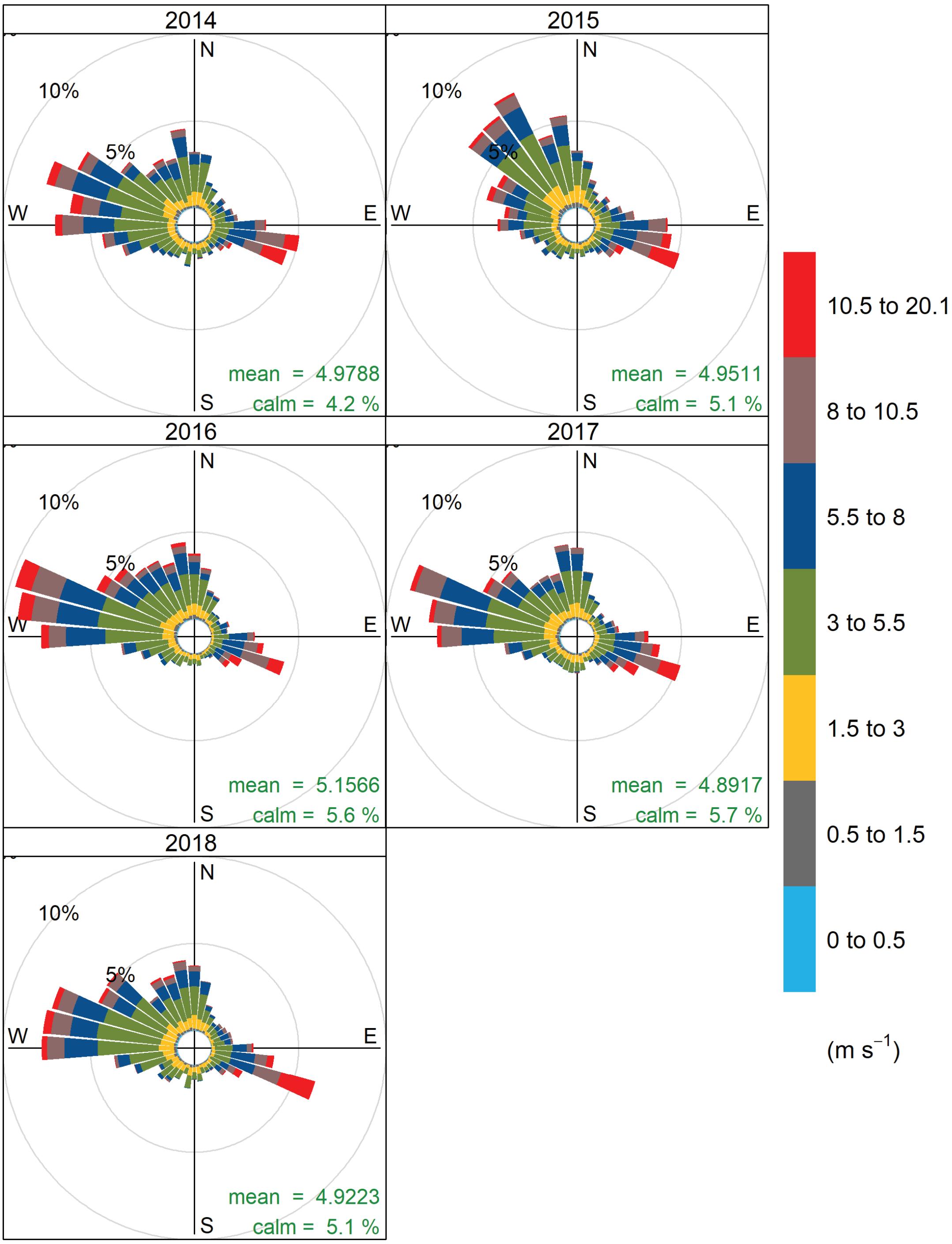


Figure A.2 Inter-annual comparison of recorded wind speed and direction – BoM Cabramurra SHMEA AWS – 2014 to 2018

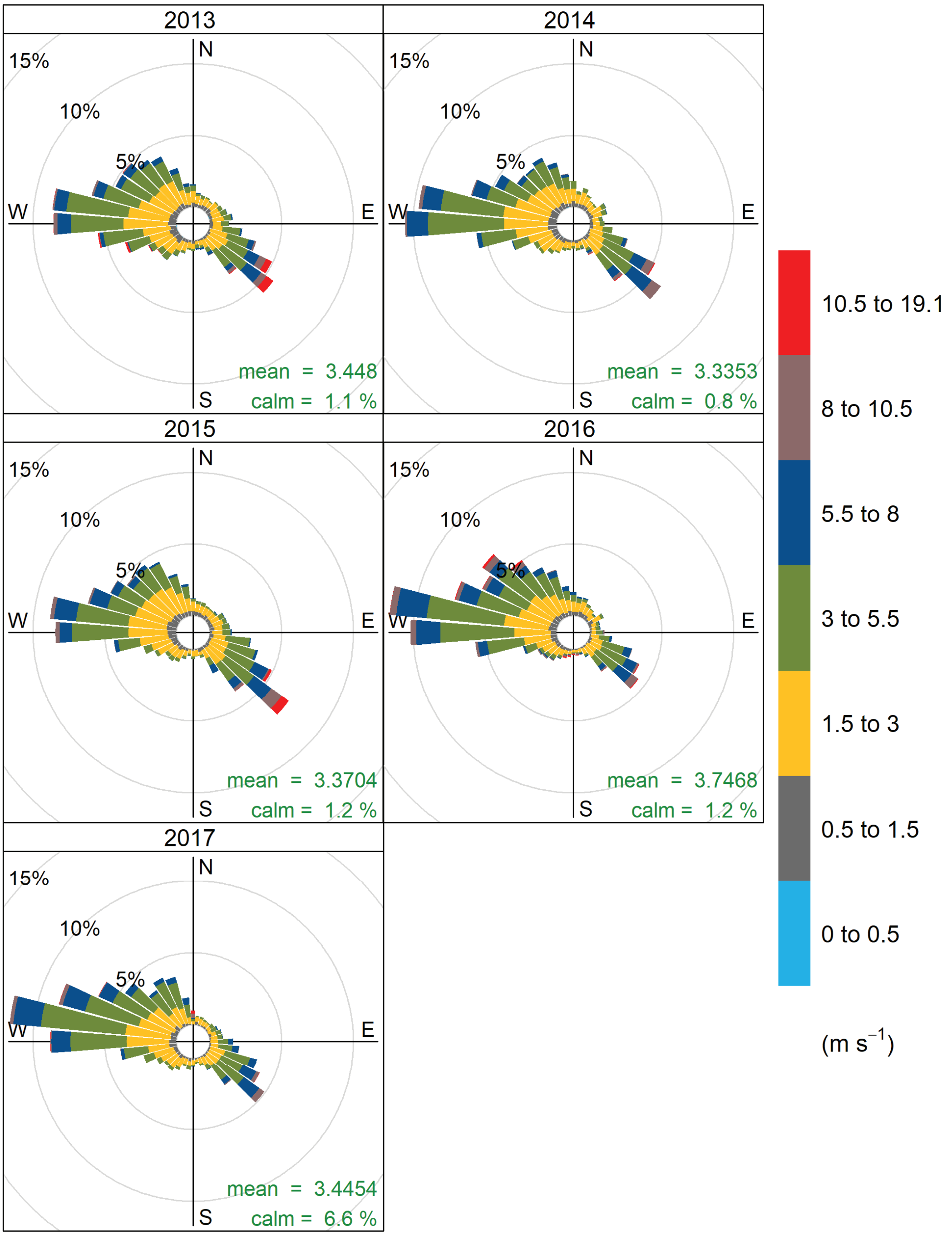


Figure A.3 Inter-annual comparison of recorded wind speed and direction – Cabramurra Airstrip – 2013 to 2017

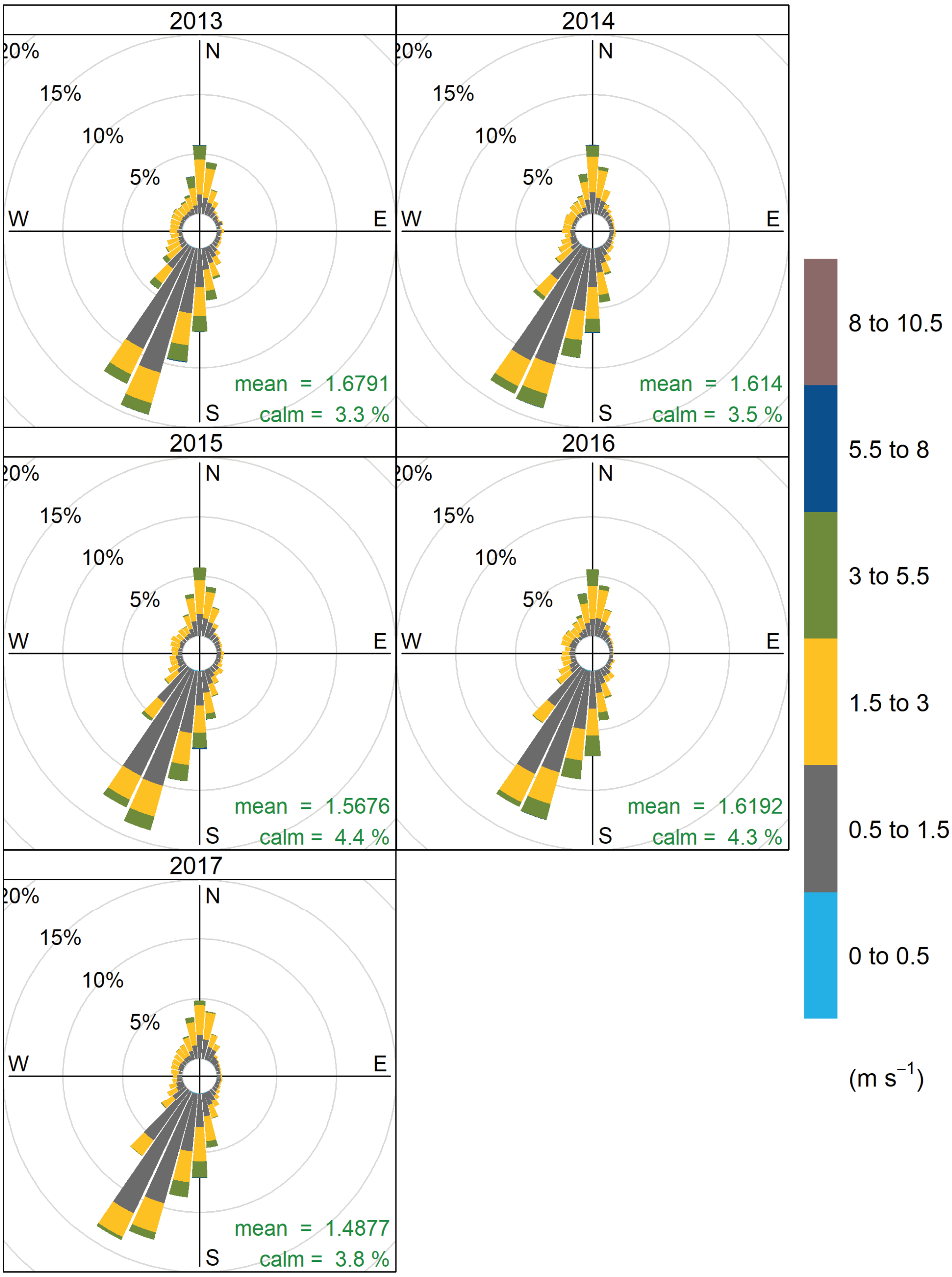


Figure A.4 Inter-annual comparison of recorded wind speed and direction – Tantangara – 2013 to 2017

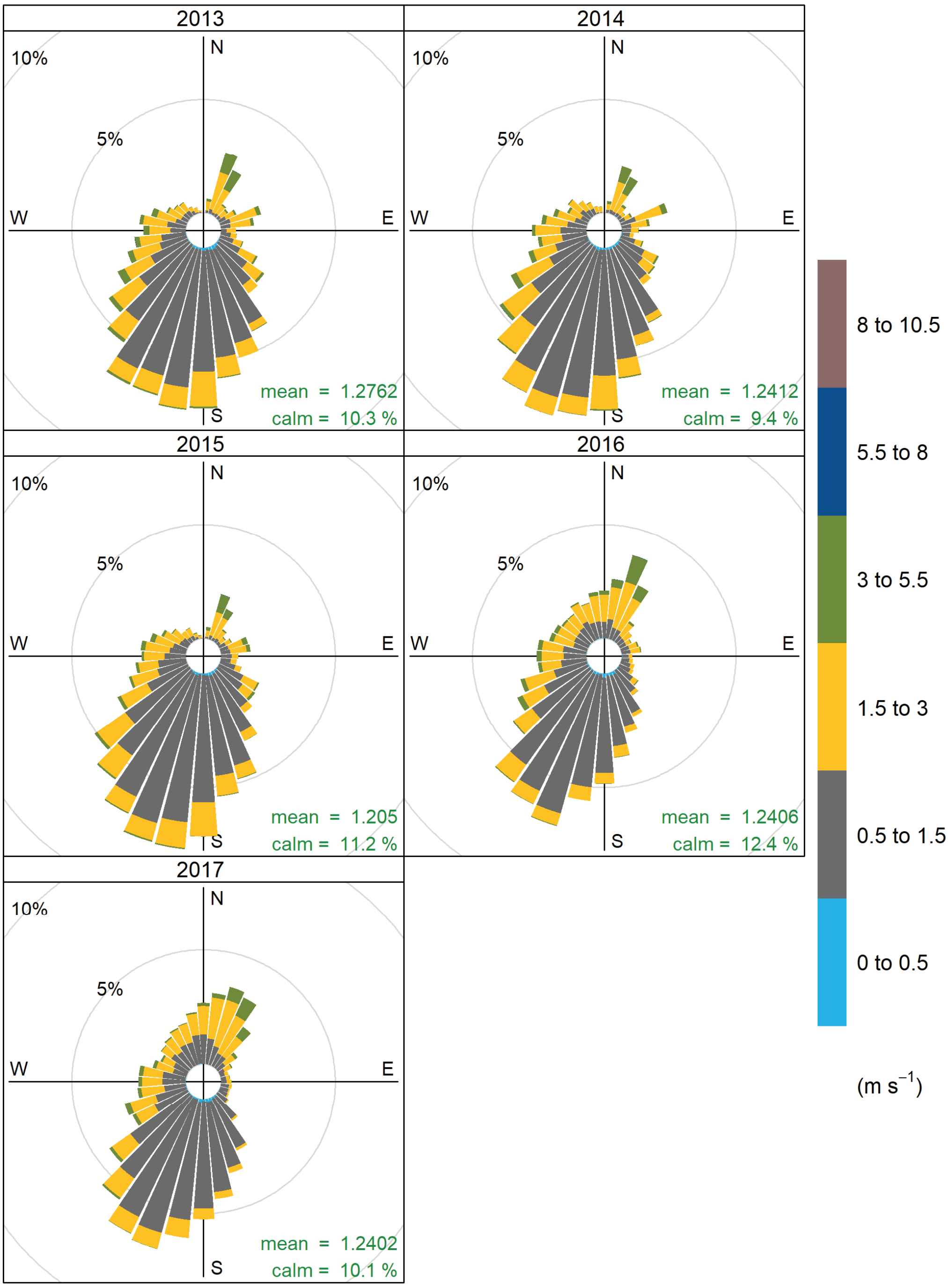


Figure A.5 Inter-annual comparison of recorded wind speed and direction – Talbingo – 2013 to 2017

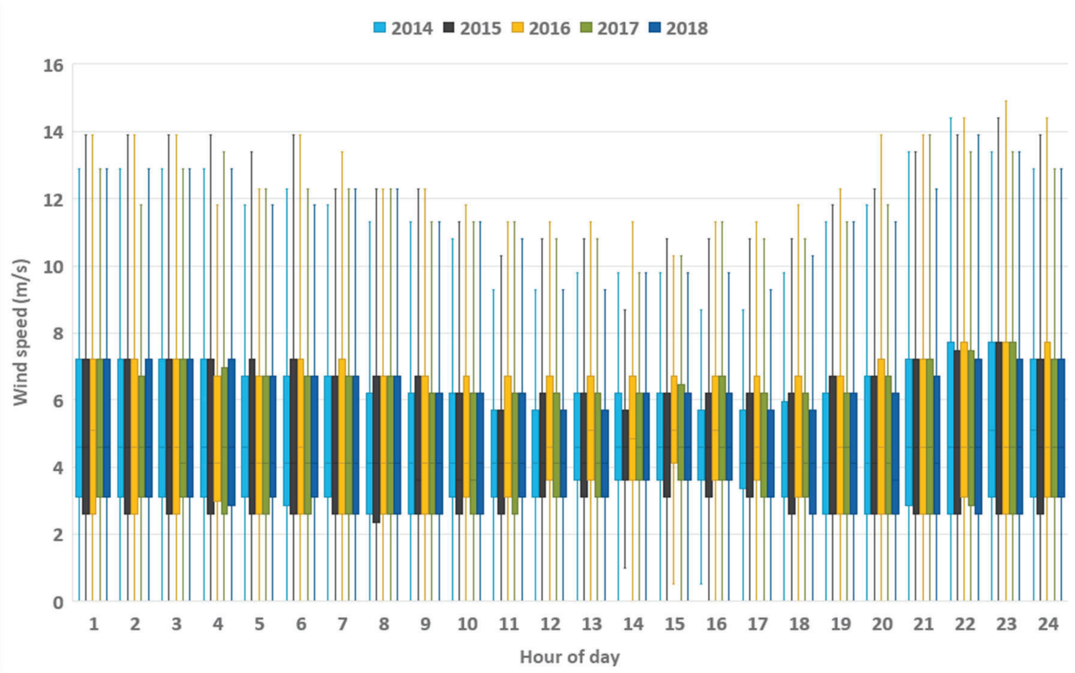


Figure A.6 Inter-annual variability in diurnal wind speed – BoM Cabramurra SHMEA AWS – 2014 to 2018

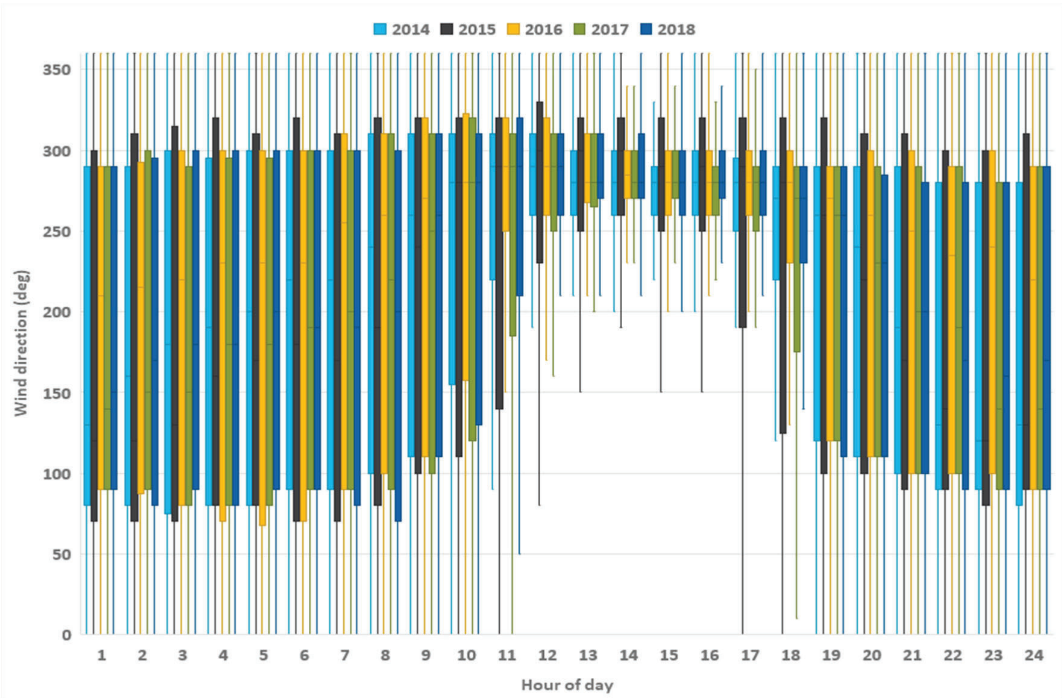


Figure A.7 Inter-annual variability in diurnal wind direction – BoM Cabramurra SHMEA AWS – 2014 to 2018

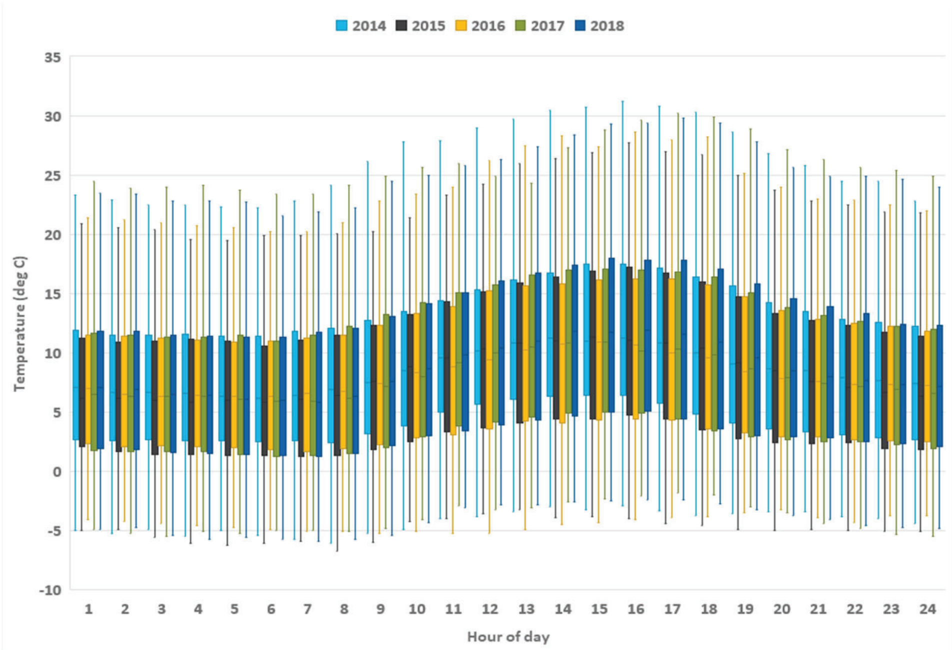


Figure A.8 Inter-annual variability in diurnal air temperature – BoM Cabramurra SHMEA AWS – 2014 to 2018

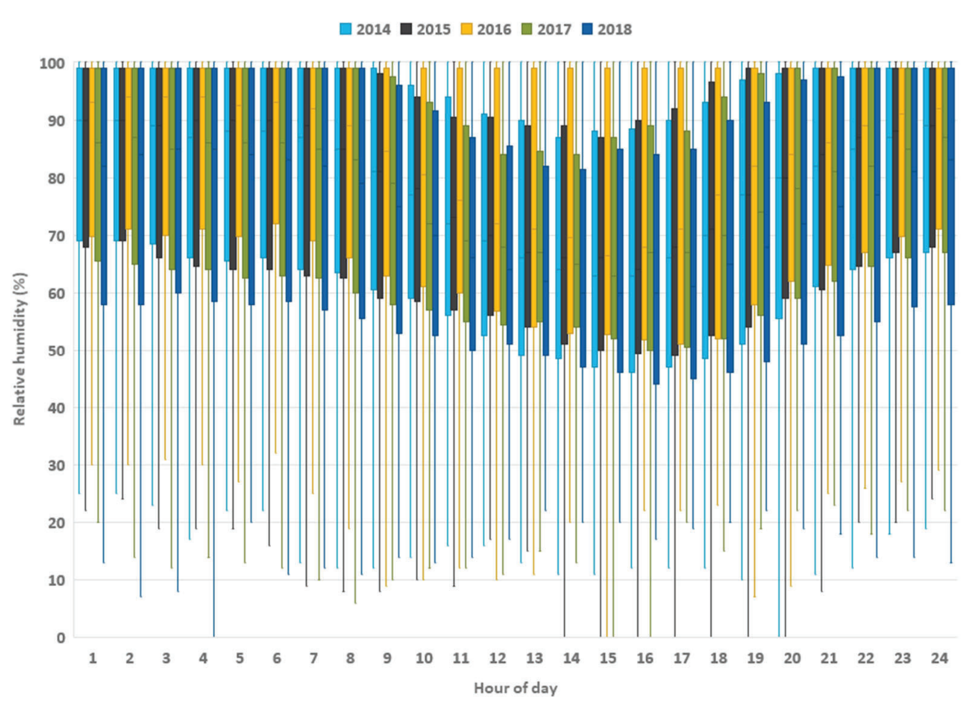


Figure A.9 Inter-annual variability in diurnal relative humidity – BoM Cabramurra SHMEA AWS – 2014 to 2018

A.1.3 Seasonal and diurnal wind roses for BoM Cabramurra SHMEA AWS and Tantangara Dam

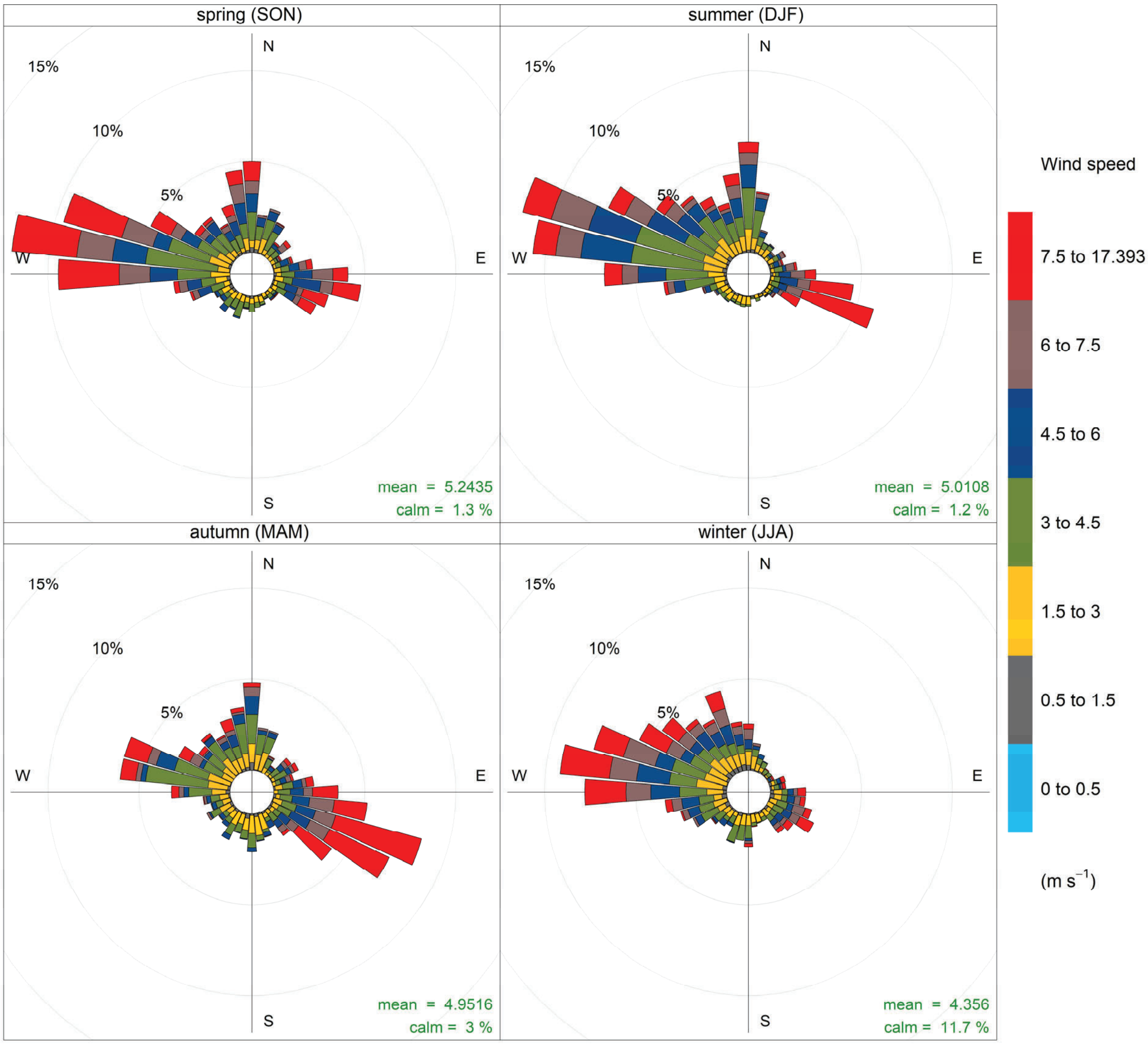


Figure A.10 Seasonal wind speed and direction – BoM Cabramurra SHMEA AWS – 2017

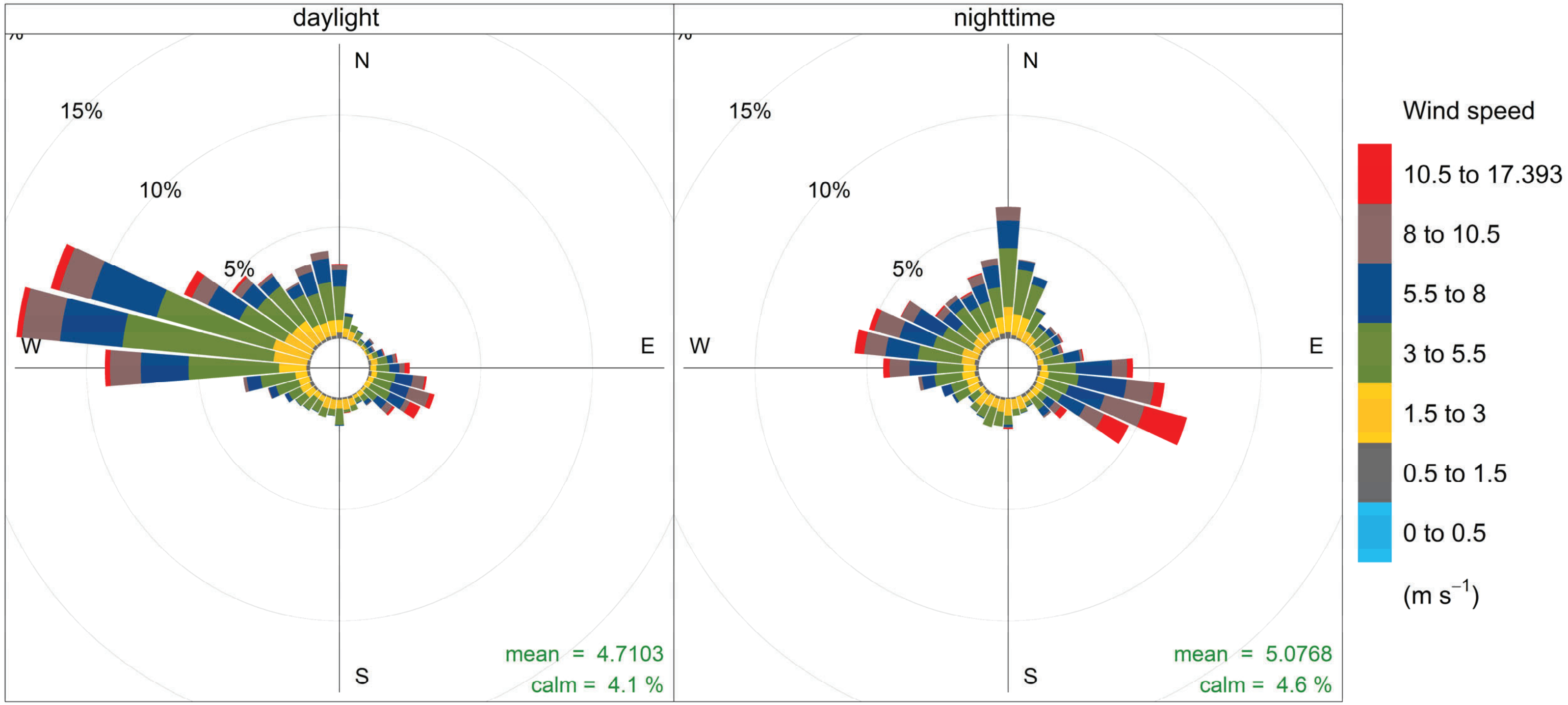


Figure A.11 Diurnal wind speed and direction – BoM Cabramurra SHMEA AWS – 2017

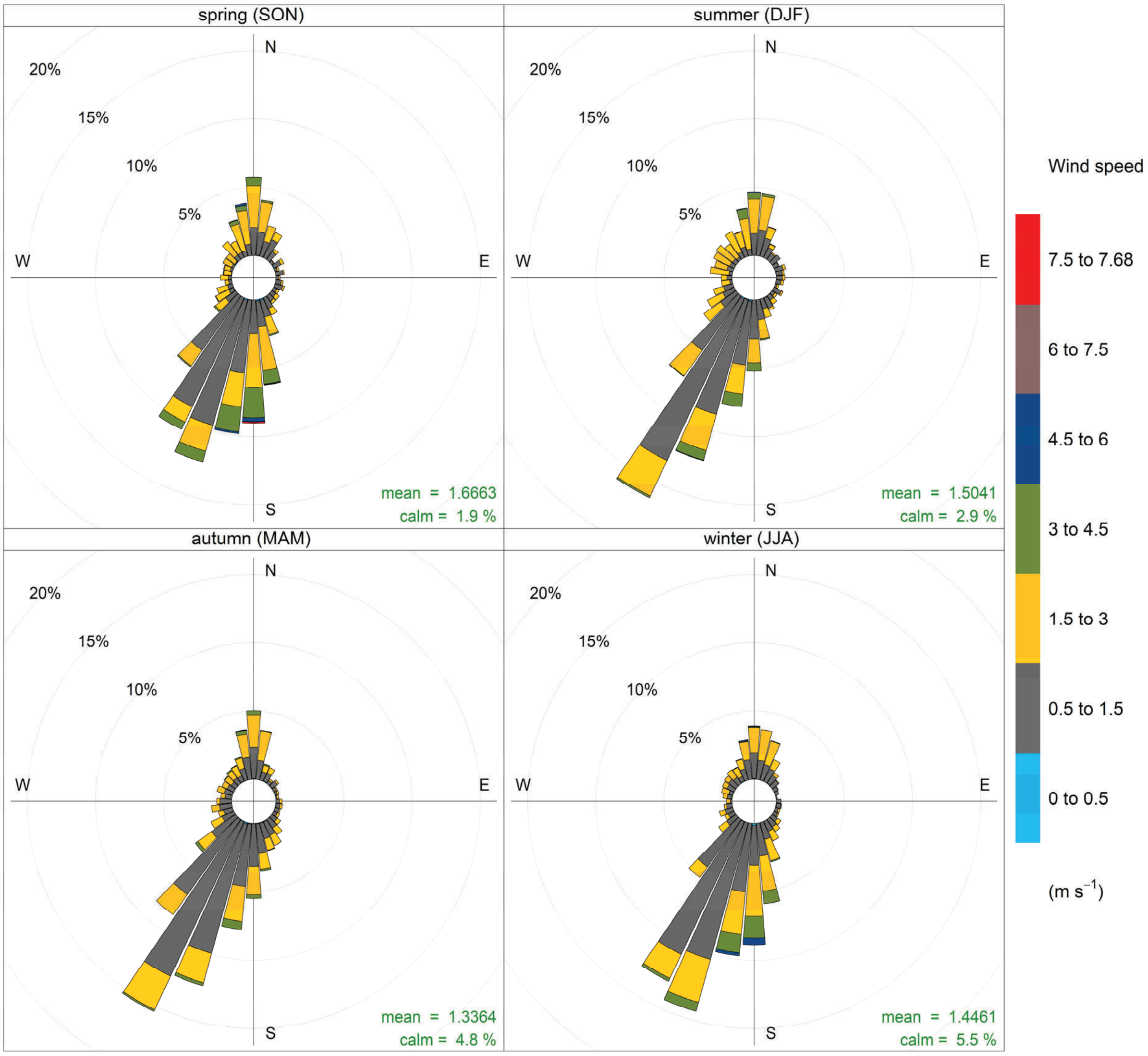


Figure A.12 Seasonal wind speed and direction – Tantangara Dam – 2017

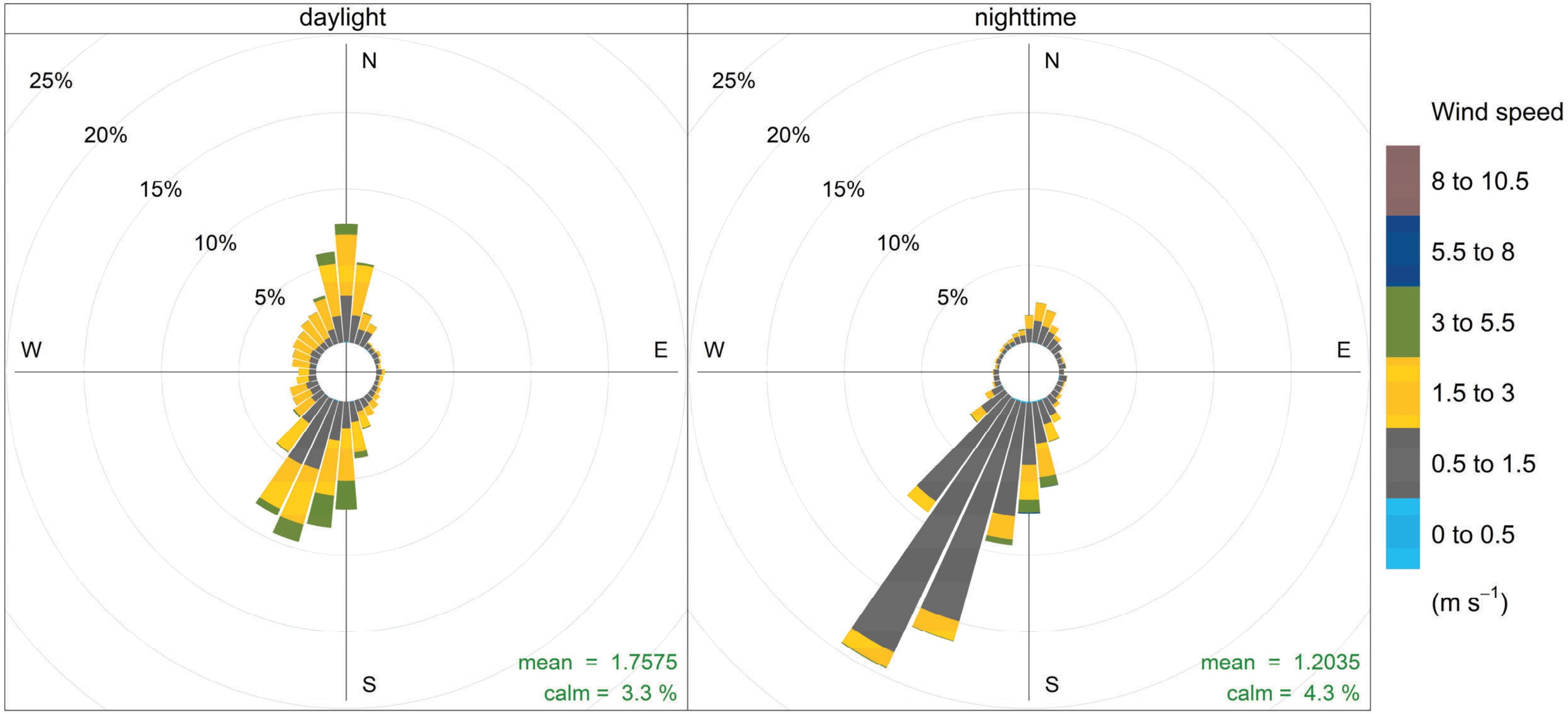


Figure A.13 Diurnal wind speed and direction – Tantangara Dam – 2017

Annexure B

Meteorological modelling and processing

B.1 TAPM modelling

To supplement the meteorological monitoring datasets adopted for this assessment, the Commonwealth Scientific and Industry Research Organisation (CSIRO) prognostic meteorological model The Air Pollution Model (TAPM) was used to generate required parameters that are not routinely measured, specifically mixing height and vertical wind/temperature profile.

TAPM was configured and run in accordance with the Section 4.5 of the Approved Methods for Modelling as follows:

- TAPM version 4.0.5;
- inclusion of high resolution (90 m) regional topography (improvement over default 250 m resolution data);
- grid domains with cell resolutions of 30 km, 10 km and 3 km. Each grid domain features 25 x 25 horizontal grid points and 35 vertical levels;
- TAPM default databases for land use, synoptic analyses and sea surface temperature; and
- TAPM defaults for advanced meteorological inputs.

A surface observations file was included in TAPM with meteorological data from the BoM Cabramurra SMHEA AWS and project-related stations at Tantangara Dam, Cabramurra Airstrip and Talbingo.

B.2 CALMET

The CALMET/CALPUFF model suite was chosen for this study. CALMET was used to produce 3-dimensional meteorological fields for use in the CALPUFF model.

In the absence of upper air measurements, CALMET can be run using prognostic upper air data (as a three-dimensional '3D.dat' file), which is used to derive an initial wind field (known as the Step 1 wind field in the CALMET model). The model then incorporates mesoscale and local scale effects, including surface observations, to adjust the wind field. This modelling approach is known as the 'hybrid' approach (TRC 2011) and is adopted for this assessment. TAPM was used to generate gridded upper air data for each hour of the model run period, for input into CALMET.

A CALMET grid of 50 km by 35 km was run with a resolution of 500 m. Surface meteorological data from the BoM Cabramurra SMHEA AWS and Tantangara Dam station were incorporated in the modelling. Cloud content and height data were also sourced from TAPM as there were no other data available in the area.

The observations at Tantangara Dam and Cabramurra provided the dominant influence on the derived wind field and the resultant dispersion meteorology within the model. The distance at which the observation influences the model (radius of influence) is determined by the CALMET setting 'RMAX'. The relative importance of the observation in the model (relative weighting of the Step 1 wind field and the observation) is determined by the CALMET setting 'R1'.

An RMAX of 10 km and R1 of 6 km was assigned in the model to reflect the local scale topographical influence seen in the observational data.

The detailed CALMET model options used are presented in Table B.1. These were selected in accordance with recommendations in the Approved Methods for Modelling and in TRC (2011). Surface observations were included in the modelling (referred to as data assimilation) to provide real-world observations and improve the accuracy of the wind fields.

Table B.1 CALMET model options used

Flag	Descriptor	Default	Value used
IEXTRP	Extrapolate surface wind observations to upper layers	Similarity theory	Similarity theory
BIAS (NZ)	Relative weighting given to vertically extrapolated surface observations versus upper air data	No default	-1, -0.989, -0.971, -0.937, -0.868, -0.731, -0.479, -0.089, 0.427, 1.0
TERRAD	Radius of influence of terrain	No default (typically 5-15 km)	5
RMAX1 and RMAX2	Maximum radius of influence over land observations in layer 1 and aloft	No default	10, 20
R1 and R2	Distance from observations in layer 1 and aloft at which observations and Step 1 wind field are weighted equally	No default	6, 12

B.2.1 CALMET model evaluation

Meteorological model evaluation was completed. It is standard practice to exclude an observation from the model, such that model evaluation can be performed for a site that has not influenced the outcome of the model. Given that there are two meteorological stations located at Cabramurra (ie the project-related Cabramurra Airstrip station and the BoM Cabramurra SHMEA AWS), the project-related site was excluded from the CALMET modelling to be used for model evaluation purposes. It is noted that there was a high percentage of missing data from the Cabramurra Airstrip station in 2017 (approximately 40%). Therefore, only data for available periods was compared for this evaluation.

Wind speed and direction data recorded at the Cabramurra Airstrip weather station during 2017, excluded as observations from the CALMET model, were used to verify the performance of CALMET in predicting wind conditions.

Wind roses comparing observed and CALMET-predicted wind conditions at the Cabramurra Airstrip weather station are shown in Figure B.1**.**

As seen in the two wind roses presented in Figure B.1**,** the observed and predicted wind direction profiles are very similar, with dominant winds occurring from the west with a less dominant southeast component also evident in both datasets. The average wind speeds were slightly higher in the CALMET predictions (5.0 m/s for CALMET compared with 3.4 m/s for observations). It is noted, however, that the Cabramurra Airstrip weather station records wind conditions at a height of 4.5 m above ground, whereas the CALMET extraction corresponds to 10 m above ground. It is considered that this would influence the difference in wind speed between the two datasets.

The percentage of annual calms (wind speeds less than 0.5 m/s) was also lower in the CALMET predictions (3.4 % compared with 6.7 % for observations).

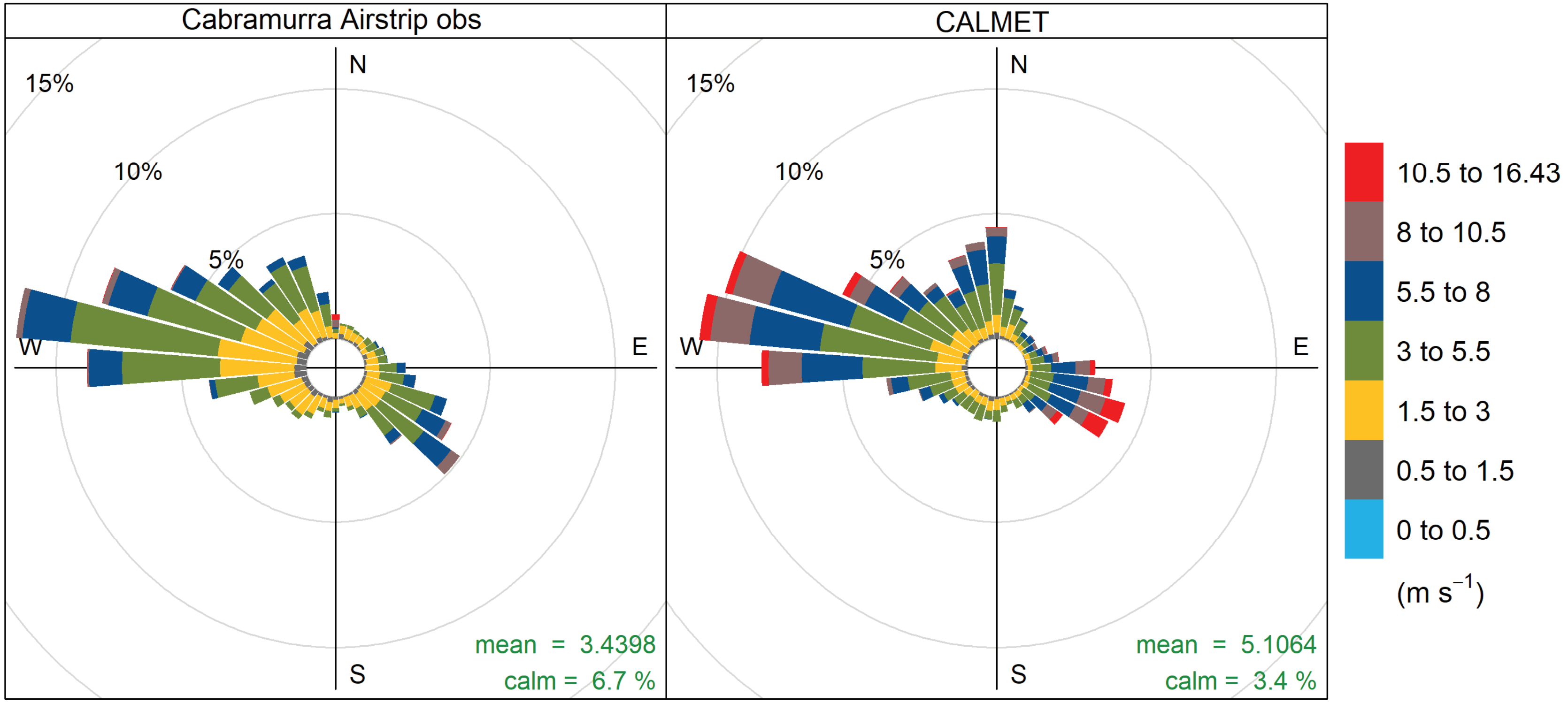


Figure B.1 **Comparison of CALMET winds with observations**

Further evaluation of the model performance is presented using statistical evaluation methods in Table B.2. The indicative performance benchmarks for bias and error are based on Emery et al. (2001). The purpose of these benchmarks was not to give a passing or failing grade to any one particular meteorological model application, but rather to put the model's results into the proper context of other models and meteorological data sets. Since 2001, the benchmarks have been promoted by the EPA-sponsored National Ad Hoc Meteorological Modeling Group and have been consistently relied upon to evaluate Pennsylvania State University / National Center for Atmospheric Research (MM5) and Weather Research and Forecasting (WRF) model performance in many regulatory modelling projects throughout Texas and the U.S.

Table B.2 Statistical evaluation for model performance

Statistical test	Description	
FAC2	$0.5 \leq \frac{M_i}{O_i} \geq 0.5$	Fraction of model predictions (M) within a factor of 2 of the observed values (O)
Mean bias (MB)	$\boldsymbol{MB} = \frac{\boldsymbol{1}}{\boldsymbol{n}} \sum_{\boldsymbol{i=1}}^{\boldsymbol{N}} \boldsymbol{M_i} - \boldsymbol{O_i}$	MB provides an indication of the mean over or underestimate of model predictions and is expressed in the same units as the quantities being considered. Indicative performance benchmark for wind speed is ≤±0.5 m/s and for temperature is ≤± 0.5 K.
Mean Gross Error (MGE)	$\boldsymbol{MGE} = \frac{\boldsymbol{1}}{\boldsymbol{N}} \sum_{\boldsymbol{i=1}}^{\boldsymbol{N}} \lvert \boldsymbol{M_i} - \boldsymbol{O_i} \rvert$	MGE provides an indication of the mean error regardless of whether it is an over or underestimate and is in the same units as the quantities being considered. Indicative performance benchmark for wind speed is ≤ 2.0 m/s and for temperature is ≤ 2.0 K.
Pearson correlation coefficient (r)	$r = \frac{1}{n-1} \sum_{i=1}^{N} \left(\frac{M_i - \bar{M}}{\sigma_M} \right) \left(\frac{O_I - \bar{O}}{\sigma_O} \right)$	The (Pearson) correlation coefficient is a measure of the strength of the linear relationship between two variables. If there is perfect linear relationship with positive slope between the two variables, r = 1.
Index of Agreement (IOA)	$IOA = 1 - \frac{\sum_{i=1}^{N} \lvert M_i - O_i \rvert}{c \sum_{i=1}^{N} \lvert O_i - \bar{O} \rvert}$	Values approaching +1 representing better model performance. (Willmott et al. 2011).

A summary of the model evaluation statistics for CALMET predicted wind speed and temperature is presented in Table B.3. The statistical evaluation for wind speed and temperature at the Cabramurra Airstrip site shows that CALMET performed well for statistics FAC2, MGE and r. CALMET showed a poorer performance of wind speed predictions for statistics MB and IOA. This is likely due to the fact the Cabramurra Airstrip weather station records wind conditions at a height of 4.5 m above ground, whereas the CALMET extraction corresponds to 10 m above ground. It is considered that this would influence the difference in wind speed between the two datasets. Overall, it is considered that CALMET has performed satisfactorily for the prediction of meteorological conditions at the Cabramurra Airstrip site.

Table B.3 Evaluation of CALMET wind speed and temperature against observations at Cabramurra Airstrip

Statistical test	Benchmark (per Table B.2)	Wind speed	Temperature
Fraction of predictions within a factor of 2 (FAC2)	Within a factor of 2 of the observed values	0.84	0.85
Mean bias (MB)	≤±0.5 m/s and for temperature is ≤± 0.5 K	1.66	0.48
Mean Gross Error (MGE)	≤ 2.0 m/s and for temperature is ≤ 2.0 K	1.85	0.88
Pearson correlation coefficient (r)	Values approaching +1 representing better model performance	0.75	0.97
Index of Agreement (IOA)	Values approaching +1 representing better model performance	0.39	0.90

Annexure C

Temporal patterns in the PM_{10} and $PM_{2.5}$ monitoring data

C.1 Temporal variations in the PM_{10} and $PM_{2.5}$ data recorded at the Civic, Florey and Monash monitoring stations

The temporal patterns in the PM_{10} and $PM_{2.5}$ monitoring data were examined using the 'timeVariation' function in the 'openair' software (Carslaw 2019). The timeVariation function examines variation in average concentrations by hour of the day, day of the week and month of the year.

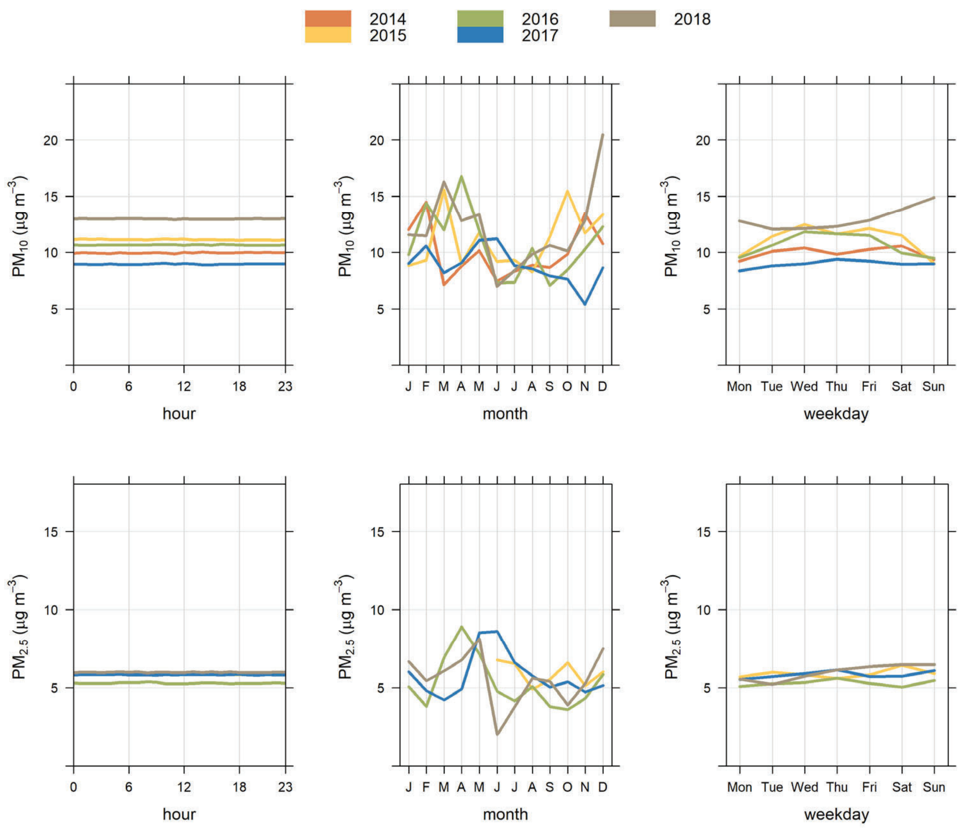


Figure C.1 Time variation in PM_{10} and $PM_{2.5}$ at the Civic station

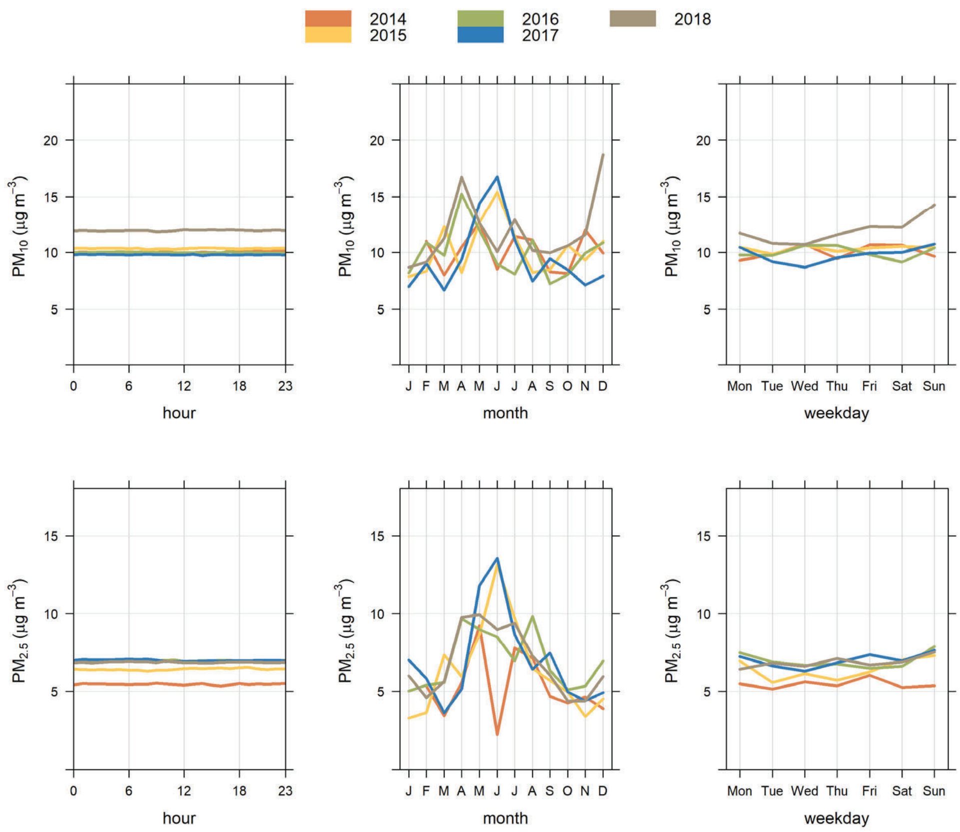


Figure C.2 Time variation in PM_{10} and $PM_{2.5}$ at the Florey station

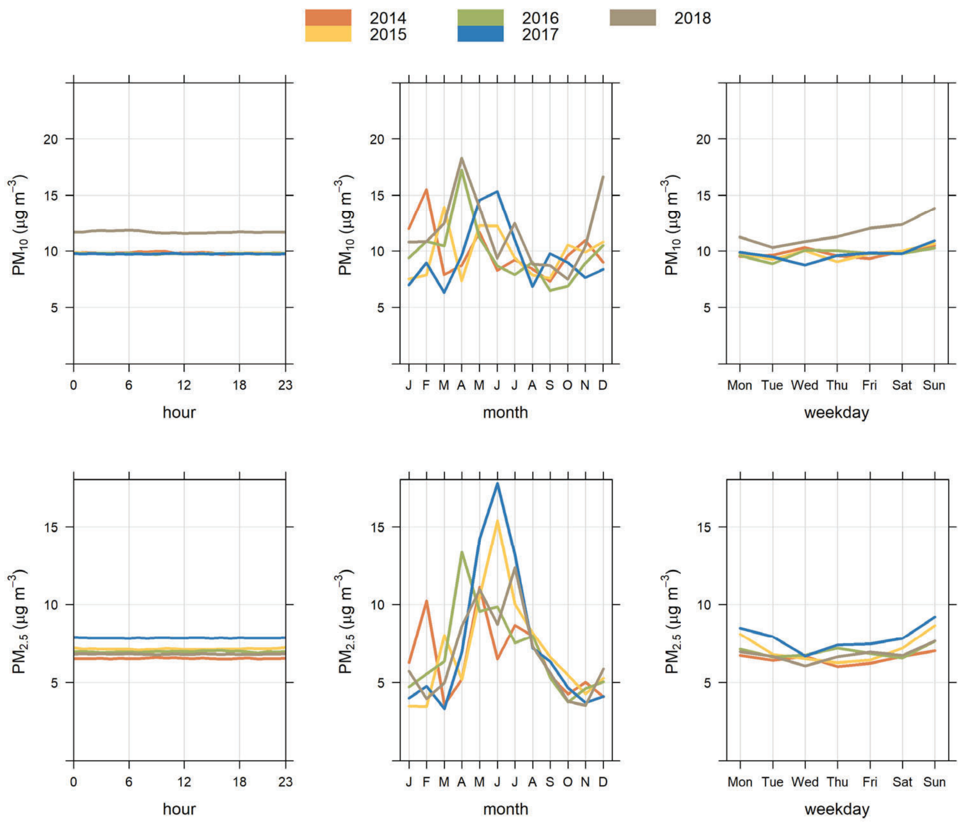


Figure C.3 Time variation in PM_{10} and $PM_{2.5}$ at the Monash station

Annexure D

Emissions inventory background

D.1 Introduction

Particulate matter emissions from the Snowy 2.0 Main Works construction scenario were quantified through the application of accepted published emission estimation factors, collated from a combination of United States Environmental Protection Agency (US-EPA) AP-42 Air Pollutant Emission Factors and NPI emission estimation manuals, including the following:

- US-EPA AP-42 Chapter 11.9 – Western Surface Coal Mining (US-EPA 1998);
- US-EPA AP-42 Chapter 13.2.1 – Paved roads (US-EPA 2011);
- US-EPA AP-42 Chapter 13.2.2 – Unpaved roads (US-EPA 2006a); and
- US-EPA AP-42 13.2.4 – Aggregate handling and storage piles (US-EPA 2006b).

Particulate releases were quantified for TSP, PM_{10} and $PM_{2.5}$ as documented in subsequent sections.

D.2 Sources of particulate matter emissions

Sources of particulate matter emissions associated with the site include:

- conveyors transferring spoil to the surface;
- loading spoil to trucks;
- unloading spoil from trucks to spoil disposal areas and stockpiles;
- dozers working on spoil disposal areas and stockpiles;
- concrete batching plant processes;
- wind erosion from material storage areas;
- vehicles travelling on paved and unpaved roads; and
- diesel combustion from plant equipment, vehicles and generators.

D.3 Particulate matter emissions inventory

The emissions inventory developed for the operations at the site is presented in Table D.1.

Table D.1 Emissions inventory

Source name	Emission estimate TSP (kg/year)	Emission estimate PM_{10} (kg/year)	Emission estimate $PM_{2.5}$ (kg/year)	Activity rate	Units	TSP emission factor	PM_{10} emission factor	$PM_{2.5}$ emission factor	Unit	Parameter 1	Unit	Parameter 2	Unit	Parameter 3	Unit	Parameter 3	Unit	Reduction factor	Emission control	Emission factor source
Tunnel spoil handling																				
Conveyer transferring spoil from Talbingo portal to surface	594	281	43	3,302,363	t/y	0.0002	0.0001	0.00001	kg/t	2.9	Average wind speed (m/s)	10	Moisture content (%)							AP-42 13.2.4
Loading spoil from conveyor to trucks - Talbingo portal	5,652	2,673	405	3,302,363	t/y	0.0017	0.0008	0.00012	kg/t	2.9	Average wind speed (m/s)	2	Moisture content (%)							AP-42 13.2.4
Unloading spoil from trucks to Talbingo spoil disposal	8,983	4,249	643	5,249,141	t/y	0.0017	0.0008	0.00012	kg/t	2.9	Average wind speed (m/s)	2	Moisture content (%)							AP-42 13.2.4
Dozer working on spoil - Talbingo disposal	102,621	24,799	10,775	12,264	h/y	16.7	4.0	1.8	kg/h	10	Silt content (%)	2	Moisture content (%)					0.5	Watering	AP-42 11.9
Conveyer transferring spoil from MAT/ECVT portals to surface	5,581	2,640	400	2,894,414	t/y	0.0019	0.0009	0.00014	kg/t	3.2	Average wind speed (m/s)	2	Moisture content (%)							AP-42 13.2.4
Loading spoil from conveyor to trucks - MAT/ECVT portals	5,581	2,640	400	2,894,414	t/y	0.0019	0.0009	0.00014	kg/t	3.2	Average wind speed (m/s)	2	Moisture content (%)							AP-42 13.2.4
Dozer working on spoil at MAT/ECVT portals	428	202	31	221,743	t/y	0.0019	0.0009	0.00014	kg/t	3.2	Average wind speed (m/s)	2	Moisture content (%)							AP-42 13.2.4
Conveyer transferring spoil from HRT portal to surface	428	202	31	221,743	t/y	0.0019	0.0009	0.00014	kg/t	3.2	Average wind speed (m/s)	2	Moisture content (%)							AP-42 13.2.4
Loading spoil from conveyor to trucks HRT portal	428	202	31	221,743	t/y	0.0019	0.0009	0.00014	kg/t	3.2	Average wind speed (m/s)	2	Moisture content (%)							AP-42 13.2.4
Unloading spoil from trucks to stockpile at SMH	428	202	31	221,743	t/y	0.0019	0.0009	0.00014	kg/t	3.2	Average wind speed (m/s)	2	Moisture content (%)							AP-42 13.2.4
Loading spoil from SMH stockpile to road trucks	25,655	6,200	2,694	3,066	h/y	16.7	4.0	1.8	kg/h	10	Silt content (%)	2	Moisture content (%)					0.5	Watering	AP-42 11.9
Dozer working on spoil at SMH surge stockpile	25,655	6,200	2,694	3,066	h/y	16.7	4.0	1.8	kg/h	10	Silt content (%)	2	Moisture content (%)					0.5	Watering	AP-42 11.9
Conveyer transferring spoil from Tantangara portal to surface	1,570	743	112	2,038,549	t/y	0.0008	0.0004	0.00006	kg/t	1.6	Average wind speed (m/s)	2	Moisture content (%)							AP-42 13.2.4
Loading spoil from Tantangara portal to trucks	2,058	973	147	2,672,038	t/y	0.0008	0.0004	0.00006	kg/t	1.6	Average wind speed (m/s)	2	Moisture content (%)							AP-42 13.2.4
Trucks unloading spoil at Tantangara portal	488	231	35	633,490	t/y	0.0008	0.0004	0.00006	kg/t	1.6	Average wind speed (m/s)	2	Moisture content (%)							AP-42 13.2.4
Trucks unloading spoil to Tantangara spoil disposal	2,058	973	147	2,672,038	t/y	0.0008	0.0004	0.00006	kg/t	1.6	Average wind speed (m/s)	2	Moisture content (%)							AP-42 13.2.4
Dozer working on spoil - Tantangara spoil disposal	102,621	24,799	10,775	12,264	h/y	16.7	4.0	1.8	kg/h	10	Silt content (%)	2	Moisture content (%)					0.5	Watering	AP-42 11.9
All hauling activities																				
Lobs Hole Ravine Road - between Link Road and Mine Trail intersection	3,659,828	987,997	98,800	2,598,150	VKT/year	1.41	0.38	0.04	kg/VKT	6.4	Road silt content (%)	12.9	Haul distance (km)	100,704	Loads/year	19	Average weight (t)			AP-42 13.2.1
Lobs Hole Road - between Main Yard and Talbingo intake/portal (paved)	7,761	1,490	360	387,617	VKT/year	0.1	0.02	0.00	kg/VKT	0.6	Road silt loading (g/m²)	2.0	Haul distance (km)	96,904	Loads/year	33	Average weight (t)	0.75	Water carts	AP-42, S13.2.2
Lobs Hole Road - between Main Yard and Talbingo intake/portal	141,729	38,261	3,826	310,093	VKT/year	1.83	0.49	0.05	kg/VKT	6.4	Road silt loading (g/m²)	1.6	Haul distance (km)	96,904	Loads/year	33	Average weight (t)	0.75	Water carts	AP-42, S13.2.2
Lobs Hole Road - between Talbingo intake/portal and Talbingo spoil disposal	441,956	119,309	11,931	793,765	VKT/year	2.23	0.60	0.06	kg/VKT	6.4	Road silt content (%)	5.0	Haul distance (km)	79,045	Loads/year	52	Average weight (t)	0.75	Water carts	AP-42, S13.2.2
Mines Trail - between Main Yard and MAT/ECVT portal	656,922	177,341	17,734	1,481,051	VKT/year	1.77	0.48	0.05	kg/VKT	6.4	Road silt content (%)	4.7	Haul distance (km)	157,559	Loads/year	31	Average weight (t)	0.75	Water carts	AP-42, S13.2.2
Marica Access Road - between all sites and SMH	104,703	28,265	2,827	244,821	VKT/year	1.71	0.46	0.05	kg/VKT	6.4	Road silt content (%)	8.6	Haul distance (km)	14,284	Loads/year	29	Average weight (t)	0.75	Water carts	AP-42, S13.2.2
Tantangara Road - between SMH and Tantangara portal (uncontrolled)	1,597,005	431,123	43,112	1,202,910	VKT/year	1.33	0.36	0.04	kg/VKT	6.4	Road silt content (%)	15.4	Haul distance (km)	39,157	Loads/year	16	Average weight (t)			AP-42, S13.2.2
Tantangara Road - between SMH and Tantangara portal (paved)	1,519	291	71	156,629	VKT/year	0.039	0.007	0.002	kg/VKT	0.6	Road silt loading (g/m²)	2.0	Haul distance (km)	39,157	Loads/year	16	Average weight (t)			AP-42 13.2.1
Tantangara spoil access road	204,577	55,227	5,523	367,769	VKT/year	2.23	0.60	0.06	kg/VKT	6.4	Road silt content (%)	3.8	Haul distance (km)	48,906	Loads/year	52	Average weight (t)	0.75	Water carts	AP-42, S13.2.2
Concrete batching																				
Concrete batching plants - all sites	9,437	3,773	1,198																	Usage multipled by emissions intensity from Polo Flat segment project
All wind erosion																				
Wind erosion from Talbingo spoil area	18,615	9,308	1,396	21.9	Area (ha)	850	425	64	kg/ha/year											AP-42 11.9
Wind erosion from Marica portal spoil stockpile	850	425	64	1.0	Area (ha)	850	425	64	kg/ha/year											AP-42 11.9
Wind erosion from SMH spoil stockpile	850	425	64	1.0	Area (ha)	850	425	64	kg/ha/year											AP-42 11.9
Wind erosion from Tantangara spoil area	55,505	27,753	4,163	65.3	Area (ha)	850	425	64	kg/ha/year											AP-42 11.9
All diesel combustion																				
Diesel combustion – all sources (trucks, electricity generation)	101,502	101,502	93,043																	Miscellaneous - engine specifications
Total (kg/y)	**7,293,585**	**2,060,697**	**313,504**																	

D.4 Project-related input data used for particulate matter emission estimates

The material property inputs used in the emission estimates are summarised in Table D.2.

Table D.2 Material property inputs for emission estimation

Material properties	Value	Source of information
Paved road silt loading (g/m^2)	0.6	AP-42 S13.2.1, Paved roads, Table 13.2.1-2
Unpaved road silt content (%)	6.4	AP-42 S13.2.2, Unpaved roads emission factor documentation, Table 13.2.2-1
Spoil silt content (%)	10	Jacobs 2018, Snowy 2.0 Exploratory Works
Spoil moisture (%)	2	Jacobs 2018, Snowy 2.0 Exploratory Works

D.5 Concrete batching activities

In the absence of specific details relating to concrete batching activities within the Snowy 2.0 Main Works construction compounds, concrete batching plant emissions have been estimated based on the anticipated amount of concrete production required and the calculated emissions intensity (kg dust per m^3 of concrete produced) of the Polo Flats Segment Factory (EMM 2019).

D.6 Diesel combustion emissions

Diesel combustion emissions were calculated using the following assumptions. Emissions were estimated and added to the fugitive emissions provided as a total in Section 6.3.

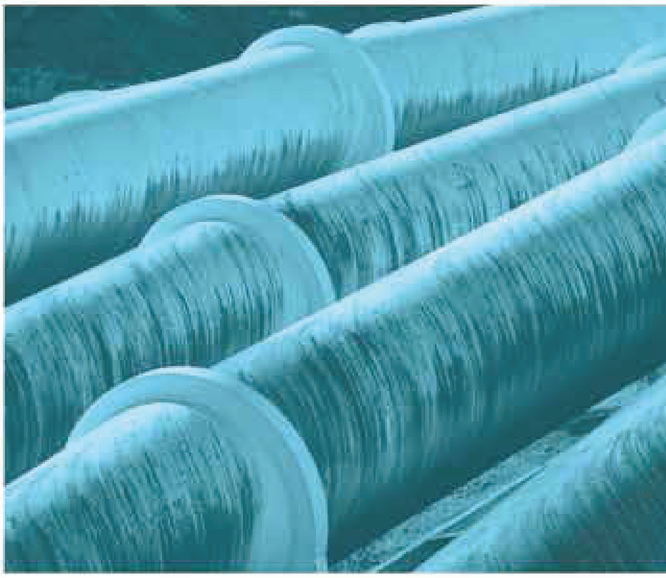
- annual diesel consumption for construction machinery, mobile equipment and vehicles and diesel generators of approximately 28 million litres for a 12-month period, derived from the total projected diesel consumption of 85 million litres;
- emission factors from the NPI Emission Estimation Technique Manual for Combustion Engines (NPI 2008) – (diesel industrial vehicles - miscellaneous); and
- apportioning the total diesel emissions across the project site based on ratio of estimated TSP, PM_{10}, $PM_{2.5}$ and NO_X emissions for each activity.

Table D.3 presents the total estimated emissions for diesel combustion.

Table D.3 Diesel combustion emissions – total Snowy 2.0 Main Works area (kg/y)

	TSP emissions	PM_{10} emissions	$PM_{2.5}$ emissions	NO_x emissions
Total	101,502	101,502	93,043	1,268,774



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