# Vales Point Power Station Air Quality Assessment for Group 5 Exemption Extension

**Prepared for:**

## Delta Electricity

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## Final

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# Glossary

| Term | Definition |
|---|---|
| $\mu g/m^3$ | micrograms per cubic metre |
| µm | microns |
| °C | degrees Celsius |
| °K | degrees Kelvin |
| g/s | grams per second |
| km | kilometre |
| m | metre |
| m/s | metres per second |
| $m^2$ | square metres |
| $m^3$ | cubic metres |
| $m^3/s$ | cubic metres per second |
| $mg/Nm^3$ | milligrams per normalised cubic metre |
| MW | megawatt |
| ppb | parts per billion |
| pphm | parts per hundred million |
| **Nomenclature** | **Definition** |
| $H_2SO_4$ | sulfuric acid |
| $NO_2$ | nitrogen dioxide |
| $NO_x$ | oxides of nitrogen |
| $O_2$ | oxygen |
| $O_3$ | ozone |
| $PM_{10}$ | particulate matter with a diameter less than 10 micrometres |
| $PM_{2.5}$ | particulate matter with a diameter less than 2.5 micrometres |
| $SO_2$ | sulfur dioxide |
| $SO_3$ | sulfur trioxide |
| VOC | volatile organic compounds |
| **Abbreviations** | **Definition** |
| Air NEPM | National Environment Protection (Ambient Air Quality) Measure |
| BoM | Bureau of Meteorology |
| CEMS | Continuous Emissions Monitoring System |
| CSIRO | The Commonwealth Scientific and Industrial Research Organisation |
| DPIE | Department of Planning, Industry and Environment |
| EGM | Eulerian Grid Module |
| EPA | Environmental Protection Authority |
| EPL | Environment Protection Licence |
| GMR | Greater Metropolitan Region (of Sydney) |
| IOA | Index Of Agreement |
| IRTAPS | The Inter-regional Transport of Air Pollutants Study |
| LBL | Load-Based Licensing |
| LPM | Lagrangian Particle Module |
| MAQS | Metropolitan Air Quality Study |
| NEPM | National Environment Protection Measure |
| NPI | National Pollutant Inventory Database |
| NSW | New South Wales |
| OLM | Ozone-Limiting Method |
| POEO Act | *Protection of the Environment Operations Act 1997* |
| RMSE | Root Mean Square Error |
| TAPM | The Air Pollution Model |
| USEPA | United States Environmental Protection Agency |

| Term | Definition |
|---|---|
| VPPS | Vales Point Power Station |

# EXECUTIVE SUMMARY

Katestone Environmental Pty Ltd (Katestone) was commissioned by Delta Electricity to complete an Air Quality Assessment of the Vales Point Power Station (VPPS). The purpose of the air quality assessment is to support a variation to VPPS's existing Environmental Protection Licence 761 (EPL).

Delta Electricity is seeking approval from the New South Wales (NSW) Environment Protection Authority (EPA) to extend the exemption of Group 5 standards of concentration under *Protection of the Environment Operations (Clean Air) Regulation 2010* for nitrogen oxides (NOx) emissions from Points 2 and 3 at VPPS.

The air quality assessment has been conducted in accordance with the requirements defined in the Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales (NSW EPA, 2016) (Approved Methods for Modelling). The dispersion modelling has been conducted using the CSIRO's TAPM meteorological and dispersion model. TAPM is suitable for the application and accounts for factors that are important for characterising atmospheric dispersion on the Central Coast. The TAPM model is recognised in the Approved Methods for Modelling as an appropriate model for use in NSW. The TAPM model is recognised in the literature as providing robust overpredictions of peak statistics. The 99.9th percentile of 1-hour average predicted concentrations is generally recognised as providing a more realistic indication of peak levels rather than maximum (100th percentile) predictions. Both are presented for consistency with the Approved Methods for Modelling.

Air quality on the Central Coast is generally good, with the only measured exceedances of the air quality standards in recent years relating to high particulate concentrations during natural events, specifically regional dust episodes or bushfires. Analysis of local monitoring data has demonstrated that the contribution of VPPS to measured annual mean concentrations of $SO_2$, NOx and, in particular $PM_{2.5}$ is small. However, the influence of emissions from VPPS on concentrations of $SO_2$ and NOx is evident at the specific times when the monitors are downwind of the power station, albeit with total concentrations still well below the air quality standards.

A review of the literature on regional ozone formation, secondary particulate formation and inter-regional transport of air pollutants has also been carried out, focused on identifying the potential contribution of emissions from VPPS to any such processes. It is expected that measures to reduce NOx and $SO_2$ emissions at VPPS would not have a discernible impact on ozone or secondary particulate concentrations across the NSW Greater Metropolitan Region, with any resultant change likely to fall well within the uncertainty bounds of the instruments used for the measurements. There is, therefore, no justification for performing an in-depth inter-regional pollution transport study for this application.

Analysis of emissions data from VPPS over the period 2010 to 2020 has concluded that concentrations of all air pollutants have been below the EPL limits in recent years and, with the exception of NOx, below the Group 6 Clean Air Regulation limits. NOx concentrations in the stack emissions have been consistently reducing over time.

It should be noted that the burner tips on Boiler 6 at VPPS were replaced with low-NOx burner tips earlier in 2021, thus the emissions modelled in this report are likely to over-state ground-level concentrations of $NO_2$ with the new low-NOx burner tips in place. Experience over the last five years at VPPS with low-NOx burner tips installed on Boiler 5 is that the Group 5 standard of concentration for NOx has been met for >99% of the time. It is likely that the same outcome will now be achieved for Boiler 6 at VPPS following installation of the low-NOx burner tips.

Dispersion modelling has been conducted of all regulated air pollutants from VPPS including NOx, $SO_2$, particulate matter (as $PM_{10}$ and $PM_{2.5}$), fluoride and metals. This modelling has demonstrated that emissions from VPPS contribute a relatively small amount to ground-level concentrations of most pollutants (with the exception of $NO_2$ and $SO_2$). For these air pollutants there is no risk of exceedance of the assessment criteria.

Modelled ground-level annual average concentrations of $NO_2$ and $SO_2$ due to VPPS are a fraction of the respective assessment criteria.

The modelling has shown that the maximum 1-hour average concentrations of $NO_2$ associated with emissions from VPPS will not lead to any exceedances of the assessment criterion, in isolation.

Combining ground-level concentrations of $NO_2$ from VPPS with the contributions of other nearby power stations (namely Eraring and Colongra) and background concentrations only results in exceedances of the 1-hour average assessment criterion if an extremely conservative conversion ratio of NOx to $NO_2$ of 40% is assumed. This ratio was only applied as a sensitivity test and the application of the more realistic ratio for peak concentrations of 20% does not result in any exceedances of the assessment criterion. Comparison of modelled versus measured concentrations of $NO_2$ at the Wyee monitoring station has further demonstrated that the model performs very well when using the 20% conversion ratio.

It is, therefore, concluded that there will be no exceedances of the $NO_2$ assessment criteria in the vicinity of VPPS.

For maximum 1-hour concentrations of $SO_2$, some limited areas of exceedance of the assessment criterion of 570 $\mu g/m^3$ are predicted, inclusive of a small number of residential properties, but no more than one hour of exceedance is predicted in any one year. No exceedances of the 24-hour or annual average assessment criteria for $SO_2$ are predicted.

Ground-level concentrations of $SO_2$ from VPPS have been combined with the contributions of the other nearby power stations, and background concentrations, and comparison of modelled and measured concentrations of $SO_2$ at the Wyee monitoring station has demonstrated that the model significantly over-predicts concentrations of $SO_2$. Therefore, while the maximum 1-hour average model predictions exceed the assessment criterion over relatively large areas of the north-western part of the model domain, it is likely that these concentrations have been significantly over-predicted. This over prediction is shown by Origin Energy's measurements of ambient concentrations of $SO_2$ at Dora Creek where the maximum 1-hour average concentration of $SO_2$ in the period 2018-2020 was 188.1 $\mu g/m^3$. This is much lower than the maximum model prediction and is well below the assessment criterion.

In the vicinity of VPPS, no more than two hours of exceedance are predicted in any one year; bearing in mind the model over-predictions, it would seem likely that the assessment criterion will not be exceeded in the vicinity of VPPS.

It is, therefore, concluded that exceedances of the 1-hour, 24-hour or annual mean criteria for $SO_2$ are highly unlikely in the main area of influence of VPPS. Exceedances may occur closer to Eraring but it is important to note that its emissions and therefore potential impacts are likely to have been over-stated. The contribution of VPPS concentrations of $SO_2$ near Eraring was found to be minimal.

Exceedances of the 10-minute average criterion are possible, but these have not been investigated in detail in this study because easy compliance with the criterion has been achieved at the 99.9th percentile. Any such exceedances would be very limited in number, and comparison of modelled versus measured $SO_2$ concentrations at the Wyee monitoring station suggests that concentrations have been over-predicted, especially at the highest concentrations. As such, exceedances of the 10-minute average criterion are unlikely.

To estimate the reduction in emissions of NOx due to the application of Group 5 and Group 6 standards of concentration, the time varying emissions from the last three years of operations have been amended so that any NOx concentrations that exceed the respective limits are replaced with the relevant Group limit value. For Group 5 at least, relatively few hours of data had to be replaced. This analysis demonstrates that, relative to emissions in 2018, 2019 and 2020, the total annual emissions of NOx with the application of the Group 5 standard of concentration reduce by between 1.4 and 5.4%, depending on the year, while the application of the Group 6 standard of concentration reduces total annual emissions of NOx by between 27.1 and 33.0%, depending on the year. However, low-NOx burner tips were installed in Boiler 6 earlier in 2021, and Boiler 6 has historically had much higher NOx emissions than Boiler 5. As such, this analysis is likely to greatly over-state the emissions reductions that would occur by achieving the standards of concentration, and it has been estimated that the realistic scale of reductions in annual mass emissions of NOx would be around 0.5% by achieving the Group 5 standard of concentration and around 20% by achieving the Group 6 standard of concentration.

Dispersion modelling has been repeated for the emission scenarios where the Group 5 and Group 6 standards of concentration for NOx are achieved. Taking VPPS in isolation, adoption of the Group 5 and Group 6 standards of concentration for NOx would reduce the maximum 1-hour average concentration of $NO_2$ anywhere on the modelled grid by 4.5% and 50.5%, respectively, relative to emissions in 2018-2020. Maximum annual average concentrations of $NO_2$ due to VPPS in isolation adopting the Group 5 and Group 6 standards of concentration would reduce by 5.0% and 30.9%, respectively, relative to emissions in 2018-2020. Actual reductions will be much lower because these results do not account for the installation of low-NOx burner tips in Boiler 6 in 2021.

For the cumulative concentrations of $NO_2$, the implementation of Group 5 and Group 6 standards of concentration at VPPS provides much smaller overall changes. Maximum 1-hour average concentrations of $NO_2$ would reduce by 4.5% with the implementation of the Group 5 standard of concentration, and by around 12.6% with the implementation of the Group 6 standard of concentration, relative to emissions in 2018-2020. Maximum annual average concentrations of $NO_2$ are predicted to reduce by just 0.7% with the implementation of the Group 5 standard of concentration, or 2.9% with the implementation of the Group 6 standard of concentration, relative to emissions in 2018-2020. Actual reductions will be much lower because these results do not account for the installation of low-NOx burner tips in Boiler 6 in 2021.

# 1. INTRODUCTION

Katestone Environmental Pty Ltd (Katestone) was commissioned by Delta Electricity to complete an Air Quality Assessment of the Vales Point Power Station (VPPS). The purpose of the air quality assessment is to support a variation to VPPS's existing Environmental Protection Licence 761 (EPL).

Delta Electricity is seeking approval from the New South Wales (NSW) Environment Protection Authority (EPA) to extend the exemption of Group 5 standards of concentration under the *Protection of the Environment Operations (Clean Air) Regulation 2010* for nitrogen oxides (NOx) emissions from Points 2 and 3 (the two ducts that take exhaust gas from the bag filters to the main stack) at VPPS.

On 23 December 2020, the NSW EPA received an application from Delta Electricity to vary EPL 761. On 19 February 2021 the NSW EPA wrote to Delta Electricity advising that additional information was required. On 5 March 2021, Delta Electricity wrote to the NSW EPA seeking input on the specific assessment requirements. On 10 May 2021, NSW EPA replied with a detailed list of requirements. Part 6 of the NSW EPA's letter (items (a) to (p)) identified the requirements for the Air Quality Impact Assessment.

On 8 June 2021, Delta Electricity, Hugh Malfroy of Malfroy Environmental Strategies Pty Ltd and Simon Welchman of Katestone met with the NSW EPA to discuss the NSW EPA's requirements. At the meeting, the NSW EPA agreed to a staged approach of delivery. This report includes a detailed assessment of local air quality (Part 6, Items (a) to (j)) and a preliminary assessment of potential impacts on regional and inter-regional air quality to evaluate the need for detailed photochemical modelling of ground-level ozone and secondary particle formation.

The following scope of works has been conducted and is presented in this report:

- Regulatory framework for air quality has been described.
- Existing air environment has been described including:
    - Land-use and topography
    - Location of sensitive receptors
    - Existing air quality covering 10 years of ambient monitoring data
    - Regional air quality based on recent reviews of air quality in the regions conducted by NSW EPA.
- Emissions analysis considering 10-years of stack testing and continuous emissions monitoring data to the end of 2020.
- Meteorological modelling for a 3-year period to the end of 2020 using the CSIRO's TAPM model.
- Dispersion modelling of VPPS emissions using TAPM to assess potential impacts on local air quality covering the 3-year period to the end of 2020. The following scenarios were intended to be produced:
    - Emissions representative of current normal operations, which routinely meet the existing Environment Protection Licence (EPL) limits (i.e., NOx 1,500 mg/m$^3$; $SO_2$ 1,700 mg/m$^3$; particles 50 mg/m$^3$ – during normal operations emissions are typically well below these thresholds)
    - Emissions representative of Group 5 and Group 6 standards of concentration for NOx (i.e., 800 mg/m$^3$ and 500 mg/m$^3$)
    - Emissions representative of feasible mitigation measures identified in Part 5 of NSW EPA's letter.

- Cumulative air quality impact assessment for $NO_2$, $SO_2$ and particles considering:
    - other existing power stations in the region
    - other significant existing emission sources
    - any currently approved developments which would be significant emission sources
    - background air quality.

The air quality assessment has been conducted in accordance with the requirements defined in the *Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales* (NSW EPA, 2016) (Approved Methods for Modelling).

# 2. LEGISLATIVE FRAMEWORK FOR AIR QUALITY

## 2.1 Overview

The regulation of air pollution in NSW is provided for in the *Protection of the Environment (Operations) Act 1997* (POEO Act), which is underpinned by a number of regulatory instruments that address air quality including:

- *Protection of the Environment Operations (Clean Air) Regulation 2010* (Clean Air Regulation) – imposes generic operational requirements for activities and plant.
- Environmental Protection Licence (EPL) – A licence held by the operator of a scheduled activity that details the activities that may be carried out at the premises and the conditions that must be met to retain that permission.
- *Approved Methods for the Modelling and Assessment of Air Pollutants in NSW* (Approved Methods for Modelling) – provides statutory requirements for the assessment and modeling of air emissions from a premises.
- *Approved Methods for Sampling and Analysis of Air Pollutants in NSW* (Approved Methods for Sampling) – provides statutory requirements for the measurement of air emissions from a premises.
- Load-based licensing (LBL) – an incentive-based scheme where license fees are linked to pollutant loads.

## 2.2 Protection of the Environment (Operations) Act 1997

The POEO Act provides a framework for the:

- Licensing and imposition of licence conditions by NSW EPA in relation to activities that are defined under Schedule 1 of the POEO Act
- Development of Protection of the Environment Policies
- Definition of offences and penalties in relation to air pollution under Sections 124-129
- Definition of offences relating to licensing and conditions
- Development of regulations and guidelines that promulgate impact assessment criteria and emission standards for industry
- Provision of a mechanism for public participation in the environmental assessment of activities that may be licensed by NSW EPA, in conjunction with the *Environmental Planning and Assessment Act 1979* (EP&A Act).

The management of air pollution in NSW is dealt with in *Part 5.4* (sections 124-135) of the POEO Act. This includes the general requirement that non-residential premises do not cause air pollution by failing to operate or maintain plant, carry out work or deal with materials in a proper and efficient manner (sections 124-126).

Section 128 of the POEO Act requires each premises to comply with any air emission standards prescribed by applicable regulations; where standards are not prescribed for a particular air impurity, all practical means must be taken to prevent or minimise air pollution. The Clean Air Regulation specifies emission standards that are relevant to Section 128 of the POEO Act.

## 2.3 Protection of the Environment (Clean Air) Regulation 2010

The Clean Air Regulation prescribes standards of concentration for certain activities and plant in NSW. The standards of concentration are in-stack emission limits and are the maximum emissions permissible from prescribed activities anywhere in NSW. Limits are based on levels that are achievable through the application of reasonably available technology and good environmental practices. The standards of concentration depend on the Group to which the premises belongs, which is defined by Section 32 of the Clean Air Regulation:

> *(1) Subject to this Division, an activity carried out, or plant operated, on scheduled premises:*
>
> > *(a) belongs to Group 1 if:*
> >
> > > *(i) it commenced to be carried on, or to operate, before 1 January 1972, or*
> > >
> > > *(ii) it commenced to be carried on, or to operate, on or after 1 January 1972 as a result of a pollution control approval granted under the Pollution Control Act 1970 pursuant to an application made before 1 January 1972, or*
> >
> > *(b) belongs to Group 2 if it commenced to be carried on, or to operate, on or after 1 January 1972 as a result of a pollution control approval granted under the Pollution Control Act 1970 pursuant to an application made on or after 1 January 1972 and before 1 July 1979, or*
> >
> > *(c) belongs to Group 3 if it commenced to be carried on, or to operate, on or after 1 July 1979 as a result of a pollution control approval granted under the Pollution Control Act 1970 pursuant to an application made on or after 1 July 1979 and before 1 July 1986, or*
> >
> > *(d) belongs to Group 4 if it commenced to be carried on, or to operate, on or after 1 July 1986 as a result of a pollution control approval granted under the Pollution Control Act 1970 pursuant to an application made on or after 1 July 1986 and before 1 August 1997, or*
> >
> > *(e) belongs to Group 5 if it commenced to be carried on, or to operate, on or after 1 August 1997 as a result of:*
> >
> > > *(i) a pollution control approval granted under the Pollution Control Act 1970 pursuant to an application made on or after 1 August 1997 and before 1 July 1999, or*
> > >
> > > *(ii) an environment protection licence granted under the Protection of the Environment Operations Act 1997 pursuant to an application made on or after 1 July 1999 and before 1 September 2005, or*
> >
> > *(f) belongs to Group 6 if it commenced to be carried on, or to operate, on or after 1 September 2005, as a result of an environment protection licence granted under the Protection of the Environment Operations Act 1997 pursuant to an application made on or after 1 September 2005.*
>
> *(2) Any activity or plant that would, but for this subclause, belong to Group 6 is taken to belong to Group 5 if it is the subject of a development consent in respect of which the EPA had given general terms of approval (within the meaning of section 93 of the Environmental Planning and Assessment Act 1979) before 1 September 2005.*

VPPS originally belonged to Group 2 because Boilers 5 and 6 commenced operation in 1978 and 1979, respectively.

However, Group 2 requirements have been phased out under Section 35 of the Clean Air Regulation, which states:

*(1) On and from 1 January 2012, any activity or plant that, immediately prior to that date, belonged to Group 2 (including any activity or plant previously in Group 1) is taken to belong to Group 5.*

*(2) An activity or plant is not taken to belong to Group 5 by virtue of subclause (1) if the conditions of the licence for the activity or plant state that it is taken to belong to Group 1 or 2.*

Therefore, any Group 2 plant is taken to belong to Group 5 unless the EPL includes a condition that the plant is taken to belong to Group 2.

The Clean Air Regulation standards of concentration for electricity generation (using standard fuels) for Group 2 and Group 5 activities are summarised in Table 1. The Clean Air Regulation standards of concentration apply at all times except during start-up and shutdown; the Clean Air Regulation provides an exemption to compliance with the standards of concentration during start-up and shutdown.

**Table 1 Clean Air Regulation standards of concentration for electricity generation for Group 2 and 5 Activities using standard fuels**

| Air impurity | Activity or plant | Standard of concentration | |
|---|---|---|---|
| | | Group 2 | Group 5 ** |
| Solid particles (Total) | Any activity or plant using a liquid or solid standard fuel or a non-standard fuel | 250 mg/m³ * | 100 mg/m³ |
| Nitrogen dioxide ($NO_2$) or nitric oxide (NO) or both, as $NO_2$ equivalent | Any boiler operating on a fuel other than gas, including a boiler used in connection with an electricity generator that forms part of an electricity generating system with a capacity of 30 MW or more | 2,500 mg/m³ *** | 800 mg/m³ |
| Fluorine ($F_2$) and any compound containing fluorine as total fluoride (HF equivalent) | Any activity or plant using a liquid or solid standard fuel or a non-standard fuel | 50 mg/m³ *** | 50 mg/m³ |
| Smoke | Any activity or plant using a liquid or solid standard fuel or a non-standard fuel<br>(in approved circumstances) | Ringelmann 3 or 60% opacity | Ringelmann 3 or 60% opacity |
| | Any activity or plant using a liquid or solid standard fuel or a non-standard fuel<br>(in other circumstances) | Ringelmann 1 or 20% opacity | Ringelmann 1 or 20% opacity |

Table note:
* Reference conditions are dry, 273K, 101,3kPa, 12% $CO_2$
** Reference conditions are dry, 273K, 101,3kPa, 7% $O_2$
*** Reference conditions are dry, 273K, 101,3kPa

## 2.4 Exemptions under Clean Air Regulation

Where it can be demonstrated that the operation of Group 2 plant that is subject to phase out under Section 35 will not result in any adverse environmental or human health impacts, a licence variation may be granted by the NSW EPA exempting the premises from complying with Group 5 standards for a period of up to five years. The requirements and determination of a licence variation application (application) for an exemption from Group 5 facility are specified in Section 35, 36 and 37 of the Clean Air Regulation.

Section 35 states:

> *(3) An application for the variation of the conditions of a licence for the purpose of including a statement referred to in subclause (2) must be made—*
>
> > *(a) in the case of an application for the first such variation, on or before 1 January 2011, and*
> >
> > *(b) in the case of an application for any subsequent variation, no later than 12 months before the date on which the current variation expires pursuant to subclause (4).*
>
> *(4) A variation of the conditions of a licence under this clause expires at the end of 5 years after the date on which notice of the variation is given to the holder of the licence under section 58 of the Act.*

Section 36 (Alternative standards imposed by licence conditions) states:

> *An application for the variation of the conditions of a licence for any activity, plant or emission unit for the purpose of including a statement referred to in clause 33 (3), 34 (2) or 35 (2) is to be accompanied by a report containing each of the following—*
>
> *(a) particulars of the concentration or rates at which air impurities are emitted as a result of the carrying out of the activity or operation of the plant, based on sampling, analysis and monitoring carried out in accordance with the Approved Methods (Sampling and Analysis) Publication,*
>
> *(b) the results of an air pollutant impact assessment, conducted in accordance with the Approved Methods (Modelling and Assessment) Publication, in relation to—*
>
> > *(i) the activity, plant or emission unit concerned, and*
> >
> > *(ii) any other activity carried on, or plant or emission unit operated, at the scheduled premises concerned,*
>
> *(c) details of any pollution reduction programs that have been established in relation to the activity, plant or emission unit,*
>
> *(d) details of any control equipment that has been installed in relation to the activity, plant or emission unit,*
>
> *(e) such other information as may be relevant to demonstrate the acceptability of impacts associated with the alternative standards arising from the proposed variation of conditions.*

Section 37 (Determination of application for variation of licence) states:

> *(1) In determining an application to vary the conditions of a licence for any activity or plant for the purposes of clause 33, 34 or 35, the EPA must consider the impact on local and regional air quality and amenity of a decision to grant the application, having regard to—*
>
> > *(a) any pollution reduction programs that have been established, or that the holder of the licence has agreed to establish, in relation to the activity or plant, and*
> >
> > *(b) any control equipment that has been installed, or that the holder of the licence has agreed to install, in relation to the activity or plant, and*

(c) *any load reduction agreement that has been entered into between the EPA and the applicant under Division 4 of Part 1 of Chapter 2 of the Protection of the Environment Operations (General) Regulation 2009, and*

(d) *the principles of ecologically sustainable development set out in section 6 (2) of the Protection of the Environment Administration Act 1991, and*

(e) *such other matters as are relevant.*

(2) *A statement referred to in clause 33 (3), 34 (2) or 35 (2) that is included in the conditions of the licence for any activity, plant or emission unit pursuant to an application made in accordance with clause 36 may not state that the activity or plant belongs to a Group with a lower number than that of the Group to which the activity or plant previously belonged.*

(3) *Nothing in this clause prevents the EPA, when granting an application to vary the conditions of a licence under this clause, from including other conditions in the licence, including conditions imposing more stringent standards of concentration than those applicable to the Group to which the activity or plant will belong as a consequence of the variation.*

*Note—*

*Refusal of an application to vary the conditions of a licence may be appealed under section 287 of the Act. In this regard, an application is taken to have been refused if it is not granted within 60 days after it is duly made.*

In June 2011, Delta Electricity received formal notification granting an exemption to the Group 5 standard of concentration for oxides of nitrogen (NOx) until 1 January 2017, but with a more stringent EPL NOx emission limit of 1,500 mg/m$^3$ compared with the Group 2 standard of concentration for NOx of 2,500 mg/m$^3$. Delta Electricity successfully re-applied for the exemption to be extended for a further 5 years to 1 January 2022 in 2015.

## 2.5 VPPS Environment Protection License

An EPL permits the holder of the licence to undertake an activity that is included in Schedule 1 of the POEO Act. The EPL specifies the intensity of the activity that can be undertaken and the conditions that must be met whilst the activity is undertaken with respect to regulating the activity's environmental impact.

Delta Electricity operates VPPS under EPL 761 which includes the following in relation to air quality:

- Identification of discharge points for setting emission limits and monitoring requirements
- Limit conditions that specify the maximum concentration that may be emitted from a discharge point, which are reproduced in Table 2
- Load limits that specify the maximum annual pollutant discharge allowed from the premises
- Operating conditions that, for activities utilising standard fuels, tend to reflect the requirements of the license for the operator to maintain plant and equipment and deal with materials in a proper and efficient manner
- Monitoring conditions that specify the frequency and method required to monitor emissions of air pollutants from discharge points
- Reporting conditions.

**Table 2 VPPS EPL limits for air pollutants that apply to Boiler 5 and Boiler 6**

| Pollutant | EPL 761 Air Concentration Limit |
|---|---|
| Cadmium | 0.2 |
| Chlorine | 20 |
| Fluorine | 30 |
| Hydrogen chloride | 50 |
| Mercury | 0.05 |
| NOx | 1,500[1], 1,100[2] |
| Solid particles | 50 |
| Sulfuric acid mist and sulfur trioxide (as $SO_3$) | 100 |
| Sulfur dioxide | 1,700[1], 1,400[2] |
| Type 1 and 2 substances in aggregate | 0.75 |
| VOC as n-propane equivalent | 10 |

Table notes:
[1] 100th percentile concentration limit
[2] 99th percentile concentration limit

## 2.6 Approved Methods for Modelling

In NSW, air quality impact assessments of new activities or amendments to existing activities are carried out in accordance with the Approved Methods for Modelling, which lists the statutory methods for modelling and assessing emissions of air pollutants from stationary sources. The Approved Methods for Modelling is subordinate legislation under Part 4 of the Clean Air Regulation.

The purpose of an air quality impact assessment is to demonstrate that the proposal is designed, constructed and operated in a manner that minimise air quality impacts (including nuisance dust and odour) and minimises risks to human health and the environment to the greatest extent practicable.

The Approved Methods for Modelling lists the statutory methods for modelling and assessing emissions of air pollutants from major projects in NSW. The Approved Methods for Modelling is referred to in:

- Conditions attached to statutory instruments including environmental assessment requirements under Part 4 of the *Environmental Planning and Assessment Act 1979* (EP&A Act)
- Part 5: Air Impurities Emitted from Activities and Plant in the Clean Air Regulation.

In general, the Approved Methods for Modelling includes information and methods for the following:

- Preparation of emissions inventory data
- Preparation of meteorological data
- Accounting for background concentrations and dealing with elevated background concentrations
- Dispersion modelling
- Interpretation of dispersion modelling results
- Impact assessment criteria for:
    - Sulfur dioxide ($SO_2$), nitrogen dioxide ($NO_2$), ozone ($O_3$), lead (Pb), $PM_{2.5}$, $PM_{10}$, total suspended particulates (TSP), deposited dust, carbon monoxide (CO) and hydrogen fluoride (HF)
    - Individual and complex mixtures of toxic air pollutants

    - Individual and complex mixtures of odorous air pollutants
- Modelling of chemical transformation
- Procedures for developing site-specific emission limits, including hydrogen sulfide.

This air quality assessment has been conducted in accordance with the Approved Methods for Modelling. Impact assessment criteria that are relevant to the assessment are reproduced in Table 3.

**Table 3 Impact assessment criteria (Approved Methods for Modelling)**

| Pollutant | Averaging period | Impact assessment criterion (μg/m³) |
|---|---|---|
| $NO_2$ | 1-hour | 246 |
| | Annual | 62 |
| $SO_2$ | 10-minutes | 712 |
| | 1-hour | 570 |
| | 24-hour | 228 |
| | Annual | 60 |
| $PM_{10}$ | 24-hour | 50 |
| | Annual | 25 |
| $PM_{2.5}$ | 24-hour | 25 |
| | Annual | 8 |
| Hydrogen Fluoride | 24-hour | 2.9 |
| | 7-day | 1.7 |
| | 30-day | 0.85 |
| | 90-day | 0.5 |
| Chlorine | 1-hour | 50 |
| Hydrogen Chloride | 1-hour | 140 |
| Sulfuric acid | 1-hour | 18 |
| Antimony | 1-hour | 9 |
| Arsenic | 1-hour | 0.09 |
| Beryllium | 1-hour | 0.004 |
| Cadmium | 1-hour | 0.018 |
| Chromium | 1-hour | 0.09[1] |
| Lead | Annual mean | 0.5 |
| Manganese | 1-hour | 18 |
| Mercury | 1-hour | 1.8[2] |
| Nickel | 1-hour | 0.18 |

Table notes:

[1] Impact assessment criterion for Chromium VI compounds

[2] Impact assessment criterion for Mercury inorganic

The Approved Methods for Modelling requires that an air quality assessment addresses the potential for cumulative impacts with existing activities by the addition of site specific or site representative background concentrations of specific air pollutants; those relevant to this assessment are $SO_2$, $NO_2$, Pb, $PM_{2.5}$, $PM_{10}$ and HF.

# 3. ASSESSMENT METHODOLOGY

## 3.1 Literature review for ozone and secondary particle formation

An assessment of the potential for significant regional ozone formation, secondary particulate formation and inter-regional transport of air pollutants has been conducted by considering existing relevant literature. Since the mid-1990s, considerable research has been conducted into air quality in the Greater Metropolitan Region of NSW. Much of this research is of a very high standard and is directly relevant to Vales Point Power Station (VPPS). Beginning with the Metropolitan Air Quality Study of 1996, relevant studies dealing with ozone formation, secondary particle formation and inter-regional transport of air pollutants have included:

- NSW EPA, 1996, MAQS Metropolitan Air Quality Study: outcomes & implications for managing air quality.
- CSIRO, 2002, Inter-regional Transport of Air Pollutants Study (IRTAPS), Investigation Report ET/IR 570R.
- Malfroy, H., Cope, M., Nelson, P., 2005, An assessment of the contribution of coal-fired power station emissions to atmospheric particle concentrations in New South Wales, International Clean Air and Environment Conference (17th: 2005).
- Hibberd, M.F., Keyword, M.D., Selleck, P.W., Cohen, D.D., Stelcer, E., Scorgie, Y., Chang, L., 2016. Lower Hunter Particle Characterisation Study Final Report 2016. Technical Report. Report prepared by CSIRO, ANSTO and the NSW Office of Environment and Heritage on behalf of the NSW Environment Protection Authority. Sydney.
- David D Cohen, Armand J Atanacio, Eduard Stelcer, David Garton, 2016, Sydney Particle Characterisation Study, PM2.5 Source Apportionment in the Sydney Region between 2000 and 2014, Australian Nuclear Science and Technology Organisation.
- Hiep Nguyen Duc, Lisa T.-C. Chang, Toan Trieu, David Salter and Yvonne Scorgie, 2018, Source Contributions to Ozone Formation in the New South Wales Greater Metropolitan Region, Australia, Atmosphere 9, no. 11: 443.
- Lisa T.-C. Chang *, Yvonne Scorgie, Hiep Nguyen Duc, Khalia Monk, David Fuchs and Toan Trieu, 2019, Major Source Contributions to Ambient $PM_{2.5}$ and Exposures within the New South Wales Greater Metropolitan Region, Atmosphere 2019, 10(3), 138.
- DPIE, 2020, Air Quality Study for the NSW Greater Metropolitan Region, A Sydney Air Quality Study Program Report
- Richard A. Broome, Jennifer Powell, Martin E. Cope, Geoffrey G. Morgan, 2020, The mortality effect of $PM_{2.5}$ sources in the Greater Metropolitan Region of Sydney, Australia, Environment International, Volume 137.

These studies have been considered in the context of NSW EPA's air emissions inventory for 2013 and NPI data for the ten-year period to 2019/20 to draw inferences as to the significance of VPPS to ozone, secondary particle formation and inter-regional transport.

## 3.2 Existing environment

Existing air quality conditions in the vicinity of VPPS have been identified through the analysis of air quality monitoring data from local monitoring stations. The focus of the analysis has been on identifying the contribution of VPPS and, to a lesser extent, other nearby power stations (namely Colongra and Eraring) to measured concentrations at the monitoring stations. However, the data have also been used to inform baseline concentrations for use in the dispersion modelling assessment.

Air quality and meteorological monitoring data from monitoring sites operated by Delta Electricity and the NSW EPA have been imported into the R software package for detailed analysis.

Delta Electricity operates or has operated monitoring sites at Wyee, Munmorah School and Mirabooka. However, only Wyee has more than a few months of data capture in the past ten years, therefore the analysis of data from sites operated by Delta Electricity has focussed solely on this site.

The two nearest NSW EPA sites are Wyong and Morisset, although Morisset has only operated since November 2020, thus the analysis of data from NSW EPA sites has focussed solely on Wyong.

The locations of the nearby monitoring sites are shown alongside the locations of the power stations in the area in Figure 1.

**Figure 1** **Power Stations and Air Quality Monitoring Station Locations**

Imagery ©2021 Google.

The analysis has involved the production of a large number of plots and statistics; only those considered most pertinent to the objective of identifying the contribution of VPPS to locally measured concentrations have been presented in Section 5 of this report.

Seven different types of plots are presented, these being:

- Wind roses, which show the frequency of winds of different speeds blowing from wind sectors of 30°, either on a seasonal or an annual basis. Mean wind speeds and the frequency of calms are also presented.
- Pollution roses, which are similar to wind roses, use colour to show the frequency of pollutant concentrations in set bands by wind direction. Their shape is identical to those of wind roses, as they still plot the frequency of winds by direction, but their colouring reflects pollutant concentration rather

than wind speed. Mean concentrations and the frequency of calms are also presented. They are useful in identifying whether certain wind directions might tend to result in higher or lower concentrations than others.

- Proportion contribution roses differ to the other roses, presenting the proportion contribution to the period mean concentrations by wind direction. The radial extent of each rose arm reflects the percentage of the period mean concentration that winds from that 30° sector have contributed, while the colouring of the arm reflects the magnitude of the concentrations measured under those wind conditions. These are very useful in highlighting which wind directions carry the most pollution to a monitor over a given period of time, as well as whether especially high concentrations from specific wind directions are contributing a significant portion of the mean, as might be expected for the wind directions that place a monitor downwind of a nearby power station.
- Polar plots present average pollutant concentrations by wind direction and binned wind speed, with colour reflecting the average concentrations and the radial axis the wind speed. They can be very useful in identifying whether specific wind speed and direction combinations lead to higher average concentrations; for example a ‘blob’ of colour denoting higher concentrations that is offset from the centre of the plot likely represents a point source of emissions located in that general direction. The further from the centre of the plot a ‘blob’ is located, the more distant the source. Another example would be a line of higher concentrations running across a plot, slightly offset from the centre; this would likely denote a line source, such as a road, on that side of the monitor.
- Polar annulus plots present average pollutant concentrations by wind direction and time (in this report, they are presented by hour of the day). The centre of the ‘donut’ is the first hour of the day, while the outer edge is the last hour of the day. These plots really highlight how concentrations can differ by time of day and by wind direction, but their interpretation requires careful consideration of local wind conditions as well, as winds from a certain direction may be more common at certain times of the day (e.g. sea breezes).
- TheilSen plots present monthly average concentrations with a slope fitted that is an estimate of the trend in concentrations over that period of time. The slope estimate and confidence intervals are plotted and numerical information presented, in this case the trend and confidence intervals as a percentage per year. The statistical significance of the trend is also presented, with *** representing a 99.9% confidence interval, ** a 99% confidence interval, * a 95% confidence interval and + a 90% confidence interval.
- Scatter plots have been used to present contemporaneous measured concentrations of different pollutants, to identify whether elevated concentrations of one tend to coincide with elevated concentrations of the other. These have focussed ion using $SO_2$ as a marker for power station emissions.

## 3.3 Analysis of VPPS emissions data

Stack testing and continuous emission monitoring data collected between 2010 and 2020 have been analysed in Section 6 to identify how the actual emissions from VPPS compare to the emission limits set in its EPL. This measured data has then been used to inform some of the scenarios modelled, and the discussion around the potential impacts of emissions from VPPS.

## 3.4 Dispersion model

The Air Pollution Model (TAPM) has been used in this assessment; TAPM is an atmospheric model developed by the Commonwealth Scientific and Industrial Research Organisation (CSIRO). TAPM integrates a prognostic meteorological model and an air dispersion model. TAPM is an incompressible, primitive equation model with a terrain-following vertical coordinate for three-dimensional simulation, which can be run in either hydrostatic or non-hydrostatic mode. TAPM resolves regional scale meteorology and incorporates local terrain and land use information to predict meteorological conditions representative of the locations of interest.

The dispersion modelling component of TAPM uses the meteorology and turbulence from the meteorological component. The Eulerian Grid Module (EGM) solves prognostic equations for the mean and variance of concentration; while near-source dispersion is optimised by using the Lagrangian Particle Module (LPM). More detailed discussion of the model can be found on the TAPM Technical Report (CSIRO, 2008).

## 3.5 Model configuration and assessment scenarios

TAPMv4 was used to predict local meteorological conditions and pollution dispersion for the Central Coast Area for the years 2018, 2019 and 2020. The meteorological component of the model was configured to run in a nested domain, with resolutions of 30 km, 10 km, 3 km, and 1 km, with 45 grid points along the x- and y- axes, centred at Vales Point, and 25 vertical grid levels.

Further details of the dispersion modelling methodology, and meteorological approach, are provided in Appendix A1.

Emissions of $NO_X$ were modelled in TAPM within a fine mesh grid of 1km using LPM for near field dispersion before converting to EGM for far field calculations. The conversion timestep from LPM to EGM was set to 900 s (TAPM default).

In terms of pollutant concentrations and mass emissions, three emissions scenarios were modelled for VPPS:

- Scenario 1: Current operation emissions, based upon the analysis of stack testing and continuous emission monitoring data
- Scenario 2: Group 5 standard of concentration for NOx
- Scenario 3: Group 6 standard of concentration for NOx

It was not considered necessary to model emissions at the current license limits, as the emissions monitoring results set out in Section 6 for the past 10 years demonstrate that these would produce unrealistic results, as emissions are typically well below the license limits.

The relevant pollutant emission rates under each scenario are set out in Section 3.6, along with the physical stack emission parameters modelled.

The scenarios assessed in terms of cumulative impacts associated with emissions from other nearby power stations, and existing baseline concentrations, are described further in Section 3.6.3.

## 3.6 Modelled emissions

Table 4 details the basic stack characteristics employed in all modelling of emissions from VPPS. All other release parameters are variable, and the values used in the modelling are detailed further in the following sections.

**Table 4 Stack characteristics for dispersion modelling of VPPS**

| Parameter | Value | Units |
|---|---|---|
| Stack height | 178 | m |
| Stack radius | 5.15 | m |

### 3.6.1 NOx and $SO_2$

NOx and $SO_2$ concentrations are continuously measured in the exhaust system of the power station. Measured data have been used to build a variable emission file that has been input to the model. The variable emissions file contains exit velocity, temperature and NOx and $SO_2$ mass emission rates for each hour of the years 2018 to 2020.

The continuous monitoring system does not measure volume flow or velocity, thus it was necessary to estimate these parameters based on an assumed linear relationship between load and volume flow. The maximum normalised volume flow rate measured in the stack testing carried out between 2010 and 2020 (see Section 6 for the presentation of the stack emissions monitoring data) was 833 $m^3/s$ for Boiler 5 and 800 $m^3/s$ for Boiler 6. It was assumed that these maximum volume flow rates would correspond relatively closely to the maximum loads measured by the continuous emissions monitoring system, these being 664 MW for Boiler 5 and 695 MW for Boiler 6. Hour-by-hour normalised volume flow rates were estimated from the load data, with actual volume flow rates and exit velocities then derived using the concurrent temperature measurement.

Where gaps occurred in the continuous emissions monitoring data, a conservative approach was taken to filling these, seeking to represent a realistic worst-case scenario. For example, where load data were missing but concentration data were available, it was assumed that the boiler was operating at its maximum load measured at any time in 2018 to 2020. Missing pollutant concentration data for one pollutant were filled either using an average ratio of $SO_2$/NOx, where the other pollutant was available, or using the maximum measured at any time in 2018 to 2020 for the relatively few occasions when data for neither pollutant were available, yet the boiler was operational.

Table 5 provides a summary of the data input via the time varying emissions file; the minimum values of zero relate to the rare occasions when neither boiler at VPPS was operational. Table 6 presents the total annual NOx and $SO_2$ emissions calculated from the time varying emissions data. These are higher than the totals reported in the NPI for each year, demonstrating the conservative approach adopted in the modelling.

**Table 5** **Summary of time varying emissions data employed in the modelling of NOx and $SO_2$ emissions from VPPS (2018-2020)**

| Parameter | Minimum | Maximum | Mean | Median |
|---|---|---|---|---|
| NOx Emission Rate (g/s) | 0.0 | 1,825.5 | 748.2 | 745.4 |
| $SO_2$ Emission Rate (g/s) | 0.0 | 2,190.4 | 769.9 | 780.1 |
| Temperature (°K) | 293.15[1] | 400.1 | 381.5 | 381.6 |
| Velocity (m/s) | 0.0 | 29.3 | 18.71 | 19.6 |

Table note:

[1] A temperature of 20°C was applied to hours when a boiler was not operational.

**Table 6** **Total annual VPPS pollutant emissions calculated from time varying emissions data (tonnes/year)**

| Pollutant | 2018 | 2019 | 2020 |
|---|---|---|---|
| NOx | 24,395 | 24,891 | 21,580 |
| $SO_2$ | 24,094 | 27,937 | 20,894 |

### 3.6.2 Other pollutants

Table 7 and Table 8 present the stack characteristics and emission rates used in the dispersion modelling of emissions from VPPS for pollutants other than NOx and $SO_2$. These were modelled separately using constant emission parameters and pollutant emission rates, which can be expected to overstate the actual impacts. The modelled emission rates in Table 8 are based on measured concentrations from annual stack testing (summarised in Section 6). For the assessment of hydrogen fluoride concentrations against the impact assessment criteria in the Approved Methods for Modelling, it has been assumed that the measured fluorides concentration is entirely hydrogen fluoride.

**Table 7 Physical emission parameters for dispersion modelling of other pollutants**

| Parameter | Value | Units |
|---|---|---|
| Temperature | 369 [1] | deg K |
| Velocity | 26 | m/s |

Table note:

[1] Minimum temperature measured in stack testing of Boilers 5 and 6 between 2010 and 2020, a worst-case assumption.

**Table 8 Emission rates for dispersion modelling of other pollutants**

| Pollutant | 2018 | 2019 | 2020 |
|---|---|---|---|
| **Emission concentration (mg/Nm$^3$)** | | | |
| Chlorine | 0.27 | 0.12 | 0.11 |
| Fluorides | 1.83 | 1.27 | 1.69 |
| Hydrogen chloride | 3.90 | 0.31 | 0.58 |
| Solid particles | 6.50 | 20.27 | 4.35 |
| Sulfuric acid mist and sulfur trioxide (as $SO_3$) | 17.11 | 6.39 | 8.43 |
| Antimony | 0.00007 | 0.00003 | 0.00030 |
| Arsenic | 0.00009 | 0.00005 | 0.00008 |
| Beryllium | 0.00005 | 0.00004 | 0.00004 |
| Cadmium | 0.00307 | 0.00030 | 0.00281 |
| Chromium | 0.00137 | 0.00086 | 0.00156 |
| Cobalt | 0.00009 | 0.00009 | 0.00004 |
| Lead | 0.00177 | 0.00130 | 0.00076 |
| Manganese | 0.00110 | 0.02519 | 0.01309 |
| Mercury | 0.00014 | 0.00042 | 0.00027 |
| Nickel | 0.00175 | 0.00099 | 0.00142 |
| Selenium | 0.00010 | 0.00014 | 0.00040 |
| Tin | 0.00031 | 0.00058 | 0.00076 |
| Vanadium | 0.00009 | 0.00004 | 0.00006 |
| **Mass emission rate (g/s)** | | | |
| Chlorine | 0.41 | 0.18 | 0.17 |
| Fluorides | 2.75 | 1.91 | 2.53 |
| Hydrogen chloride | 5.86 | 0.46 | 0.87 |
| Solid particles | 9.76 | 30.42 | 6.53 |
| Sulfuric acid mist and sulfur trioxide (as $SO_3$) | 25.68 | 9.59 | 12.65 |
| Antimony | 0.00011 | 0.00004 | 0.00046 |
| Arsenic | 0.00013 | 0.00007 | 0.00013 |
| Beryllium | 0.00008 | 0.00006 | 0.00006 |
| Cadmium | 0.00461 | 0.00045 | 0.00421 |
| Chromium | 0.00206 | 0.00129 | 0.00234 |
| Cobalt | 0.00013 | 0.00014 | 0.00005 |
| Lead | 0.00265 | 0.00195 | 0.00115 |
| Manganese | 0.00165 | 0.03780 | 0.01965 |

| Pollutant | 2018 | 2019 | 2020 |
|---|---|---|---|
| Mercury | 0.00021 | 0.00062 | 0.00040 |
| Nickel | 0.00263 | 0.00148 | 0.00213 |
| Selenium | 0.00015 | 0.00020 | 0.00060 |
| Tin | 0.00046 | 0.00087 | 0.00114 |
| Vanadium | 0.00013 | 0.00006 | 0.00010 |

### 3.6.3 Group 5 and Group 6 standards of concentration

For Scenarios 2 and 3 (see Section 3.5), the time varying emissions input into the model have been edited so that any NOx concentrations that exceed the respective Group 5 and Group 6 standards of concentration are replaced with the relevant Group limit value. For Boiler 5, only 169 hours of NOx concentration data had to be replaced across the three years in order to reflect compliance with the Group 5 standard of concentration (which is less than 1% of hours); for Boiler 6, 11,247 hours (49%) of data were replaced (but it should be remembered that low-NOx burner tips have since been installed in Boiler 6). To achieve the Group 6 standard of concentration, 93.8% of the data for Boiler 5 had to be replaced, while 99.6% of the data had to be replaced for Boiler 6.

The pollutant emission concentrations pertaining to Scenarios 2 and 3 are detailed in Table 9; mass emission rates were calculated hour-by-hour using the concurrent volume flow and temperature data.

**Table 9 Emission rates for dispersion modelling of Scenarios 2 and 3**

| Pollutant | Scenario 2: Group 5 standard of concentration | Scenario 3: Group 6 standard of concentration |
|---|---|---|
| NOx **e**mission concentration (mg/Nm$^3$) | 800 | 500 |

### 3.6.4 Emissions representative of feasible mitigation

The NSW EPA's letter of 10 May 2021 requested dispersion modelling of VPPS emissions that are representative of feasible mitigation measures identified in the report prepared in response to Part 5 of NSW EPA's letter. Delta Electricity commissioned Jacobs to complete the response to Part 5 of the NSW EPA's letter (Jacobs, 2021b).

In relation to potential NOx emission controls, Jacobs (2021b) found the following that is of relevance to this study:

- The NOx reduction measures that are feasible for implementation when considering both the technical and cost implications are:
    - Burner optimisation for NOx control using air staging with an estimated maximum emissions reduction potential of 10%
    - Continued cofiring of up to 3% biomass with an estimated NOx reduction potential of 2% on average
- Whilst the NOx reductions from these measures have been estimated, the benefits of a retrofitted NOx control system are uncertain.
- None of the feasible NOx reduction measures would guarantee compliance with the Group 5 standard of concentration of 800mg/Nm$^3$ for 100% of the time.
- None of the feasible NOx reduction measures could achieve the Group 6 standard of concentration of 500mg/Nm$^3$.

In relation to potential SOx emission controls, Jacobs (2021c) found that none were viable.

As a result, it has not been possible to derive a robust set of emissions data for scenarios representative of additional mitigation being installed, thus no such scenarios have been modelled.

## 3.7 Cumulative assessment

As well as VPPS, emissions from other nearby power stations have also been accounted for in the study. Details are provided in the following sections.

### 3.7.1 Existing power stations

Emissions from the Eraring coal-fired power station and Colongra gas-fired peaking power station have also been modelled in TAPM. Preliminary physical emission parameters for these facilities, and NOx mass emission rates, have been taken from Table 2 of the 2010 Dispersion Modelling Study of Emissions of Oxides of Nitrogen from the Vales Point Power Station (Katestone, 2010). The physical emission parameters are detailed in Table 10; emissions from each stack at each facility have been modelled as separate sources, as it is common for not all to be operational at the same time. The NOx emissions for Eraring in Table 10 are unrealistically high, and have only been used to derive a conservative $PM_{10}$ emission rate; more realistic time varying emissions data for NOx and $SO_2$ have been used in the modelling (see Table 13).

**Table 10 Emission parameters for Eraring and Colongra**

| Parameter | Eraring | Colongra |
|---|---|---|
| Stack Locations (x,y) | 361950,6340900<br>361900,6340700 | 364363,6324555<br>364387,6324528<br>364414,6324494<br>364439,6324466 |
| Stack heights above ground (m) | 200 | 35 |
| Stack diameters (m) | 10.5 | 12 |
| Exit velocity (m/s) | 26.2 | 44 |
| Temperature (°K) | 403 | 791 |
| NOx Emissions (g/s) | 1,685 (per stack) | 38.6 (per stack) |

Emission rates of $SO_2$ (for Colongra only) and $PM_{10}$ have been scaled from the NOx mass emission rates in Table 10 based upon total mass emissions reported in the National Pollutant Inventory (NPI) for the past three years. Scaling factors for Colongra and Eraring are summarised in Table 11 and Table 12, respectively.

**Table 11 Scaling of $SO_2$ and $PM_{10}$ emission rates from NOx for Colongra**

| Year | Annual emissions (kg) | | | Ratios | |
|---|---|---|---|---|---|
| | NOx | $SO_2$ | $PM_{10}$ | $SO_2$/NOx | $PM_{10}$/NOx |
| 2017/18 | 7,212 | 28 | 407 | 0.0038 | 0.0565 |
| 2018/19 | 14,073 | 71 | 870 | 0.0051 | 0.0618 |
| 2019/20 | 12,424 | 57 | 744 | 0.0046 | 0.0599 |
| Max Ratio | | | | 0.0051 | 0.0618 |
| Modelled NOx Emission Rate (g/s) | | | | 38.6 | |
| Derived $SO_2$ and $PM_{10}$ emission rates, respectively (g/s) | | | | 0.20 | 2.39 |

Table 12 **Scaling of $PM_{10}$ emission rates from NOx for Eraring**

| Year | Annual emissions (tonnes) | | | Ratio $PM_{10}$/NOx |
|---|---|---|---|---|
| | NOx | $SO_2$ | $PM_{10}$ | |
| 2017/18 | 21,374 | 39,313 | 245 | 0.011 |
| 2018/19 | 23,000 | 45,000 | 230 | 0.010 |
| 2019/20 | 20,000 | 39,000 | 180 | 0.009 |
| Max Ratio | | | | 0.011 |
| Assumed NOx Emission Rate (g/s) | | | | 1,685 |
| Derived $PM_{10}$ Emission Rate (g/s) | | | | 19.3 |

Colongra predominantly operates on natural gas, which will produce very low emissions of $SO_2$ and $PM_{10}$, which are reflected in Table 11. However, Colongra has approval to also operate on diesel. Emissions of $SO_2$ and $PM_{10}$ are higher when the plant operates on diesel, thus it is necessary to uplift the emission rates derived in Table 11 for the consideration of peak impacts.

The calculated emission rates have been uplifted based on published emission rates for $SO_2$ and $PM_{10}$ for combustion engines operating on natural gas and distillate oil in Chapter 3.1 (Stationary Gas Turbines) of the US EPA's Compilation of Air Pollutant Emissions Factors (AP-42) (USEPA, 2000). These emission factors suggest that $SO_2$ emissions will be 9.7 times higher when operating on diesel as compared to natural gas, with $PM_{10}$ emissions being 1.8 times higher. As such, mass emission rates of 1.9 g/s for $SO_2$ and 4.3 g/s for $PM_{10}$ have been used for each generator at Colongra.

Colongra is a peaking plant, and therefore operates relatively infrequently. Publicly available load data have been interrogated to establish in which hours of 2018, 2019 and 2020 each of the generators at Colongra was operating. In the dispersion modelling it has been conservatively assumed that whenever a generator is operating, it is operating at full load and emitting as per the parameters described in Table 10 and with the mass emission rates described in the above paragraph. Assuming that the generators are all operating at full load and on diesel is likely to greatly overstate the potential impact of emissions from Colongra.

Time varying emissions data for Eraring were provided by Origin Energy. This dataset was based upon stack testing data under different load scenarios, and produced a dataset with variable exit velocity, temperature and NOx and $SO_2$ emissions, depending on the load for each unit in any given hour.

Table 13 provides a summary of the data input via the time varying emissions file. Table 14 presents the total annual NOx and $SO_2$ emissions calculated from the time varying emissions data (both stacks combined). Whilst the periods of coverage are different (calendar year versus financial year), a simple comparison shows that the emissions estimated for Eraring are about 53% higher than that reported to the NPI for NOx and 37% higher for $SO_2$ (comparing Table 12 and Table 14). This demonstrates that the approach adopted in the modelling is conservative.

Table 13 **Summary of time varying emissions data employed in the modelling of NOx and $SO_2$ emissions from Eraring (2018-2020)**

| Parameter | Minimum | Maximum | Mean | Median |
|---|---|---|---|---|
| **North Stack** | | | | |
| NOx Emission Rate (g/s) | 133.0 | 722.7 | 534.2 | 535.5 |
| $SO_2$ Emission Rate (g/s) | 233.6 | 1657.6 | 919.7 | 828.8 |
| Temperature (°K) | 371.1 | 395.9 | 384.9 | 393.1 |
| Velocity (m/s) | 4.6 | 26.3 | 19.7 | 20.0 |
| **South Stack** | | | | |
| NOx Emission Rate (g/s) | 0.0 | 722.7 | 503.2 | 535.5 |

| Parameter | Minimum | Maximum | Mean | Median |
|---|---|---|---|---|
| $SO_2$ Emission Rate (g/s) | 0.0 | 1657.6 | 864.7 | 642.6 |
| Temperature (°K) | 273.15[1] | 395.9 | 384.3 | 393.1 |
| Velocity (m/s) | 0.0 | 26.3 | 18.6 | 20.0 |

Table note:

[1] A temperature of 0°C was applied to hours when units were not operational.

**Table 14 Total annual Eraring pollutant emissions calculated from time varying emissions data (tonnes/year)**

| Pollutant | 2018 | 2019 | 2020 |
|---|---|---|---|
| NOx | 33,051 | 33,742 | 31,436 |
| $SO_2$ | 59,505 | 58,515 | 50,956 |

### 3.7.2 Proposed power stations

The assessment has also accounted for the potential emissions from the proposed Newcastle Power Project and Hunter Power Project. Emission parameters and pollutant mass emission rates for these proposed facilities have been taken from the air quality assessments prepared in support of their respective planning and environmental approvals applications (ERM, 2019) (Jacobs, 2021). In order to ensure a worst-case approach, where multiple emissions scenarios were modelled in these assessments, the scenario with the highest pollutant mass emissions has been used. The emission parameters adopted in the modelling are detailed in Table 15. For the Hunter Power Project, the two stacks were combined into a single point source for the model.

**Table 15 Emission parameters for proposed power stations**

| Parameter | Newcastle Power Project | Hunter Power Project |
|---|---|---|
| Stack Locations (x,y) | 378949,6368561<br>378951,6368597<br>378956,6368659 | 357515,6371437 |
| Stack heights above ground (m) | 32 | 36 |
| Stack diameters (m) | 3.6 (stacks 1&2), 4.025 (stack 3) | 9.8 |
| Exit velocity (m/s) | 30 | 22.1 |
| Temperature (°C) | 288 | 250 |
| NOx Emissions (g/s) | 6.5 (per stack) | 98.8 |
| $SO_2$ Emissions (g/s) | 0.48 (per stack) | 0.72 |

### 3.7.3 Background levels for the cumulative assessment

Representative hour-by-hour background concentrations have been extracted from the local monitoring data, using data from a number of sites to exclude the contributions of the power stations that have been modelled explicitly.

Measured data from the Wyong station have been used as the primary source of background data, but these measurements will include contributions from the power stations during winds from between 0-60 degrees (see Section 5.1.5), which need to be removed from the background dataset. There are also missing data that need to be replaced with representative values.

The first step to construct the representative hour-by-hour background dataset has been to fill missing wind direction data at the Wyong station with concurrent measurements from Wyee as a first preference, on the assumption that conditions at the two sites are likely to be similar, given that they are only 12 km apart. Where wind direction data for a given hour were missing in both datasets, the value for the previous hour in the combined dataset was used.

The next step was to combine representative pollutant concentration data. Missing concentration data at Wyong during winds from 60-360 degrees were filled with concurrent measurements from Wyee. For those hours when the wind direction at Wyong was between 0-60 degrees, concentration data have been taken from the Beresfield monitoring station, located to the northwest of Newcastle and uninfluenced by nearby industrial sources during winds from those directions. As a final step, any missing concentration data in this combined dataset have been filled with the measurement from the previous hour.

The resultant time series of NO, $NO_2$, $SO_2$, $PM_{10}$, $PM_{2.5}$ and $O_3$ concentrations for the years 2018-2020 have been used to represent background concentrations in the absence of local power station influences. The relatively minor contribution from more distant power stations will also be captured in the background data and, consequently, have not been explicitly modelled in this study. The dataset is summarised in Table 16. Some elevated $SO_2$ concentrations are incorporated into this dataset, suggesting that the local power station influence has not been entirely removed; it is, therefore, likely to represent a worst-case characterisation of background concentrations for the area. The 95th and 99.9th percentiles of background concentrations have been presented to demonstrate that the dataset contains a very limited number of elevated background concentrations, which are highly unlikely to coincide with peak power station contributions.

**Table 16 Summary of background concentrations dataset used – NO, $NO_2$ and $SO_2$ (µg/m$^3$)**

| Year | NO (1-hr) | | | | $NO_2$ (1-hr) | | | | $SO_2$ (1-hr) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Mean | Max | 99.9th | 95th | Mean | Max | 99.9th | 95th | Mean | Max | 99.9th | 95th |
| 2018 | 4.9 | 272.2 | 164.8 | 28.5 | 9.9 | 75.7 | 61.5 | 34.7 | 1.7 | 95.5 | 54.9 | 6.5 |
| 2019 | 5.3 | 237.4 | 141.3 | 29.3 | 8.9 | 92.8 | 62.7 | 31.5 | 1.6 | 135.7 | 63.3 | 6.4 |
| 2020 | 4.8 | 174.4 | 134.8 | 26.7 | 7.7 | 72.4 | 53.9 | 28.7 | 1.4 | 131.2 | 50.2 | 5.5 |
| Criterion[1] | - | | | | 62 | 246 | | | 60 | 570 | | |

Table note:
[1] Approved Methods for Modelling

**Table 17 Summary of background concentrations dataset used – particulates and $O_3$ (µg/m$^3$)**

| Year | $PM_{10}$ (24-hr) | | | $PM_{2.5}$ (24-hr) | | | $O_3$ (1-hr) | |
|---|---|---|---|---|---|---|---|---|
| | Mean | Max | Days >50 | Mean | Max | Days >25 | Mean | Max |
| 2018 | 18.6 | 138.3 | 7 | 6.7 | 18.1 | 0 | 37.7 | 155.2 |
| 2019 | 22.8 | 240.1 | 24 | 10.3 | 177.7 | 23 | 39.2 | 213.2 |
| 2020 | 16.4 | 90.5 | 4 | 6.4 | 67.8 | 6 | 38.7 | 216.1 |
| Criterion[1] | 25 | 50 | 0 | 8 | 25 | 0 | - | 214 |

Table note:
[1] Approved Methods for Modelling

In relation to background concentrations of lead, the NSW Government's Annual NEPM Compliance Report for 2011 concluded that:

> *"Annual averages throughout New South Wales are now typically less than 0.03µg/m$^3$ with many 24-hour average samples below the minimum detection limit for lead of 0.007µg/m$^3$ using ICP-AES (Inductively Coupled Plasma-Atomic Emission Spectroscopy) analysis. Since 2002 the highest annual*

*average recorded in New South Wales was 0.09µg/m$^3$ at Wallsend during 2003, only 18% of the standard*

*With a complete ban on lead in petrol now in force, the primary source of lead in air at the regional scale has been eliminated.*

*The Office of Environment and Heritage began phasing out ambient lead monitoring for the AAQ NEPM during 2004. All lead monitoring ceased from 1st January 2005.*

*A report summarising the case for a cessation of lead monitoring was approved by NEPC".*

On this basis, an annual average background lead concentrations of 0.03µg/m$^3$ has been assumed.

## 3.8 NOx to $NO_2$ conversion

For the assessment of annual mean ground-level $NO_2$ concentrations, it has been assumed that 100% of the model output NOx concentrations is $NO_2$, which is a very conservative assumption. For the assessment of peak 1-hour average concentrations of $NO_2$, a more realistic conversion ratio 20% has been used. This value was used in Sunset Power's previous exemption application (Katestone, 2010). Further details of the robustness of this approach were provided in a supplementary report (Malfroy Environmental Strategies Pty Ltd, 2010), which concluded that *the single, fixed ratio (of 0.2) is likely to under-estimate $NO_2$ concentrations at low NOx concentrations and over-estimate $NO_2$ concentrations at high NOx concentrations*.

Recent monitoring data from the air quality monitoring stations nearest VPPS have been analysed to confirm that this conclusion still holds true. Figure 2 presents a plot of the ratio of NOx/$NO_2$ against the total NOx concentration (as $NO_2$) using all available data from the Morisset, Wyee and Wyong monitoring stations since 2010 (see Sections 3.2 and 5 for details of the time periods for which data were available for each site). The plot highlights that when total NOx concentrations are elevated, the ratio of NOx/$NO_2$ tends to be low, typically below 0.2, although there are some measurements with a higher ratio.

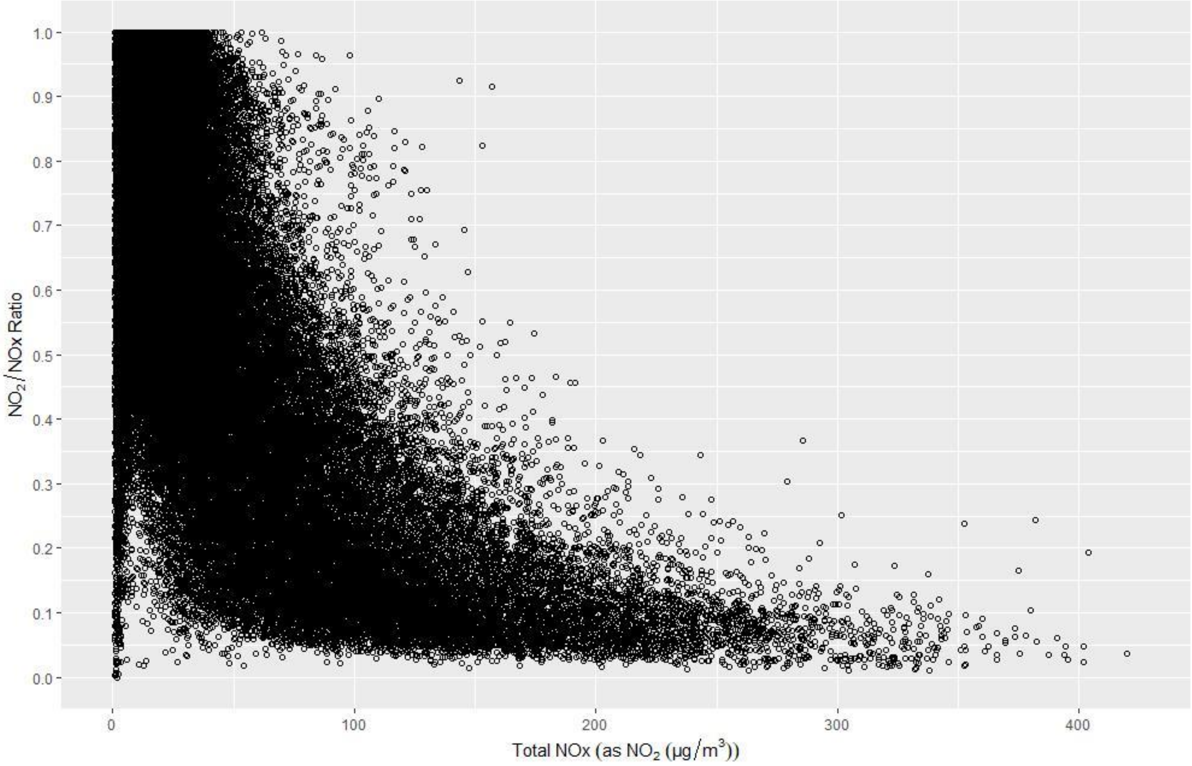


**Figure 2 Measured $NO_2$/NOx Ratio against total NOx – all 3 nearby monitoring sites**

The appropriate ratio to use has been investigated further by looking at the ratios at the individual sites, as presented in Figure 3, Figure 4 and Figure 5.

The measured data from Wyee, which is the site nearest VPPS and the one with the most available data, confirm that the $NO_2$/NOx ratio is consistently below 0.2 when NOx concentrations are at their highest. This is an important observation, as NOx will convert to $NO_2$ with time, thus it would be expected that ratios would be higher further from the main sources of NOx. This is evident in the plot for Wyong (which is located much further from VPPS and Eraring), where the ratios associated with the highest total NOx concentrations are higher, lying between 0.1 and 0.4. There are also far fewer high concentrations of NOx at Wyong, which is to be expected given the additional dispersion and dilution that will occur with distance from the power stations.

It is important to note that the peak modelled NOx concentrations shown in Figure 86 in Section 7.1.1 occur closer to VPPS than at the Wyee monitoring station, thus it is likely that the appropriate ratio to apply to these would be less than 0.2 when total NOx concentrations are elevated. As such, it is judged that a ratio of 0.2 is an appropriate, conservative factor to apply to modelled power station NOx contributions when assessing peak 1-hour concentrations. Nevertheless, in order to assess the full range of possible outcomes, a sensitivity test using a ratio of 0.4 was also produced, although the results when using 0.2 are likely to be considerably more realistic (this is evidenced later in the assessment through comparison of measured versus modelled concentrations – see Figure 102 and Figure 103). Application of the ratio of 0.4 can be expected to (and is demonstrated in Figure 103 to) significantly over-state peak $NO_2$ concentrations, in particular those nearest the power stations.

The Morisset monitor has only been operational since November 2020, so there is limited data available from this site to inform the analysis. In the data that are available, measured total concentrations of NOx do not reach high levels, thus it is unsurprising that the ratios are not especially low at the highest concentrations measured. The data still very much fit the pattern show in Figure 2.

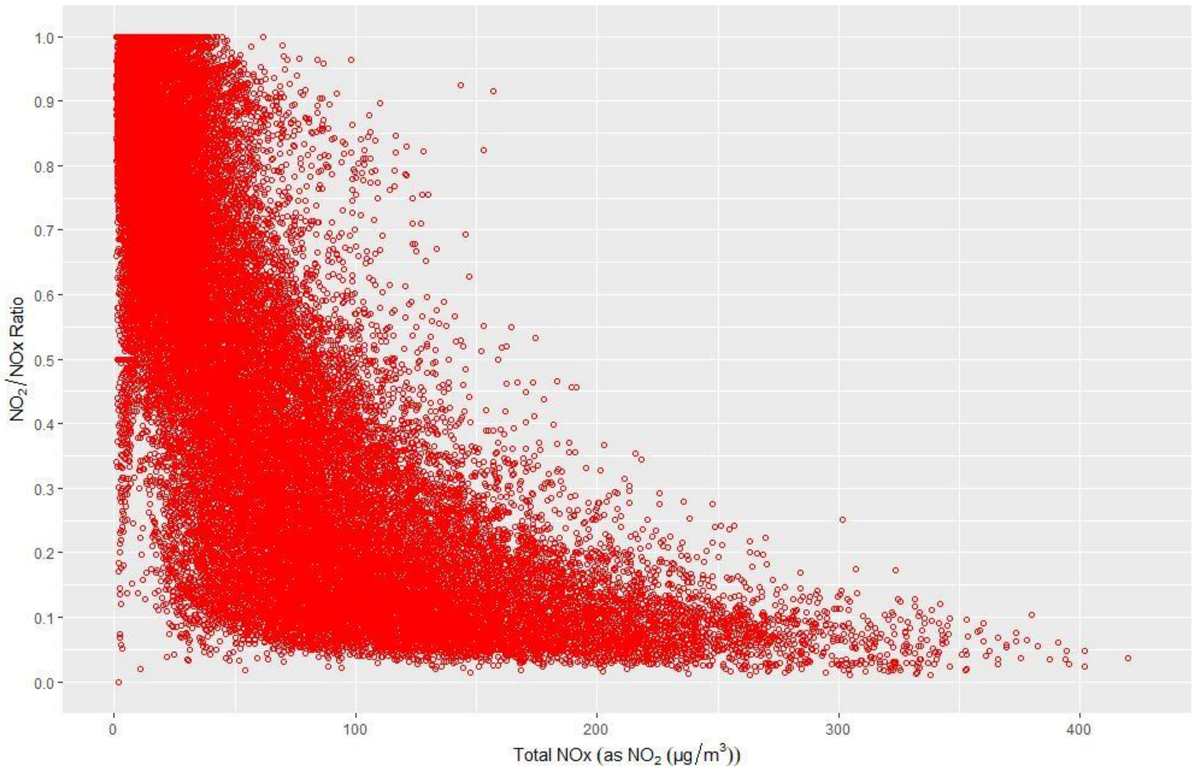


Figure 3 Measured $NO_2$/NOx Ratio against total NOx – Wyee

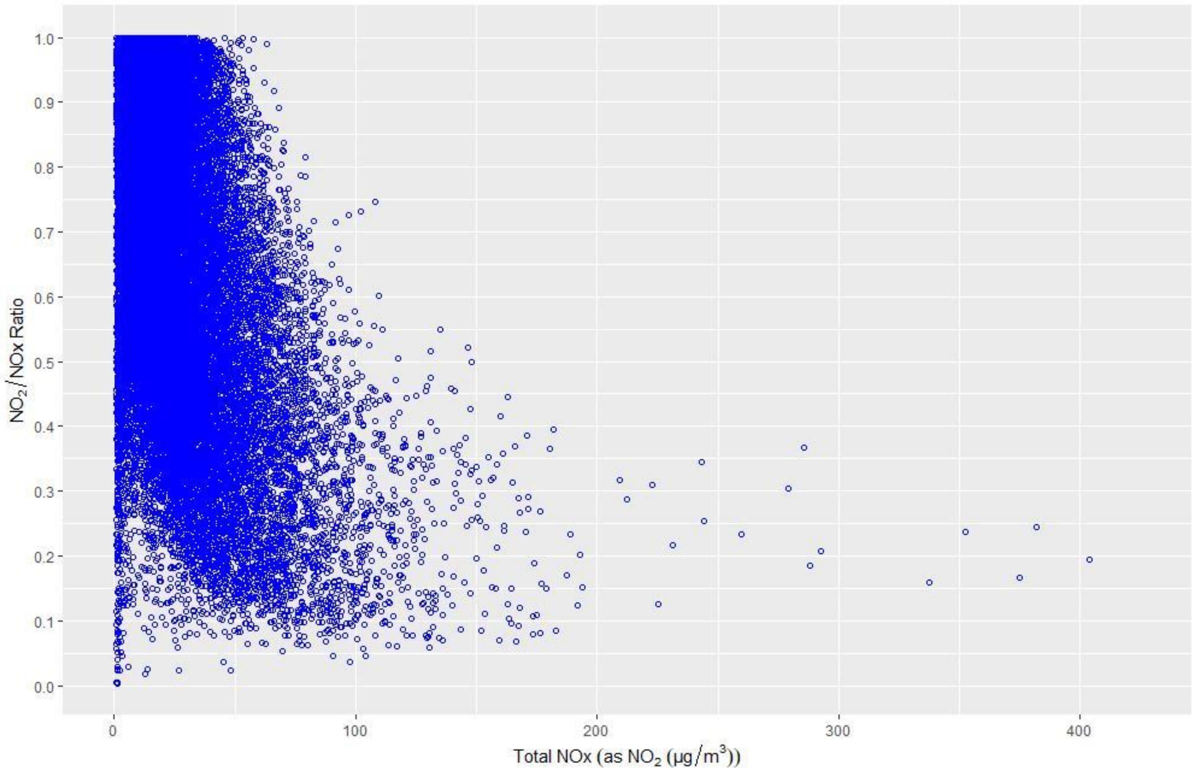


**Figure 4** Measured $NO_2$/NOx Ratio against total NOx – Wyong

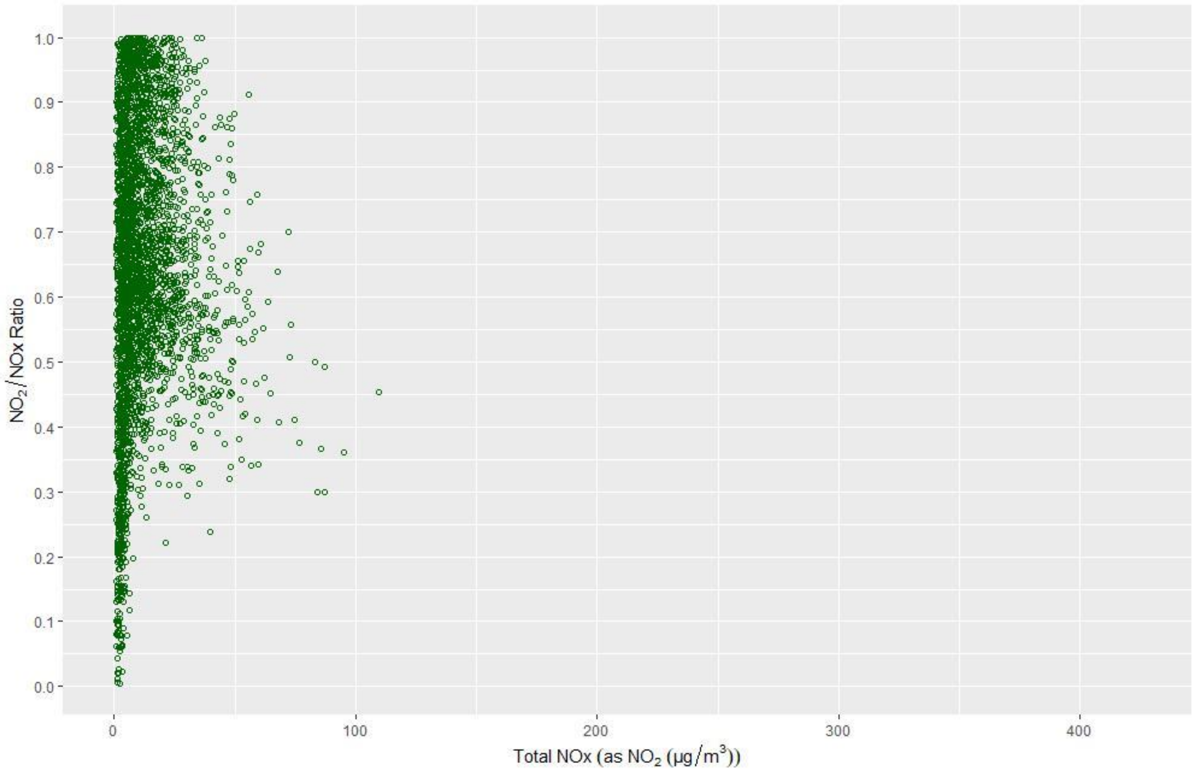


**Figure 5** Measured $NO_2$/NOx Ratio against total NOx – Morisset

In order to align with the requirements of the Approved Methods for Modelling, $NO_2$ concentrations at specific receptors were also predicted using the Ozone Limiting Method (OLM), using the background data compiled as described in Section 3.7.3.

## 3.9 Sensitive Receptors

Due to the large extent of the model domain, it is not feasible to identify or present results for every individual sensitive receptor location. Instead the assessment has focussed on assessing concentrations where they are greatest; contour plots of both annual average and peak concentrations have been analysed to identify key sensitive receptors (see Section 7.1.1), with these receptors detailed in Table 18 and their locations shown in Figure 6.

The receptors have been selected to be representative of worst-case exposure in each local area/direction so that, for example, residents of Morisset can be confident that they will experience concentrations no higher than those at receptors 1, 3 or 4, while residents of Kingfisher Shores or Chain Valley Bay can be confident that they will experience concentrations no higher than those at receptor 10. Detailed geographical representations of modelled concentrations are provided in the contour plots in Section 7.

**Table 18 Specific sensitive receptors**

| Receptor ID | Description | Easting (m) | Northing (m) |
|---|---|---|---|
| 1 | Sunshine | 366382.8 | 6335139.5 |
| 2 | Properties off Summerhayes Road | 361634.0 | 6328680.9 |
| 3 | Wyee Point | 362403.5 | 6331907.7 |
| 4 | Balcolyn | 364877.8 | 6337321.7 |
| 5 | Durren | 349876.4 | 6326906.2 |
| 6 | Mannering Park | 363355.7 | 6330175.9 |
| 7 | Blue Haven/San Remo | 361678.6 | 6324862.2 |
| 8 | Lake Munmorah | 366691.0 | 6326607.9 |
| 9 | Summerland Point | 366166.6 | 6331969.8 |
| 10 | Macquarie Shores | 365058.1 | 6328289.6 |

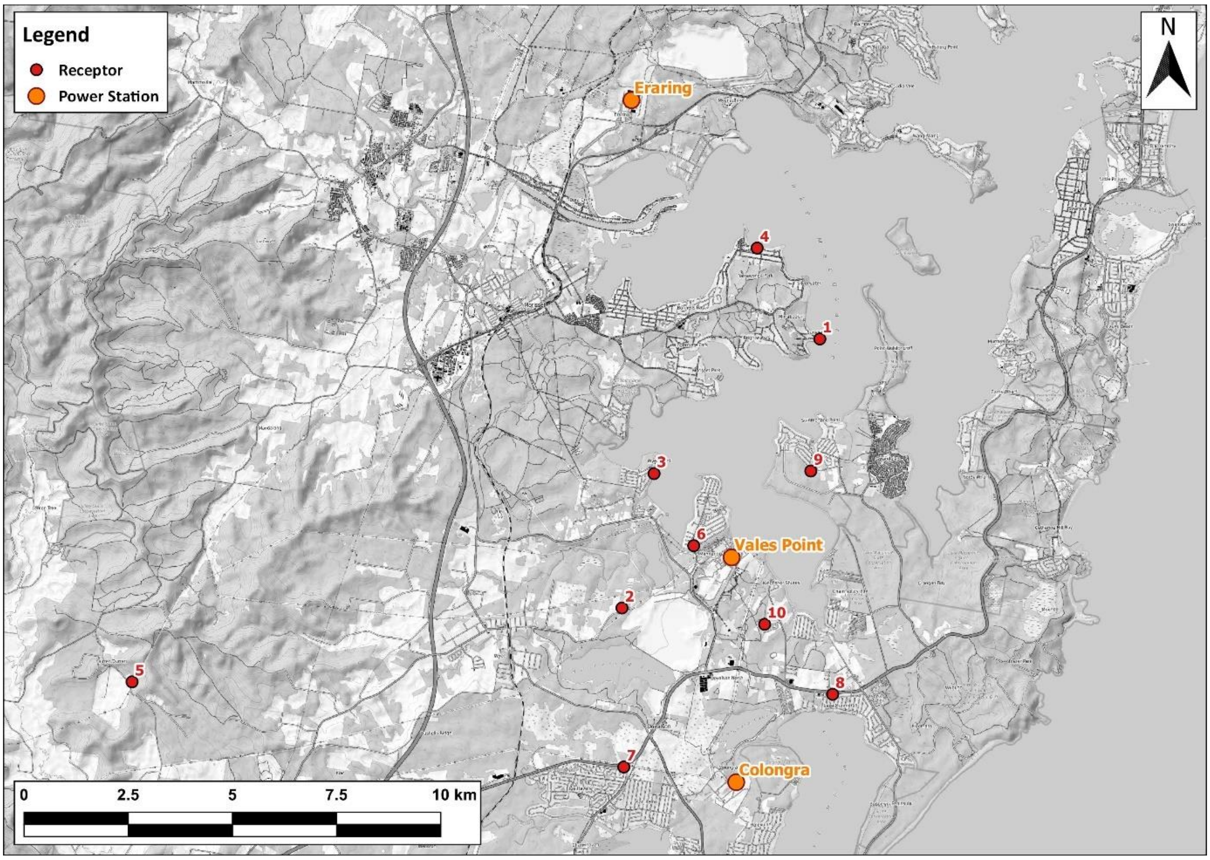


Figure 6 Selected Sensitive Receptors

## 3.10 Presentation of results

Maximum contributions from VPPS to ground-level concentrations anywhere in the model domain have been tabulated for all pollutants and averaging periods. For $NO_2$ and $SO_2$, concentrations as a result of VPPS in isolation, and total concentrations with the contributions of other local sources, have been tabulated for the specific sensitive receptors set out in Table 18. In most cases, concentrations at specific receptors have been interpolated from the grid of maximum concentrations for each pollutant and averaging period; the exception to this is for $NO_2$ concentrations calculated via the OLM method, for which time series of modelled NOx concentrations had to be output for the grid point nearest to the specific sensitive receptor.

Contour plots of $NO_2$ and $SO_2$ contributions from VPPS, contributions from the other power stations, and total cumulative ground-level concentrations (including baseline concentrations) have all been produced, and are presented in Section 7.

Contour plots of annual average concentrations, maximum 1-hour average concentrations and maximum 24-hour average concentrations (in the case of $SO_2$) have been produced. In the case of 1-hour average concentrations, contour plots of the 99.9th percentile (9th highest 1-hour average) have also been produced. The 99.9th percentile contour plots have been produced by calculating the 99.9th percentile of 1-hour average concentrations in each of the three years 2018, 2019 and 2020, and taking the maximum of these three values for each modelled grid point. Various studies have suggested that the 99.9th percentile of 1-hour average concentrations provides a more robust characterisation of potential peak impacts produced by dispersion models (e.g., Lilley W. et al., 2007).

The predicted ground-level concentrations have been assessed by comparison with the relevant impact assessment criteria for NSW that are contained in the Approved Methods for Modelling (detailed in Section 2.6).

Modelled and measured NOx/$NO_2$ and $SO_2$ concentrations at the Wyee monitoring station have also been compared through use of Q-Q plots, to evaluate the model performance. In these cases it has again been necessary to use time series of modelled concentrations output for the modelled grid point nearest to the Wyee monitoring station.

## 3.11 Limitations and uncertainty

A limitation of this study is that it relies on the accuracy of a number of data sets that feed into the dispersion model. These data sets have been sourced from the following:

- Meteorological monitoring observations from the Bureau of Meteorology and those at the air quality monitoring sites operate by the NSW EPA and Delta Electricity
- Ambient air quality monitoring observations from the NSW EPA and Delta Electricity sites
- Synoptic and surface information datasets from CSIRO
- Land-use from aerial imagery
- Emissions information provided by Delta Electricity for VPPS and sourced from publicly available documents and resources for other sources
- Publicly available load data for Colongra power station
- Emissions information provided by Origin Energy for Eraring power station.

It is also important to note that numerical models are based on an approximation of governing equations and will inherently be associated with some degree of uncertainty. The more complex the physical model, the greater the number of physical processes that must be included. There may be physical processes that are not explicitly accounted for in the model and, in general, these approximations tend to lead to an over prediction of air pollutant levels. Wherever possible, the methodology applied has sought to ensure a realistic worst-case scenario.

# 4. LITERATURE REVIEW FOR OZONE AND SECONDARY PARTICLE FORMATION

## 4.1 Overview

As set out in Section 3.1, specific literature covering the potential for significant regional ozone formation, secondary particulate formation and inter-regional transport of air pollutants has been has been reviewed in the context of NSW EPA's air emissions inventory for 2013 and NPI data for the ten-year period to 2019/20 to draw inferences as to the potential significance of the contribution of emissions from VPPS to inter-regional transport and ozone and secondary particle formation. Key features of these studies are summarized in Table 19.

**Table 19 Comparison of key features of relevant studies of ozone and photochemical smog formation in NSW**

| Study | Date | Pollutants | Spatial/Temporal extent | Methodology | Relevance to current emission sources |
|---|---|---|---|---|---|
| MAQS | 1996 | $SO_2$, NOx, volatile organic compounds (VOCs) and reactive organic carbon | NSW GMR<br>Focus on specific days with pollution episodes | Analysis of pollutant and meteorological data alongside emissions data, with subsequent airshed modelling of 3 specific events | Moderately Relevant |
| Ayers et al. | 1999 | $PM_1$, $PM_{2.5}$, $PM_{10}$, TSP and tracer chemical species | Sydney, Brisbane, Melbourne, Canberra, Launceston and Adelaide<br>August 1996 to December 1997 | Aerosol mass concentration measurements combined with a wide variety of analyses for tracer chemical species | Highly Relevant |
| IRTAPS | 2002 | $SO_2$ as a tracer for power station emissions<br>Modelled emissions of NOx, VOCs and ROC<br>Predictions of $NO_2$/NOx and $O_3$ concentrations | NSW GMR<br>1 September 1996 to 30 April 1997, and 1 September 1997 to 30 April 1998 | Monitoring analysis, climatological approach followed by detailed modelling: simplistic TAPM modelling, chemical transport modelling | Highly Relevant |
| Malfroy et al | 2005 | Emissions of NOx, $SO_2$ and $H_2SO_4$<br>Predictions of $PM_{2.5}$ concentrations | 24 hour periods 12 March 2002 and 4 June 2002<br>NSW GMR | TAPM-Chemical Transport Model | Highly Relevant |
| Hibberd et al | 2016 | $PM_{2.5}$ (fine airborne particles) and $PM_{2.5-10}$ (coarse airborne particles). | Lower Hunter<br>March 2014 to February 2015 | Monitoring analysis, regional airshed modelling, chemical transport modelling, particle speciation and source apportionment, exposure modelling | Highly Relevant |
| Cohen et al | 2016 | $PM_{2.5}$ | Lucas Heights, Richmond, Mascot, and Liverpool monitoring sites, Sydney<br>1 January 2000 to 31 December 2014. | $PM_{2.5}$ sampling, elemental analysis, source fingerprinting | Highly Relevant |
| Duc et al | 2018 | $PM_{2.5}$, $O_3$ | Calendar year 2008<br>NSW GMR | CCAM-CTM Chemical Transport Model | Highly Relevant |
| DPIE | 2020 | $PM_{2.5}$, $PM_{10}$, $O_3$, $SO_2$, CO, NOx/$NO_2$ | NSW GMR<br>1994-2018, focus on 2003 and 2008 for | Monitoring analysis, regional airshed modelling, chemical | Moderately Relevant |

| Study | Date | Pollutants | Spatial/Temporal extent | Methodology | Relevance to current emission sources |
|---|---|---|---|---|---|
| | | | emissions and 2008 for modelling | transport modelling, particle speciation and source apportionment, exposure modelling | |
| Broome et al | 2020 | $PM_{2.5}$ | NSW GMR<br>July 2010 to June 2011 | Exposure assessment, assessment of the burden of mortality, assessment of the benefit of $PM_{2.5}$ control strategies | Moderately Relevant |

It is worth noting that many of these studies adopted a worst-case modelling approach, assuming power stations to be operating at full load continuously throughout the year. It has already been demonstrated in Section 3 that such assumptions will greatly overstate the contribution of power stations to pollutant concentrations, as they relatively rarely actually operate at full load, and even more rarely all operate at full load at the same time. As such, the studies are likely to overstate the contribution of power station emissions to ozone and secondary particle formation.

It is also relevant to note the diminishing role of coal-fired power stations in the electricity market; their loads can be expected to reduce over time, thus the results of historic studies can be expected to greatly overstate the future impact of power station emissions.

## 4.2 VPPS emissions relative to other emission sources

Vales Point Power Station (VPPS) emits between 16,000-22,000 tonnes of NOx and 12,000-21,000 tonnes of $SO_2$ each year. Table 20 puts these emissions into the context of the total annual emissions of these pollutants in the Greater Metropolitan Region and in the whole of NSW, according to the NPI and NSW EPA's 2013 Calendar Year Air Emissions Inventory for the Greater Metropolitan Region (GMR) in NSW.

**Table 20 VPPS Emissions in the Context of Total NSW Emissions (tonnes)**

| Period | Pollutant | VPPS Emissions [1] | NSW Industrial Emissions | NSW GMR Total Emissions | VPPS Proportion |
|---|---|---|---|---|---|
| 2013 Calendar Year [2] | NOx | 21,500 | - | 304,927 | 7.1% |
| | $SO_2$ | 13,000 | - | 233,306 | 5.6% |
| 2010 - 2020 | NOx | 199,486 | 1,826,468 | - | 10.9% |
| | $SO_2$ | 167,632 | 2,070,853 | - | 8.1% |

Table notes:

[1] From the NPI

[2] For VPPS emissions, this is the average of the emissions reported for the periods 2013/14 and 2014/15.

Figure 7 and Figure 8 show coal-fired power generation emissions relative to all other sources in the NSW GMR in 2013 and highlight that coal-fired power generation is the main source of both NOx and $SO_2$.

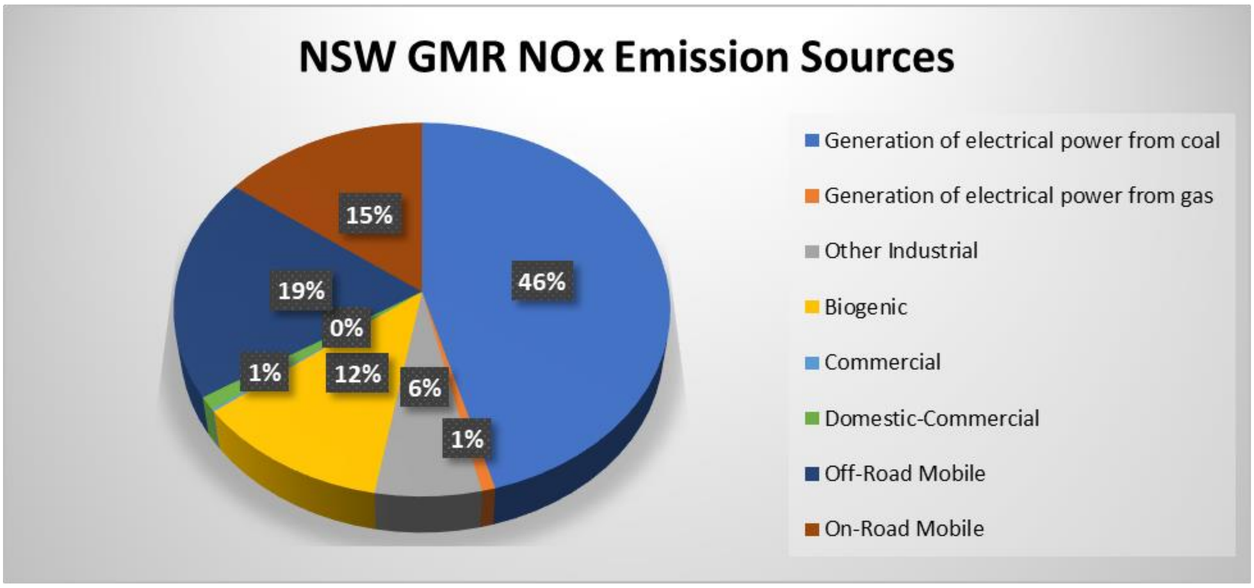


**Figure 7** Summary of NOx Emissions in NSW GMR (2013)

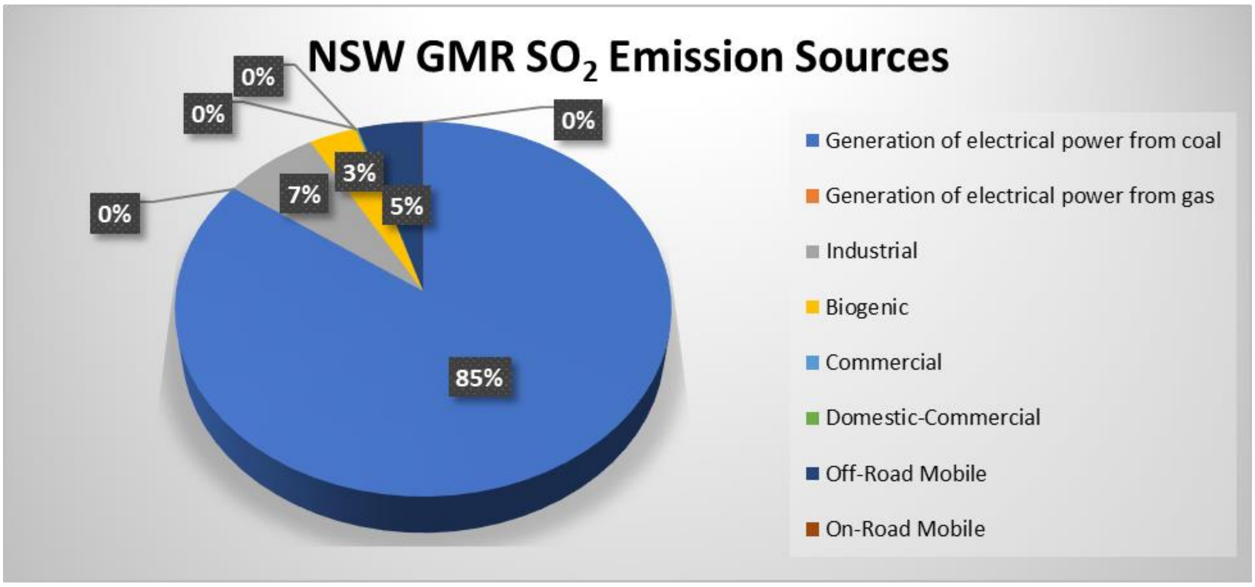


**Figure 8** Summary of $SO_2$ Emissions in NSW GMR (2013)

More recent NPI data suggest that, in 2019/20, Fossil Fuel Electricity Generation contributed 67% of the state's total industrial NOx emissions, and 89% of the total industrial $SO_2$ emissions. Of these total Fossil Fuel Electricity Generation emissions, VPPS contributed 16.8% of the total NOx emissions and 13.1% of the total $SO_2$ emissions.

Two of the Fossil Fuel Electricity Generation facilities included in the NPI are located outside of the GMR; with the emissions from these two facilities removed, VPPS makes up 17.4% of the total industrial NOx emissions and 13.1% of the total industrial $SO_2$ emissions from power stations within the GMR. Applying the proportions of total emissions from Figure 7 and Figure 8, it can be estimated that VPPS contributes approximately 8% of the total NOx emissions in the GMR and 11% of total $SO_2$ emissions.

Figure 9 presents the industrial sources of NOx emissions within approximately 35km of VPPS, coloured by total annual NOx emissions. The key industrial NOx emission sources are Eraring (the northernmost red point – 20,077 tonnes) and VPPS (the southernmost red point – 18,009 tonnes).

Figure 10 presents the industrial sources of $SO_2$. The key industrial $SO_2$ sources are Eraring (39,000 tonnes) and VPPS (20,000 tonnes). Figure 11 presents industrial sources of $PM_{2.5}$. The key industrial $PM_{2.5}$ sources are Eraring (104 tonnes) and VPPS (31 tonnes).

Viewed holistically, the figures demonstrate that Colongra is not a major industrial source of emissions of NOx, $SO_2$ or $PM_{2.5}$, and nor are any of the other industrial facilities included within the NPI within approximately 35km of VPPS, with the exception of Eraring and VPPS.

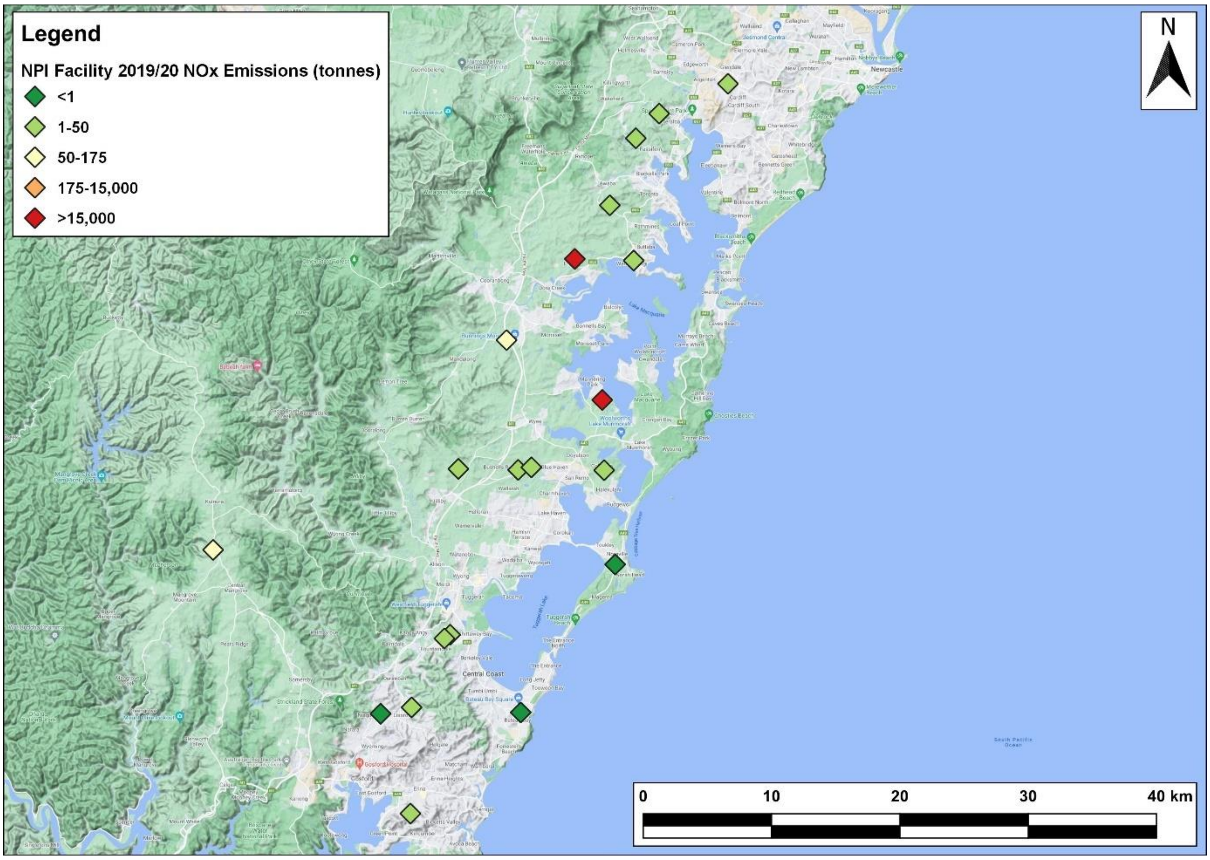


**Figure 9** NPI 2019/20 NOx Emissions Sources

Imagery ©2021 Google.

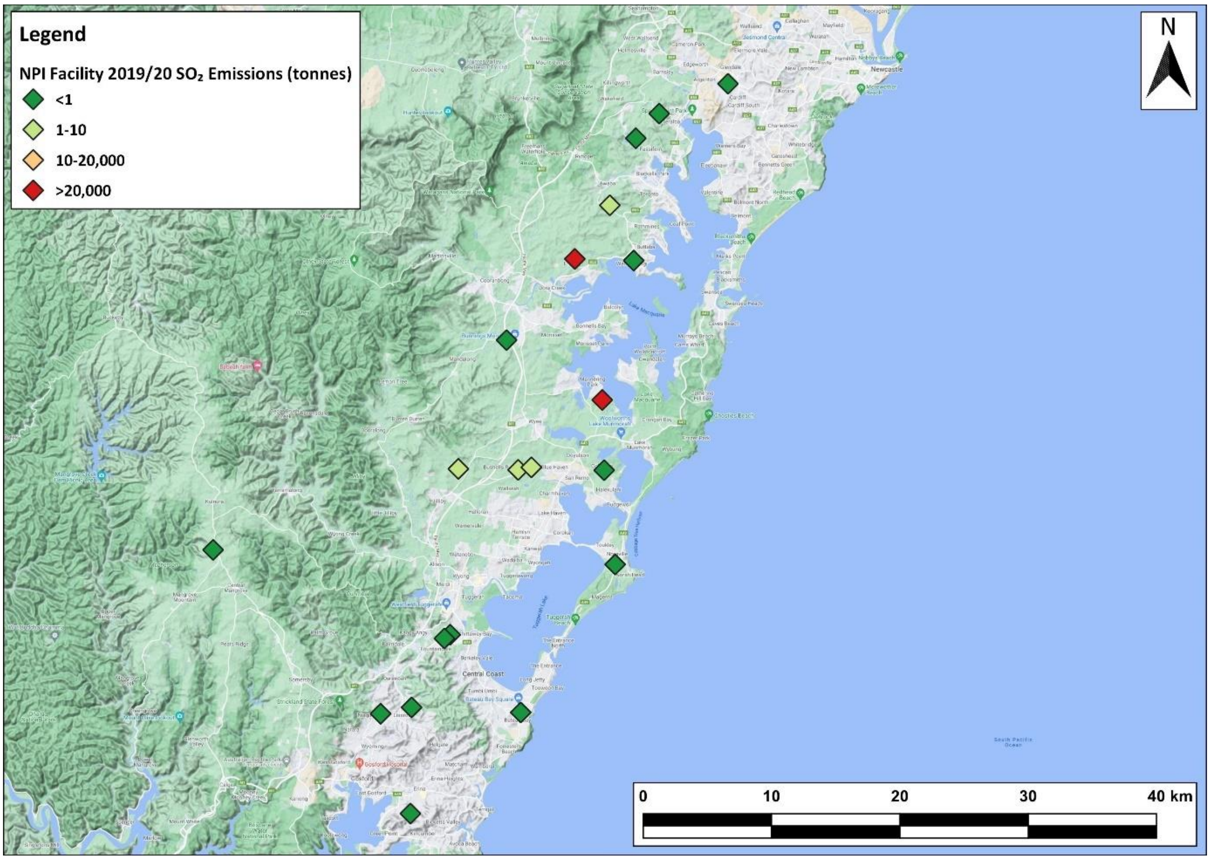


**Figure 10** NPI 2019/20 SO$_2$ Emissions Sources

Imagery ©2021 Google.

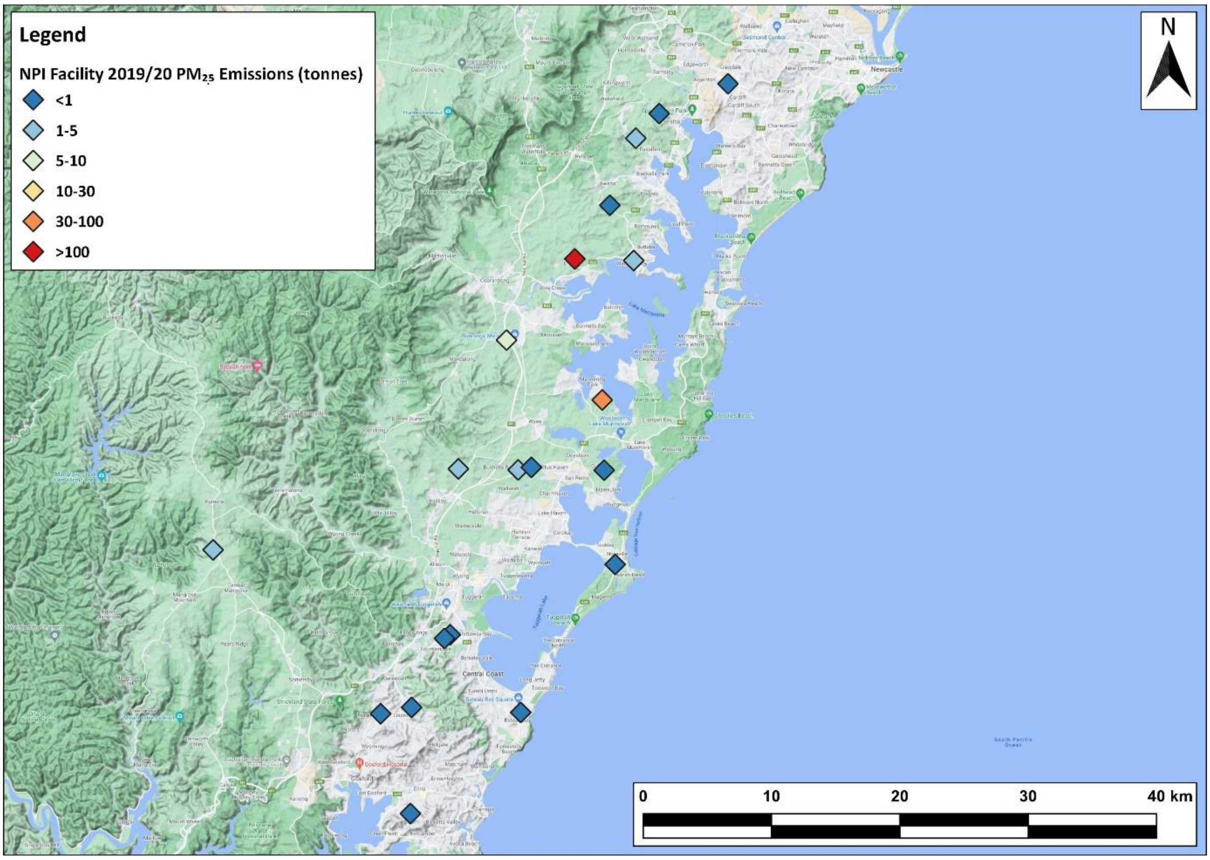


**Figure 11** NPI 2019/20 $PM_{2.5}$ Emissions Sources

Imagery ©2021 Google.

## 4.3 Study Conclusions on Secondary Particle Formation

Considerable research into secondary particle formation and its contribution to ambient concentrations of $PM_{2.5}$ has been carried out in the NSW GMR. To give context to discussion around power station contributions to total concentrations, Figure 12 summarises the measured concentrations of $PM_{2.5}$ in the state in 2020. It shows that several sites in the GMR did not achieve the annual mean Air NEPM standard, and none of the sites achieved the 24-hour Air NEPM standard. The highest annual mean concentration was 9.4 µg/m$^3$, and most sites had less than ten exceedances of the daily standard (none in the Newcastle, Central Coast or Hunter regions).

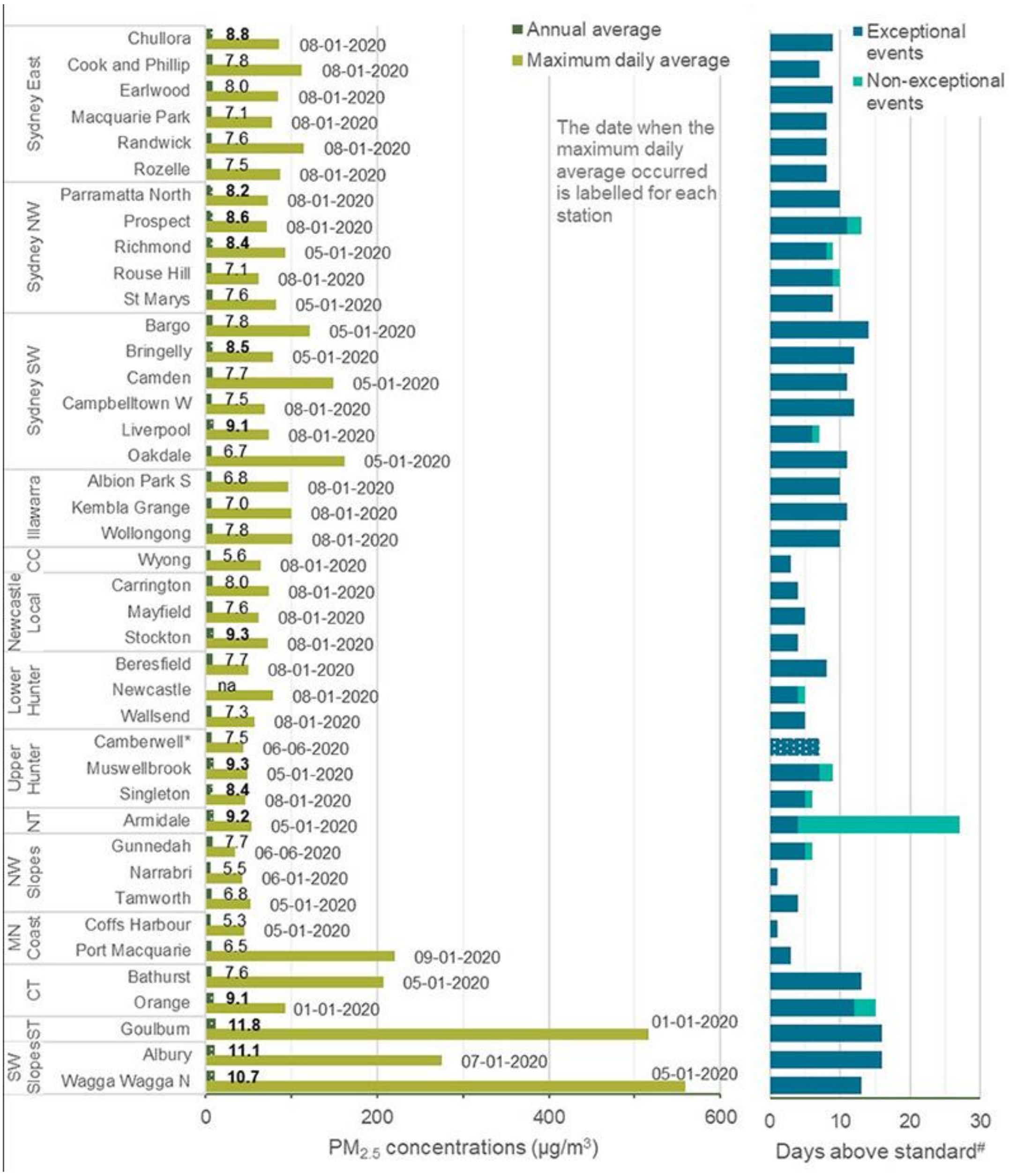


**Figure 12** **Summary of $PM_{2.5}$ observations in NSW (2020)**

The Malfroy et al. 2005 assessment of the contribution of coal-fired power station emissions to concentrations of $PM_{2.5}$ found:

- Predicted peak 24-hour average secondary concentrations of $PM_{2.5}$ as a result of power station emissions of emissions of $SO_3$ and $H_2SO_4$ were 0.9 µg/m$^3$ on the Central Coast, 6.5 µg/m$^3$ in the Hunter Valley and 1.4 µg/m$^3$ in the Western Coalfield.
- Annual mean contributions of 0.2 µg/m$^3$ on the Central Coast, 1.3 µg/m$^3$ in the Hunter Valley and 0.3 µg/m$^3$ in the Western Coalfield were predicted.

At the regional scale, days selected on the basis of possible “worst-case” power station impact in the Sydney region indicated a potential maximum power station contribution to $PM_{2.5}$ 24-hour average concentrations of 2 µg/m$^3$.

The study concluded that:

> *"power station contributions to urban particle levels are likely to be small and infrequent, a conclusion which is consistent with the findings of the earlier IRTAPS study"*

DPIE's 2020 Air Quality Study for the NSW Greater Metropolitan Region concluded that:

> *"Secondary particles formed in the air accounted for over 40% of $PM_{2.5}$ concentrations measured. Chemical transport modelling indicated that the release of VOCs from vegetation was a major source of secondary organic particles during summer, whereas wood heaters were a dominant source of these particles in autumn".*

And that:

> *"Secondary particles from power generation, industry and motor vehicles (Mixed-secondary-sulfate) reduced across sites from an average of 1.5 $\mu g/m^3$ in 2000 to 0.8 $\mu g/m^3$ in 2014".*

The Cohen et al. 2016 Sydney Particle Characterisation Study estimated that, when averaged across four sites in Sydney (Lucas Heights, Richmond, Mascot and Liverpool), about 24% of the $PM_{2.5}$ mass is ammonium sulfate, representing secondary sulfates from coal-fired power stations, oil refineries, motor vehicles and industry. However, this conclusion comes with relatively high uncertainty as ammonium sulfate concentrations were not actually measured as part of the study; instead they were estimated from total sulfur measurements. The Study goes on to say:

> *"The NSW Environment Protection Authority (NSW EPA) air emission inventory for 2008 showed that 98% of the total 246kT of sulfur dioxide emissions in NSW were associated with the coal fired power stations to the north and west of Sydney, burning 25 million tonnes of coal annually… we expect much of this Mixed-2ndryS and part of the Mixed-Ind-Saged to be associated with coal burning for power generation".*

NPI data suggest that, in 2019/20, Fossil Fuel Electricity Generation contributed 89% of the state's total industrial emissions of $SO_2$, while NSW EPA's 2013 air emissions inventory suggests that coal-fired power generation contributes 85% of the total $SO_2$ emissions in the GMR. As such, it is likely that a repeat of this study would conclude that less than 24% of the $PM_{2.5}$ mass is now a result of power station emissions.

The Ayers et al. 1999 Chemical and Physical Properties of Australian Fine Particles Pilot Study measured the non-sea salt sulfate component of particulate concentrations and concluded that they make up just 4.5% of $PM_{2.5}$ in Sydney, a much lower percentage.

The Hibberd et al. 2016 Lower Hunter Particle Characterisation Study concluded that secondary ammonium sulfate constituted about 10% of total $PM_{2.5}$ mass at the four Lower Hunter monitoring sites included in that study. It also estimated that:

> *"Coal particles could contribute up to 10% of the $PM_{2.5\text{-}10}$ particles"*.

Based on chemical speciation, the report concluded that

> *"Non-sea-salt sulfate accounts for 10–12% of the mass annually".*

The Broome et al.2020 mortality effect of $PM_{2.5}$ sources in the Greater Metropolitan Region of Sydney study identified power station emissions to be responsible for 11% of the population-weighted mean anthropogenic concentration of $PM_{2.5}$ in the Greater Metropolitan Region of Sydney. This conclusion broadly aligns with that from the Lower Hunter Particle Characterisation Study, and is considered likely to represent a robust estimate. Broome et al. concluded that:

> *"Around 1.2% of mortality (5,900 Years of Life Lost (YLL)) was attributable to long-term exposure to all anthropogenic $PM_{2.5}$, including 0.3% (1,400 YLL) attributable to wood heater–related $PM_{2.5}$, 0.2% (990 YLL) to on-road sources and 0.1% (620 YLL) to power stations".*

Based on the conclusions of all of these studies, it is likely that power station emissions are contributing around 0.6-1.0 µg/m$^3$ (around 11%) of measured annual mean concentrations of $PM_{2.5}$ across the region (on average), and certainly no more than 2 µg/m$^3$. Using the figure of 1 µg/m$^3$, which is consistent with most of the studies and still relatively conservative (being >11% of total concentrations), and assuming that it is reasonable to conclude that if VPPS contributes 13.1% of the total $SO_2$ emissions from power stations within the GMR then it will also contribute around 13.1% of total power station related $PM_{2.5}$, it is likely to contribute no more than 0.13 µg/m$^3$ to annual mean $PM_{2.5}$ concentrations, on average.

It can, therefore, be expected that measures to reduce NOx and $SO_2$ emissions at VPPS would not have discernible impact on secondary particulate concentrations across the NSW Greater Metropolitan Region, with any resultant change likely to fall well within the uncertainty bounds of the instruments used for the measurements.

## 4.4 Study Conclusions on Ozone

MAQS 1996 acted as precursor to many of the other studies referenced here, finding evidence of inter-regional transport and suggesting that power station emissions might account for, or contribute to, some ozone episodes. The study concluded that:

> *"In view of the evidence supporting inter-regional transport of emissions from sources in the Upper Hunter Valley, Newcastle and Central Coast there is a need to examine the conditions conducive for such transport in more detail, and to consider the possible impact on ozone concentrations in Sydney…Other scenarios not discussed in this report are the inter-regional transport of northern MAQS emissions along the coast and into the Illawarra region, and the possible contribution to photochemical smog in Sydney of emissions from power stations to the west (Hyde et al, 1997, p. 13-20)."*

However, subsequent airshed modelling suggested that:

> *"NOx control in general, and industrial NOx reductions in particular, are usually counter-productive to reducing maximum ozone concentrations, and population exposure to ozone and $NO_2$".*

The Inter-regional Transport of Air Pollutants Study (IRTAPS) of 2002 aimed to determine the effects of power station emissions on the annual frequency distribution of ozone ($O_3$) concentrations, as well as the potential contribution of inter-regional transport on high $O_3$ case study days. When modelling using simplified photochemistry, the study identified that:

> *"over the seven months modelled, an exceedence of the NEPM ozone standard (10 pphm) was predicted to occur on 28 days. (Note that this may be compared with the 10 days on which exceedences actually occurred for the same period as recorded by the monitoring network). On about 80% of these days power station emissions were predicted to make less than a 5% contribution to the maximum ozone concentration. The maximum power station contribution to these events was between 10 -15% occurring on a single day. On a further 5 days power station emissions contributed between 5 - 10% to the ozone event".*

Figure 13 usefully summarises the modelled power station contributions from IRTAPS modelling of January-April 1997 and January-March 1998, highlighting that power stations were not predicted to contribute significantly to high-ozone episodes.

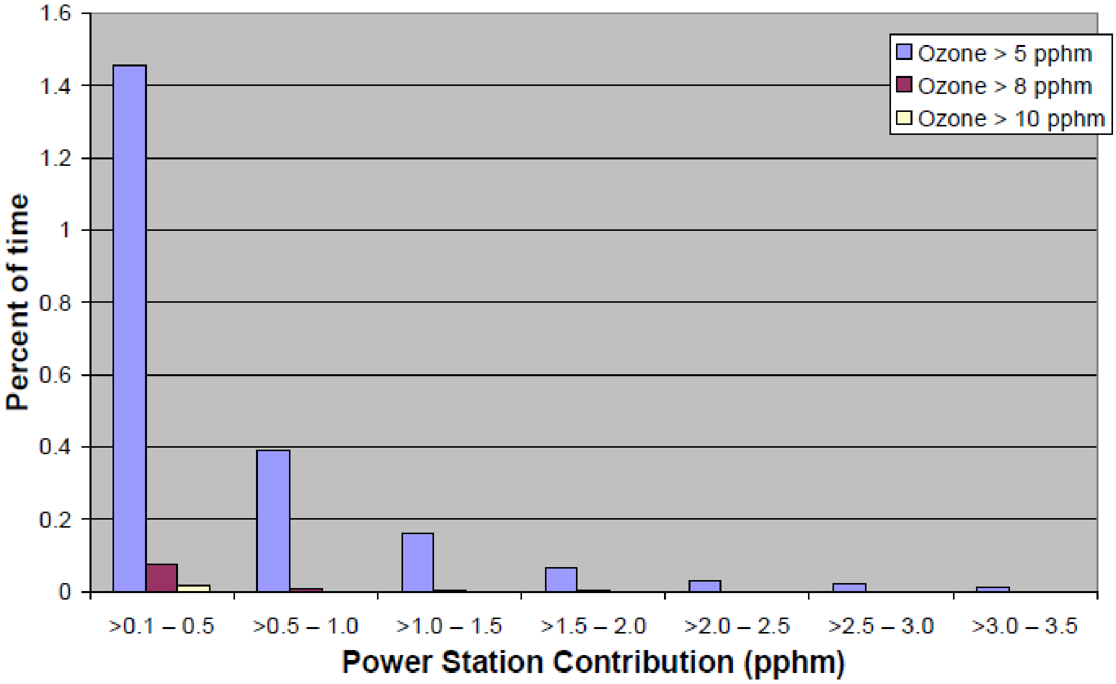


**Figure 13** **Percentage of time that power stations contribute positively to ozone at stated ranges**

The study summarized the simplified photochemistry model results as follows:

> *"The modelled results show:*
>
> - *For the majority of the time power station emissions have no effect on ozone occurrence in Sydney, even when ozone concentrations are elevated above naturally occurring concentrations.*
> - *For ozone events predicted to reach the long term reporting target of 8 pphm, power stations typically made little contribution. The maximum power station contribution during these elevated ozone events was less than 2 pphm, which occurred for one hour, at one monitoring site".*

Modelling of specific ozone events using an urban airshed model and full chemistry produced results that are less straightforward to summarise, but in general terms the modelling predicted a power station contribution of no more than 5 ppb in urban areas, or 20 ppb in rural areas.

Finally, the study concluded that:

> *"the contribution of power station emissions to ozone levels greater than air quality guidelines is, at most, small and infrequent. Hence, it is not likely that the magnitude and frequency of ozone events in the Sydney region would be significantly reduced by additional controls on power station NOx emissions".*

Duc et al. investigated source contributions to ozone formation in the Greater Metropolitan Region, and identified that:

> *"Among the anthropogenic sources, commercial and domestic sources are the main contributors to ozone concentration in all regions. Power station or motor vehicle sources, depending on the region, are the next main contributors to ozone formation. However, in the cooler months, these sources (power stations and motor vehicles) decrease the level of ozone".*

The analysis shows power station contributions of up to around 10% of daily 1-hour maximum ozone concentrations in the warmer months, but that, in winter, power station emissions would result in reduced ozone concentrations. Commercial and domestic contributions were frequently over 20%, with biogenic (natural) contributions typically around 60%. The contribution of power station emissions to the monthly average of daily maximum 1-hour ozone concentrations was well below 5 ppb.

Duc et al. drew the following conclusion with regard to power station emissions, although it is obvious from the above that power stations are not the key sources in the analysis, and it is worth noting that the study did not actually predict any exceedances of the 1-hour average air quality standard for ozone in northwest Sydney (the highest concentrations were predicted in rural areas to the far south west and north west of the city):

> *"A reduction in power station emission will significantly improve the ozone concentration in the North West of Sydney, but less so in other regions of the GMR".*

In terms of smog formation, the report concluded:

> *"Motor vehicles are less a problem compared to commercial-domestic and power station sources except for the South West of Sydney. However, the South West of Sydney has more smog episodes than other regions in the GMR, therefore, to reduce the high frequency of ozone events, control of motor vehicle emission should be given more priority than control of emission from power station sources".*

The study concluded the following:

> *"Biogenic emission is the major contributor to ozone formation in all regions of the GMR due to their large emission of VOC. Of anthropogenic emissions, commercial and domestic sources are the main contributors to ozone concentration in all regions. These commercial and domestic sources (except wood heaters) have much higher emission of most VOC species but less NOx than other sources, such as mobile sources, and hence contribute more to ozone formation in all the metropolitan regions compared to other sources. The commercial and domestic sources should be the focus for policy makers to manage the ozone level in the GMR.*
>
> *Furthermore, based on the results of this study, the following policy-relevant suggestions are proposed to regulate the ozone level in particular Sydney regions:*
>
> - *In the North West of Sydney, power station emission control will improve the ozone concentration there as well as in the Lower Hunter and the Illawarra regions.*
> - *In the South West of Sydney, which has more smog episodes than other regions in the GMR, control of motor vehicle emissions should be given priority to reduce the high frequency of ozone events in the Sydney basin".*

To summarise the findings on ozone, it is clear that power stations rarely make up a significant portion of peak short-term concentrations, almost certainly no more than 10%, and it should be noted that power station contributions are typically greatest when total concentrations are relatively low (compared to the air quality standards). If VPPS contributes 17.4% of the total power station NOx emissions in the region, then it will be contributing no more than around 1.7% of peak ozone concentrations, on average. For the bulk of the time, the contribution will be much lower. Therefore, it must again be concluded that emissions controls at VPPS in isolation are highly unlikely to have a discernible effect on ozone concentrations across the NSW Greater Metropolitan Region.

# 5. EXISTING ENVIRONMENT

## 5.1 Measurements at Wyee

Table 21 and Table 22 summarise annual air pollutant measurements made at Wyee since September 2013, which is the period of available data from VPPS. Concentrations have been well below the short-term and annual air quality criteria for $NO_2$ and $SO_2$. For $PM_{2.5}$, exceedances of both the annual and 24-hour average criteria were measured in 2019, with the high concentrations measured (relative to the other years) likely a result of the extensive bushfires that occurred in this year. Elevated short-term concentrations of $PM_{2.5}$ occur in most years as a result of natural events, either regional dust events or bushfires, or both. The 24-hour average standard for $PM_{2.5}$ has been exceeded in most years.

**Table 21 Measured Annual Average Pollutant Concentrations at Wyee ($\mu g/m^3$)**

| Year | NO | | $NO_2$ | | $SO_2$ | | $PM_{2.5}$ | |
|---|---|---|---|---|---|---|---|---|
| | DC[1] | Conc[2] | DC[1] | Conc[2] | DC[1] | Conc[2] | DC[1] | Conc[2] |
| 2013 | 31.0 | 12.8 | 31.0 | 12.1 | - | - | - | - |
| 2014 | 95.6 | 14.3 | 95.6 | 12.4 | 48.8 | 3.4 | 98.3 | 5.9 |
| 2015 | 97.1 | 15.9 | 97.1 | 11.7 | 96.7 | 4.0 | 97.7 | 7.1 |
| 2016 | 90.1 | 38.2 | 90.1 | 16.1 | 89.1 | 2.8 | 89.4 | 6.8 |
| 2017 | 99.6 | 19.6 | 99.6 | 20.6 | 99.9 | 2.1 | 99.0 | 6.7 |
| 2018 | 99.8 | 18.8 | 99.8 | 13.6 | 99.8 | 3.1 | 97.9 | 6.1 |
| 2019 | 98.4 | 18.5 | 98.4 | 12.1 | 98.5 | 3.1 | 98.1 | 10.0 |
| 2020 | 97.1 | 14.9 | 97.1 | 11.0 | 97.2 | 2.4 | 98.9 | 6.7 |
| Criterion[3] | - | - | - | 62 | - | 60 | - | 8 |

Table notes:

[1] Data Capture Rate (%)

[2] Annual Mean Concentration

[3] Approved Methods for Modelling

**Table 22 Measured Peak Short-term Pollutant Concentrations at Wyee ($\mu g/m^3$)**

| Year | $NO_2$ | $SO_2$ | | $PM_{2.5}$ |
|---|---|---|---|---|
| | 1-hour Max | 1-hour Max | 24-hour Max | 24-hour Max |
| 2013 | 67.1 | - | - | - |
| 2014 | 68.5 | 200.0 | 24.1 | 17.5 |
| 2015 | 87.8 | 178.5 | 35.2 | 26.3 |
| 2016 | 73.5 | 139.2 | 24.6 | 35.7 |
| 2017 | 143.5 | 135.1 | 21.0 | 81.2 |
| 2018 | 75.5 | 221.9 | 37.2 | 30.9 |
| 2019 | 93.1 | 263.3 | 45.8 | 173.8 |
| 2020 | 70.6 | 290.8 | 30.2 | 45.9 |
| Criterion[1] | 246 | 570 | 228 | 25 |

Table note:

[1] Approved Methods for Modelling

Figure 14 presents seasonal wind roses for the entire Wyee dataset. These highlight that prevailing winds are mainly from the west, with winds from the south also being reasonably frequent year-round. In spring and summer, winds from the northeast are also relatively common. It should be noted that wind data were only captured at Wyee from 7 July 2014. The dataset for which the wind roses have been produced covers 7 July 2014 to 30 June 2021.

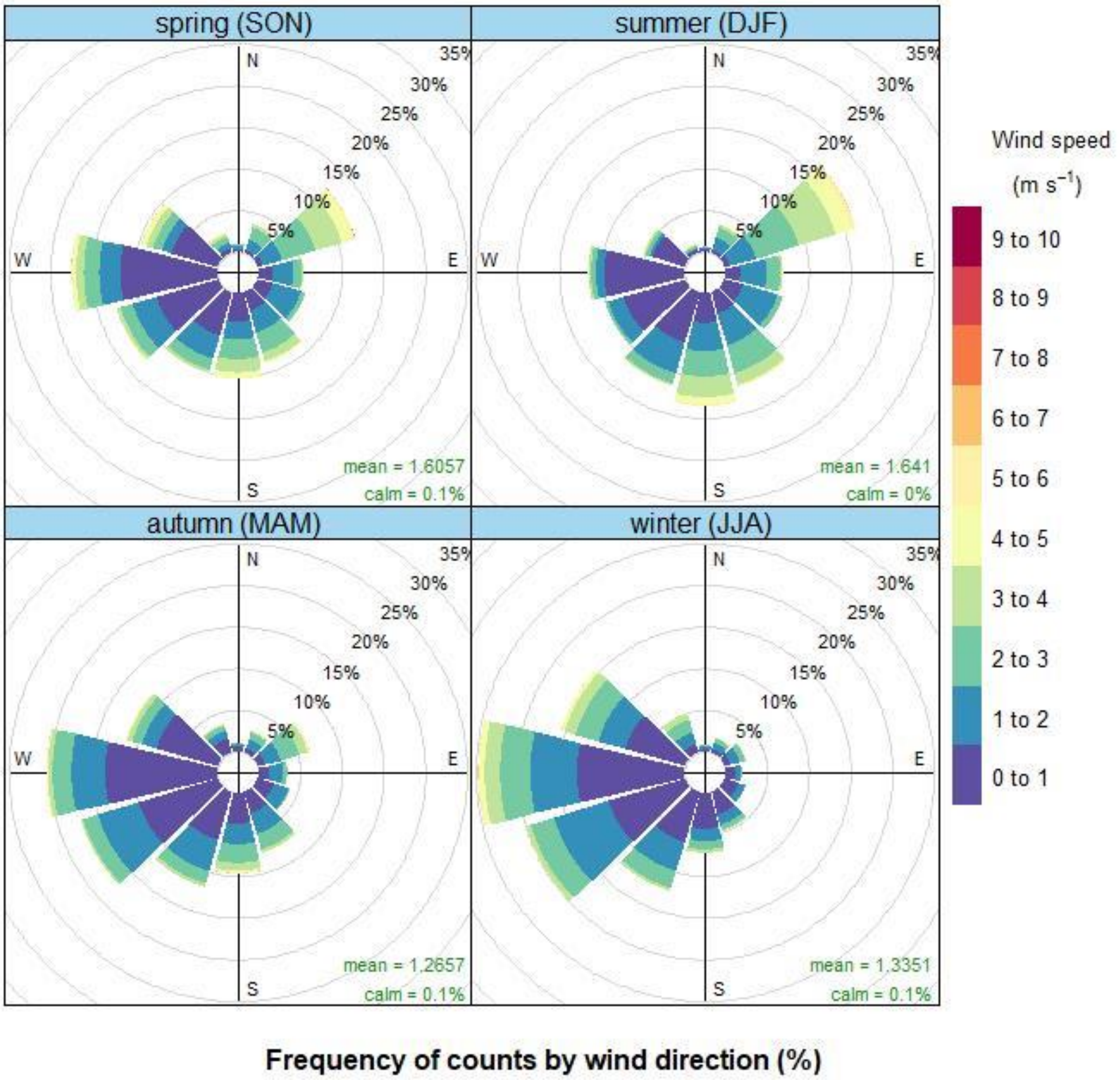


**Figure 14** **Wyee Seasonal Wind Rose**

All of the plots presented below cover the period 7 July 2014 to 31 May 2021 where the plot relies on wind data, or 1 September 2013 to 31 May 2021 where wind data is not relied upon (e.g. TheilSen plots). In the case of $SO_2$, valid data were captured from 5 July 2014, so $SO_2$ plots cover the period 5 July 2014 to 31 May 2021. In the case of $PM_{2.5}$, data were available from 1 January 2014, so $PM_{2.5}$ plots cover the period 5 July 2014 to 31 May 2021.

### 5.1.1 NO plots

Figure 15 presents seasonal pollution roses for Wyee for NO. The roses highlight that the highest concentrations tend to occur during winds from the west, which are also the most frequent winds. The roses highlight that winds from the northeast are common in autumn and winter, but that they are typically associated with low concentrations of NO, as are winds from the east, suggesting relatively little contribution from VPPS. The proportion contribution roses in Figure 16 confirm this, with very little by way of proportion contribution to mean concentrations during winds from the northeast.

However, high average concentrations during stronger winds from the east-northeast and north-northeast evident in Figure 17 are clearly the contribution of distant point sources; VPPS and Eraring, respectively. Nevertheless, these sources are infrequently downwind and thus are minor contributors to annual mean concentrations. There is no obvious contribution from Colongra.

The polar annulus plot in Figure 18 highlights that average concentrations are highest in the late afternoon/early evening during winds from all directions, but where winds from the northeast are only associated with elevated concentrations at this time of day, winds form the west are associated with elevated concentrations throughout the daylight hours. This is almost certainly the contribution of the busy M1 Pacific Motorway located some 500 m to the west of the monitoring station.

The TheilSen plot in Figure 19 highlights that there is no clear trend in NO concentrations at this monitor.

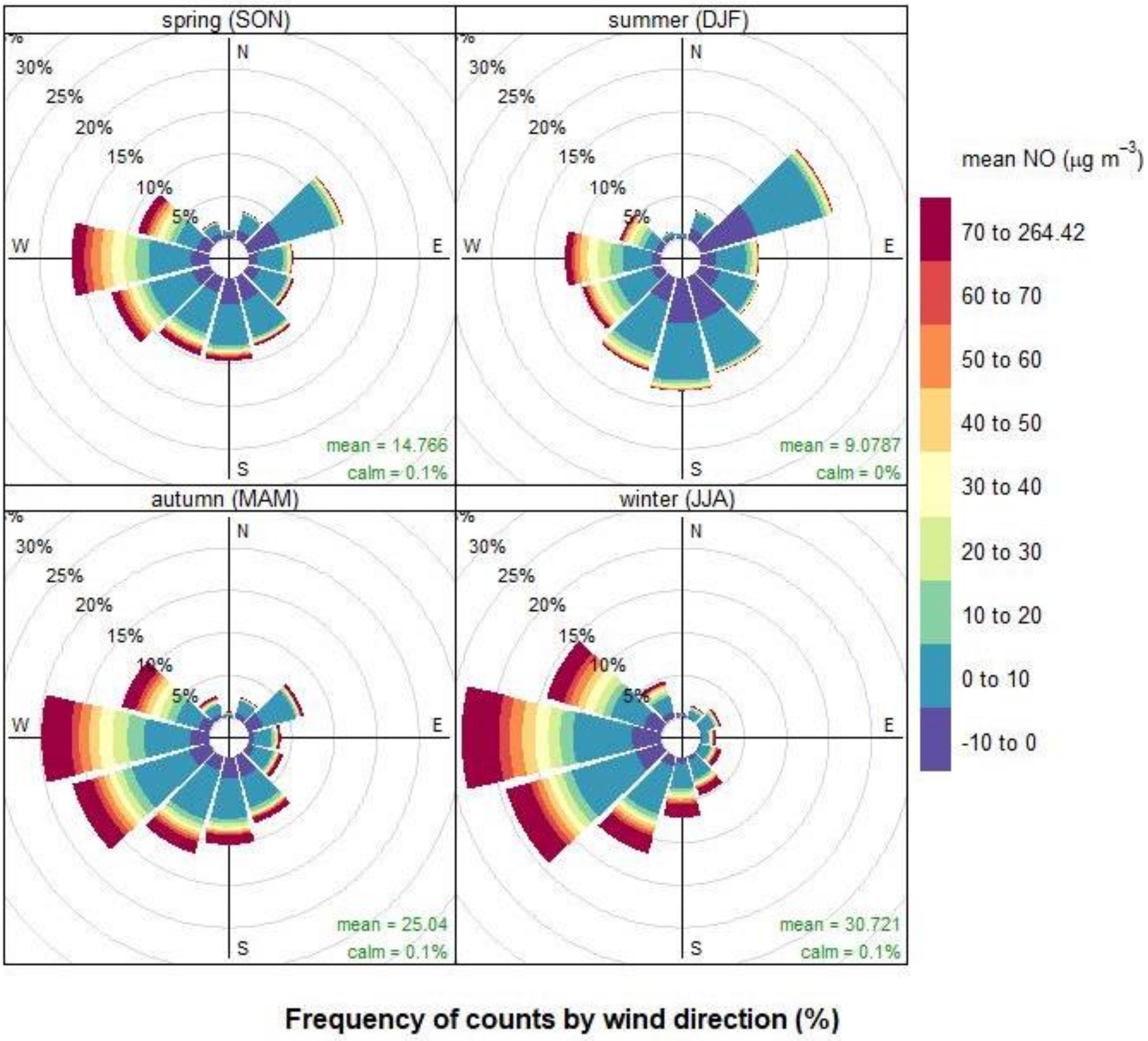


**Figure 15** Wyee Pollution Rose for NO (µg/m$^3$)

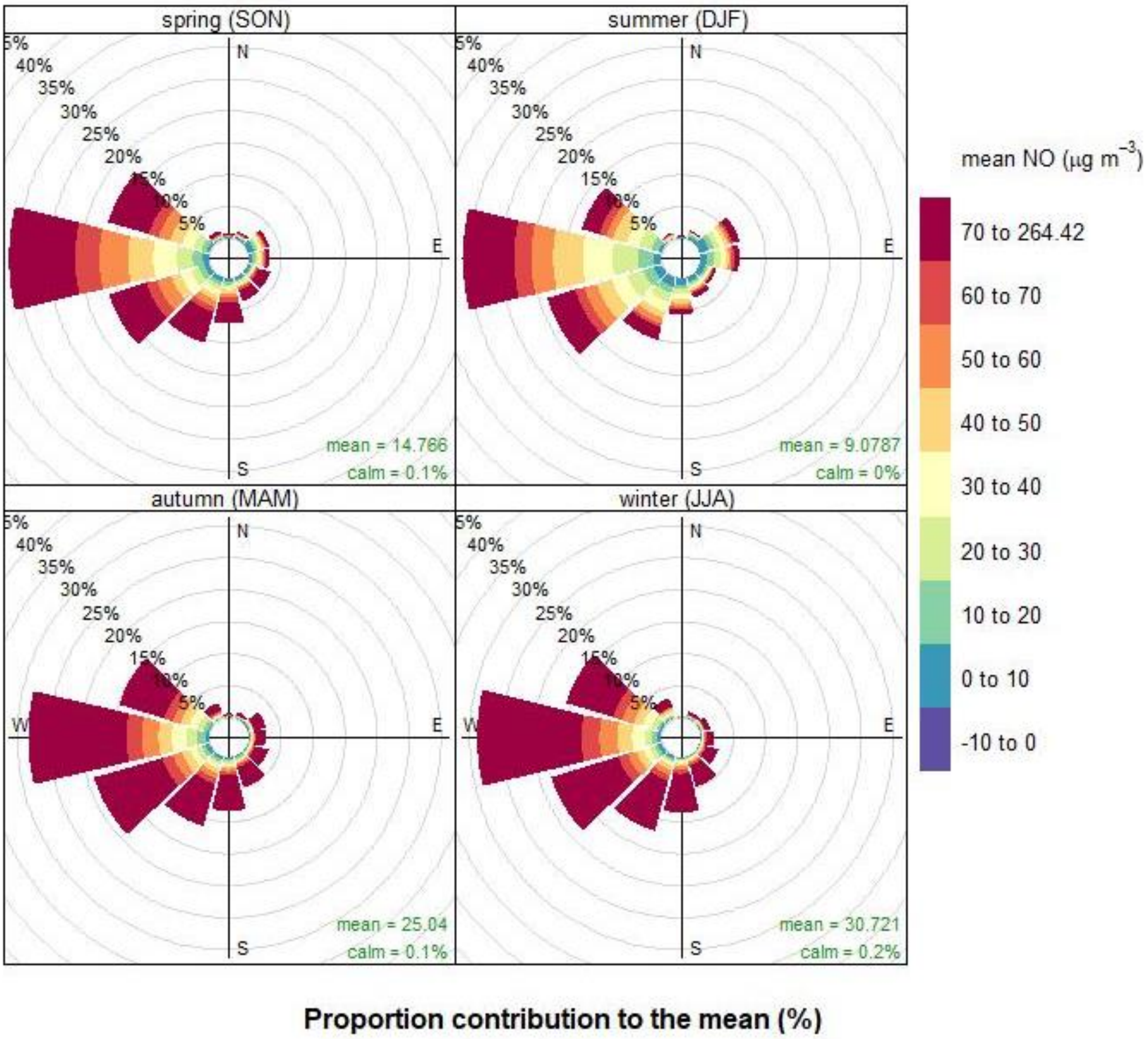


**Figure 16** Wyee Proportion Contribution Rose for NO (µg/m$^3$)

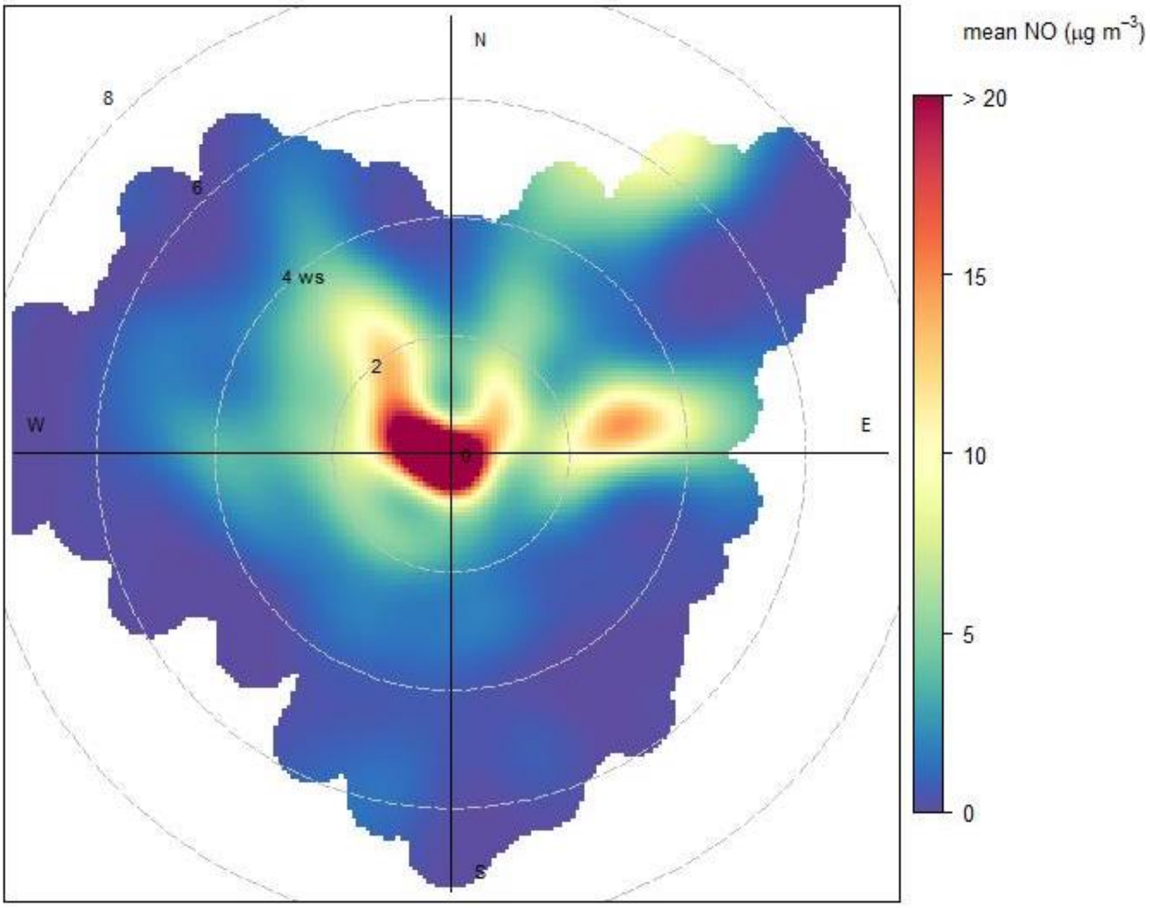


**Figure 17** Wyee Polar Plot for NO (µg/m$^3$)

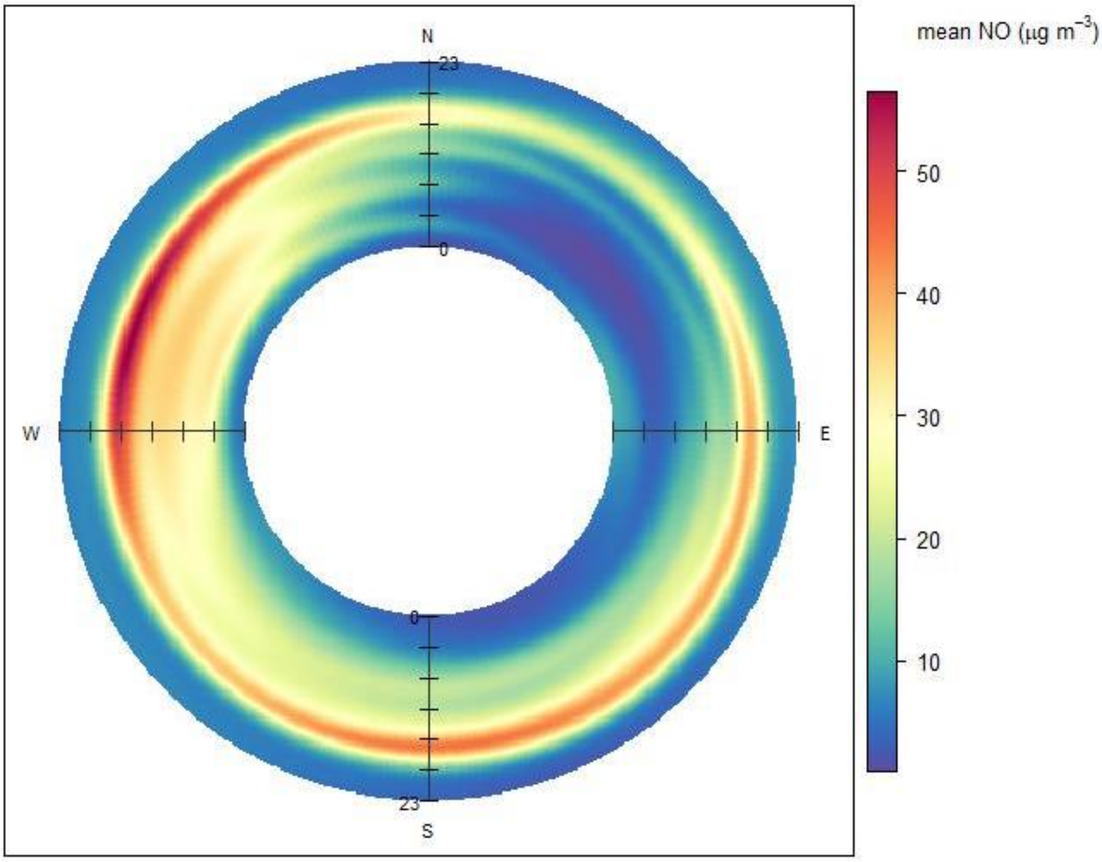


Figure 18 Wyee Polar Annulus Plot for NO (µg/m$^3$)

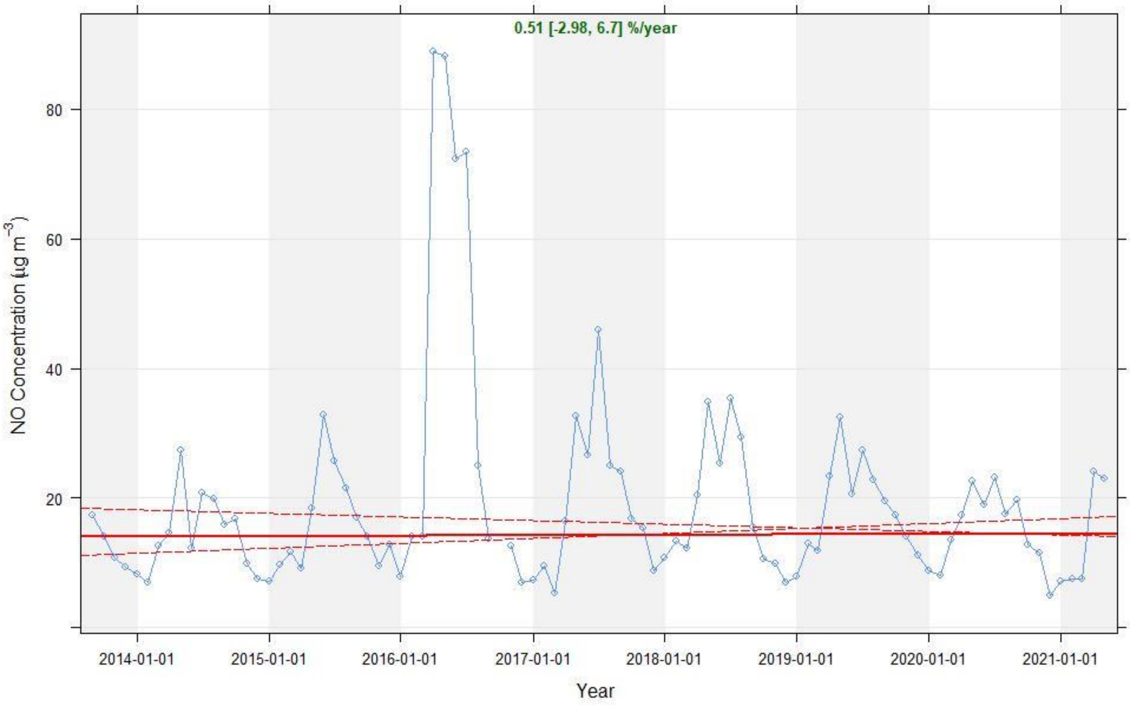


Figure 19 Wyee TheilSen Plot for NO (µg/m$^3$)

### 5.1.2 $NO_2$ plots

The pollution rose for $NO_2$ presented in Figure 20 is very similar to that for NO (Figure 15). However, the proportion contribution rose presented for $NO_2$ in Figure 21 is quite different to that for NO, with a far more significant contribution during winds from the east and northeast, which are common in spring and summer.

The polar plot in Figure 22 highlights that average concentrations during winds that place Wyee downwind of the power stations are proportionally higher than for NO, and there also appears to be a contribution from Colongra during winds from the east-southeast. The polar annulus plot in Figure 23 is very different to that for NO, reflecting the influence of chemistry, with the highest concentrations occurring in the early morning, before sunrise. Significant contributions from power stations would not be expected at this time of day, due to the elevated plume release in a stable atmosphere, and this is evident in the low concentrations that occur during winds from the northeast in the early morning. The ground-level emissions from vehicles on the motorway to the west of the monitor, however, appear to result in high concentrations of $NO_2$ at this time of day, before sunlight can have its influence. Figure 24 shows that there is also no significant trend in $NO_2$ concentrations over time at Wyee.

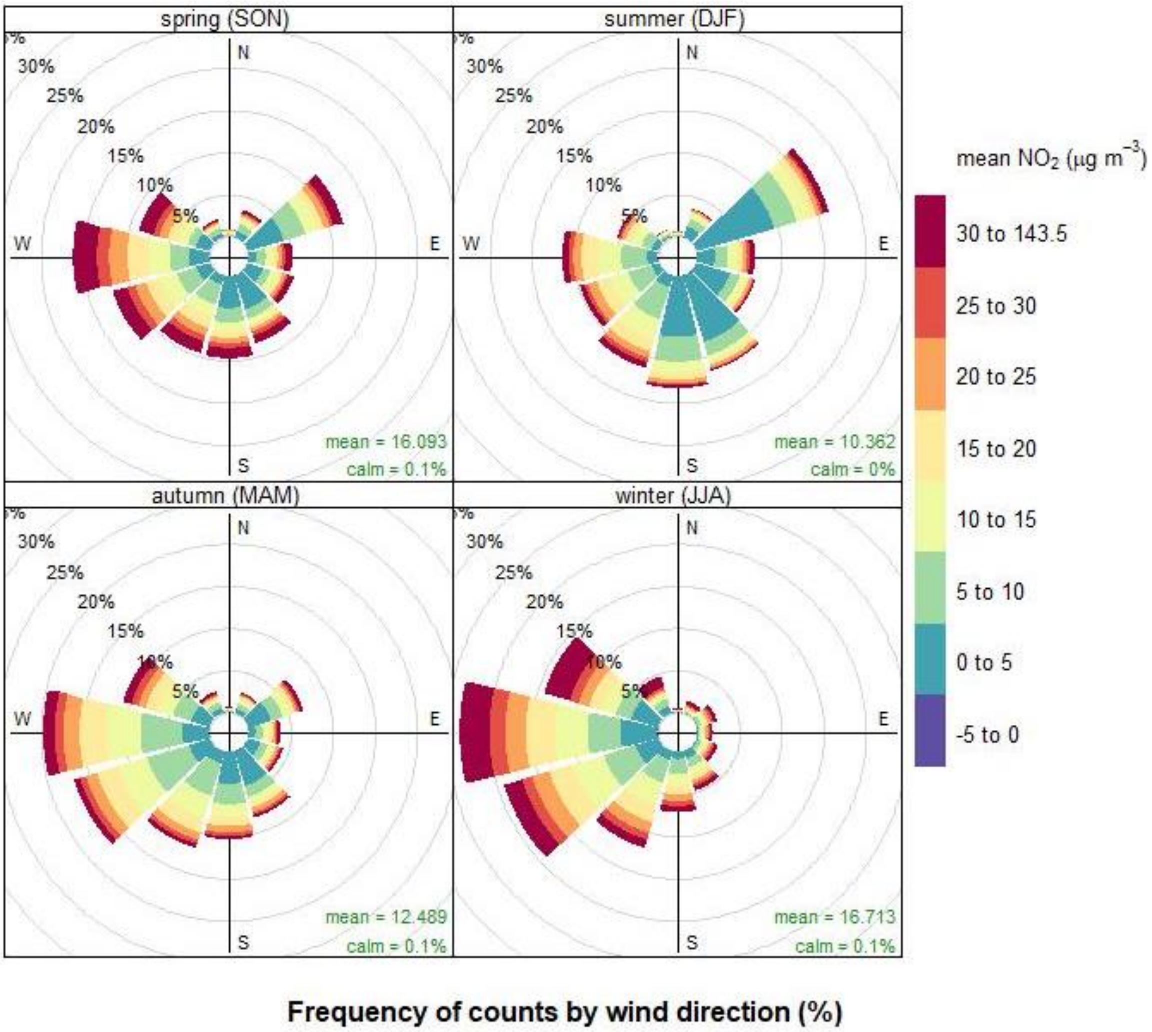


**Figure 20** Wyee Pollution Rose for $NO_2$ (µg/m$^3$)

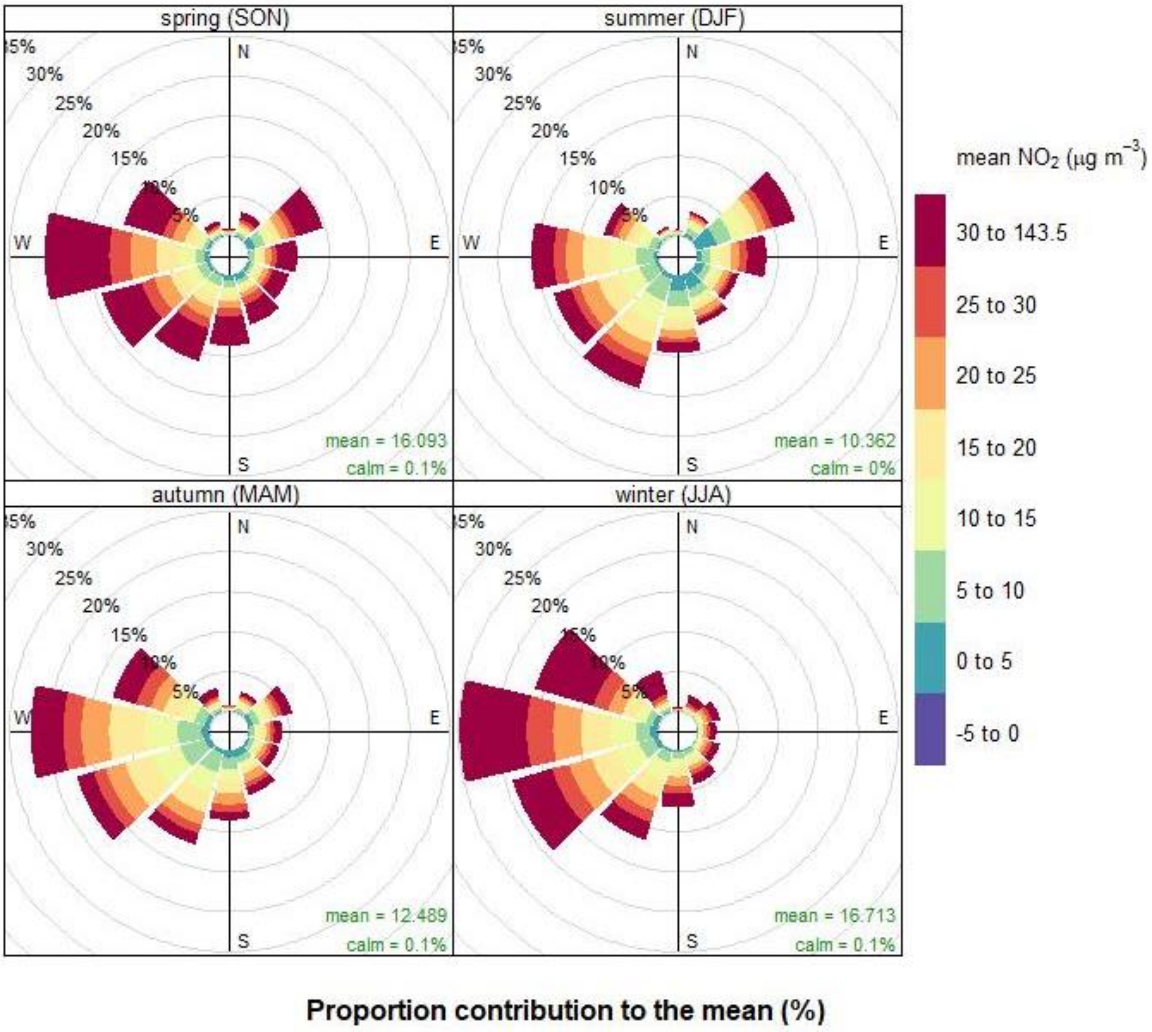


**Figure 21** Wyee Proportion Contribution Rose for $NO_2$ (µg/m$^3$)

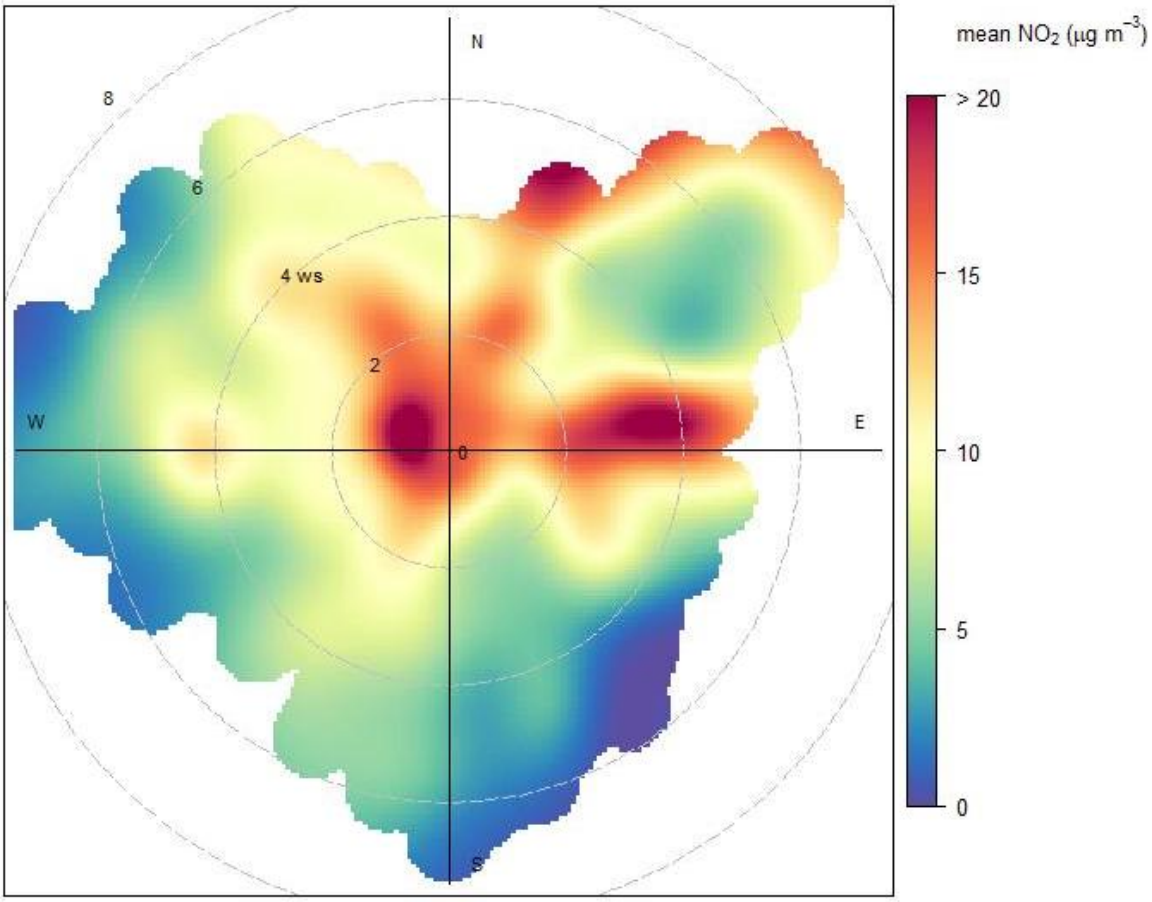


**Figure 22** Wyee Polar Plot for $NO_2$ ($\mu g/m^3$)

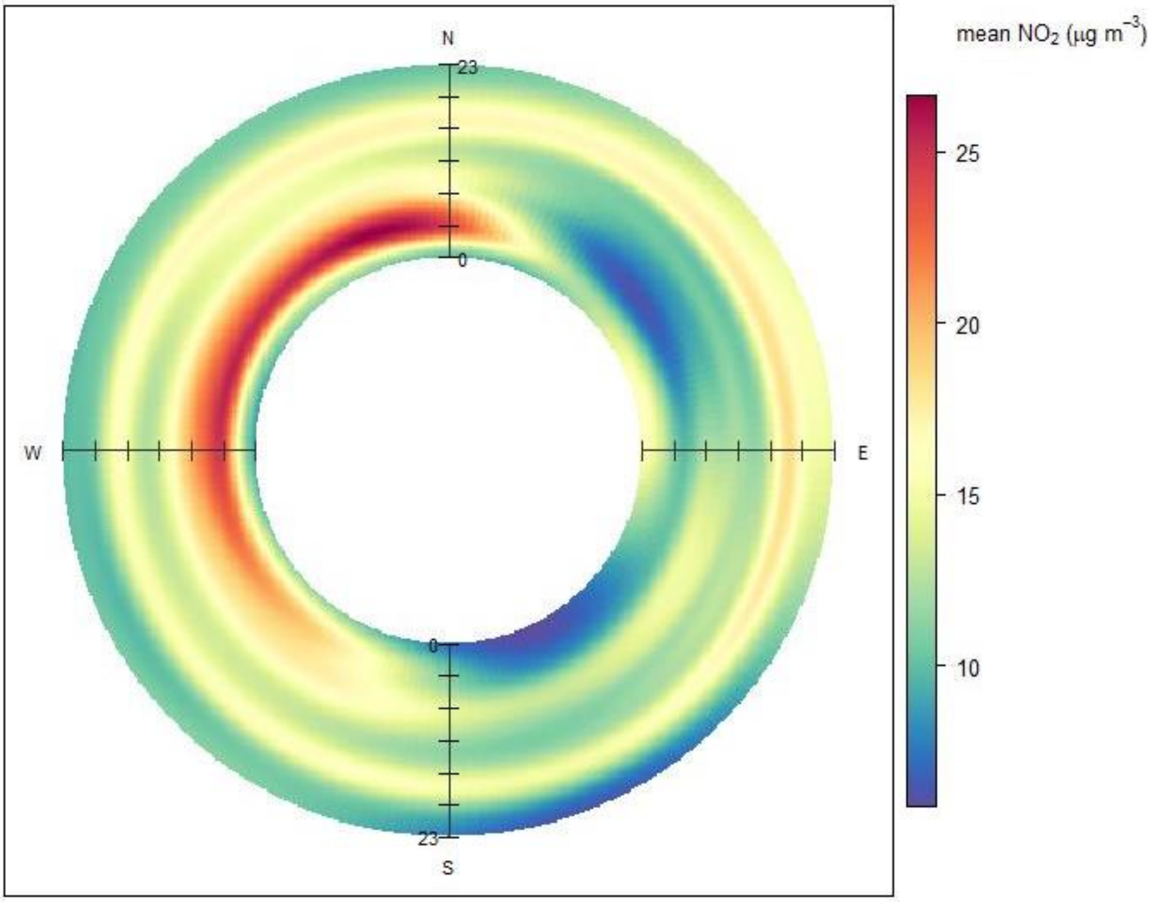


**Figure 23** Wyee Polar Annulus Plot for NO$_2$ (µg/m$^3$)

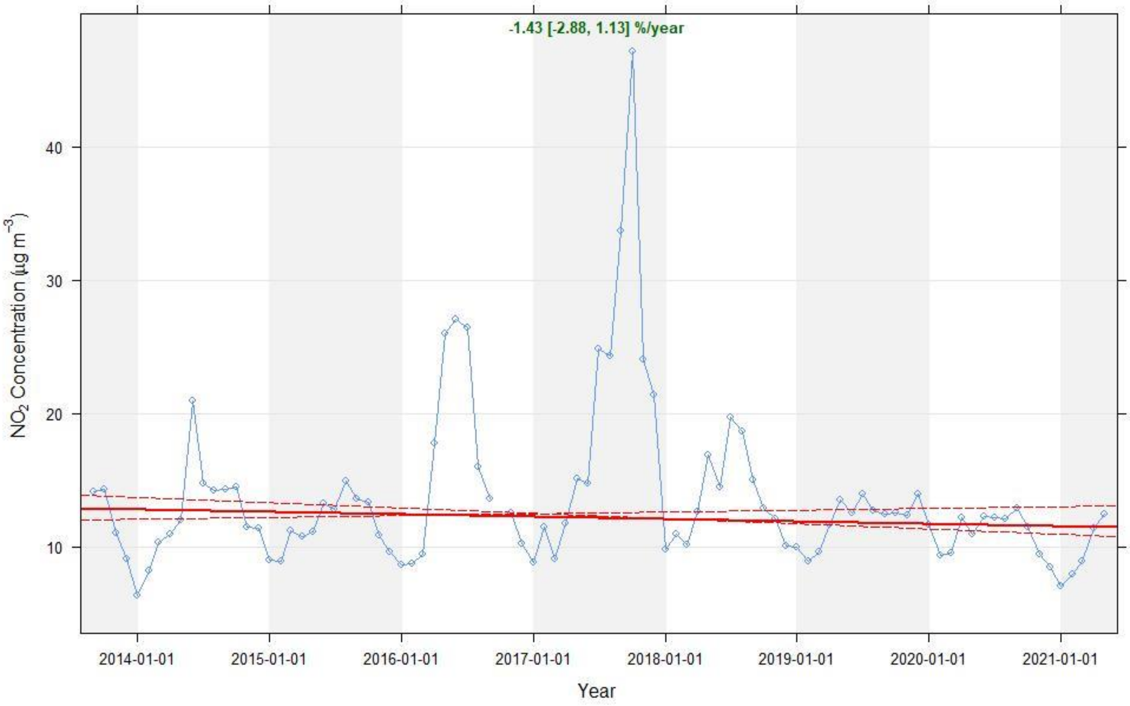


**Figure 24** Wyee TheilSen Plot for NO$_2$ (µg/m$^3$)

### 5.1.3 $SO_2$ plots

The polar plot for $SO_2$ presented in Figure 25 highlights that average concentrations are highest when the monitor is downwind of either Eraring or VPPS. The pollution roses in Figure 26 demonstrate the same. The proportion contribution roses in Figure 27 demonstrate that the bulk of the annual mean concentrations is made up of higher concentrations during winds that place the monitor downwind of VPPS. The contribution from Eraring to the north-northeast appears much smaller.

The polar annulus plot in Figure 28 highlights that the higher concentrations during winds from the east to northeast are most common in the late evening; this is because this is the time of day when winds from this direction are most common, but the increased mixing that occurs at this time of day will also be resulting in higher concentrations.

The TheilSen plot in Figure 29 demonstrates that there has been a reduction in concentrations of $SO_2$ over time at a rate of around 5.84%/year, statistically significant at the 95% confidence interval. Given that VPPS is very obviously the primary source of $SO_2$ measured at the monitor, it would seem logical to infer that the power station's $SO_2$ emissions have reduced over time. However, emissions data reported to the NPI does not support this hypothesis, thus it is unclear why there is a downward trend in concentrations of $SO_2$ at Wyee.

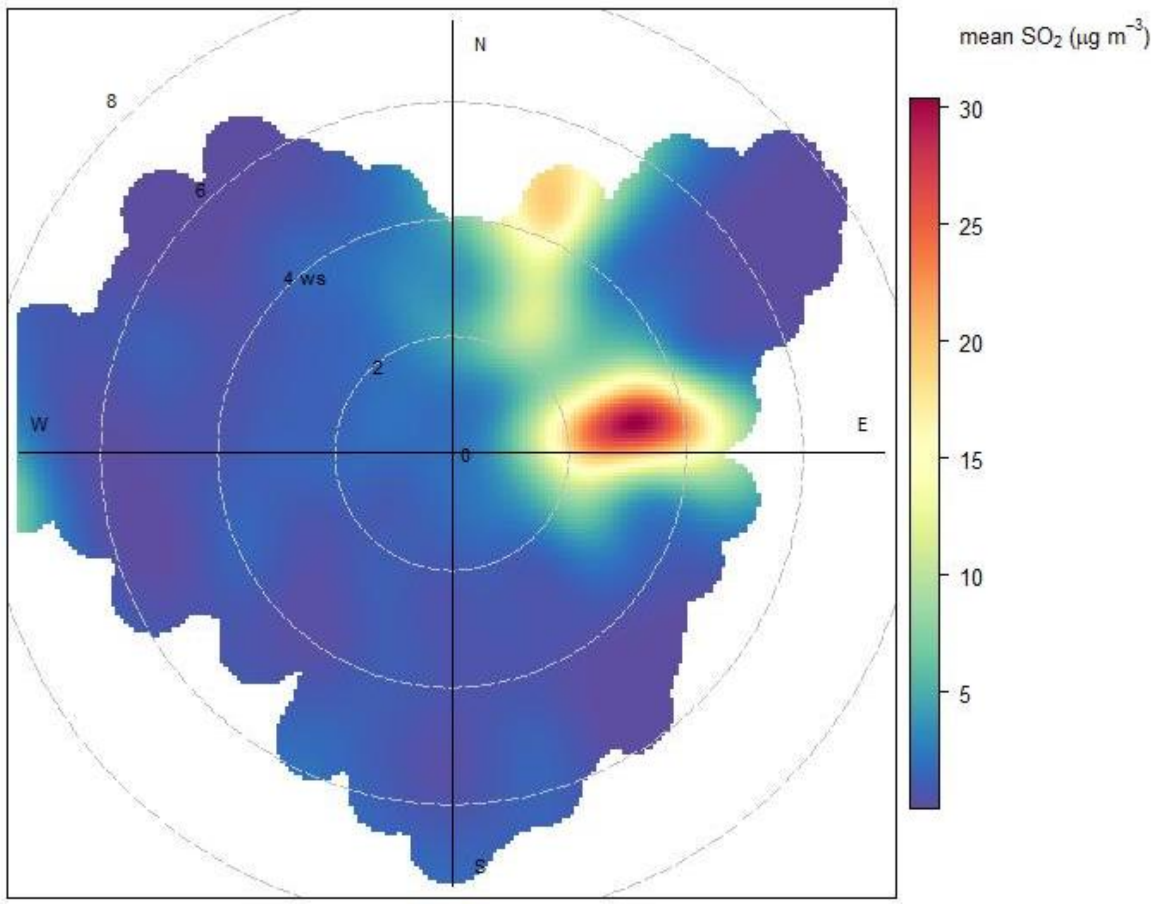


**Figure 25** **Wyee Polar Plot for $SO_2$ ($\mu g/m^3$)**

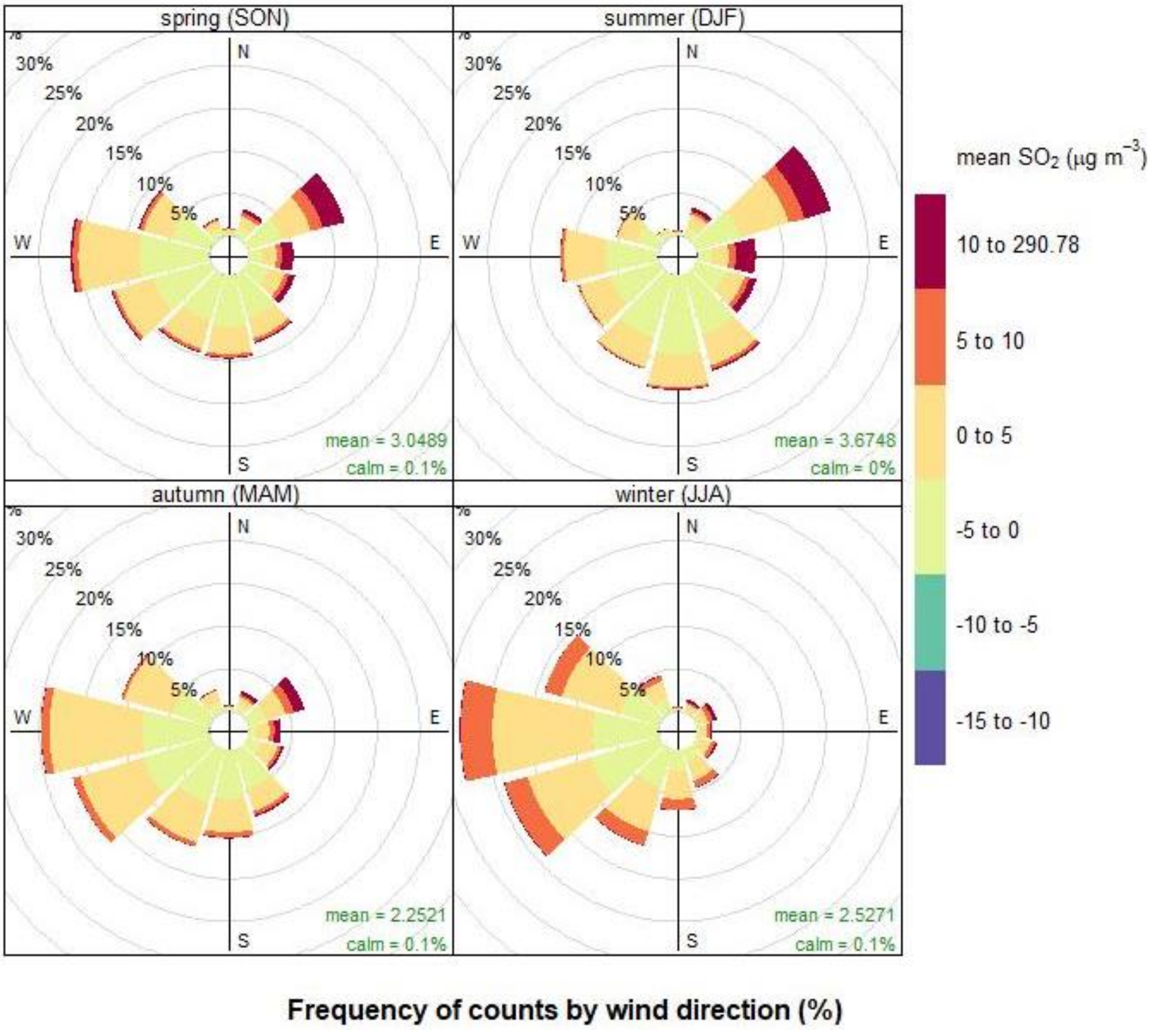


**Figure 26** Wyee Pollution Rose for $SO_2$ (µg/m$^3$)

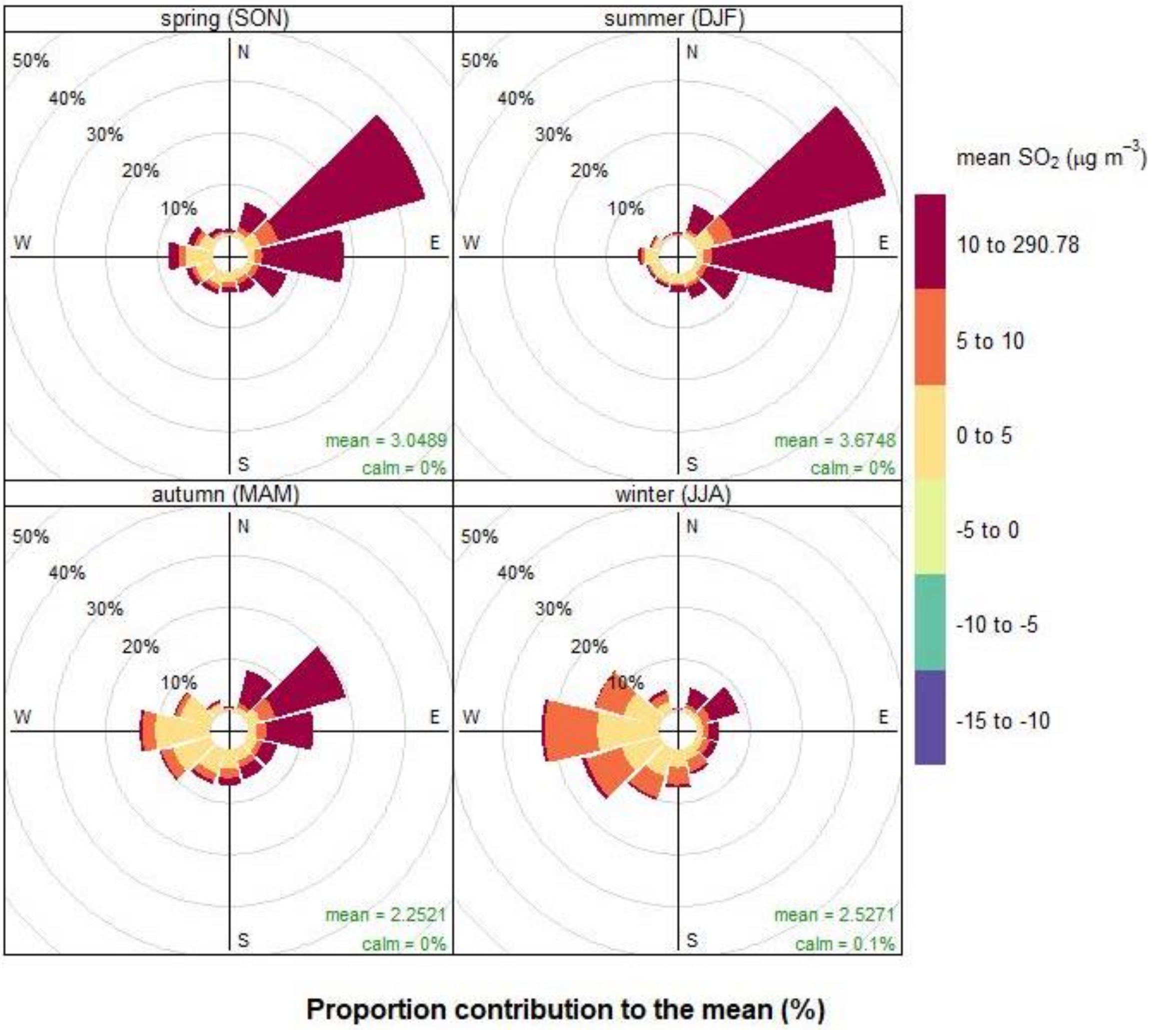


**Figure 27** Wyee Proportion Contribution Rose for $SO_2$ (µg/m$^3$)

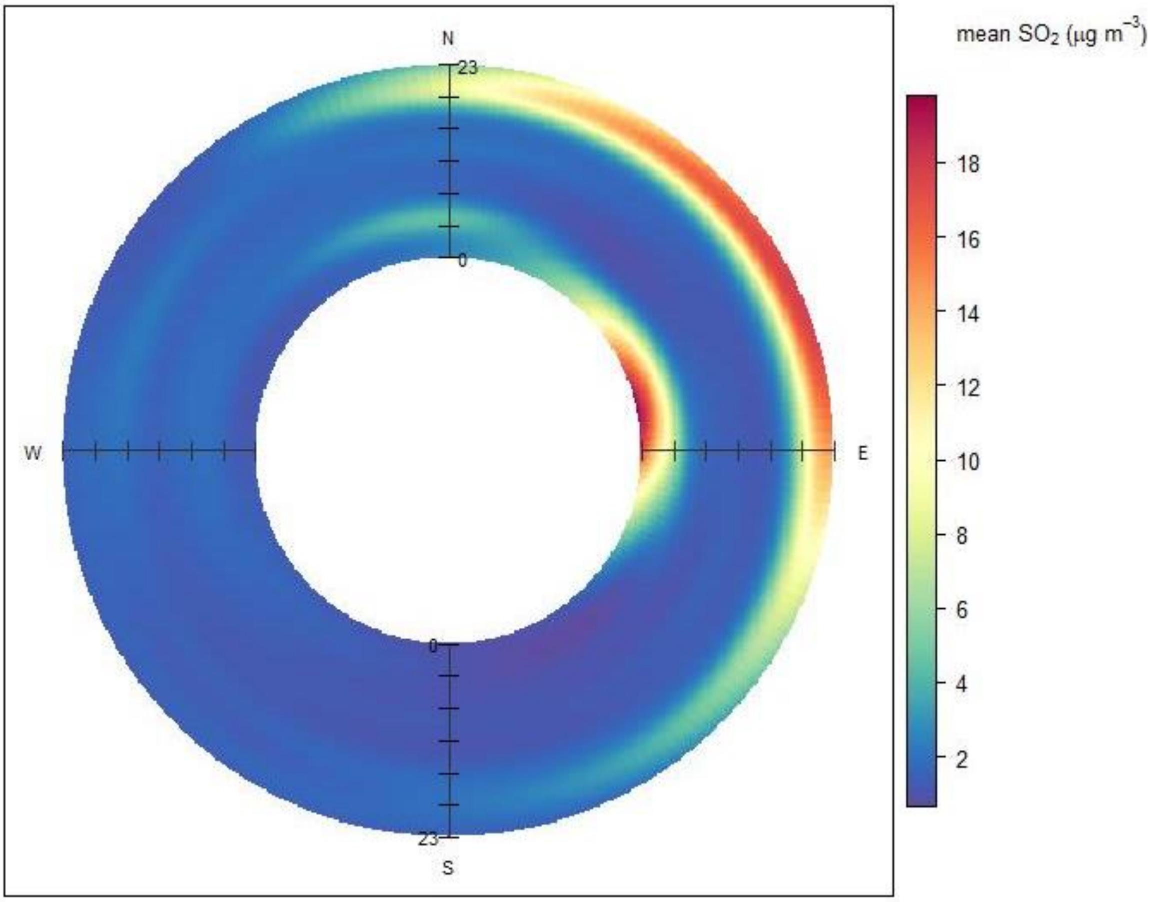


Figure 28 Wyee Polar Annulus Plot for $SO_2$ (µg/m$^3$)

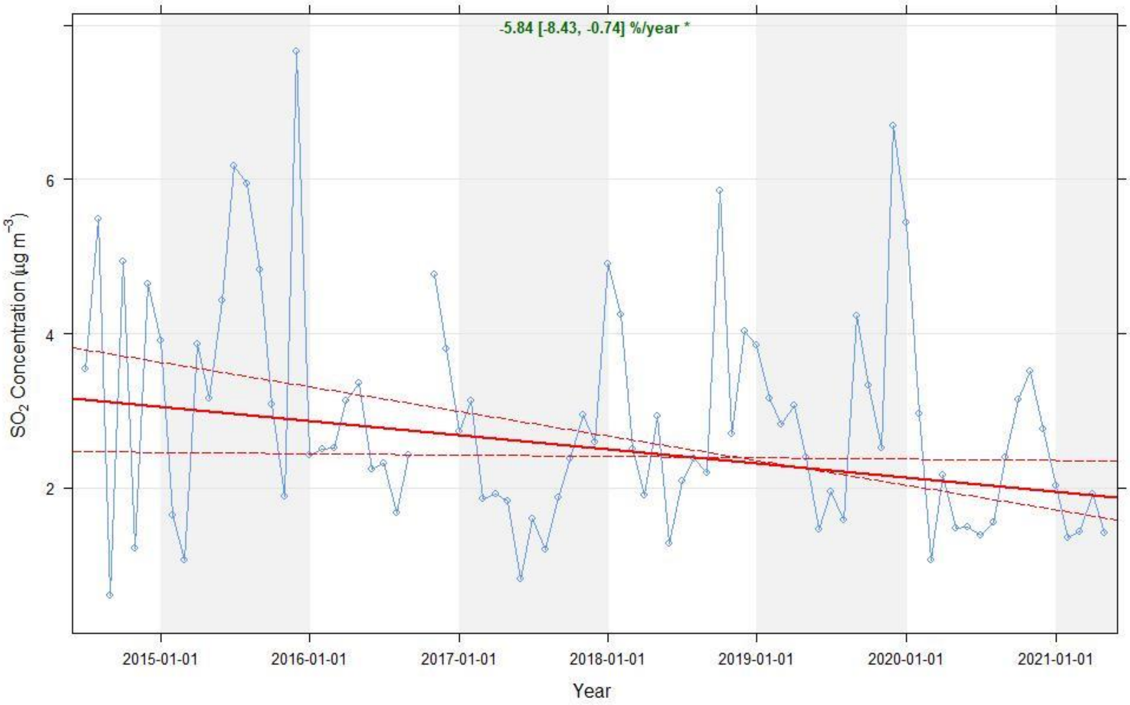


Figure 29 Wyee TheilSen Plot for $SO_2$ (µg/m$^3$)

### 5.1.4 $PM_{2.5}$ plots

The pollution rose for $PM_{2.5}$ presented in Figure 30 looks very similar to those for NO and $NO_2$. The proportion contribution roses presented for $PM_{2.5}$ in Figure 31 very much reflect the seasonal wind roses presented in Figure 14, suggesting that there are few distinct sources contributing to measured concentrations. Concentrations of $PM_{2.5}$ tend not to differ much with wind direction. The polar plot in Figure 32 highlights that stronger winds from almost all directions tend to be associated with higher average concentrations. The higher concentrations during strong winds from the south-southwest may represent the transport of the urban plume from Sydney to Wyee.

The polar annulus plot in Figure 33 shows that concentrations tend to be highest at night; this may be an association with wind speed, as average wind speeds measured at Wyee tend to be much higher at night, although it may also reflect the stable atmosphere at night reducing mixing and keeping ground-level emissions close to ground. Figure 34 shows that there is no significant trend in concentrations of $PM_{2.5}$ over time at Wyee.

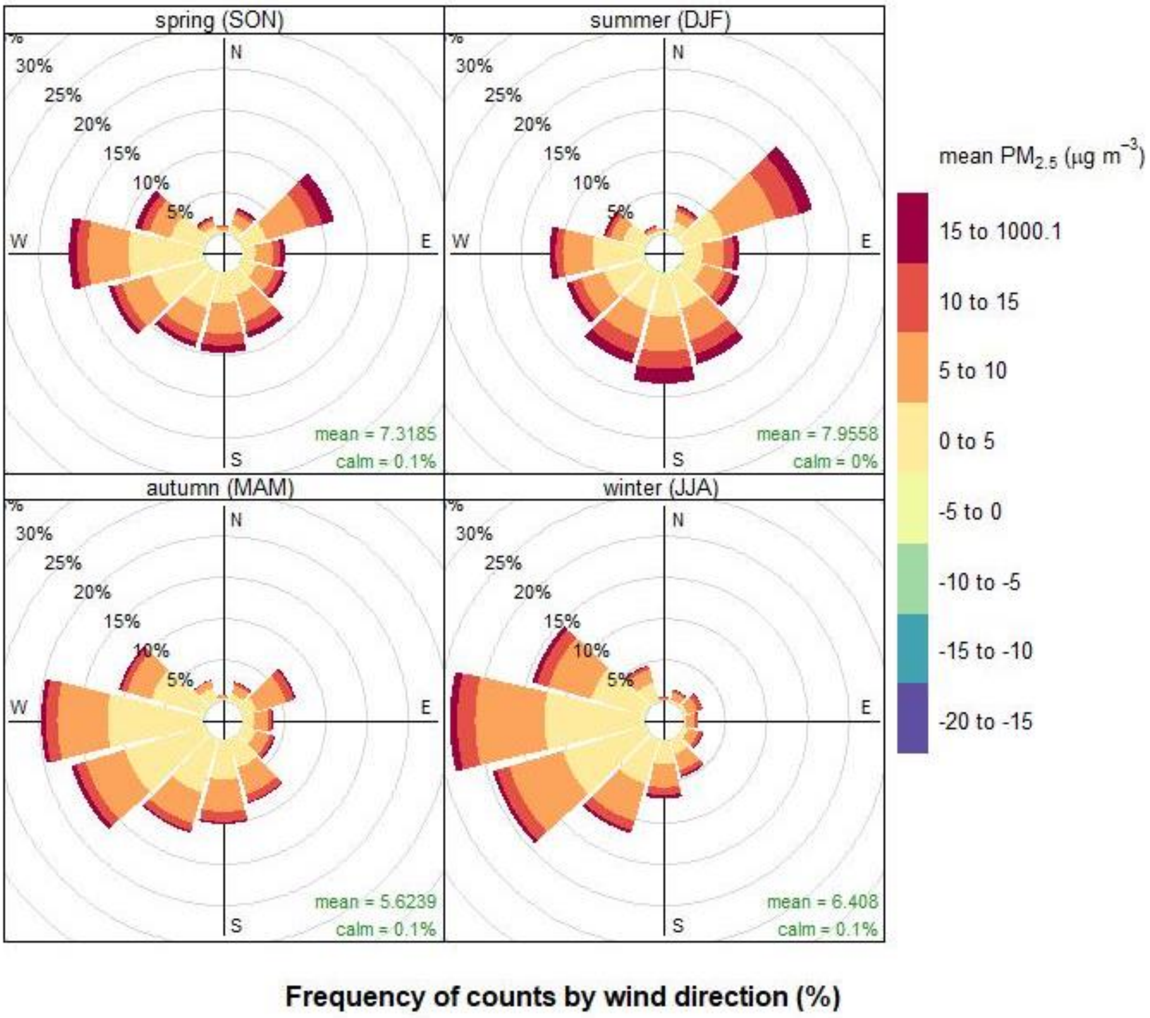


**Figure 30** Wyee Pollution Rose for $PM_{2.5}$ ($\mu g/m^3$)

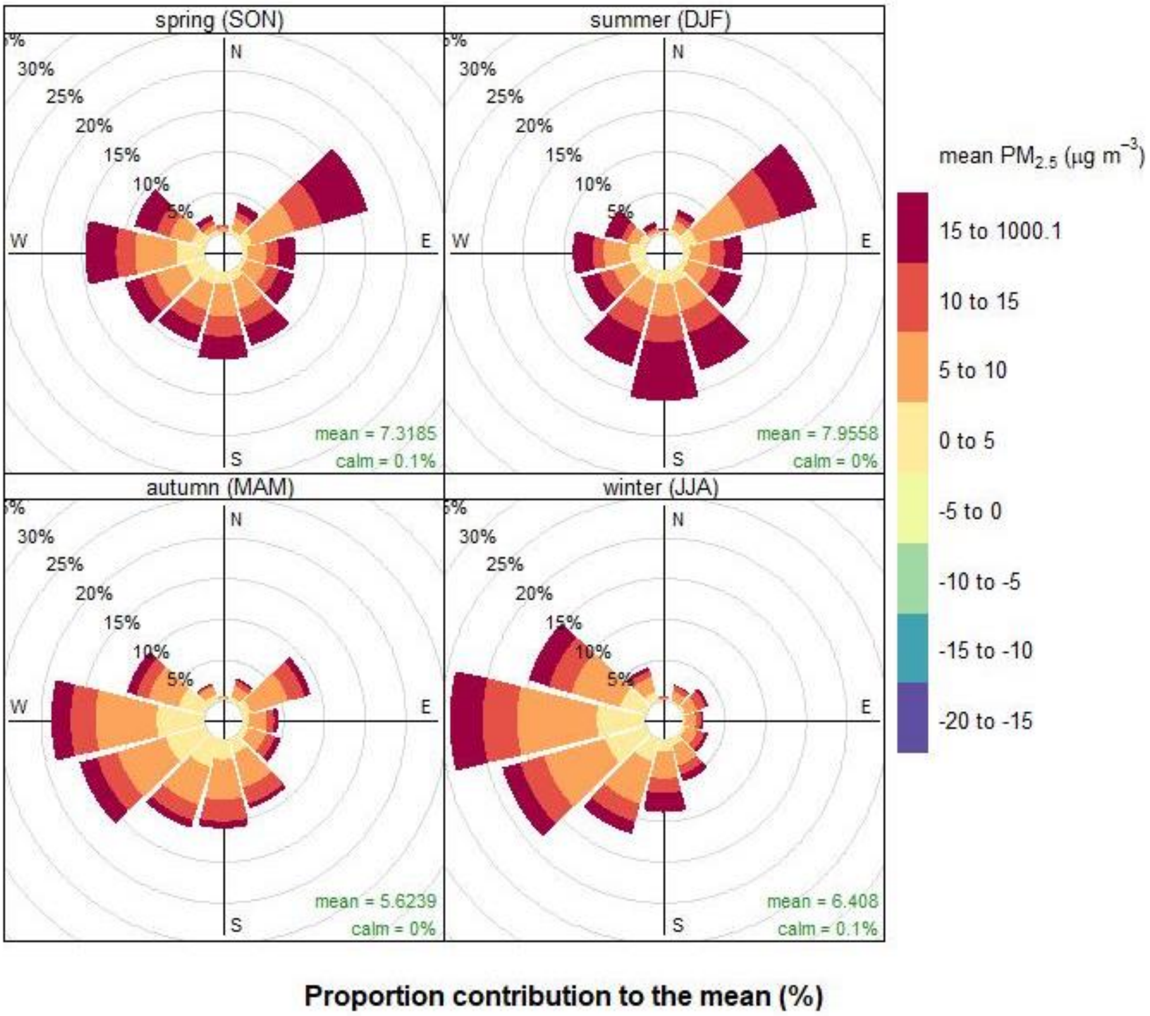


**Figure 31** Wyee Proportion Contribution Rose for $PM_{2.5}$ ($\mu g/m^3$)

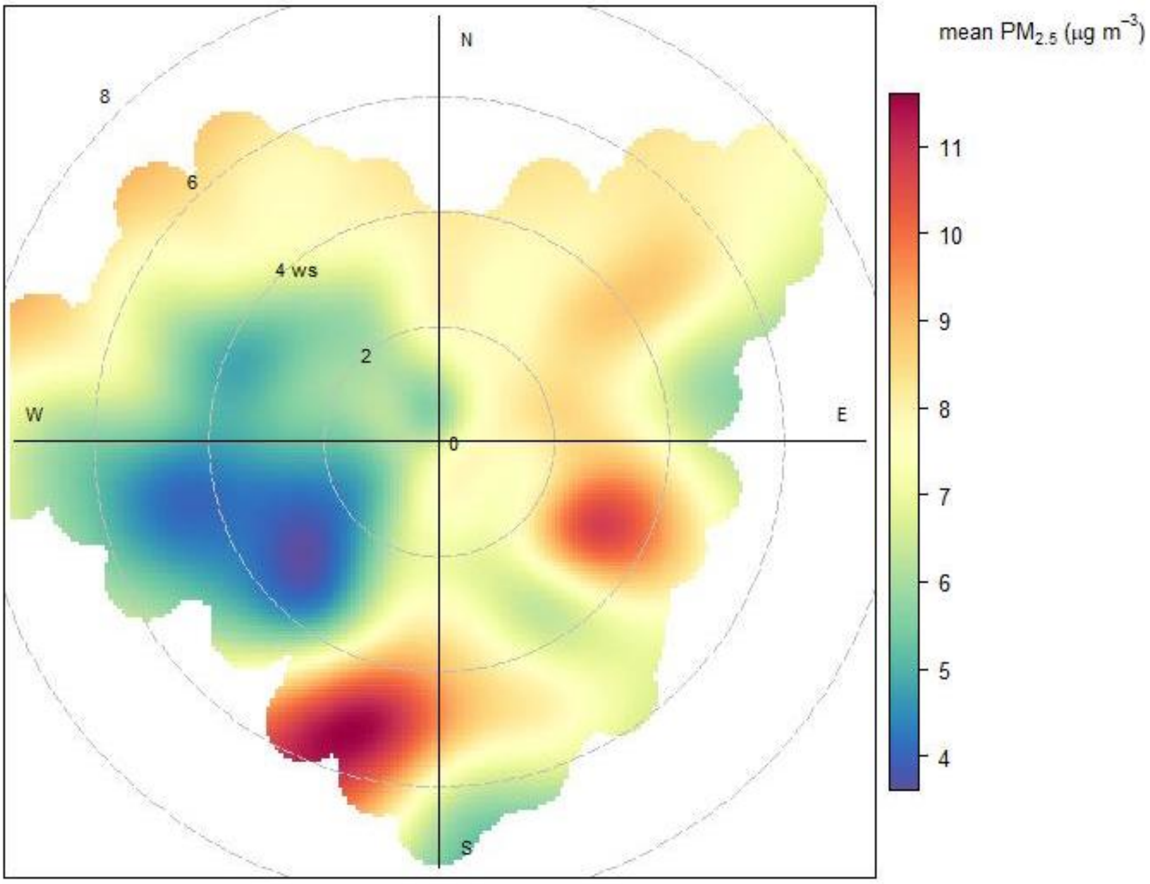


Figure 32 Wyee Polar Plot for $PM_{2.5}$ ($\mu g/m^3$)

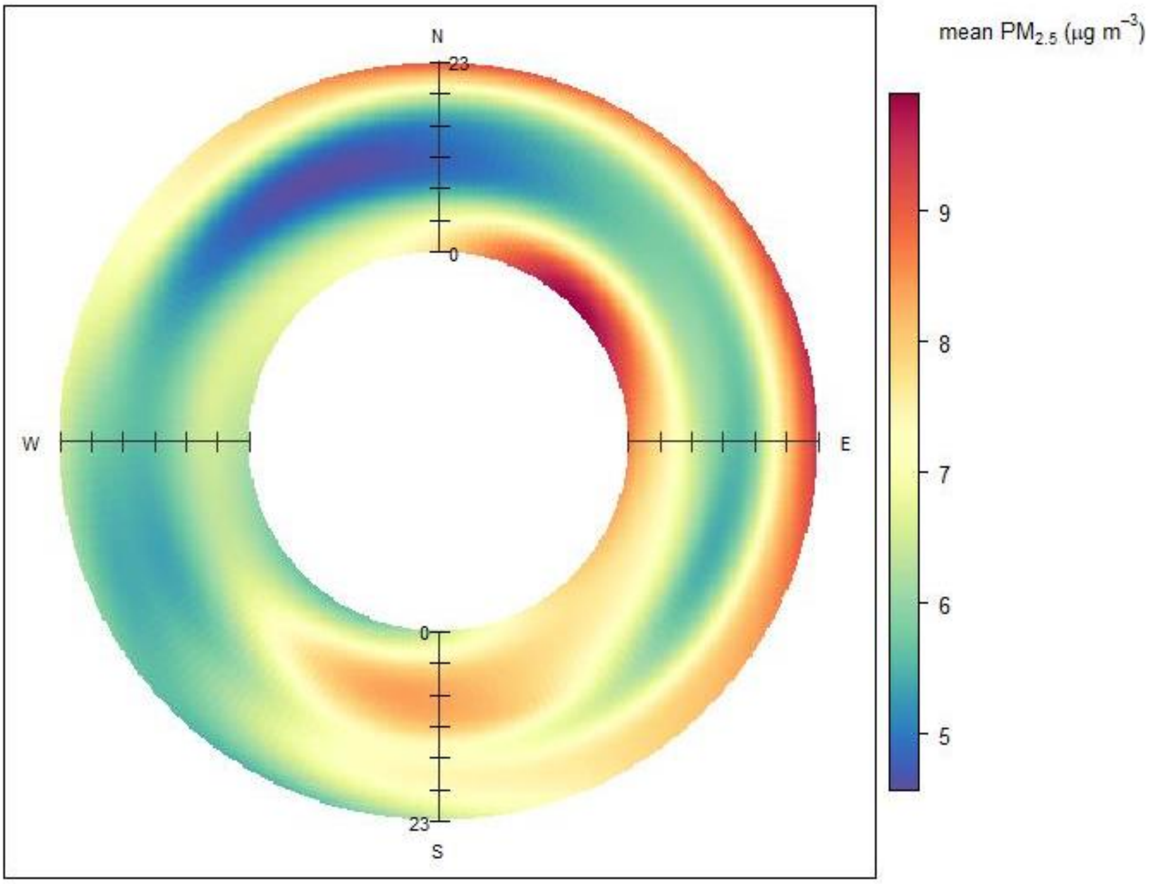


**Figure 33** Wyee Polar Annulus Plot for $PM_{2.5}$ ($\mu g/m^3$)

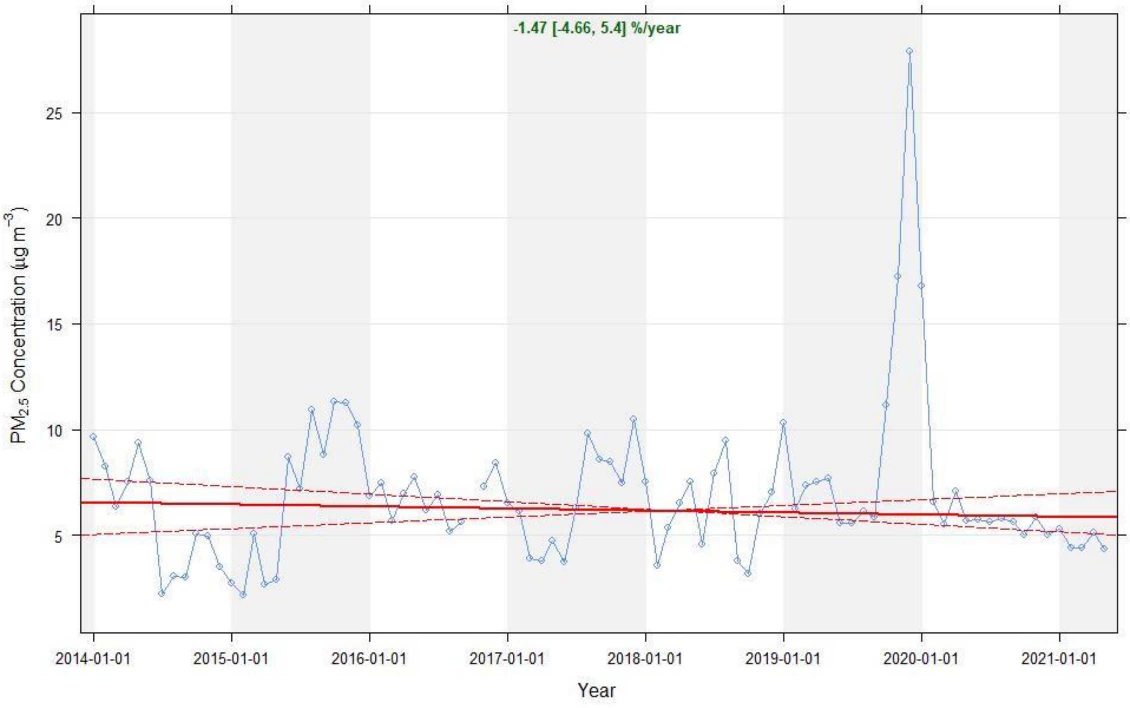


**Figure 34** Wyee TheilSen Plot for $PM_{2.5}$ ($\mu g/m^3$)

### 5.1.5 Comparator plots

VPPS and Eraring power station are likely to represent the primary sources of $SO_2$ in the Central Coast region, with few other sources likely to contribute significantly to elevated concentrations of $SO_2$. It is, therefore, worthwhile to consider concentrations of $SO_2$ against concentrations of the other pollutants, to identify whether peak concentrations of those pollutants coincide with peak concentration of $SO_2$, and thus whether power station emissions are likely to be contributing to elevated concentrations of the other pollutants.

Figure 35, Figure 36 and Figure 37 present scatter plots of contemporaneous concentrations of $SO_2$ against $NO_2$, NO and $PM_{2.5}$, respectively. Figure 35 demonstrates that it is very common for concentrations of $NO_2$ to be elevated at Wyee when concentrations of $SO_2$ are not; indeed, the two highest $NO_2$ concentrations occur when the concentrations of $SO_2$ are negligible. However, there are occasions when elevated concentrations of $NO_2$ align with elevated concentrations of $SO_2$, albeit fairly infrequently. Overall, the plot suggests that power station emissions are unlikely to be the primary source of $NO_2$ at Wyee.

Figure 36 demonstrates that the highest NO concentrations are not associated with power station emissions, NO concentrations are consistently below 150 µg/m$^3$ when there is a power station $SO_2$ signal.

Figure 37 shows no relationship at all between $SO_2$ and $PM_{2.5}$ concentrations, suggesting that the key sources of these pollutants are different, and thus that power stations contribute minimally to $PM_{2.5}$ concentrations at Wyee.

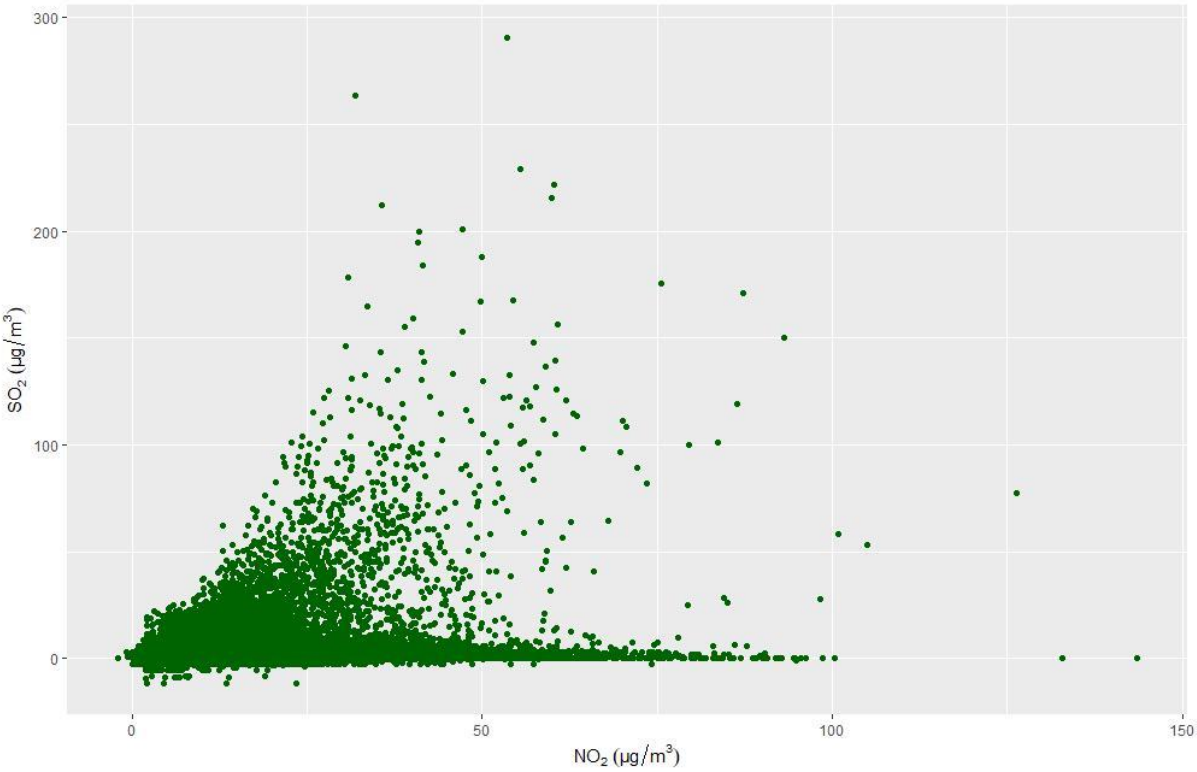


**Figure 35** **Wyee $NO_2$ versus $SO_2$ (µg/m$^3$)**

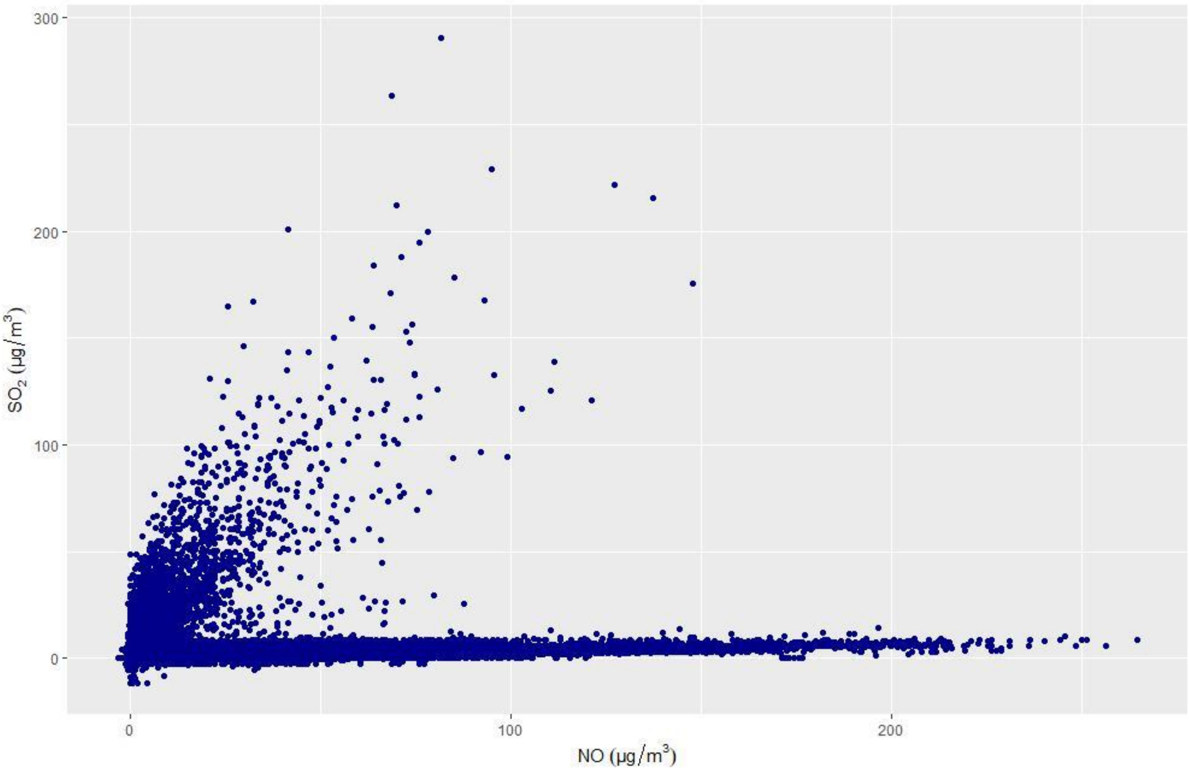


**Figure 36** Wyee NO versus SO₂ (µg/m³)

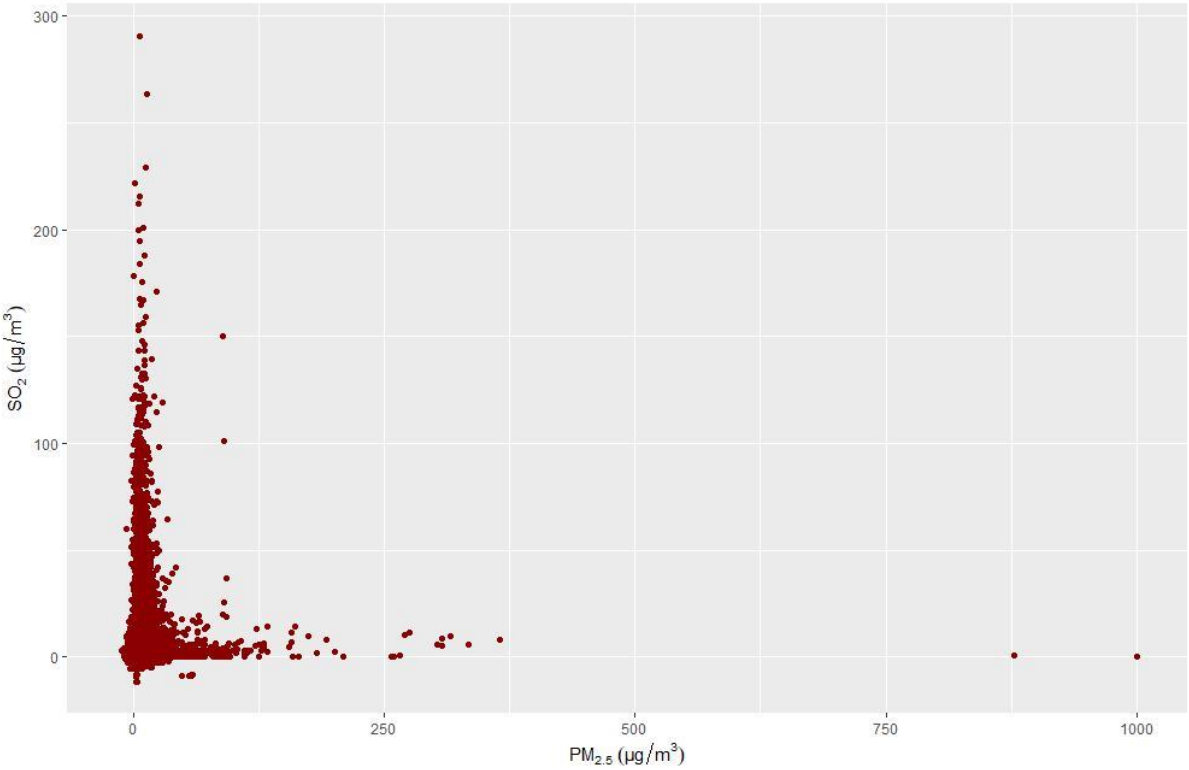


**Figure 37** Wyee PM₂.₂ versus SO₂ (µg/m³)

## 5.2 Measured Concentrations at Wyong

Table 23 and Table 24 summarise pollutant measurements made at Wyong since 2013. The monitor was commissioned in October 2012. Similar to Wyee, concentrations have been well below the Air NEPM standards for $NO_2$ and $SO_2$, with exceedances of both the annual and 24-hour standards for $PM_{2.5}$ in 2019, with the high concentrations measured (relative to the other years) likely a result of the bushfires that occurred in this year. The 24-hour standard for $PM_{2.5}$ has been exceeded in only four of the eight presented years at Wyong.

**Table 23 Measured Annual Average Pollutant Concentrations at Wyong (µg/m$^3$)**

| Year | NO | | $NO_2$ | | $SO_2$ | | $PM_{2.5}$ | |
|---|---|---|---|---|---|---|---|---|
| | DC[1] | Conc[2] | DC[1] | Conc[2] | DC[1] | Conc[2] | DC[1] | Conc[2] |
| 2013 | 94.7 | 3.8 | 94.7 | 10.3 | 94.7 | 2.1 | 89.0 | 6.7 |
| 2014 | 94.3 | 3.2 | 94.3 | 10.2 | 93.7 | 1.8 | 94.1 | 5.5 |
| 2015 | 93.8 | 3.0 | 93.8 | 9.3 | 92.9 | 1.7 | 93.6 | 5.2 |
| 2016 | 93.4 | 3.0 | 93.4 | 9.6 | 94.4 | 1.6 | 94.8 | 5.8 |
| 2017 | 94.3 | 2.7 | 94.3 | 10.2 | 92.9 | 1.8 | 95.0 | 5.8 |
| 2018 | 93.6 | 2.6 | 93.6 | 8.9 | 94.2 | 2.2 | 90.2 | 6.8 |
| 2019 | 94.0 | 2.8 | 94.0 | 7.8 | 94.4 | 2.0 | 90.4 | 10.4 |
| 2020 | 93.3 | 2.9 | 93.3 | 7.0 | 93.7 | 1.7 | 95.4 | 5.7 |
| Criterion[3] | - | - | - | 62 | - | 60 | - | 8 |

Table notes:
[1] Data Capture Rate (%)
[2] Annual Mean Concentration
[3] Approved Methods for Modelling

**Table 24 Measured Peak Short-term Pollutant Concentrations at Wyong (µg/m$^3$)**

| Year | $NO_2$ | $SO_2$ | | $PM_{2.5}$ |
|---|---|---|---|---|
| | 1-hour Max | 1-hour Max | 24-hour Max | 24-hour Max |
| 2013 | 84.9 | 84.3 | 15.6 | 56.2 |
| 2014 | 70.6 | 113.9 | 12.4 | 19.5 |
| 2015 | 66.1 | 197.2 | 26.9 | 13.0 |
| 2016 | 93.4 | 92.6 | 13.4 | 19.8 |
| 2017 | 104.7 | 133.6 | 18.9 | 28.7 |
| 2018 | 71.9 | 176.5 | 22.1 | 18.0 |
| 2019 | 74.0 | 173.8 | 18.1 | 195.7 |
| 2020 | 72.4 | 198.5 | 22.0 | 62.7 |
| Criterion[1] | 246 | 570 | 228 | 25 |

Table note:
[1] Approved Methods for Modelling

Figure 38 presents seasonal wind roses for the entire Wyong dataset (15 October 2012 to 5 August 2021). These highlight that prevailing winds are mainly from the north and northwest, with winds from the southeast also being reasonably frequent year-round. In summer, winds from the south and east are common, while in winter winds from the west-northwest are relatively common alongside those with a more northerly component.

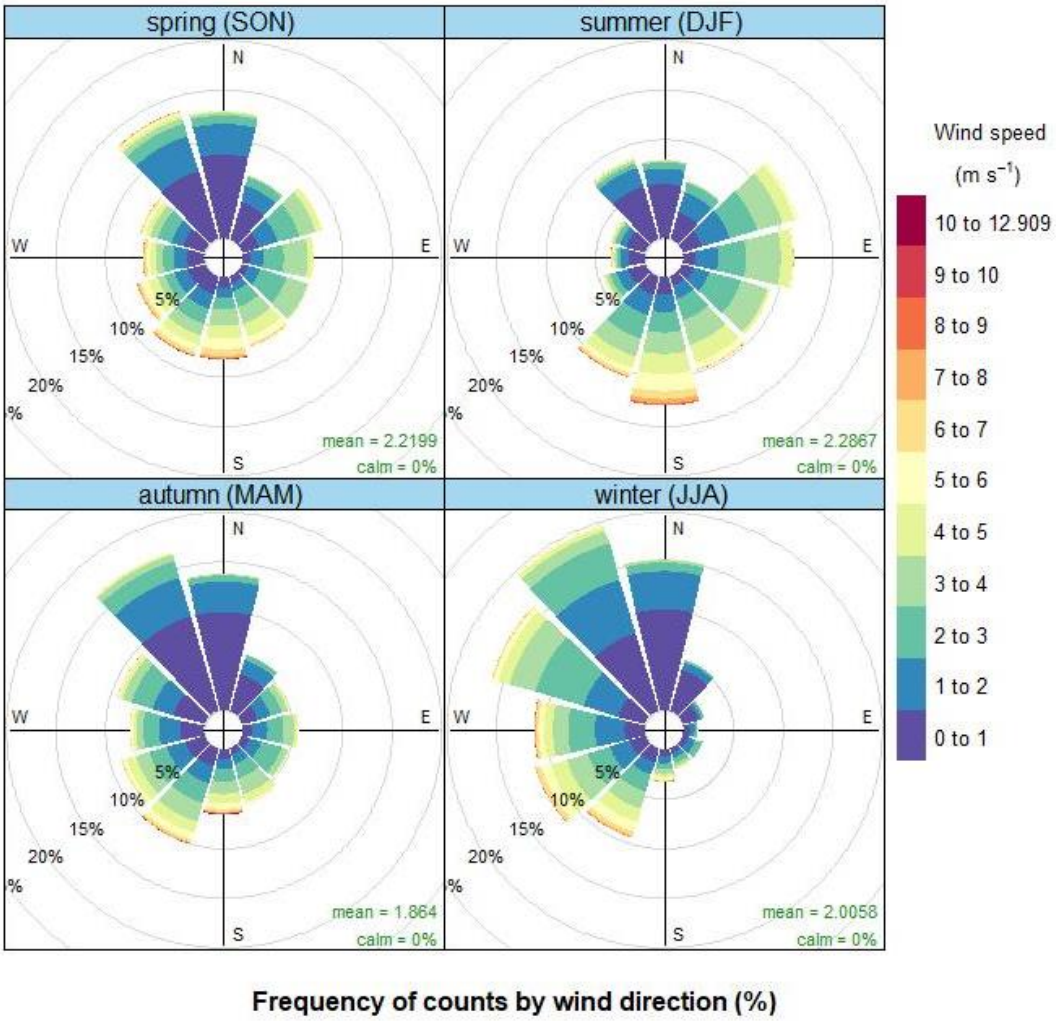


**Figure 38** **Wyong Seasonal Wind Rose**

### 5.2.1 $SO_2$ plots

For Wyong, winds from a relatively narrow band of directions (roughly 15-55°) would place the monitor downwind of Eraring and/or Vales Point power stations. This sector is obvious in the polar plot for concentrations of $SO_2$ shown in Figure 39, as well as the polar annulus plot shown in Figure 40. Figure 40 shows that the higher concentrations tend to occur in the late evening, which is also when winds from the northeast tend to occur. This is somewhat counter-intuitive, as the stable atmospheric conditions at night will usually minimise the transport of elevated power station emissions down to ground-level, but there may be some residual instability lingering after sunset, and concentrations are highest in summer when the days are longer.

Figure 41 and Figure 42 also show that the highest concentrations occur during winds form the northeast, with Figure 42 demonstrating that it is higher concentrations during winds from the northeast quadrant that contribute most of the measured mean concentrations of $SO_2$.

Figure 43 suggests a slight downward trend in concentrations of $SO_2$ at Wyong, but not a statistically significant one.

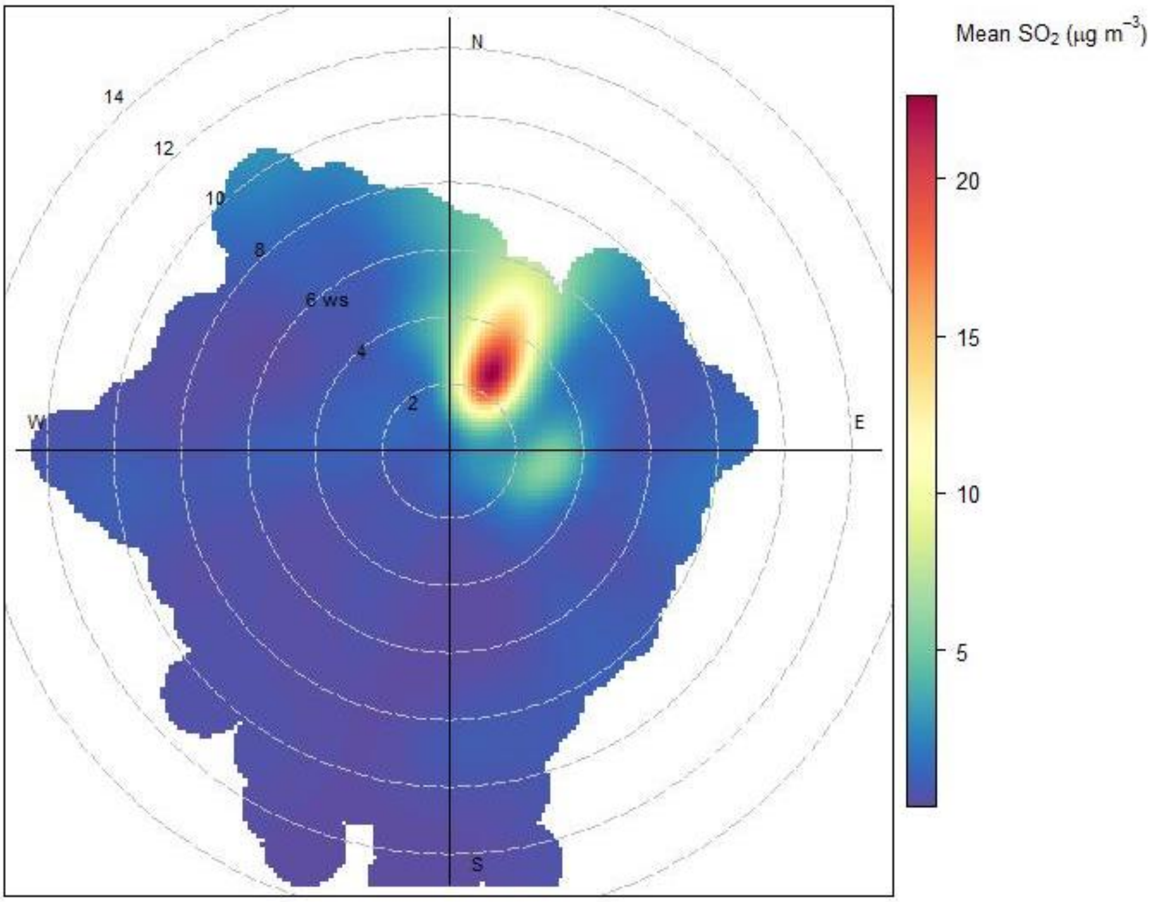


**Figure 39** **Wyong Polar Plot for $SO_2$ (µg/m$^3$)**

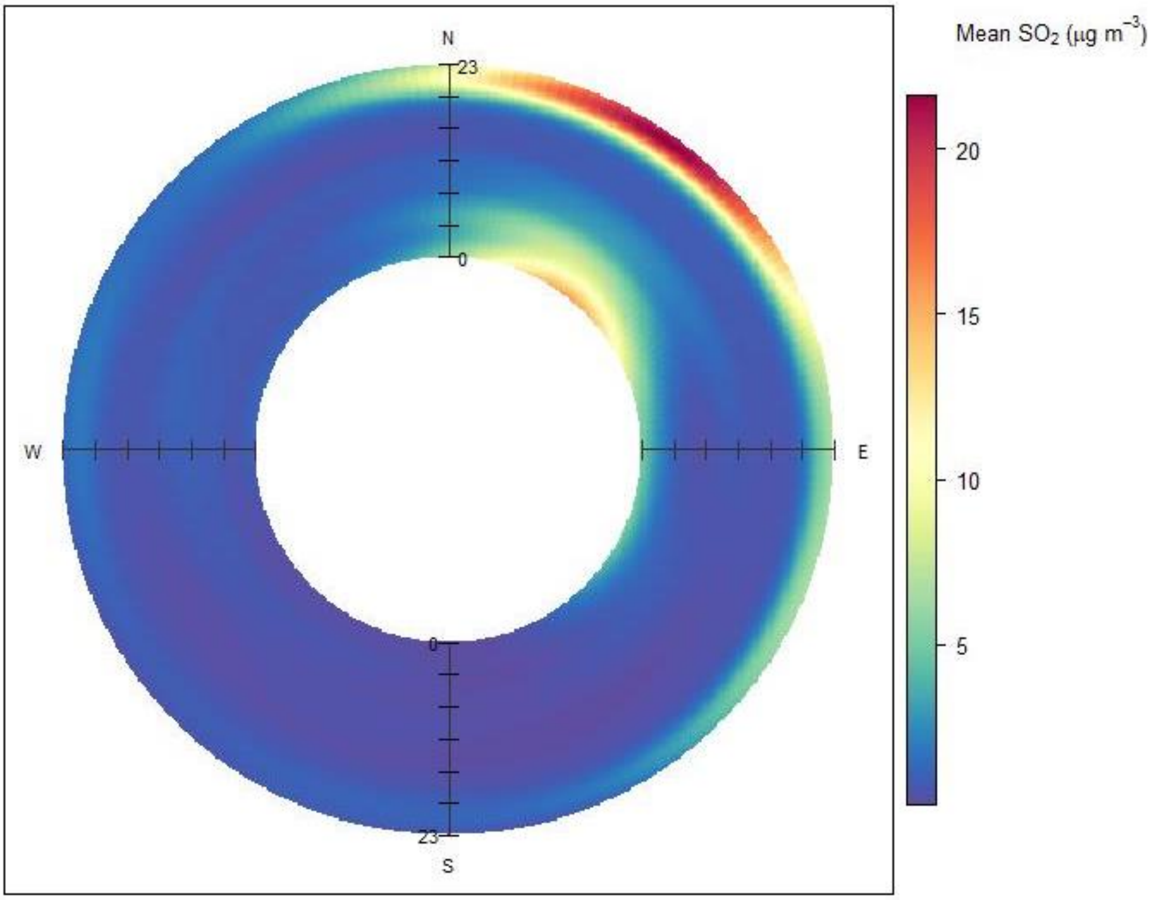


**Figure 40** **Wyong Polar Annulus Plot for $SO_2$ (µg/$m^3$)**

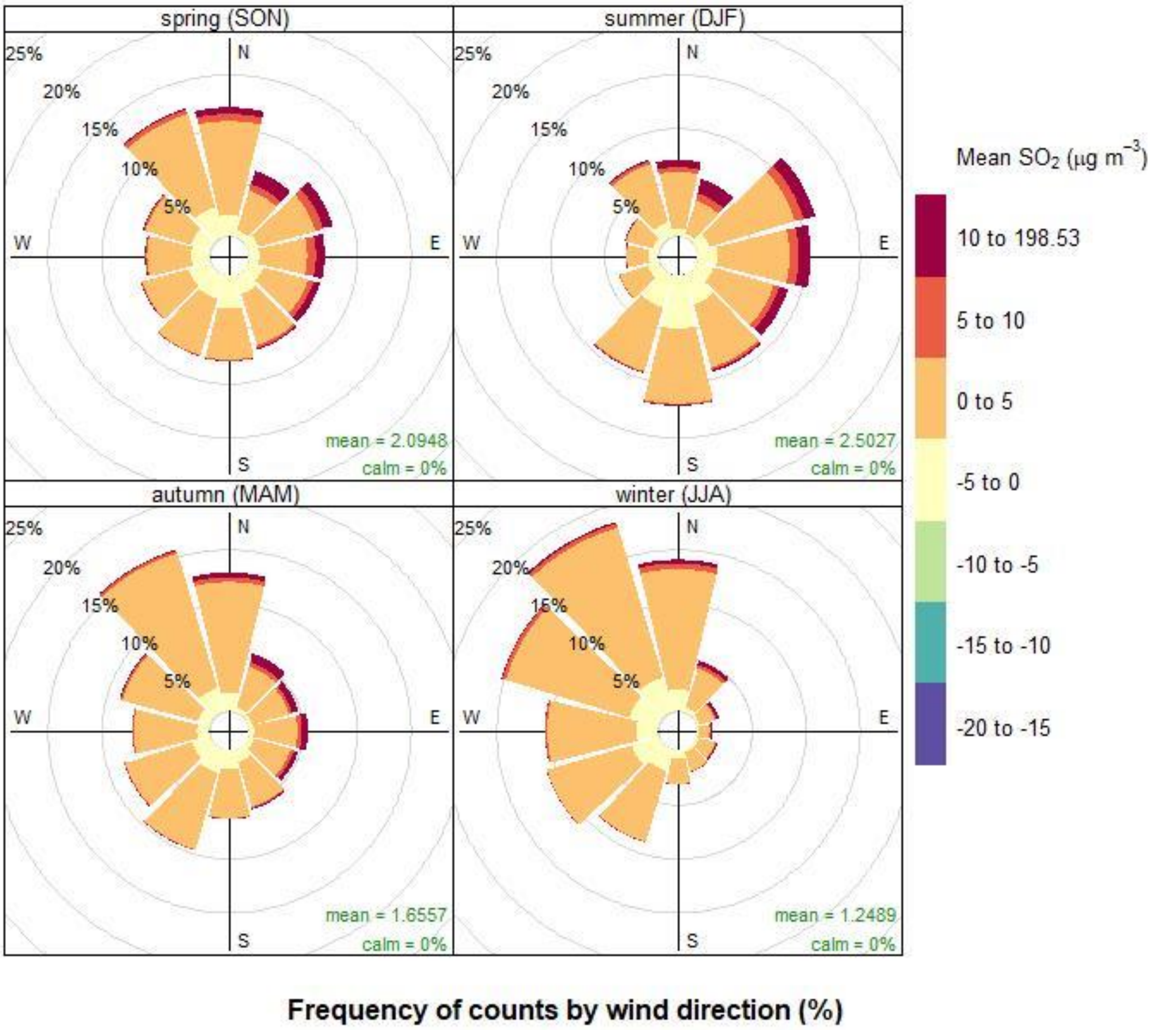


**Figure 41** Wyong Pollution Rose for $SO_2$ (µg/m$^3$)

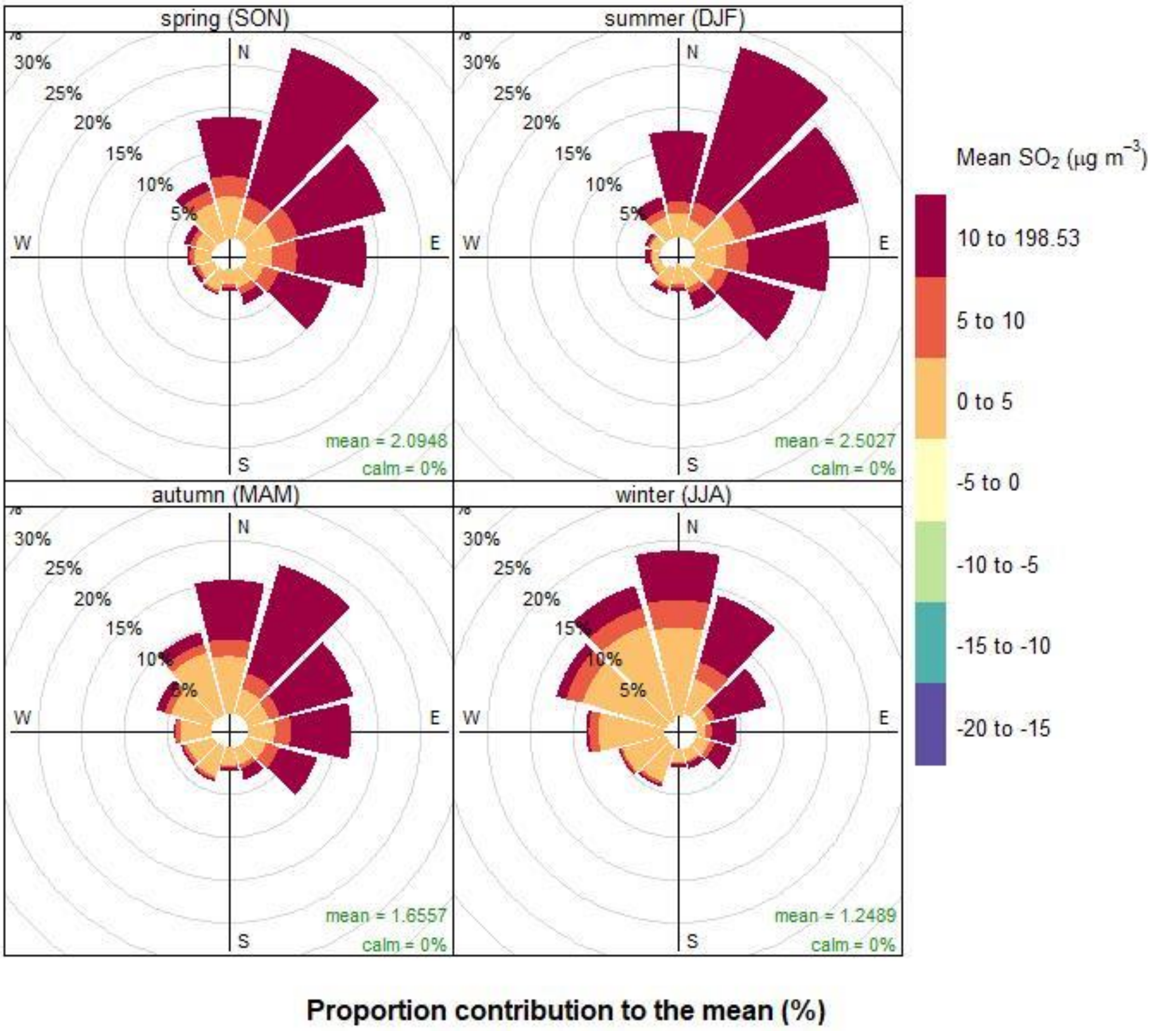


**Figure 42** Wyong Proportion Contribution Rose for $SO_2$ ($\mu g/m^3$)

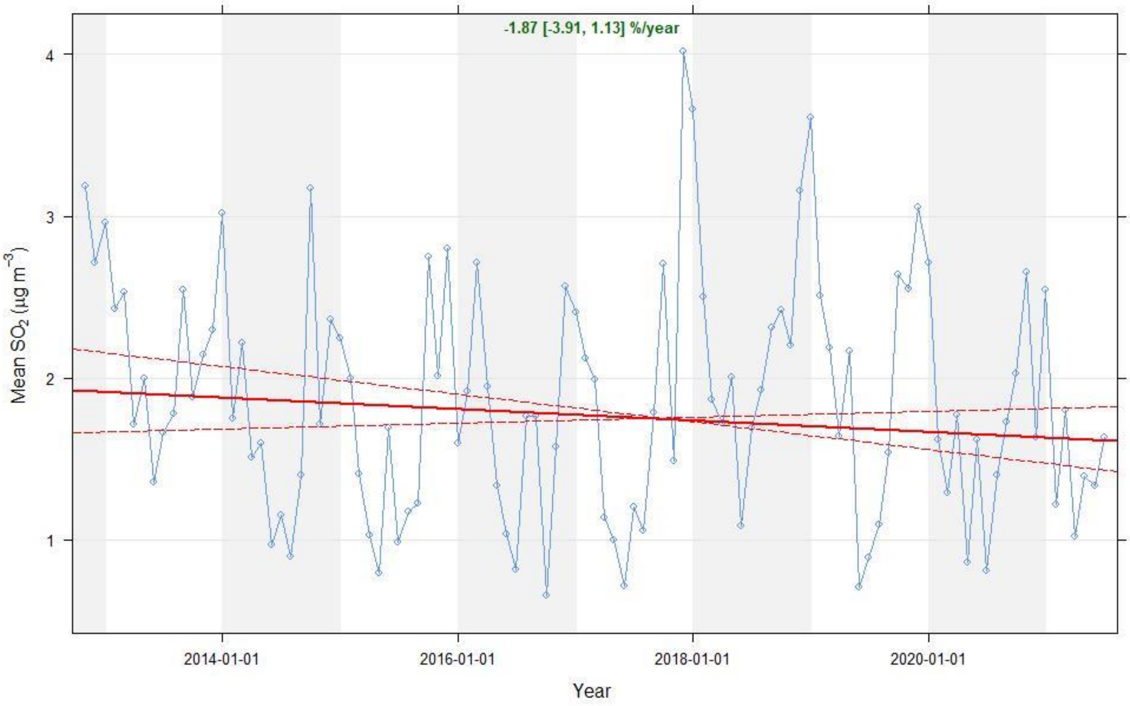


**Figure 43** Wyong TheilSen Plot for $SO_2$ (µg/m$^3$)

### 5.2.2 NO plots

The polar plot in Figure 45 highlights that the highest NO concentrations are also associated with stronger winds from the north-northeast, suggesting that it is the power stations that are also the source of these. Again, the polar annulus plot in Figure 45 highlights that these conditions tend to occur in the evening, which is when winds from this direction most commonly occur.

Figure 46 and Figure 47 further highlight that the highest concentrations occur during winds from the north, and that these winds contribute substantially to the composition of mean concentrations.

The TheilSen plot in Figure 48 shows no significant trend in NO concentrations at Wyong.

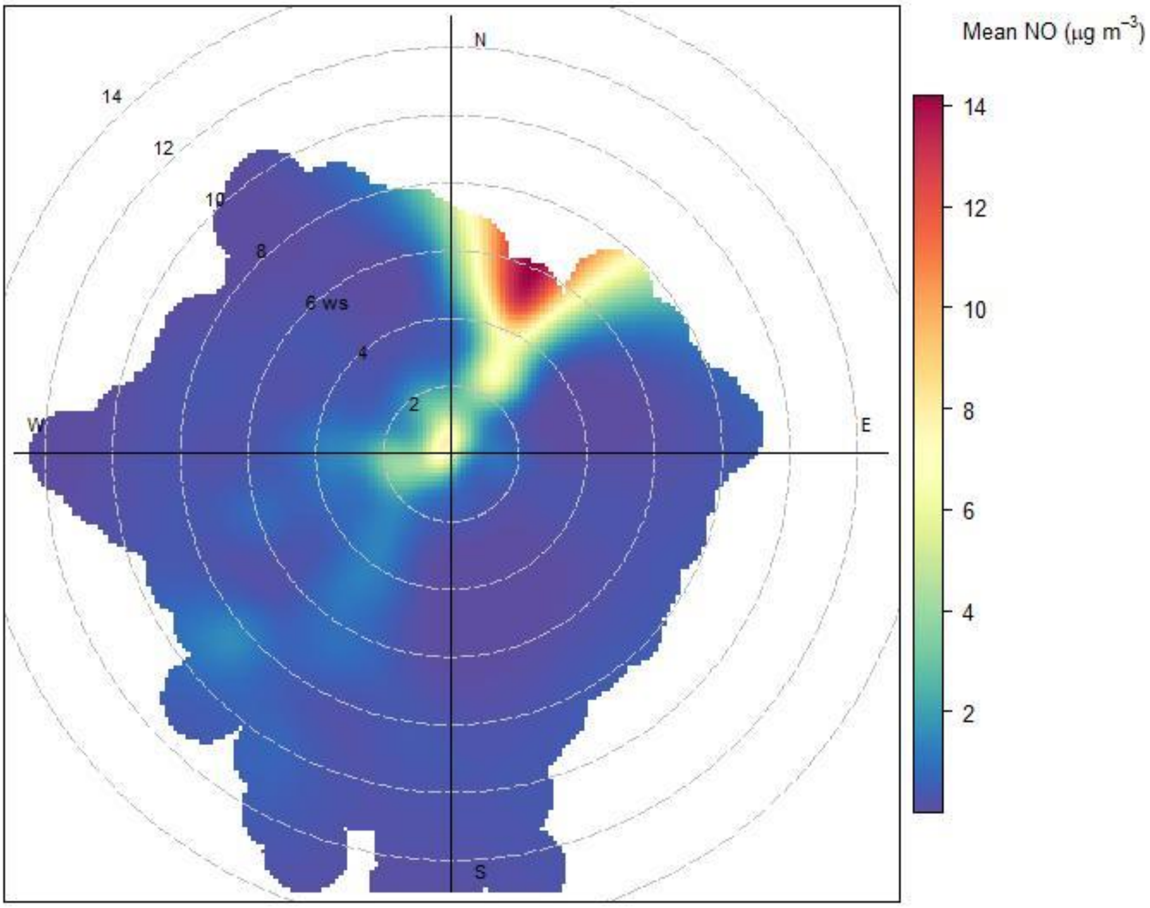


**Figure 44** **Wyong Polar Plot for NO (μg/m$^3$)**

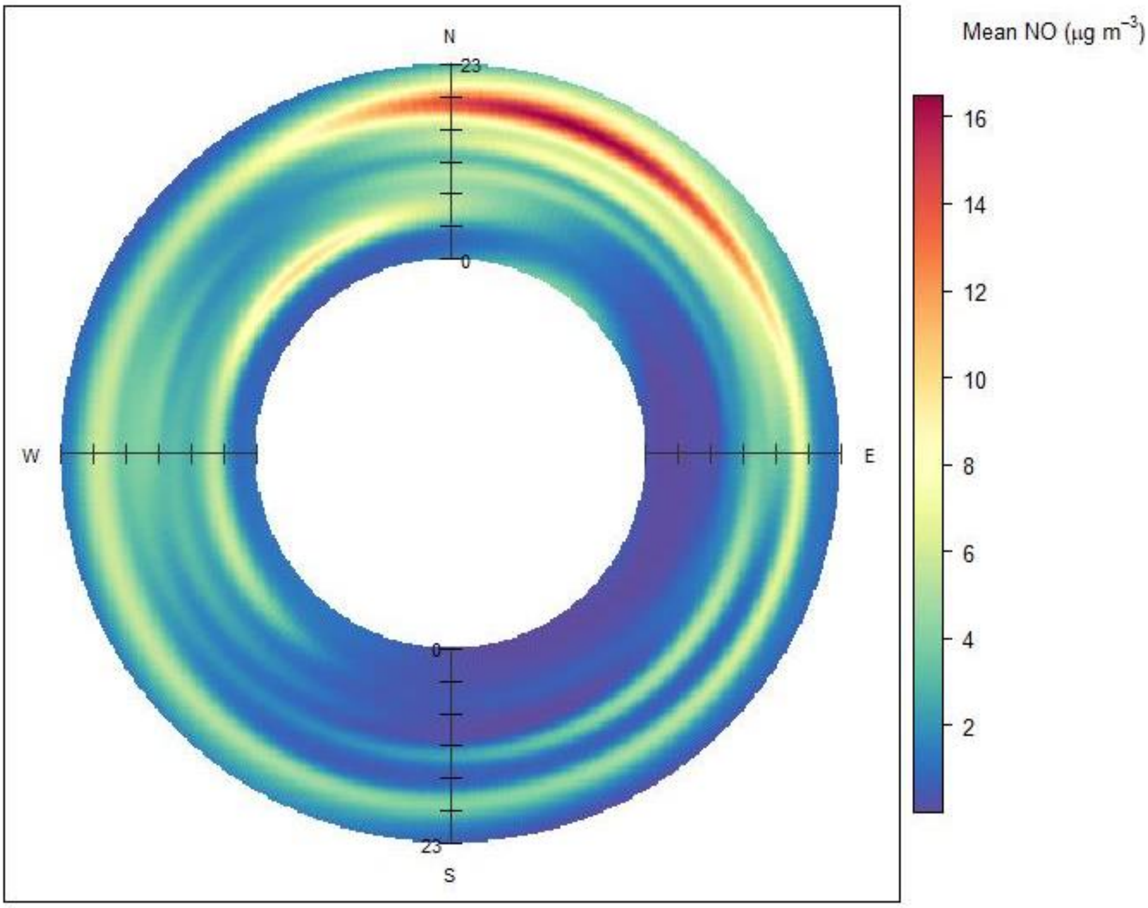


**Figure 45** Wyong Polar Annulus Plot for NO (µg/m$^3$)

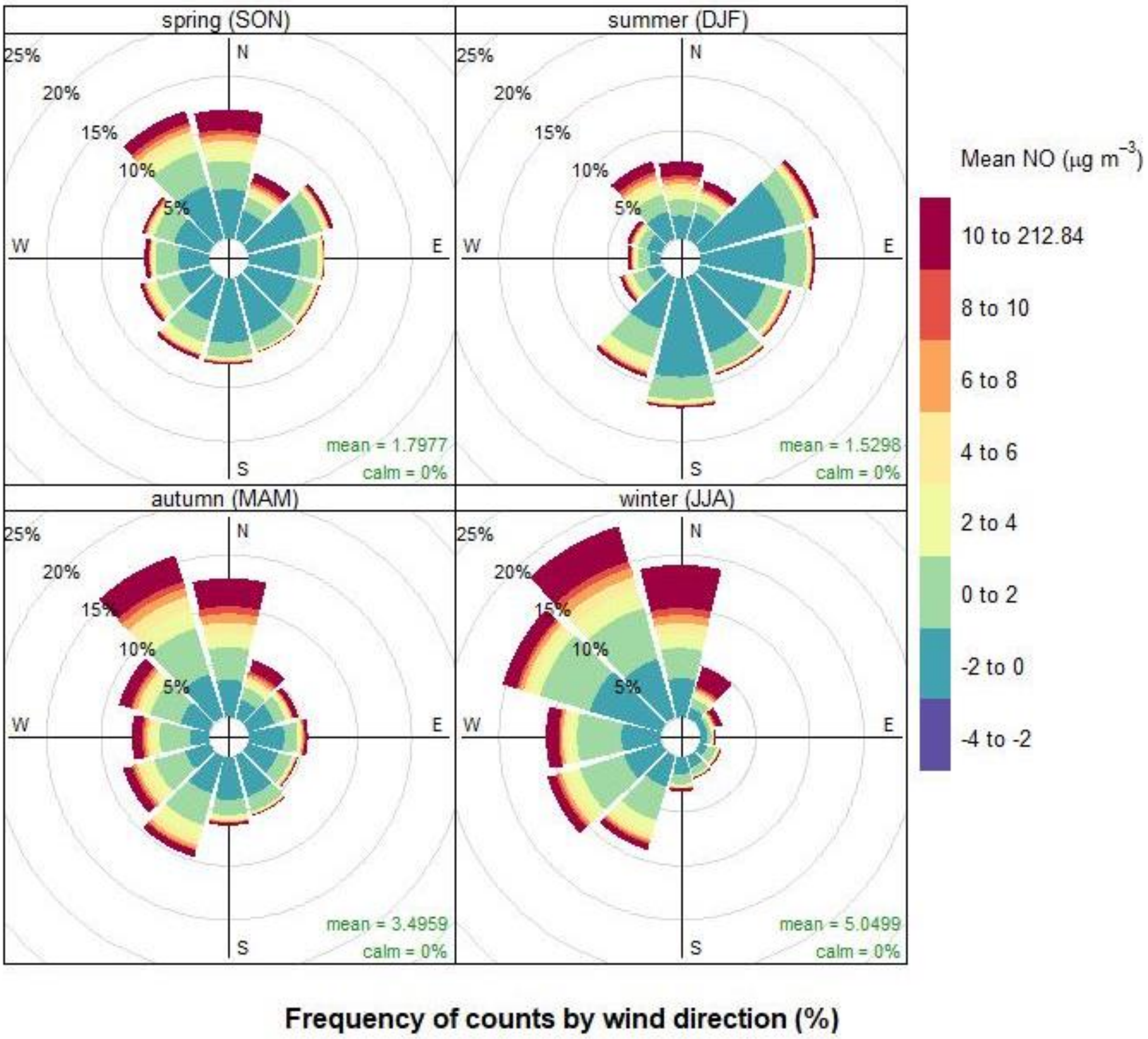


Figure 46 Wyong Pollution Rose for NO (µg/m$^3$)

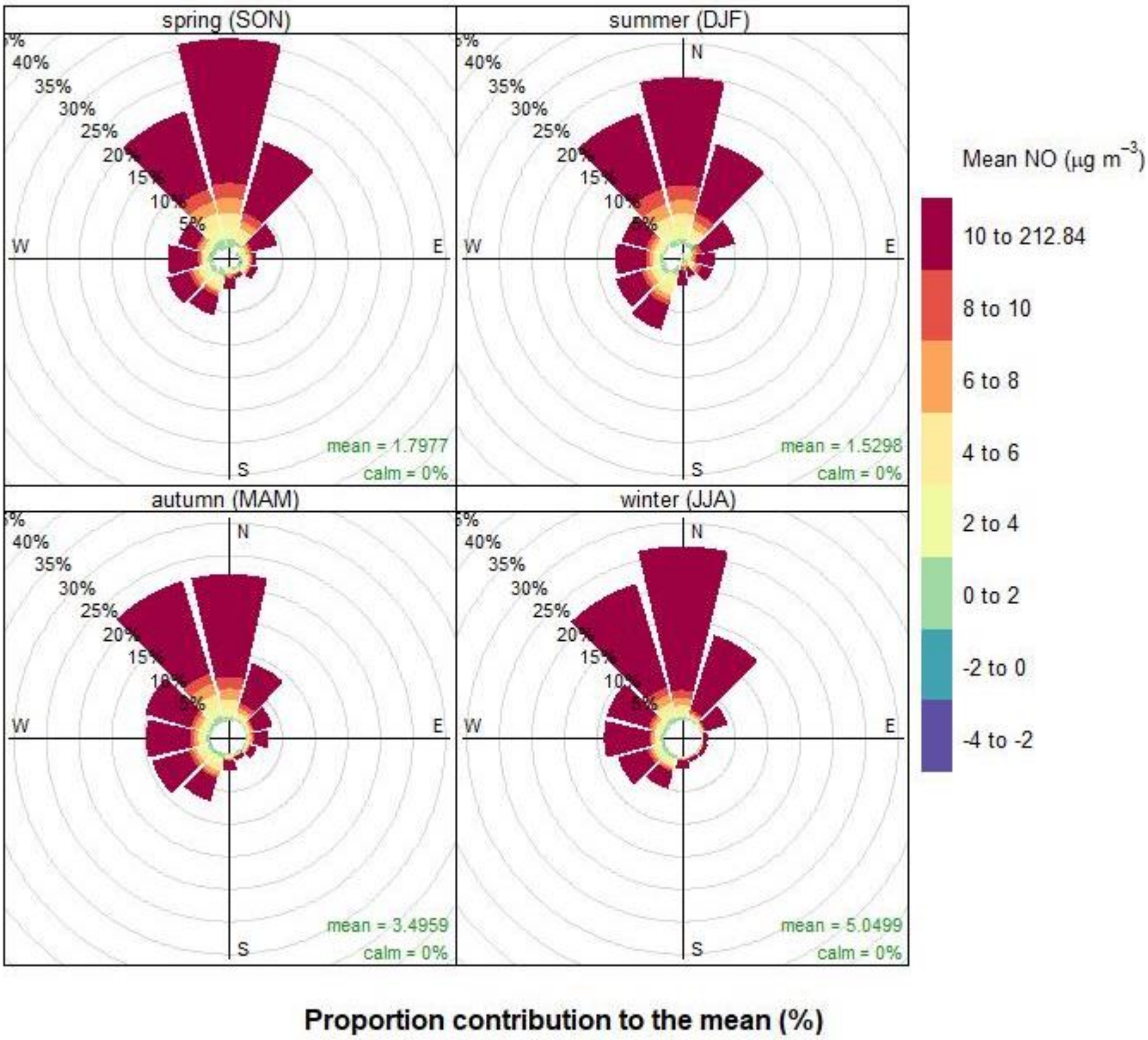


**Figure 47** Wyong Proportion Contribution Rose for NO (µg/m$^3$)

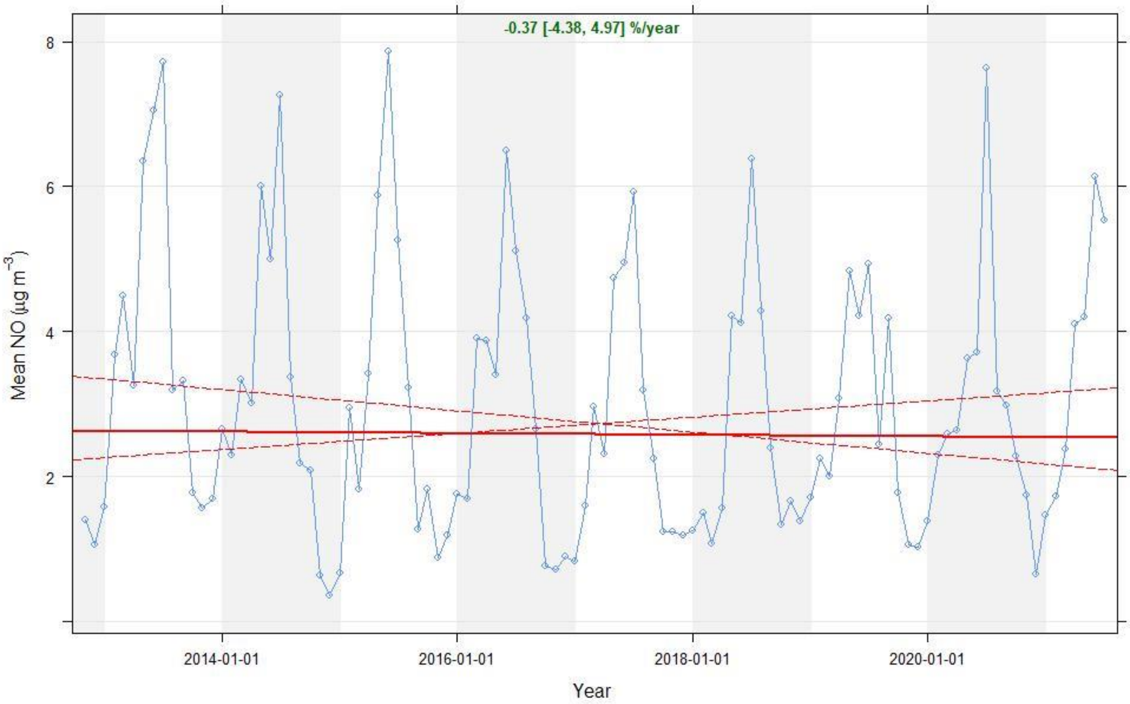


Figure 48 Wyong TheilSen Plot for NO (µg/m³)

### 5.2.3 $NO_2$ plots

Figure 49 is a polar plot of concentrations of $NO_2$. Figure 49 features a line running from the north-northeast to the south-southeast, offset slightly to the west, suggested a line source of emissions running in this direction to the west of the monitor. This would appear to reflect the orientation and position of the M1 Pacific Motorway, thus it is likely that emissions from traffic on this road dominate concentrations measured at Wyong. Some of the higher concentrations during winds from the northeast may be a contribution from the power stations, but it would seem unlikely that this is a substantial contribution.

The polar annulus plot in Figure 50 further emphasizes that it is winds with a westerly element that lead to the highest measured concentrations at Wyong, and thus that the contribution of the power stations is relatively small.

Figure 51 and Figure 52 further highlight this, with Figure 52 demonstrating that winds from the north-northeast and northeast are minor contributors to mean measured concentrations.

The TheilSen plot in Figure 53 shows a downward trend in $NO_2$ concentrations at Wyong that is statistically significant at the 99.9% confidence interval, with concentrations reducing by around 3.9% per year between 2013 to 2021, most likely a result of reductions in vehicle emissions on the M1 Pacific Motorway.

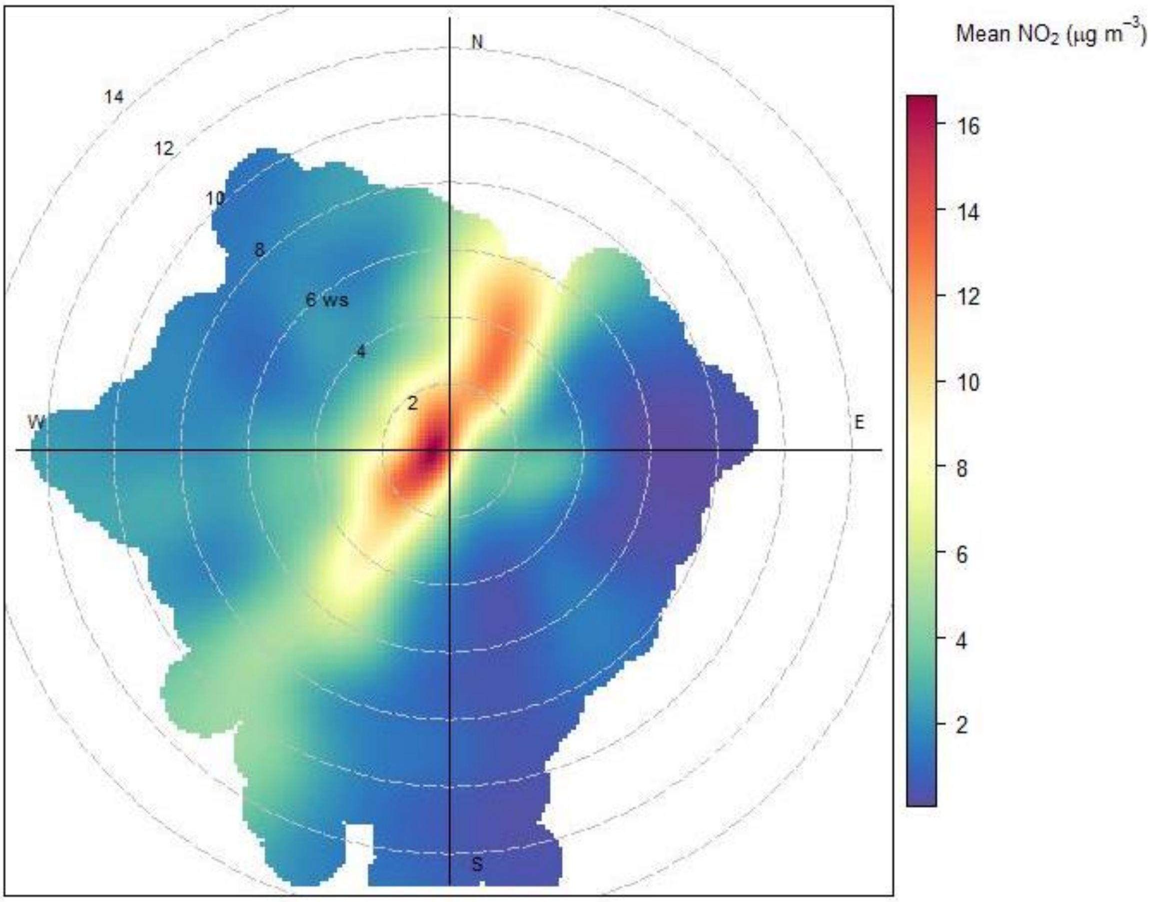


**Figure 49** **Wyong Polar Plot for $NO_2$ (µg/m$^3$)**

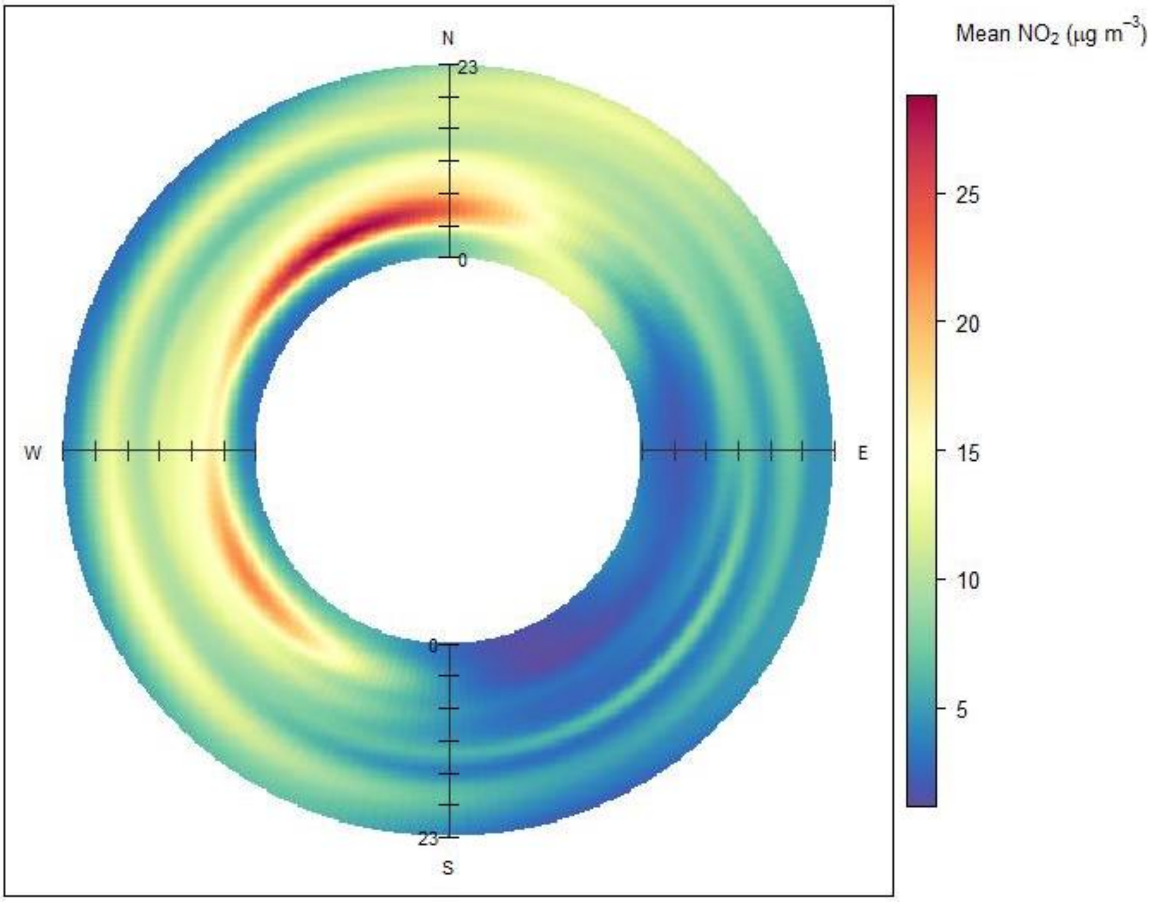


Figure 50 Wyong Polar Annulus Plot for $NO_2$ (µg/m$^3$)

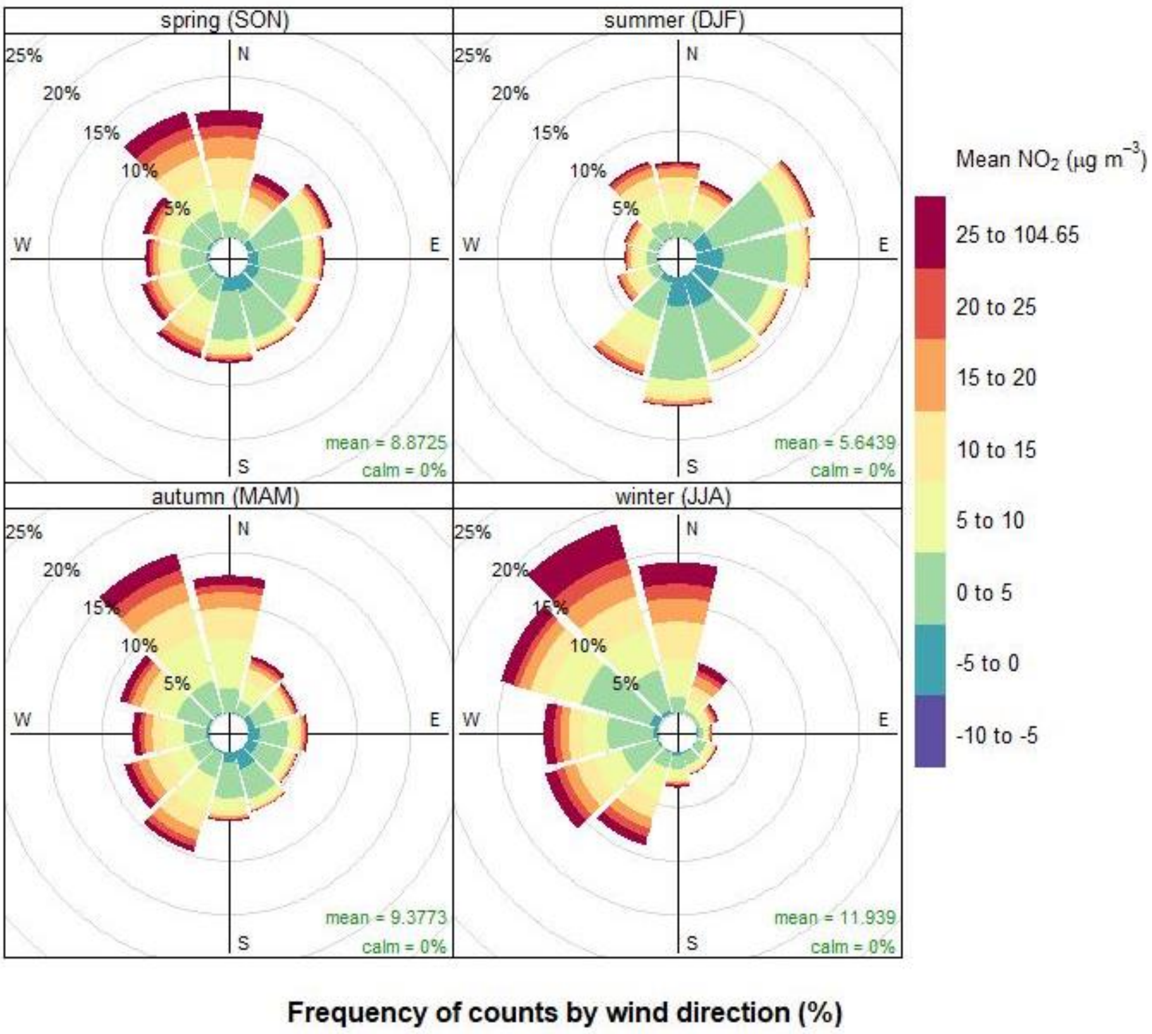


**Figure 51** Wyong Pollution Rose for NO$_2$ (µg/m$^3$)

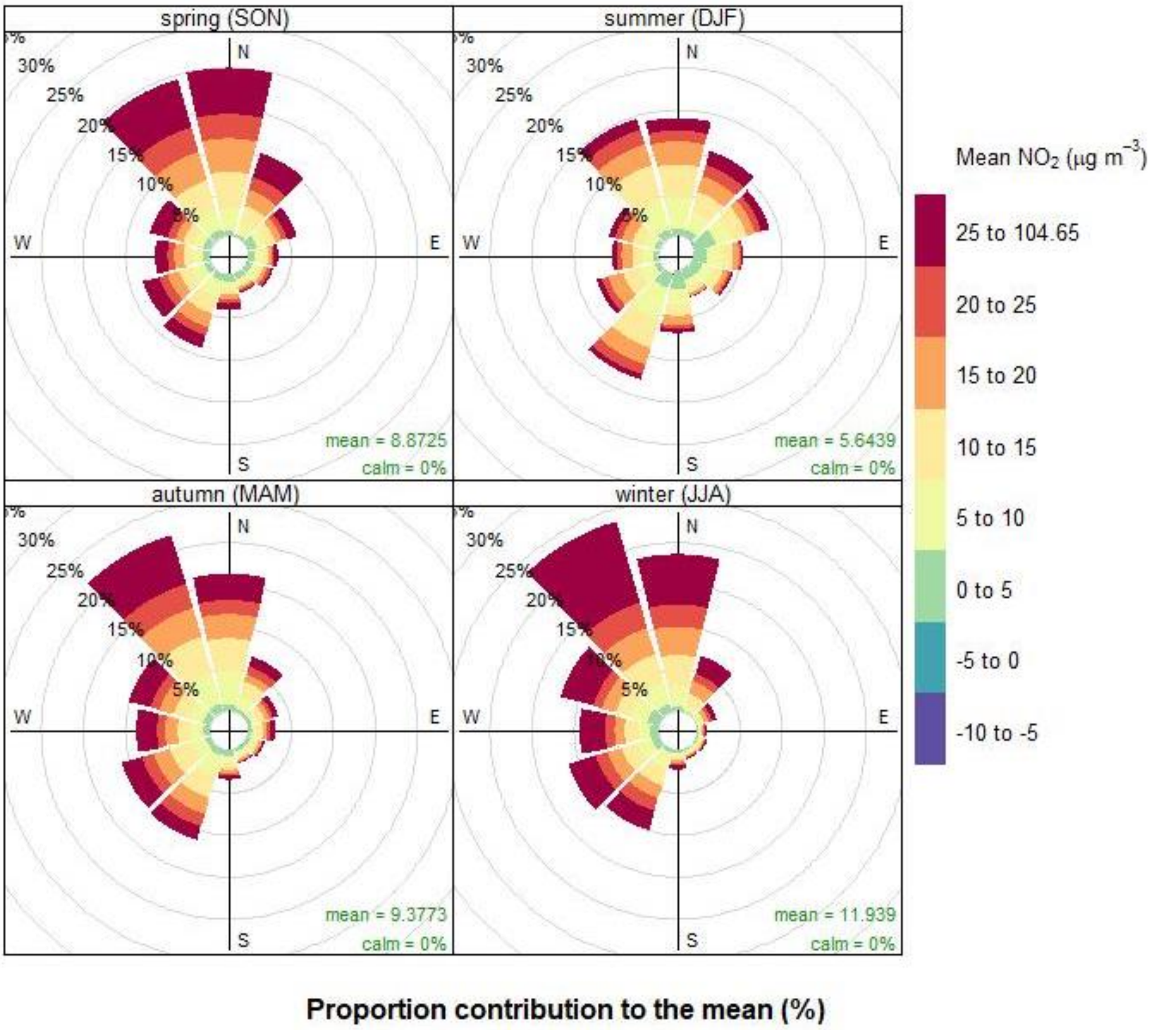


Figure 52 Wyong Proportion Contribution Rose for $NO_2$ ($\mu g/m^3$)

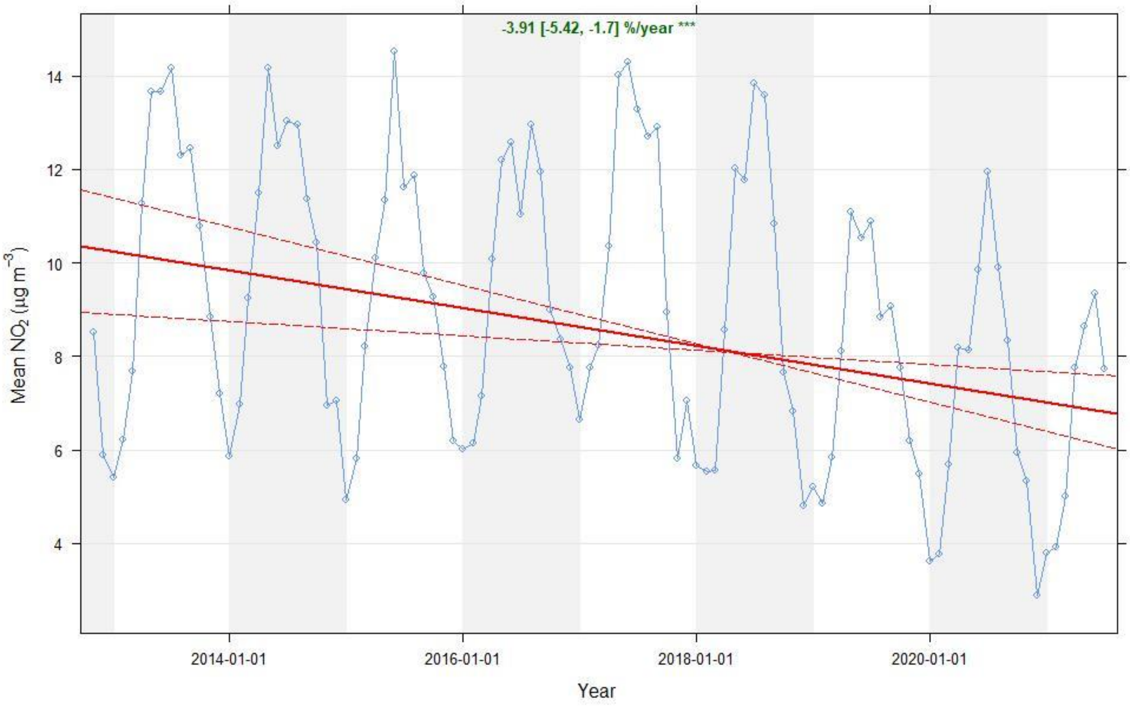


Figure 53 Wyong TheilSen Plot for $NO_2$ (µg/m$^3$)

### 5.2.4 $PM_{2.5}$ plots

The plots for $PM_{2.5}$ in Figure 54, Figure 55, Figure 56 and Figure 57 show that, similar to Wyee, there are few distinct sources contributing to measured concentrations of $PM_{2.5}$, with concentrations and contributions depending more on wind direction than anything else. There is no obvious contribution from the power stations and Figure 58 shows that there has been no significant trend in measured concentrations of $PM_{2.5}$.

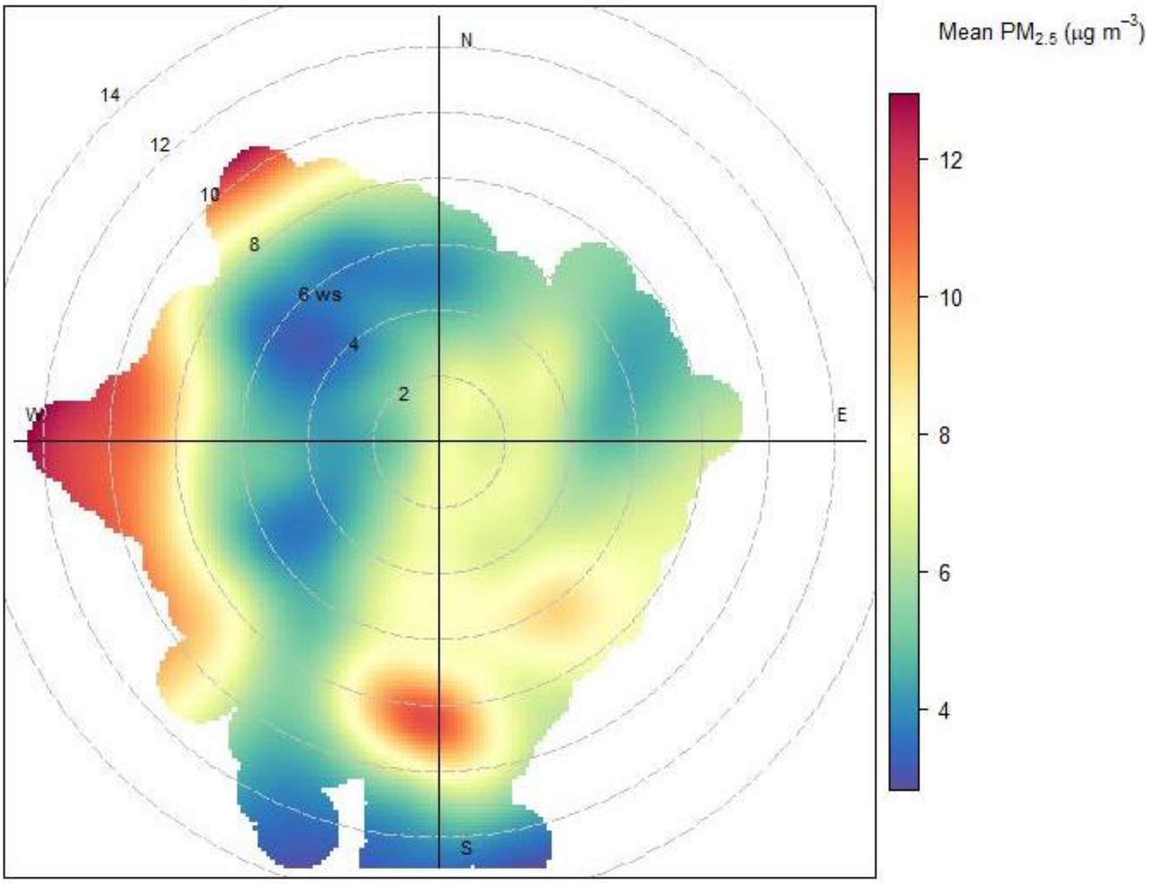


**Figure 54** Wyong Polar Plot for $PM_{2.5}$ (µg/m$^3$)

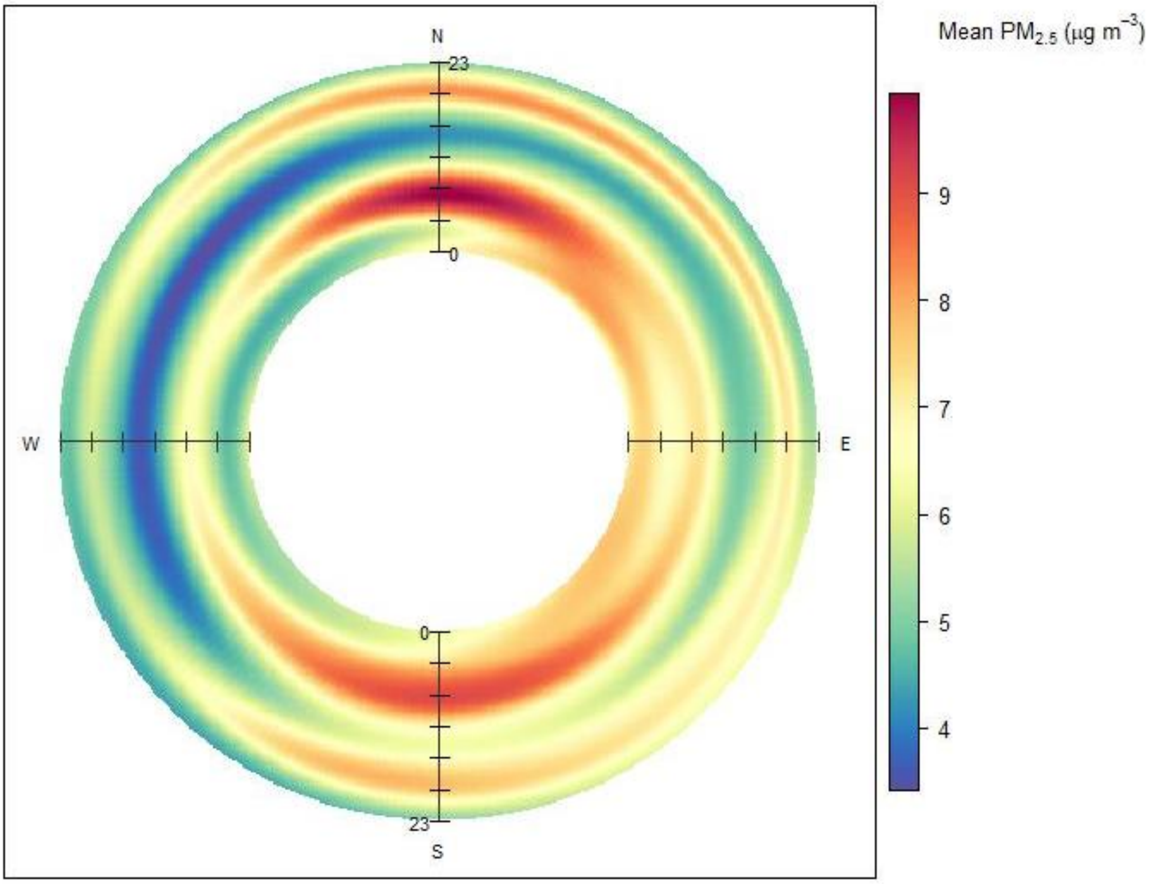


Figure 55 Wyong Polar Annulus Plot for $PM_{2.5}$ (µg/m$^3$)

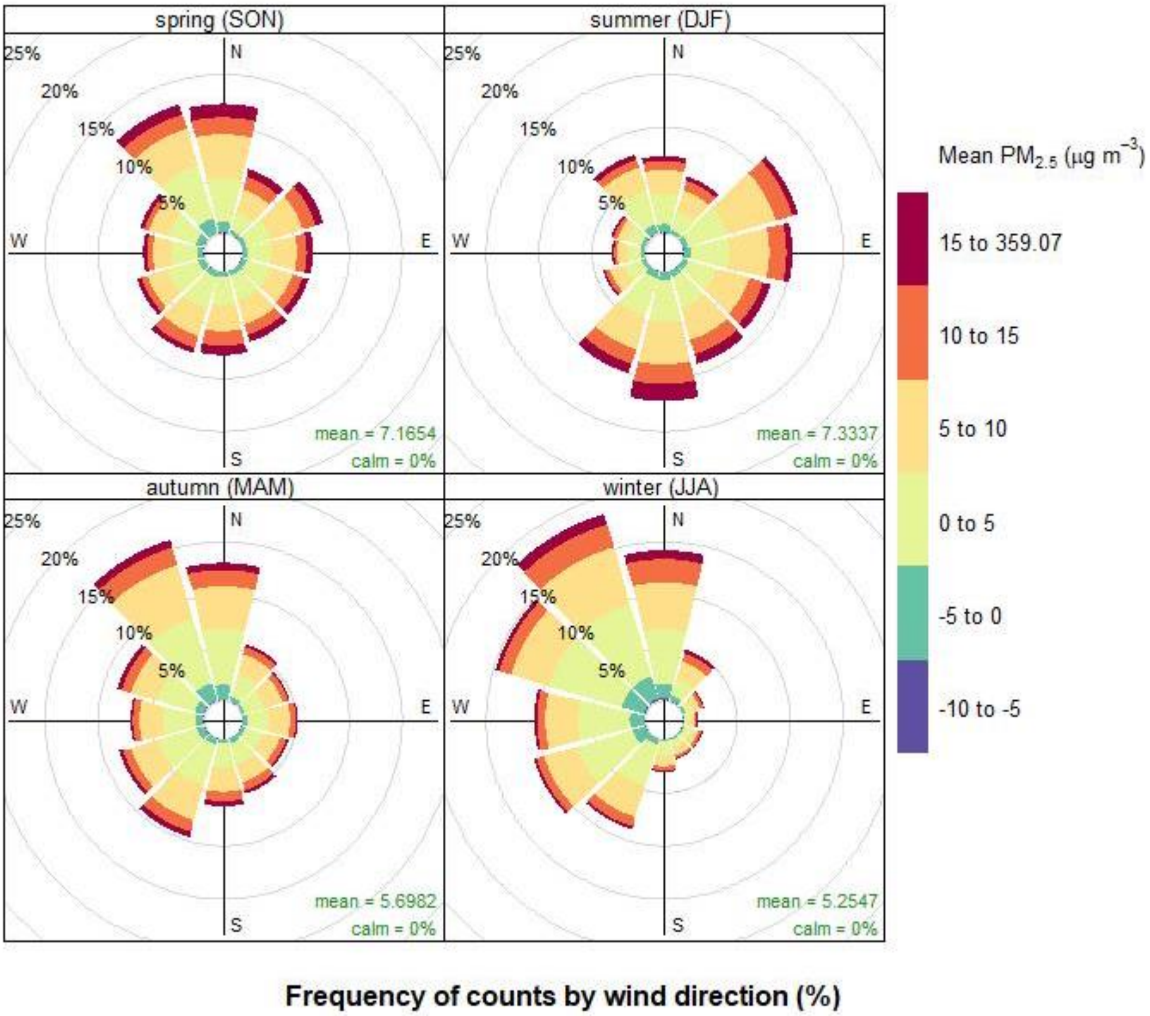


Figure 56 Wyong Pollution Rose for $PM_{2.5}$ (µg/m$^3$)

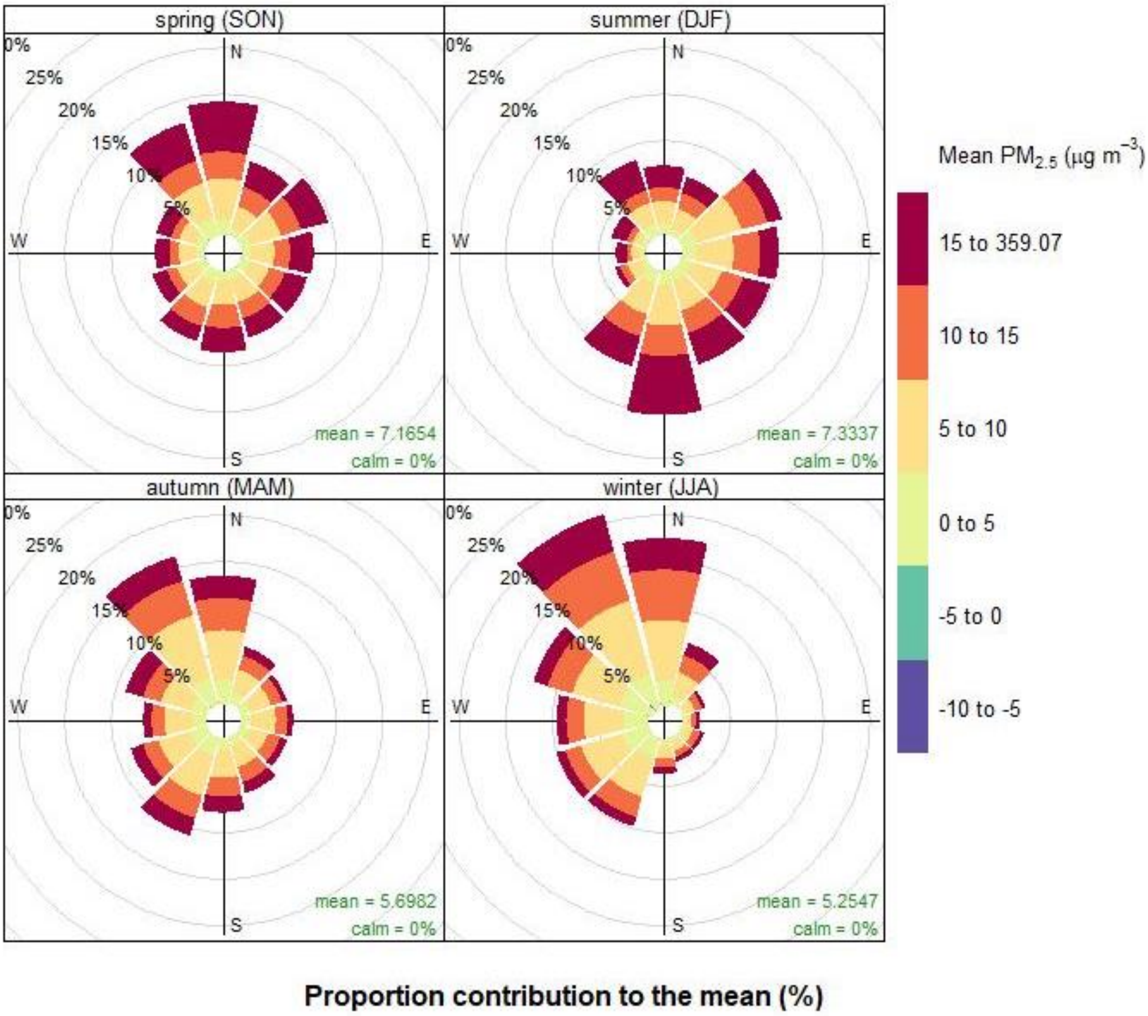


Figure 57 Wyong Proportion Contribution Rose for $PM_{2.5}$ (µg/m$^3$)

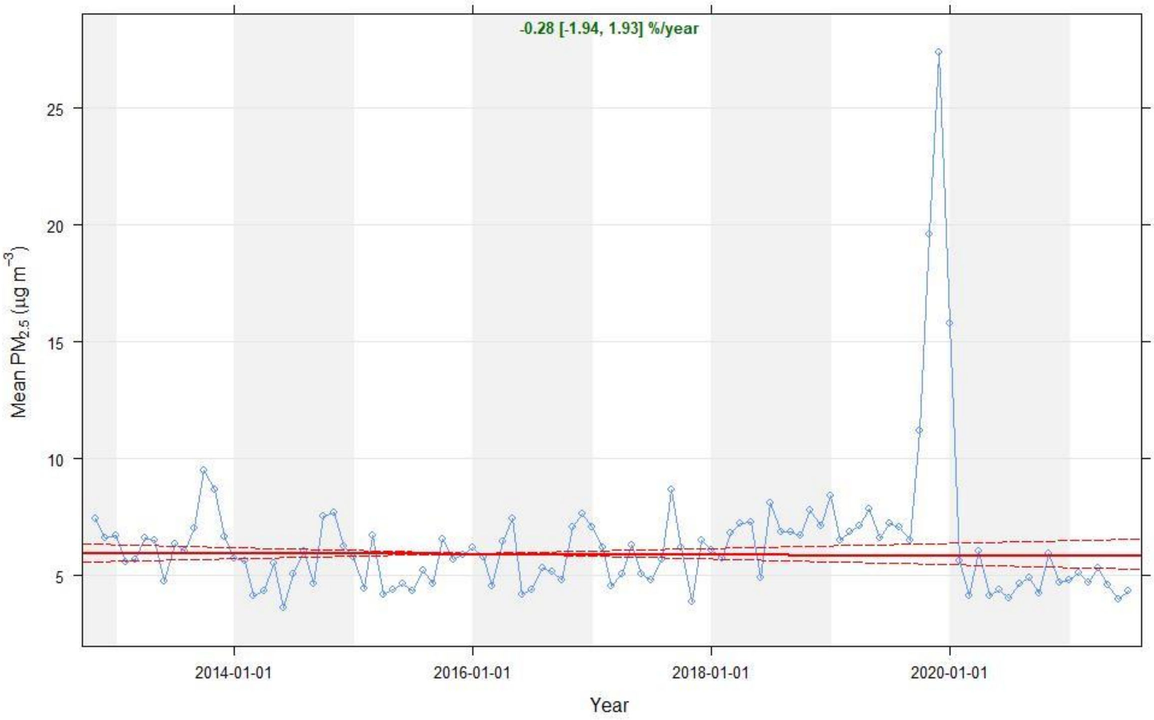


**Figure 58** **Wyong TheilSen Plot for $PM_{2.5}$ (µg/$m^3$)**

### 5.2.5 Comparator plots

Figure 59, Figure 60 and Figure 61 present scatter plots of contemporaneous concentrations of $SO_2$ against $NO_2$, NO and $PM_{2.5}$, respectively. Figure 59 demonstrates that, similar to Wyee, it is very common for concentrations of $NO_2$ to be elevated at Wyong when concentrations of $SO_2$ are not, with the highest $NO_2$ concentrations occurring when the concentration of $SO_2$ is negligible. However, there are occasions when elevated concentrations of $NO_2$ coincide with elevated concentrations of $SO_2$. As at Wyee, the plot suggests that power station emissions are unlikely to be the primary source of $NO_2$ at Wyong.

Similar to Wyee, Figure 60 demonstrates that the highest concentrations of NO are not associated with power station emissions; NO concentrations are consistently below 100 µg/$m^3$ when there is a power station $SO_2$ signal.

Figure 61 shows no distinct relationship between $SO_2$ and $PM_{2.5}$ concentrations, suggesting that power stations contribute minimally to $PM_{2.5}$ concentrations at Wyong.

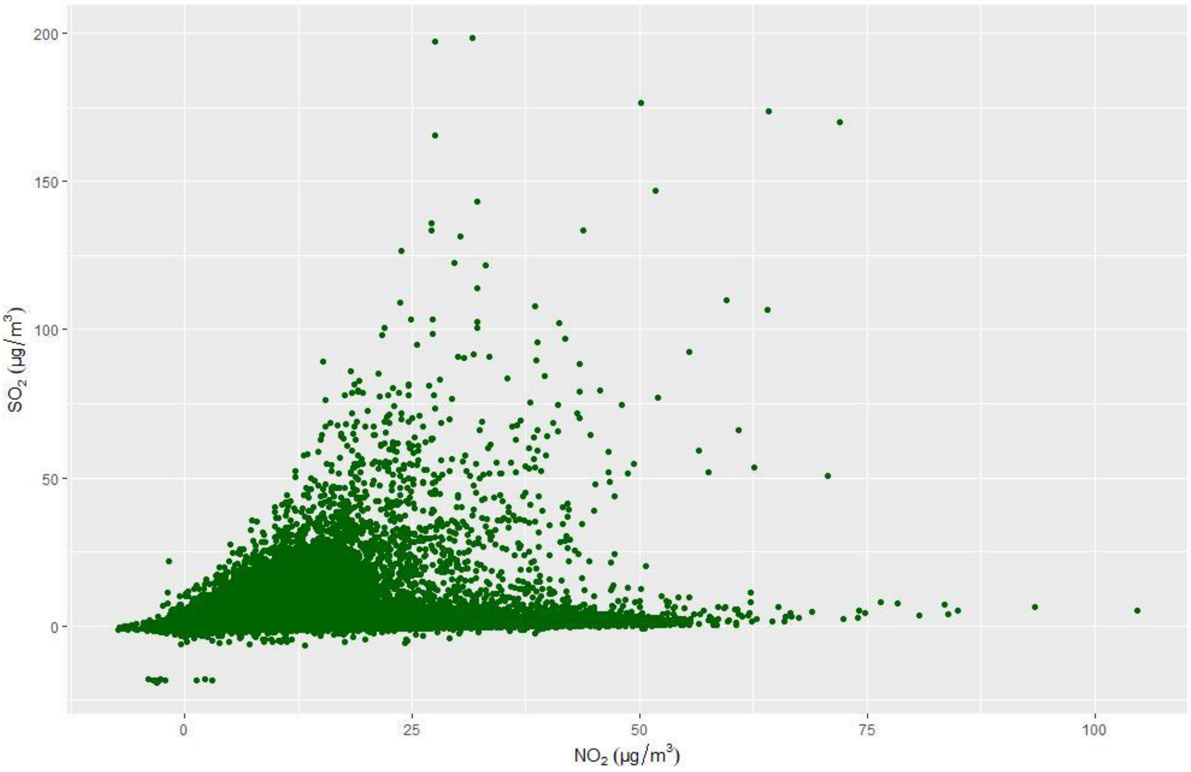


**Figure 59** **Wyong NO$_2$ versus SO$_2$ (µg/m$^3$)**

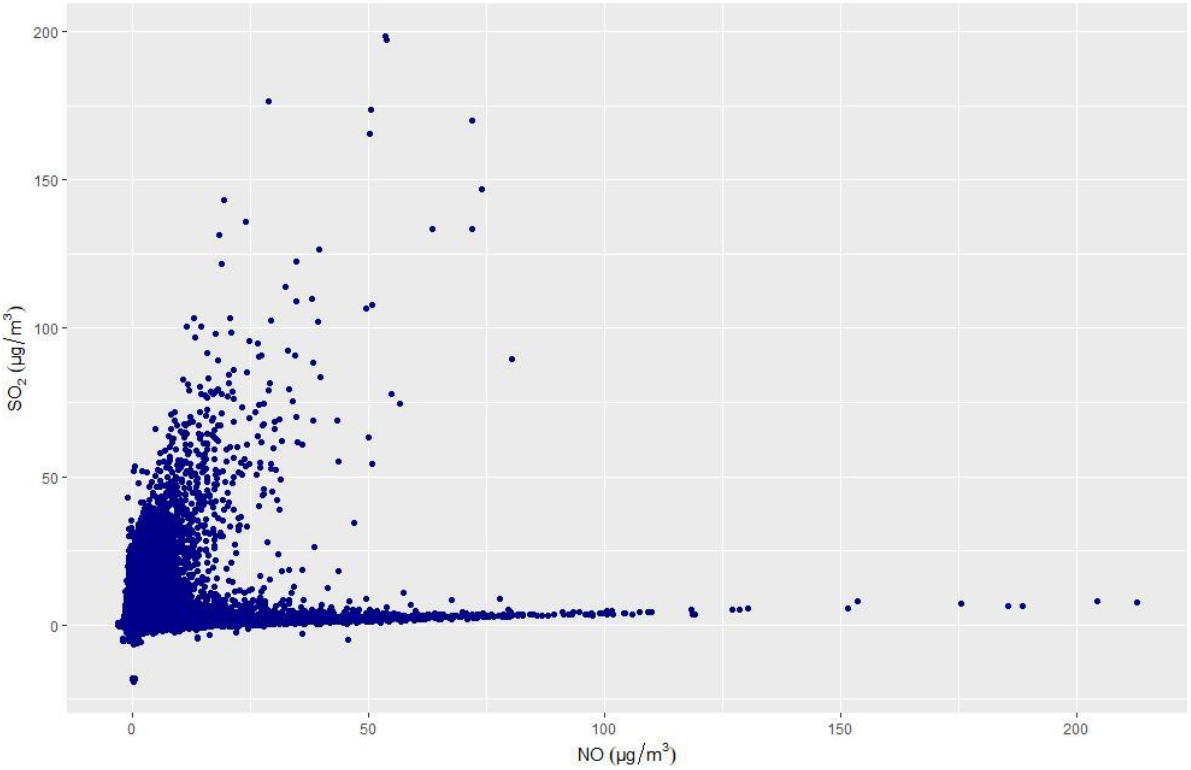


**Figure 60** **Wyong NO versus SO$_2$ (µg/m$^3$)**

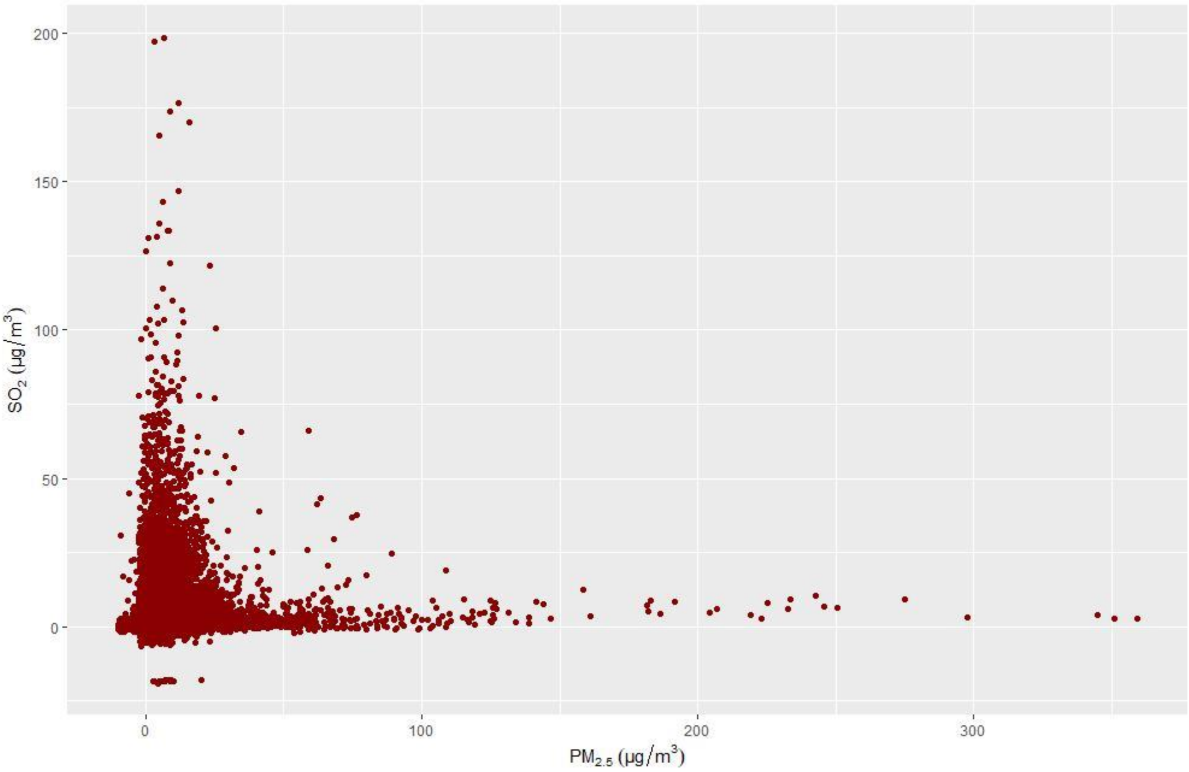


**Figure 61** **Wyong $PM_{2.2}$ versus $SO_2$ (µg/m$^3$)**

## 5.3 Frequency Distributions

Figure 62, Figure 63, Figure 64 and Figure 65 present frequency distributions of hourly average concentrations measured at Wyee and Wyong. The plots show that high concentrations are generally very infrequent at both sites, but that for all pollutants Wyee tends to measure higher peak concentrations (albeit below the air quality criteria for all pollutants bar $PM_{2.5}$), likely due to its relative proximity to the power stations in the case of $SO_2$, but also due to its relative proximity to the M1 Pacific Motorway for NO and $NO_2$.

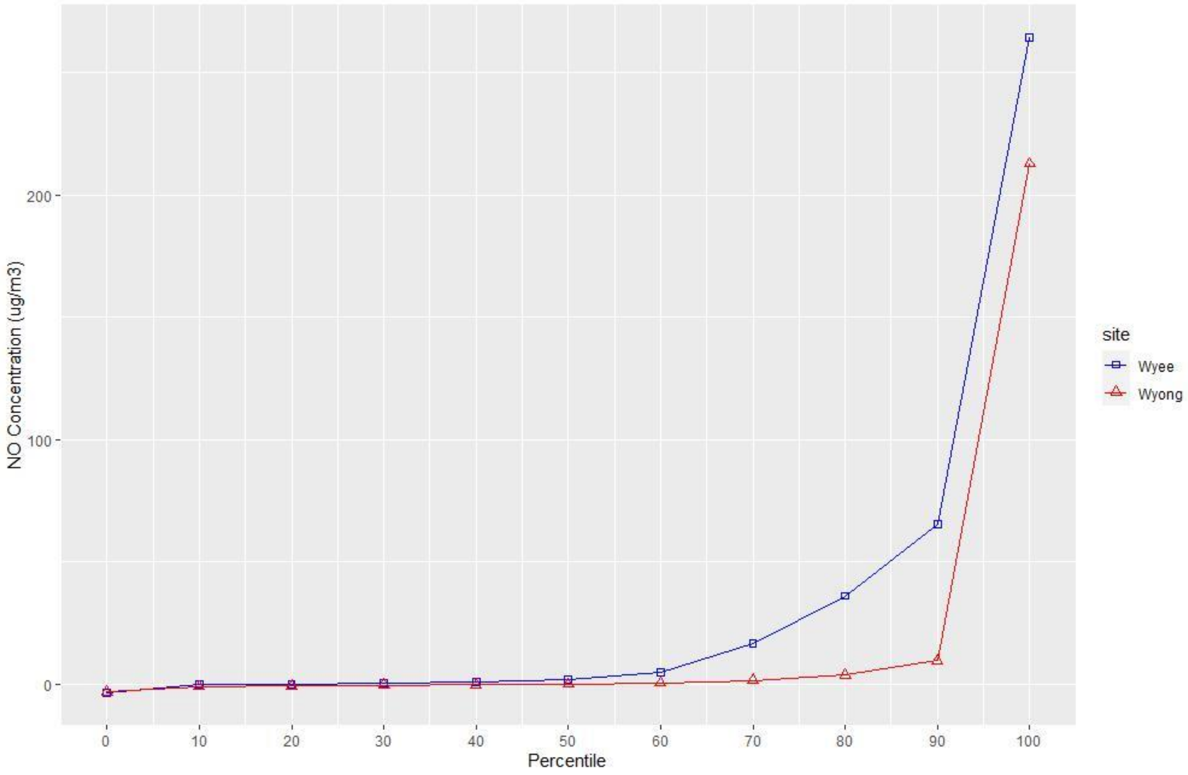


**Figure 62** Frequency Distribution of Hourly Average NO Concentrations (µg/$m^3$)

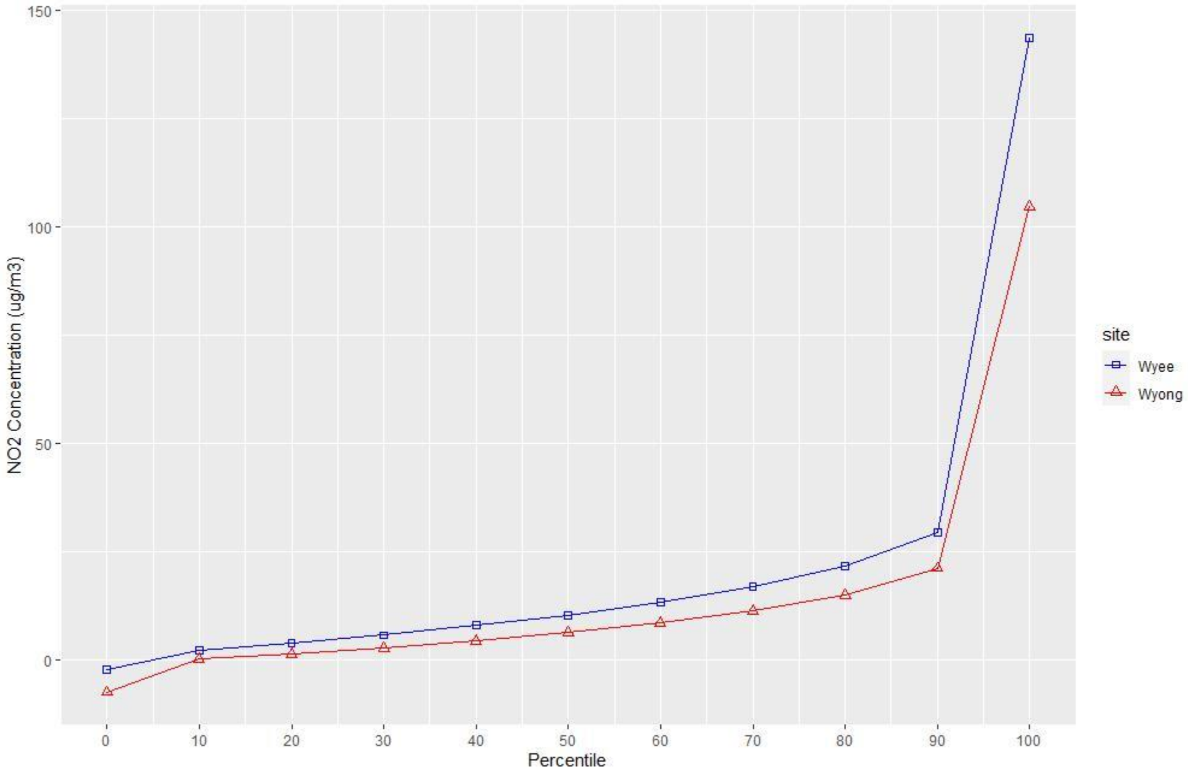


Figure 63 Frequency Distribution of Hourly Average $NO_2$ Concentrations (µg/m$^3$)

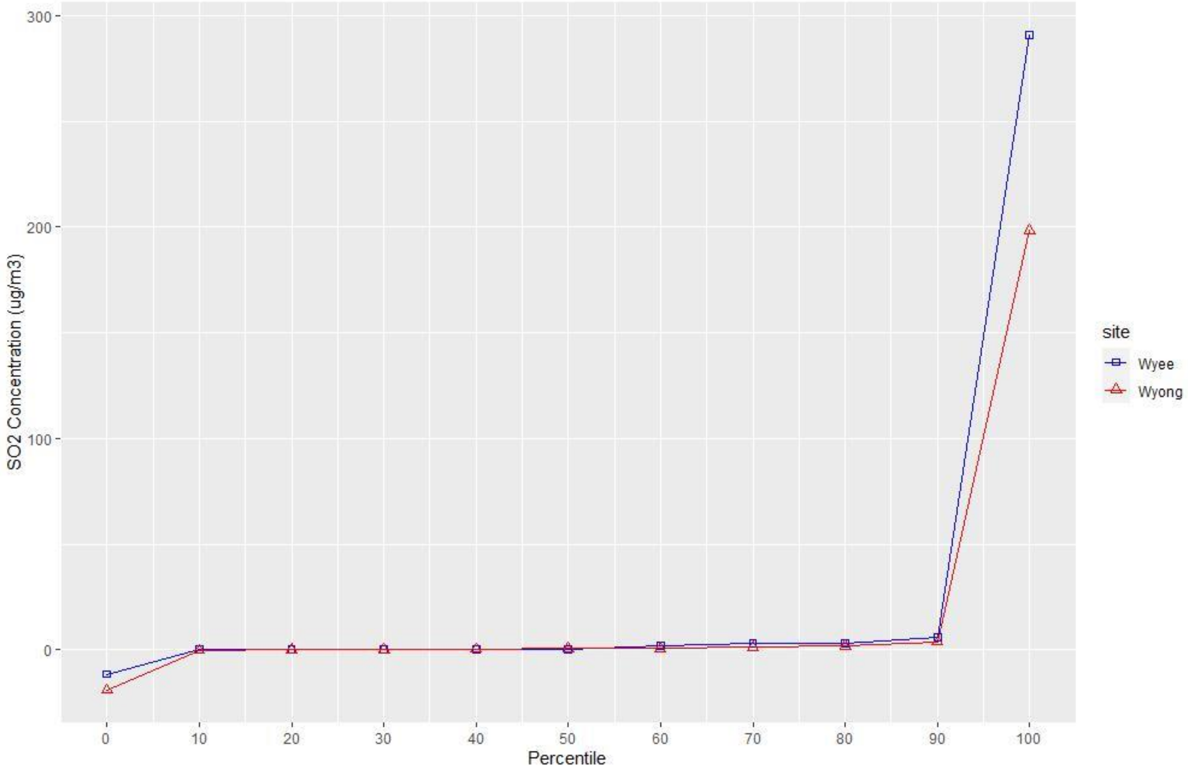


Figure 64 Frequency Distribution of Hourly Average Concentrations of $SO_2$ (µg/m$^3$)

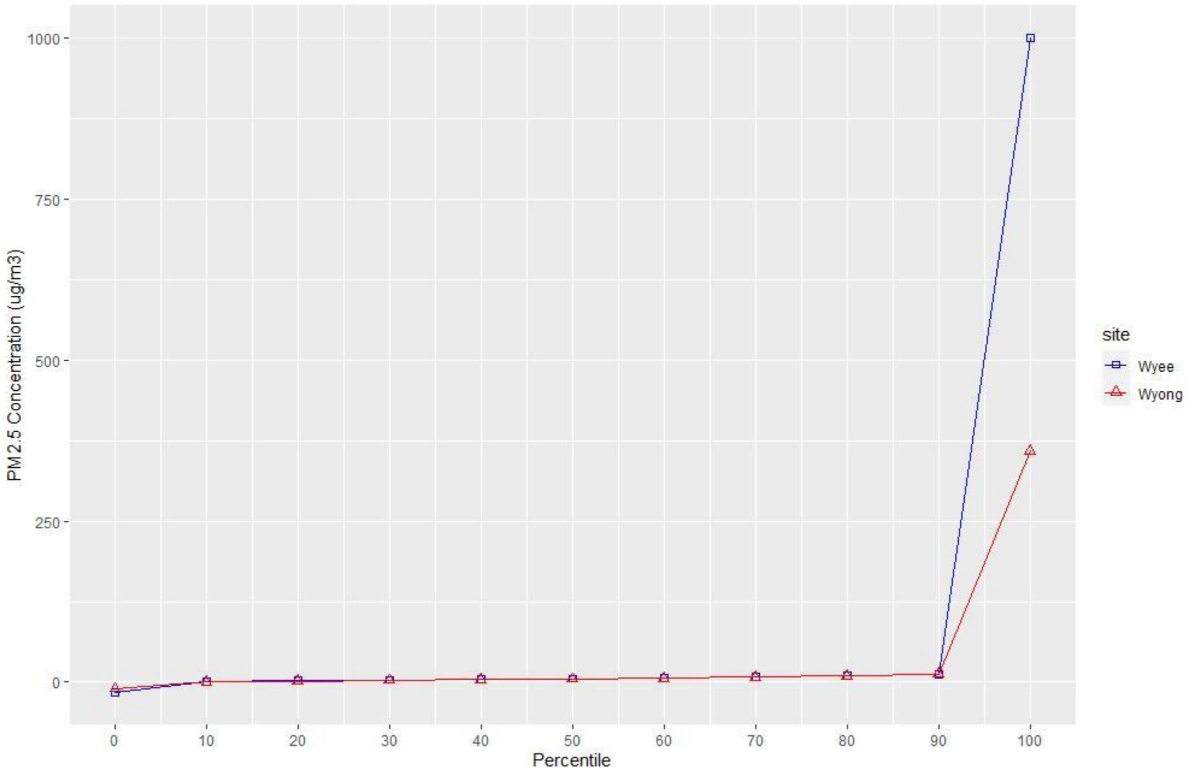


**Figure 65** Frequency Distribution of Hourly Average Concentrations of $PM_{2.5}$ ($\mu g/m^3$)

## 5.4 Derived VPPS Contributions

This analysis has considered whether the ratio of $SO_2$ to NO or $NO_2$ can be used as a reliable tracer of power station contributions. Figure 66 and Figure 67 present polar plots of these ratios for Wyee. The plots appear to show elevated average ratios during winds when Wyee is downwind of VPPS and Eraring, but both also show elevated ratios during stronger winds from the west, the source of which is not known. Figure 66 also shows elevated ratios during winds from the east-southeast, the direction of Colongra power station, which is odd given that this power station is predominantly gas-fired and thus not likely to be a significant source of $SO_2$. Ratios are also slightly elevated under a variety of different wind speeds and directions, highlighted by the yellow areas that appear in both plots.

The pollution roses presented in Figure 68 and Figure 69 further demonstrate that both high and low ratios occur during winds from all directions. While high ratios are more common during winds from the northeast, the direction of VPPS, it is clear that these ratios cannot be used as a reliable signal of power station contributions. Bearing in mind how obvious the power station $SO_2$ contributions are, as demonstrated in Figure 25, Figure 26 and Figure 27, it is judged that consideration of wind direction alone is likely to enable a reasonable estimate of VPPS's contribution to mean concentrations of $SO_2$ at Wyee. Such an analysis will produce less robust outcomes for $NO_2$, given the greater influence of other sources, but these should still be reasonably accurate given that there are few significant sources in the same direction as VPPS (principally minor roads and small urban areas).

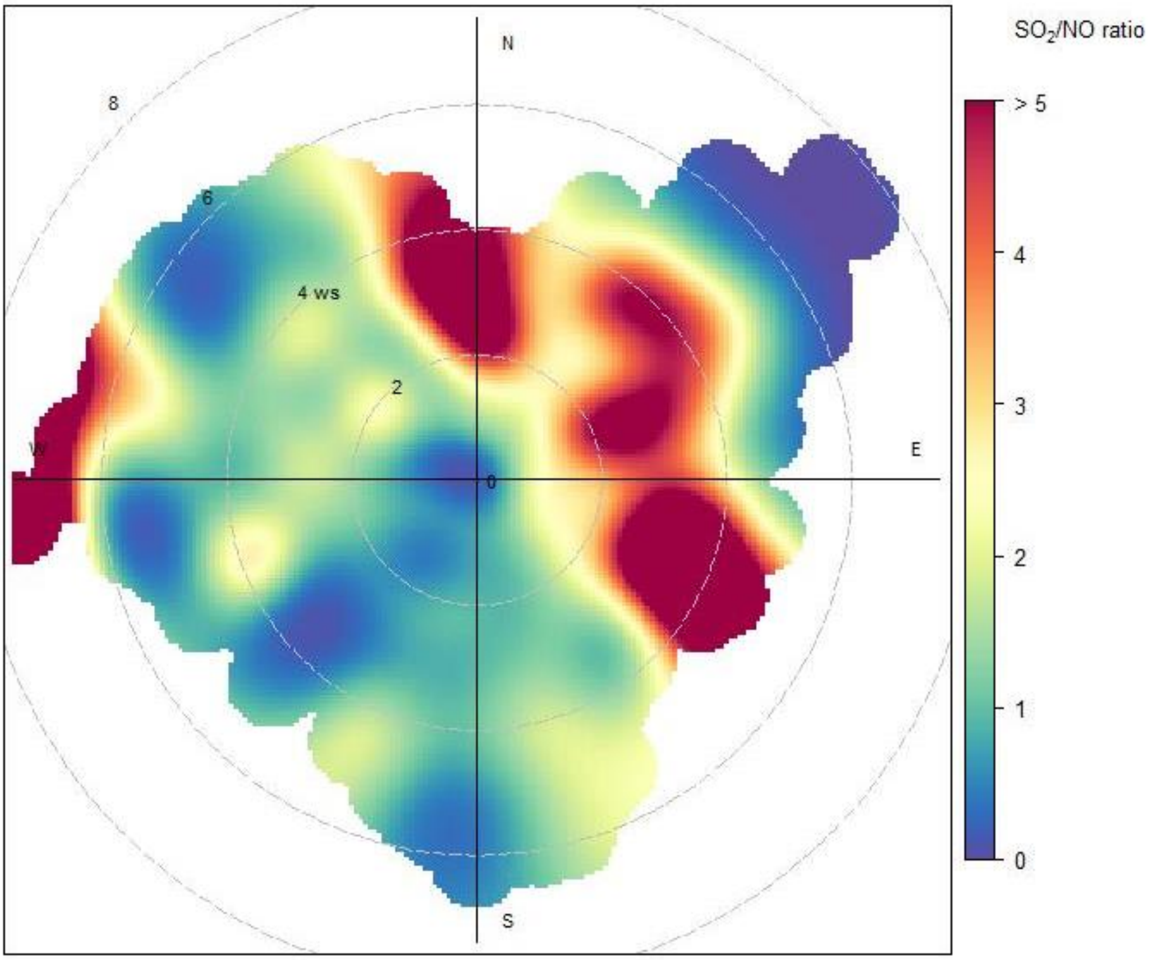


**Figure 66 Wyee Polar Plot of the Ratio of $SO_2$/NO**

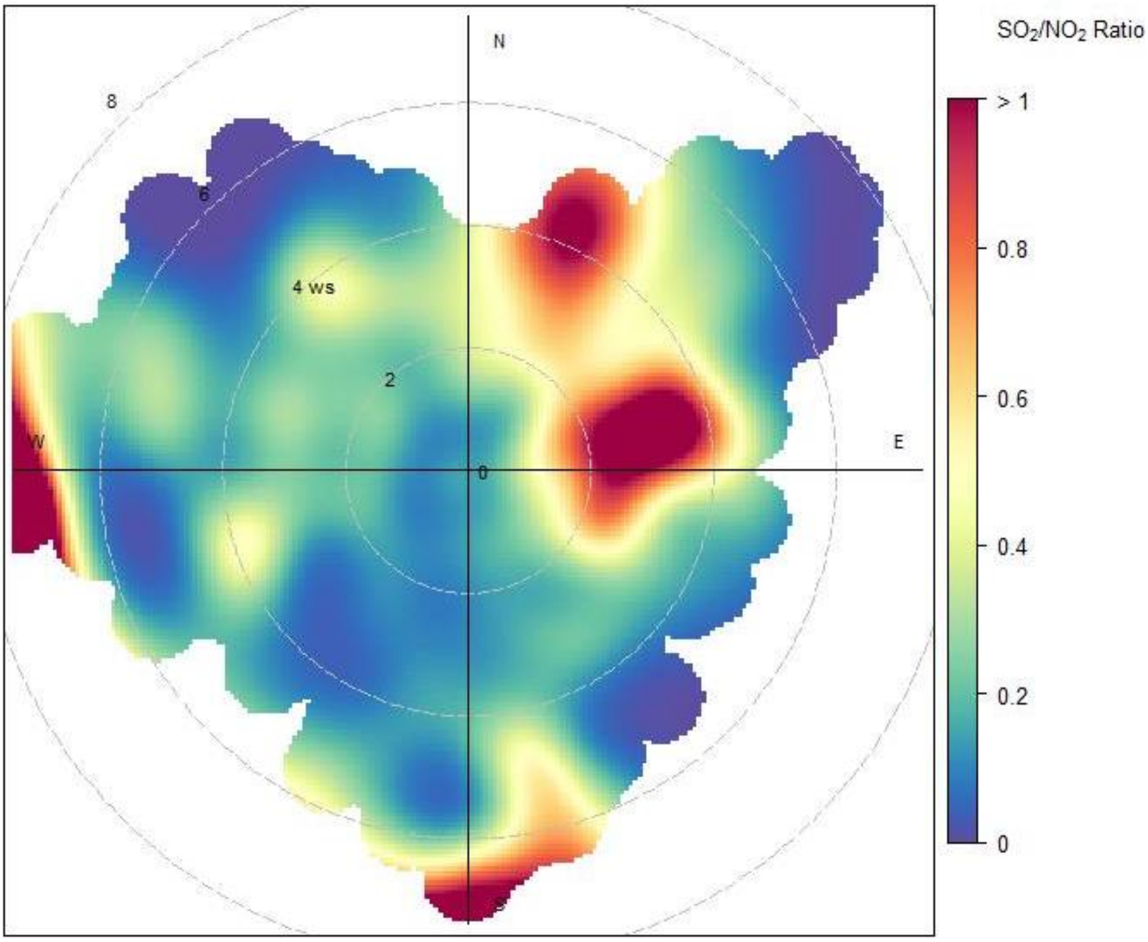


**Figure 67** Wyee Polar Plot of the Ratio of $SO_2/NO_2$

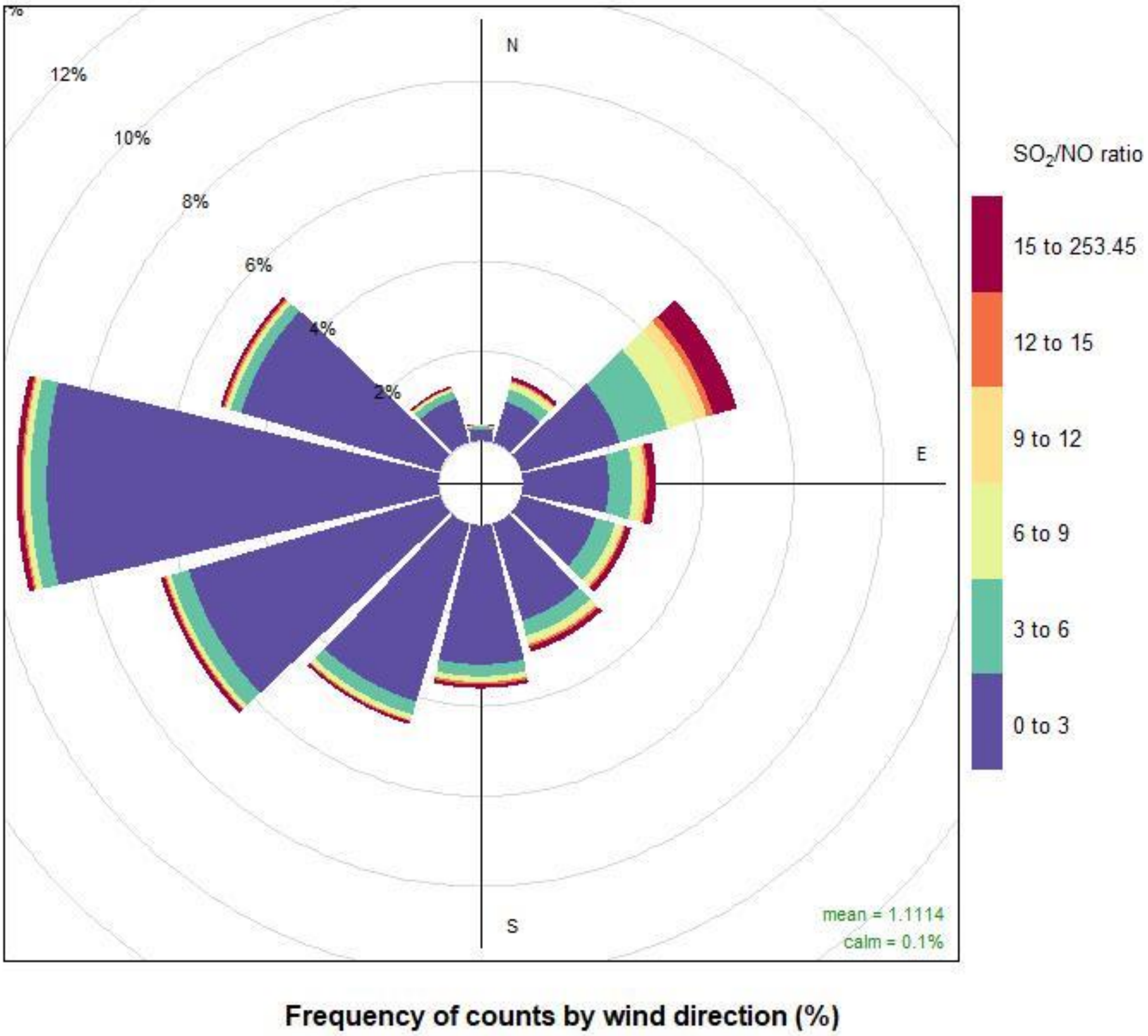


Figure 68 Wyee Pollution Rose of the Ratio of $SO_2$/NO

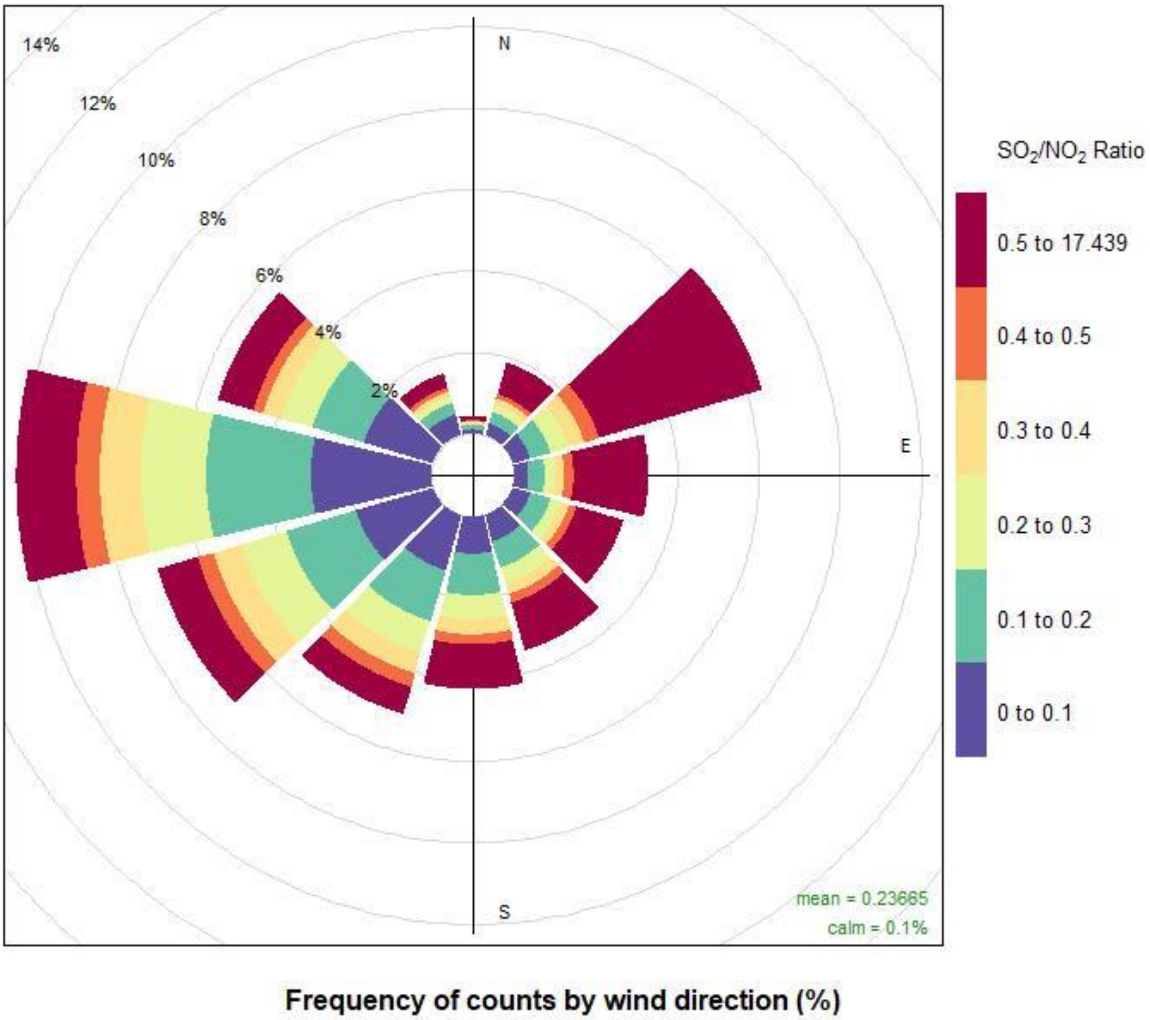


**Figure 69 Wyee Pollution Rose of the Ratio of $SO_2$/$NO_2$**

Figure 25 demonstrates very clearly the wind directions that carry emissions from VPPS to Wyee; these are winds from between 70-100 degrees. Table 25 analyses the contribution of winds from this sector to annual mean concentrations of $SO_2$ at Wyee, focusing on the calendar years for which good data capture rates were achieved for both $SO_2$ and wind data.

While Table 25 demonstrates that average concentrations during winds that place Wyee downwind of VPPS are much higher than the annual mean concentration, they are sufficiently infrequent that VPPS does not contribute more than around 28% of the annual mean concentrations measured in any one year. It is the low, but not negligible, concentrations that occur under other wind conditions that contribute the most to the annual mean.

It must be remembered that these estimates are likely to overstate the contribution of VPPS, as there will be other sources contributing to measured concentrations at Wyee during winds from 70-100 degrees.

**Table 25** **Estimated Maximum VPPS Contribution to Measured Annual Mean Concentrations of $SO_2$ at Wyee (µg/m$^3$)**

| Year | Wind Direction 70-100° | | All Wind Directions | | Contribution from 70-100° | |
|---|---|---|---|---|---|---|
| | Count[1] | Conc[2] | DC[1] | Conc[2] | Conc[2] | % |
| 2015 | 459 | 12.5 | 8,472 | 4.0 | 0.67 | 16.9 |
| 2016 | 449 | 10.1 | 7,823 | 2.8 | 0.58 | 20.4 |
| 2017 | 515 | 9.8 | 8,747 | 2.1 | 0.58 | 28.0 |
| 2018 | 465 | 13.9 | 8,743 | 3.1 | 0.74 | 23.9 |
| 2019 | 457 | 16.5 | 8,626 | 3.1 | 0.87 | 28.3 |
| 2020 | 386 | 10.2 | 8,538 | 2.4 | 0.46 | 18.9 |

Table notes:
[1] Number of hours valid data in that year
[2] Average Concentration

Taking the same approach for $NO_2$, Table 26 presents the calculated contribution to annual mean $NO_2$ concentrations at Wyee during winds from 70 to 100 degrees. It shows that average concentrations when the wind is from 70-100 degrees are broadly similar to those during winds from other directions. Thus, it can be estimated that VPPS contributes no more than 6.4% of measured annual mean concentrations of $NO_2$ at Wyee.

**Table 26** **Estimated Maximum VPPS Contribution to Measured Annual Mean $NO_2$ Concentrations at Wyee (µg/m$^3$)**

| Year | Wind Direction 70-100° | | All Wind Directions | | Contribution from 70-100° | |
|---|---|---|---|---|---|---|
| | Count[1] | Conc[2] | DC[1] | Conc[2] | Conc[2] | % |
| 2015 | 462 | 12.7 | 8,510 | 11.7 | 0.69 | 5.9 |
| 2016 | 453 | 15.6 | 7,915 | 16.1 | 0.89 | 5.5 |
| 2017 | 515 | 21.4 | 8,724 | 20.6 | 1.26 | 6.1 |
| 2018 | 465 | 16.4 | 8,743 | 13.6 | 0.87 | 6.4 |
| 2019 | 457 | 14.0 | 8,622 | 12.1 | 0.74 | 6.1 |
| 2020 | 386 | 12.2 | 8,532 | 11.0 | 0.55 | 5.0 |

Table notes:
[1] Number of hours valid data in that year
[2] Average Concentration

It is not considered necessary to repeat this for NO or $PM_{2.5}$, as it has already been demonstrated that the contribution from VPPS is minimal for these pollutants.

Another approach that can be taken is to subtract measurements from a monitor that is upwind of a pollution source from those from a downwind monitor. During winds from 70-100 degrees, Wyee is downwind of VPPS, but Wyong is not (nor is it downwind of Colongra under those specific wind sectors). Wyong does, perhaps, have more in the way of other confounding influences during winds from this direction, in terms of the greater density of urban areas and roads to the east-northeast as compared to Wyee, but the monitor is distant from any such sources in this direction, thus these confounding influences should be small.

Table 27 and Table 28 present the same analysis as Table 25 and Table 26, but with the average concentrations under winds from 70-100 degrees calculated from a dataset where the concentration at Wyong had been subtracted from that at Wyee. The analysis should produce a more realistic estimate of the contribution of VPPS to measured concentrations, but it would be reasonably worst-case to assume that the actual contribution falls somewhere between the results of the two sets of analyses. The analysis has used wind data from Wyee, given that this site is the primary focus of the analysis, but it must be acknowledged that the wind roses for Wyee and

Wyong are quite different (see Figure 14 and Figure 38), which introduces some additional uncertainty to this particular analysis.

With concentrations at Wyong subtracted from those at Wyee, the derived contribution of VPPS is smaller, ranging from 11.0% to 18.7% of the annual mean for $SO_2$ and 2.7% to 4.2% of the annual mean for $NO_2$.

**Table 27** **Estimated VPPS Contribution to Measured Annual Mean Concentrations of $SO_2$ at Wyee by Subtraction of Upwind Measurements (µg/m³)**

| Year | Wind Direction 70-100° | | All Wind Directions | | Contribution from 70-100° | |
|---|---|---|---|---|---|---|
| | Count[1] | Conc[2] | DC[1] | Conc[2] | Conc[2] | % |
| 2015 | 441 | 8.5 | 8,472 | 4.0 | 0.44 | 11.0 |
| 2016 | 441 | 5.8 | 7,823 | 2.8 | 0.33 | 11.6 |
| 2017 | 492 | 5.5 | 8,747 | 2.1 | 0.31 | 15.0 |
| 2018 | 448 | 7.4 | 8,743 | 3.1 | 0.38 | 12.2 |
| 2019 | 448 | 11.1 | 8,626 | 3.1 | 0.58 | 18.7 |
| 2020 | 380 | 8.0 | 8,538 | 2.4 | 0.36 | 14.6 |

Table notes:
[1] Number of hours valid data in that year
[2] Average Concentration

**Table 28** **Estimated VPPS Contribution to Measured Annual Mean $NO_2$ Concentrations at Wyee by Subtraction of Upwind Measurements (µg/m³)**

| Year | Wind Direction 70-100° | | All Wind Directions | | Contribution from 70-100° | |
|---|---|---|---|---|---|---|
| | Count[1] | Conc[2] | DC[1] | Conc[2] | Conc[2] | % |
| 2015 | 451 | 6.4 | 8,510 | 11.7 | 0.34 | 2.9 |
| 2016 | 441 | 7.9 | 7,915 | 16.1 | 0.44 | 2.7 |
| 2017 | 499 | 15.2 | 8,724 | 20.6 | 0.87 | 4.2 |
| 2018 | 448 | 9.6 | 8,743 | 13.6 | 0.49 | 3.6 |
| 2019 | 437 | 8.7 | 8,622 | 12.1 | 0.44 | 3.6 |
| 2020 | 379 | 8.9 | 8,532 | 11.0 | 0.40 | 3.6 |

Table notes:
[1] Number of hours valid data in that year
[2] Average Concentration

## 5.5 Regional Trends

Consistent with the monitoring results presented in Sections 5.1 and 5.1.5, the NSW EPA reviewed air quality in the Lake Macquarie and Wyong region between 2013 and 2016 (NSW EPA, 2016) and found it was consistently good to very good. The only exceedances of the air quality criteria related to particulate concentrations during natural events (specifically regional dust events, although it is well known the bushfires can also cause exceedances, as they later did in 2019/20).

The NSW Government's Air Quality Study for the NSW Greater Metropolitan Region (2020) (GMR Study) looked at trends in emissions and pollutant concentrations over time, and also projected future trends in emissions. It is useful to compare the conclusions of this study to the trends identified in the above analysis.

The GMR Study predicts that emissions of $PM_{2.5}$, $SO_2$ and NOx will all increase into the future until at least 2036. It also suggests that, in the GMR as a whole, emissions of these pollutants have plateaued or increased between

2008 and 2021. The same is true for ‘non-urban’ emissions, which includes emissions from power stations in the region.

Overall, the GMR Study appears to align with the outcomes of the analysis presented in this report, with no significant trend in measured pollutant concentrations for most pollutants at Wyee and Wyong. However, a significant downward trend in concentrations of $SO_2$ is apparent at Wyee, and a very significant downward trend in $NO_2$ concentrations is apparent at Wyong. This highlights that, in specific locations, trends in pollutant concentrations will not necessarily align with trends in regional emissions, as emissions from specific sources that dominate concentrations at those specific locations may not trend in the same direction as regional emissions.

Emissions from VPPS are unlikely to increase significantly in the future; in reality NOx emission from VPPS should have reduced appreciably in 2021 with the installation of the new low-NOx burner tips in Boiler 6. If regional emissions of $PM_{2.5}$, $SO_2$ and NOx all increase into the future, as predicted by the GMR Study, then the relative contribution of VPPS to local and regional pollutant concentrations can be expected to diminish over time, as emissions from other sources become more prominent.

# 6. COMPARISON OF EMISSIONS TO EPL

## 6.1 Overview

In accordance with its EPL, VPPS conducts monitoring of emissions from Boilers 5 and 6. Monitoring is conducted via stack testing for all air pollutants and by continuous emissions monitoring systems (CEMS) for NOx (as $NO_2$ equivalent) and $SO_2$.

## 6.2 Stack tests

Stack testing of Boilers 5 and 6 at VPPS conducted between 2010 and 2020 has been considered in the following analysis. All air pollutants were sampled for this ten-year period with the exception of NOx, which was not monitored by stack tests prior to 2013. The concentrations of all air pollutants were measured to be below the EPL limits and, with the exception of NOx, below the standards of concentration in the Clean Air Regulation for Group 6 plant and equipment.

Measurements of the following air pollutants were found to be most significant compared to the EPL concentration limits:

- Nitrogen oxides – 70% to 81% of the EPL concentration limit
- Solid particles – 18% - 68% of the EPL concentration limit
- Sulfur dioxide – 52% - 59% of the EPL concentration limit.

Figure 70 to Figure 72 present the measured concentrations of NOx, solid particles and $SO_2$ during each stack test between 2010 and 2020. Measured concentrations are relatively consistent over the monitoring period, except for significantly lower concentrations of $SO_2$ in both boilers in 2013/2014, and the elevated solid particle measurement in Boiler 6 in 2018/19. No clear trends are visible in the measured data.

**Table 29** **Evaluation of concentrations measured in Boilers 5 and 6 against EPL 761 Air concentration limits**

| Pollutant | EPL 761 Air Concentration Limit | Boiler 5 | | Boiler 6 | |
|---|---|---|---|---|---|
| | | Maximum concentration measured | % of EPL Limit | Maximum concentration measured | % of EPL Limit |
| Cadmium | 0.2 | 0.02 | 10% | 0.031 | 16% |
| Chlorine | 20 | 3.8 | 19% | 1.8 | 9% |
| Fluorine | 30 | 11.1 | 37% | 8.5 | 28% |
| Hydrogen Chloride | 50 | 6.1 | 12% | 8 | 16% |
| Mercury | 0.05 | 0.0008 | 2% | 0.0013 | 3% |
| NOx | 1,500[1] | 1,054 | 70% | 1,219 | 81% |
| Solid particles | 50 | 9.2 | 18% | 34.1 | 68% |
| Sulfuric acid mist and sulfur trioxide (as $SO_3$) | 100 | 40 | 40% | 27 | 27% |
| Sulfur dioxide | 1,700[1] | 880 | 52% | 1,005 | 59% |
| Type 1 and 2 substances in aggregate | 0.75 | 0.04 | 5% | 0.22 | 30% |
| VOC as n-propane equivalent | 10 | 0.9 | 9% | 4.3 | 43% |

Table note:
[1] 100th percentile concentration limit

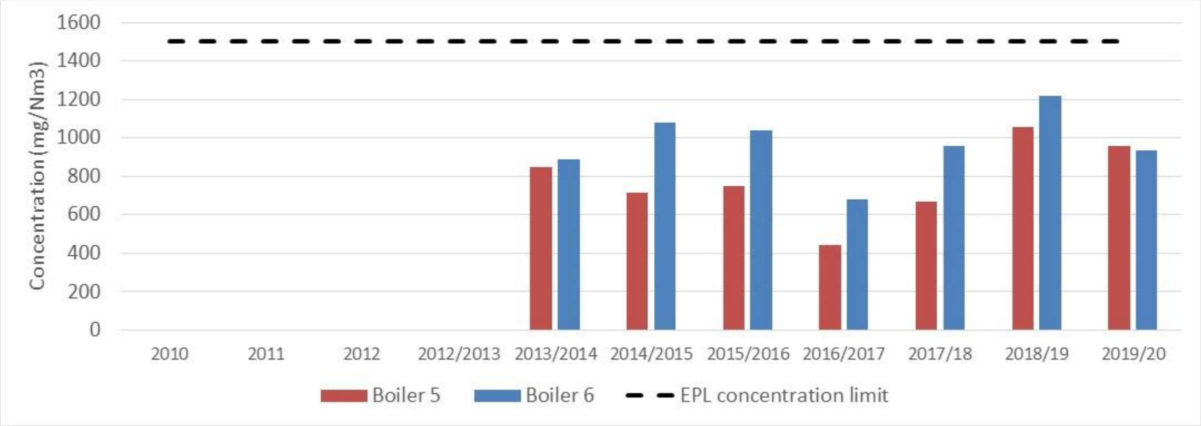


**Figure 70** Concentrations of NOx measured in Boilers 5 and 6 (no monitoring prior to 2012)

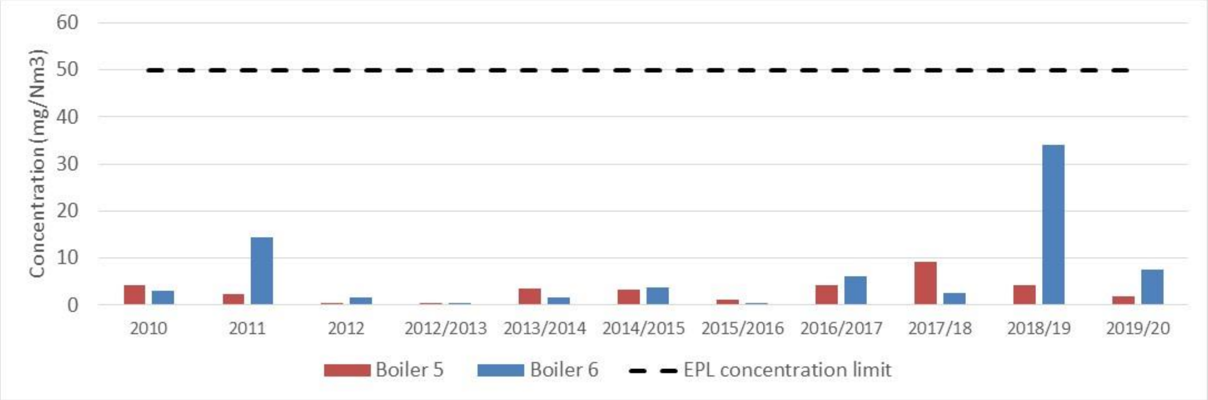


**Figure 71** Concentrations of solid particles measured in Boilers 5 and 6

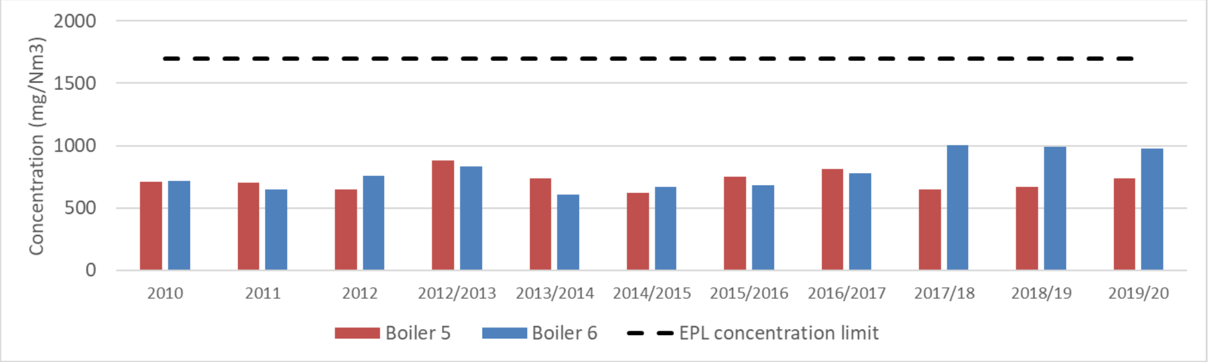


**Figure 72** Concentrations of $SO_2$ measured in Boilers 5 and 6

## 6.3 Continuous monitoring

Continuous monitoring equipment is installed in two of the four ducts associated with each boiler. Table 30 summarises the data available from the last ten years. These data have been analysed and reviewed to identify trends over time in the following sections.

Data validation and processing steps have been conducted, which resulted in a very small number of data points being removed from the analysis (possibly partially due to the limited availability of oxygen and load data as described in Table 30). The following validation criteria were applied:

- Concentrations during loads below 200 MW removed (9 hours for Boiler 5, none for Boiler 6)
- Concentrations with oxygen levels above 15% removed (12 hours for Boiler 5, 1 hour for Boiler 6)
- Concentrations from points 5A and 5B associated with Boiler 5 and points 6A and 6B associated with Boiler 6 have been averaged.

**Table 30 Summary of availability of continuous in-stack monitoring data**

| Parameter | Data availability | |
|---|---|---|
| | Boiler 5 – sampling points 5A and 5B | Boiler 6 – sampling points 6A and 6B |
| NOx concentration | 31 July 2013 – 28 June 2021 | 31 July 2013 – 9 April 2021 |
| $SO_2$ concentration | 31 July 2013 – 28 June 2021 | 2 October 2013 - 9 April 2021 |
| Oxygen concentration | 1 January 2018 - 30 June 2021 | 1 January 2018 - 9 April 2021 |
| Load | 1 January 2018 - 30 June 2021 | 1 January 2018 - 9 April 2021 |

### 6.3.1 Concentrations of NOx

Table 31 summarises the concentrations of NOx (as $NO_2$ equivalent) measured in Boiler 5 and 6 between 2013 and 2021. The variation in measured concentrations over time during this period can be seen in Figure 73, and the distribution of concentrations is presented in Figure 74.

The data for NOx shows the following trends:

- Concentrations of NOx in both boilers have been steadily decreasing over the past ten years
- Concentrations of NOx in boiler 6 have consistently measured higher than those measured in boiler 5.

Figure 75 and Figure 76 show the concentrations of NOx as a function of load, for Boiler 5 and 6, respectively. These figures show that concentrations of NOx generally increase with load, but this is far more apparent for boiler 6.

**Table 31 Summary statistics for concentrations of NOx (mg/Nm³, dry, 7% $O_2$)**

| Year | Boiler 5 | | | Boiler 6 | | |
|---|---|---|---|---|---|---|
| | Data capture (%) | Average (mg/Nm³) | Max 1-hour (mg/Nm³) | Data capture (%) | Average (mg/Nm³) | Max 1-hour (mg/Nm³) |
| 2013[1] | 94.7 | 830 | 1,111 | 78.8 | 1,040 | 1,312 |
| 2014 | 58.2 | 753 | 1,176 | 92.5 | 1,057 | 1,549 |
| 2015 | 94.4 | 659 | 1,083 | 93.2 | 989 | 1,274 |
| 2016 | 92.0 | 617 | 1,060 | 76.5 | 912 | 1,367 |
| 2017 | 91.2 | 593 | 1,055 | 84.6 | 793 | 1,087 |
| 2018 | 73.8 | 616 | 977 | 88.9 | 838 | 1,162 |
| 2019 | 89.6 | 622 | 900 | 87.7 | 791 | 1,108 |
| 2020 | 85.0 | 610 | 1,117 | 85.6 | 740 | 1,197 |
| 2021[2] | 93.3 | 577 | 815 | 52.3 | 692 | 996 |

Table notes:

[1] Data available from 31 July 2013

[2] Data available to 30 June 2021

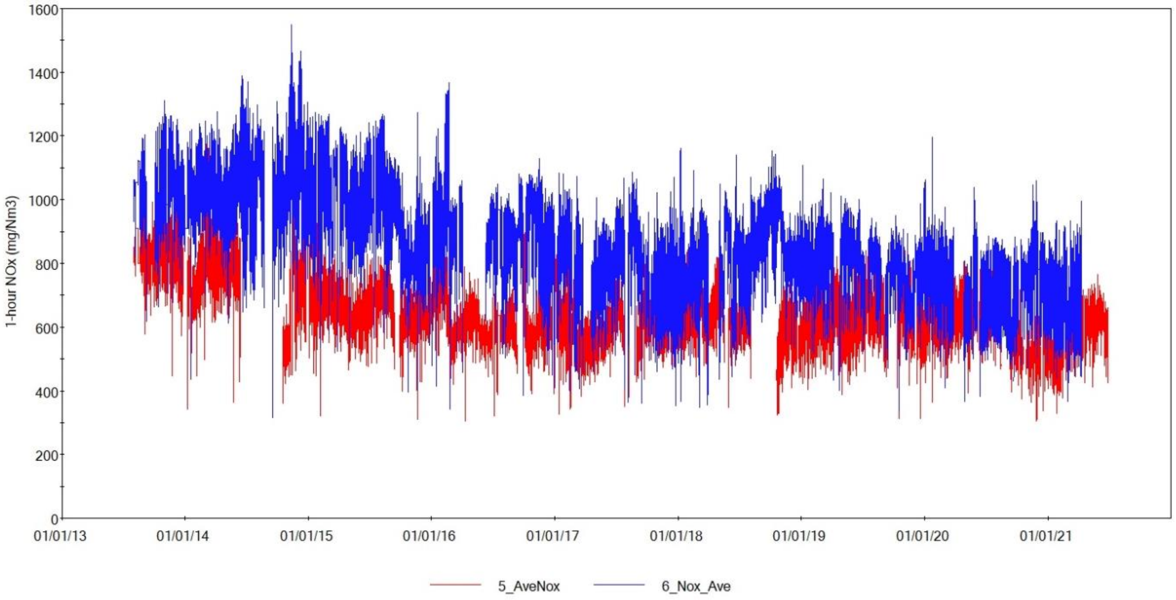


**Figure 73** Time series of concentrations of NOx (1-hour average, mg/Nm³, dry, 7% $O_2$) in boiler 5 and 6

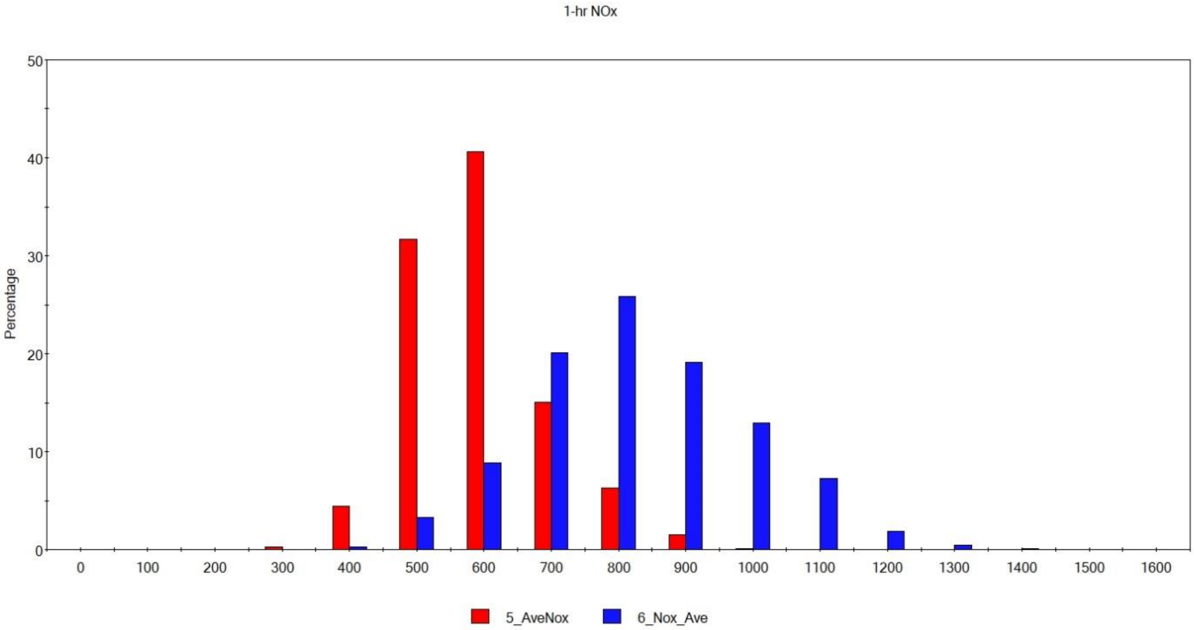


**Figure 74** Distribution of concentrations of NOx (1-hour average, mg/Nm³, dry, 7% $O_2$) in boiler 5 and 6

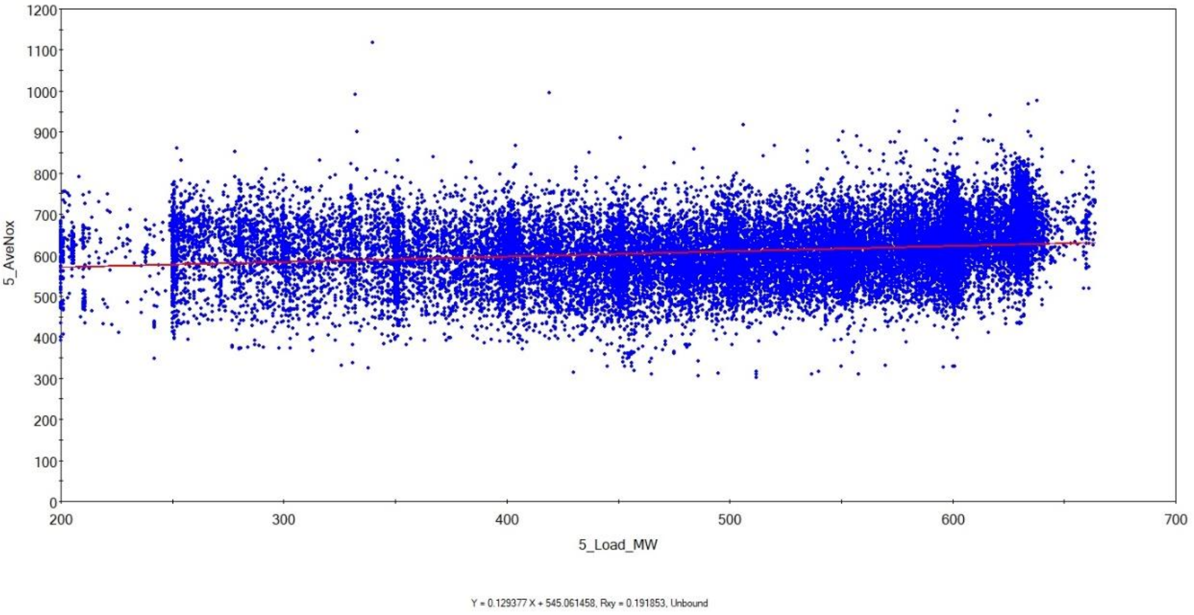


Figure 75 Concentration of NOx (1-hour average, mg/Nm³, dry, 7% $O_2$) vs Load in boiler 5

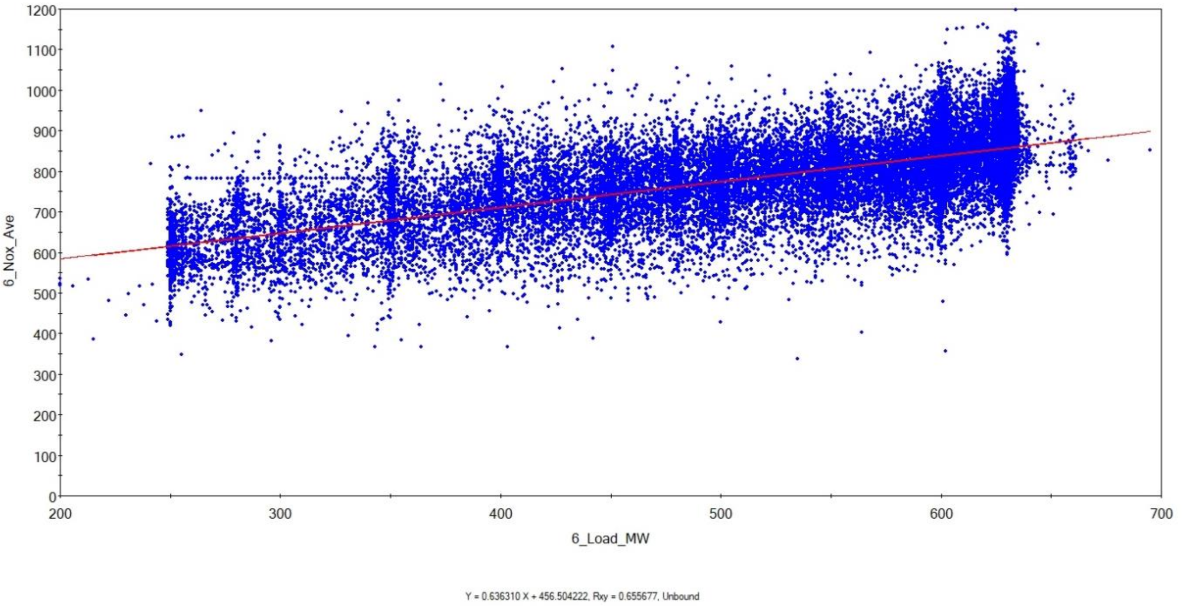


Figure 76 Concentrations of NOx (1-hour average, mg/Nm³, dry, 7% $O_2$) vs Load in boiler 6

Table 32 and Figure 77 show the percentage of time that concentrations of NOx have been measured to be above the Group 5 and EPL limits. This shows that due to the decrease in concentrations of NOx over time, the percentage of time above the Group 5 standard of concentration is reducing for both boilers. Since 2015, the 1-hour average concentration of NOx in both boilers has not exceeded the EPL 100th percentile limit of 1,500mg/Nm³. Since 2013 in Boiler 5 and 2017 in Boiler 6, the 1-hour average concentration of NOx complied with the 99th percentile limit of 1,100mg/Nm³.

**Table 32** **Percentage of time concentration of NOx above Group 5 and EPL limits**

| Year | Boiler 5 | | | Boiler 6 | | |
|---|---|---|---|---|---|---|
| | % of time > 800 mg/Nm$^3$ (Group 5) | % of time > 1,100 mg/Nm$^3$ (EPL 99th %) | % of time > 1,500 mg/Nm$^3$ (EPL limit) | % of time > 800 mg/Nm$^3$ (Group 5) | % of time > 1,100 mg/Nm$^3$ (EPL 99th %) | % of time > 1,500 mg/Nm$^3$ (EPL limit) |
| 2013 | 67.6 | 0.0 | 0.0 | 78.2 | 18.5 | 0.0 |
| 2014 | 18.9 | 0.2 | 0.0 | 91.0 | 32.4 | 0.1 |
| 2015 | 1.1 | 0.0 | 0.0 | 86.2 | 22.1 | 0.0 |
| 2016 | 2.2 | 0.0 | 0.0 | 65.6 | 1.8 | 0.0 |
| 2017 | 0.4 | 0.0 | 0.0 | 42.7 | 0.0 | 0.0 |
| 2018 | 0.6 | 0.0 | 0.0 | 59.4 | 0.3 | 0.0 |
| 2019 | 0.8 | 0.0 | 0.0 | 44.6 | 0.0 | 0.0 |
| 2020 | 0.5 | 0.0 | 0.0 | 24.1 | 0.0 | 0.0 |
| 2021 | 0.0 | 0.0 | 0.0 | 7.9 | 0.0 | 0.0 |

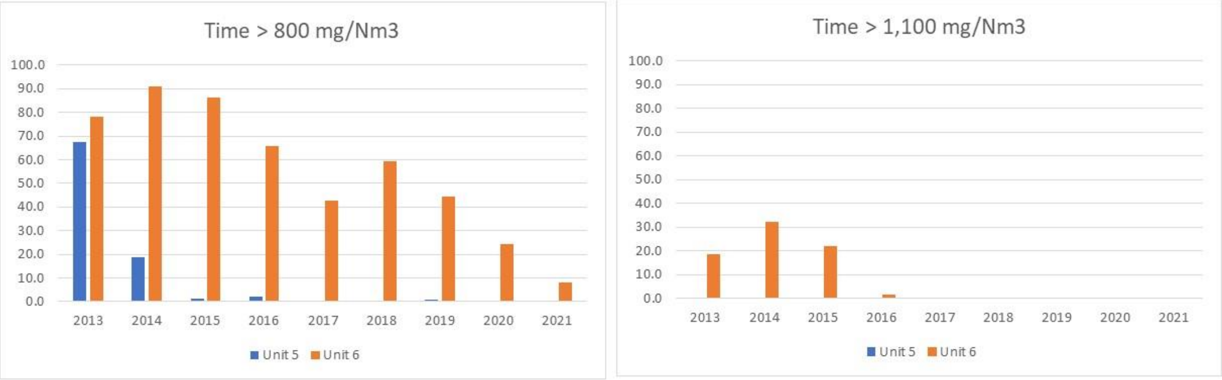


**Figure 77** **Percentage of time above Group 5 standard of concentration and 1,100 mg/Nm$^3$**

## 6.3.2 Concentrations of SO$_2$

Table 33 summarises the concentrations of SO$_2$ measured in Boilers 5 and 6 between 2013 and 2021. The variation in measured concentrations over time during this period can be seen in Figure 78, and the distribution of concentrations is presented in Figure 79.

The measurements of SO$_2$ show the following trends:

- Concentrations of SO$_2$ measured in Boiler 5 and 6 are comparable over the monitoring period.
- Concentrations of concentrations measured in Boiler 6 prior to November 2014 display a much larger range of values, and much higher concentrations, than Boiler 5, though similar variations on the scale of weeks can be seen.
- Figure 80 shows the nature of the concentration variations in Boiler 6, which are characterised by one or several elevated concentrations that typically appear to be outliers amongst the remaining concentrations that are similar in magnitude to those measured in Boiler 5.
- Excluding data prior to November 2014, there is a slight upward trend over the period.
- From approximately September 2017 to December 2019, higher concentrations were recorded, with larger ranges.

- It has been confirmed through discussion with Delta Electricity that much of the variability in $SO_2$ emissions relates to coal from different sources being used over different periods of time (e.g., coal with a lower sulfur content was used from late-2014 to mid-2017).

Figure 81 and Figure 82 show the concentrations of $SO_2$ as a function of load, for Boilers 5 and 6, respectively. These figures show there is a minor increase in concentrations of $SO_2$ with load, and this is more apparent in the data from Boiler 6.

**Table 33 Summary statistics for $SO_2$ (1-hour average, mg/Nm³, dry, 7% $O_2$)**

| Year | Boiler 5 | | | Boiler 6 | | |
|---|---|---|---|---|---|---|
| | Data capture (%) | Average 1-hr (mg/Nm³) | Max 1-hr (mg/Nm³) | Data capture (%) | Average 1-hr (mg/Nm³) | Max 1-hr (mg/Nm³) |
| 2013[1] | 94.9 | 673 | 880 | 55.1 | 630 | 1,406 |
| 2014 | 62.6 | 519 | 996 | 92.3 | 553 | 1,437 |
| 2015 | 94.3 | 566 | 725 | 93.1 | 493 | 747 |
| 2016 | 92.0 | 588 | 828 | 76.4 | 525 | 784 |
| 2017 | 91.2 | 668 | 1,280 | 84.6 | 608 | 1,188 |
| 2018 | 73.9 | 756 | 1,293 | 89.1 | 712 | 1,242 |
| 2019 | 89.7 | 803 | 1,428 | 87.9 | 782 | 1,604 |
| 2020 | 85.0 | 666 | 1,199 | 85.6 | 641 | 1,153 |
| 2021[2] | 93.3 | 682 | 933 | 93.3 | 630 | 910 |

Table notes:

[1] Data available from 31 July 2013

[2] Data available to 30 June 2021

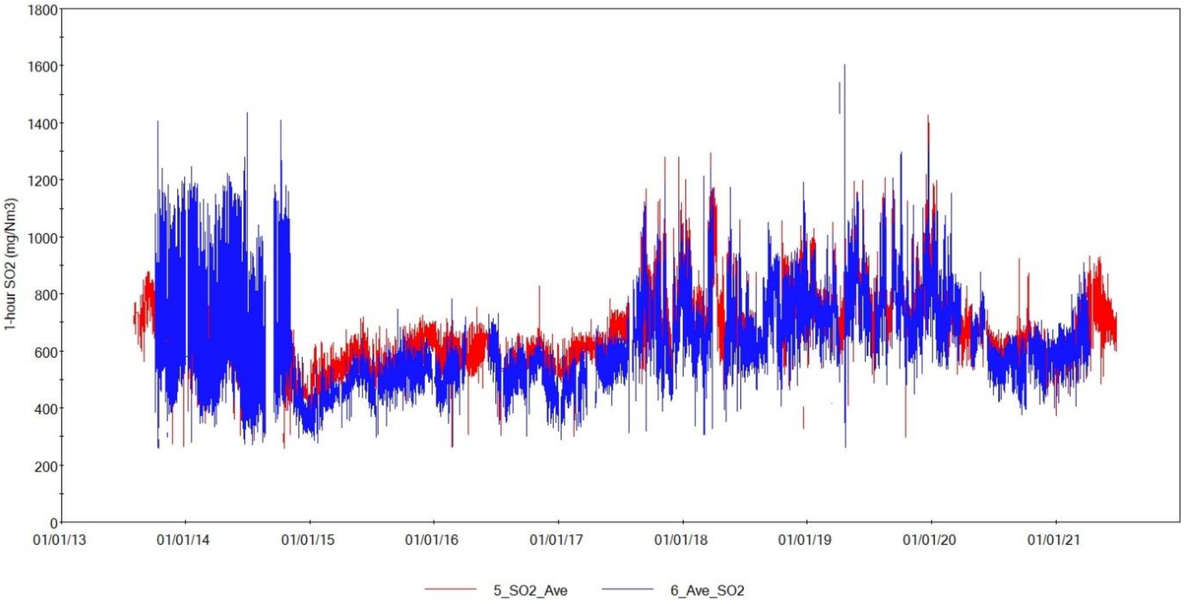


**Figure 78 Concentrations of $SO_2$ (1-hour average, mg/Nm³, dry, 7% $O_2$) in Boilers 5 and 6**

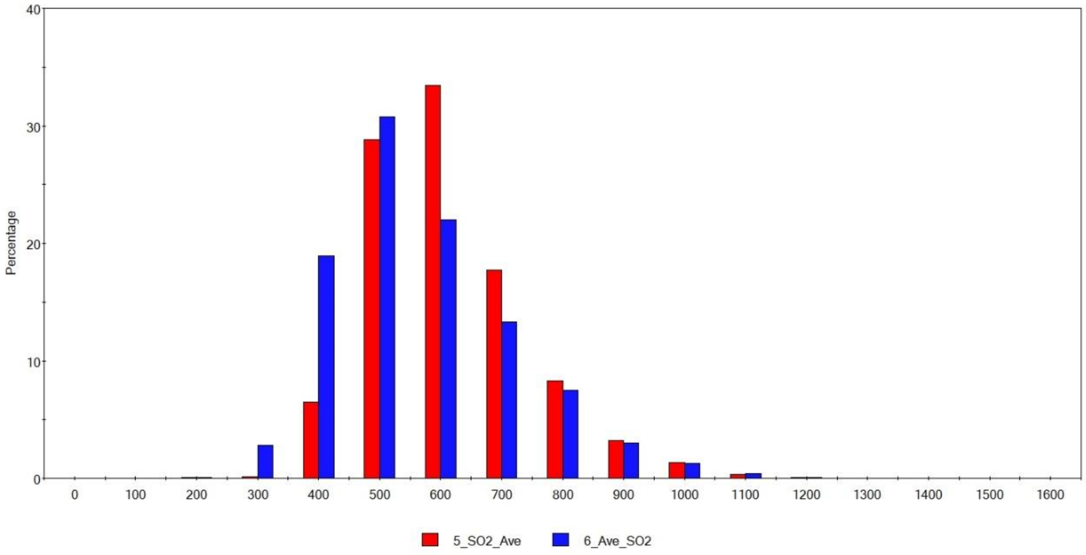


Figure 79 Distribution of 1-hour concentrations of $SO_2$ (1-hour average, mg/Nm³, dry, 7% $O_2$) in Boilers 5 and 6

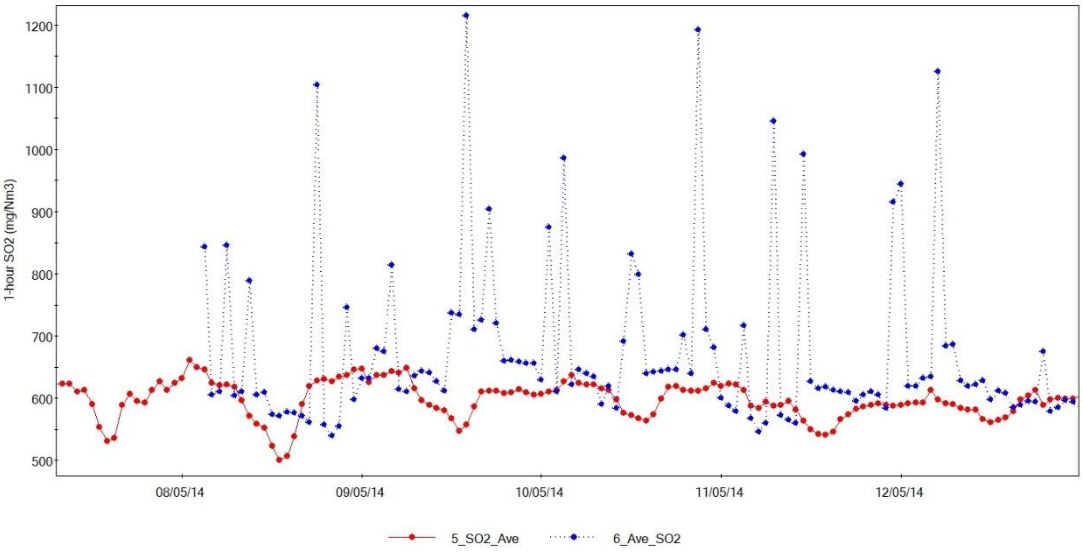


Figure 80 Typical pattern of concentrations of $SO_2$ measured in Boiler 5 versus Boiler 6

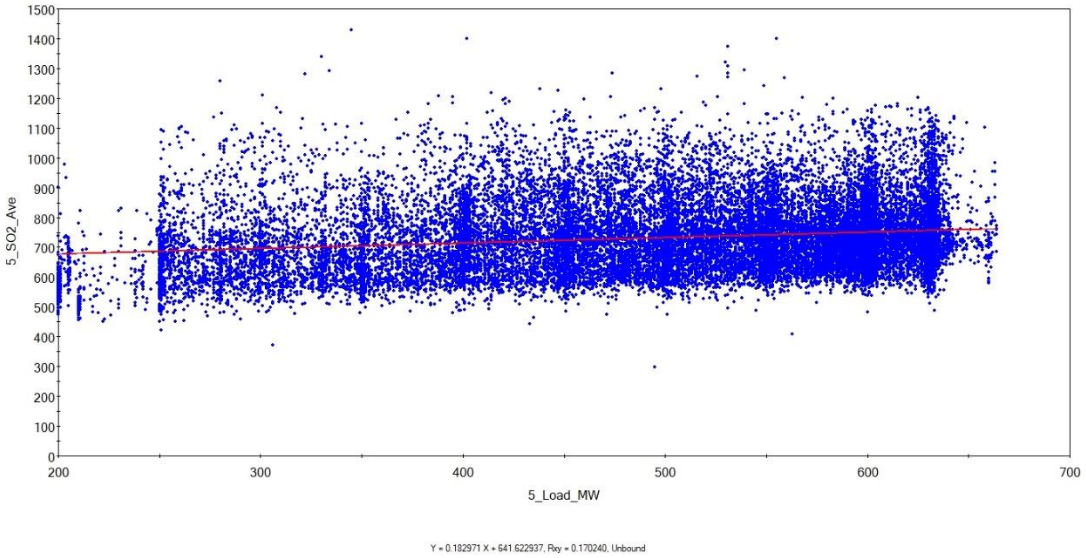


Figure 81 Concentrations of $SO_2$ (1-hour average, mg/Nm³, dry, 7% $O_2$) vs Load in Boiler 5

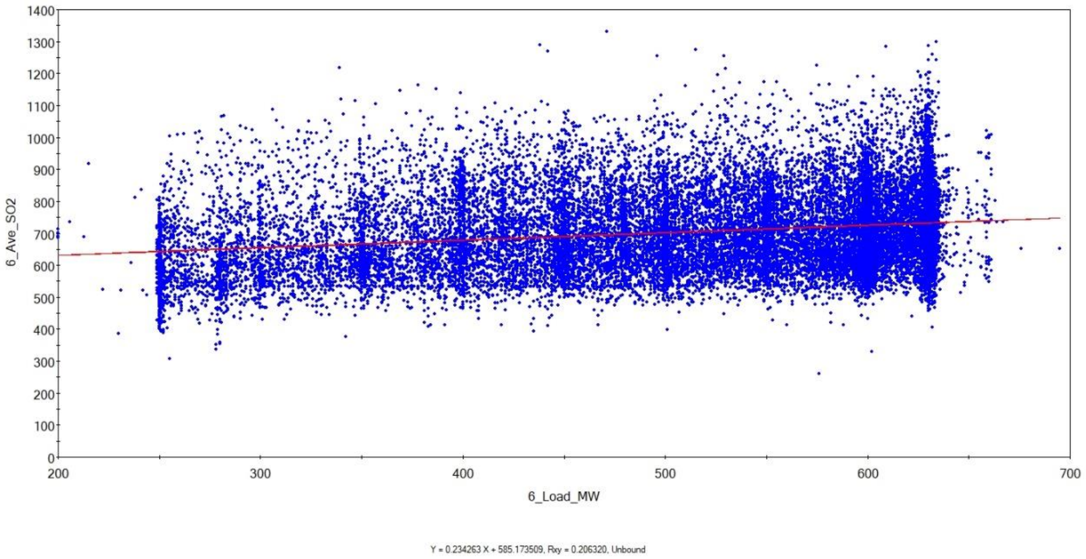


Figure 82 Concentrations of $SO_2$ (1-hour average, mg/Nm³, dry, 7% $O_2$) vs Load in Boiler 6

Table 34 shows the percentage of time that concentrations of $SO_2$ have been measured to be above the current EPL limit of 1,700 mg/Nm$^3$ and the 99th percentile limit of 1,400 mg/Nm³. Table 34 shows the following:

- Boilers 5 and 6 have complied with the EPL limit of 1,700 mg/Nm$^3$ throughout the period.
- Concentrations measured in Boilers 5 and 6 comply with the 99th percentile EPL limit of 1,400 mg/Nm$^3$.

Table 34 Number of hours that concentration of $SO_2$ are above EPL concentration limits

| Year | Boiler 5 | | Boiler 6 | |
|---|---|---|---|---|
| | Hours > 1,400 mg/Nm$^3$ (EPL 99th %) | Hours > 1,700 mg/Nm$^3$ (EPL limit) | Hours > 1,400 mg/Nm$^3$ (EPL 99th %) | Hours > 1,700 mg/Nm$^3$ (EPL limit) |
| 2013 | 0 | 0 | 1 | 0 |
| 2014 | 0 | 0 | 3 | 0 |
| 2015 | 0 | 0 | 0 | 0 |
| 2016 | 0 | 0 | 0 | 0 |
| 2017 | 0 | 0 | 0 | 0 |
| 2018 | 0 | 0 | 0 | 0 |
| 2019 | 1 | 0 | 4 | 0 |
| 2020 | 0 | 0 | 0 | 0 |
| 2021 | 0 | 0 | 0 | 0 |

# 7. DISPERSION MODELLING RESULTS

The results of the modelling exercise are set out below. It should be noted that all plots reflect the maximum concentrations across the modelled receptor grid in any of the three years 2018 to 2020.

## 7.1 Current operations

### 7.1.1 VPPS in Isolation

#### 7.1.1.1 $NO_2$

Figure 83 presents a contour plot of the maximum predicted contribution of VPPS to annual average ground-level concentrations of $NO_2$, assuming that 100% of NOx is converted to $NO_2$, which overstates concentrations. The maximum contributions are small (less than 5.3%) relative to the assessment criterion of 62 µg/m$^3$. The maximum predicted annual average concentration of $NO_2$ anywhere on the receptor grid over the three-year modelled period is 3.3 µg/m$^3$.

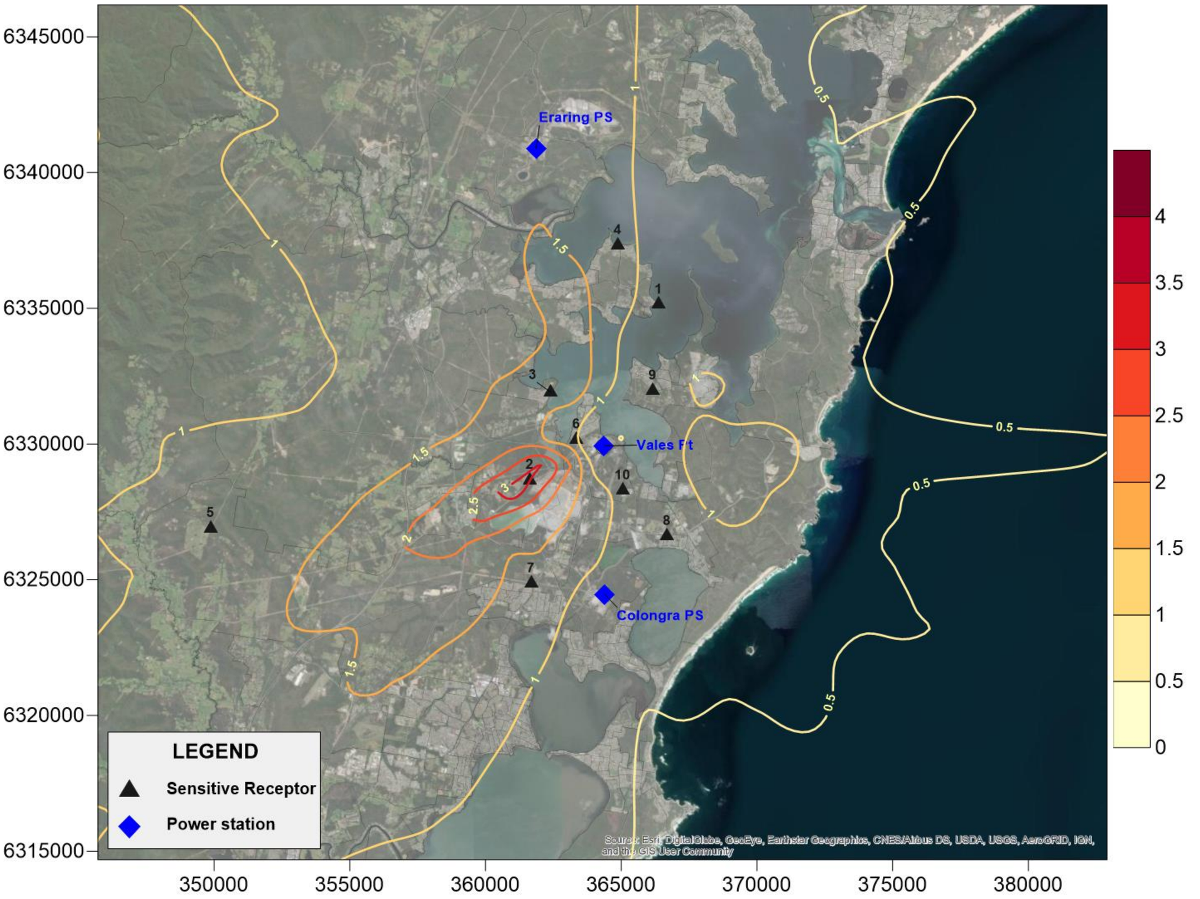


Figure 83 Annual average ground-level concentrations of $NO_2$ – VPPS in isolation

Figure 84 presents a contour plot of the maximum 1-hour average ground-level concentrations of $NO_2$ due to VPPS in isolation assuming that 20% of NOx is converted to $NO_2$ (see Section 3.8). The plot identifies no risk of an exceedance of the assessment criterion of 246 µg/m³ as a result of emissions from VPPS in isolation. The maximum predicted 1-hour average concentration anywhere on the receptor grid is 185.9 µg/m³.

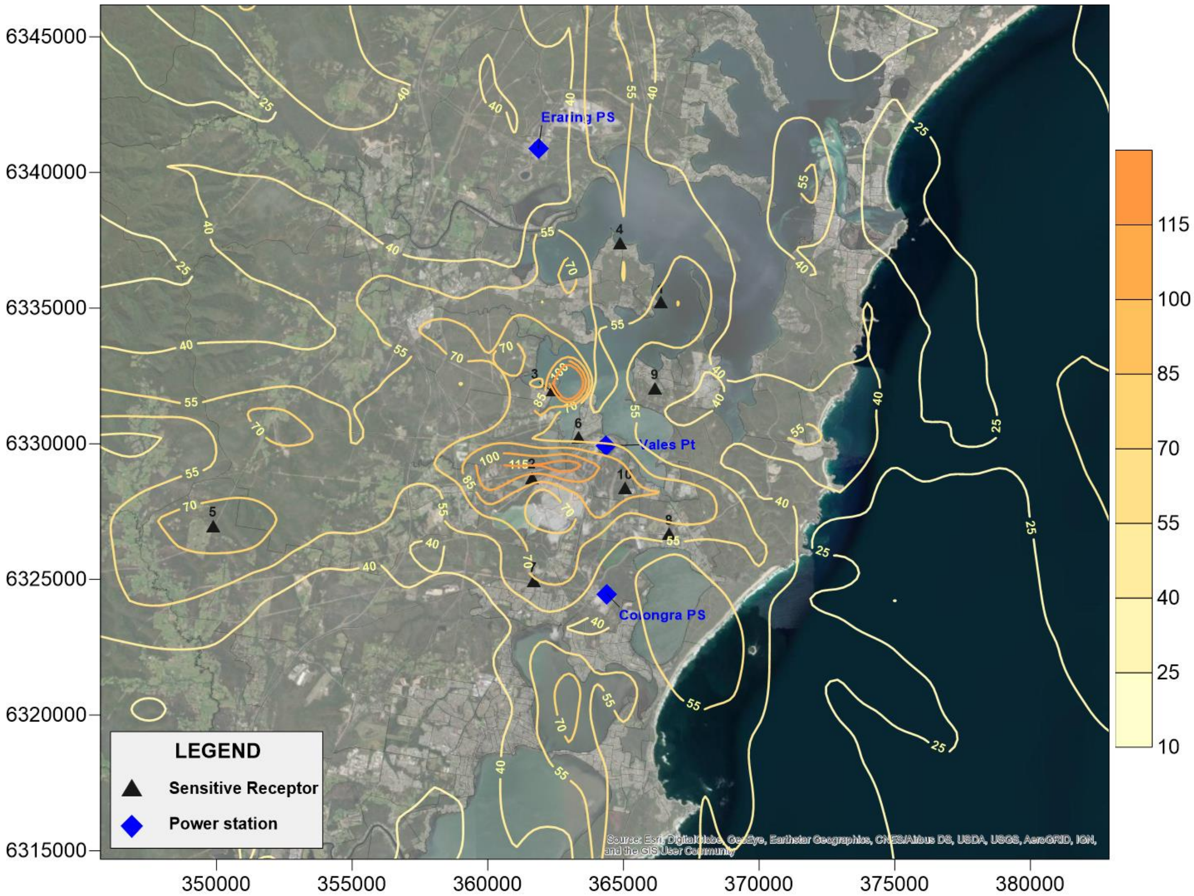
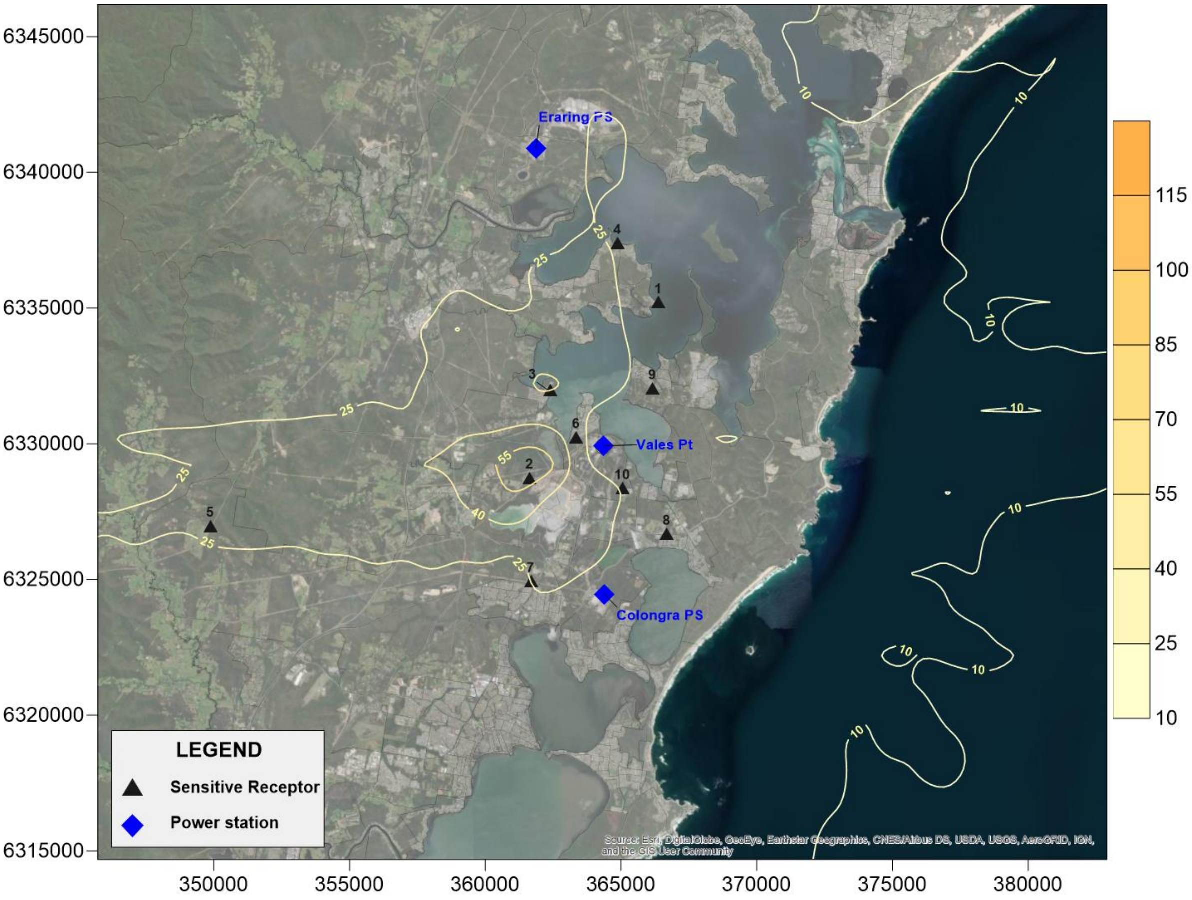


**Figure 84** Maximum 1-hour average ground-level concentrations of $NO_2$ – VPPS in isolation – 20% $NO_2$/NOx

Figure 85 presents a contour plot of the maximum 99.9th percentile of 1-hour average ground-level concentrations of $NO_2$ due to VPPS in isolation, again assuming that 20% of NOx is converted to $NO_2$. This plot has been produced by calculating the 99.9th percentile of 1-hour concentrations for each of the three years 2018, 2019 and 2020, and taking the maximum of these three values for each modelled grid point. The maximum predicted 99.9th percentile of 1-hour average concentrations anywhere on the receptor grid in this scenario is 68.1 µg/m$^3$, little more than a third of the maximum 1-hour concentration, which suggests that high contributions from VPPS are rare events.



Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

**Figure 85** **Maximum 99.9th percentile of 1-hour average ground-level concentrations of $NO_2$ – VPPS in isolation – 20% $NO_2$/NOx**

To test the sensitivity of predicted concentrations of $NO_2$ to the rate of conversion of NOx to $NO_2$, Figure 86 presents a contour plot of the maximum 1-hour ground-level concentrations of $NO_2$ assuming that 40% of NOx is converted to $NO_2$. The predicted maximum 1-hour average concentration of $NO_2$ anywhere on the receptor grid under this scenario is 371.9 µg/m$^3$, which is significantly higher than the maximum concentration measured over 10 years at Wyee. It is demonstrated later (in Figure 103) that this scenario likely produces unrealistic $NO_2$ concentrations, thus the focus should be on the results using the 20% ratio in Figure 84.

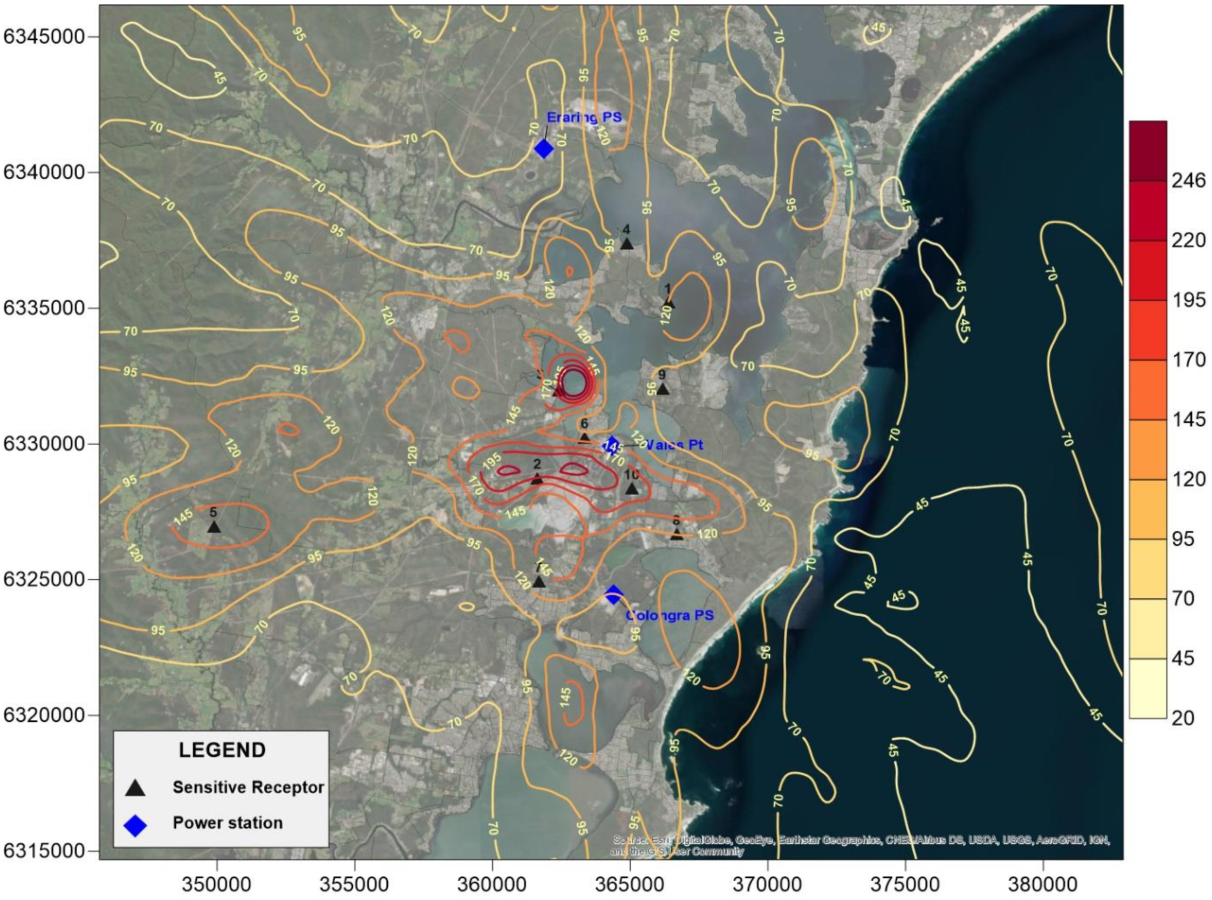


**Figure 86** Maximum 1-hour average ground-level concentrations of $NO_2$ – VPPS in isolation – 40% $NO_2$/NOx

Table 35 presents modelled concentrations at the specific sensitive receptors set out in Table 18 and Figure 6, and at the Wyee and Wyong monitoring stations, using the different approaches to predicting $NO_2$ from NOx set out in Section 3.8. No exceedances of the assessment criteria are predicted at the selected sensitive receptors. The OLM method has used the background dataset described in Section 3.7.3, which may understate total concentrations due to not explicitly incorporating contributions from any other power stations at this stage; see Section 7.1.2.1 for a full cumulative assessment.

It was estimated in Section 5.4 that VPPS would contribute between 0.34 and 1.26 µg/m$^3$ to annual mean $NO_2$ concentrations at Wyee. The modelled concentration in Table 35 does, therefore, seem realistic, but perhaps leans toward an over-estimation.

**Table 35** **Modelled VPPS $NO_2$ contributions at specific sensitive receptors using various NOx to $NO_2$ conversion methods (µg/m$^3$)**

| Receptor | Annual average 100% $NO_2$/NOx | Max 1-hr | | Max 99.9th %ile 1-hr | | OLM-Method[2] | | |
|---|---|---|---|---|---|---|---|---|
| | | 20% $NO_2$/NOx | 40% $NO_2$/NOx | 20% $NO_2$/NOx | 40% $NO_2$/NOx | Annual average | Max 1-hr | Max 99.9th %ile 1-hr |
| 1 | 0.82 | 60.6 | 121.5 | 18.1 | 36.2 | 0.75 | 91.6 | 69.8 |
| 2 | 2.80 | 93.0 | 189.1 | 56.5 | 113.1 | 1.71 | 133.2 | 102.7 |
| 3 | 1.64 | 104.0 | 213.2 | 38.9 | 77.7 | 1.23 | 132.8 | 97.6 |
| 4 | 1.21 | 53.2 | 103.4 | 23.9 | 47.8 | 0.99 | 94.6 | 72.0 |
| 5 | 1.13 | 76.6 | 155.0 | 26.2 | 52.4 | 0.87 | 101.1 | 77.1 |
| 6 | 1.05 | 64.6 | 138.7 | 32.3 | 64.6 | 0.88 | 105.5 | 84.8 |
| 7 | 1.37 | 66.4 | 134.2 | 24.7 | 49.4 | 1.11 | 100.8 | 77.1 |
| 8 | 0.86 | 59.4 | 118.1 | 19.7 | 39.4 | 0.68 | 116.7 | 72.3 |
| 9 | 0.74 | 43.1 | 86.6 | 19.2 | 38.3 | 0.65 | 88.0 | 71.7 |
| 10 | 0.77 | 93.5 | 182.0 | 24.1 | 48.1 | 0.57 | 100.5 | 72.8 |
| Wyong | 1.19 | 30.9 | 61.8 | 14.8 | 29.6 | 1.25 | 109.4 | 82.3 |
| Wyee | 1.64 | 59.2 | 118.1 | 36.6 | 73.3 | 1.02 | 78.6 | 56.7 |
| Criterion[1] | 62 | 246 | | | | 62 | 246 | |

Table notes:

[1] Approved Methods for Modelling

[2] No background $NO_2$ concentration has been added to the derived VPPS contribution at this stage; background concentrations are added alongside the cumulative contributions of Eraring and Colongra in Table 39.

Figure 87 presents a Q-Q plot of modelled versus measured 1-hour average concentrations of NOx at the Wyee monitoring station. The Q-Q plot is constructed by ranking the measured and modelled concentrations from lowest to highest, with corresponding ranks in each series plotted (e.g. the 150th highest modelled concentrations is plotted against the 150th highest measured concentration). Q-Q plots are commonly used to evaluate the performance of models against measurements.

Figure 87 suggests that the model is under-predicting NOx concentrations in the absence of the contribution of background sources; this is unsurprising, especially given the monitor's proximity to the M1 Pacific Motorway, which will be a regular source of NOx. Adding the cumulative contribution of background sources, plus that or Eraring and Colongra power stations, as is done in Section 7.1.2.1, should produce a closer fit. However, it must be noted that the highest modelled concentration of NOx without inclusion of background is only slightly lower than the highest measured concentration, suggesting that the model over-predicts maximum 1-hour average concentrations. This propensity for the model to over-estimate peak concentrations is more clearly demonstrated for $SO_2$ (see the following Section).

The supplementary report (Malfroy Environmental Strategies Pty Ltd, 2010) prepared as part of Sunset Power's previous exemption application investigated the meteorological conditions that resulted in the two highest modelled concentrations from that study, and concluded that the TAPM predictions for the critical boundary layer factors probably resulted in maximum concentrations being over-estimated. It is reasonable to think that this may be happening again in this updated study, although the specific meteorological conditions at the times of maximum predicted concentrations have not been investigate din detail.

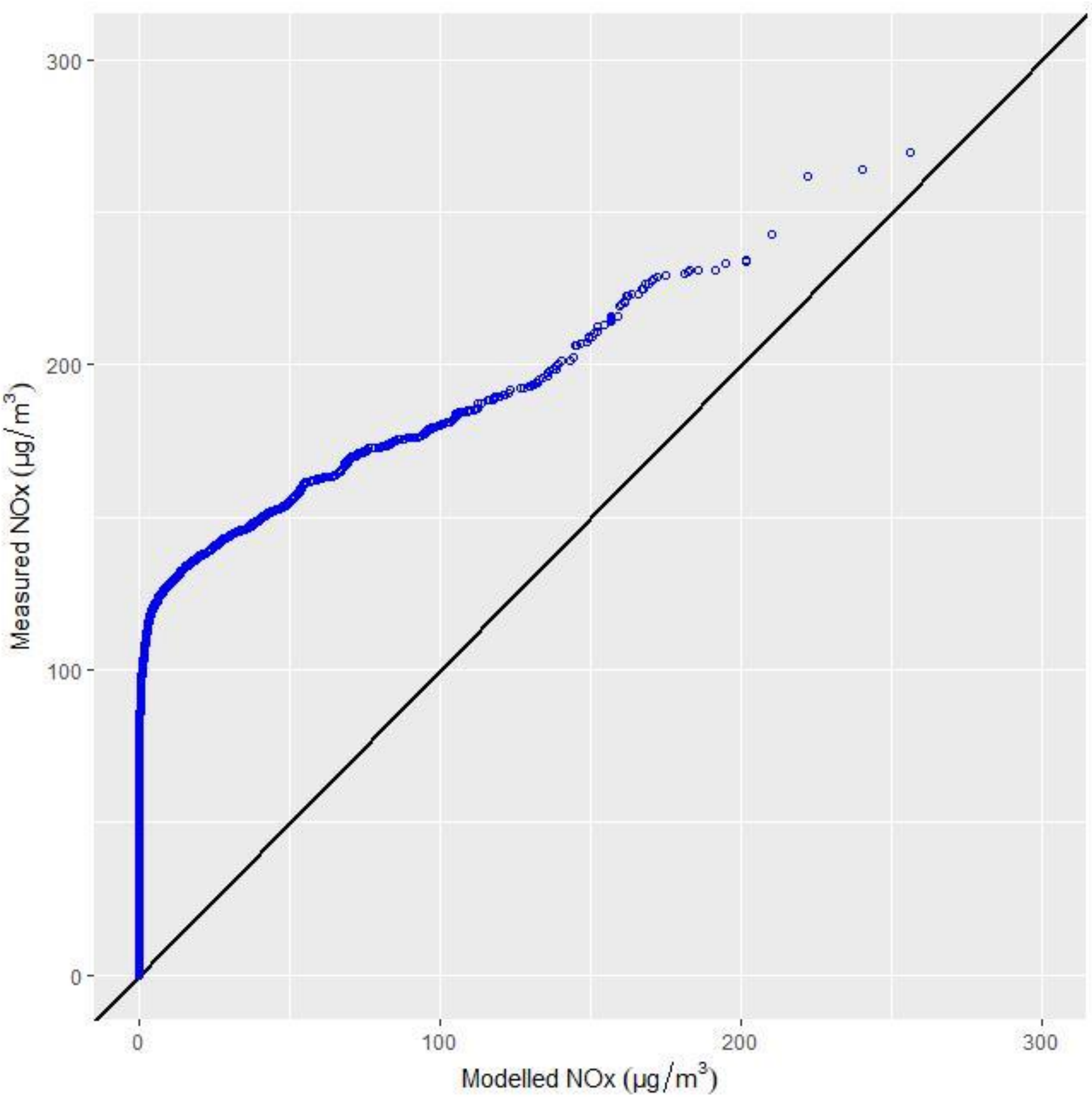


**Figure 87** Q-Q Plot of predicted 1-hour average ground level concentrations of NOx at Wyee – VPPS in isolation

### 7.1.1.2 SO$_2$

Figure 88 presents a contour plot of the maximum predicted contribution from VPPS to annual average ground-level concentrations of SO$_2$. The maximum contributions are small (less than 5.7%) relative to the assessment criterion of 60 µg/m$^3$. The maximum predicted annual average concentration of SO$_2$ anywhere on the receptor grid over the three-year modelled period was 3.4 µg/m$^3$.

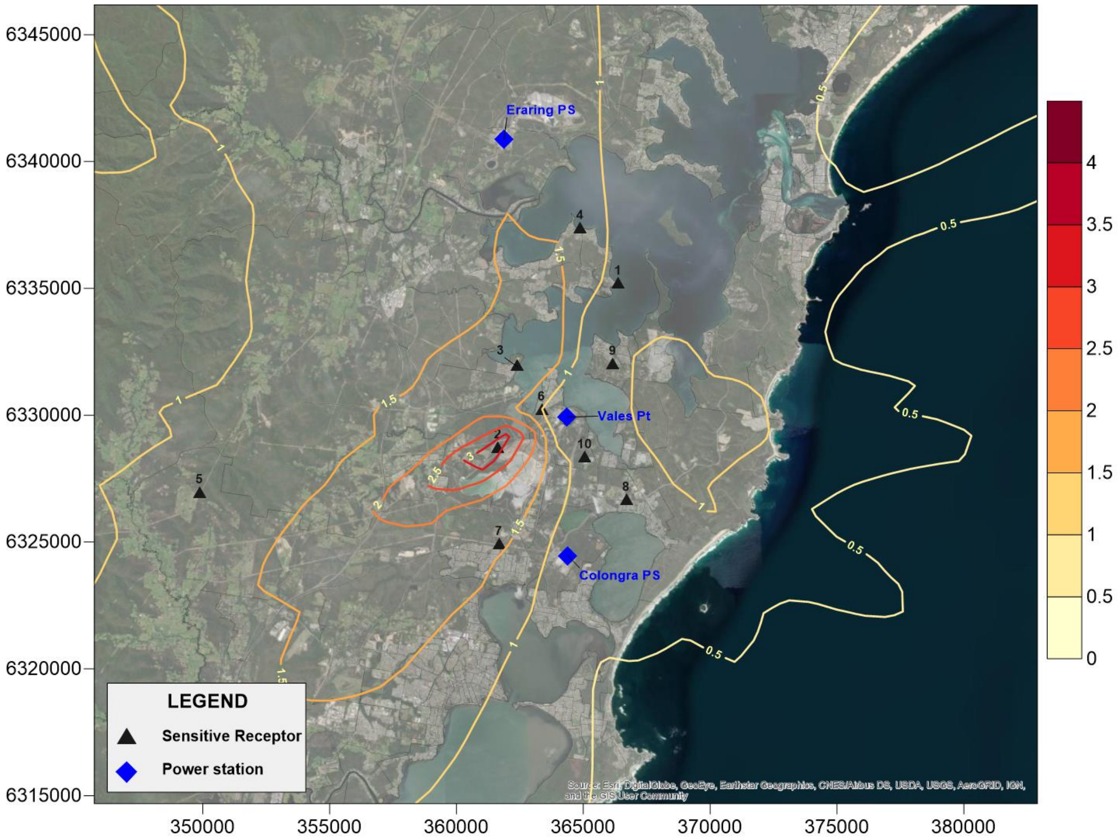


**Figure 88** Annual average ground-level concentrations of SO$_2$ – VPPS in isolation

Figure 89 presents a contour plot of the maximum 24-hour average ground-level concentrations of $SO_2$ due to VPPS in isolation.  The plot identifies no risk of an exceedance of the assessment criterion of 228 µg/m$^3$ as a result of emissions from VPPS in isolation.  The maximum predicted 24-hour average concentration anywhere on the receptor grid is 101.4 µg/m$^3$.

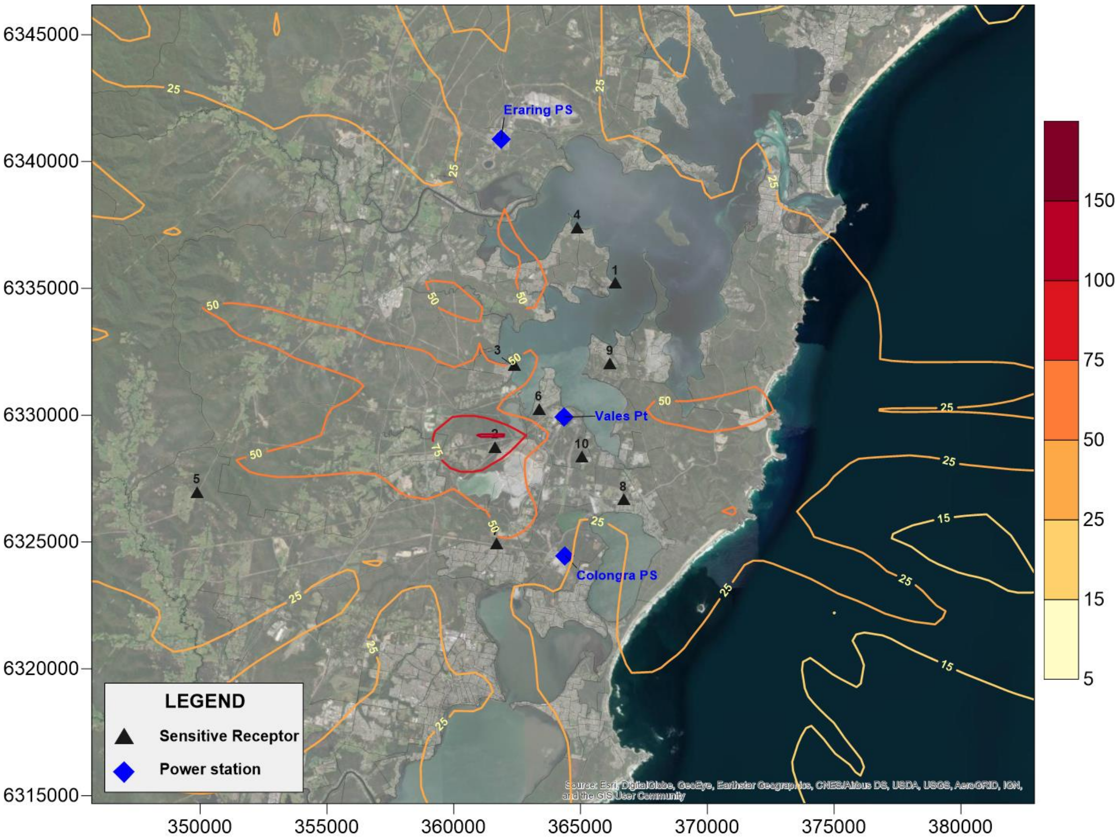


**Figure 89** Maximum 24-hour average ground-level concentrations of $SO_2$ – VPPS in isolation

Figure 90 presents a contour plot of the maximum 1-hour average ground-level concentrations of $SO_2$ due to VPPS in isolation. The plot suggests that emissions from VPPS in isolation could lead to exceedances of the assessment criterion of 570 µg/m$^3$ over two small areas, one to the north and one to the southwest of VPPS. The maximum modelled concentration anywhere on the receptor grid was 833 µg/m$^3$. The evaluation of the model outputs against monitoring data (see Figure 92) suggests that peak concentrations are overestimated by the model.

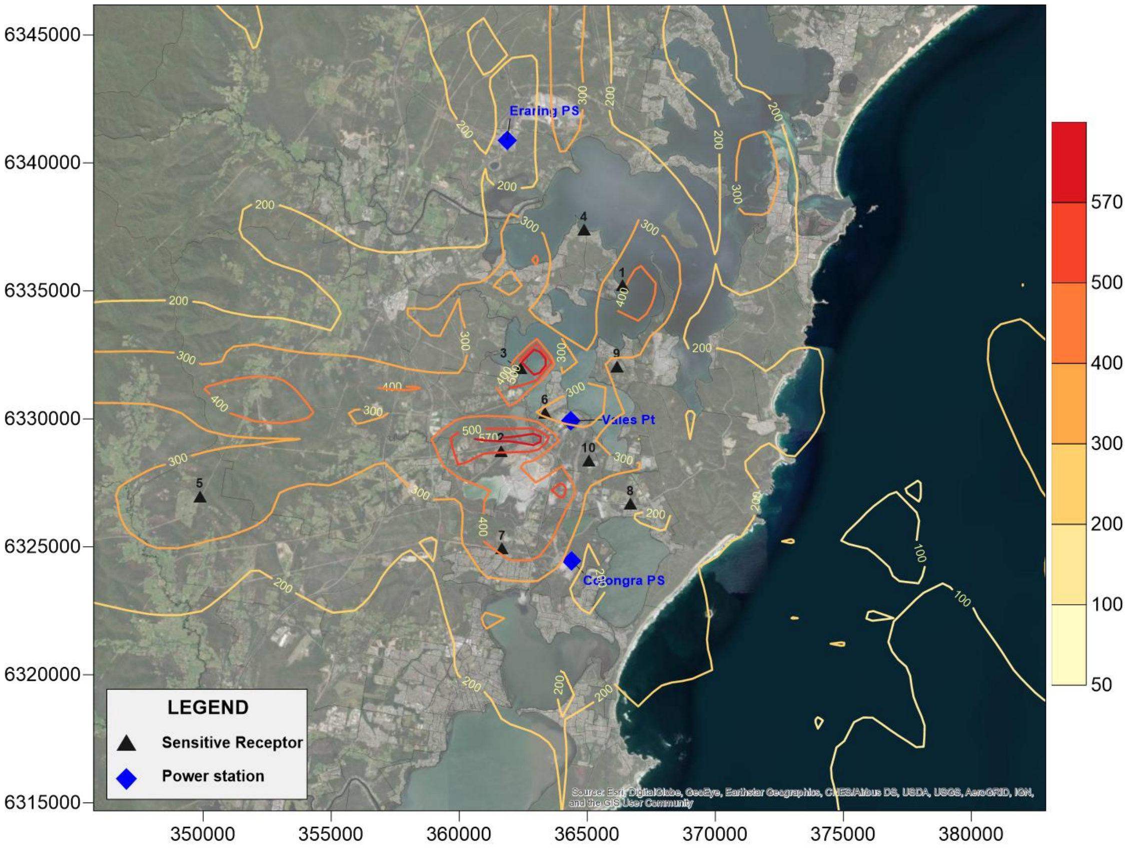


**Figure 90** Maximum 1-hour average ground-level concentrations of $SO_2$ – VPPS in isolation

Figure 91 presents a contour plot of the maximum 99.9th percentile of 1-hour average ground-level concentrations of $SO_2$ due to VPPS in isolation across the three years modelled. The maximum modelled concentration anywhere on the receptor grid was 407 µg/m³, which is less than 50% of the peak concentration, suggesting that such high concentrations (and concentrations above the assessment criterion) are rare.

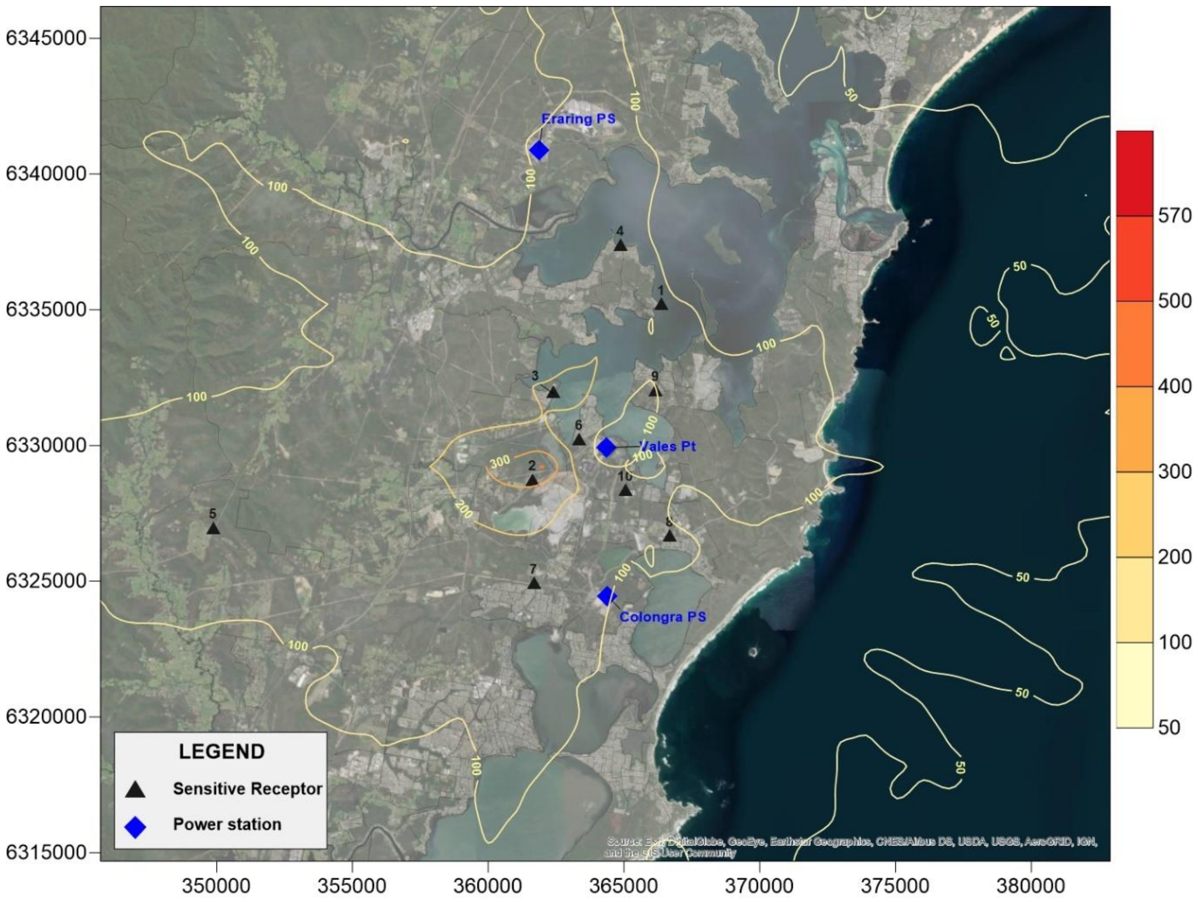


**Figure 91** Maximum 99.9th percentile of 1-hour average ground-level concentrations of $SO_2$ – VPPS in isolation

Table 36 presents modelled concentrations at the specific sensitive receptors set out in Table 18 and Figure 6, as well as at the Wyee and Wyong monitoring stations. It also includes predicted contributions from VPPS to maximum 10-minute average concentrations of $SO_2$. Ten-minute average concentrations have been estimated from 1-hour average concentrations using the approach developed by Hibberd (1998).

No exceedances of the assessment criteria are predicted, except for the maximum 10-minute averages, which are predicted to exceed the assessment criterion at a number of receptors. The evaluation of the model against monitoring data below suggests that peak 1-hour average concentrations of $SO_2$ are overestimated by the model and, consequently, peak 10-minute average concentrations are also likely to be overestimated. It should also be noted that the 10-minute average concentrations derived from the maximum 99.9th percentile of 1-hour $SO_2$ concentrations across the three years modelled are below the assessment criterion.

It was estimated in Section 5.4, that VPPS would contribute between 0.31 and 0.87 µg/m³ to annual mean $SO_2$ concentrations at Wyee. The modelled concentration in Table 36 is considerably higher than this, suggesting that the model is likely to be over-predicting annual average concentrations of $SO_2$.

**Table 36 Modelled VPPS $SO_2$ contributions at specific sensitive receptors (µg/m³)**

| Receptor | Annual mean | Max | | | Max 99.9th percentile | | |
|---|---|---|---|---|---|---|---|
| | | 24-hr | 1-hr | 10-minute | 24-hr | 1-hr | 10-minute |
| 1 | 0.92 | 39.2 | 391.0 | **774.2** | 31.1 | 101.6 | 201.1 |
| 2 | 2.88 | 88.1 | 499.9 | **989.8** | 82.6 | 311.5 | 616.7 |
| 3 | 1.83 | 51.5 | 525.2 | **1,039.9** | 46.3 | 208.1 | 412.0 |
| 4 | 1.24 | 29.9 | 241.8 | 478.8 | 29.1 | 138.3 | 273.8 |
| 5 | 1.12 | 43.5 | 379.1 | **750.6** | 37.6 | 130.8 | 259.0 |
| 6 | 1.03 | 34.5 | 288.2 | 570.7 | 32.6 | 156.3 | 309.5 |
| 7 | 1.55 | 45.2 | 419.8 | **831.1** | 38.0 | 139.3 | 275.8 |
| 8 | 0.84 | 29.9 | 229.4 | 454.3 | 28.2 | 110.0 | 217.9 |
| 9 | 0.82 | 37.8 | 292.6 | 579.3 | 29.0 | 100.0 | 198.0 |
| 10 | 0.79 | 44.7 | 357.2 | 707.3 | 36.7 | 125.0 | 247.5 |
| Wyong | 1.33 | 25.1 | 142.9 | 283.0 | 23.5 | 82.6 | 163.6 |
| Wyee | 1.66 | 60.8 | 327.9 | 649.2 | 51.2 | 190.7 | 377.6 |
| Criterion[1] | 60 | 228 | 570 | 712 | 228 | 570 | 712 |

Table note:

[1] Approved Methods for Modelling

Figure 92 presents a Q-Q plot of modelled versus measured 1-hour average concentrations of $SO_2$ at the Wyee monitoring station. The plot shows a very close alignment for peak 1-hour average concentrations without the inclusion of other background emission sources. However, the measured concentrations will include contributions from the other nearby power stations and from other background sources, while the modelled concentrations at this stage do not (see Section 7.1.2.2 for cumulative results). As such, it is likely that the model is over-predicting.

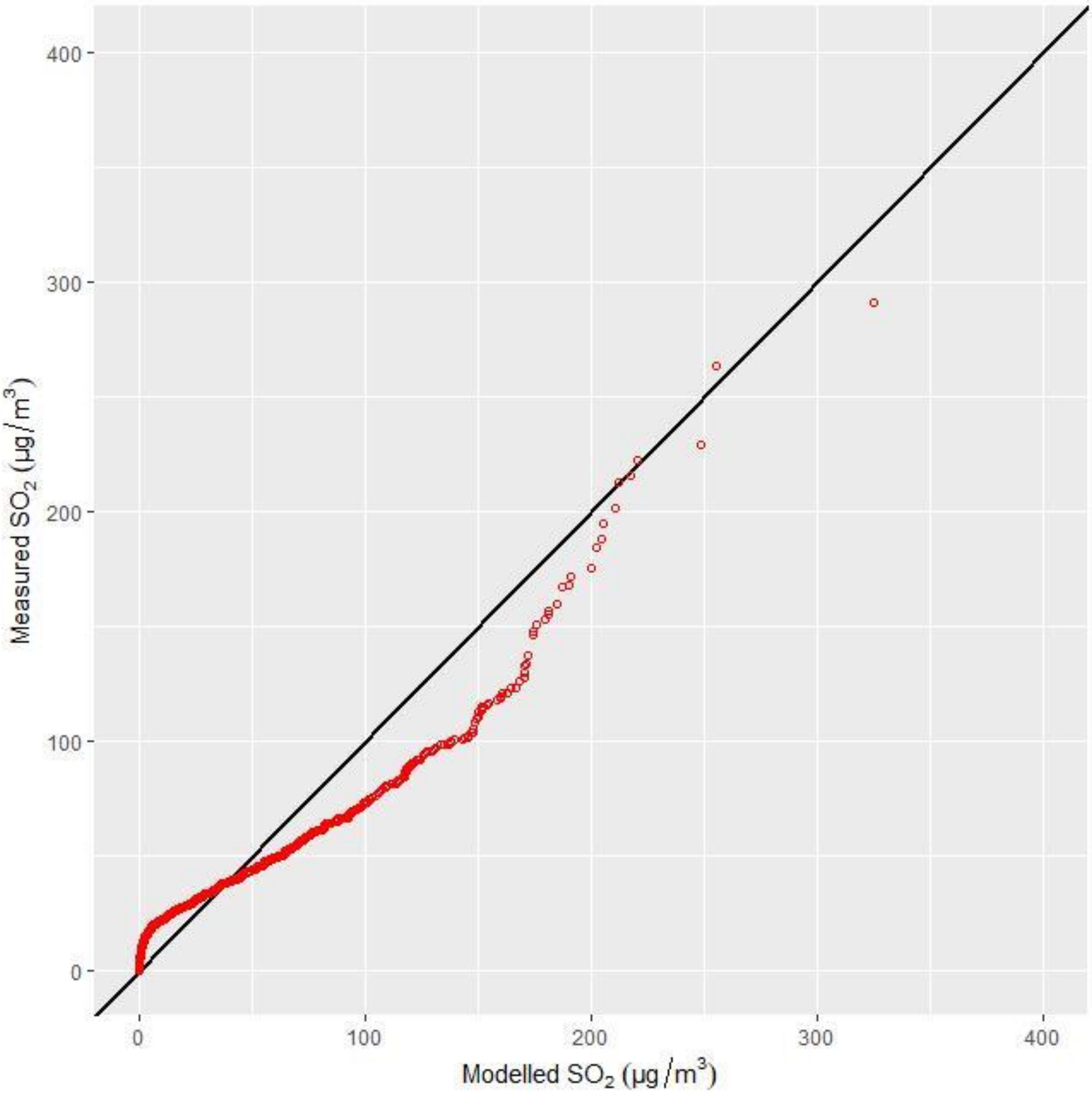


**Figure 92** QQ Plot of ground level $SO_2$ concentrations at Wyee – VPPS in isolation

### 7.1.1.3 Other pollutants

Table 37 summarises the maximum predicted contribution of VPPS in isolation to concentrations of all of the other air pollutants anywhere on the grid of receptors. The maximum contribution is for cadmium, which is predicted to be, at most, 16.1% of its assessment criterion.

**Table 37 Modelled grid maximum VPPS contributions to other pollutants (µg/m$^3$)**

| Pollutant | Averaging period | Concentration | Criterion | % of criterion |
|---|---|---|---|---|
| Chlorine | 1-hour | 0.255 | 50 | 0.5% |
| Hydrogen Fluoride | 24-hour | 0.273 | 2.9 | 9.4% |
|  | 7-day | 0.056 | 1.7 | 3.3% |
|  | 30-day | 0.032 | 0.85 | 3.8% |
|  | 90-day | 0.019 | 0.5 | 3.7% |
| Hydrogen Chloride | 1-hour | 3.677 | 140 | 2.6% |
| Solid particles (as $PM_{10}$) | 24-hour | 2.878 | 50 | 5.8% |
|  | Annual mean | 0.037 | 25 | 0.1% |
| Solid particles (as $PM_{2.5}$) | 24-hour | 2.878 | 25 | 11.5% |
|  | Annual mean | 0.037 | 8 | 0.5% |
| Sulfuric acid mist and sulfur trioxide (as SO3) | 1-hour | 2.501 | 18[1] | 13.9% |
| Antimony | 1-hour | 0.00026 | 9 | <0.1% |
| Arsenic | 1-hour | 0.00008 | 0.09 | 0.1% |
| Beryllium | 1-hour | 0.00006 | 0.004 | 1.5% |
| Cadmium | 1-hour | 0.00290 | 0.018 | 16.1% |
| Chromium | 1-hour | 0.00135 | 0.09[2] | 1.5% |
| Cobalt | 1-hour | 0.00014 | - | - |
| Lead | Annual mean | 0.00001 | 0.5 | <0.1% |
| Manganese | 1-hour | 0.03764 | 18 | 0.2% |
| Mercury | 1-hour | 0.00062 | 1.8[3] | <0.1% |
| Nickel | 1-hour | 0.00165 | 0.18 | 0.9% |
| Selenium | 1-hour | 0.00035 | - | - |
| Tin | 1-hour | 0.00087 | - | - |
| Vanadium | 1-hour | 0.00008 | - | - |

Table notes:
[1] Impact assessment criterion for sulfuric acid
[2] Impact assessment criterion for chromium VI compounds
[3] Impact assessment criterion for mercury inorganic

The Approved Methods for Modelling explains that, for pollutants other than $SO_2$, $NO_2$, $O_3$, lead, $PM_{2.5}$, $PM_{10}$, and hydrogen fluoride, there is no need to consider total concentrations and, given that the contributions from VPPS in isolation will not exceed the respective assessment criteria, it is concluded that emissions from VPPS will not have a significant impact on concentrations of these pollutants.

For $PM_{2.5}$ and $PM_{10}$, total concentrations are presented in Section 7.1.2.3.

For lead, adding the modelled VPPS contribution of 0.00001 µg/m$^3$ to the background concentration of 0.03 µg/m$^3$ (the derivation of which is discussed in Section 3.7.3) represents a change of just 0.03%, or 0.002% of the assessment criterion. In this context, the lead contribution from VPPS can be considered negligible, and there is no risk of an exceedance of the assessment criterion.

Background concentration data for hydrogen fluoride are not available, and it is assumed that concentrations will be extremely low. As such, with VPPS contributions being no more than 9.4% of the assessment criteria, it is judged that there is no risk of an exceedance of the assessment criteria for hydrogen fluoride.

### 7.1.2 Cumulative concentrations of air pollutants

This section presents pollutant total pollutant concentrations in the years 2018 to 2020 accounting for the contribution of background, VPPS, Eraring and Colongra.

#### 7.1.2.1 $NO_2$

Figure 93 and Figure 94 present contour plots of cumulative maximum annual average ground-level concentrations of $NO_2$, without and with the contribution of VPPS, respectively. Total concentrations are well below the assessment criterion, with a maximum predicted concentration in either scenario of 14.6 µg/m$^3$, which is just 24% of the assessment criterion of 62 µg/m$^3$.

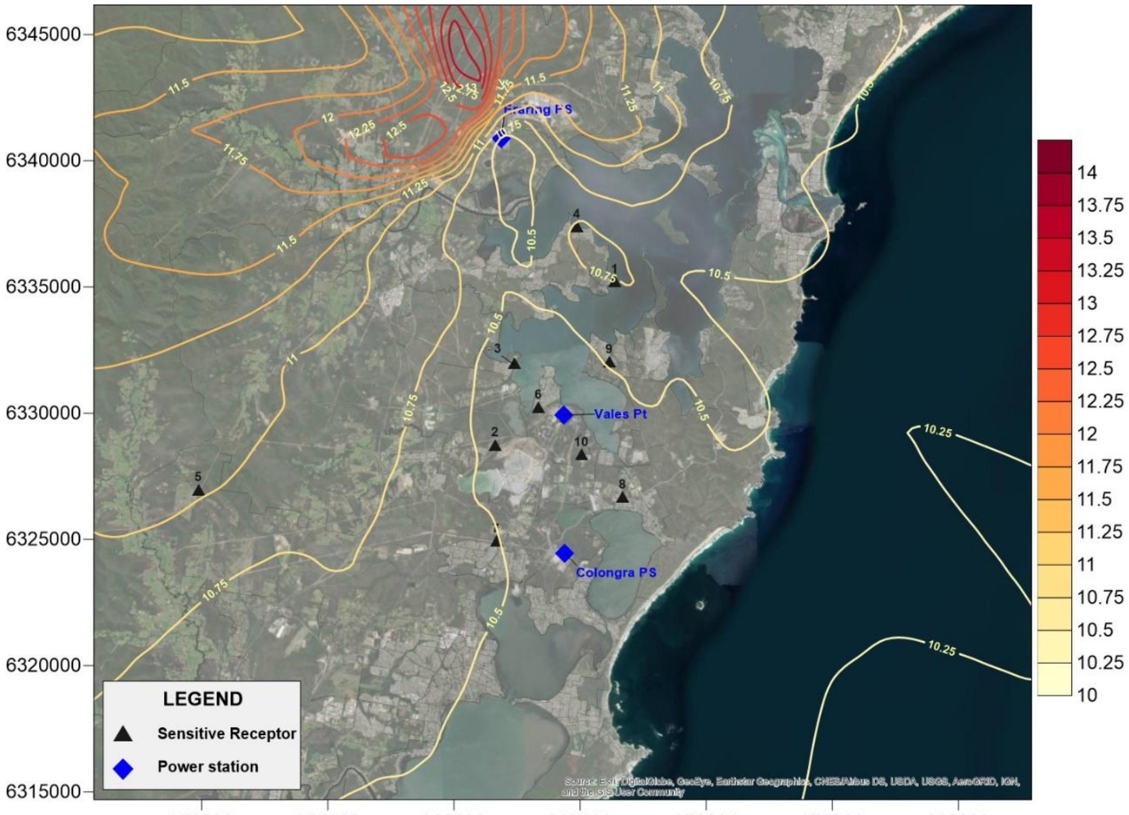


**Figure 93** **Cumulative annual average ground-level concentrations of $NO_2$ – without VPPS**

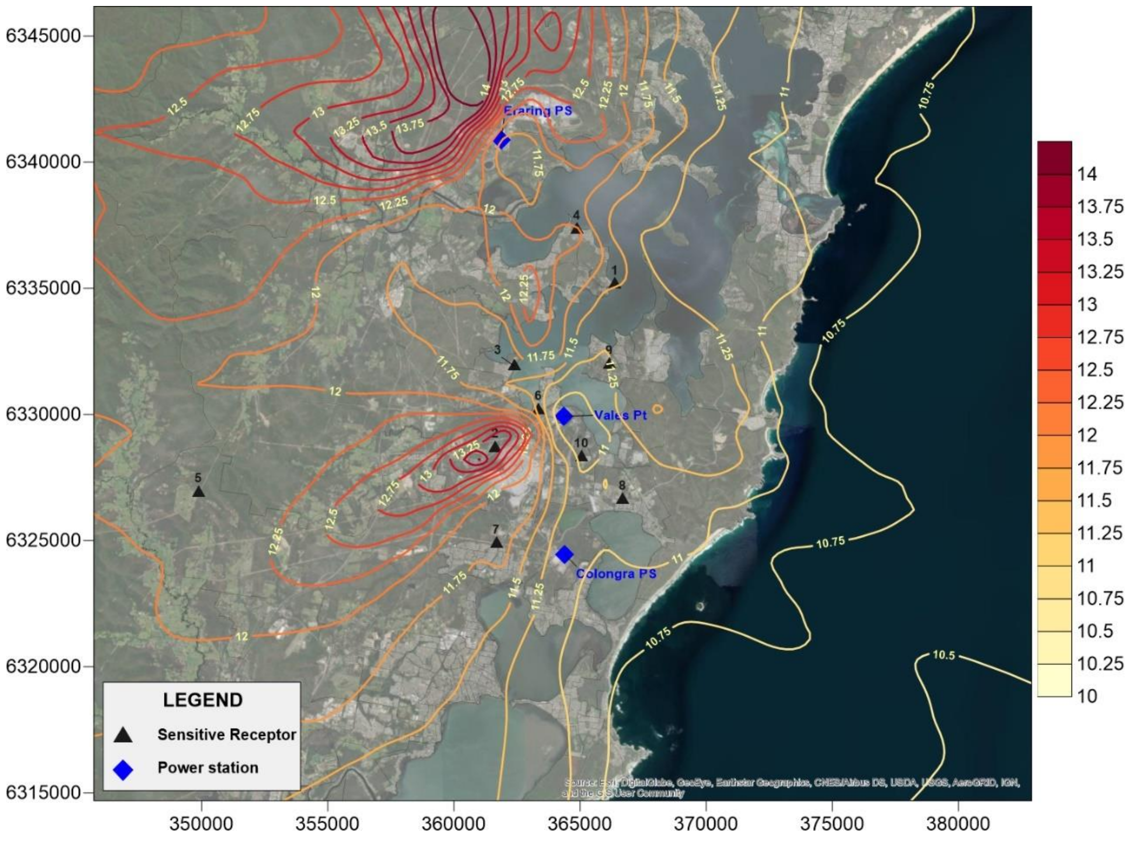


Figure 94 Cumulative annual average ground-level concentrations of $NO_2$ – with VPPS

Figure 95 and Figure 96 present contour plots of cumulative maximum 1-hour average ground-level concentrations of $NO_2$ (assuming that 20% of power station NOx is $NO_2$) across the three years modelled, without and with the contribution of VPPS, respectively. No exceedances of the assessment criterion of 246 µg/m$^3$ are predicted, with a maximum concentration of 162.5 µg/m$^3$ predicted in the vicinity of Eraring power station in Figure 95, and 185.9 µg/m$^3$ predicted in the vicinity of VPPS in Figure 96.

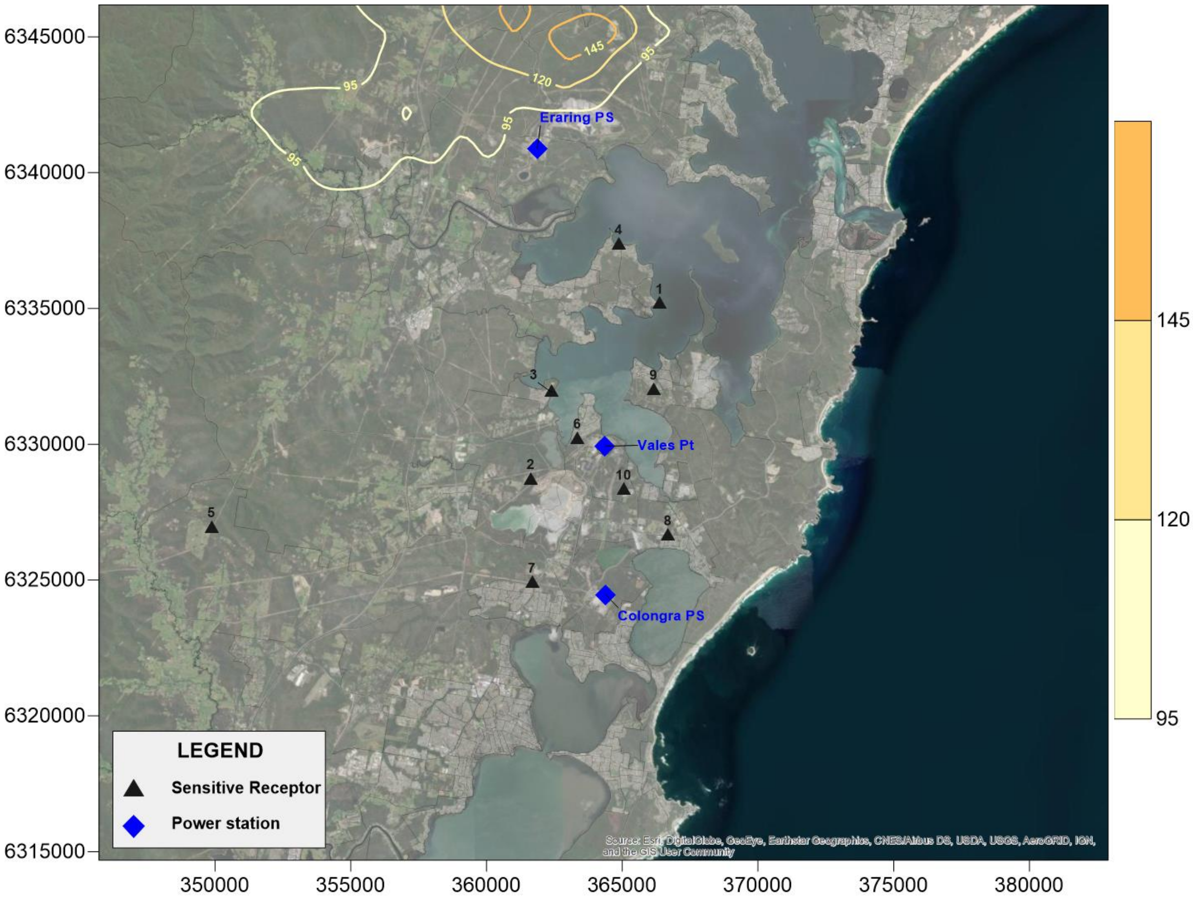


**Figure 95** Cumulative maximum 1-hour average ground-level concentrations of $NO_2$ – without VPPS – 20% $NO_2$/NOx

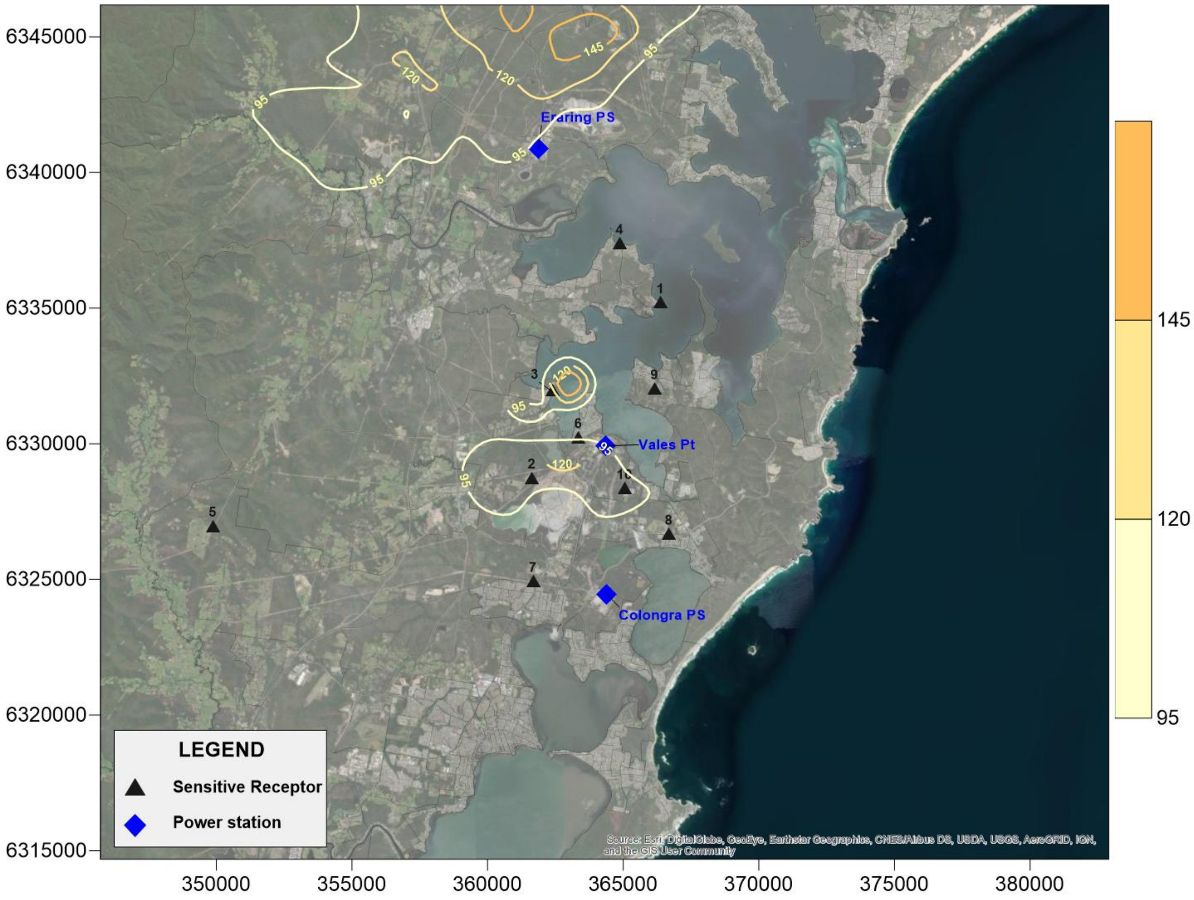


**Figure 96** **Cumulative maximum 1-hour average ground-level concentrations of $NO_2$ – with VPPS – 20% $NO_2$/NOx**

Figure 97 and Figure 98 present contour plots of cumulative maximum 99.9th percentile of 1-hour average ground-level concentrations of $NO_2$ (again assuming that 20% of power station NOx is $NO_2$) across the three years modelled, without and with the contribution of VPPS, respectively. No exceedances of the assessment criterion of 246 µg/m$^3$ are predicted, with a maximum predicted concentration of 74.7 µg/m$^3$ in Figure 97 and 78.9 µg/m$^3$ in Figure 98.

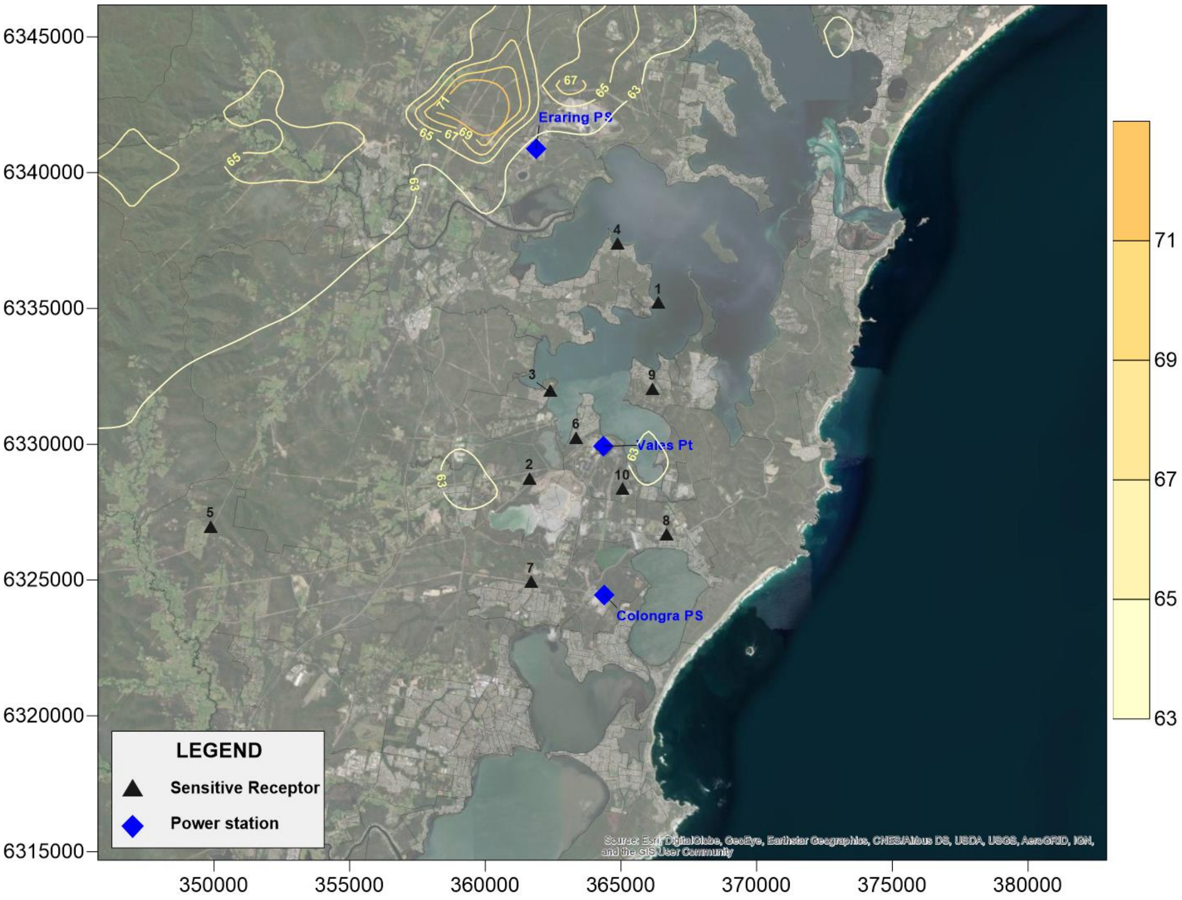


**Figure 97** Cumulative maximum 99.9th percentile of 1-hour average ground-level concentrations of $NO_2$ – without VPPS – 20% $NO_2$/NOx

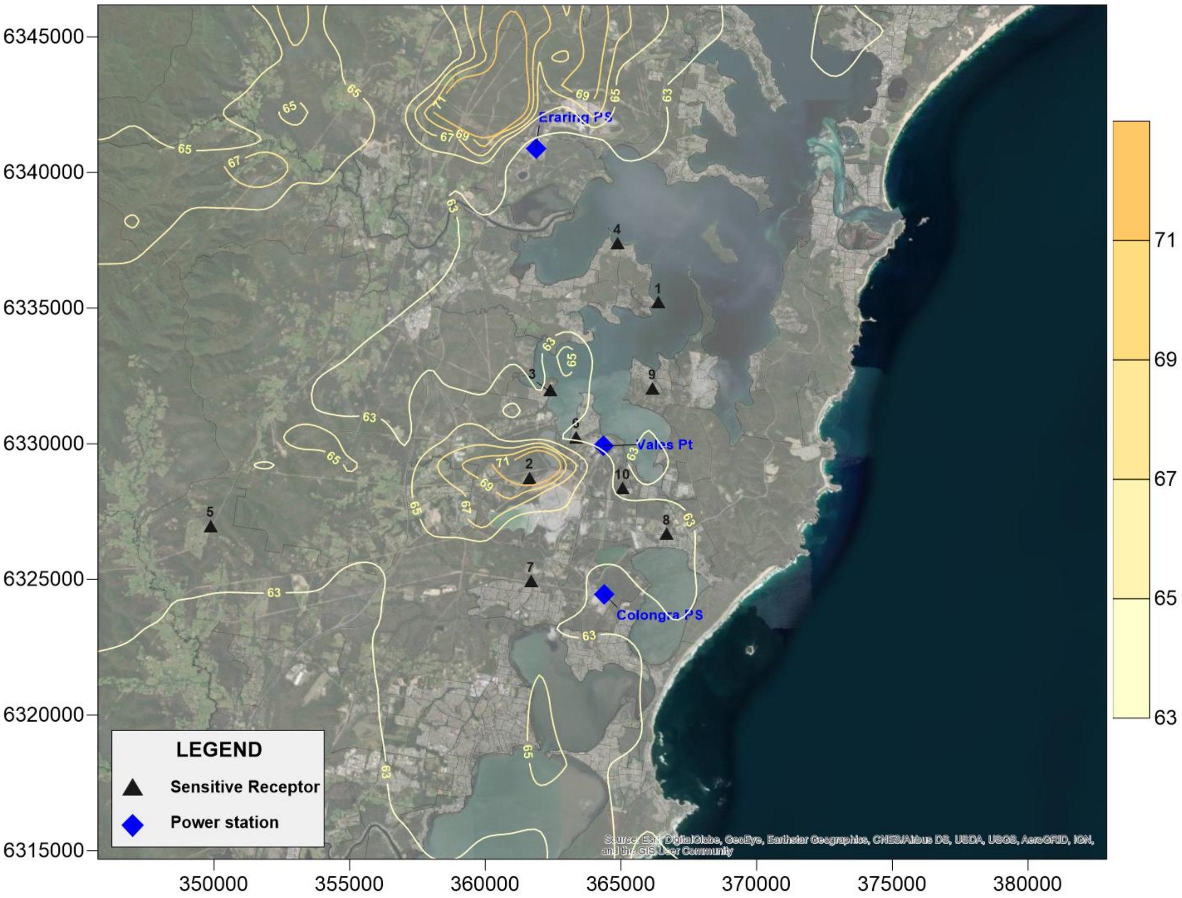


**Figure 98** Cumulative maximum 99.9th percentile of 1-hour average ground-level concentrations of $NO_2$ – with VPPS – 20% $NO_2$/NOx

Figure 99 and Figure 100 present contour plots of maximum 1-hour average ground-level concentrations of $NO_2$ without and with the contribution of VPPS for the sensitivity test scenario assuming that 40% of power station NOx is converted to $NO_2$. In this scenario, a maximum concentration of 296.0 µg/m$^3$ is predicted in the vicinity of Eraring power station in Figure 99, and a maximum concentration of 371.9 µg/m$^3$ is predicted in the vicinity of VPPS in Figure 100. These predicted concentrations are significantly higher than the maximum concentration measured over 10 years at Wyee, and it is demonstrated later (in Figure 103) that this scenario produces unrealistic $NO_2$ concentrations. Therefore, they are provided for completeness only and should not be treated as providing a realistic representation of potential impacts.

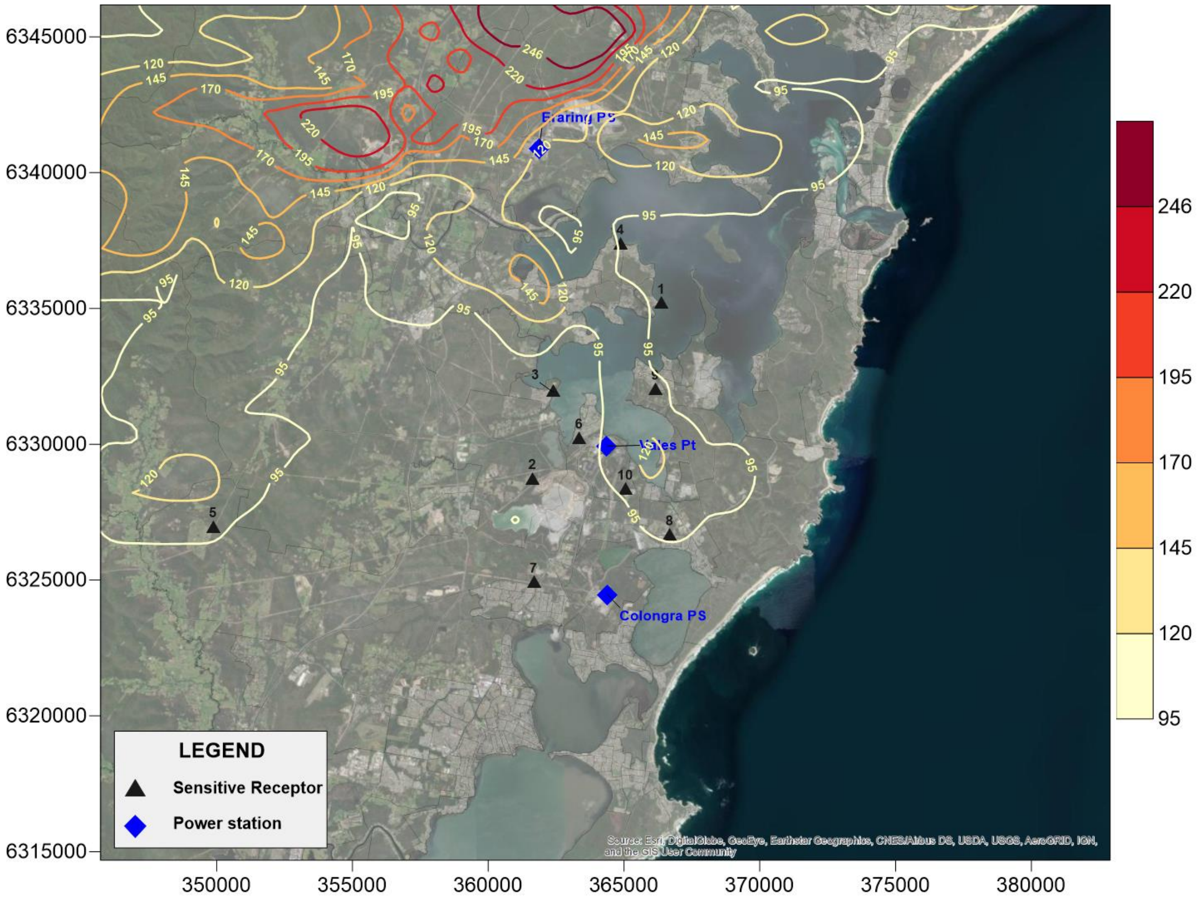


**Figure 99** Cumulative maximum 1-hour average ground-level concentrations of $NO_2$– without VPPS – 40% $NO_2$/NOx

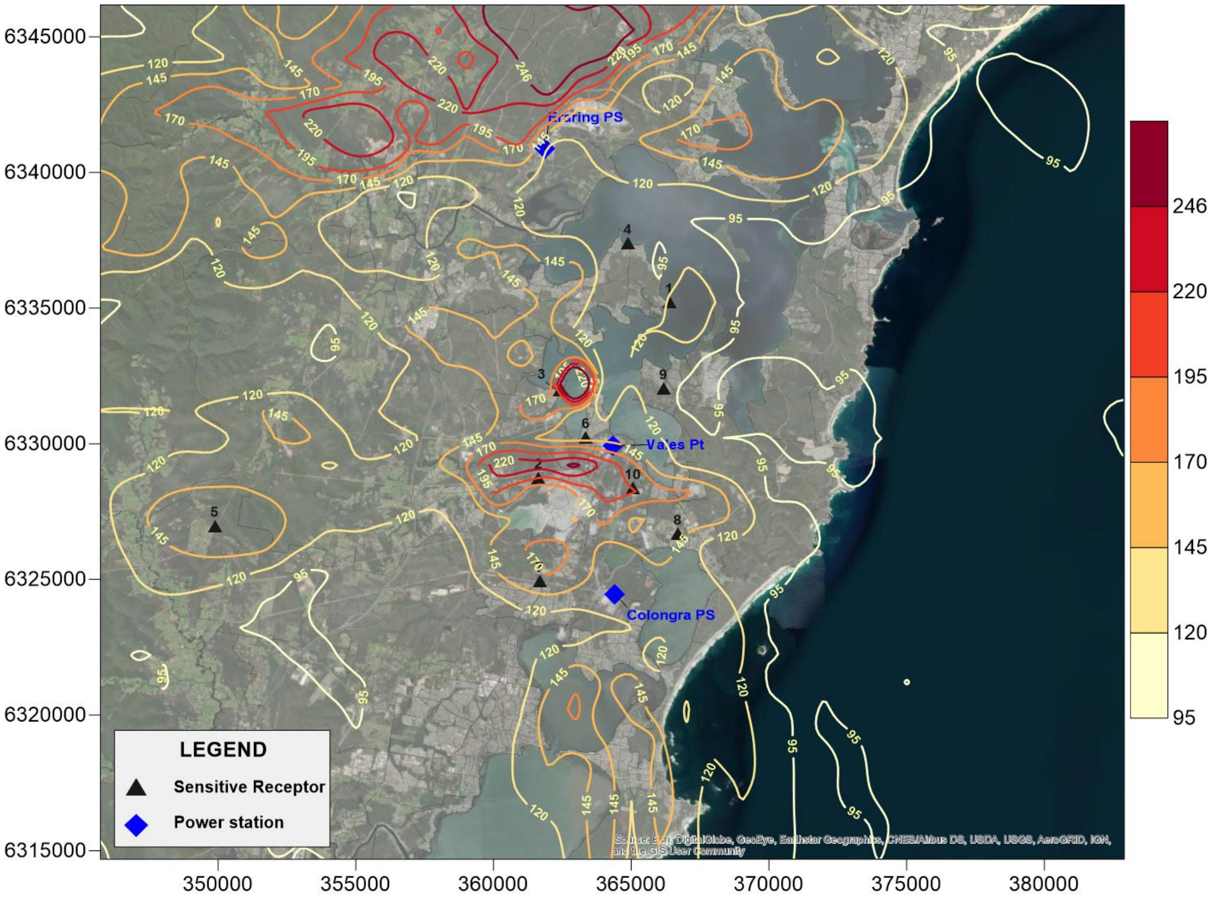


**Figure 100** Cumulative maximum 1-hour average ground-level concentrations of $NO_2$ – with VPPS – 40% $NO_2$/NOx

Table 38 presents predicted total cumulative ground-level concentrations of $NO_2$ at the specific sensitive receptors set out in Table 18 and Figure 6, with and without the contribution of VPPS. Table 39 presents total cumulative ground-level concentrations of $NO_2$ calculated using the OLM method. No exceedances of the assessment criterion are predicted at the selected sensitive receptors. It should be noted that the relatively constant concentrations in the maximum 1-hour dataset are a reflection of there being an hour in 2019 with a very high $NO_2$ concentrations of 92.8 µg/m$^3$ in the background dataset used for the cumulative assessment (see Table 16).

**Table 38** **Modelled total cumulative ground-level concentrations of $NO_2$ at specific sensitive receptors (µg/m$^3$)**

| Receptor | Annual mean | | Max 1-hr (20% $NO_2$/NOx) | | Max 99.9th %ile of 1-hr (20% $NO_2$/NOx) | | Max 1-hr (40% $NO_2$/NOx) | |
|---|---|---|---|---|---|---|---|---|
| | Without VPPS | With VPPS | Without VPPS | With VPPS | Without VPPS | With VPPS | Without VPPS | With VPPS |
| 1 | 10.7 | 11.5 | 92.8 | 92.8 | 62.7 | 62.7 | 92.8 | 123.4 |
| 2 | 10.5 | 13.3 | 92.8 | 106.8 | 62.7 | 72.2 | 92.8 | 193.2 |
| 3 | 10.4 | 11.6 | 92.8 | 119.2 | 62.7 | 63.5 | 92.8 | 218.1 |
| 4 | 10.8 | 12.0 | 92.8 | 92.8 | 62.7 | 62.7 | 94.0 | 112.9 |
| 5 | 11.0 | 12.2 | 92.8 | 92.8 | 62.7 | 64.1 | 99.6 | 164.6 |
| 6 | 10.4 | 11.4 | 92.8 | 93.7 | 62.7 | 62.9 | 92.8 | 137.8 |
| 7 | 10.5 | 11.8 | 92.8 | 92.8 | 62.7 | 63.9 | 92.8 | 156.7 |
| 8 | 10.5 | 11.1 | 92.8 | 92.8 | 62.7 | 63.7 | 96.3 | 148.7 |
| 9 | 10.5 | 11.2 | 92.8 | 92.8 | 62.7 | 62.7 | 98.0 | 99.3 |
| 10 | 10.4 | 10.9 | 92.8 | 101.8 | 62.7 | 62.7 | 97.9 | 195.3 |
| Wyong | 10.6 | 11.7 | 92.8 | 92.8 | 62.7 | 62.7 | 92.8 | 101.9 |
| Wyee | 10.8 | 12.4 | 92.8 | 92.8 | 62.7 | 65.6 | 92.8 | 134.5 |
| Criterion[1] | 62 | | 246 | | 246 | | 246 | |

Table note:

[1] Approved Methods for Modelling

**Table 39** **Modelled cumulative $NO_2$ concentrations at specific sensitive receptors using the OLM method (µg/m$^3$)**

| Receptor | Annual mean | Max 1-hr | 99.9th %ile of 1-hr |
|---|---|---|---|
| 1 | 11.3 | 116.1 | 89.5 |
| 2 | 12.1 | 144.3 | 111.7 |
| 3 | 11.2 | 134.6 | 98.0 |
| 4 | 11.7 | 116.1 | 89.9 |
| 5 | 11.8 | 105.7 | 81.3 |
| 6 | 11.2 | 108.5 | 87.3 |
| 7 | 11.4 | 135.2 | 91.9 |
| 8 | 10.9 | 118.2 | 83.9 |
| 9 | 11.1 | 105.2 | 79.8 |
| 10 | 10.8 | 108.7 | 85.1 |
| Wyong | 11.8 | 114.2 | 90.4 |
| Wyee | 11.4 | 124.0 | 73.3 |
| Criterion[1] | 62 | 246 | 246 |

Table note:

[1] Approved Methods for Modelling

Figure 101 presents a Q-Q plot of cumulative modelled versus measured concentrations of NOx at the Wyee monitoring station. It suggests that the model under-predicts lower concentrations of NOx and over-predicts the highest concentrations of NOx.

The under-prediction of lower concentrations of NOx may be an artifact of relying on NOx measurements at Wyong as the primary source of background concentrations. Comparing the measured concentrations at Wyee in Table 21 and Table 22 to those at Wyong in Table 23 and Table 24 highlights that concentrations of NOx at Wyee are typically considerably higher, primarily because of higher concentrations of NO. This could be because of Wyee's proximity to the Pacific Motorway. Nevertheless, concentrations at Wyong are likely to be more reflective of background conditions across most of the study area than those at Wyee, thus they remain appropriate even if the lower concentrations do not quite fit the monitoring data at Wyee.

Given that modelled annual mean concentrations of $NO_2$ are so far below the assessment criterion, any average model underprediction would not affect the conclusion that the annual mean criterion will not be exceed in the study area as a result of power station emissions.

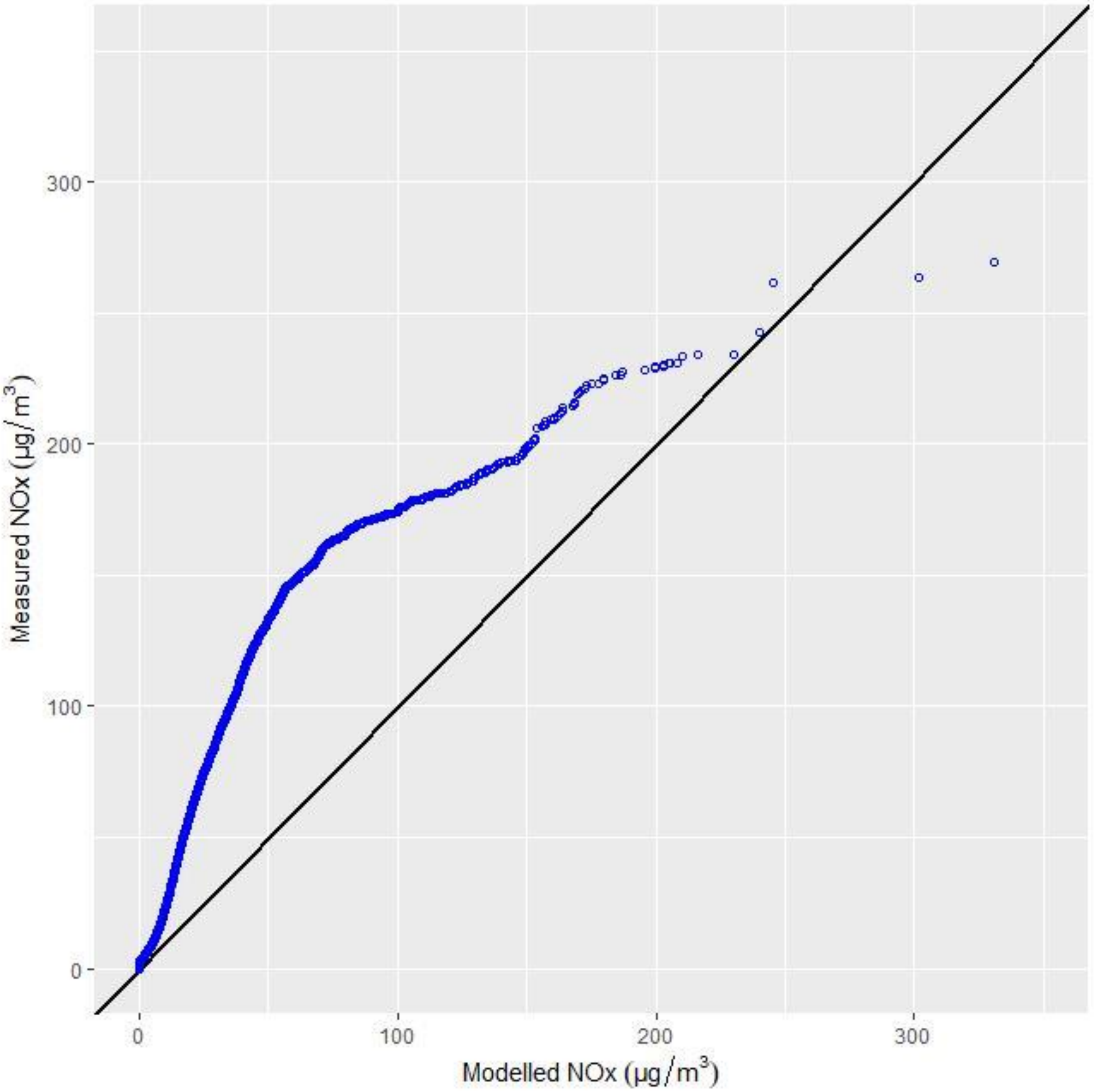


**Figure 101** QQ Plot of total cumulative ground level NOx concentrations at Wyee

While it is useful to consider the model predictions of total NOx concentrations, it is predictions of $NO_2$ concentrations that are most relevant. Figure 102 and Figure 103 present Q-Q plots of cumulative modelled versus measured concentrations of $NO_2$ at the Wyee monitoring station, for scenarios assuming conversion rates of power station NOx to $NO_2$ of 20% and 40%, respectively. When a conversion ratio of 20% is assumed, the model generally performs very well. It under-estimates concentrations when they are below around 30 µg/m$^3$, but for the most part very accurately predicts the magnitude of concentrations above this. The maximum predicted concentration aligns almost perfectly, but the five highest concentrations below this are slightly under-predicted. Nevertheless, when compared to the results when a conversion ratio of 40% is assumed (Figure 103), which show consistent over-prediction of the concentrations above around 30 µg/m$^3$, Figure 102 suggest that 20% is the most appropriate conversion ratio to apply.

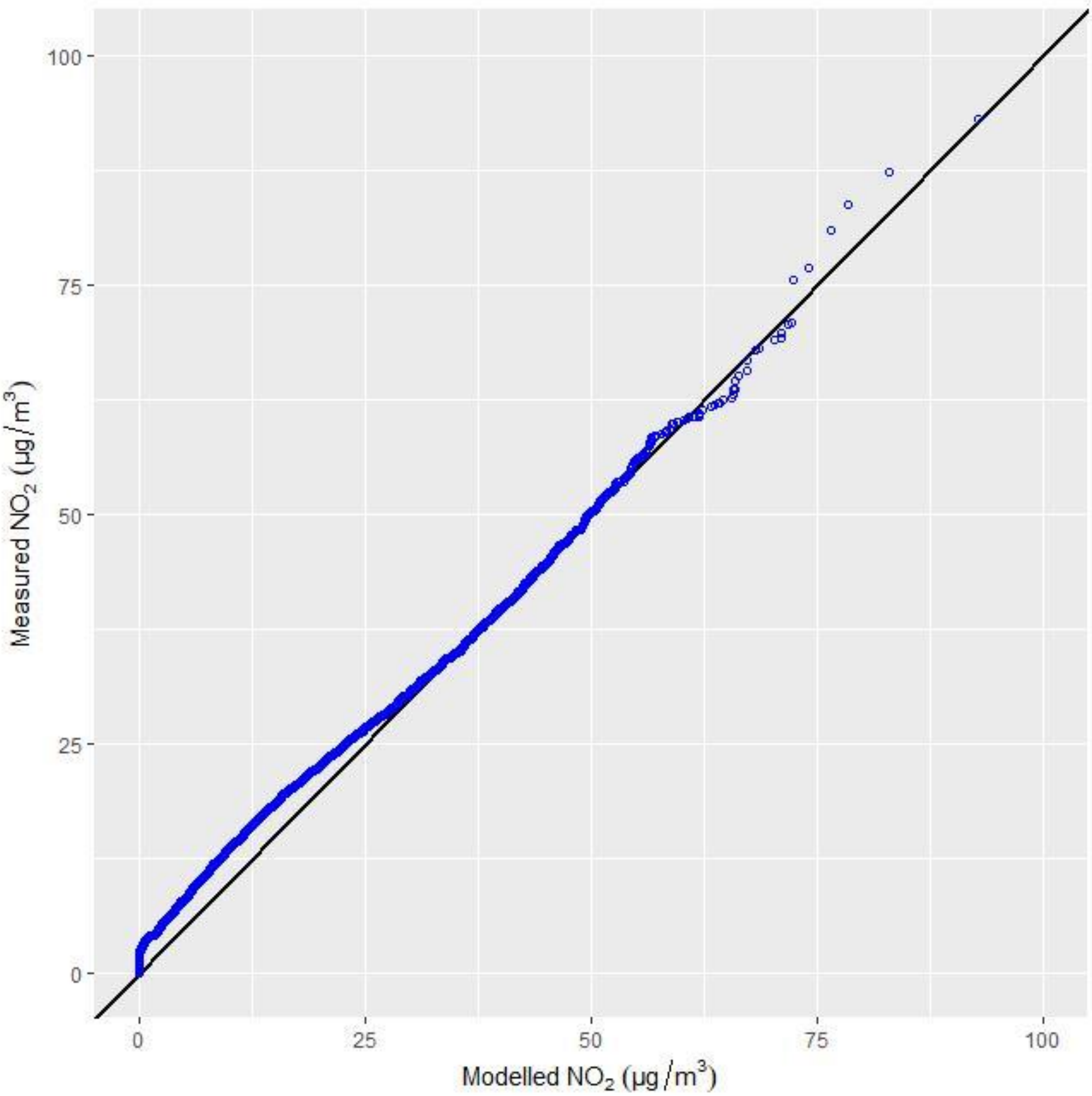


Figure 102 QQ Plot of total cumulative ground level $NO_2$ concentrations at Wyee – 20% $NO_2/NO_x$

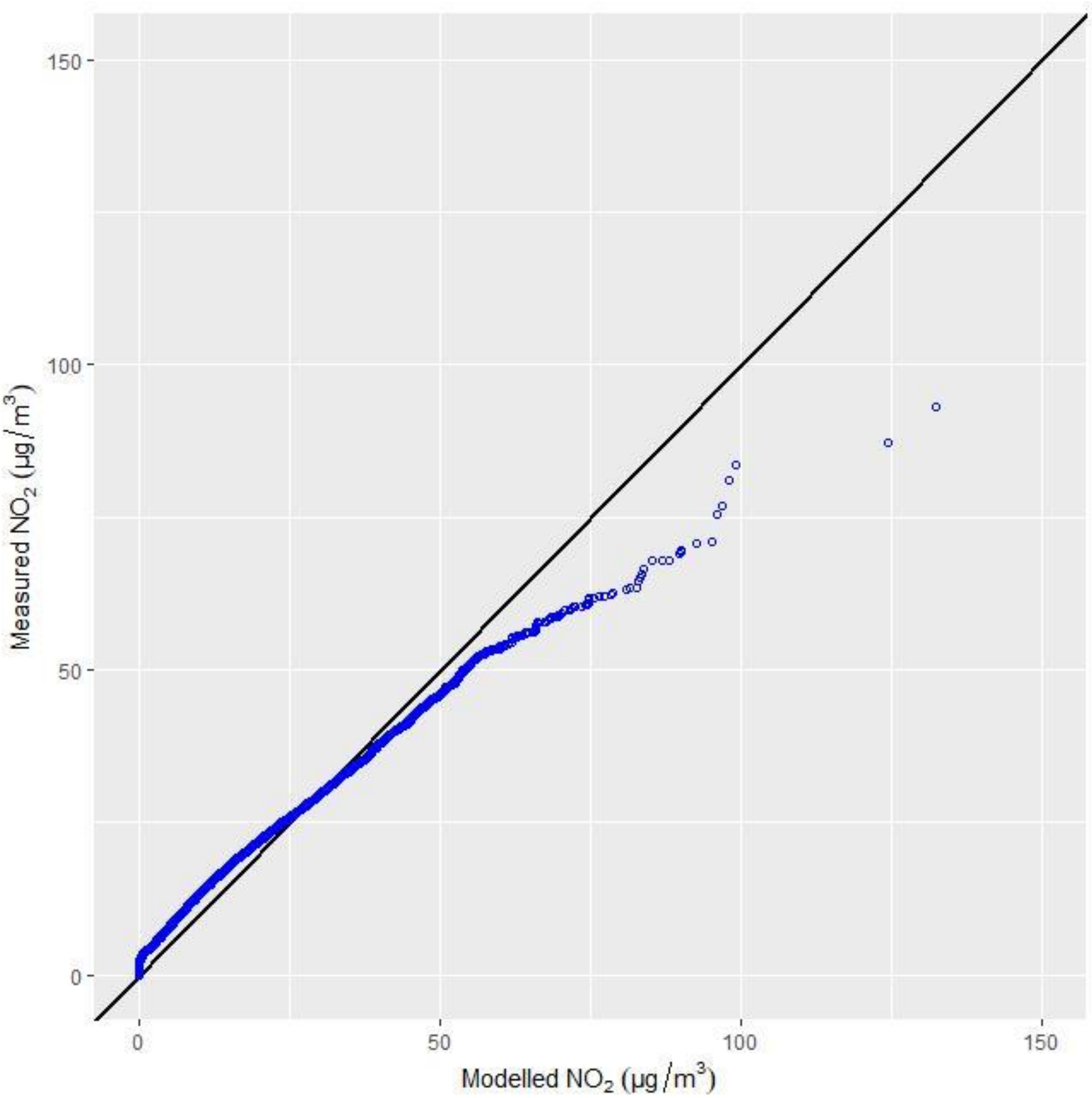


**Figure 103** QQ Plot of total cumulative ground level $NO_2$ concentrations at Wyee – 40% $NO_2$/NOx

### 7.1.2.2 $SO_2$

Figure 104 and Figure 105 present contour plots of cumulative maximum annual average ground-level concentrations of $SO_2$, without and with the contribution of VPPS, respectively. Total concentrations are well below the assessment criterion, with a maximum predicted concentration in either scenario of 9.2 µg/m$^3$, which is just 15% of the assessment criterion of 60 µg/m$^3$.

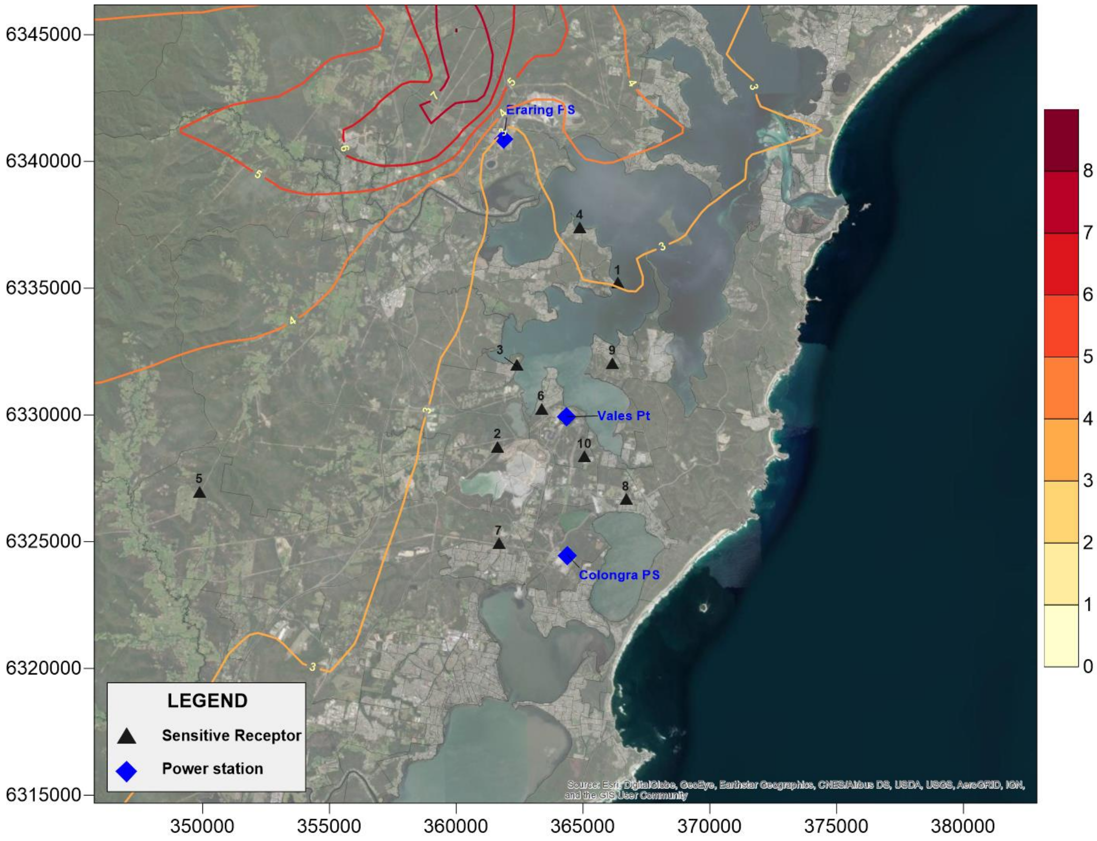


**Figure 104 Cumulative annual average ground-level concentrations of $SO_2$ – without VPPS**

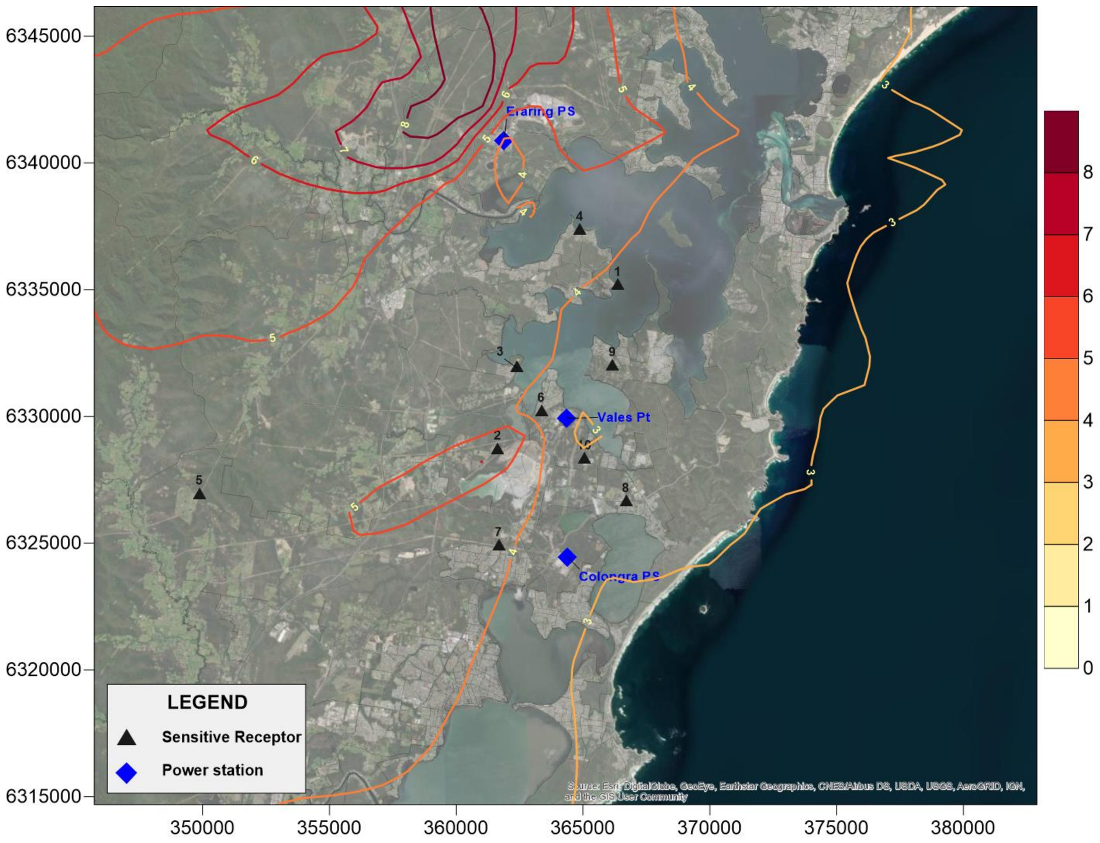
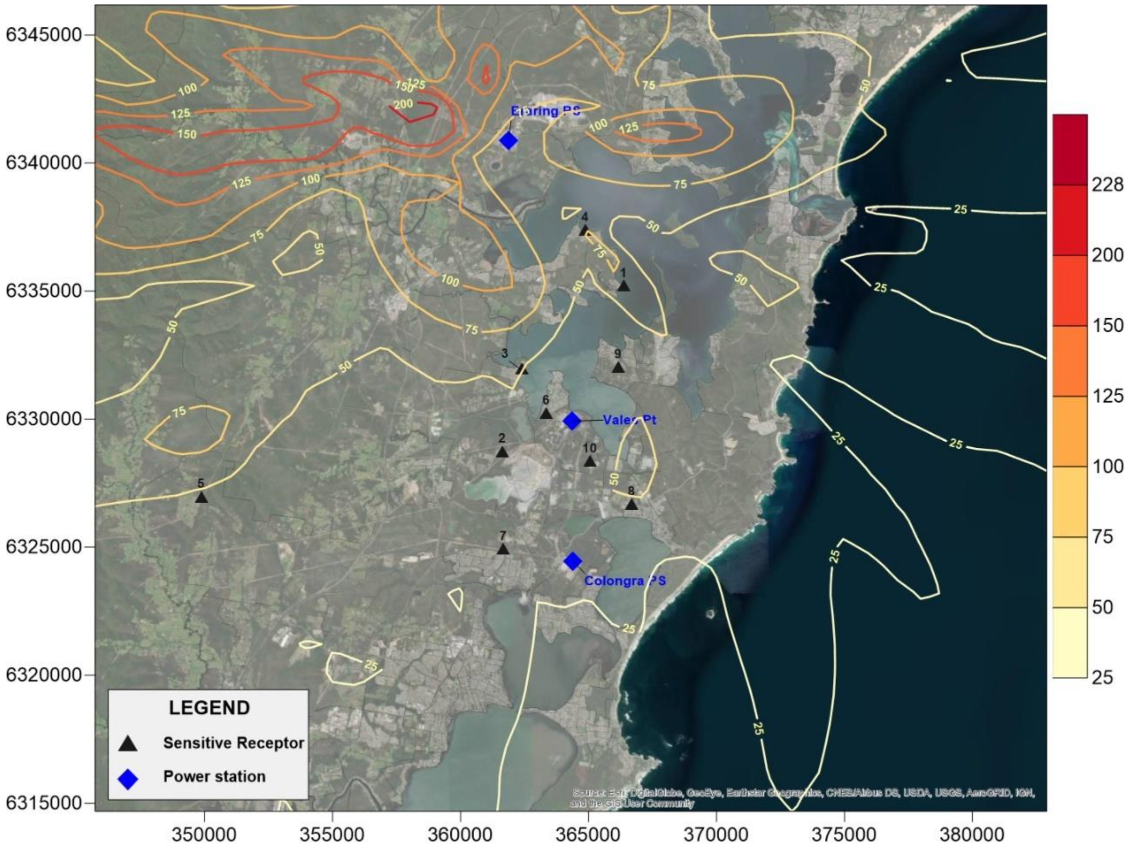


**Figure 105** Cumulative annual average ground-level concentrations of $SO_2$ – with VPPS

Figure 106 and Figure 107 present contour plots of the maximum 24-hour average ground-level concentrations of $SO_2$ without and with the contribution of VPPS, respectively. The plots demonstrate that the assessment criterion of 228 µg/m³ will not be exceeded anywhere in the study area, in either scenario. The maximum modelled concentration anywhere on the receptor grid in either scenario is 218.5 µg/m³.



Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

**Figure 106** **Cumulative maximum 24-hour average ground-level concentrations of $SO_2$ – without VPPS**

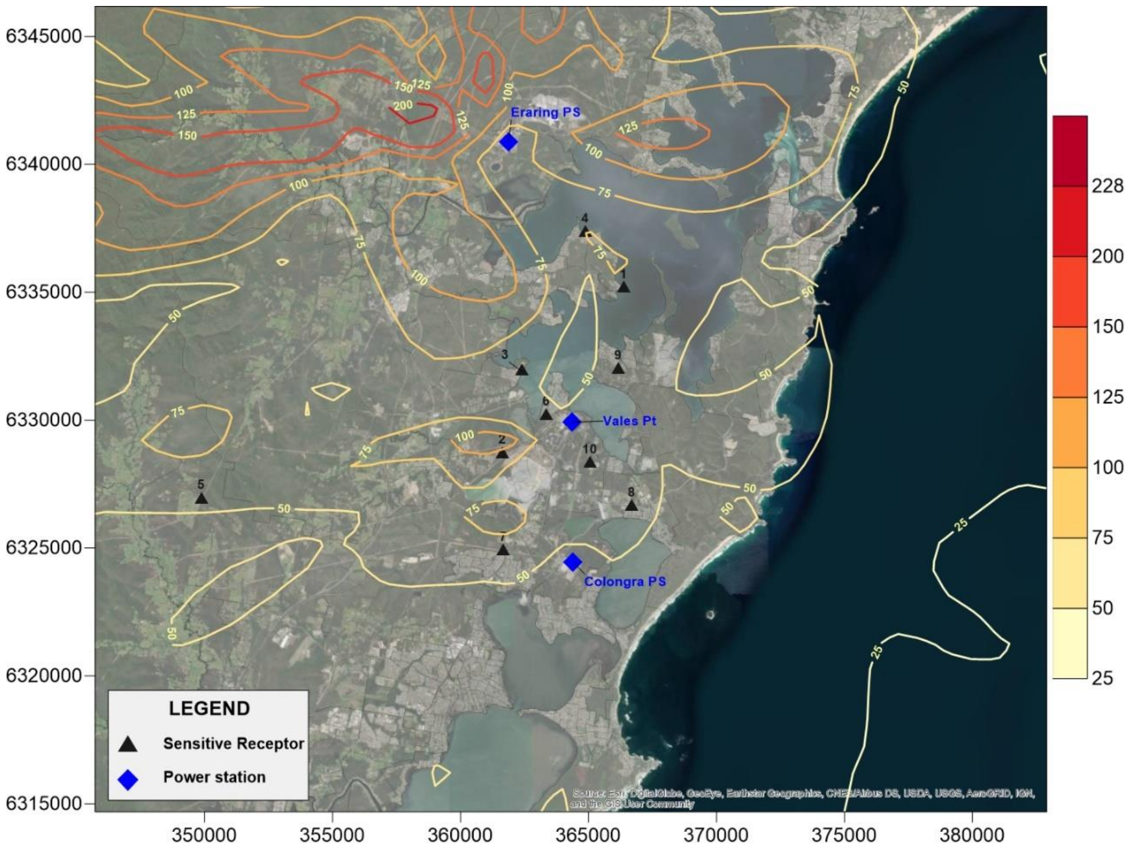


**Figure 107** Cumulative maximum 24-hour average ground-level concentrations of $SO_2$ – with VPPS

Figure 108 and Figure 109 present contour plots of the maximum 1-hour average ground-level concentrations of $SO_2$, without and with the contribution of VPPS, respectively. The elevated concentrations to the northwest of the plots are broadly consistent with the model results presented in the EIS prepared for the Eraring power station upgrade and capacity increase that was approved in 2006, but as detailed in Section 3.7.1, the impacts of emissions from Eraring are likely to have been over-stated in the modelling, due to the use of coarse and conservative assumptions in the production of the time-varying emissions for this facility. It is also relevant to note that the model has predicted maximum 1-hour concentrations of $SO_2$ approaching the assessment criterion at Dora Creek, yet the monitoring station located in Dora Creek that is operated by Origin Energy measured a maximum 1-hour average concentration of $SO_2$ of 188.1 µg/m$^3$ in the years 2018-2020, lending further weight to the conclusion that the model is over-predicting peak concentrations of $SO_2$.

The addition of the contribution of VPPS in Figure 109 introduces four additional small areas of exceedance of the assessment criterion. These are:

- One located primarily over water to the east of Wyee Point, containing no sensitive receptors
- One running east to west to the west of the coal storage area at VPPS, containing no sensitive receptors
- One to the northwest of Doyalson, which includes two or three residential properties along Wyee Road
- One to the southeast of VPPS that includes a number of properties within the westernmost portion of Lake Munmorah.

Analysis of modelled concentrations has identified a maximum of 14 hours in any one year with concentrations above the assessment criterion of 570 µg/m$^3$ at any one location; this occurs to the northwest of Eraring and is almost exclusively a result of modelled emissions from Eraring. Within 5 km of VPPS, there is one grid point where two exceedances are predicted in one year and eleven grid points with a maximum of one exceedance in any one year.

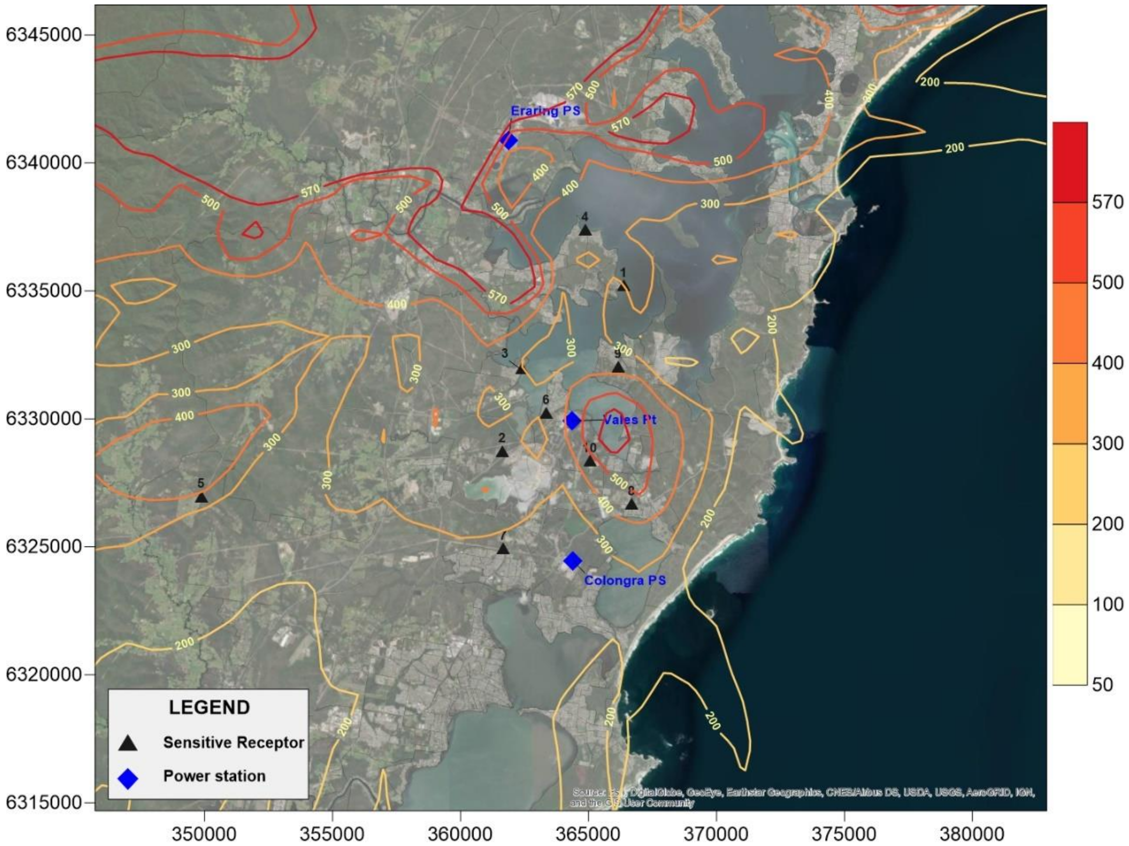


**Figure 108** Cumulative maximum 1-hour average ground-level concentrations of $SO_2$ – without VPPS

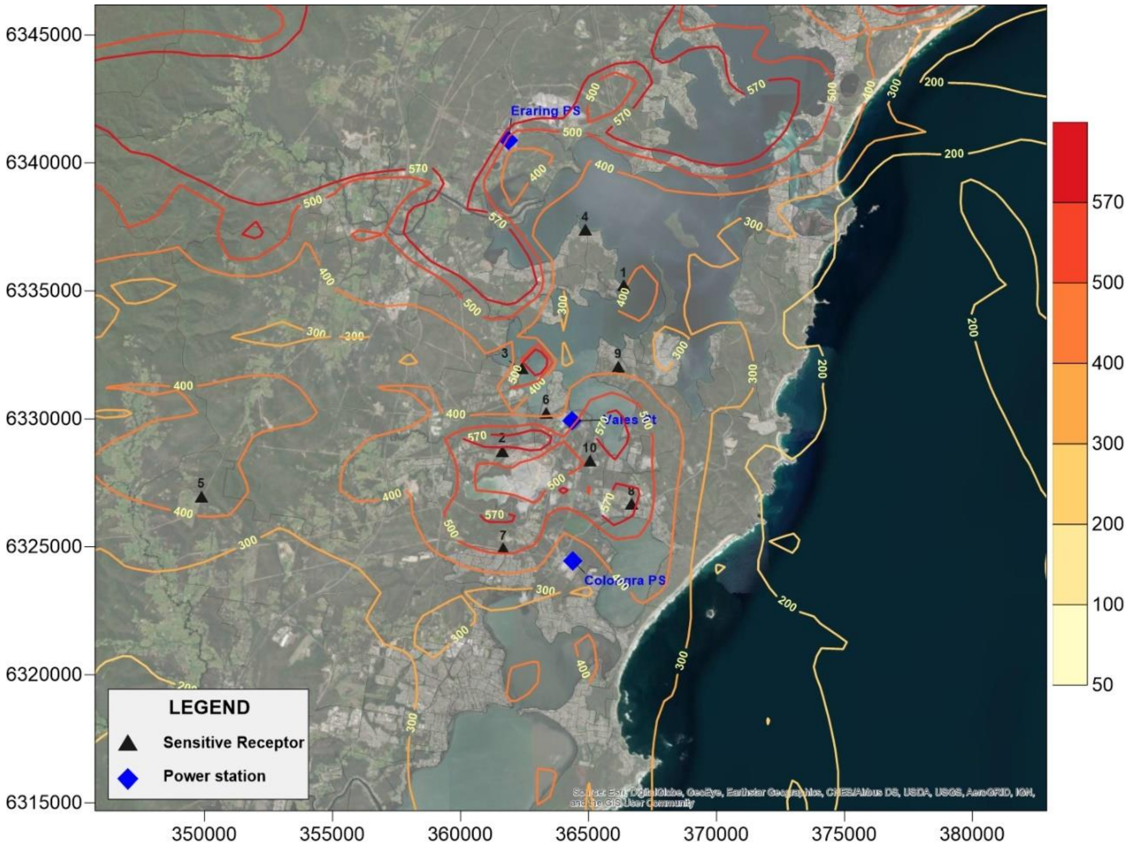
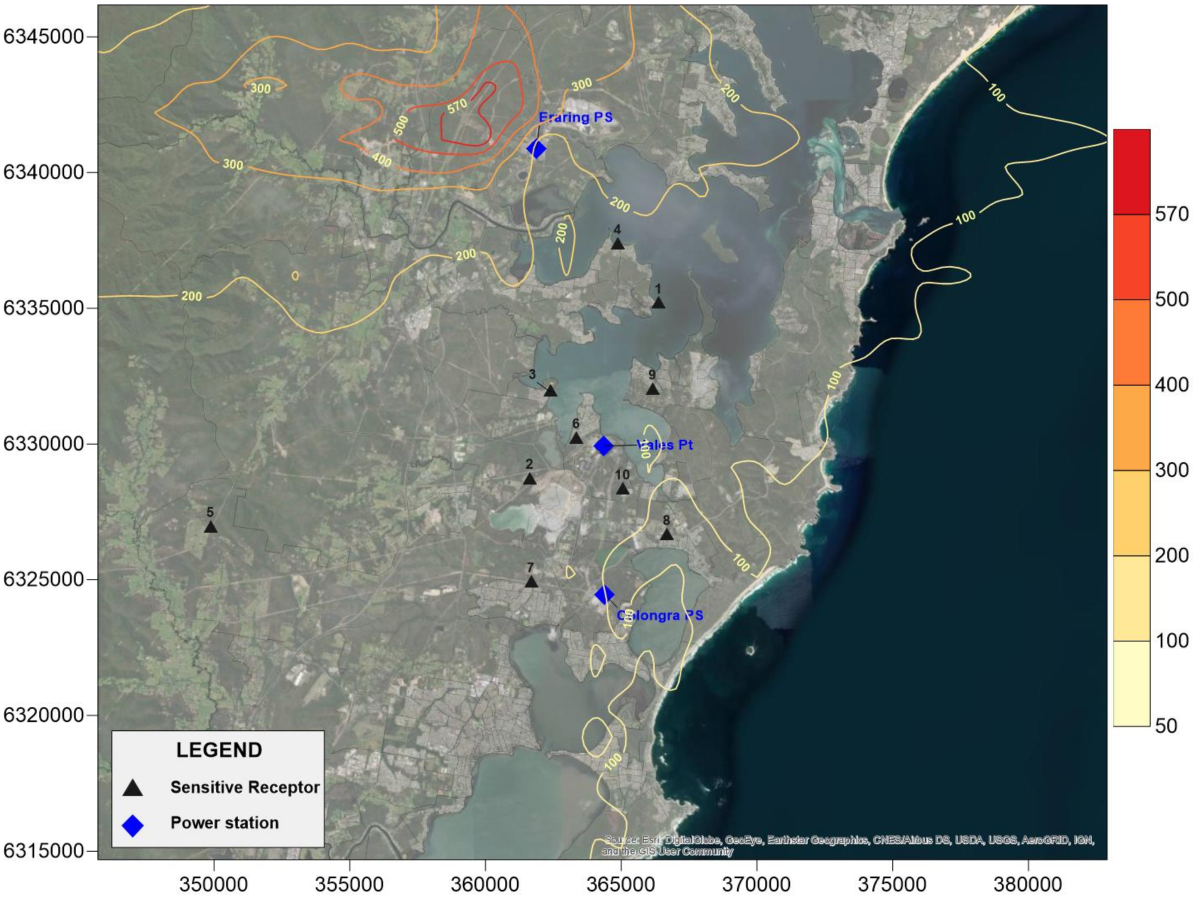


**Figure 109** Cumulative maximum 1-hour average ground-level concentrations of $SO_2$ – with VPPS

Figure 110 and Figure 111 present contour plots of the maximum 99.9th percentile of 1-hour average ground-level concentrations of $SO_2$, without and with the contribution of VPPS, respectively.

The maximum 99.9th percentile of 1-hour average concentration of $SO_2$ anywhere on the receptor grid without VPPS is 605 µg/m³ (Figure 108). The maximum 99.9th percentile of 1-hour average concentration of $SO_2$ with the contribution of VPPS is 642 µg/m³. These concentrations are less than half of the maximum 1-hour average concentrations, demonstrating that there are a very limited number of hours in which concentrations of $SO_2$ are predicted to exceed the assessment criterion.



Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

**Figure 110** Cumulative maximum 99.9th percentile of 1-hour average ground-level concentrations of $SO_2$ – without VPPS

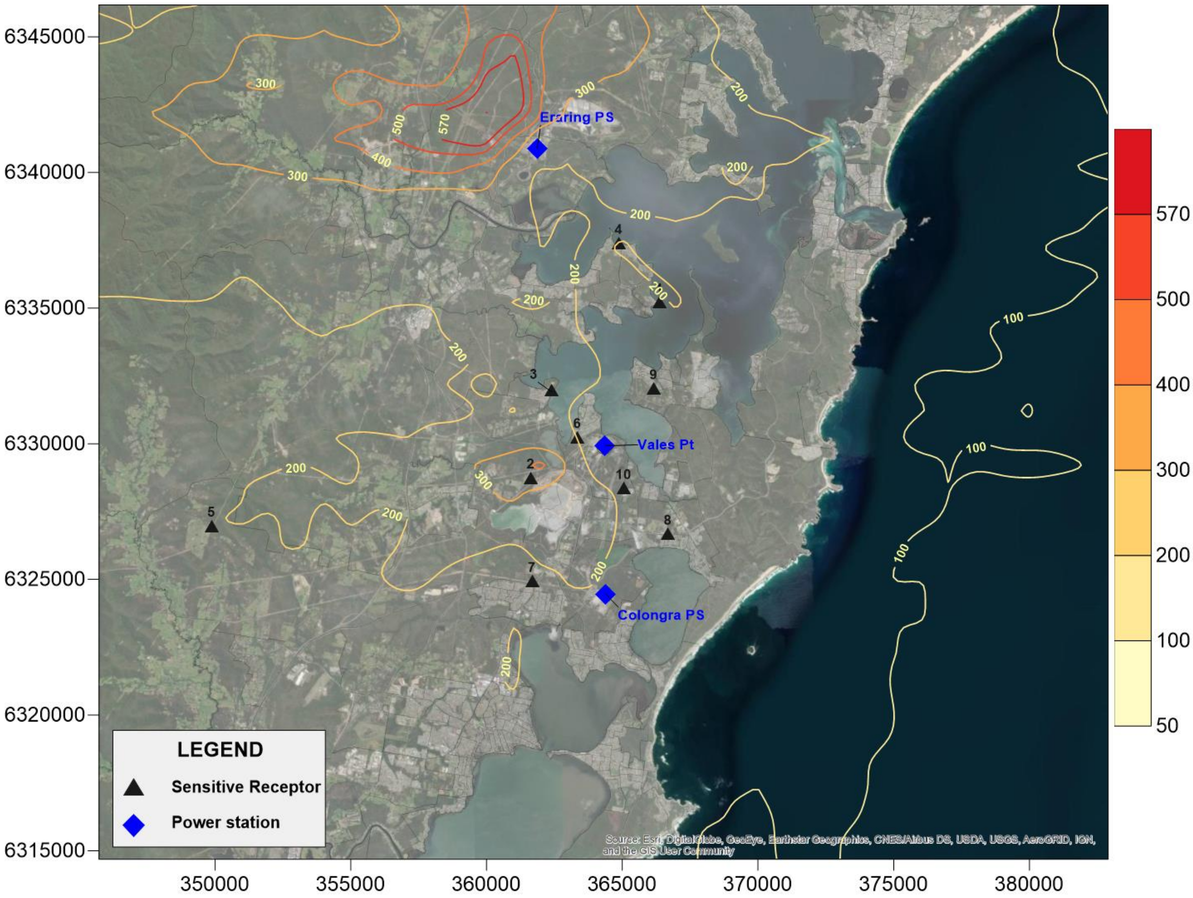


**Figure 111** Cumulative maximum 99.9th percentile of 1-hour average ground-level concentrations of $SO_2$ – with VPPS

Table 40 presents predicted total cumulative ground-level concentrations of $SO_2$ at the specific sensitive receptors set out in Table 18 and Figure 6, with and without the contribution of VPPS. As would be expected based upon the contours in Figure 109, an exceedance of the maximum 1-hour $SO_2$ assessment criterion is predicted at receptor 8, but it is worth noting that the maximum 99,9th percentile concentration here is considerably lower, at less than 25% of the assessment criterion, suggesting that it is very specific, and rare, meteorological conditions within the model that are predicting high $SO_2$ concentrations in the Lake Munmorah area.

**Table 40** **Modelled total cumulative ground-level concentrations of $SO_2$ at specific sensitive receptors ($\mu g/m^3$)**

| Receptor | Annual mean | | Max 24-hr | | Max 1-hr | | Max 99.9th %ile of 1-hr | |
|---|---|---|---|---|---|---|---|---|
| | Without VPPS | With VPPS | Without VPPS | With VPPS | Without VPPS | With VPPS | Without VPPS | With VPPS |
| 1 | 3.0 | 3.8 | 65.3 | 67.8 | 297.5 | 392.1 | 173.8 | 189.1 |
| 2 | 2.6 | 5.4 | 39.5 | 93.7 | 354.9 | 548.3 | 146.1 | 341.5 |
| 3 | 2.5 | 4.3 | 49.6 | 58.4 | 296.9 | 528.1 | 156.2 | 233.9 |
| 4 | 3.2 | 4.3 | 73.3 | 74.3 | 333.4 | 333.7 | 187.8 | 201.5 |
| 5 | 3.6 | 4.7 | 45.1 | 55.2 | 367.4 | 424.9 | 141.8 | 194.7 |
| 6 | 2.5 | 3.5 | 34.3 | 52.5 | 332.5 | 379.4 | 114.0 | 198.9 |
| 7 | 2.7 | 4.2 | 36.0 | 67.7 | 241.0 | 514.0 | 133.1 | 188.6 |
| 8 | 2.6 | 3.2 | 46.9 | 58.5 | 450.9 | **572.4** | 94.6 | 140.6 |
| 9 | 2.6 | 3.4 | 32.6 | 58.2 | 371.0 | 371.0 | 113.3 | 169.1 |
| 10 | 2.5 | 3.1 | 41.6 | 63.4 | 468.8 | 520.0 | 107.3 | 173.0 |
| Wyong | 2.9 | 4.2 | 26.8 | 36.8 | 174.7 | 221.6 | 132.3 | 143.6 |
| Wyee | 3.1 | 4.7 | 41.9 | 77.2 | 330.3 | 441.0 | 146.3 | 232.4 |
| Criterion[1] | 60 | | 228 | | 570 | | 570 | |

Table note:

[1] Approved Methods for Modelling

Figure 112 presents a Q-Q plot of modelled versus measured concentrations of $SO_2$ at the Wyee monitoring station. The plot demonstrates that the model is consistently over-predicting $SO_2$ concentrations at Wyee, especially at the highest concentrations. This casts some doubt on the predicted exceedances of the assessment criterion identified in the vicinity of VPPS in Figure 109. It would appear likely that these highest concentrations will have been over-predicted by as much as 50% (the maximum modelled concentration in Figure 112 is >150% of the highest measured concentration); if the concentrations in Figure 109 were divided by 1.5 then there would be no exceedances in the vicinity of VPPS, although some would remain near Eraring, but these will be at least in part a result of the overestimation of Eraring's emissions.

With the model having predicted that VPPS could cause an exceedance of the 1-hour average $SO_2$ assessment criterion in only two hours a year as an absolute maximum, and given that the concentrations in these hours are reasonably likely to have been substantially over-predicted, it is reasonable to conclude that emissions from VPPS will not, in fact, lead to any exceedances of the 1-hour average $SO_2$ assessment criterion.

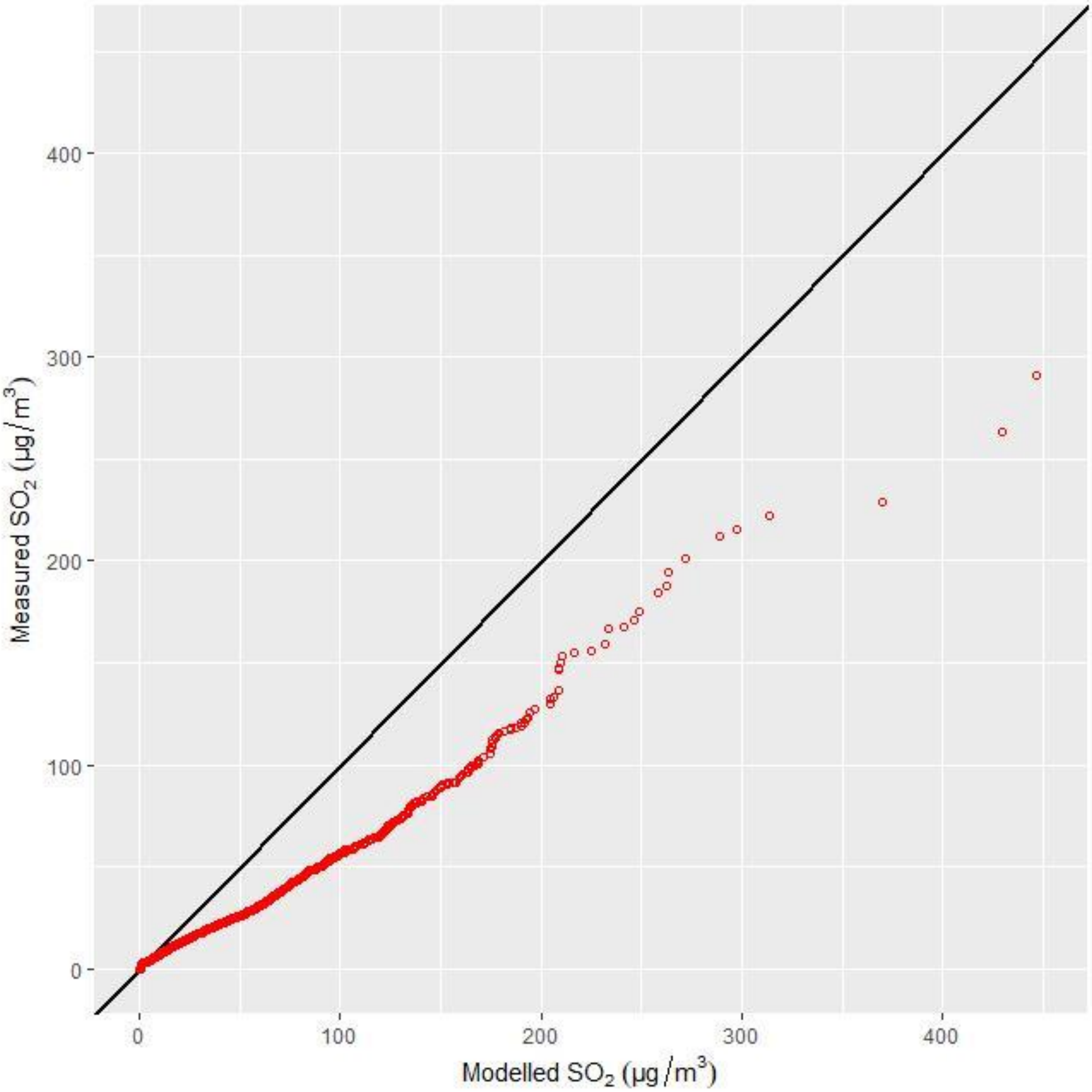


**Figure 112** **QQ Plot of total cumulative ground-level concentrations of $SO_2$ at Wyee**

### 7.1.2.3 Solid Particles

For $PM_{2.5}$ and $PM_{10}$, maximum total concentrations anywhere across the receptor grid incorporating background concentrations (see Section 3.7.3) and the contribution of Eraring and Colongra power stations (with and without the contribution of VPPS) are presented in Table 41. These results clearly show that VPPS does not contribute significantly to maximum 24-hour and annual average concentrations of $PM_{10}$ and $PM_{2.5}$. As stated in Section 5, high concentrations occur as a result of bushfires and regional dust events.

It can be seen in Table 41 by comparing the concentrations without VPPS to those with VPPS that the contribution of VPPS to maximum concentrations is extremely small (no more than 0.1 µg/m$^3$). The very high concentrations predicted are almost entirely the background contribution, as the years 2018 to 2020 encapsulated several regional dust events and the extreme bushfire events of 2019/20 (Table 22 and Table 24 highlight the very high concentrations measured during these events at the Wyee and Wyong monitoring stations). Therefore, while maximum 24-hour concentrations are presented for completeness (and to align with the Approved Methods for Modelling), they are only useful in the context of this study to demonstrate the small contribution of power stations to particulate concentrations when compared to natural events.

**Table 41 Total cumulative concentrations of $PM_{2.5}$ and $PM_{10}$ (µg/m$^3$)**

| Pollutant | Averaging period | Maximum Total Concentration | | Criterion | % of criterion |
|---|---|---|---|---|---|
| | | Without VPPS | With VPPS | | |
| $PM_{10}$ | 24-hour | 241.5 | 241.6 | 50 | 483% |
| | Annual mean | 23.0 | 23.0 | 25 | 92.0% |
| $PM_{2.5}$ | 24-hour | 179.1 | 179.1 | 25 | 716% |
| | Annual mean | 10.6 | 10.6 | 8 | 133% |

Where existing levels exceed air quality criteria, the Approved Methods for Modelling also requires a determination of the number of additional exceedances as a result of the subject premises. Table 42 compares the number of days per year that exceed the 24-hour average assessment criterion with and without the contribution from VPPS, these being the maximum number at any receptor on the entire grid. The results suggest that the contribution from VPPS does not change the maximum number of days on which the criterion is exceeded in any one year.

It must be remembered that the modelling of emissions from VPPS and Eraring for these scenarios has assumed continuous operation at high load throughout the year (see Section 3.7.1), which will have greatly overstated their contributions to particulate concentrations. It has also been assumed that all solid particles are both $PM_{10}$ and $PM_{2.5}$.

**Table 42 Days above 24-Hour Assessment Criteria for $PM_{2.5}$ and $PM_{10}$ – Cumulative**

| Pollutant | Criterion (µg/m$^3$) | Days above Criterion | |
|---|---|---|---|
| | | Without VPPS | With VPPS |
| $PM_{10}$ | 50 | 25 | 25 |
| $PM_{2.5}$ | 25 | 24 | 24 |

### 7.1.3 Future cumulative considerations

All of the assessment work presented above is intended to reflect conditions in the past years 2018, 2019 and 2020. Part of the scope of works is also to consider the effect on cumulative concentrations of the operation of the proposed Newcastle Power Project (NPP) and Hunter Power Project (HPP).

Modelled $NO_2$ and $SO_2$ concentrations as a result of emissions from these facilities are presented in Figure 113, Figure 114, Figure 115, Figure 116 and Figure 117. In all cases the modelled contributions in the vicinity of VPPS are very small and would make a negligible contribution to total concentrations. It is, therefore, judged unnecessary to produce additional plots and statistics that incorporate these contributions, as they would have no effect on the conclusions drawn.

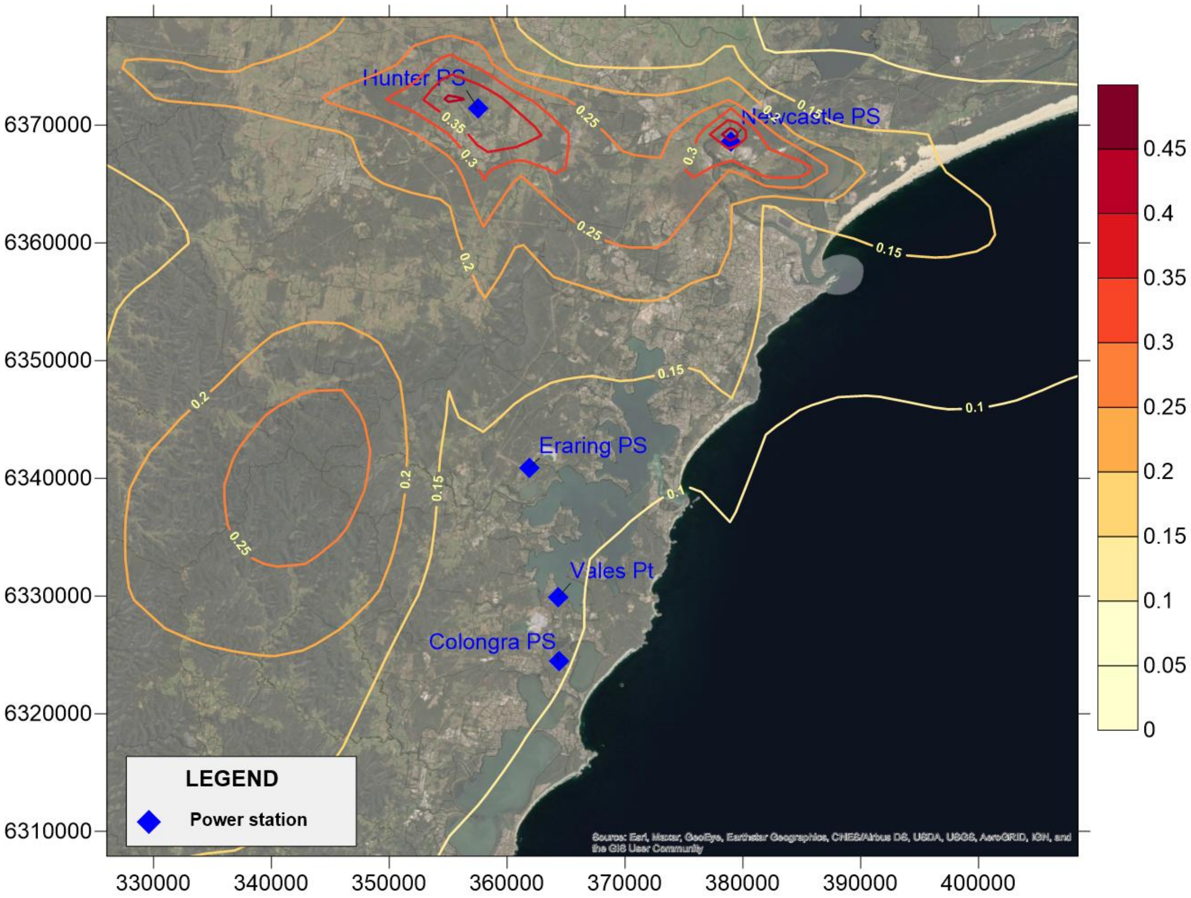


**Figure 113** Maximum annual average ground-level concentrations of $NO_2$ ($\mu g/m^3$) – NPP & HPP

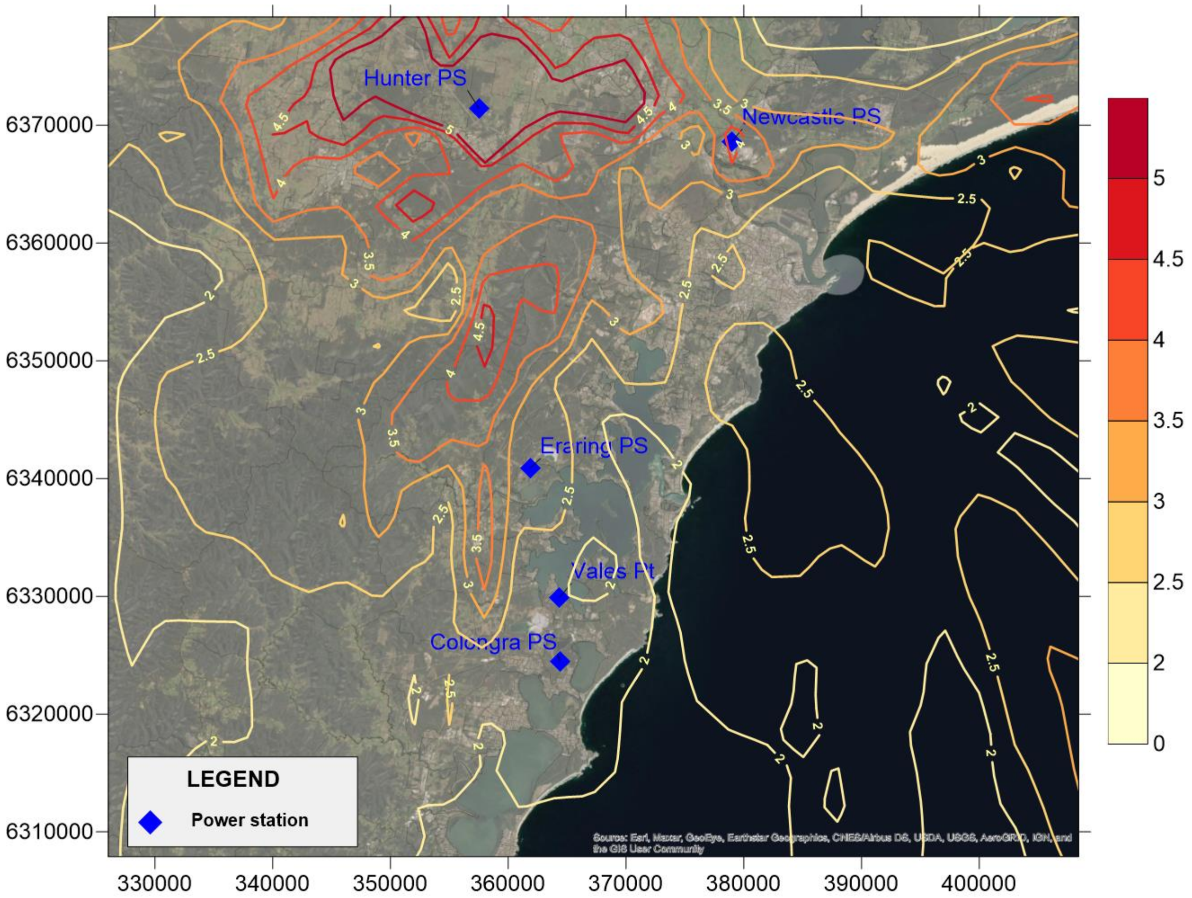


**Figure 114** Maximum 1-hour average ground-level concentrations of $NO_2$ concentrations ($\mu g/m^3$) (20% $NO_2$:NOx ratio) – NPP & HPP

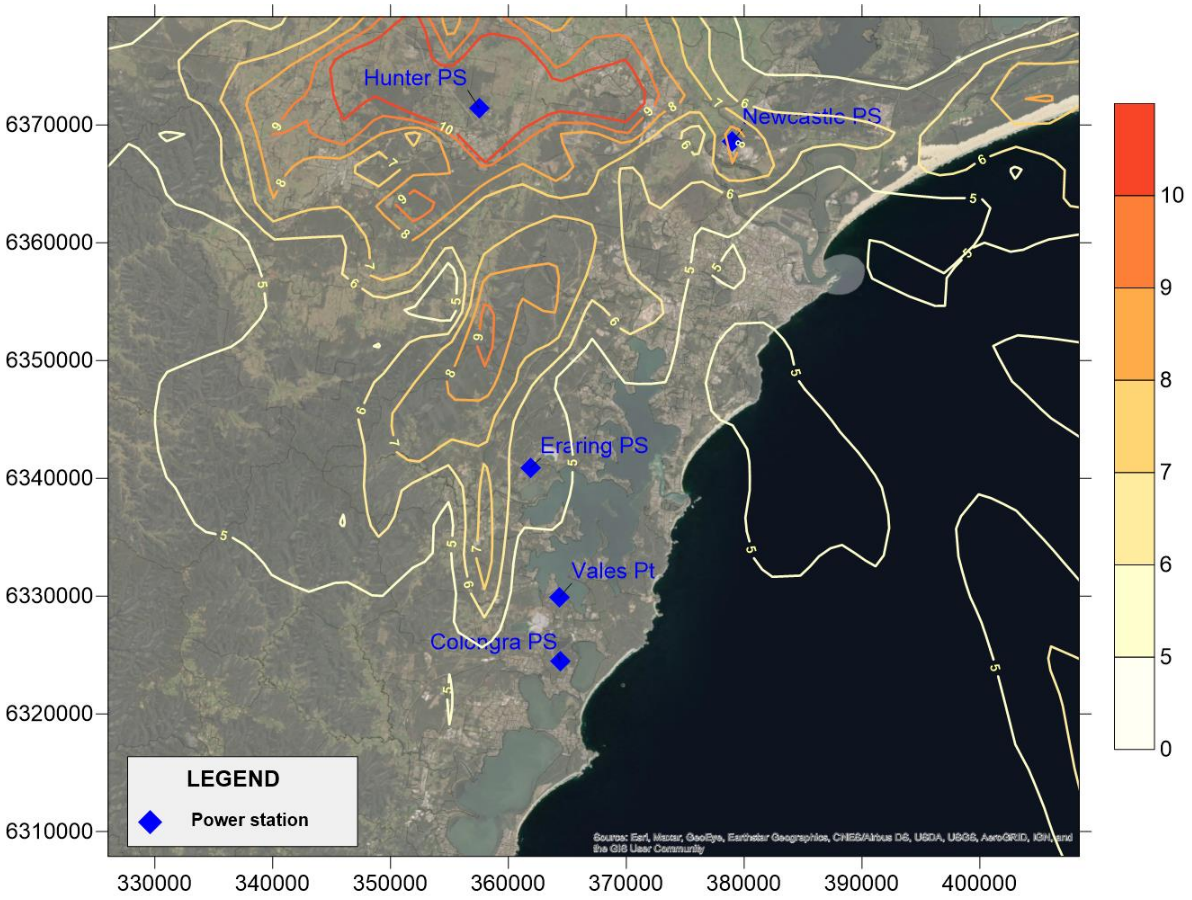


**Figure 115** Maximum 1-hour average ground-level concentrations of $NO_2$ (µg/m$^3$) (40% $NO_2$:NOx ratio) – NPP & HPP

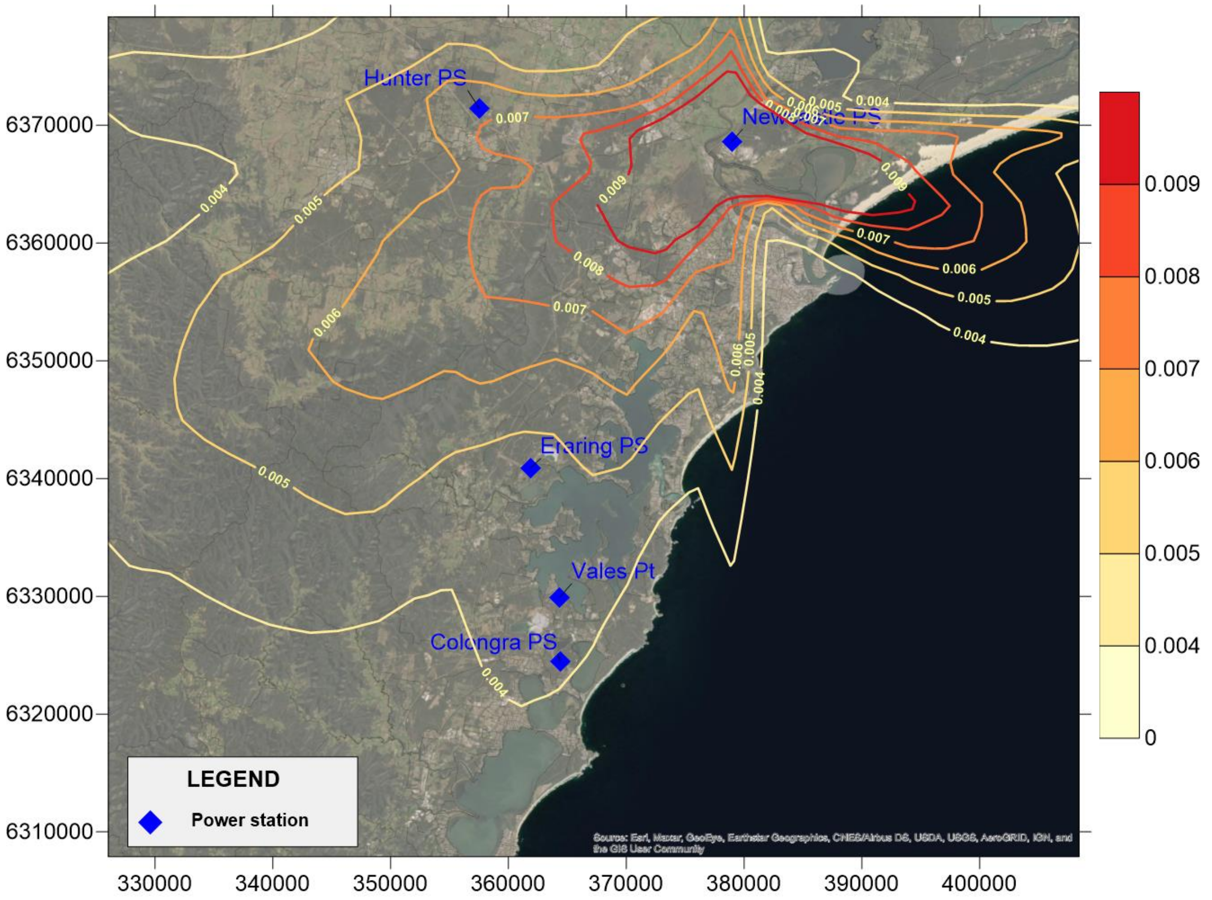


**Figure 116** Maximum annual average ground-level concentrations of $SO_2$ concentrations ($\mu g/m^3$) – NPP & HPP

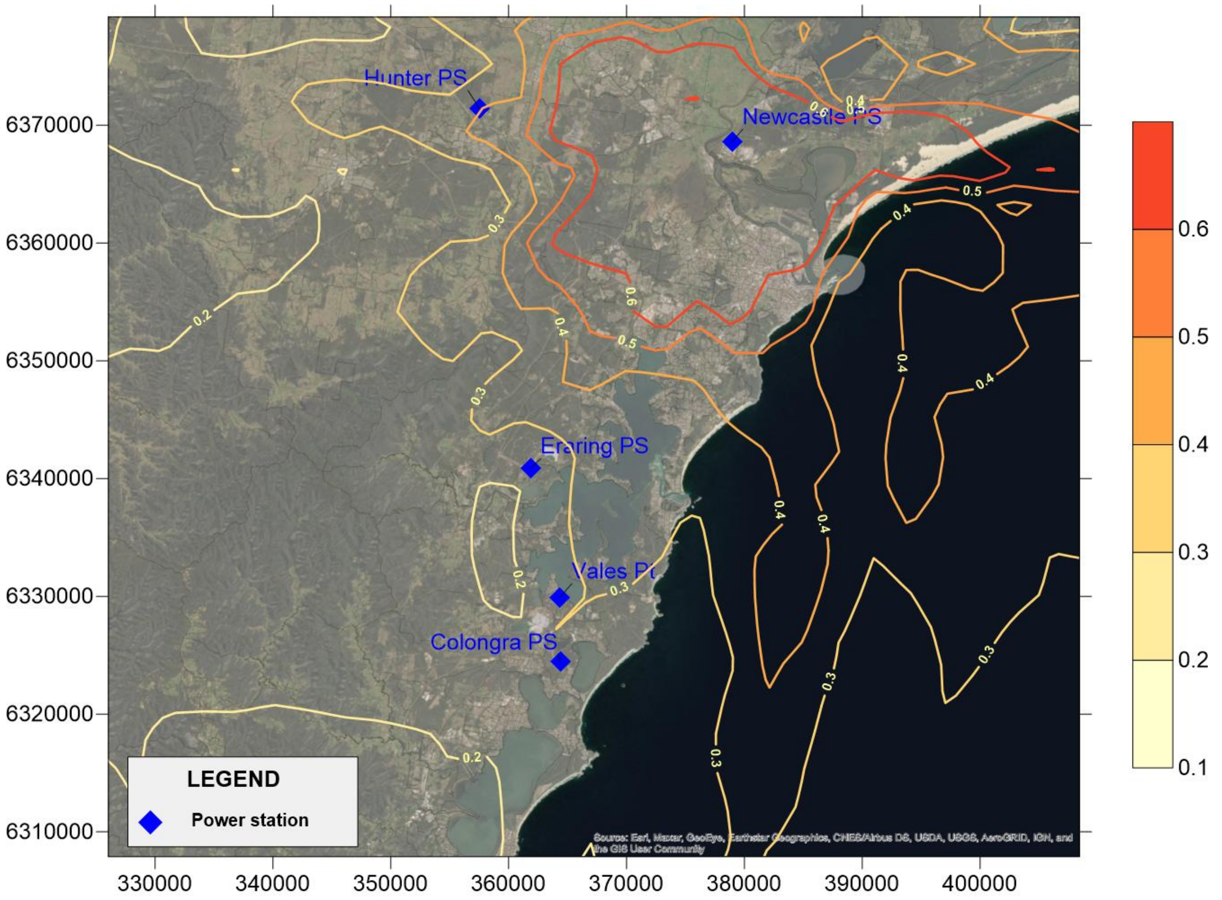


Figure 117 Maximum 1-hour average ground-level concentrations of $SO_2$ (µg/m$^3$) – NPP & HPP

## 7.3 Revised emission limits

This section compares how ground-level concentrations of $NO_2$ might vary as a result of the Group 5 and Group 6 standards of concentration being achieved at VPPS. To estimate the reduction in emissions of NOx due to the application of Group 5 and Group 6 standards of concentration, the time varying emissions from the last three years of operations have been amended so that any NOx concentrations that exceed the respective limits are replaced with the relevant Group standard of concentration. Relative to annual emissions in 2018, 2019 and 2020, total annual emissions of NOx with the application of the Group 5 standard of concentration reduce by between 1.4 and 5.4%. With the application of the Group 6 standard of concentration, total annual emissions of NOx reduce by between 27.1 and 33.0%. However, this comparison is unrealistic if the intention is to compare to current emissions from VPPS, as low-NOx burner tips were installed in Boiler 6 in 2021.

To give some context to the likely reductions compared to the current scenario whereby low-NOx burner tips have been installed in Boiler 6, the reduction in annual emissions that would be achieved as a result of compliance with the Group 5 and Group 6 standards of concentration for NOx are set out in Table 43. This demonstrates that, for Boiler 5, compliance with the Group 5 standard of concentration would result in no more than a 0.5% reduction in annual emissions of NOx, while compliance with the Group 6 standard of concentration would result in around a 20% reduction.

Therefore, if the recent upgrade in the Boiler 6 burner tips were to be accounted for, it is likely that the overall reductions in emissions from VPPS relative to the current situation would be as follows:

- Group 5 standard of concentration would reduce emissions of NOx from VPPS by, at most, 0.5%
- Group 6 standard of concentration would reduce emissions of NOx from VPPS by, at most, 20%.

Consequently, Table 43 overestimates the future benefits of implementation of Group 5 and Group 6 standards of concentration in Boiler 6 because it does not account for the recent installation of low-NOx burner tips.

**Table 43 VPPS annual mass emissions of NOx with achievement of Group 5 and Group 6 standards of concentration for NOx**

| Year | Annual mass emission of NOx (tonnes) | | | % Reduction | |
|---|---|---|---|---|---|
| | Current Operation | Group 5 | Group 6 | Group 5 | Group 6 |
| **Boiler 5** | | | | | |
| 2018 | 9,439 | 9,428 | 7,582 | 0.1 | 19.7 |
| 2019 | 11,490 | 11,467 | 9,155 | 0.2 | 20.3 |
| 2020 | 9,887 | 9,840 | 8,006 | 0.5 | 19.0 |
| **Boiler 6** | | | | | |
| 2018 | 14,956 | 13,661 | 8,763 | 8.7 | 41.4 |
| 2019 | 13,401 | 12,857 | 8,389 | 4.1 | 37.4 |
| 2020 | 11,693 | 11,448 | 7,716 | 2.1 | 34 |

### 7.3.1 VPPS in Isolation

As a starting reference point, Figure 118 is a reproduction of Figure 84 (with an amended scale), presenting maximum 1-hour average ground-level concentrations of $NO_2$ from any of the three years 2018 to 2020, assuming that 20% of modelled power station NOx is $NO_2$ (which has been demonstrated to be the appropriate assumption). Given that VPPS meets its existing license limits, it is not considered necessary to present any alternative scenarios based on the existing license limits, as Figure 118 reflects the potential impacts of operations under the existing license limits.

Figure 119 and Figure 120 present maximum 1-hour average ground-level concentrations of $NO_2$ assuming that the Group 5 and Group 6 standards of concentration for NOx are achieved, respectively.

Figure 121, Figure 122 and Figure 123 present annual average ground-level concentrations of $NO_2$ under the three scenarios.

Table 44 uses the maximum modelled concentrations anywhere on the receptor grid to identify the percentage reductions in concentrations that could reasonably be expected by achieving the Group 5 and Group 6 standards of concentration for NOx, for both VPPS in isolation and cumulatively with the contributions from other sources.

These plots demonstrate that the implementation of the Group 5 standard of concentration would have a very limited influence on maximum 1-hour average ground-level concentrations of $NO_2$. Implementation of the Group 6 standard of concentration unsurprisingly results in a much greater reduction in maximum 1-hour average concentrations of $NO_2$ due to VPPS, with the maximum concentration predicted reducing by over 50%.

Implementation of the Group 5 standard of concentration would have very little effect on annual mean concentrations. Implementation of the Group 6 standard of concentration would have a greater effect, reducing the annual mean concentrations at the location of maximum contribution from VPPS by 30.9%.

It should be borne in mind that all of these values have been calculated by comparison against emissions in 2018, 2019 and 2020, when NOx emissions from Boiler 6 were considerably higher than they are since the installation of low-NOx burner tips earlier in 2021. The actual reductions relative to the current operation at VPPS will be smaller.

**Table 44** **Modelled Reductions to maximum $NO_2$ concentrations with achievement of Group 5 and Group 6 standards of concentration for NOx – VPPS in isolation**

| Averaging period | Maximum Modelled Concentration (µg/m$^3$) | | | % Reduction | |
|---|---|---|---|---|---|
| | Current Operation | Group 5 | Group 6 | Group 5 | Group 6 |
| Max 1-hour | 185.9 | 177.6 | 92.1 | -4.5% | -50.5% |
| Annual Mean | 3.3 | 3.1 | 2.3 | -5.0% | -30.9% |

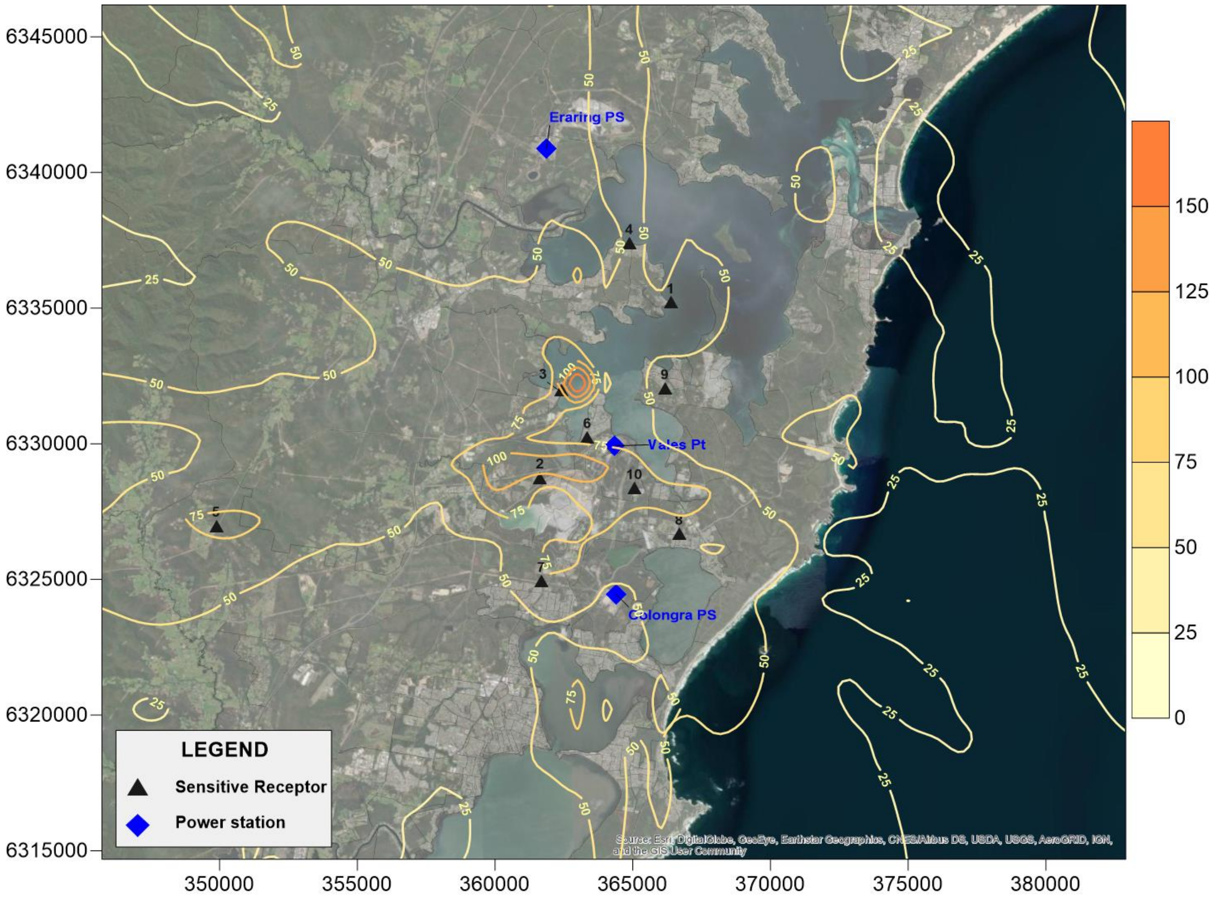


**Figure 118** **Maximum 1-hour average ground-level concentration of $NO_2$ (µg/m$^3$) (20% $NO_2$:NOx) – VPPS in Isolation - Current Operation**

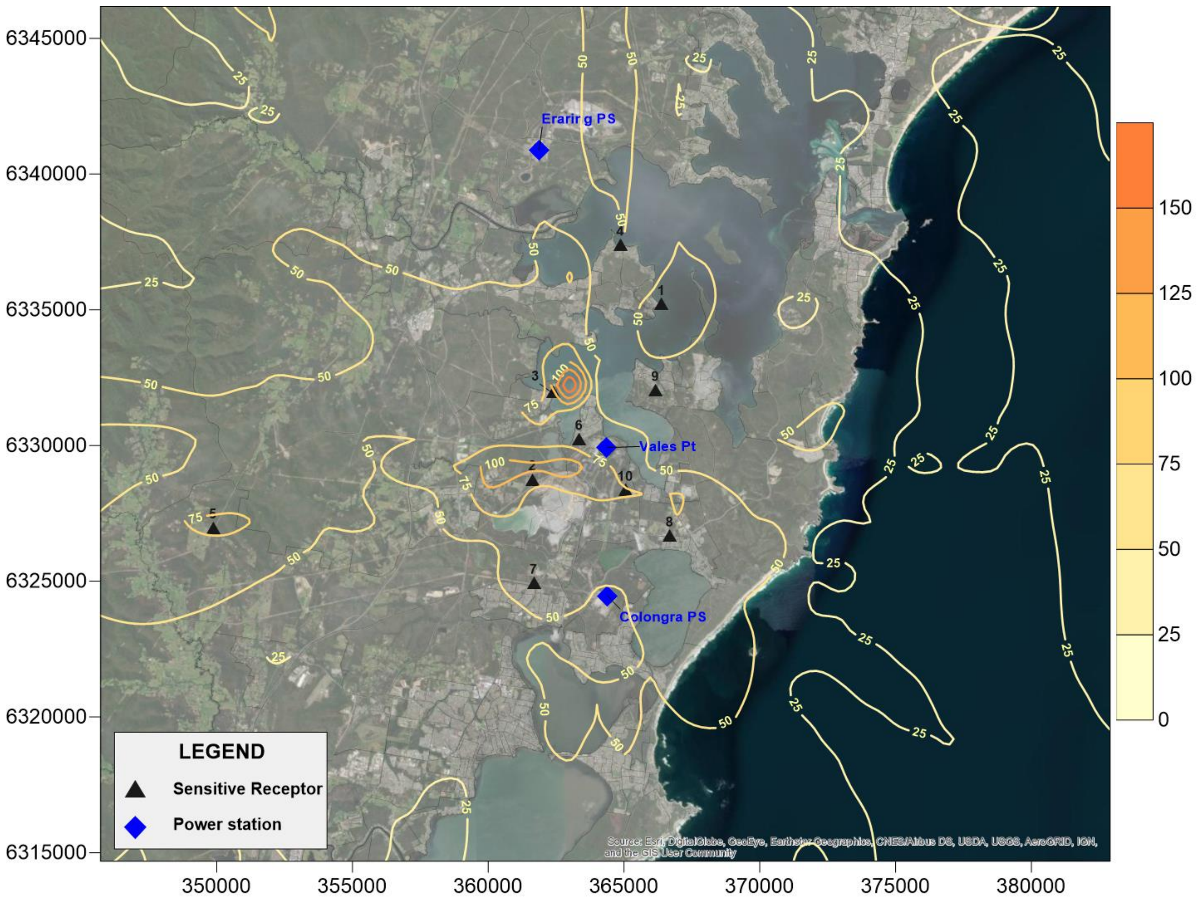
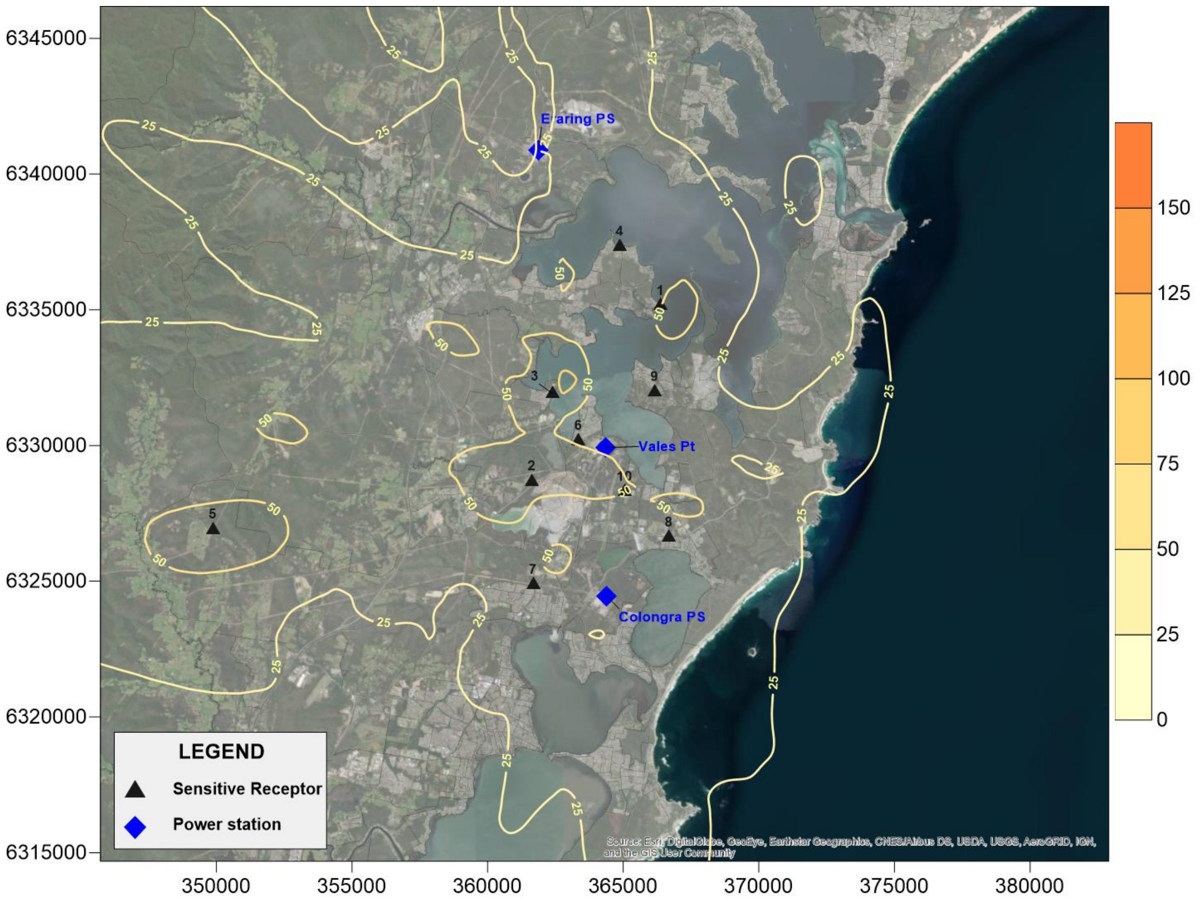


Figure 119 Maximum 1-hour average ground-level concentration of $NO_2$ (µg/m$^3$) (20% $NO_2$:NOx) – VPPS in Isolation – Achieve Group 5 standard of concentration



Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

**Figure 120** **Maximum 1-hour average ground-level concentration of $NO_2$ (µg/m$^3$) (20% $NO_2$:NOx) – VPPS in Isolation – Achieve Group 6 standard of concentration**

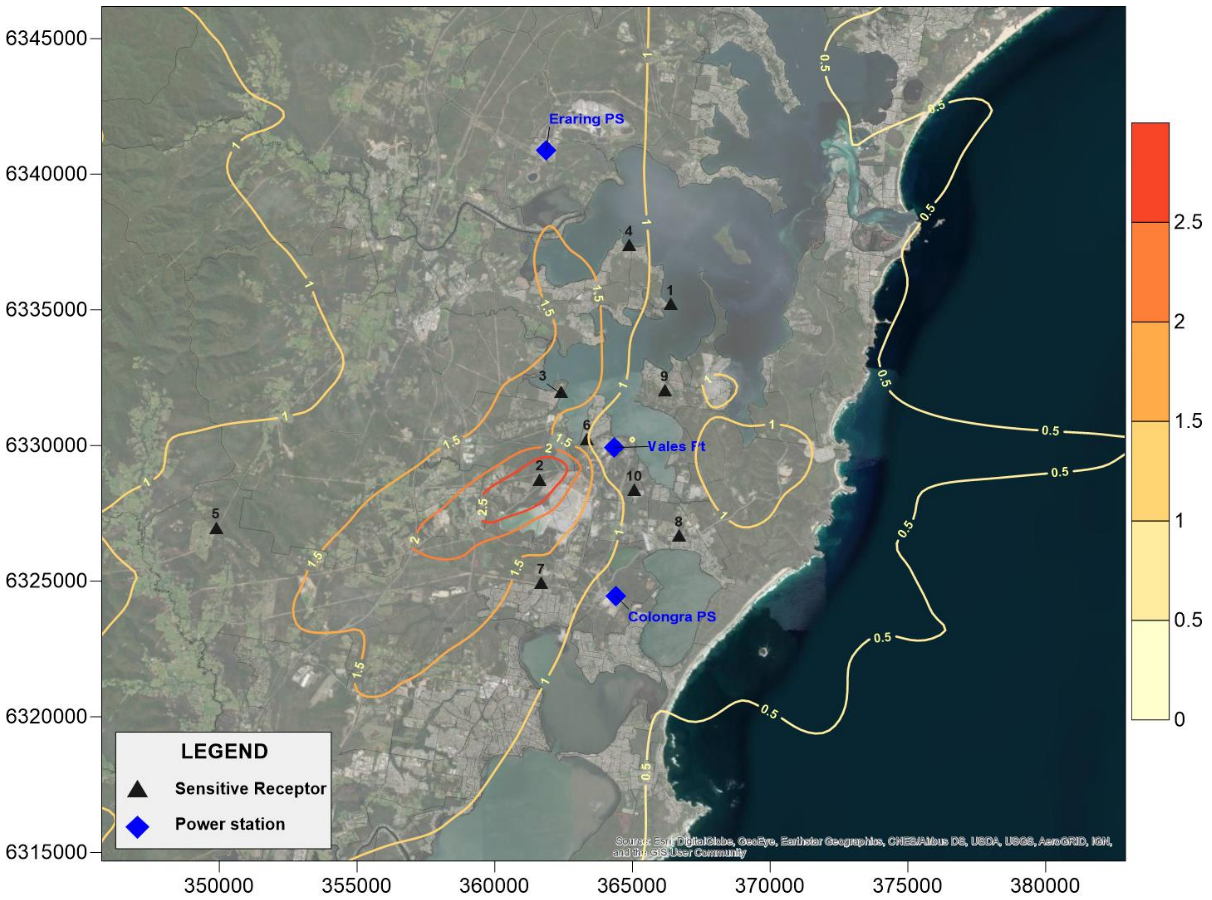


Figure 121 Maximum annual average ground-level concentration of $NO_2$ ($\mu g/m^3$) – VPPS in Isolation – Current Operation

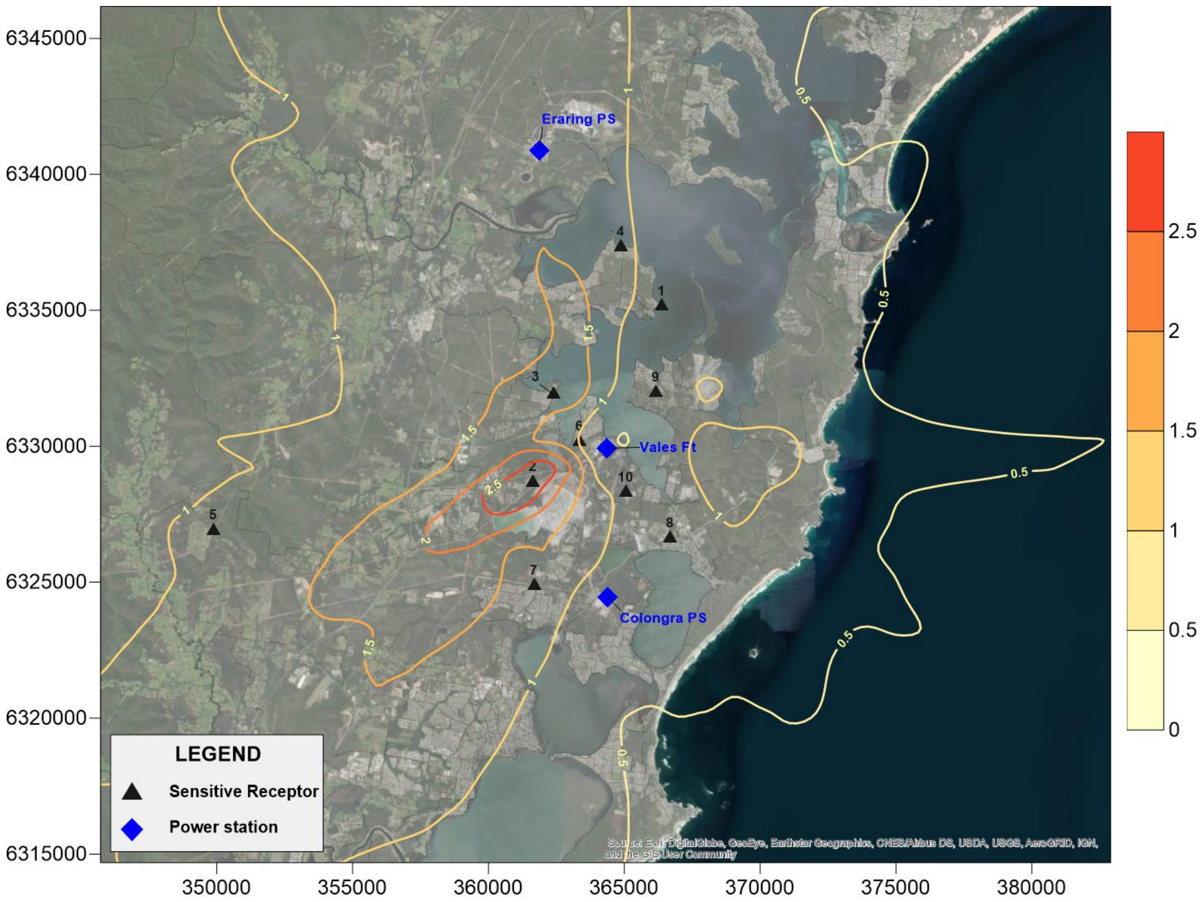


Figure 122 Maximum annual average ground-level concentration of $NO_2$ (µg/m$^3$) – VPPS in Isolation – Achieve Group 5 standard of concentration

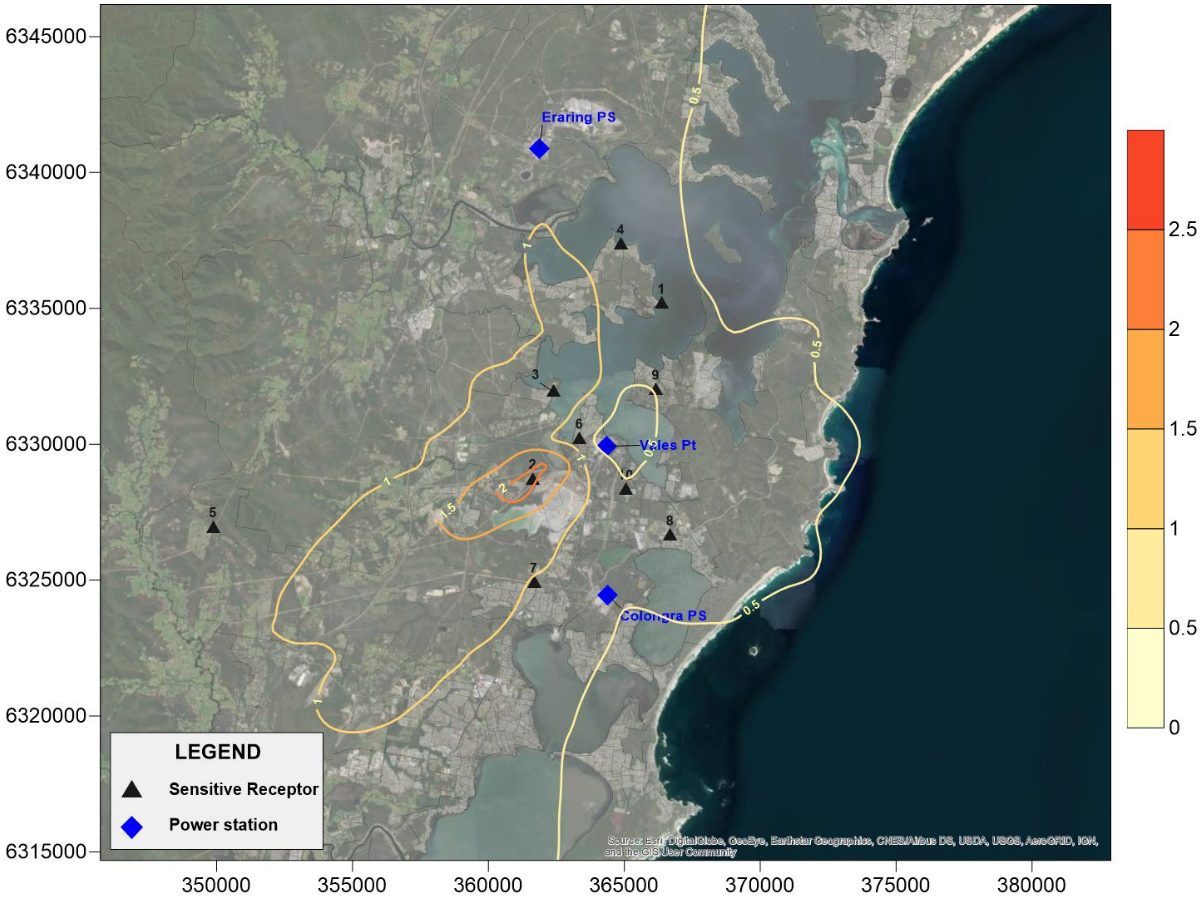


Figure 123 Maximum annual average ground-level concentration of $NO_2$ (µg/m$^3$) – VPPS in Isolation – Achieve Group 6 standard of concentration

### 7.3.3 Cumulative concentrations

Figure 124 is a reproduction of Figure 96 (with an amended scale), presenting maximum cumulative 1-hour average ground-level concentrations of $NO_2$ from any of the three years 2018 to 2020, assuming that 20% of modelled power station NOx is $NO_2$. Figure 125 and Figure 126 present maximum cumulative ground-level concentration contours assuming that the Group 5 and Group 6 standards of concentration for NOx are achieved, respectively.

Figure 127, Figure 128 and Figure 129 present maximum annual average concentrations of $NO_2$ under the three scenarios.

Table 45 identifies the percentage reductions in maximum cumulative 1-hour average ground-level concentrations of $NO_2$ that could reasonably be expected by achieving the Group 5 and Group 6 standards of concentration for NOx.

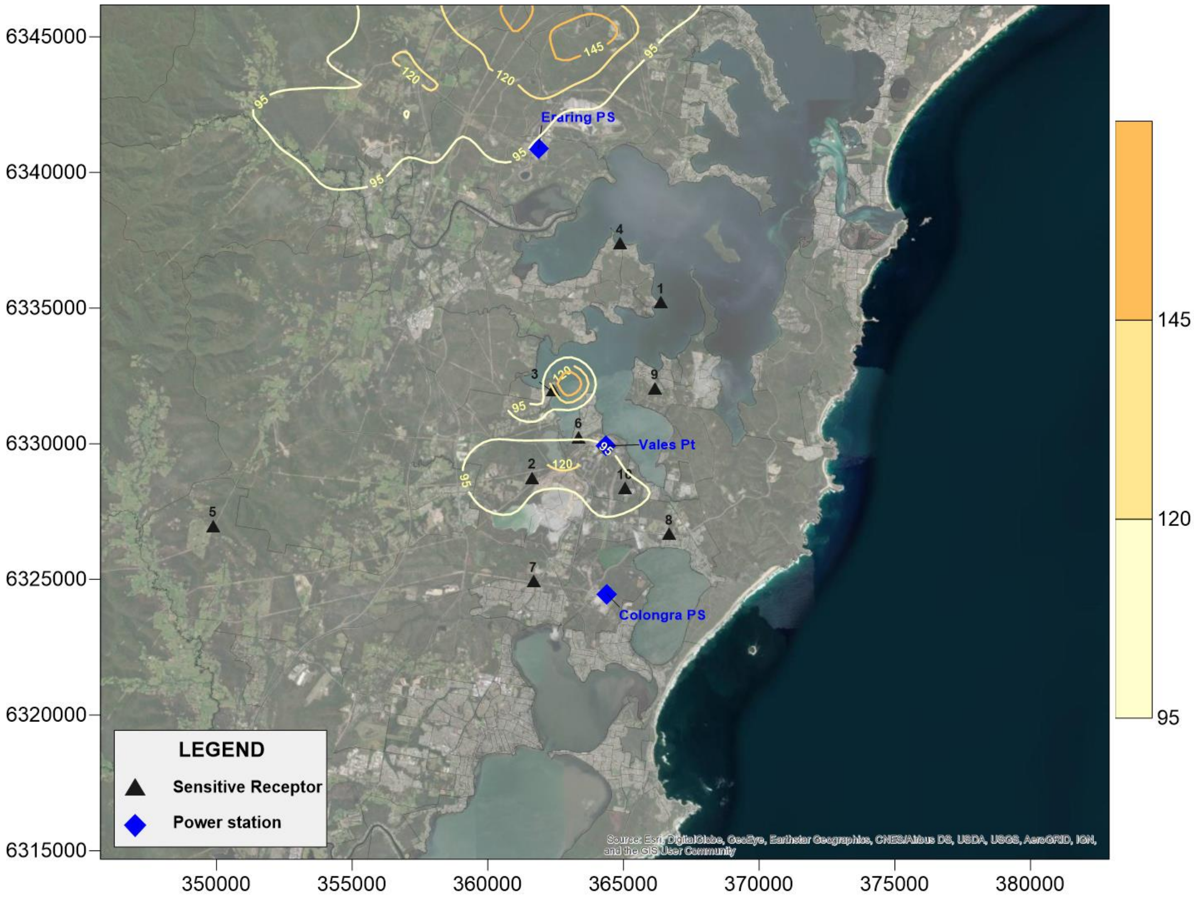
When considered cumulatively, the effect of the implementation of the Group 5 and Group 6 standards of concentration for NOx at VPPS is much smaller. Maximum annual average concentrations of $NO_2$ would decrease by just 0.7% and 2.9% with the implementation of the Group 5 and Group 6 standards of concentration, respectively.

The reduction is greater for maximum 1-hour average ground-level concentrations of $NO_2$, with a reduction of 4.5% predicted with implementation of the Group 5 standard of concentration, or 12.6% with the implementation of the Group 6 standard of concentration. The reduction to cumulative maximum 1-hour average concentrations achieved by implementing the Group 5 standard of concentration is the same (4.5%) as for VPPS in isolation (Table 44) as VPPS is the dominant source of concentrations at these peak times; a background concentration has been added to the values in Table 45, but for the peak hour this is so small that it does not change the rounded number reported. The maximum 1-hour average concentration of $NO_2$ for implementation of the Group 6 standard of concentration is higher Table 45 than in Table 44 because it occurs in the vicinity of Eraring power station as a result of emissions from that facility.

It should again be borne in mind that all of these values have been calculated by comparison against emissions in 2018, 2019 and 2020, when NOx emissions from Boiler 6 were considerably higher than they are since the installation of low-NOx burner tips earlier in 2021. The actual reductions relative to the current operation at VPPS will be smaller.

**Table 45 Modelled Reductions to maximum cumulative $NO_2$ concentrations with achievement of Group 5 and Group 6 standards of concentration for NOx**

| Averaging period | Maximum Modelled Concentration (µg/m$^3$) | | | % Reduction | |
|---|---|---|---|---|---|
| | Current Operation | Group 5 | Group 6 | Group 5 | Group 6 |
| Max 1-hour | 185.9 | 177.6 | 162.5 | -4.5% | -12.6% |
| Annual Mean | 14.6 | 14.5 | 14.2 | -0.7% | -2.9% |



Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

**Figure 124** Maximum 1-hour average ground-level concentration of $NO_2$ (µg/m$^3$) (20% $NO_2$:NOx) – Cumulative - Current Operation

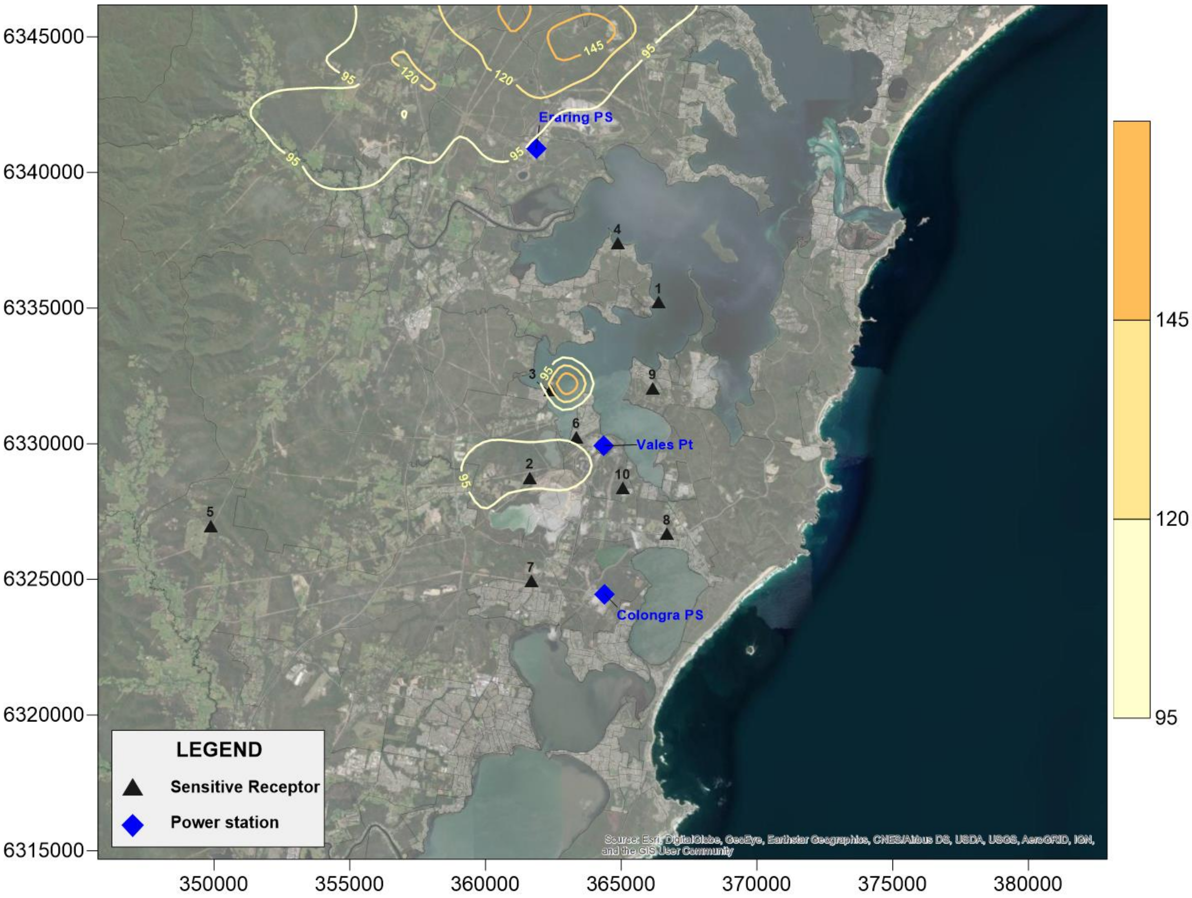


**Figure 125** Maximum 1-hour average ground-level concentrations of $NO_2$ (μg/m$^3$) (20% $NO_2$:NOx) – Cumulative – Achieve Group 5 standard of concentration

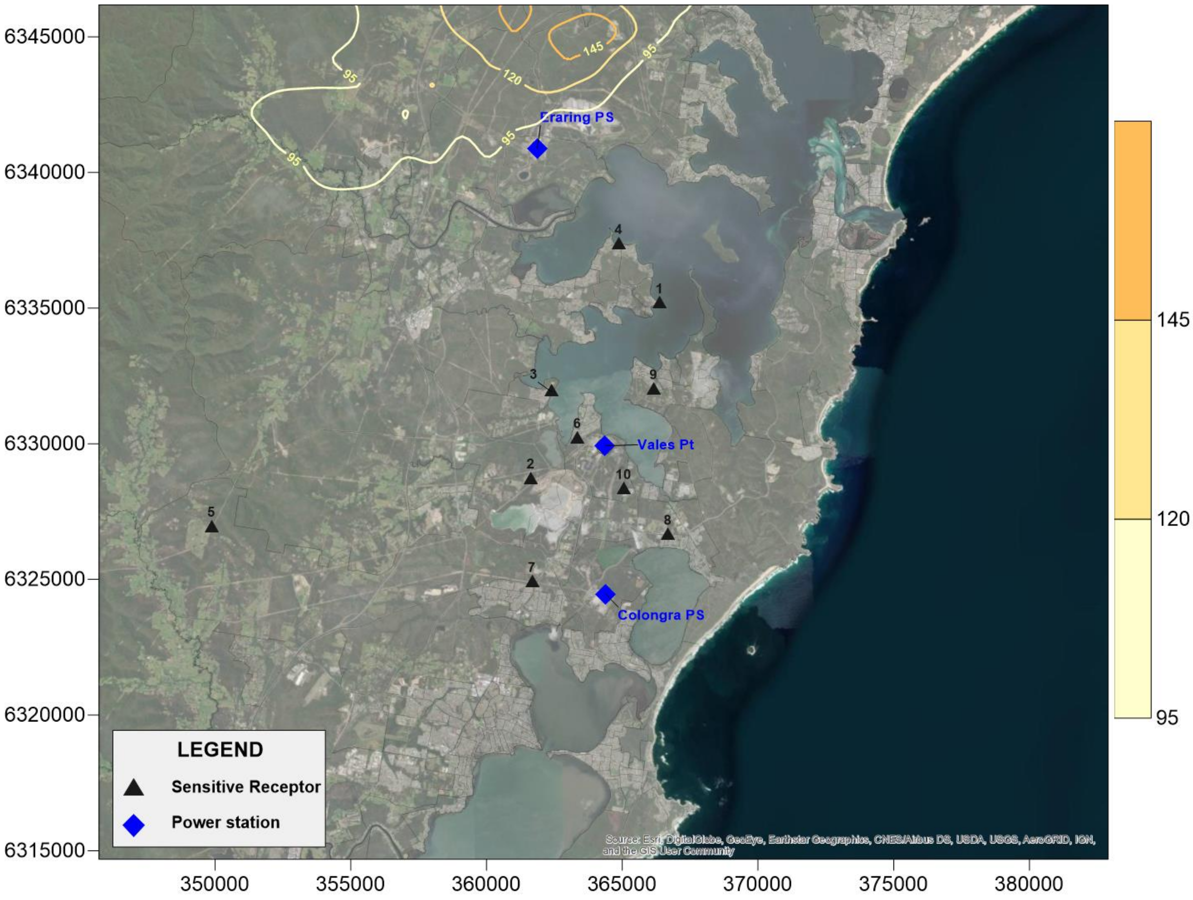


Figure 126 Maximum 1-hour average ground-level concentration of $NO_2$ (µg/m$^3$) (20% $NO_2$:NOx) – Cumulative – Achieve Group 6 standard of concentration

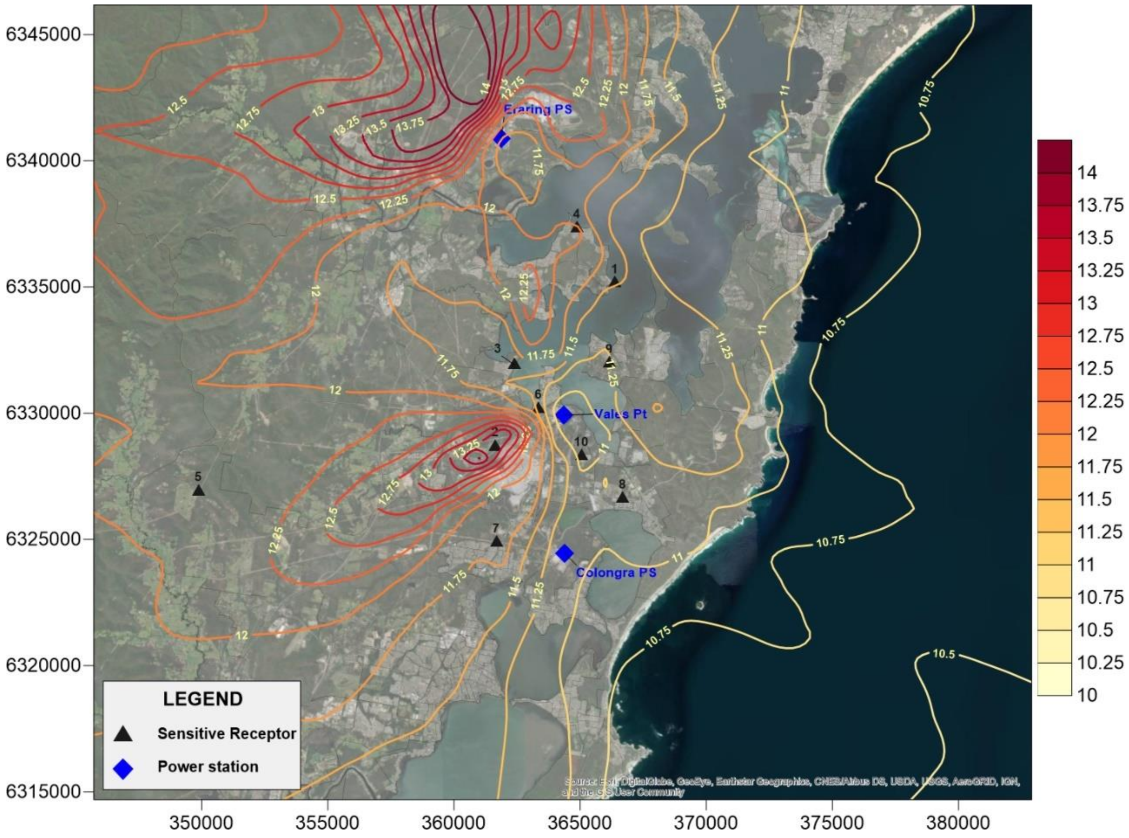


**Figure 127** Maximum annual average ground-level concentrations of $NO_2$ (µg/m$^3$) – Cumulative – Current Operation

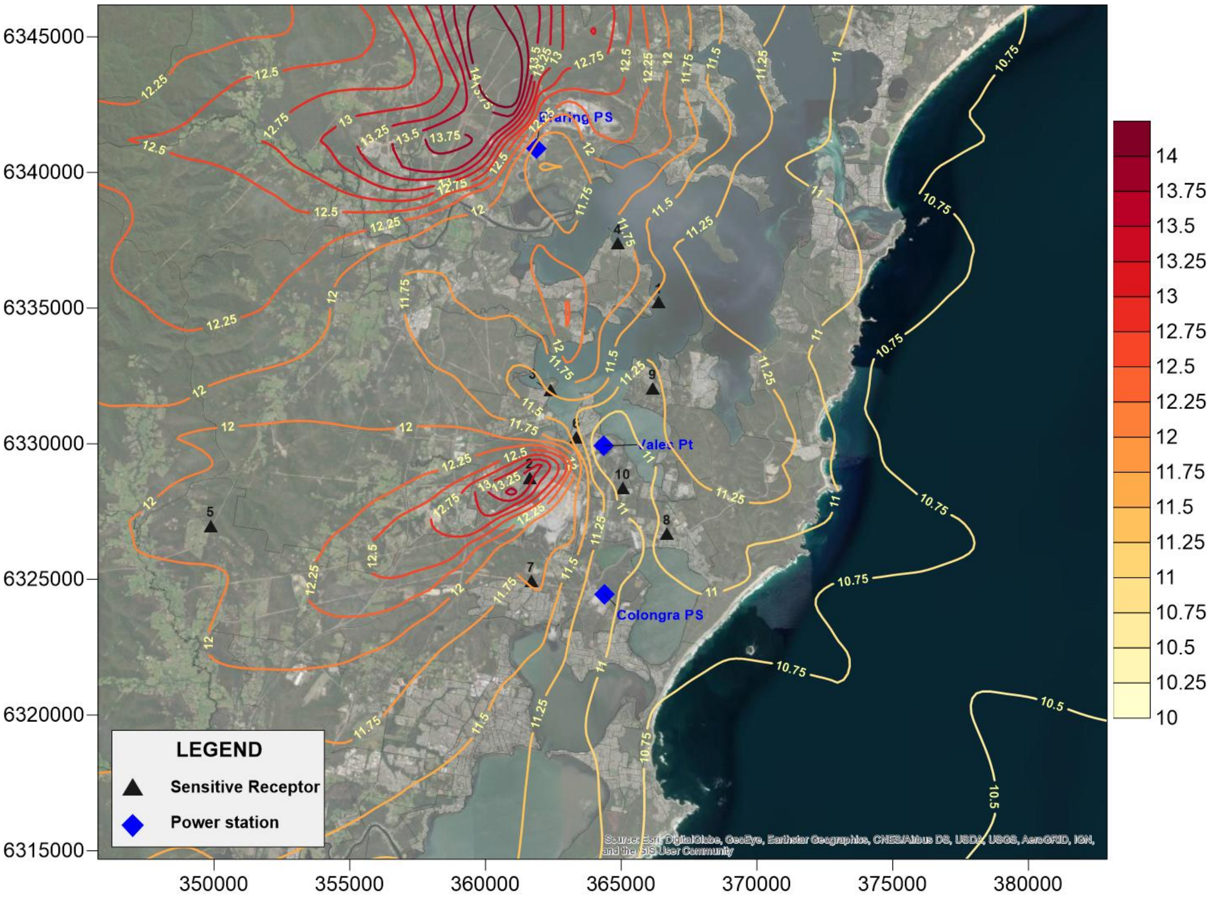


Figure 128 Maximum annual average ground-level concentrations of $NO_2$ (µg/m$^3$) – Cumulative – Achieve Group 5 standard of concentration

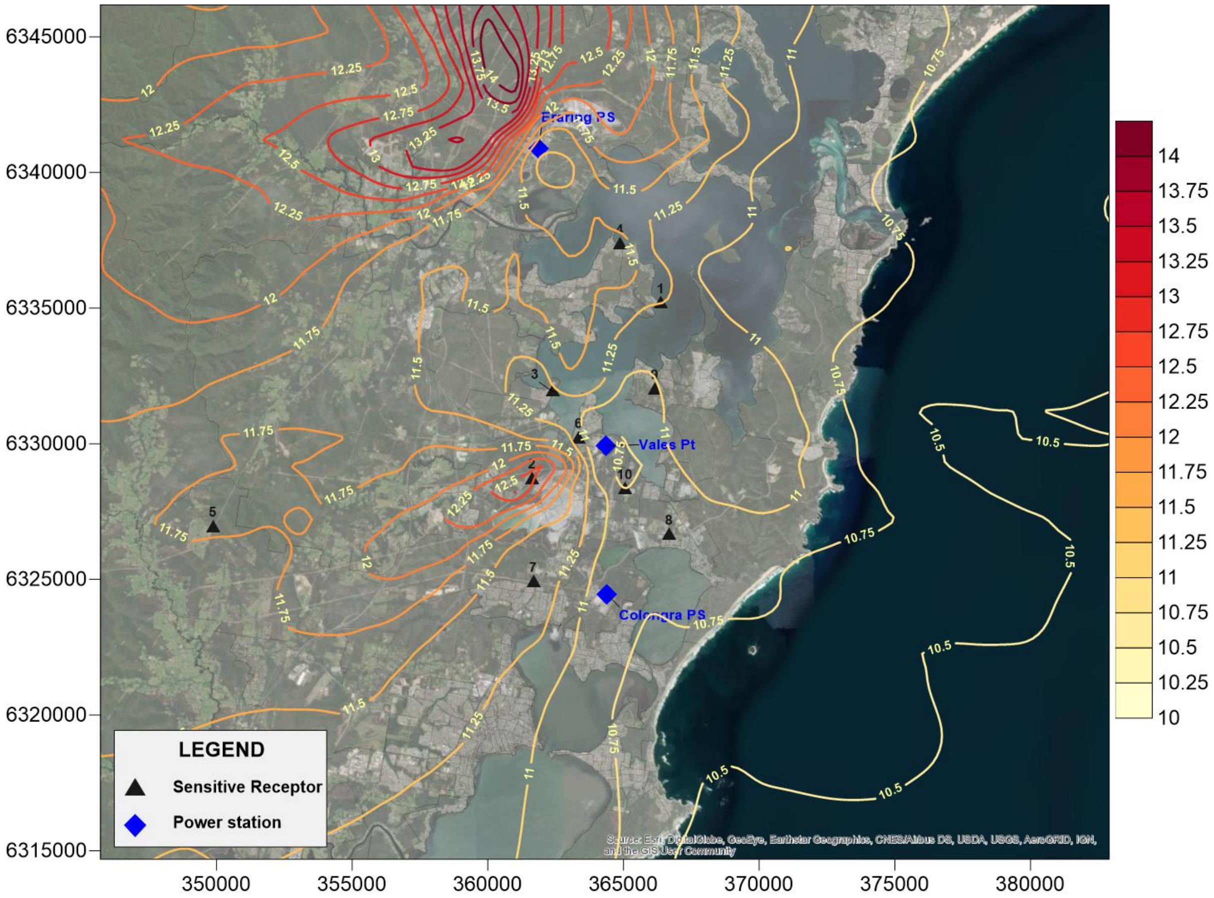


**Figure 129** Maximum annual average ground-level concentrations of $NO_2$ (µg/m$^3$) – Cumulative – Achieve Group 6 standard of concentration

# 8. CONCLUSIONS

Air quality on the Central Coast is generally good, with the only measured exceedances of the air quality standards in recent years relating to high particulate concentrations during natural events, specifically regional dust episodes or bushfires. Analysis of local monitoring data has demonstrated that the contribution of VPPS to measured annual mean concentrations of $SO_2$, NOx and, in particular $PM_{2.5}$ is small. However, the influence of emissions from VPPS on concentrations of $SO_2$ and NOx is evident at the specific times when the monitors are downwind of the power station, albeit with total concentrations still well below the air quality standards.

A review of the literature on regional ozone formation, secondary particulate formation and inter-regional transport of air pollutants has also been carried out, focused on identifying the potential contribution of emissions from VPPS to any such processes. It is expected that measures to reduce NOx and $SO_2$ emissions at VPPS would not have a discernible impact on ozone or secondary particulate concentrations across the NSW Greater Metropolitan Region, with any resultant change likely to fall well within the uncertainty bounds of the instruments used for the measurements. There is, therefore, no justification for performing an in-depth inter-regional pollution transport study for this application.

Analysis of emissions data from VPPS over the period 2010 to 2020 has concluded that concentrations of all air pollutants have been below the EPL limits in recent years and, with the exception of NOx, below the Group 6 Clean Air Regulation limits. NOx concentrations in the stack emissions have been consistently reducing over time.

It should be noted that the burner tips on Boiler 6 at VPPS were replaced with low-NOx burner tips earlier in 2021, thus the emissions modelled in this report are likely to over-state ground-level concentrations of $NO_2$ with the new low-NOx burner tips in place. Experience over the last five years at VPPS with low-NOx burner tips installed on Boiler 5 is that the Group 5 standard of concentration for NOx has been met for >99% of the time. It is likely that the same outcome will now be achieved for Boiler 6 at VPPS following installation of the low-NOx burner tips.

Dispersion modelling has been conducted of all regulated air pollutants from VPPS including NOx, $SO_2$, particulate matter (as $PM_{10}$ and $PM_{2.5}$), fluoride and metals. This modelling has demonstrated that emissions from VPPS contribute a relatively small amount to ground-level concentrations of most pollutants (with the exception of $NO_2$ and $SO_2$). For these air pollutants there is no risk of exceedance of the assessment criteria.

Modelled ground-level annual average concentrations of $NO_2$ and $SO_2$ due to VPPS are a fraction of the respective assessment criteria.

The modelling has shown that the maximum 1-hour average concentrations of $NO_2$ associated with emissions from VPPS will not lead to any exceedances of the assessment criterion, in isolation.

Combining ground-level concentrations of $NO_2$ from VPPS with the contributions of other nearby power stations (namely Eraring and Colongra) and background concentrations only results in exceedances of the 1-hour average assessment criterion if an extremely conservative conversion ratio of NOx to $NO_2$ of 40% is assumed. This ratio was only applied as a sensitivity test and the application of the more realistic ratio for peak concentrations of 20% does not result in any exceedances of the assessment criterion. Comparison of modelled versus measured concentrations of $NO_2$ at the Wyee monitoring station has further demonstrated that the model performs very well when using the 20% conversion ratio.

It is, therefore, concluded that there will be no exceedances of the $NO_2$ assessment criteria in the vicinity of VPPS.

For maximum 1-hour concentrations of $SO_2$, some limited areas of exceedance of the assessment criterion of 570 $\mu g/m^3$ are predicted, inclusive of a small number of residential properties, but no more than one hour of exceedance is predicted in any one year. No exceedances of the 24-hour or annual average assessment criteria for $SO_2$ are predicted.

Ground-level concentrations of $SO_2$ from VPPS have been combined with the contributions of the other nearby power stations, and background concentrations, and comparison of modelled and measured concentrations of $SO_2$ at the Wyee monitoring station has demonstrated that the model significantly over-predicts concentrations of $SO_2$. Therefore, while the maximum 1-hour average model predictions exceed the assessment criterion over relatively large areas of the north-western part of the model domain, it is likely that these concentrations have been significantly over-predicted. This over prediction is shown by Origin Energy's measurements of ambient concentrations of $SO_2$ at Dora Creek where the maximum 1-hour average concentration of $SO_2$ in the period 2018-2020 was 188.1 $\mu g/m^3$. This is much lower than the maximum model prediction and is well below the assessment criterion.

In the vicinity of VPPS, no more than two hours of exceedance are predicted in any one year; bearing in mind the model over-predictions, it would seem likely that the assessment criterion will not be exceeded in the vicinity of VPPS.

It is, therefore, concluded that exceedances of the 1-hour, 24-hour or annual mean criteria for $SO_2$ are highly unlikely in the main area of influence of VPPS. Exceedances may occur closer to Eraring but it is important to note that its emissions and therefore potential impacts are likely to have been over-stated. The contribution of VPPS concentrations of $SO_2$ near Eraring was found to be minimal.

Exceedances of the 10-minute average criterion are possible, but these have not been investigated in detail in this study because easy compliance with the criterion has been achieved at the 99.9th percentile. Any such exceedances would be very limited in number, and comparison of modelled versus measured $SO_2$ concentrations at the Wyee monitoring station suggests that concentrations have been over-predicted, especially at the highest concentrations. As such, exceedances of the 10-minute average criterion unlikely.

To estimate the reduction in emissions of NOx due to the application of Group 5 and Group 6 standards of concentration, the time varying emissions from the last three years of operations have been amended so that any NOx concentrations that exceed the respective limits are replaced with the relevant Group limit value. For Group 5 at least, relatively few hours of data had to be replaced. This analysis demonstrates that, relative to emissions in 2018, 2019 and 2020, the total annual emissions of NOx with the application of the Group 5 standard of concentration reduce by between 1.4 and 5.4%, depending on the year, while the application of the Group 6 standard of concentration reduces total annual emissions of NOx by between 27.1 and 33.0%, depending on the year. However, low-NOx burner tips were installed in Boiler 6 earlier in 2021, and Boiler 6 has historically had much higher NOx emissions than Boiler 5. As such, this analysis is likely to greatly over-state the emissions reductions that would occur with achievement of the limits, and it has been estimated that the realistic scale of reductions in annual mass emissions of NOx would be around 0.5% with achievement of the Group 5 standard of concentration and around 20% with achievement of the Group 6 standard of concentration.

Dispersion modelling has been repeated for the emission scenarios where the Group 5 and Group 6 standards of concentration for NOx are achieved. Taking VPPS in isolation, adoption of the Group 5 and Group 6 standards of concentration for NOx would reduce the maximum 1-hour average concentration of $NO_2$ anywhere on the modelled grid by 4.5% and 50.5%, respectively, relative to emissions in 2018-2020. Maximum annual average concentrations of $NO_2$ due to VPPS in isolation adopting the Group 5 and Group 6 standards of concentration would reduce by 5.0% and 30.9%, respectively, relative to emissions in 2018-2020. Actual reductions will be much lower because these results do not account for the installation of low-NOx burner tips in Boiler 6 in 2021.

For the cumulative concentrations of $NO_2$, the implementation of Group 5 and Group 6 standards of concentration at VPPS provides much smaller overall changes. Maximum 1-hour average concentrations of $NO_2$ would reduce by 4.5% with the implementation of the Group 5 standard of concentration, and by around 12.6% with the implementation of the Group 6 standard of concentration, relative to emissions in 2018-2020. Maximum annual average concentrations of $NO_2$ are predicted to reduce by just 0.7% with the implementation of the Group 5 standard of concentration, or 2.9% with the implementation of the Group 6 standard of concentration, relative to emissions in 2018-2020. Actual reductions will be much lower because these results do not account for the installation of low-NOx burner tips in Boiler 6 in 2021.

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# APPENDIX A METEOROLOGICAL AND DISPERSION MODELLING METHODOLOGY

## A1 METEOROLOGY

### A1.1 TAPM meteorology

TAPM (The Air Pollution Model) was developed by the CSIRO and has been validated by the CSIRO, Katestone and others for many locations in Australia, in south-east Asia and in North America (CSIRO, 2008). Katestone has extensive experience with TAPM for sites throughout Australia and in parts of America, Bangladesh, New Caledonia and Vietnam. The model performs well in simulating regional wind patterns and has proven to be a useful tool for simulating meteorology in locations where monitoring data is unavailable.

TAPM is a prognostic meteorological model which predicts the flows important to regional and local scale meteorology, such as sea breezes and terrain-induced flows from the larger-scale meteorology provided by the synoptic analyses. TAPM solves the fundamental fluid dynamics equations to predict meteorology at a mesoscale (20 km to 200 km) and at a local scale (down to a few hundred metres). TAPM includes parameterisations for cloud/rain micro-physical processes, urban/vegetation canopy and soil, and radiative fluxes.

TAPM requires synoptic meteorological information for the region. This information is generated by a global model similar to the large-scale models used to forecast the weather. The data were supplied on a grid resolution of approximately 75km, and at elevations of 100m to 5km above the ground. TAPM uses this synoptic information, along with specific details of the location such as surrounding terrain, land-use, soil moisture content and soil type to simulate the meteorology of a region as well as at a specific location.

TAPM version 4.0.4 was configured with the following parameters:

- 1 January 2018 to 31 December 2020 modelled
- 45 x 45 grid point domain with an outer grid of 30 km and nesting grids of 10 kilometres, 3 kilometres, and 1 kilometre.
- Grid centred the Vales Point Power Station site (-33°9.5’, 151°32.5’).
- Geoscience Australia 9-second digital elevation model terrain data.
- Default land use data edited for consistency with aerial imagery, and urban areas edited to urban low.
- 25 vertical grid levels.
- Advanced options set to default.
- Data from the BoM monitoring stations at Norah Head assimilated with a radius of influence of 10km over 3 vertical levels with a quality factor of 1.
- Data from the BoM monitoring stations at Cooranbong assimilated with a radius of influence of 6km over 2 vertical levels with a quality factor of 0.7.

### A1.1.1 Wind speed and wind direction

The annual, seasonal and diurnal distributions of winds predicted by TAPM for 2018, 2019 and 2020 are presented in Figure A1, Figure A2 and Figure A3, respectively.

The winds across all three years are generally light to moderate with an average wind speed of 2.73 to 2.79 m/s and predominant north-easterlies, southerlies and west-south-westerlies (Figure A1).

There is a variation in wind direction throughout the seasons of the year (Figure A2). Spring and summer are characterised by predominant north-easterly winds. During autumn, winds are predominantly from the south, and westerlies are most frequent during winter.

There is a marked variation in both wind direction and wind speed during the day and night, with wind speeds increasing throughout the day to be at their strongest during the afternoon (midday – 6pm) and lightest overnight (Figure A3).

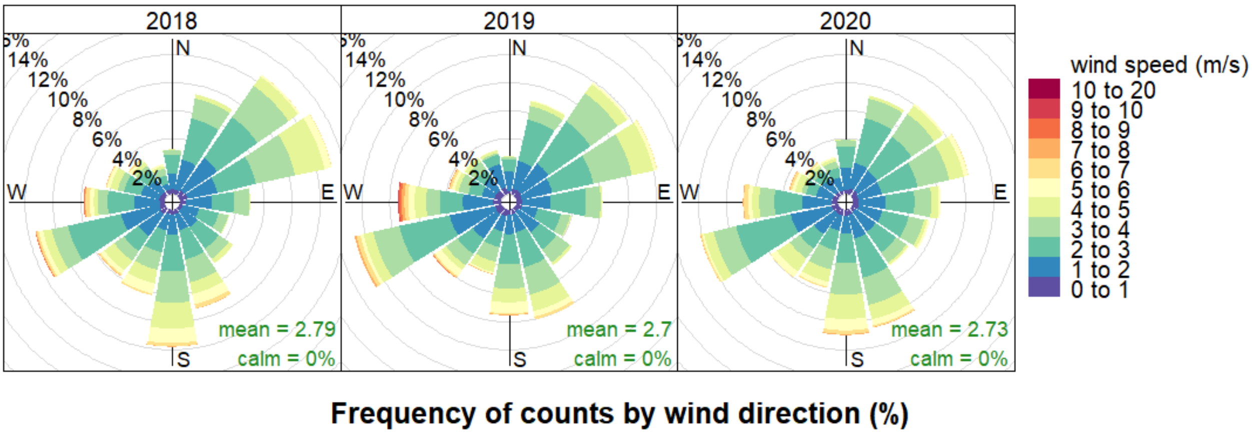

**Figure A1** **Annual distribution of winds at the Project site predicted by TAPM for 2018, 2019 and 2020**

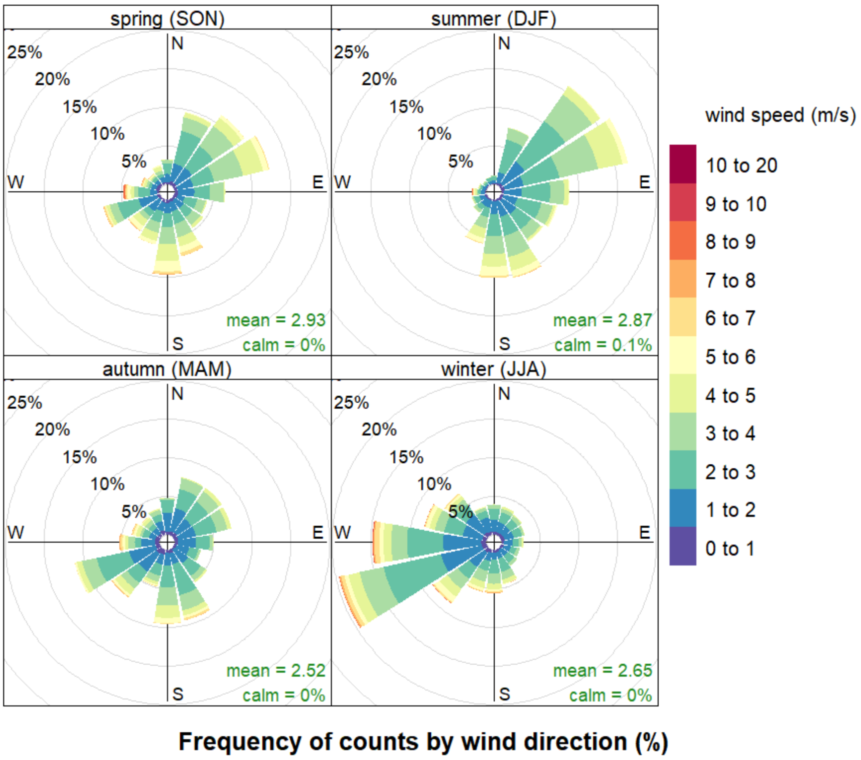

**Figure A2** Seasonal distribution of winds at the Project site predicted by TAPM for 2018, 2019 and 2020

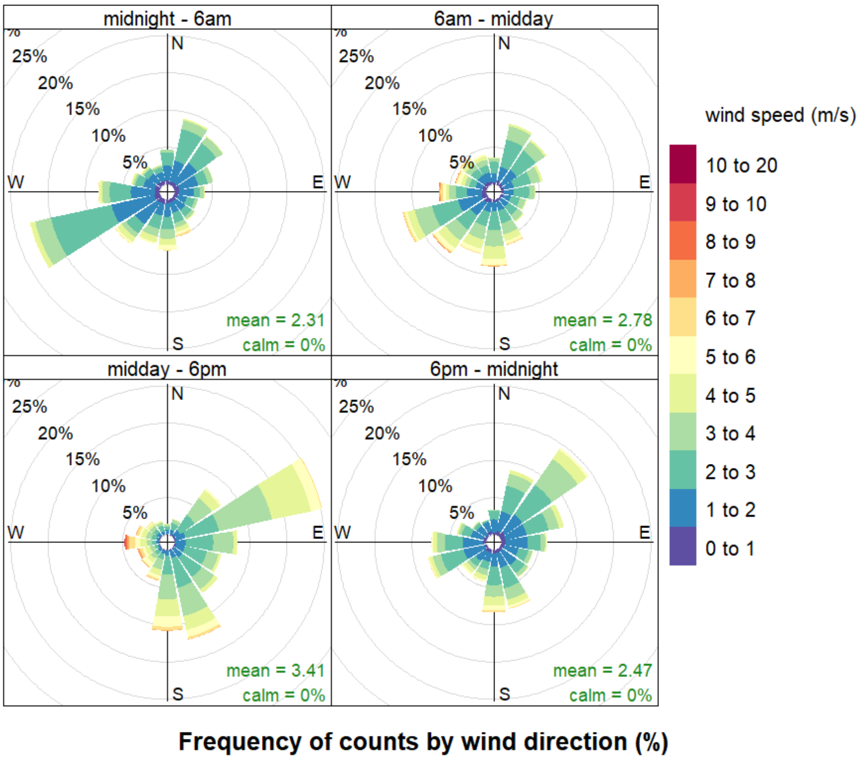

**Figure A3** Diurnal distribution winds at the Project site predicted by TAPM for 2018, 2019 and 2020

### A1.1.2 Atmospheric Stability and Mixing height

Stability classification is a measure of the stability of the atmosphere and can be determined from wind measurements and other atmospheric observations. The stability classes range from A Class, which represents very unstable atmospheric conditions that may typically occur on a sunny day, to F Class stability which represents very stable atmospheric conditions that typically occur during light wind conditions at night. Unstable conditions (Classes A to C) are characterised by strong solar heating of the ground that induces turbulent mixing in the atmosphere close to the ground. This turbulent mixing is the main driver of dispersion during unstable conditions. Dispersion processes for Class D conditions are dominated by mechanical turbulence generated as the wind passes over irregularities in the local surface. During the night, the atmospheric conditions are generally stable (often Classes E and F).

Figure A4 shows the distribution of stability classes at the Project site extracted from the TAPM dataset, where Class A represents the most unstable conditions and Class F represents the most stable. Neutral (D class) conditions are present throughout the day, comprising 46% of total time. Very stable (F class) conditions are the next most frequent (26% of total time) and only occur between 5 pm and 6 am.

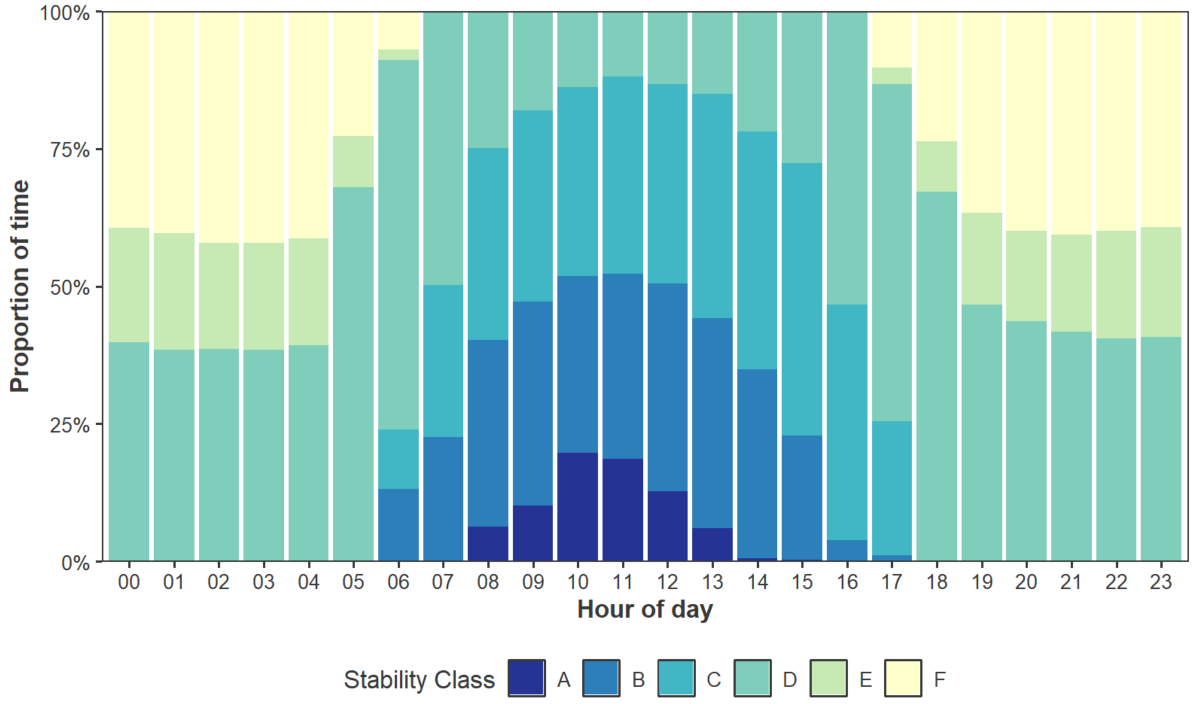

**Figure A4** **Frequency distribution of atmospheric stability conditions at the Project site predicted by TAPM/CALMET**

The mixing height defines the height of the mixed atmosphere above the ground (mixed layer), which varies diurnally. Particulate matter or other pollutants released at or near the ground will become dispersed within the mixed layer. During stable atmospheric conditions, the mixing height is often quite low and particulate dispersion is limited to within this layer. During the day, solar radiation heats the ground and causes the air above it to warm, resulting in convection and an increase to the mixing height. The growth of the mixing height is dependent on how well the warmer air from the ground can mix with the cooler upper level air and, therefore, depends on meteorological factors such as the intensity of solar radiation and wind speed. Strong winds cause the air to be well mixed, resulting in a high mixing height.

Mixing height information extracted from the TAPM dataset at the Project site is presented in Figure A5 as a diurnal frequency (box and whisker) plot. The data shows that, on average, the mixing height develops around 7 am and peaks at 12 pm before descending until 6 pm.

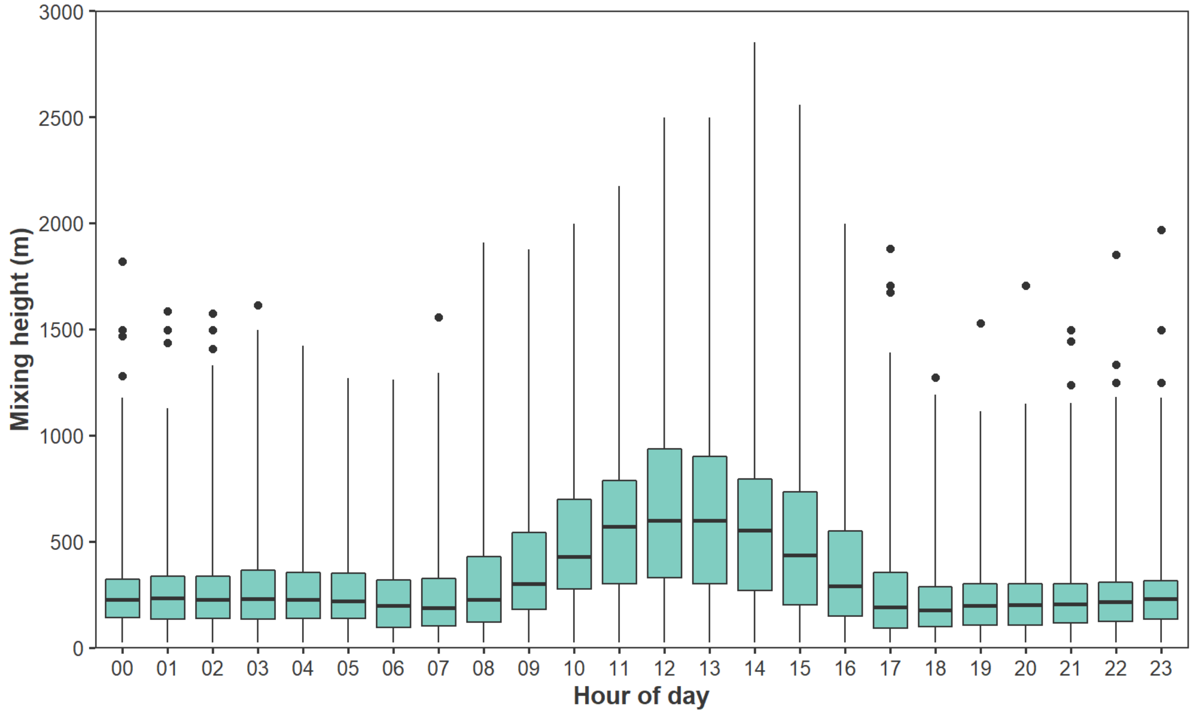

**Figure A5** Diurnal profile of mixing height at the Project site predicted by TAPM for 2018, 2019 and 2020

## A1.2 Local terrain and land-use

Vales Point power station is located at an elevation of less than 10m above sea level, on the edge of one of Lake Macquarie's many bays, approximately 8km west of the coast. To the east, most land is covered by the Lake Macquarie and Munmorah state conservation areas and rises to approximately 60m above sea level. Small residential areas are also located on the edges of Lake Macquarie and scattered across the wider area, with the nearest being located approximately 600m northwest of the power station. Approximately 7.5km to the west, the Pacific Motorway runs north/south and terrain generally increases further west to heights of approximately 200m 20km from the power station.

## A1.3 Comparison of TAPM output with observational data

The model validation in the following sections compares observational meteorological data with data derived from running TAPM.

Table A1 presents statistical comparisons of TAPM output (wind speed and temperature) to meteorological data recorded at the BOM meteorological monitoring site located at Norah Heads, while Table A2 presents a comparison for the Cooranbong meteorological monitoring site. The TAPM output was extracted from the closest inner grid point to the location of each meteorological monitoring site.

The following statistical measures of model accuracy are presented in the tables:

The mean bias, which is the mean model prediction minus the mean observed value. Values of the mean bias close to zero show good prediction accuracy.

The root mean square error (RMSE), which is the standard deviation of the differences between predicted values and observed values. The RMSE is non-negative and values of the RMSE close to zero show good prediction accuracy. The RMSE is given by:

$$\mathrm{RMSE} = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(P_i - O_i)^2}$$

Where:

$N$ is the number of observations,

$P_i$ are the hourly model predictions and

$O_i$ are the hourly observations.

The index of agreement (IOA), which takes a value between 0 and 1, with 1 indicating perfect agreement between predictions and observations. The IOA is calculated following a method described in Willmott (1982), using the equation:

$$\mathrm{IOA} = 1 - \frac{\sum_{i=1}^{N}(P_i - O_i)^2}{\sum_{i=1}^{N}(|P_i - O_{mean}| + |O_i - O_{mean}|)^2}$$

Where:

$N$ is the number of observations,

$P_i$ are the hourly model predictions,

$O_i$ are the hourly observations and

$O_{mean}$ is the observed observation mean.

**Table A1 A comparison of the observed meteorological data with the first-level TAPM output at Norah Heads**

| Statistic | "Good" value | Wind speed | | | Temperature | | |
|---|---|---|---|---|---|---|---|
| | | Benchmark | Observational data | TAPM | Benchmark | Observational data | TAPM |
| Mean | - | - | 4.7 | 3.8 | - | 18.6 | 18.7 |
| Standard deviation | - | - | 2.9 | 2.0 | - | 4.5 | 3.8 |
| Minimum | - | - | 0.0 | 0.0 | - | 5.3 | 7.9 |
| Maximum | - | - | 20.1 | 14.3 | - | 40.8 | 37.6 |
| Bias | 0 | <±0.5 m/s | -0.88 | | <±0.5 °C | 0.06 | |
| Root mean square error (RMSE) | Close to 0 | <2 m/s | 1.37 | | - | 1.94 | |
| Index of agreement | Close to 1 | >0.6 | 0.93 | | ≥0.8 | 0.94 | |

**Table A2** A comparison of the observed meteorological data with the first-level TAPM output at Cooranbong

| Statistic | "Good" value | Wind speed | | | Temperature | | |
|---|---|---|---|---|---|---|---|
| | | Benchmark | Observational data | TAPM | Benchmark | Observational data | TAPM |
| Mean | - | - | 1.2 | 2.9 | - | 17.3 | 18.3 |
| Standard deviation | - | - | 1.4 | 1.5 | - | 6.6 | 4.7 |
| Minimum | - | - | 0.0 | 0.0 | - | -3.2 | 4.7 |
| Maximum | - | - | 9.3 | 10.2 | - | 44.2 | 38.7 |
| Bias | 0 | <±0.5 m/s | -1.67 | | <±0.5 °C | 0.99 | |
| Root mean square error (RMSE) | Close to 0 | <2 m/s | 2.65 | | - | 5.92 | |
| Index of agreement | Close to 1 | >0.6 | 0.41 | | ≥0.8 | 0.69 | |