INDEPENDENT AIR QUALITY REVIEW

NORTHCONNEX (M1-M2) PROJECT

SSI-6136

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1 SUMMARY

The preliminary review of the NorthConnex Technical working paper: Air quality (Air Quality Impact Assessment, AQIA) (**AECOM, 2014a**) found no major technical error in the modelling but identified some omissions and aspects of the report that require clarification. The Proponent has provided the necessary information in its Response to Submissions report, *Environmental Impact Statement – Submissions and Preferred Infrastructure Report (SPIR)* (**AECOM, 2014b**), and has adequately addressed the issues raised in the preliminary review, which included examination of elevated receptors, in-tunnel air quality and the assessment of a worst case emissions scenario and clarification of a range of matters.

The subsequent detailed review examined the updated modelling files in detail and did not identify any significant issues. The review examined model performance under the predicted worst case dispersion conditions. The peak hour of impact was found to be anomalous due to model limitations, and to overestimate the effects at receptors by a large margin.

Regardless, the results clearly show that the stack design performs well at dispersing air emissions above ground level. The good performance is related to two important features of the tunnel design; the placement of the stack near to the exit portal; and, a variable velocity stack configuration. These design elements, or a design with equivalent or better performance under the full range of operating conditions should be maintained in the final detailed tunnel design.

Although the issue of using overly conservative assumptions was identified in the preliminary review, it was not considered to be significant. However the revised assessment increased NO_2 emissions by 60% at the request of the NSW EPA, but did not refine the other assumptions. The review identified that overestimation of potential NO_2 impacts is a significant issue in the revised assessment which consequently does not present the likely NO_2 effects that may be experienced by the community.

The review therefore conducted an independent, conservative screening level assessment of potential NO_2 impacts in the community arising from the operation of the stacks, and found that the peak 1-hour maximum NO_2 level over the year would be many times lower than that calculated by the proponent (using the identical air dispersion modelling results). The Proponent's over predictions arise mainly from overly conservative application of background data and a conservative NO_x to NO_2 conversion method.

The AQIA and SPIR conclude that the Project, on balance, has an overall positive effect on surface air quality for the population. The conclusions arise for two key reasons; firstly the Project will remove heavy vehicles from Pennant Hills Road, and even if these heavy vehicles are in future replaced by passenger vehicles, this would still result in a net air quality improvement for receptors along Pennant Hills Road as the heavy vehicles are a significantly larger source of emissions than any cars that may in future replace them on the road.

Secondly, the modelling results show that the stack design results in a significant dilution of in-tunnel pollutant concentrations at ground level near the stacks. The concentrations at the locations most affected by the stacks are low, and the total effect on air quality is within the normal variability recorded in the ambient air quality levels across Sydney. Thus the potential change due to the Project is unlikely to alter the existing situation significantly.

The review thus supports the Proponent's conclusions and recommends appropriate approval conditions that would ensure that the Project does not adversely affect tunnel users and the community.

2 INTRODUCTION

This report has been prepared by Todoroski Air Sciences (TAS) for the Department of Planning and Environment. The report presents an Independent Air Quality Review for the NorthConnex (M1-M2) Project SSI-6136 (hereafter referred to as the Project) proposed by Roads and Maritime Services (referred to as the Proponent).

This report summarises the findings of the preliminary review of the NorthConnex Technical working paper: Air quality (Air Quality Impact Assessment, AQIA) (**AECOM, 2014a**). A detailed review of the AQIA including the technical air dispersion modelling files is also provided, along with the Proponent's response to the preliminary review and an outline of pertinent matters. The key technical issues are discussed in the body of the report, and the complete list of technical issues examined in the review is summarised in **Table A-1** in **Appendix A,** which includes a summary of the issue, the Proponent's response to the issue and any review comments that may be relevant.

3 SCOPE OF THE REVIEW

3.1 Scope of the preliminary review

The preliminary review covers the following:

- *Review the air quality assessment in the Environmental Impact Statement (EIS) and comment on the technical adequacy and completeness of the air quality impact assessment. The Preliminary Review shall take into account relevant air quality guidelines, requirements and legislation. The review shall include, but is not limited to:*
    - *assessment of the assessment methodology and approach (including selection of ambient air quality monitoring locations and collation of baseline data, and selection of model/calculation approach) with reference to the Approved Methods for the Modelling and Assessment of Air Pollutants in NSW (EPA 2005) and air quality impact assessment best practice; and*
    - *analysis of the results of the air quality impact assessment, including the impacts of the proposal on in-tunnel, local and regional air quality, with reference to applicable legislation, guidelines and comparable projects;*
- *Consider whether additional information is required to address gaps in the air quality impact assessment. The consultant shall take into account relevant statutory and non-statutory guidelines and requirements for the assessment of air quality impacts; and*
- *Prepare a report on the findings of the Preliminary Review.*

3.2 Scope of the EIS review

A detailed review of the EIS follows the preliminary assessment, and covers the following:

a. Consolidate the findings of the Preliminary Review, following department comments on the report required under task 3.1・・;

b. review the appropriateness and effectiveness of management and mitigation measures recommended for the Project, taking into account relevant guidelines, industry best practice and research or monitoring evidence (preferably published);

c. review agency comments on the air quality impact assessment;

d. review the RMS reports submitted following exhibition:

- when the response to submissions report is submitted — review the RMS response to air quality impacts raised in submissions received on the proposal; and
- if a preferred infrastructure report is submitted — undertake a review of the air quality impacts of the amendments to the proposal; and

e. prepare a report on the findings of the EIS Review, including:

- adequacy and completeness of the air quality impact assessment;
- compliance of the Project with applicable legislation and guidelines;
- adequacy and appropriateness of the management and mitigation measures recommended for the Project; and
- recommended actions and conditions of approval that could be applied to avoid, minimise, mitigate, and/or manage the residual air quality impacts (should the department recommend approval of the Project).

4 FINDINGS OF THE PRELIMINARY REVIEW OF THE AIR QUALITY ASSESSMENT

The sections below provide an outline of key findings of the preliminary of the review.

Table A-1 in **Appendix A** summarises the key regulatory requirements that were considered in the review, the proponent's response to any matters raised in the preliminary review and where relevant, any subsequent review comments.

The AQIA uses several meteorological models which apply a range of measured weather data in developing a large, three-dimensional, hourly varying meteorological file for the region, and nested within this a more spatially detailed meteorological file that was applied in the air dispersion models. The meteorological models consider local terrain effects. The air dispersion models calculate how air pollutants are released and how they are dispersed under the effects of the meteorology. The models were run for each hour, for up to three years to calculate the pollutant concentrations that may occur at receptors.

Two air dispersion models were used, the CAL3QHCR traffic model was used to calculate roadside emissions at a large number of road cross sections along Pennant Hills Road. This model uses hourly varying meteorological and traffic emissions data specific to each section of the road.

The CALPUFF model was used to calculate ground level concentrations near the stacks, using hourly varying meteorological data, for various scenarios, including constant worst case emissions for every hour of the year.

The results are presented in the AQIA tables and isopleths (pollution contours) showing the effects of the Project.

The traffic emissions data for the Project were calculated based on standard traffic emissions factors, it is noted that a peer review of the factors was conducted and is described in the AQIA.

Background data (i.e. the existing pollutant concentrations in the ambient air) were added to the predicted effects to determine the total cumulative effects that may arise.

Overall, the preliminary review of the AQIA found that there does not appear to be any significant technical error with the modelling, as apparent from examination of the report. A detailed, point by point examination of the AQIA report per the technical requirements of the NSW EPA Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales **DEC (2005)** is presented in **Table A-1** in **Appendix A**.

A response as relevant to each issue identified in the review is provided in **Table A-1** in **Appendix A.**

The preliminary review identified several aspects of the AQIA that did not meet some of the technical requirements of the Approved Methods.

It is observed that the Approved Methods are not designed for, and are not directly applicable to the assessment of road projects, but in the absence of specific guidelines for road projects, it is industry practice to adopt the best applicable requirements of the Approved Methods, and to apply the principles therein.

Overall the preliminary review found that in general the key environmental air quality requirements are adequately addressed, that the AQIA is generally adequate, it follows a valid but generally conservative methodology and that no significant issue in regard to the robustness of the technical air dispersion modelling is apparent.

The overly conservative nature of the assessment, in making the most conservative assumption at almost every step in the assessment calculations was discussed in the preliminary review. As the AQIA showed a large margin of compliance with criteria, no significant issues were found due to over-conservatism in the approach and overestimation of potential impacts in the preliminary review. The issue of conservatism in the assessment approach is however discussed in more detail later in this report in the context of the need for the community to be provided with a realistic estimate of likely impacts, and the revised assessment increasing NO_2 emissions by 60% at the request of the EPA. (EPA suggested a NO_2 to NO_x ratio of 16% from vehicle emissions be applied and this results in an increase of up to 60% of the 1-hr average NO_2 concentration, see page 296, Volume 1 of the SPIR.)

The preliminary review found that some aspects of the AQIA were incomplete, and required further assessment and clarification. These aspects included:

1. Elevated receptors (for example, high apartment blocks) near stacks needed to be assessed;

2. Emission concentrations from the stacks were not shown;
3. Insufficient detail was provided to permit the reviewer to determine whether the worst case situation for in-tunnel air quality had been assessed.

A discussion of the Proponent's response to these key aspects, and the related issues is outlined below.

4.1 Response to the key issues identified in the preliminary review

4.1.1 Elevated receptors

The AQIA was found to be incomplete in regard to predicted impacts at elevated receptors in the vicinity of each of the stacks. Elevated receptors include the upper levels of multistorey buildings. The Approved Methods requires the assessment to be made at all existing and likely future sensitive receptors. There are presently elevated receptors in the vicinity of the stacks and it is likely that there will be new elevated receptors in the vicinity of the stacks in future.

The preliminary review recommended that an assessment of the potential impacts on elevated receptors in the vicinity of the stacks be provided. This may be important as it could be used by state and local planning bodies to control the permitted height of new elevated receptors in the vicinity of the stacks, such that pollutant effects on any future elevated receptors can be managed.

The Proponent's response to this issue is as follows:

> *Assessment of potential air quality impacts at elevated receivers is provided in response to the submission from Ku-ring-gai Council (refer to page 685 to page 688, Section 7.3.1 of the submissions and preferred infrastructure report).*

Pages 684 to 687, Chapters 5 – 7, of the SPIR outline the same issue raised by Ku-ring-gai Council, and the Proponent's detailed response to the issue.

The response is generally adequate, but appears to imply that potential effects at more distant elevated locations would also be *"beyond the extent of measureable air quality effects"* on the basis of the low effects at more distant locations at ground level. This may not be strictly correct as generally the effects above ground level at any location near a stack would be greater than the ground level effects at the same location. However, given the low emissions rates from the stacks in the first instance, the thrust of what is implied is valid because it is reasonable to expect generally low levels at more distant locations (either at or above ground level).

The Proponent conducted a screening level assessment at elevated receptors up to a height of 20 m, which is approximately the height of a six or seven storey apartment. The Proponent's results are presented in Table 7-31, on Page 687, of the SPIR (**AECOM, 2014b**).

The predicted pollutant concentrations at the elevated locations at various distances away from the stacks are not presented in the response, limiting the usefulness of the response in regard to good practice future planning decisions in the vicinity of the stacks. Also only limited information is provided in regard to the Southern ventilation outlet. It is noted that due to the downhill grade it would be reasonable to expect that the emissions and hence effects would be lower for the southern outlet, however as the location is not as well exposed to the regionally prevailing winds, this may mean there is less dispersive potential in the southern area relative to the northern area.

As the issue was raised in the preliminary review and has not been comprehensively detailed by the Proponent, TAS re-ran the Proponent's CALPUFF modelling for all of the scenarios as part of its independent review.

The results from the TAS modelling identified that Scenario 3 (Design Analysis A) would have the most potential for impact and this scenario was therefore modelled in more detail to examine the potential for effects to arise at elevated receptors in the vicinity of both the Northern and Southern ventilation outlets.

The results for the northern ventilation outlet are presented in **Table 1** at various distances out to 2,000m from the ventilation outlet, and various heights up to 72m above ground level. The results for the southern outlet contain lower values and hence are not presented.

The results shown in red font and red shading indicate the most impacted receptors at various distances, at each receptor height examined. The light grey shaded parts of the table indicate where there may be a discernible or potentially measureable effect.

Table 1: Modelling data obtained by running Proponent's model - 24-hour average PM_{10} results ($\mu g/m^3$)

North	Receptor height above ground level (m)t						
Distance from site (m)	0	12	24	36	48	60	72
30	0.5	6.1	47.7	121.9	87.9	56.6	52.2
40	0.6	9.3	55.4	105.9	75.9	56.6	42.0
50	0.6	2.2	15.2	44.2	52.5	41.2	26.9
60	1.1	4.4	27.8	58.2	50.7	45.1	29.0
70	0.6	0.7	10.7	44.8	38.1	35.1	24.5
80	1.4	3.1	19.0	47.1	44.8	35.1	27.0
90	0.6	1.1	12.7	34.6	33.0	28.7	21.4
100	1.4	2.6	14.6	23.5	29.6	25.1	23.5
200	1.7	2.5	12.3	34.2	33.2	25.5	20.2
300	1.8	2.4	6.5	12.4	12.7	13.3	11.3
400	1.5	1.8	3.5	5.4	6.5	7.4	6.6
500	1.4	1.5	2.0	3.3	4.2	4.2	4.4
600	1.1	1.2	1.8	2.4	2.9	3.4	3.3
700	1.1	1.2	1.4	1.7	2.2	2.5	3.0
800	1.1	1.2	1.4	1.7	1.9	2.1	2.3
900	1.0	1.0	1.2	1.4	1.6	1.8	1.9
1000	0.9	0.9	1.0	1.2	1.3	1.6	1.7
1100	0.9	0.9	1.0	1.1	1.1	1.3	1.5
1200	0.8	0.8	0.9	0.9	1.1	1.4	1.4
1300	0.7	0.7	0.8	0.9	1.1	1.3	1.3
1400	0.6	0.7	0.7	0.8	1.0	1.2	1.2
1500	0.6	0.6	0.6	0.8	1.0	1.2	1.1
1600	0.6	0.6	0.6	0.7	0.9	1.0	1.1
1700	0.5	0.5	0.6	0.6	0.8	0.9	0.9
1800	0.4	0.5	0.5	0.6	0.7	1.1	0.9
1900	0.4	0.4	0.4	0.5	0.6	0.7	0.8
2000	0.4	0.4	0.4	0.5	0.6	0.6	0.8

The data indicate that for planning purposes, there is no significant air quality constraint due to the Project on receptors up to 12 m high (~4 storey's), but beyond this height elevated receptors several hundred metres away may experience some tangible effect. Overall, the application of good planning practice indicates that in the interim, it would be preferable to limit the upper height of new receptors to:

- 2 storey's high within 60m of the ventilation outlets;
- 12m high (~4 storeys) within 300m of the ventilation outlets;
- 36m high (~12 storeys) within 500m of the ventilation outlets;

This interim suggestion should be reviewed after operation of the tunnel commences and there has been verification of the actual emissions rates, which are likely to be lower than applied in the assessment.

4.1.2 Stack emissions concentration

The AQIA did not provide the in-stack emission concentrations, or sufficient technical detail to enable the preliminary review to conclusively determine whether the worst case situation for in-tunnel air quality had been assessed, and some clarification in this regard was requested.

The Proponent's summary response to this issue is as follows:

> *Table 2-38 (forecast traffic 2019), Table 2-39 (forecast traffic 2029), Table 2-40 (design analysis A), Table 2-41 (design analysis B 2019) and Table 2-42 (design analysis B 2029) on page 152 to page 161 of the submissions and preferred infrastructure report provide the emissions inventories for the air quality impact assessment as mass emission rates and discharge concentrations.*

The review notes that the requested data are provided in the SPIR as outlined by the Proponent.

The data appear to be hourly average values, per hour of day, for the key pollutants for each ventilation outlet, and for each of the scenarios assessed. The data are summarised in **Table 2.**

The values presented in **Table 2** for Scenarios 2a, 2b and 3 correspond with the maximum 1-hour average concentration of emissions over the day. As scenarios 4a and 4b apply a constant emission concentration over the day, the values presented in **Table 2** for these two scenarios correspond with the maximum 1-hour average mass emission rates over the day. The maximum emission scenario results are shown in bold font.

Table 2: Maximum hourly stack emission rates and concentrations

Scenarios	South stack (S) / North stack (N)	Time of day	CO		NO_x		PM_{10}		$PM_{2.5}$	
			g/s	mg/m^3	g/s	mg/m^3	g/s	mg/m^3	g/s	mg/m^3
S2a	S	9:00	2.253	3.634	2.616	4.220	0.242	0.391	0.229	0.369
	N	18:00	3.774	6.088	5.424	8.748	0.319	0.515	0.302	0.487
S2b	S	9:00	2.686	4.333	2.930	4.725	0.293	0.472	0.276	0.446
	N	18:00	4.506	7.268	5.977	9.640	0.378	0.610	0.357	0.576
S3	S	9:00	5.321	8.582	6.098	9.836	0.569	0.918	0.538	0.868
	N	16:00	**6.346**	**10.236**	**9.982**	**16.100**	**0.614**	**0.990**	**0.580**	**0.936**
S4a	S	8:00-10:00, 15:00-17:00	2.253	3.634	2.616	4.220	0.242	0.391	0.229	0.369
	N	16:00-18:00	3.774	6.088	5.424	8.748	0.319	0.515	0.302	0.487
S4b	S	7:00-18:00	2.686	4.333	2.930	4.725	0.293	0.472	0.276	0.446
	N	10:00-19:00	4.506	7.268	5.977	9.640	0.378	0.610	0.357	0.576

It needs to be noted that the NO_x data have been provided, as shown in **Table 2**, and the NO_2 emission rates and levels would be a sub-fraction (i.e. 16%) of that for NO_x.

It also needs to be noted that the average in-tunnel (along tunnel length) pollutant concentrations would be substantially lower than these levels, and may be close to half of the level in **Table 2** when considering that tunnel emissions at the entrance start at a level equivalent to the ambient level and steadily increase along the length of the tunnel reaching a maximum near to the stack offtake.

4.1.3 Potential worst case in-tunnel air quality

Insufficient detail was originally provided to permit the preliminary review to identify that the worst case situation for in-tunnel air quality had been assessed, hence clarification was requested.

The Proponent's response to this issue is as follows:

> *Discussion of the worst case assessment scenario for the project is provided in Section 2.73 (from page 125 to page 127) of the submissions and preferred infrastructure report.*

Section 2.7.3 of the SPIR provides a clear outline of the various design scenarios and the rationale for selecting them.

The question of whether the SPIR has identified the worst case emissions scenario, rather than the maximum traffic scenario is not fully explained in Section 2.7.3, but is shown clearly in Table 2-3 of Section 2.5.1, (vol. 1 p58) of the SPIR. This section identifies the pollutant concentrations at the stack offtake at different traffic speeds, and shows that maximum in-stack concentrations correspond to operating speeds below 80km/hr.

4.1.4 Miscellaneous data

Other less significant issues such as providing the BPIP electronic modelling files, correcting omissions and minor errors or typos, and clarification of background monitoring data use are detailed in **Table A-1** in **Appendix A**.

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5 DETAILED REVIEW OF THE REVISED AIR QUALITY ASSESSMENT

5.1 Modelling scenario selection

The review notes that a range of scenarios were assessed by the Proponent. These are:

- Scenario 2(a and b) which is referred to as Expected 2019 and Expected 2029 traffic;
- Scenario 3, which is referred to as Design Analysis A; and
- Scenario 4(a and b) which is referred to as Design Analysis B (2019 and 2029);

The tunnel ventilation stack emission rates for these scenarios are presented in **Table 2** and Figure 1.

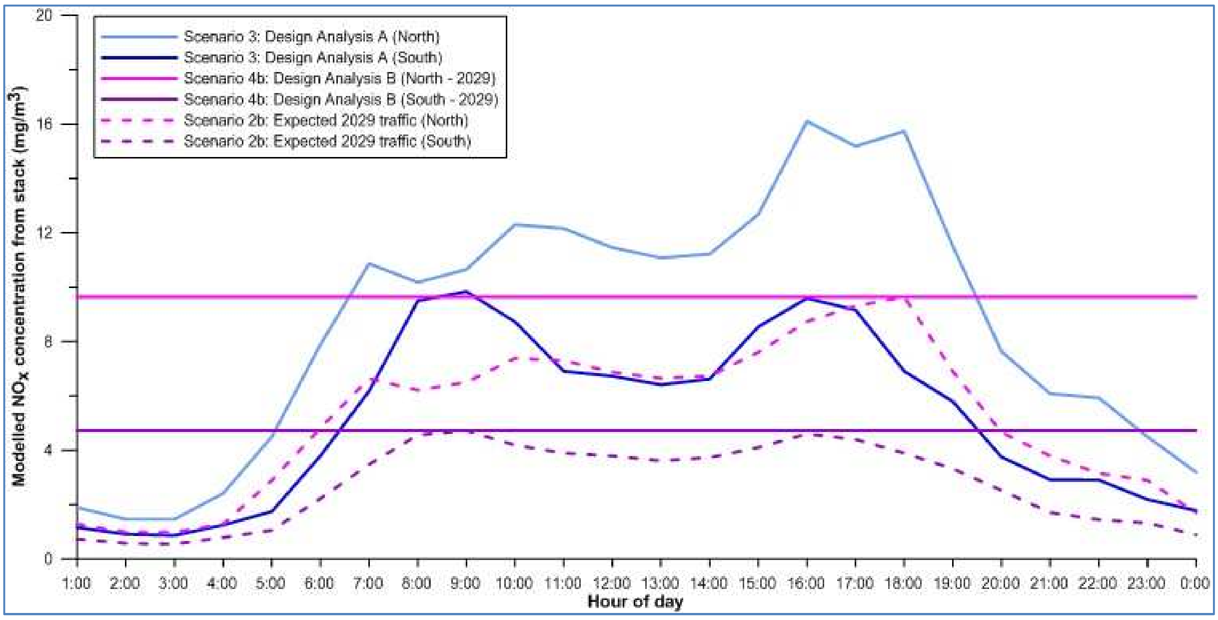

Figure 1: Maximum hourly stack emission rates and concentrations

Figure 1 shows that:

- the maximum hourly emissions over the day from the ventilation stacks per Scenario 3 follow the daily traffic profile for the hypothetical maximum traffic numbers (and emissions) that the tunnel can accommodate; and,
- a constant hourly stack emission rate is used for Scenario 4, and is set at the maximum rate in the peak hour expected for the actual traffic throughput profile (which is represented by Scenario 2).

Two key observations are apparent when comparing the scenarios, Scenario 2 and 4 will underestimate the hypothetical maximum emissions at peak traffic throughput during the day, and Scenario 4 will overestimate even the hypothetical maximum emissions in the night time.

The review considers that it is more important to not underestimate the theoretically possible stack emissions and thus considers that Scenario 3 (Design Analysis A) is the most relevant scenario to use when evaluating the likely upper bound of possible Project impacts.

The review also considers that it is preferable to provide a relatively realistic estimate of the upper bound of potential effects, and that significantly overestimating impacts at say 2 am (e.g. by approx. a factor of 10 fold per Scenario 4) when there is little actual prospect for such emissions is not ideal.

5.2 Air dispersion modelling results

The preliminary review did not identify any significant technical issue to be apparent in the modelling conducted.

The detailed review of the modelling files confirms that the modelling is generally correct, and that there is no key error or technical fault. The user selected modelling inputs appear to be reasonable, and the modelled results all show sensible trends. The review used three dimensional data analysis techniques and a physical check of the user input model settings in forming this view.

Some of the assumptions applied in estimating emissions and also in converting the modelled NO_x results to likely NO_2 results are not supported by the review. This matter affects the subsequent analysis and processing of the modelling results to produce the final predicted results, but does not affect the veracity of the actual air dispersion modelling results, and hence is discussed further in the next section.

TAS staff re-ran the modelling and produced the same results as those shown by the Proponent. All five scenarios were run for the highest emitting northern ventilation stack.

Scenario 3 (Design Analysis A) was found to have the greatest scope for potential impacts and was also run for the southern ventilation stack, and for both stacks at variable receptor heights up to 72m above ground level (corresponding to hypothetical potential future receptor locations up to approximately 24 storeys high). The results that TAS produced at ground level matched the Proponent's results, and it is safe to assume that the TAS results at the elevated receptors would also be the same as the Proponent's.

The detailed review of the modelling also examined typical worst case dispersion conditions in detail. The review examined the modelling results using a three dimensional rendering of the outputs, as this is an effective means of finding any technical errors in the modelling. The results presented in the figures below are two dimensional representations of the 3 dimensional analysis conducted. The results and images all show the same 1-hour average stack plume for a poor dispersion condition. Note that the stack emissions plume is cropped at a height of 72 m in this case.

The various images show the shape of the plume per the colour range specified in the legend. Note that the low concentrations data are progressively removed in each image to reveal the shape of the higher concentration portions of the plume within.

A key observation is that for this poor dispersion situation, with the plume heading directly towards the more elevated terrain, the core of the plume remains well above ground level, and only the well dispersed, low concentration outer parts of the plume interact with the surface or taller buildings. This can be clearly seen in the side view of the plume, (i.e. looking approx. south and along the existing M1 motorway from a position that is the north of the proposed northern ventilation stack location.)

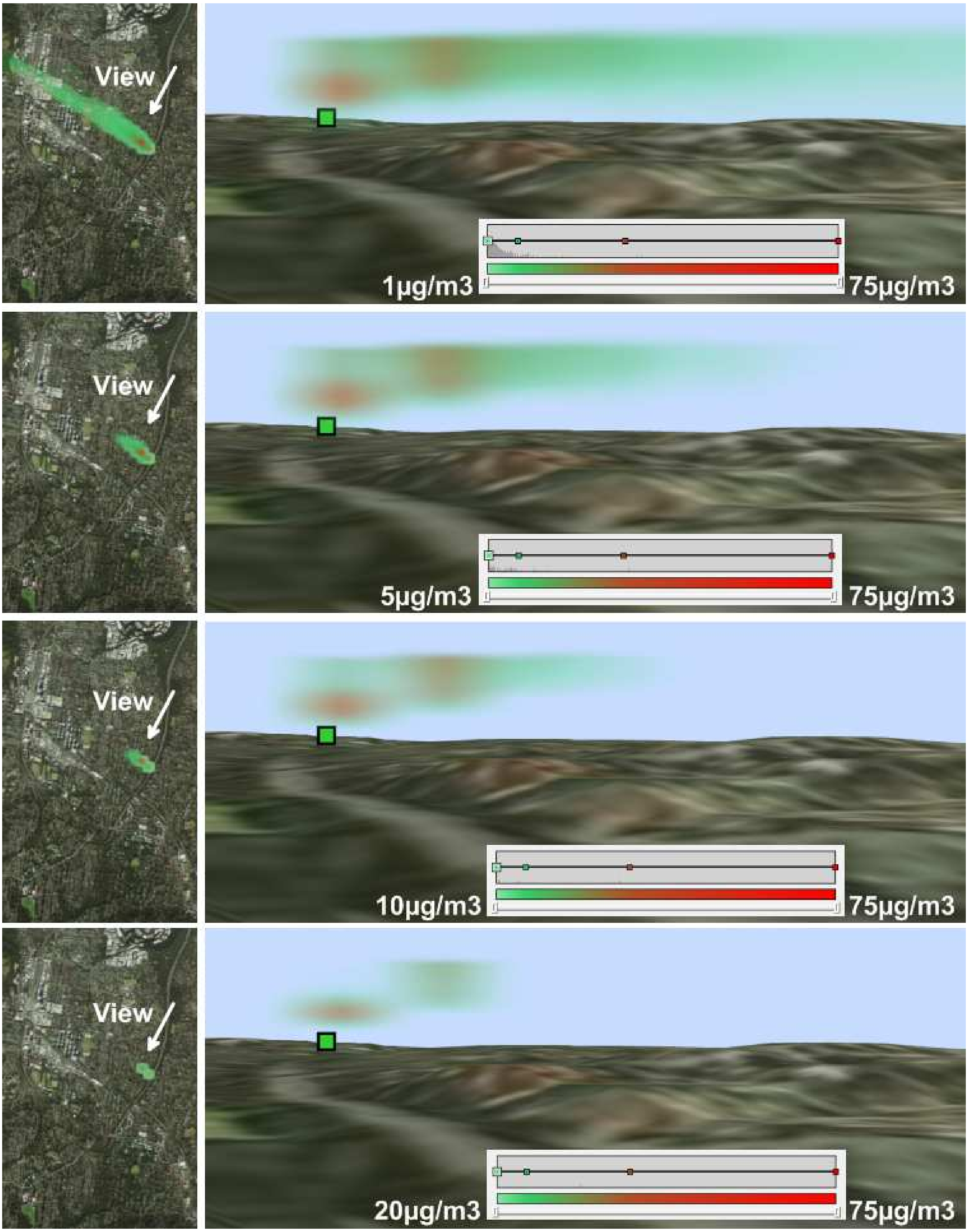

Figure 2: Visualisation of a typical worst case hour of stack emissions, (plume travelling over elevated terrain)

5.2.1 Peak impacting hour predictions – model performance

Model performance for the most impacting hours for NO_2 was examined by the Proponent and the detailed review.

The Proponent's review is detailed on pages 241 to 348 of the SPIR report (Volume 1). The Proponent shows, for CO emissions in Figure 2-38 on Page 345 of the SPIR report that the two most impacted hours are "outliers" in that these do not appear to be plausible results.

The results for NO_2 show concentrations of approximately 85 to 92µg/m^3 for the worst case hour in any year, concentrations of 38 to 67 for the second highest hour and 37 to 65 for the third hour.

Examination of the highest impacting hours by the review generally agrees with the Proponent's analysis that the highest hours of effect appear to be modelling outliers.

For example for the most impacted hour modelled, the review identified that there was an approximate 180 degrees shift in the wind direction over the hour, from approximately southwest to northeast (sweeping around through the west).

It needs to be noted that the model only considers hourly average weather conditions. The model allows all of the existing emissions to remain in the air, and these emissions and the next hour's emissions are acted on by the hourly average data.

The review conducted an examination of the modelled outputs using 3-D visualisation techniques on this day. This shows that:

- in the hours before the maximum impacting hour occurs, the results are sensible, and that the plume was dispersing normally down wind;
- at the time of the most impacting hour the modelled results show that the plume blew back into itself (and had not swept around in an arc as would actually occur in practice, or would be shown if the modelling had used a sub-hourly time step). Also at this time a full hour of emissions is released by the model into air containing the previous hours' of emissions that is now blowing back into itself and is hugging the stack. The model responded like this because the net average wind speed input for the hour was close to zero (i.e. for an hour with wind from the left and wind from the right, the hourly average wind speed can be a zero). To be more precise for the technical reader, please note that the wind speed input to the model is a vector average of the actual sub hourly data. The vector averaging is generally done by the operator of the weather station, (e.g. Bureau of Meteorology provides hourly data) and when a near 180 degree wind change occurs at about half past the hour, this can result in near zero wind speeds. This can strongly affect the modelling results in that hour in unrealistic and inaccurate ways (see also Appendix B).
- in the following hour, the emissions begin to move away from the stack, and due to the inaccurate bunching of the pervious few hours of emissions, this and the next hours of emissions produces further inaccurately high results at receptors.

As part of the review of this issue, the Proponent was asked to provide further details of its analysis, as presented in **Appendix B.**

The review notes that its independent analysis agrees with the Proponent's analysis. Overall, it is noted that whilst the actual weather conditions over the hour represent a relatively common wind reversal event (a wind change) that occurs every few days or weeks, the particular combination of the full range of meteorological parameters that are input to the model for this hour that arise from the hourly averaging of the actual sub hourly data have produced an invalid combination of meteorological dispersion conditions that cannot realistically occur, and thus produce an inaccurate model result in this hour.

The other outlier hour in the CO results presented by the proponent appears to arise due to stack-tip downwash causing the emissions to impinge onto the M1 motorway roadway. This result occurs in modelling year 2009. The Proponent's Figure 2-30, on Page 323 of the SPIR shows the effects on this hour of the 15metre and 20metre tall stack option. The 20m tall stack scenario appears to result in effects closer to the stack than the 15m scenario, which does not appear to be correct, as generally, all other things being equal, a taller stack would result in a lower level of effect at further distance from the stack. The TAS modelling results indicate that the Proponent's figure may be incorrectly mixing/ mislabelling the data for the 15m and 20m scenarios (if the figure is showing NO_2 results).

The 2009 data set appears to contain approximately 4 or 5 hours during which stack tip downwash may occur. Generally, modelling using 2009 is not preferred by the reviewer as 2009 included severe dust storms and drought conditions.

However, it is perhaps more important to note that relative to the highest NO_2 levels of 90 and 92µg/m^3 in 2010 and 2011, the result for the 2nd highest impacting hour in the year is significantly lower, i.e. a NO_2 level of approximately 57 and 38µg/m^3 in 2010 and 2011 respectively.

The Proponent has not removed the outlier data from its assessment, and instead of applying the second highest results from 2010 or 2011 (that are likely to be more reliable), the Proponent's evaluation of impacts is based on the maximum outlier result.

5.3 Emissions estimation and impact analysis assumptions

The overly conservative nature of the assessment, in generally making the most conservative assumption at almost every step in the assessment calculations was outlined in the preliminary review. As the AQIA showed a large margin of compliance with criteria, any potential issue of over-conservatism in the approach and overestimation of potential impacts was not considered to be significant in the preliminary review.

However, in the context of further increasing NO_2 emissions by 60% at the request of the EPA, and not adjusting the already overly conservative assumptions, and including anomalous outlier data to represent the maximum hour of impact, the review considers that the revised assessment presented in the SPIR does not provide the community with a realistic estimate of likely impacts.

The following key assumptions are considered to be overly conservative and to lead to unnecessary overestimation in the likely NO_2 impacts:

- The adoption of the highest hourly measured background
- The use of the OLM approach which assumes instant NO to NO_2 conversion and the conversion of all of NO or O_3, whichever is limiting; and,

- The use of an NO2:NOx ratio of the emitted vehicle exhaust of 16 per cent as recommended by the EPA.

Perhaps the only assumption that may not be conservative in the AQIA was the assumption that the NO_2 fraction in the vehicle NO_x emissions would be 10%. The NSW EPA has recommended that a level of 16% be applied. This is considered to be reasonable in the context of the trend towards an increasingly larger proportion of diesel passenger vehicles which tend to emit a greater fraction of NO_2.

By revising this assumption, the Proponent increases the assessed in-tunnel NO_2 levels by 60% in the SPIR relative to the AQIA.

However, in the SPIR, the Proponent did not refine its conservative assumptions (such as the use of the Ozone Limiting Method (OLM)) that affect the transformation of NO_x to NO_2 once released from the tunnel ventilation stacks, nor did it omit anomalous outlier data, resulting in an unrealistic level of impact at receptors in the vicinity of the stacks.

This issue is examined in detail in the next section.

5.4 Examination of NO_x to NO_2 assumptions

A screening level approach using the NSW EPA's Janssen method was applied to test the Proponent's conversion of NO_x results to NO_2 results using the OLM method.

NO_2 is a subtraction of the NO_x released by motor vehicles, and over time will react in the atmosphere to form NO_2. The reaction time varies according to temperature, time of day and the other reactive chemicals in the atmosphere at the time. This conversion is important as NO_2 is the harmful pollutant of concern, and whilst only a relatively small fraction of NO_2 is initially emitted from vehicle exhausts (and hence the tunnel stack) the fraction of NO_2 in the NO_x emissions will often increase after release.

For this assessment, the NO_X to NO_2 ratio at receptor locations was estimated using an empirical equation for estimating the oxidation rate of the emissions as outlined in the Approved Methods (**NSW DEC, 2005**) and developed by **Janssen et al.** (**1988**). This method consists of calculating the ratio of NO_2 to NO_X as determined by the atmospheric conditions and distance from the maximum recorded level to the source, per the following equation:

$$NO_2 / NO_x = A(1 - \exp(-\alpha x)) \qquad \text{Equation 1.}$$

where:

x = the distance from the source

A and α are classified according to Ozone concentration, wind speed and season (Janssen et al. (1988) provides values for A and α).

A screening Level 1 assessment per this method was carried out by adding maximum predicted NO_2 levels with the maximum background NO_2 concentrations to predict the total impact of NO_2. The maximum NO_2 background level in any hour of the year at any location was used, even though it may not occur in the same hour as the maximum predicted NO_2 level.

By re-running the Proponent's modelling, the predicted maximum impacts were found to occur approximately 91m to 430m from the source. Using these distances, and the most conservative possible A and α (km^{-1}) constant values that can be applied per the Janssen method of 0.93 and 0.8 respectively, the maximum ratio of NO_2 to NO_x conversion for the Project was calculated to range from 6.5% to 27%.

The maximum total NO_2 concentration was determined by applying a ratio of NO_2 to NO_x to the predicted maximum one-hour average NO_x concentrations, and adding the result to the maximum 1-hour average background NO_2 concentrations at any location at any time during the year.

The results are summarised in **Table 3**, with results for the Project in isolation shown in bold font. The results show that at the maximum NO_2 level at the most affected location due to the Project ranges from 13 to 24 $\mu g/m^3$, and cumulative effects (assuming that the highest hour of measured background data occurs on the same hour at the Project maximum hour over the year) range from 94 to 117$\mu g/m^3$.

In contrast, the Proponent's maximum NO_2 levels at the most affected location due to the Project (up to 91.8$\mu g/m^3$) were found to be the same as the NO_x emissions for many of the hours in the year. In fact the top 10 and top approximately 70 hours in the year of the Proponent's data would appear to be the same in 2011, which means that the Proponent applied a 100% conversion of NO_x to NO_2 at receptors for the key hours of the year.

Table 3: Review calculated maximum hourly predicted NO_2 concentrations at most affected receptor locations*

Year	Max predicted 1-hr average NO_X ($\mu g/m^3$)	x-coordinate (m)	y-coordinate (m)	Distance from source (m)	NO_2/NO_X	Max Predicted NO_2 ($\mu g/m^3$)	Max background NO_2 ($\mu g/m^3$)	Cumulative NO_2 ($\mu g/m^3$)	Percent of criteria
	Northern stack (325359, 6268211)								
2009	264.5	325410	6268286	90.7	6.5%	**17.2**	100	117.2	47.6%
2010	124.7	325210	6268186	151.1	10.6%	**13.2**	81	94.2	38.3%
	125.3	325210	6268161	157.2	11.0%	**13.8**	81	94.8	38.5%
2011	164.6	325260	6268061	179.7	12.5%	**20.5**	75	95.5	38.8%
	Southern stack (319233, 6262984)								
Year	Max predicted 1-hr average NO_X ($\mu g/m^3$)	x-coordinate (m)	y-coordinate (m)	Distance from source (m)	NO_2/NO_X	Max Predicted NO_2 ($\mu g/m^3$)	Max background NO_2 ($\mu g/m^3$)	Cumulative NO_2 ($\mu g/m^3$)	Percent of criteria
2009	131.2	319360	6262985	126.9	9.0%	**11.8**	100	111.8	45.4%
2010	88.7	319585	6262735	431.0	27.1%	**24.0****	81	105.0	42.7%
2011	128.7	319410	6263186	268.7	18.0%	**23.2**	75	98.2	39.9%

* Note that this is not necessarily at a residence (e.g. along the M1 motorway for the northern stack).
** Highest predicted NO_2 concentration

Further examination identified that the worst case hour of impact occurred within approximately 90m to 430m from the stack, and thus there would generally only be tens of seconds for the atmospheric reactions to occur. Thus in practice, given that the affected receptors are relatively close, a 100% conversion of NO_x to NO_2 is unlikely to occur for the majority of the time for the highest effects at the most affected receptor locations and means that it is most likely that the Proponent has significantly overestimated NO_2 levels at receptors.

It is considered that there are two core assumptions that the Proponent makes that lead to its overestimation of NO_2 levels:

1. The maximum Ozone level from various stations is used to represent the background level, rather than a naturally occurring profile of Ozone levels at any one point. Ozone is a reactive chemical that facilitates the conversion of NO_x to NO_2, but the rate of the reaction is also affected by the ambient temperature and the ambient level of NO_2, and a range of other factors. In short however, the artificially exaggerated daily Ozone profile applied by the Proponent would lead to more Ozone reactivity than would otherwise occur, and per the OLM method, this would convert more NO_x to NO_2 that would be likely in practice.

2. The OLM method inherently assumes instantaneous conversion of NO_x to NO_2, per the quantum of Ozone at the time. However, the actual conversion reaction would be far slower, resulting in a much smaller fraction of NO_x being converted to NO_2 by the time the emissions reach receptors in practice.

The Janssen Method (which also makes some significant assumptions) is however empirically based (i.e. based on measured data) and factors in the distance between the most impacted receptor and the source of emissions, and also the wind speed. This means the method will consider the time taken for emissions to reach a receptor and the likely progression of the NO_x to NO_2 reaction to perhaps better reflect the likely case at both far and close receptors.

The Janssen method settings applied in the review were selected as those which are most conservative and thus lead to the maximum calculable NO_2 quantities at receptors. However, even using a conservative level 1 screening approach with these settings, the method produces significantly lower maximum NO_2 results than the Proponent's reported results.

The results produced by the review using the Jansen approach are generally consistent with the measured data in the vicinity of other road tunnels (e.g. Lane Cove Tunnel) and for the reasons outlined above are considered to be more representative of the likely maximum effects that may occur due to the Project.

The results show a significantly larger margin of compliance than the Proponent's assessment.

5.5 In-tunnel air quality

The preliminary review requested further details in order to allow this review to be able to independently evaluate the potential levels of in-tunnel air pollutants due to traffic emissions. These details have been provided in the SPIR, and the review considered the information to positively confirm that the conditions leading to maximum in-tunnel air emissions had been identified.

The question then arises as to whether the likely in-tunnel air pollutant levels, or more importantly, the tunnel user's likely exposure to pollutants in the tunnel would be acceptable or not. To make such an evaluation it is necessary to apply a suitable criterion or guideline level to compare with the likely in-tunnel pollutant/ exposure levels.

In its submission, NSW Health raises concerns about in-tunnel air quality, but does not suggest an appropriate guideline level that might apply to assess the acceptability of in-tunnel air emissions in the tunnel. The review has considered NSW Health's submission, and notes the desire to minimise motorists' exposure to in-tunnel pollutants as far as is practicable.

On the basis of the ratio of the available ambient air quality guideline levels relative to the calculated in-tunnel pollutant level, it is possible to identify the pollutant with most potential to cause impact on tunnel users. The limiting pollutant identified on this basis would appear to be NO_2.

The National Environment Protection Measure (Air Quality) and EPA's ambient air quality criteria for NO_2 apply to the general population as a 1-hour average exposure level. Thus the available NSW and Australian criteria reflect the acceptable levels measured at say an ambient monitoring site situated away from the effects of industry or busy roads, and are indicative of the underlying level that the majority of the population would experience. It should be noted that these criteria have been applied to assess out of tunnel air quality and thus to protect the wellbeing of the community living around the Project. However, the criteria would not be suitable for assessing a motorist's exposure to in-tunnel NO_2 pollutants during a normal trip through the tunnel which would take in the order of 10 minutes. Such criteria would be overly protective of motorist's exposure, and may not be practically achievable in the in-tunnel environment.

Australian occupational health criteria for NO_2 are available and are applied to healthy working adults in the workplace. However it cannot be assumed that young children, asthmatics and other susceptible motorists or passengers would not use the tunnel. Hence occupational standards should not be applied to assess in-tunnel air quality as they would not reasonably protect the health of all tunnel users.

The US National Research Council of the National Academies, Committee on Acute Exposure Guideline Levels, Committee on Toxicology, Board on Environmental Studies and Toxicology, Division on Earth and Life Studies in its 2012 publication; *Acute Exposure Guideline levels for Selected Airborne Chemicals, Volume 11*, **NRC (2012)** promulgates an Acute Exposure Guideline Level (AEGL) criteria for NO_2 that would appear to be suitable to apply in this case.

Further details of the guideline are outlined at **Appendix C**, where a pertinent extract guideline is reproduced for convenience.

There are three levels of AEGL, level 1, 2 and 3. The AEGL-1 criterion is the most stringent and is set at a level at which a susceptible individual may experience relatively minor effects that cease after exposure ends.

The AEGL–1 criteria for NO_2 are based on the evidence obtained from many well regarded studies including human exposure trials on susceptible individuals, including asthmatics. AEGL guidelines state that

"Airborne concentrations below the AEGL-1 represent exposure concentrations that could produce mild and progressively increasing but transient and nondisabling odor, taste, and sensory irritation or certain asymptomatic, nonsensory effects. With increasing airborne concentrations above each AEGL, there is a progressive increase in the likelihood of occurrence and the severity of effects described for each corresponding AEGL. Although the AEGL values represent threshold levels for the general public, including susceptible subpopulations, such as infants, children, the elderly, persons with asthma, and those with other illnesses, it is recognized that individuals, subject to idiosyncratic responses, could experience the effects described at concentrations below the corresponding AEGL."

The AEGL-1 for NO_2 exposure is set at a level of 0.5ppm, which is an average concentration of NO_2 that is a little more than 1mg/Nm^3, and applies equally to exposures of 10 minutes, 30 minutes, 1-hour, 4 hours and 8 hours. (Note that in this context a 15-minute average can also be applied.)

The rationale for adopting this level as the AEGL-1 is outlined in the guideline as follows:

"For AEGL-1, a concentration of 0.5 ppm was adopted for all time points. Although the response of asthmatics to NO_2 is variable, asthmatics were identified as a potentially susceptible population. The evidence indicates that some asthmatics exposed to NO_2 at 0.3-0.5 ppm might respond with either subjective symptoms or slight changes in pulmonary function that are not clinically significant. In contrast, some asthmatics did not respond to NO_2 at concentrations of 0.5-4 ppm. Because of the weight of evidence, the study by Kerr et al. (1978, 1979) was considered the most appropriate for derivation of AEGL-1 values. They reported that 7/13 asthmatics experienced slight burning of the eyes, slight headache, and chest tightness or labored breathing with exercise when exposed at 0.5 ppm for 2 h; at this concentration, the odor of NO_2 was perceptible but the subjects became unaware of it after about 15 min. No changes in any pulmonary function tests were found immediately following the chamber exposure (Kerr et al. 1978, 1979). Therefore, 0.50 ppm was considered a no-adverse-effect level for the asthmatic population. Since asthmatics are potentially the most susceptible population, no uncertainty factor was applied. Time scaling was not performed because adaptation to mild sensory irritation occurs. In addition, animal responses to NO_2 exposure have demonstrated a much greater dependence on concentration than on time; therefore, extending the 2-h concentration to 8 h should not exacerbate the human response."

It is noted that other jurisdictions have applied the same level as an in-tunnel limit for NO_2, but it is not known whether the limits were set on the basis of the AEGL-1 guideline, or were derived otherwise.

The review considers that reasonably applicable, robustly formulated health exposure guidelines exist (in other jurisdictions), and there is also precedent for in-tunnel NO_2 limits at these guideline levels, and thus recommends that to adequately protect tunnel users, and in the absence of any alternative NSW or Australasian guidance that may apply in this case, that the tunnel be designed such that under normal operations it will achieve a level of 0.5ppm or 1mg/Nm^3 for NO_2 as a rolling 15-minute average over the length of the tunnel.

In regard to what may be an acceptable an upper limit of NO_2 exposure that could be applied by tunnel designers to develop a tunnel design that will manage infrequent and extraordinary situations, rather than normal tunnel operations, it is noted that AEGL guidelines state that the *"evidence indicates that some asthmatics exposed to NO_2 at 0.3-0.5 ppm might respond with either subjective symptoms or slight changes in pulmonary function that are not clinically significant. In contrast, some asthmatics did not respond to NO_2 at concentrations of 0.5-4 ppm."* This indicates an upper bound above 4ppm may not be reasonable to manage potential health effects, and that the potential upper bound for NO_2 levels could reasonably lie in the range of 0.5 to 4ppm.

It is understood that the Proponent is capable of developing a feasible tunnel design that under abnormal conditions could operate at a level significantly lower than the upper range level of 4ppm.

The Proponent's design criteria are set out in Table 2.2 of the SPIR and indicate that it would be feasible for the tunnel to be designed to meet a level of 1ppm as an upper limit. Also, as outlined in the NSW Health submission, it is appropriate that the lowest level that is practical to achieve should be applied to manage in-tunnel air quality effects, and thus it is suggested that the tunnel designers consider adopting an upper limit under abnormal conditions at a level that is one quarter of the upper limit of the range, i.e. adopt a level of 1 ppm, or 2mg/Nm^3 for NO_2 as a rolling 15-minute average over the length of the tunnel.

It needs to be noted that at the entrance of a road tunnel, the air quality is essentially the same as that on the road, but once in the tunnel the pollutant concentration steadily increases (unless there is a fresh air intake) until it reaches the tunnel exit or a tunnel ventilation outlet offtake.

The in-tunnel exposure level for a motorist is approximately equivalent to the average NO_2 level along the tunnel, which would vary from a low level to a level that is approximately double the average at the end.

Therefore it could be expected that the stack emissions would be at a level that is approximately equivalent to double the motorist exposure level or the average levels along the tunnel.

This approximate relationship makes it possible to estimate whether the air quality effects of the Project (both in-tunnel and out of tunnel), will be governed by the in-tunnel levels (that protect motorist's health) or the in-stack levels (that protect resident's health). The relationship is applied in the next section examines the potential stack emissions limits necessary to protect residents health.

5.5.1 Stack emission limits

To determine acceptable stack emission limits it needs to be determined which one of the two inherently necessary outcomes (the need to protect motorists in the tunnel and also to protect the residents near the tunnel) are the limiting factor in the tunnel and stack design. It could be that in-stack limits that are needed to protect resident's health may be more stringent (or not) than the in-tunnel limits needed to protect motorists. Thus the in-stack limits should not be set in isolation, and should consider both the in-tunnel and environmental air quality levels that need to be achieved.

The limits that are necessary to protect motorists (as detailed in Section 5.5) translate to equivalent in-stack limits of approximately 2mg/m^3 under normal operations and up to 4mg/m^3 for rare extraordinary events.

The question thus arises whether these limits (i.e. the stack limits equivalent to in-tunnel limits that protect motorists in the tunnel) will be sufficient to protect the residents in the surrounding environment.

The possibility that more stringent limits may be necessary can be examined by looking at the predicted effects to residents, and the in-stack concentrations that correspond to those effects at receptors.

As outlined in Section 5.5, the review identified that NO_2 is the limiting pollutant for in tunnel air quality. Examination of the Proponent's predicted impacts (see Table 2-77 on page 305 of the SPIR) confirms that this is also the case for ambient air quality effects at receptors near the ventilation stacks.

Examination of the NO_2 results calculated by this review (see **Table 3**) shows lower NO_2 predictions, but that the maximum 1-hour predicted level for the Project of 24.0µg/m^3 could be up to approximately 10% of the criteria level of 246µg/m^3. This also indicates that the predicted NO_2 levels are the limiting factor[1].

Referring to **Table 3** the review identifies that the worst case impact would be a 1-hour maximum level of 24µg/m^3 at the receptor most affected by the Project. This is a Project contribution of approximately 10% to the total maximum NO_2 level, and arises for the southern ventilation stack operating with emissions per Scenario 3 (Design Analysis A scenario).

The upper bound of the cumulative impact (determined by adding the maximum 1-hour NO_2 background level in that year with the maximum predicted level, even though these may not occur on the same day) is also identified in **Table 3** which shows that in this case the maximum impact would be 105µg/m^3, a total level which is 141µg/m^3 below the criterion level.

[1] Please note that the Proponent indicates that VOC levels could be up to 18.5% of the criteria, but as the criteria for the various VOC substances are not cumulative criteria, and the NO_2 criteria are cumulative criteria, when background NO_2 levels which are up to 30 to 40% of the criteria are added to the NO_2 predictions to arrive at the total cumulative level, this would make 1-hour average NO_2 the limiting criteria pollutant.

The available margin of compliance is thus (141/24 =) 5.9 fold, meaning that the maximum NO_2 impact at the most impacted receptor, on the most impacted hour over the three years assessed would need to be 5.9 times higher for there to be an adverse effect.

It is next necessary to determine whether 5.9 times the modelled in-stack concentration that resulted in the maximum impact is lower than the in-stack limit that is equivalent to the in-tunnel limit that protects motorists. If this is the case, it would mean that an in-stack level that is 5.9 times higher than the modelled rate is the limiting factor in the design of the tunnel, but if not, it means that the recommended in-tunnel level is the limiting factor.

The modelled in-stack concentrations for the maximum impact were per Scenario 3 (Design Analysis A scenario) which has a maximum modelled NO_x emission rate of 9.836mg/m^3 (see **Table 2**). The modelled NO_2 emission rate was 16% of this value, (up from 10% in the original assessment as requested by NSW EPA) and was 1.57mg/m^3.

The results show that the worst case impact due to the Project would have to be 5.9 times higher than was modelled to lead to adverse effects. That would mean that emissions from the southern stack at a maximum rate of 1.57 x 5.9 = 9.29mg/m^3 would be needed to cause an adverse impact at the most impacted location.

This means that the recommended in-tunnel limits for NO_2 as a 15-minute average along the length of the tunnel of 1mg/Nm^3 under normal conditions, and 2mg/Nm^3 under rare extraordinary events are the limiting conditions, and it should not be permitted to have in-stack limits more than approximately double these levels (noting that the equivalent level in the stack would be approximately double the average along the tunnel).

This indicates that in-stack limits for NO_2 as a 1-hour average should not be set at levels above 2mg/Nm^3 under normal conditions, and 4mg/Nm^3 under rare extraordinary events. These limits are set at less than half of the level needed to protect residents but are at the levels needed to protect motorists using the tunnel.

The recommended limits are the most stringent feasibly achievable limits that can be applied in this case. The recommended limits are based on the tunnel design criteria, as these are in the lower part of the range of levels that could be applied to protect motorists, and are many times lower than the levels needed to protect residents.

5.6 Portal emissions

It is understood that portal emissions are not proposed, and it is observed that the placement of a stack near the exit portal is essentially ideal in regard to maximising the capacity of the tunnel ventilation system to avoid portal emissions.

It is noted that many tunnels can operate with portal emissions at any time or at certain times of the day, such as low volume traffic conditions at night. The Health Risk Assessment states that if portal emissions are to be considered in future, this would be the subject of an appropriate assessment and approval, including a health risk assessment. Thus portal emissions are not considered further.

5.7 Observations on tunnel design

The design of the tunnel, with stacks at the end is considered a positive aspect of the Project. This configuration encourages air to flow along with the traffic, and is superior in regard to minimising air pollution relative to designs which attempt to draw air against the flow of traffic, or push air along a side tunnel towards a more distant stack.

The proposed tunnel design configuration also makes good use of the propensity of the naturally warmer in-tunnel air to rise upwards. The design thus allows the most polluted air to be captured, mixed with fresh intake from the exit portal and to be dispersed via the stack.

To design a stack that would ensure good air dispersion into the atmosphere with low effects at ground level is not difficult, and requires only reasonable care to ensure that the upwards velocity, temperature and height of the stack are correctly matched with the expected air flows and pollutant concentrations.

The design for this Project proposes a variable stack outlet and hence has the capacity to maximise the vertical discharge velocity. This is a good feature of the proposed design as it maximises air dispersion across a range of tunnel air ventilation rates. An example is for the case of low volumes of night time traffic and hence low air flow through the tunnel and stack. By using the smaller ventilation outlet opening in these conditions, the emissions can be released with a higher vertical velocity (than from a stack with a fixed opening size), resulting in better dispersion of the emissions. Similarly, under heavy traffic with high air flow conditions, the opening can be increased so that the maximum amount of fresh air can be drawn in and discharged with the traffic emissions out of the stack at a high velocity.

In this regard, the proponent has noted that:

> *The environmental impact statement presents segmentation of the project's ventilation outlets as only one potential design solution. Subject to detailed design, an equivalent outcome (in terms of outlet discharge velocity) may be proposed. Any design alternative design approach would be confirmed as provided equivalent or superior outcomes to those presented in the environmental impact statement and submissions and preferred infrastructure report.*

The review considers that it is important that these key positive aspects of the design, (or alternatives achieving demonstrably equivalent or superior outcomes) are put in place in order to minimise air quality effects.

Observations made in the preliminary review in this regard are that the 15m tall stack design in the AQIA appeared to balance aesthetics against maximising the pollutant release height. Whilst the AQIA results showed low levels of effect and thus no fundamental issue with the proposed 15m stack height in regard to effectively dispersing air pollutants, and in light of the need to consider elevated receptors, the question was raised in the preliminary review as to whether an increased stack height would lead to any significantly better outcomes.

In regard to this question, the Proponent has replied as follows;

> *Section 3.2 of the submissions and preferred infrastructure* [RTS] *report presents an analysis of feasible and reasonable measures to further reduce in-tunnel and ambient exposures to vehicle emissions. This analysis includes consideration of air quality, human health, other environmental, engineering and cost factors. Based on this analysis, the project has been amended to increase the height of the north ventilation outlet and the southern ventilation outlet by five metres. This amendment to the project is assessed in detail in Section 9.2 of the submission and preferred infrastructure report.*

It is noted that the revised air assessment results presented in the SPIR consider a 20m tall stack. Relative to the AQIA assessment results for a 15m tall stack, the results for the 20m tall stack show reduced pollutant impacts, except for NO_2 impacts which did not reduce in every case. However this is not connected to the stack heights, and arises as there was a 60% increase applied in the NO_2 emission rate at the request of the NSW EPA, and also due to some anomalies and inherent model limitations for the peak hour of impact.

6 DISCUSSION

The approach adopted in the AQIA and the SPIR is generally conservative and is most likely to overstate impacts due to the application of maximum background data and the conservative model assumptions. The AQIA and SPIR appears to have applied the most conservative assumption at each step of the assessment. Thus in almost every case the AQIA and SPIR appears to select the assumption most likely to lead to the greatest predicted impact.

In the opinion of the reviewer, the inherent overestimation is concerning for NO_2 effects due to the stacks. The review identified that maximum hypothetical effects from the Project may contribute a maximum 1-hour average NO_2 level[2] over the year of up to approximately 24µg/m^3, whereas the Proponent has indicated that this could be as high as 91.8µg/m^3. Given that the review also applied a conservative calculation approach, in all likelihood the actual effects would be even lower than either result.

It is observed that the investigation and analysis of the data collected before and after the operation of the Lane Cove Tunnel did not find any tangible effects on air quality, which lends support to the reviewer's opinion that actual NO_2 levels for the Project would be greatly lower than estimated by the Proponent. The Lane Cove Tunnel investigations also align with the Proponent's conclusion that there would be minimal effects at receptors in the vicinity of the stacks.

The AQIA and SPIR conclude that the Project, on balance has an overall positive effect on surface air quality for the population. The conclusions arise because:

- the Project will remove heavy vehicles from Pennant Hills Road. Even if these heavy vehicles are in future replaced by passenger vehicles, this would still result in a net improvement in air quality for the receptors along Pennant Hills Road as the heavy vehicles are a significantly larger source of emissions than any cars that may in future replace them on the road;
- the modelling results show that the stack design results in a significant dilution of in-tunnel pollutant concentrations at ground level near the stacks. The concentrations at the locations

[2] Note that the review does not exclude any modelling results even if a potentially anomalous outlier.

most affected by the stacks are low, and the total effect on air quality is within than the normal variability recorded in the ambient air quality levels across Sydney. Thus the potential change due to the Project is unlikely to alter the existing situation significantly.

The review also makes observations regarding positive aspects of the proposed tunnel design.

These include the placement of stacks near to the exit of the tunnel. This configuration would limit potential portal emissions, and would result in a near ideal stack placement for minimising net impacts on the population. Road tunnels where the stacks were relocated to a position well away from the exits of the tunnel resulted in some of the poorest in-tunnel air quality and some of the highest operating costs for tunnels in NSW.

The review makes a recommendation to maintain this key element (stacks near the exit portals or an equivalent or superior alternative option) of the tunnel design, as with all other variables being equal, other potential options could lead to worse air quality effects on residents and tunnel users.

Another design feature that the review supports and recommends be maintained in the final design is the variable ventilation opening (or an equivalent or superior alternative option) which allows higher vertical velocities to be achieved. This feature would improve air dispersion under a wider range of conditions and this would lead to reduced air quality impacts for more of the time.

7 GENERAL COMMENTS REGARDING ROAD TUNNELS AND STACKS

There are many common public misconceptions and concerns about emissions from road tunnel stacks.

These include a misconception that the stack emissions will "rain down" upon residents near the stack, and therefore that the residents would be exposed to concentrated traffic pollutant emissions[3]. In reality the opposite occurs as stacks are highly effective at dispersing air pollution, and the pollutant emissions released from a reasonably designed stack will only reach ground level at highly diluted concentrations, and at significantly lower levels than traffic pollutant concentrations along an equivalent surface roads.

Due to this, compared to the emissions of exactly the same traffic on a surface road, a reasonably well designed road tunnel stack that collects these emissions and disperses them into the air will result in lower pollutant levels near the stack than near the same road (if it were on the surface). Thus the places where the population live, work and breathe the air would have lower pollutant levels. This will occur under all weather conditions, as the conditions that result in the poorest stack dispersion also result in poor dispersion of road side emissions.

[3] There is some potential for stack tip downwash to occur. This is where the plume can momentarily be brought to ground, generally as a plume whorl that is brief and transient. It is noted that this would be a rare, momentary phenomena for a well-designed stack, and the taller the stack, and higher the velocity of the vented air, the lower the likelihood of such an occurrence.

To better understand the scale of the dilution that occurs between the stack tip and ground level, it may help to consider that the plume from a stack is generally warm, and thus buoyant and is directed upwards at a high velocity when released. The plume, say in perfectly still and uniform atmospheric conditions will be projected upwards and will continue to rise up and would not reach the ground. The plume in this situation would hypothetically be shaped like a large ever-widening cone of air. As the pollutants travel away from the stack they disperse through an ever increasing volume of clean air, greatly reducing pollutant concentrations with distance from the stack. In another situation, the plume from a stack can be bent in a sideways arc due to a cross wind. When there is a wind which can do this, the plume will not stay in a neat cone bent sideways as the wind causes mixing of the air which breaks the plume apart and forces the traffic pollution to mix with even more fresh air. Thus two factors are at play; as the wind speed increases the edge of the dispersed plume will of course come closer to the ground, but the wind will also cause the plume to be better dispersed and the pollution will be more diluted.

As a general rule of thumb, stacks dilute air emissions (between the stack tip and the ground) by at least approximately 50 to 100 times, and most industrial stacks achieve dilution ratios closer to approximately 1,000 times. Very tall, hot stacks may achieve higher dilution ratios. The dilution achieved for a particular stack will depend on several key factors including the vertical velocity of the discharge, temperature (relative to the ambient) and the height of the stack above ground. For large volume discharges such as road tunnel stacks, the volume of the discharged air will also be significant and may affect the net buoyancy of the plume (it takes a longer time for the larger mass of air to cool as it rises upward, and it can travel further up).

The case of a layer of warm air above the stack, also known as a temperature inversion, is also worth considering. These conditions can occur in a valley on still, cool (usually winter) nights after a sunny day.

These conditions can lead to the poorest stack dispersion as the plume may not disperse as freely as it otherwise could. However it needs to be considered that these conditions do not generally coincide with peak hour traffic and that the same conditions also lead to the poorest dispersion situation from a surface road. Thus if the surface road's emissions were released via a stack the net effects at receptors would be lower (than the same emissions release via a stack) even under such conditions. Thus it is still better to collect and release traffic emissions via a stack if the objective is to minimise overall air pollution at the surface.

Whilst collecting traffic emissions and discharging them via a stack will result in better air quality at ground level, the in-tunnel air quality would be worse than surface road air quality, and this needs to be carefully managed for road tunnel projects. Having a sufficient number of properly positioned stacks and fresh air intakes is a crucial aspect of achieving acceptable in-tunnel air quality and better surface air quality. For example, for this Project, adding a stack near the middle of the proposed tunnel could approximately halve the in-tunnel user exposure to traffic pollution, and would also reduce above ground impacts near the stacks (which are relatively small in any case due to good stack dispersion).

Another issue is the expectation that road tunnel stacks should be filtered. Whilst conceptually this would make sense, after all the pollutant emissions are contained in the tunnel and are under the control of the operator, it turns out that treatment/ filtration is generally not a feasible option due to the large volumes of in-tunnel air and the low levels of pollution in road tunnel air.

In-tunnel air is significantly different to the emissions in a stack serving an industrial process, as it is necessary for the air in a tunnel to be diluted with fresh air to make it safe for tunnel users to breathe.

A simple way to appreciate the differences is to consider that the pollution in tunnels comes predominantly from vehicle exhaust (there is some tyre and brake dust also), and that most vehicles already have some form of pollution control, such as catalytic converters or particulate filters on diesel vehicles. This already "filtered" exhaust air from vehicles is diluted with fresh air in the tunnel so that the in-tunnel air is safe for users to breathe. There is often further dilution in the stack as there may be additional fresh air drawn in at the exit to manage portal emissions. Thus already "filtered" vehicle pollution is diluted to the point where the volume of air discharged via the stack can be hundreds of times greater (than the volume of vehicle exhaust air) and thus contains a lower level of emissions than the filtered air produced by the commercially viable treatment options available for such large volumes of air.

However, a typical stack from an industrial process can have some form of filtration or pollution control applied to successfully reduce the pollutant concentrations. This is because the industrial stack emissions are more like emissions from vehicle exhaust, but without pollution control equipment and without dilution with fresh air. This means that the pollutant concentrations in industrial stacks are high enough so that pollution control equipment can provide a significant cleaning effect

Generally in-tunnel pollutant levels are too low to be further treated as they are already cleaner than the output (filtered air) that viable industrial scale filters are capable to achieving at a commercially viable installation. This coupled with the large volumes of air in a tunnel generally makes the filtration of in-tunnel air unviable.

8 SUGGESTIONS FOR APPROVAL CONDITIONS

The NSW Environment Protection Authority and the Department of Health have made recommendations for approval conditions and the Department of Planning and Environment have developed draft conditions of approval.

The suggested conditions, as set out in **Appendix D**, closely follow those applied to the Lane Cove Tunnel.

It is recommended that the Proponent, NSW Health and the EPA be consulted on the details of the conditions prior to their finalisation. This is because it is important to develop the conditions such that they:

- Remain open to recent advances in tunnel monitoring technology; and
- Are flexible enough to permit the final tunnel design to improve on the environmental outcomes, but rigid enough to not allow worse outcomes for the community and tunnel users than shown in the SPIR.

The review identified health based guidelines that could be applied as in-tunnel limits which would ensure that the tunnel is designed and operated in a manner that would reasonably protect motorists from adverse effects.

The review also identified that in-tunnel air quality is the limiting factor for the design and operation of the tunnel, and thus any in-stack limits should reflect the equivalent in-tunnel limits, and would therefore need to be set at more stringent levels than the in-stack limits necessary to protect residents from adverse effects.

On this basis the review has recommended in-tunnel and in-stack limits that are equivalent. The recommended limits are as follows:

In-tunnel limits:

- 1mg/Nm^3 under normal conditions, and 2mg/Nm^3 under rare extraordinary events for NO_2 as a 15-minute average along the length of the tunnel; and,

In-stack limits:

- 2mg/Nm^3 under normal conditions, and 4mg/Nm^3 under rare extraordinary events for NO_2 as a 1-hour average

The review considers that it is important to minimise any special circumstances (rare extraordinary events), and to not permit unabated emissions in such circumstances. This is the reason that an absolute cap on emissions even under such circumstances has been set. It is also recommended that such events not be permitted to occur more than 1% of the time, and that there be escalating consequences if this should occur.

It should be noted that special circumstances would not include emergency situations such as a fire, where it is unreasonable to expect compliance to occur.

The review also advises caution in adopting in-stack particulate compliance limits. This is because the predicted in-tunnel particulate levels from motor vehicles are predicted to be very low, (approx. 1mg/m^3), and this concentration is too low to be reliably measured using the required regulatory methods. Adopting a higher criterion, could resolve the inability of the methods to reliably make such low measurements, but this could be reasonably seen as a compliance limit that is too lax, in the context of the Proponent’s predictions, or that such a limit may permit emissions above the predicted levels.

Additionally, it will be the case that detritus from the tunnel itself, (eroding concrete and so on) which would normally be an indistinguishably small component of the sampled particulate, may on occasion be a major fraction of the measured particulate when recording such low levels. A further complication is the sheer scale of the ventilation outlet and the need to take isokinetic sampling across the dimensions of the stack per the regulatory methods. This means it may take a day or so to collect a sample, whereas an hourly sampling period is normally used. A long sampling time would “average out” any peak emissions making it even harder to make an accurate assessment.

Using alternate monitoring methods may be necessary, however the only other approved regulatory compliance monitoring methods are designed to measure much lower levels in the ambient air, and would not be reliable in the in-stack environment.

Overall, it needs to be recognised that the available regulatory methods are not ideal in this case as the methods are not suited to measuring the very low in-stack particulate concentration (or if using ambient methods in the stack to measuring the relatively high particulate concentrations relative to normal ambient environmental levels).

Regardless of the issues, it should still be attempted to conduct some particulate in-stack monitoring, but as the accuracy of the results would be dubious, the ability to enforce compliance with any set compliance limits would be compromised. Thus monitoring of particulates is advised, but setting strict compliance limits may not be prudent due to problems with actually measuring the result accurately.

Thus the option to conduct continuous monitoring of the in-stack emissions using a special method, (to be determined in consultation with the Proponent and EPA) is suggested as the primary means of assessing ongoing performance.

It may in this case also be useful to take direct measures to minimise particulate emissions from traffic using the tunnel, hence conditions that seek the Proponent and operator to assist with regulatory enforcement of smoky vehicles is suggested.

The adoption of in-tunnel visibility criteria would be likely to lead to operation of the tunnel with low particulate levels.

9 CONCLUSION

The review examined the Proponents modelling files in detail and did not identify any significant issues. The review specifically examined the model performance under the predicted worst case dispersion conditions for the worst case scenario. It was identified that one peak impact hour over the year of hourly modelling results was anomalous. Independently and by different means both the review and Proponent found the anomaly to be caused by the averaging of rapidly changing weather conditions producing an unrealistic set of hourly average weather input parameters for that hour. The anomaly for this hour arises due to an inherent model limitation, and is not an error or an indicator of poor performance, indeed the results clearly show that the stack design performs well at dispersing air emissions above ground level.

This good performance is related to two important features of the tunnel design; the placement of the stack near to the exit portal; and, a variable velocity stack configuration. These design elements, or a design with equivalent or better performance under the full range of operating conditions (including low flow traffic in the night time under poor dispersion conditions) should be maintained in the final detailed tunnel design.

Although the issue of using overly conservative assumptions was identified in the preliminary review, it was not considered to be a significant issue. However as NO_2 emissions were increased in the revised assessment by an additional 60% at the request of the NSW EPA, and all other overly conservative assumptions remained unchanged, the review has identified that over-conservatism leading to over estimation of potential impacts is a potential issue in the revised assessment specific to NO_2, and that in this regard the assessment does not present a realistic prediction of the likely effects that may be experienced by the community.

The review therefore conducted an independent, conservative screening level assessment of potential NO_2 impacts in the community arising from the operation of the stacks, and found that the peak 1-hour maximum NO_2 level over the year would be many times lower than that calculated by the proponent (using the identical air dispersion modelling results). The Proponent's over predictions arise mainly from the overly conservative application of background Ozone data in a conservative NO_x to NO_2 conversion method (OLM method).

Overall, the review considers that there is a strong basis to conclude that the Proponent's revised assessment presents unrealistically high levels of NO_2 effects due to the stacks in the community.

Overall, the Proponent uses generally conservative assumptions to calculate results that show that the Project will improve roadside air quality, or have impacts that are small and well below the criteria in the vicinity of the tunnel stacks.

The conclusion that the net effect on air quality is positive is reached when balancing the relatively significant improvements for the receptors along Pennant Hills Road with the small negative effects near the stacks.

This review supports the Proponent's conclusions and makes recommendations for appropriate approval conditions that would ensure that the Project does not adversely affect tunnel users and the community.

10 REFERENCES

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Janssen, L. H. J. M., van Wakeren, J. H. A., van Duuren, H. and Elshout, A. J. (1988) "A Classification of NO oxidation rates in power plant plumes based on atmospheric conditions". Atmospheric Environment, Volume 22, Number 1, 43-53.

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"NorthConnex Technical working paper: Air quality", prepared by AECOM for Roads and Maritime Services, July 2014.

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"Environmental Impact Statement – Submissions and Preferred Infrastructure Report", prepared by AECOM for Roads and Maritime Services, November 2014.

Appendix A

Technical Review of Adequacy of Air Assessment in regard to the Air Modelling Regulatory Requirements

Table A-1: Technical Review of Adequacy of Air Assessment in regard to the Air Modelling Regulatory Requirements

Regulatory Requirements per Approved Methods/ Contemporary Practice	Appendix G – Technical working paper: Air Quality (AQIA)	AQIA reference	Proponents response	Adequate? (Y/N)	Comments
2. Methodology	Broadly, a Level 2 (refined dispersion modelling technique using site-specific input data) assessment was applied. Assessment methodology is described in Section 4.2 of AQIA. Methodology comparison with the regulatory requirements is addressed in more detail below for specific components of the approach.	Section 4.2	*Noted*	Y	
3. Emissions inventory					
3.1 Identify all sources of air pollution and potential emissions	Traffic pollutant emission rates that were used in the AQIA are enumerated in Section 1.4 and discussed in Appendix B. Source release parameters were determined per Sections 4.2.10.1 and 4.2.10.2 and Appendix I. Variable parameter files (stack diameter, temperature, velocity, and building wakes) are not set out alongside the data. It is noted that these parameters vary according to conditions, but some example calculations need to be provided to permit the review to determine whether the calculations are correct and whether the emissions are correctly identified. Clarification is needed in regard to the constant southern ventilation outlet diameter of 7.9m as per table in Appendix I which appears to be contradictory to the variable outlet opening proposed for the ventilation outlet partition at certain times and traffic conditions. Whilst all sources are identified, some further clarification is requested.	Sections 1.4, 4.2.10.1 and 4.2.10.2, and Appendices B and I	*Noted* *The southern ventilation outlet has been assumed to be segmented in the same manner as the northern ventilation outlet (refer to Table 2-57 (page 227) of the submissions and preferred infrastructure report).*	Y	
3.3 Estimate emission rates	Emission rates are estimated using standard emission factors. Emission factors from the World Road Association (PIARC, 2012) were used to estimate the PM_{10}, NO_x and CO emissions. A safety margin was added as the factors purpose is to define minimum air	Sections 4.2.8.1 and 4.2.8.2	*Noted* *Details of how the emission inventories for the project have been calculated are provided in*	Y	

Regulatory Requirements per Approved Methods/ Contemporary Practice	Appendix G – Technical working paper: Air Quality (AQIA)	AQIA reference	Proponents response	Adequate? (Y/N)	Comments
	flows in road tunnels to achieve adequate air quality, and not for developing emissions inventories. Emission factors from NPI (DEWHA, 2008), together with the calculated emissions of PM_{10} and CO, were used to estimate the $PM_{2.5}$, total VOCs and PAHs emissions. Emission factors were recalculated by Pacific Environment Ltd (PEL) for verification. The causes of the differing results from those of AECOM are summarised in Section 4.2.8.2. Some of the results from AECOM and PEL differ by a factor of more than two. The emission factors were also compared with EPA emission factors. The factors used are appropriate, but the review is unable to calculate whether worst case emission rates have been established due to a lack of detail regarding how the tunnel air flows and traffic would be managed and what the air flow parameters could be. The review includes a detailed request for clarification in regard to the worst case design scenario for maximum traffic flow and the worst case breakdown scenario.		*Section 2.8 of the submissions and preferred infrastructure report. A discussion of the worst case scenario is provided in Section 2.7.2 (from page 125 to page 127).*		

Regulatory Requirements per Approved Methods/ Contemporary Practice	Appendix G – Technical working paper: Air Quality (AQIA)	AQIA reference	Proponents response	Adequate? (Y/N)	Comments
3.3.4 Accounting for variability in emission rates	Diurnally varying profile applied for each hour of the day. No weekend factors were incorporated. Hourly seasonal average temperature differences were applied to the Project's ambient temperature data. (Some margin of error may need to be considered as temperature data from the Lane Cove Tunnel used may not be exactly comparable to this Project given the longer length and larger number of heavy vehicles compared to the LCT.) Varying vehicle speeds, road gradients and fuel types have been taken into account in the factors used.	Sections 4.2.10.1, 4.2.10.2 and 4.2.11.1, and Appendix I	*Noted.* *Details of how the emission inventories for the project have been calculated are provided in Section 2.8 of the submissions and preferred infrastructure report.*	Y	
3.4 Calculate emission concentration for point sources i. Actual concentration of a pollutant emitted from a source (mg/Am^3) calculated using the actual gaseous volumetric flow rate (Am^3/s) and measured emission rate in Equation 3.1 ii. Concentration of a pollutant emitted from a source corrected to the reference conditions as specified in the Regulation (mg/Nm^3 @ O_2%). This is calculated using the gaseous volumetric flow	Emission concentrations from the stack were not calculated/ not shown. Note that an Oxygen correction is not applicable to the stack emissions in this situation as the tunnel is not a combustion source and is designed to operate with a normal level of oxygen in the air. The review includes a detailed request for clarification in regard to the worst case design scenario for maximum traffic flow and the worst case breakdown scenario.	-	*Table 2-38 (forecast traffic 2019), Table 2-39 (forecast traffic 2029), Table 2-40 (design analysis A), Table 2-41 (design analysis B 2019)and Table 2-42 (design analysis B 2029) on page 152 to page 161 of the submissions and preferred infrastructure report provide the emissions inventories for the air quality impact assessment as mass emission rates and discharge concentrations.* *A discussion of the worst case scenario is provided in Section 2.7.2 (from page 125 to page 127).*	Y	The SPIR provides the necessary data.

Regulatory Requirements per Approved Methods/ Contemporary Practice	Appendix G – Technical working paper: Air Quality (AQIA)	AQIA reference	Proponents response	Adequate? (Y/N)	Comments
rate corrected to normal conditions (dry, 273K, 101.3kPa) and the measured emission rate in Equation 3.1. The emission concentration (in mg/Nm^3) is then corrected to the appropriate oxygen reference condition. Further guidance on correcting to reference and equivalent values is provided in DEC (2005)					
3.5 Assess compliance with the Protection of the Environment Operations (Clean Air) Regulation.	N/A. The stack emissions were not assessed against the Regulation limits. The Regulation does not apply to emissions from traffic, but in any case it is noted that emissions would be well below the Regulation limits applicable to stack emissions from industrial plant.	N/A	*Noted*	N/A	
3.6 Presentation of emissions inventory					
i. all release parameters of stack and fugitive sources (e.g. temperature, exit velocity, stack dimensions, flow rate, moisture content, pressure, carbon dioxide and oxygen concentration) (Table 3.1)	Some of the release parameters are presented in Appendix I. Variable parameters are not presented in some specific cases, presumably as these would vary according to conditions. Clarification is needed in regard to the constant southern ventilation outlet diameter of 7.9m as per table in Appendix I which appears to be contradictory to the variable outlet opening proposed for the ventilation outlet partition at certain times and traffic conditions. Whilst all sources are identified, some further clarification is requested.	Appendix I	*The southern ventilation outlet has been assumed to be segmented in the same manner as the northern ventilation outlet (refer to Table 2-57 (page 227) of the submissions and preferred infrastructure report).* *Details of the operation of the segmentation are provided in Table 21 of the Technical Working Paper: Air Quality*	Y	The SPIR provides the necessary data.
ii. Pollutant emission concentrations and a comparison against the	N/A. But in any case it is evident that the emissions would be well below any regulatory requirements for the emissions from any scheduled or non-scheduled premises.	-	*Noted*	N/A	

Regulatory Requirements per Approved Methods/ Contemporary Practice	Appendix G – Technical working paper: Air Quality (AQIA)	AQIA reference	Proponents response	Adequate? (Y/N)	Comments
relevant requirements of the Regulation (Table 3.2)					
4. Meteorological data					
4.1 Minimum data requirements	A Level 2 impact assessment was conducted. AQIA Appendix F states that *"all data sets for all three years had less than 10 per cent missing data"* and *"when one station is missing data for a particular hour, the model will use the meteorological conditions from the next nearest station for that hour"*. This can be verified when examining the electronic modelling files for the subsequent detailed review. A brief description of the climate for each of the years modelled are presented in Appendix F of the AQIA. Meteorological evaluation of the MM5 data against the five observation stations for the modelling period are presented in Appendix F. A three-year period (January 2009 – December 2011) meteorological modelling using MM5 was conducted using data from five meteorological stations operated by the Bureau of Meteorology (BOM) and the OEH. The three-year data from BOM Sydney Airport station was compared with a 30-year statistics (of 9am and 3pm temperature, relative humidity, and wind speed) from the same station. The three-year data from Prospect station was compared with a 5-year statistical data (for temperature, wind direction and wind speed) from the same station. The approach is consistent with the required objectives of the Approved Methods, noting that the MM5 Model is considered to be at least equivalent to the nominated TAPM model in the Methods. Generally the approach applied is consistent with good	Section 4.2.4 and Appendix F	*Noted. Further information and clarification is provided in Chapter 2 of the submissions and preferred infrastructure report*	Y	

Regulatory Requirements per Approved Methods/ Contemporary Practice	Appendix G – Technical working paper: Air Quality (AQIA)	AQIA reference	Proponents response	Adequate? (Y/N)	Comments
	contemporary standards, and where not explicitly per the Approved Methods this is because the Approved Methods is out of date in this regard.				
4.2 Siting and operating meteorological monitoring equipment	AQIA applies meteorological data from stations operated by BOM and OEH. The locations of the stations are shown in Figure 4.	N/A	*Noted. Further information and clarification is provided in Chapter 2 of the submissions and preferred infrastructure report.*	Y	
4.3 Preparation of Level 1 meteorological data	N/A. A level 2 assessment was conducted	N/A		N/A	
4.4 Preparation of Level 2 meteorological data	CALMET was used to prepare a Level 2 meteorological data file for modelling purposes using data from five surface meteorological stations operated by BOM and OEH and a 3D gridded prognostic data set derived from the MM5 Model. It is noted that this approach applies three-dimensional, hourly varying data for each hour modelled in the assessment (for up to a three year period).	Table 17 of Section 4.2.7	*Noted. Further information and clarification is provided in Section 2.10 of the submissions and preferred infrastructure report*	Y	
4.5 Developing site-representative meteorological data using prognostic meteorological models	The MM5 prognostic model was used with CALMET. Input parameters into the model are summarised in Table 17 of the AQIA. Meteorological data from MM5 were statistically evaluated. The data appear to be consistent with that expected for this area, and no apparent issue can be identified. A detailed review of the electronic modelling files is to be conducted as part of the subsequent detailed review of the Project.	Sections 4.2.4 and 4.2.7, and Appendix F	*Noted. Further information and clarification is provided in Section 2.10 of the submissions and preferred infrastructure report*	Y	
5. Background air quality data, terrain, sensitive receptors and building wake effects					
5.1 Background air quality data	Background air quality data from 2009 to 2011 were taken from the two nearest OEH monitoring stations. Project monitoring data from December 2013 were also available. It appears that modelled 2019 surface road (Pennant Hills Road) data were used to represent current roadside pollutant background levels.	Sections 3.1, 6.1.1, 6.1.2 and 6.1.3	*Noted. Further information and clarification is provided in Section 2.11 of the submissions and preferred infrastructure report.* *Further discussion of the approach taken to*	Y	The clarification confirms that a conservative approach, taking the highest of several data sets has been applied.

Regulatory Requirements per Approved Methods/ Contemporary Practice	Appendix G – Technical working paper: Air Quality (AQIA)	AQIA reference	Proponents response	Adequate? (Y/N)	Comments
	The data were applied to assess PM_{10}, $PM_{2.5}$, NO2 and CO by using the maximum measured background pollutant concentrations in each hour from the roadside modelling or the maximum measured at Lindfield or Prospect OEH monitoring stations for the modelling period. Thus the maximum of the available data was used to represent the background pollutant levels. The approach is consistent with a Level 1 screening level assessment in that maximum background levels are used, however it is more consistent with a conservative Level 2 assessment as the maximum background level in each hour was used and paired with the predicted level in each hour. It could be more accurate to have applied only the locally measured data in a Level 2 assessment, but it is noted that in this case this would result in lower levels than those predicted, (whenever the background levels in the other data sets were higher). It is not completely clear whether the method of dealing with background levels was the same for the roadside (CAL3QHCR) modelling and the stack emissions (CALPUFF) modelling, but it appears that the same approach was used. Some clarification may be warranted.		*project contributions, background contributions and cumulative concentrations is provided in Section 2.14.1 of the submissions and preferred infrastructure report.* *Charts 1, 2 and 3 in the Technical Working Paper: Air Quality show a combined data set of monitoring data from the Prospect and Lindfield monitoring stations. The combined data set has taken the highest monitored value from either the Prospect monitoring station or the Lindfield monitoring station for each hour, eight hour or 24 hour period.* *An explanation of how background air quality has been defined and applied is provided in Section 2.14.1 of the submissions and preferred infrastructure report. In summary, for the purpose of the air quality impact assessments for the project, 'background air quality' has been taken as the higher of the following two values for each receiver location:* • *The monitored ambient air quality, from the combined Prospect/Lindfield combined monitoring data set; or* • *The predicted concentration from the CAL3QHCR model*		
5.2 Terrain data and sensitive receptors	Terrain and land use of the project area are briefly described in Section 3.2. The gridded terrain elevations for the modelling domain were derived from the NASA SRTM data. As the project is located in a highly built-up urban area, all grid points in the modelling domain were treated as sensitive receivers, with a higher density grid used closer to the sources (stacks) and additional receivers along the project corridor (Pennant Hills Road).	Sections 3.2, 3.3, 4.2.5, 4.2.6, Appendix E	*Further discussion of the approach taken to terrain data is provided in Section 2.12 of the submissions and preferred infrastructure report.*	Y	

Regulatory Requirements per Approved Methods/ Contemporary Practice	Appendix G – Technical working paper: Air Quality (AQIA)	AQIA reference	Proponents response	Adequate? (Y/N)	Comments
5.2 Building wake effects	Building location and dimensions applied in the building wake assessment in the CALMET modelling and are presented in Appendix H of the AQIA.	Appendix H	*Noted*	Y	
6. Dispersion modelling					
6.3 Advanced air dispersion models for specialist application	MM5 was used for meteorological modelling, together with CALMET to best consider local terrain effects. Two specialised air dispersion models were used; CAL3QHCR was used to calculate roadside pollutant emissions from surface roads (i.e. along Pennant Hills Road). His model is supported by the US EPA and is a relatively conservative, regulatory model specifically designed for road side predictions of traffic pollutants using hourly varying weather and traffic conditions, including queuing at signals. CALPUFF was used to assess the potential impacts form the stacks. CALPUFF is also a regulatory approved model designed to model air dispersion in complex terrain. The model also uses hourly varying weather and stack emissions data. 'Without project' scenario used CAL3QHCR. 'With project' scenario used CALPUFF and CAL3QHCR.	Table 13 in Section 4.2.1, Section 4.2.3	*Noted*	Y	
2.2.3 Processing dispersion model output data	Predicted ground level concentrations (glc's) of all pollutants are in the same units and for the same averaging period as the relevant impact assessment criteria	Section 6.1.1 to 6.1.8, Appendix G	*Noted*	Y	
7. Interpretation of dispersion modelling results					
7.1.2 Application of impact assessment criteria for SO_2, NO_2, O_3, Pb, PM_{10}, TSP, deposited dust, CO and HF. The Approved Methods states that the assessment criteria must	It is noted that the Approved Methods applies to Stationary Sources, which does not include emissions from motor vehicles. Technically it would appear that the Approved Methods is not applicable to the Project, but the existing industry practice is to adopt the Approved Methods for the assessment of stack emissions and as a means of assessing the effects of a Project on road side pollutant concentrations.	-	*Noted*	-	

Regulatory Requirements per Approved Methods/ Contemporary Practice	Appendix G – Technical working paper: Air Quality (AQIA)	AQIA reference	Proponents response	Adequate? (Y/N)	Comments
be applied as follows:					
a. At the nearest existing or likely future off-site sensitive receptor	The maximum predicted glcs at all the sensitive receptors were reported, with the exception of elevated receptors in the vicinity of the stacks. It is necessary to evaluate the impacts at elevated receptors in the vicinity of the stacks	Sections 6.1.1, 6.1.6 and 6.1.8, and Appendix G	*Assessment of potential air quality impacts at elevated receivers is provided in response to the submission from Ku-ring-gai Council (refer to page 685 to page 688, Section 7.3.1 of the submissions and preferred infrastructure report).*	Y	The SPIR provides such data. The data necessary for a planning body to best manage potential future issues at new high rise development is provided in the main body of this report. The data was obtained by re-running the Proponent's model. It is advised to re-examine this issue 3 years after the operation of the tunnel is confirmed, as it is likely that lower actual effect may occur.
b. The incremental impact (predicted impacts due to the pollutant source alone) for each pollutant must be reported in units and averaging periods consistent with the impact assessment criteria.	Incremental predicted glcs of all pollutants are in the same units and for the same averaging period as the relevant impact assessment criteria.	Sections 6.1.1, 6.1.6 and 6.1.8, and Appendix G	*Noted*	Y	
c. Background concentrations must be included using the procedures specified in Section 5.	Cumulative impacts, which included the background concentrations, were considered in the assessment. A conservative Level 2 assessment was conducted using the maximum background levels each hour from various monitoring sites. The AQIA contains numerous typos, incorrect cross references and other errors and omissions that need to be corrected. For example, Table 38, which presents the cumulative $PM_{2.5}$ impact assessment results, refers to Table 33 (incorrectly) for the	Sections 6.1.1, 6.1.2, 6.1.3 and 6.1.6, and Appendix G	*The air quality impact assessment presented in the environmental impact statement has now been superseded by the further assessment conducted to support the increase in project ventilation outlet heights by five metres.* *The updated assessment is presented in Chapter 2 and Section 9.2 of the submissions and preferred infrastructure report.*	Y	The SPIR provides the necessary data.

Regulatory Requirements per Approved Methods/ Contemporary Practice	Appendix G – Technical working paper: Air Quality (AQIA)	AQIA reference	Proponents response	Adequate? (Y/N)	Comments
	cumulative 24-hour average $PM_{2.5}$ assessment. Tables 33 contains data for VOC's and PAH's. Table 38 appears to be the intended table containing cumulative 24-hour $PM_{2.5}$ results. However Table 38 does not contain the date of each day considered as required by the Approved Methods. Also there are errors in the data as for example different values for the background level are shown for the 5th highest background level. Similar issues are apparent in other parts of the report and require correction and clarification. It is necessary to explain the high levels presented. Presenting a cumulative 24-hour average $PM_{2.5}$ level of 78.0µg/m^3, without any pertinent commentary is not consistent with the requirements of the Approved Methods or contemporary practice. It would be reasonable to expect that the AQIA would explain that this level is more than three times higher than the advisory reporting standard of 25µg/m^3, but is due to existing measured levels of 77.6µg/m^3 (perhaps there was a bushfire on this day). It is also noted that the annual average $PM_{2.5}$ levels is predicted to be up to 10.3µg/m^3, which is also above the advisory reporting standard for 8.0µg/m^3. The only commentary provided states that *"In all cases, the contributions from the project to the surrounding airshed were predicted to be well below the applicable air quality assessment criteria."* Whilst this may be true, (the effect of the project alone is indeed small and is well below the cumulative criteria level) it is not consistent with contemporary practice to omit evaluation of the cumulative impacts when discussing a cumulative standard. It is however noted that NSW does not have any regulatory impact assessment criteria for 24-hour $PM_{2.5}$, and the NEPM $PM_{2.5}$ advisory reporting standards referred to in this case are applicable to NEPM monitoring sites, which do not include "peak sites" near roads.				

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Regulatory Requirements per Approved Methods/ Contemporary Practice	Appendix G – Technical working paper: Air Quality (AQIA)	AQIA reference	Proponents response	Adequate? (Y/N)	Comments
	As the data provided clearly show that the Project is a small contributor to the elevated levels of existing impact, (for example the peak project contribution to the annual average $PM_{2.5}$ levels at the Southern Ventilation stack is 0.3µg/m^3 and the existing level would be 10.0µg/m^3) the information is adequate to evaluate the Project. However, it would be appropriate to carefully review the data presented in the AQIA (generally) and to correct errors, incorrect cross references, and omissions such as those outlined above.				
d. Total impact (incremental impact plus background) must be reported as the 100th percentile in concentration or deposition units consistent with the impact assessment criteria and compared with the relevant impact assessment criteria.	Cumulative impacts were reported as 100^{th} percentile and have units consistent with the relevant assessment criteria and compared against the relevant criteria. Refer to the above point regarding errors and omissions that warrant correction.	Sections 6.1.1, 6.1.2 and 6.1.3, and Appendix G	*The air quality impact assessment presented in the environmental impact statement has now been superseded by the further assessment conducted to support the increase in project ventilation outlet heights by five metres.* *The updated assessment is presented in Chapter 2 and Section 9.2 of the submissions and preferred infrastructure report.*	Y	The SPIR provides the necessary data.
7.2.2 Application of impact assessment criteria for individual toxic air pollutants. The Approved Methods states that the assessment criteria must be applied as follows:					
a. At and beyond the boundary of the facility.	The 99.9^{th} percentile predicted glcs at all the sensitive receptors (except elevated receptors), which includes receptors at and beyond the boundary, were reported, per the requirements	Sections 6.1.1, 6.1.5, 6.1.6 and 6.1.8, and Appendix G	*Noted*	Y	

Regulatory Requirements per Approved Methods/ Contemporary Practice	Appendix G – Technical working paper: Air Quality (AQIA)	AQIA reference	Proponents response	Adequate? (Y/N)	Comments
b. The incremental impact (predicted impacts due to the pollutant source alone) for each pollutant must be reported in concentration units consistent with the criteria (mg/m^3 or ppm), for an averaging period of 1 hour and as the: i. 100th percentile of dispersion model predictions for Level 1 impact assessments, or ii. 99.9th percentile of dispersion model predictions for Level 2 impact assessments	In Table 33 and a table in Appendix G, Total VOC is presented as benzo(a)pyrene, while PAHs as benzene when this should be the other way around. This appears to be a simple transcription or typographical error and should be clarified. The incremental impact are reported in concentrations consistent with the criteria and for the same averaging period. As this is a conservative Level 2 assessment, the 99.9th percentile predicted glcs at all sensitive receptors (except elevated receptors) were reported per the Approved Methods.	Sections 6.1.1, 6.1.5 and 6.1.6, and Appendix G	*Noted*	Y	
c. Polycyclic aromatic hydrocarbons (PAH) as benzo[a]pyrene (BaP) must be calculated using the potency equivalency factors for PAHs in Table 7.2c.	The PAHs were not modelled and assessed as individual species. In Appendix G, it is stated that no further analysis of PAHs were undertaken as they were well below the relevant impact assessment criteria.	Appendix G	*Noted*	N/A	
d. Dioxins and furans as toxic equivalent must be calculated according to the requirements of clause 29 of the Regulation.	N/A	N/A	*Noted*	N/A	
8. Modelling pollutant transformations					
8.1 Nitrogen dioxide assessment	The USEPA's Ozone Limiting Method (OLM) was used to predict glcs of NO_2 from NO_X.	Section 4.2.11.1	*Noted. Further information relating to the application of the OLM equation is provided in Section 2.14.2 of the submissions and preferred*	Y	The OLM method has been applied at receptors within approximately 100m of the

Regulatory Requirements per Approved Methods/ Contemporary Practice	Appendix G – Technical working paper: Air Quality (AQIA)	AQIA reference	Proponents response	Adequate? (Y/N)	Comments
			infrastructure project.		stacks, which tends to overestimate impacts as 100% of the NOx is converted to NO2 in many of the relevant hours of the year. The overestimation is confirmed when applying a screening (Level 1) Janssen approach per the Approved Methods Guidelines. The Janssen approach is better able to deal with receptor distance away from the stack than the OLM method, and shows that even using a worst case approach results in a large margin of compliance.
9. Impact assessment report					
9.1 Site plan					
- Layout of the site clearly showing all unit operations	Unit operations are not relevant in this assessment. A site layout is clearly shown.	Figure 1 of Section 1.0	*Noted*	Y	
- All emission sources clearly identified	Southern ventilation facility is not identified. Otherwise all sources are identified.	Figure 1 of Section 1.0	*The location of the southern ventilation outlet is shown in Figure 5-17 of the environmental impact statement (inter alia). The southern ventilation offtake location is clarified in Section 4.2 of the submissions and preferred infrastructure report.*	Y	
- Plant boundary	N/A	N/A		N/A	

Regulatory Requirements per Approved Methods/ Contemporary Practice	Appendix G – Technical working paper: Air Quality (AQIA)	AQIA reference	Proponents response	Adequate? (Y/N)	Comments
- Sensitive receptors (e.g. nearest residences)	As this is an urban area, essentially all locations are considered as a sensitive receptor, as shown in Figure 8.	Figure 8 of Section 4.2.6	*Noted*	Y	
- Topography	Topography and land use are presented over the modelling domain with the locations of emission sources.	Appendix E	*Noted*	Y	
9.2 Description of the activities carried out on the site	A discussion on the operation of the project and the configuration and operation of the ventilation system according to different conditions (normal traffic, low speed traffic and emergency) is in Section 2.0. The predicted tunnel traffic flows is shown in Figures 9 and 10 of Section 4.2.8.4. Section 4.2.10 discusses about the variable outlet temperature and variable ventilation outlet diameter. Tables presenting the ventilation outlets locations, height, and building dimensions and locations are in Appendix H. It is not explained in sufficient detail how in-tunnel air quality will be managed. The specific details of this issue are outlined in the review report, and additional clarification is requested.	Sections 2.0, 4.2.8.4 and 4.2.10 and Appendix H	*Noted* *Refer to discussion in the main body of this document, and references to additional information provided in the submissions and preferred infrastructure report*	Y	
9.3 Emissions inventory	The estimation of emissions used in the modelling is described in Section 4.2.8. Results of emission calculations are presented in Table 18 of Section 4.2.8. Example calculation on how the emission rate were calculated is in Appendix H. Hourly emission rates for different scenarios are tabulated in Appendix H. It is not explained in sufficient detail how in-tunnel air quality will be managed, and it is not possible to the review to conclusively	Section 4.2.8 and Appendix H	*Section 2.8 and Section 2.9 of the submissions and preferred infrastructure report detail how emissions inventories and in-tunnel air quality have been calculated.* *A discussion of the approach to tunnel ventilation operation is provided in Section 2.9.2 of the submissions and preferred infrastructure report.* *A discussion of the worst case scenario is provided in Section 2.7.2 (from page 125 to page 127).*	Y	The SPIR provides the necessary data.

Regulatory Requirements per Approved Methods/ Contemporary Practice	Appendix G – Technical working paper: Air Quality (AQIA)	AQIA reference	Proponents response	Adequate? (Y/N)	Comments
	determine whether the worst case has been correctly identified. The specific details of this issue are outlined in the review report, and additional clarification is requested.				
9.4 Meteorological data	Section 4.2.4 provides a discussion of the meteorological data used in the model runs, a comparison of the Sydney station modelling period data with its 30-year average data, and a comparison of the Prospect station modelling period data with its 5-year average data. CALMET and MM5 input parameters are summarised in Table 17 of Section 4.2.7. The following are presented in Appendix F: - A brief description of the climate for each year of the modelling period - Annual, seasonal and diurnal wind roses for each year for each of the BOM and OEH stations and extracted from CALMET for the northern and southern ventilation outlet locations - Statistical evaluation of MM5 data vs observations for 2009, 2010 and 2011 - Charts of stability class vs hour of day for Prospect and Sydney station - Charts of stability class vs wind speed for Prospect and Sydney station	Sections 4.2.4 and 4.2.7, and Appendix F	*Noted. Further information and discussion of meteorology is provided in Section 2.10 of the submissions and preferred infrastructure report.*	Y	
9.5 Background air quality data	A description of the background air quality of the project is presented. The relevant standards used for the installed monitoring stations are summarised in Table 10. The ambient monitoring data are summarised in Tables and Charts. A comparison of the data from the project monitoring stations with those from the OEH stations and predicted concentrations from the CAL3QHCR models are presented in Appendix C. There may be some ambiguity in how the background data was applied, and some further clarification is requested.	Section 3.0 and Appendix C	*Ambient air quality is discussed in Section 2.11 of the submissions and preferred infrastructure report.* *An explanation of how background air quality has been defined and applied is provided in Section 2.14.1 of the submissions and preferred infrastructure report.*	Y	The SPIR provides the necessary data.
9.6 Dispersion modelling					
- A detailed discussion and	A generic description of the models used is provided in Appendix D	Various parts	*Details of model set-up and parameters is*	Y	The SPIR provides the

Regulatory Requirements per Approved Methods/ Contemporary Practice	Appendix G – Technical working paper: Air Quality (AQIA)	AQIA reference	Proponents response	Adequate? (Y/N)	Comments
justification of all parameters used in the dispersion modelling and the manner in which topography, building wake effects and other site-specific peculiarities that may affect plume dispersion have been treated	and only some of the model inputs are discussed or outlined in various parts of Section 4.2 (e.g. Table 17). The specific model settings are not detailed, however electronic modelling files have been provided for the detailed review. (Please note that the BPIP (building wake) files have not been provided, and are requested.)	of Section 4.2 and Appendix D	*provided in Section 2.10 (CALMET/ MM5) and Section 2.13 (CALPUFF/CAL3QHCR) of the submissions and preferred infrastructure report.* *Building wake parameters are provided in Section 2.13.2 of the submissions and preferred infrastructure report. BPIP files have been provided separately.*		necessary data.
- A detailed discussion of the methodology used to account for any atmospheric pollutant formation and chemistry	The method used in this assessment for the conversion of NO_X to NO_2 is described in Section 4.2.11.1. Appendix I further discusses the method and presents other conversion methods available.	Section 4.2.11.1 and Appendix I	*Noted. Further information relating to the application of the OLM equation is provided in Section 2.14.2 of the submissions and preferred infrastructure project.*	Y	
- A detailed discussion of air quality impacts for all relevant pollutants, based on predicted ground-level concentrations at the plant boundary and beyond, and at all sensitive receptors	Section 6.1 presents the maximum and 99.9th percentile air quality impacts for all relevant pollutants based on the predicted ground-level concentrations.	Section 6.1	*Noted*	Y	
- Ground-level concentrations, hazard index and risk isopleths (contours) and tables summarising the predicted concentrations of all relevant pollutants at sensitive receptors	Ground-level concentrations isopleths are presented in Section 6.1. Tables summarising the maximum, 99.9th percentile, and up to 10th ranked glc's are also presented in Section 6.1 and Appendix G. There are no contour plots for Design Analysis A and B. There is no table summarising the predicted concentrations of all relevant pollutants at all sensitive receptors.	Section 6.1 and Appendix G	*Noted* *The design analysis scenarios were included as sensitivity analyses to aid in the examination of the potential tunnel impacts if assumptions for the normal operations were too low or to assist in regulatory licensing. Peak ground level concentrations predicted for forecast traffic volume scenarios in 2019 and 2029, and for design analysis A (worst case scenario) are presented in Section 2.15 and Section 9.2 of the submissions and preferred infrastructure report. These predicted peak ground level concentrations take into account amendments to*	Y	The SPIR provides the necessary data.

Regulatory Requirements per Approved Methods/ Contemporary Practice	Appendix G – Technical working paper: Air Quality (AQIA)	AQIA reference	Proponents response	Adequate? (Y/N)	Comments
			the emissions inventory (as detailed in Chapter 2 of the submissions and preferred infrastructure report) and the amended height of the northern and southern ventilation outlets (an increase of five metres). *Emissions inventories for all scenarios, including design analysis A and design analysis B are provided in Section 2.8.2 of the submissions and preferred infrastructure report.* *Separate to this document, modelling output files have been provided which include maximum predicted ground level concentrations at all receiver locations for each of the assessment scenarios, including design analysis A and design analysis B.*		
- All input, output and meteorological files used in the dispersion modelling supplied in a *Microsoft* Windows-compatible format	All input, output and meteorological files used in the dispersion modelling need to be supplied in a *Microsoft* Windows-compatible format. This aspect is relevant to the subsequent detailed review to be completed.	-	*Noted. Modelling files in a suitable format have been provided separately.*	-	The Proponent provided the necessary data.

Appendix B

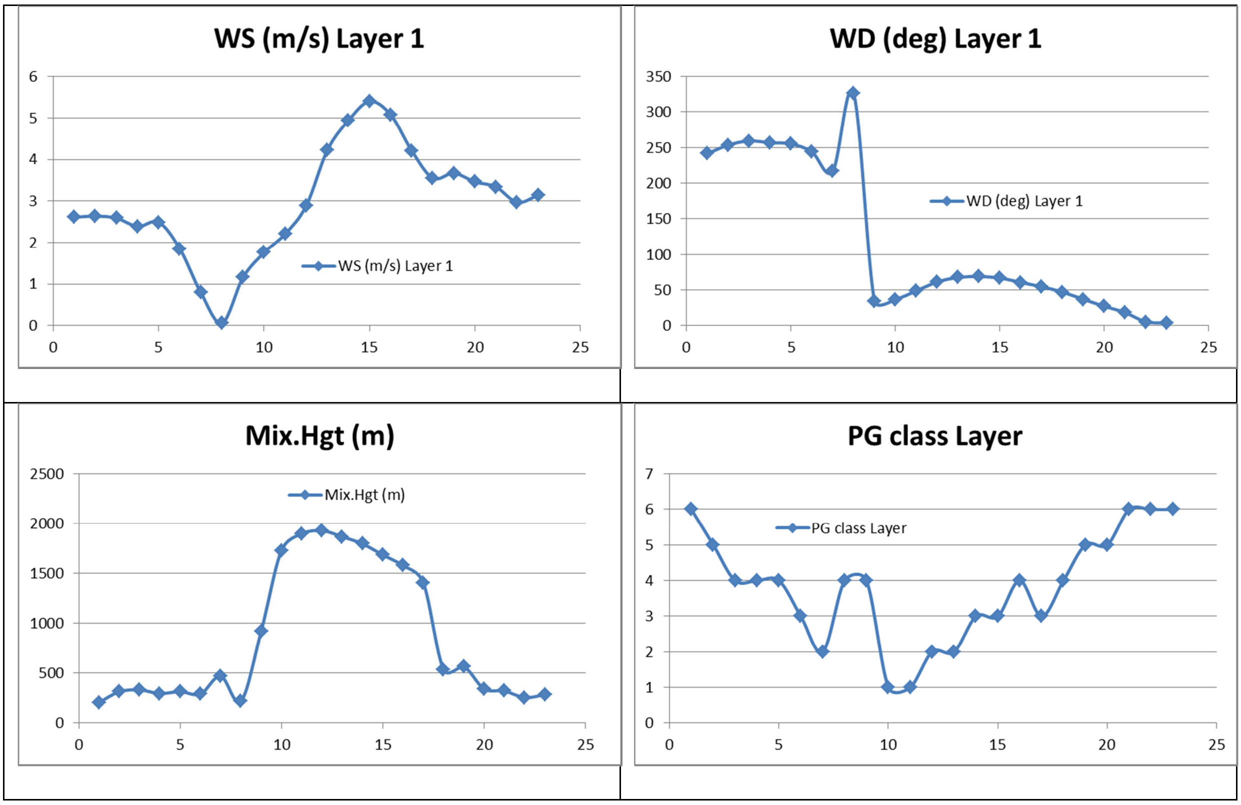
Proponent's examination of peak impacting hours for NO_2

Peak pollution concentrations have been identified to have been caused by a specific meteorological events occurring on Julian day 45 (14 February hour 17h) and Day 337 (3 December 08h) of the meteorological data. Analysis of Julian day 45 (hour 17h) has highlighted a stack tip downwash situation which has the potential to occur on just 3 days in the entire year of 2009. Of the three days when stack tip downwash could occur, peak concentrations only occur at hour 17h on Day 45. Other hours when the ambient flow is stronger than the exit velocity on day 45 are hours 19h, 20h, 21h, 22h and 23h, but downwash did not occur. No stack tip downwash events are predicted to occur for 2010 or 2011. Stack tip downwash is not considered a likely regular occurrence and has therefore been discounted as an area of concern for the dispersion modelling.

Day 337 meteorological conditions were further analysed and it was shown that the conditions which occur around the peak concentrations are characterised by the following set of events

- *180 deg wind direction change during the hour as offshore land breeze gives way to the onshore sea breeze*
- *wind speed reduction around the maximum hour*
- *mixing height reduction was accompanied by a vertical velocity reduction and change in stability class from unstable to neutral at the hour that the maximum concentration was recorded.*

***Figure 1** below shows the meteorological variables for this day at the north portal which lead to a peak concentration occurring at 08h00*



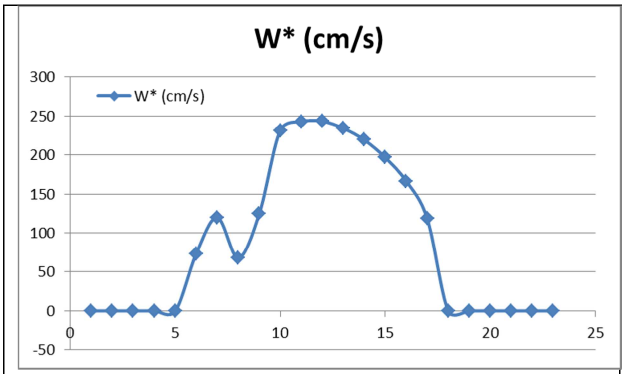


Figure 1   Meteorological Variables on 3 December, 2009 (hours 00 – 23).

The meteorological event responsible for the peak concentration is a naturally occurring part of the diurnal cycle of flow in the region. These characteristics are typically ascribed to the shift between off-shore flow during the night which gives way to on-shore winds in the morning. The sea land breeze cycle is likely to occur every single day of the year. However, although this meteorological event occurs mostly every day, there is no other hour in the entire year (2009) or in 2010 or 2011 that produces a peak concentration at this time of the day or at the interchange between the land and sea breeze. Certainly the meteorological events leading up to the peak event are not unusual and it can only be assumed that it is the combination of the massive wind direction change, that lead to a reduction in the stability class, mixing height and wind speed that caused the concentration peak which is a factor of two higher than the next highest concentration.

It is important to consider the data in context. Figure 2 shows the spread of concentrations v.s. wind speed at a single receptor. The normal distribution of concentrations is spread across a range of wind speeds, with one outlier (JDay 337) a factor of 2 times higher than the second highest concentration. If we considered the 99.9th percentile of the data, rather than the maximum which in this case is a single outlier then the spurious data would disappear.

A detailed analysis of the meteorological data against the concentration data for a full year period was undertaken to demonstrate that the peak concentration of JDay 337 (81 ug/m^3) is a spurious outlier of an otherwise normal data distribution. Similarly to JDay 45 this set of events and peak concentration outcome is not a regular occurrence. The 2D plots Shown in Figures 2, 3, 4 and 5 are representative of paired in time hourly meteorological and concentration data from the North Portal for the entire year of 2009. The plots represent the following;

- *Concentrations vs Wind Speed*
- *Concentrations vs Wind Direction*
- *Concentrations vs Stability Class*
- *Concentrations vs Mixing Height*

*The analysis has been presented in terms of the meteorological data graphed against the 2009 CO concentration. (CO data was used in the analysis as it represented a simple hourly prediction data set not influenced by atmospheric reactions as was NO_2 concentration). The four concentration plots are shown below in **Figures 2 to 5**.*

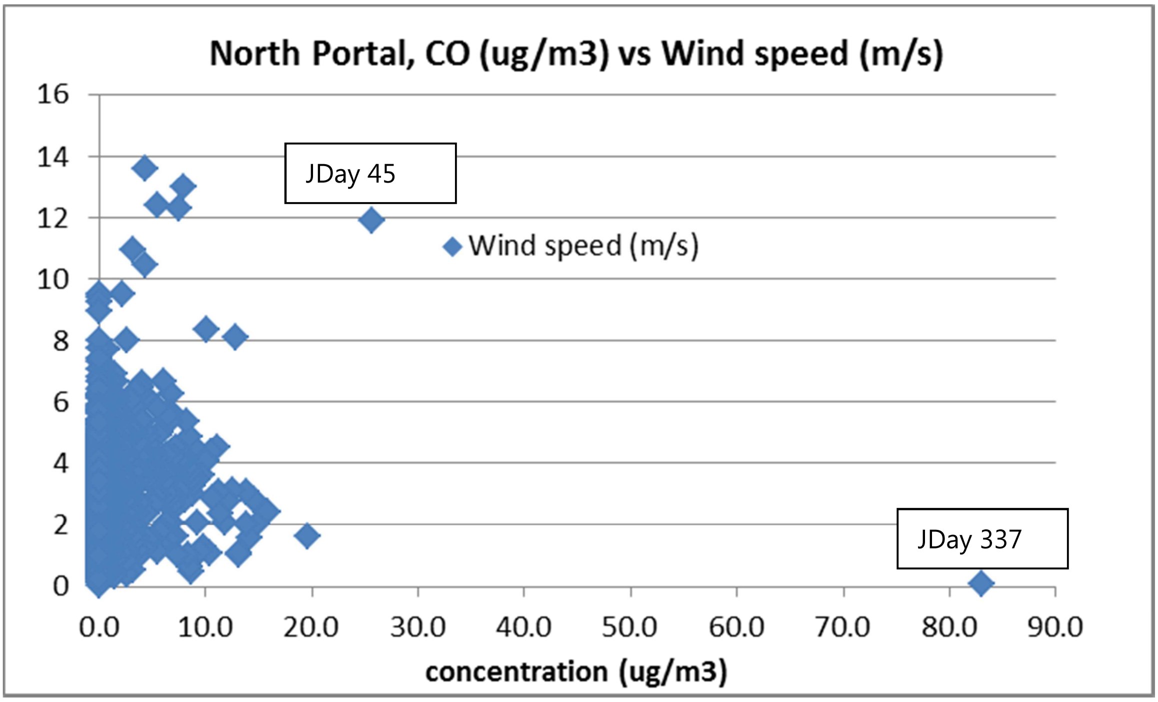


Figure 2 Concentrations vs Wind Speed. The maximum 'outlier' peak hourly concentrations of JDay 337 and JDay 45 are shown.

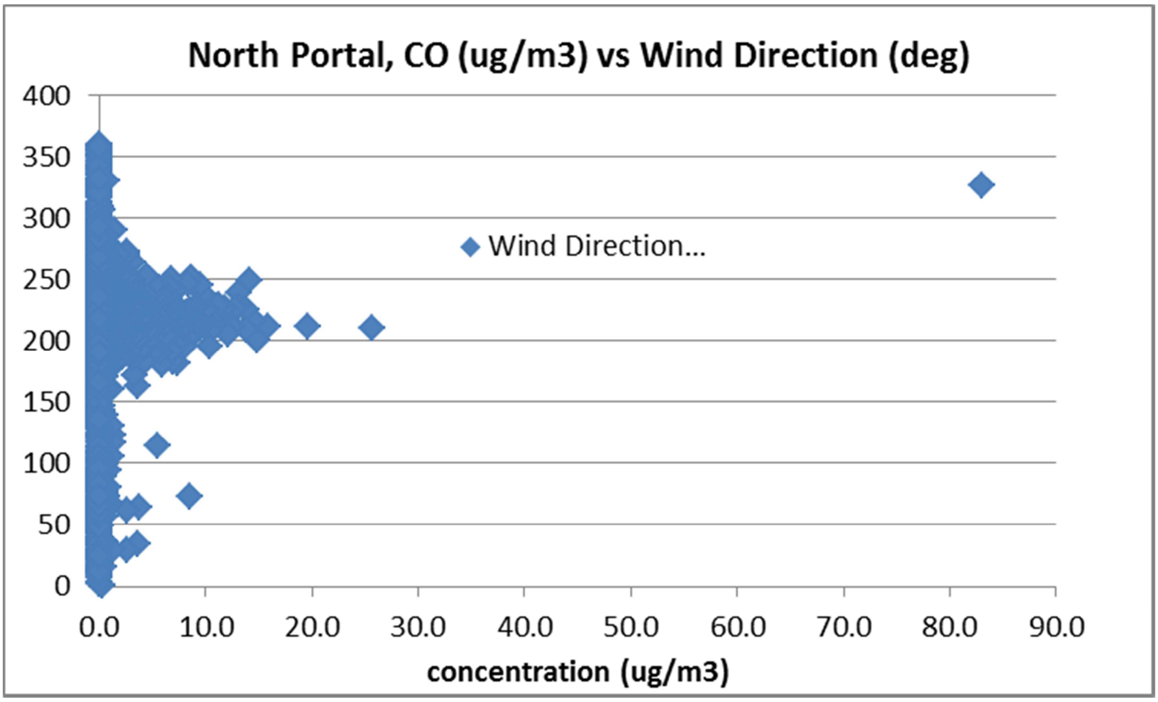


Figure 3 Concentrations vs Wind Direction

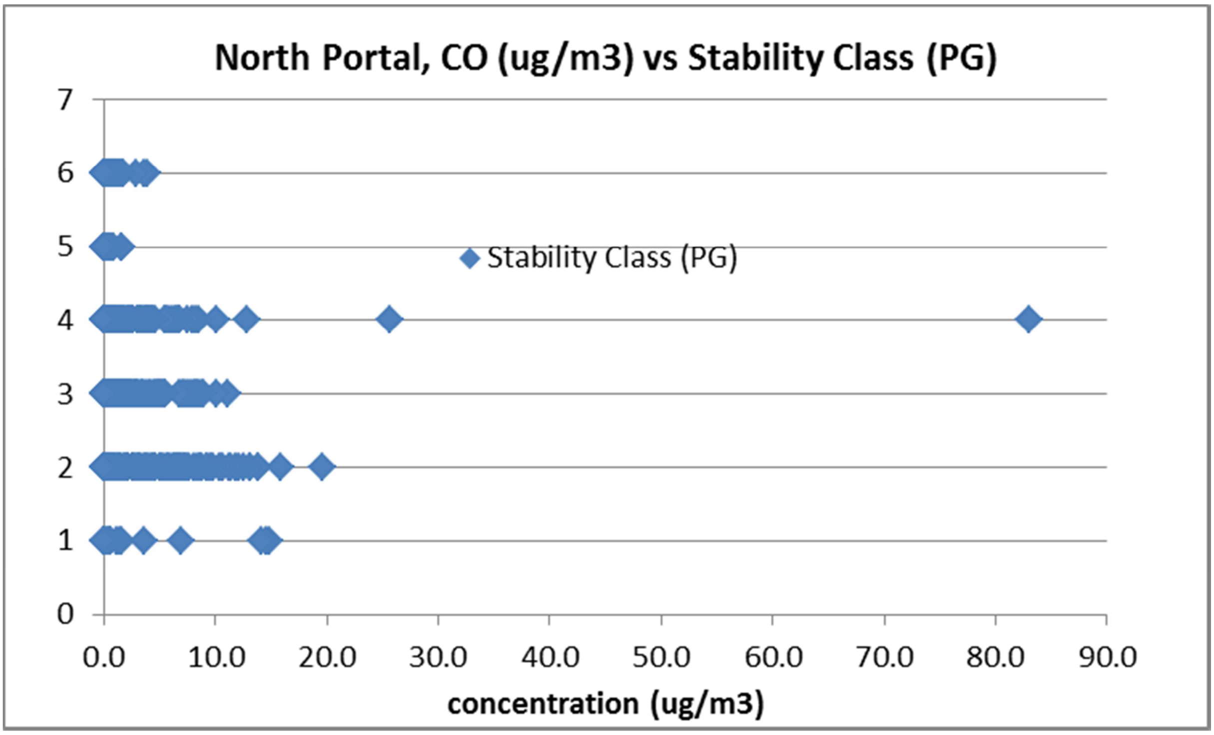


Figure 4 Concentrations vs Stability Class

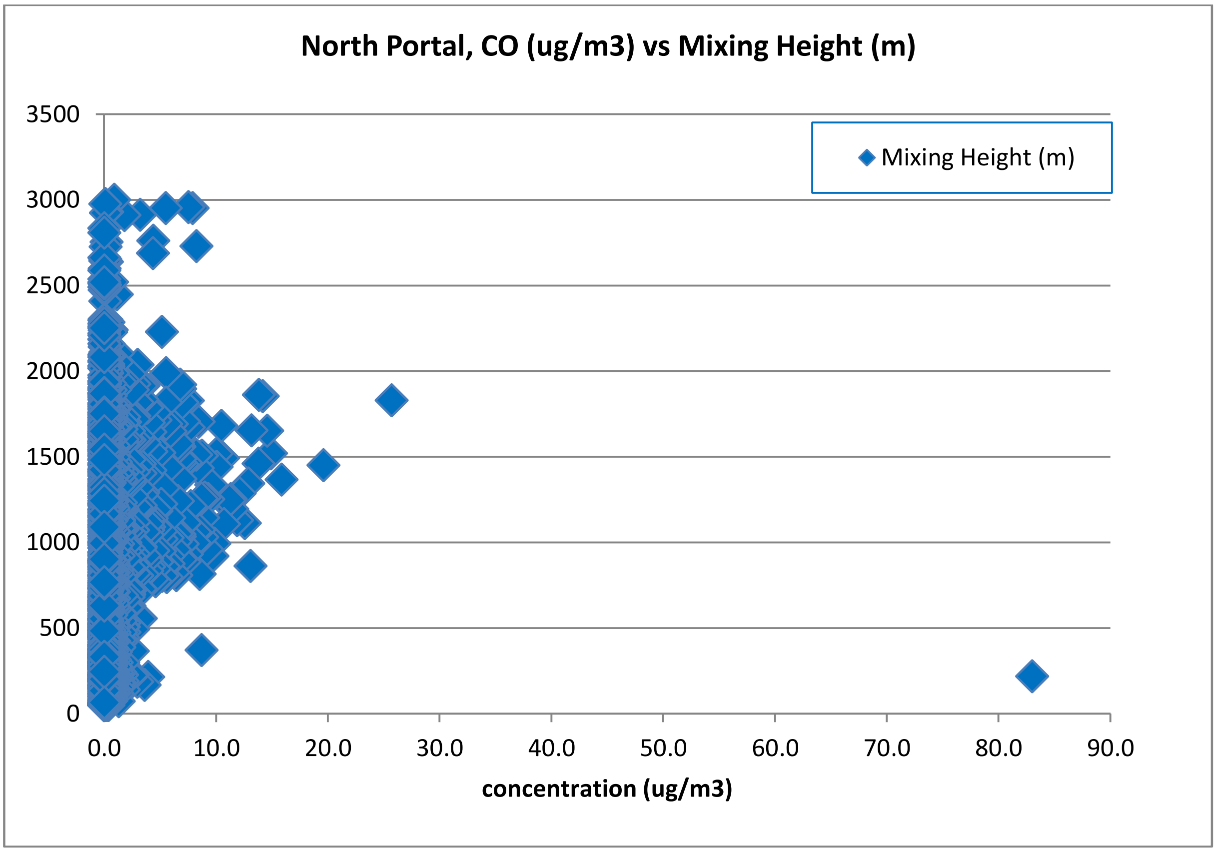


Figure 5 Concentrations vs Mixing Height

The modelling results clearly show that the single result recorded on hour 8, day 337 does not fit the normal distribution of data observed for all other meteorological conditions and can clearly be considered to be an outlier.

The offshore onshore breeze is a daily occurrence and yet no other hour at the time of the land sea breeze interface produces a concentration of any significance, therefore one can safely confirm that this hour is an outlier and not a normal by-product of this sort of event.

The above analysis is a simplistic analysis which draws broad conclusions about a highly complex meteorological situation. The broad trends and graphs above have been selected to attempt to demonstrate that the predicted concentration is not a typical effect and whilst it could be considered to be a calm condition (due to low wind speeds alone) wind speed is clearly not the only factor influencing the result. On this basis, it is not considered accurate to characterise these meteorological conditions as an effect caused by calm conditions rather it is a unique combination of modelled assumptions resulting in a single predicted data point well above the rest of the data predicted for the remaining 8759 hours of the year. It would therefore be considered acceptable to omit this data from the analysis.

Appendix C *Extract from AEGL Guidelines*

Nitrogen Oxides[4]

Acute Exposure Guideline Levels

PREFACE

Under the authority of the Federal Advisory Committee Act (FACA) P.L. 92-463 of 1972, the National Advisory Committee for Acute Exposure Guideline Levels for Hazardous Substances (NAC/AEGL Committee) has been established to identify, review, and interpret relevant toxicologic and other scientific data and develop AEGLs for high-priority, acutely toxic chemicals.

AEGLs represent threshold exposure limits for the general public and are applicable to emergency exposure periods ranging from 10 minutes (min) to 8hours (h). Three levels—AEGL-1, AEGL-2, and AEGL-3—are developed for each of five exposure periods (10 and 30 min and 1, 4, and 8 h) and are distinguished by varying degrees of severity of toxic effects. The three AEGLs are defined as follows:

AEGL-1 is the airborne concentration (expressed as parts per million or milligrams per cubic meter [ppm or mg/m^3]) of a substance above which it is predicted that the general population, including susceptible individuals, could experience notable discomfort, irritation, or certain asymptomatic, nonsensory effects. However, the effects are not disabling and are transient and reversible upon cessation of exposure.

AEGL-2 is the airborne concentration (expressed as ppm or mg/m^3) of a substance above which it is predicted that the general population, including susceptible individuals, could experience irreversible or other serious, long-lasting adverse health effects or an impaired ability to escape.

AEGL-3 is the airborne concentration (expressed as ppm or mg/m^3) of a substance above which it is predicted that the general population, including susceptible individuals, could experience life-threatening health effects or death.

Airborne concentrations below the AEGL-1 represent exposure concentrations that could produce mild and progressively increasing but transient and nondisabling odor, taste, and sensory irritation or certain asymptomatic, nonsensory effects. With increasing airborne concentrations above each AEGL, there is a progressive increase in the likelihood of occurrence and the severity of effects described for each corresponding AEGL. Although the AEGL values represent threshold levels for the general public, including susceptible subpopulations, such as infants, children, the elderly, persons with asthma, and those with other illnesses, it is recognized that individuals, subject to idiosyncratic responses, could experience the effects described at concentrations below the corresponding AEGL.

SUMMARY

Nitrogen oxide compounds occur from both natural and anthropogenic sources. Nitrogen dioxide (NO_2) is the most ubiquitous of the oxides of nitrogen and has the greatest impact on human health. Nitrogen tetroxide (N_2O_4) is a component of rocket fuels. Very few inhalation toxicity data are available on N_2O_4. Nitric oxide (NO) is an endogenous molecule that mediates the biologic action of endothelium-derived relaxing factor. The toxicity of NO is associated with methemoglobin formation and oxidation to NO_2. NO is also a component of air pollution and is generally measured as part of the total oxides of nitrogen (NO + NO_2).

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[4] This document was prepared by the AEGL Development Team composed of Carol Wood (Oak Ridge National Laboratory), Gary Diamond (Syracuse Research Corporation), Chemical Managers George Woodall and Loren Koller (National Advisory Committee [NAC] on Acute Exposure Guideline Levels for Hazardous Substances), and Ernest V. Falke (U.S. Environmental Protection Agency). The NAC reviewed and revised the document and AEGLs as deemed necessary. Both the document and the AEGL values were then reviewed by the National Research Council (NRC) Committee on Acute Exposure Guideline Levels. The NRC committee has concluded that the AEGLs developed in this document are scientifically valid conclusions based on the data reviewed by the NRC and are consistent with the NRC guidelines reports (NRC 1993, 2001).

The reactions of the oxides of nitrogen consist of a family of reaction paths that is temperature dependent and generally favors NO_2 production. A significant fraction of N_2O_4 and NO will be converted to NO_2. Since NO_2 is the most ubiquitous and the most toxic of the oxides of nitrogen, AEGL values derived from NO_2 toxicity data are considered applicable to all oxides of nitrogen. NO_2 exists as an equilibrium mixture of NO_2 and N_2O_4, but the dimer is not important at ambient concentrations (EPA 1993). When N_2O_4 is released, it vaporizes and dissociates into NO_2, making it nearly impossible to generate a significant concentration of N_2O_4 at atmospheric pressure and ambient temperatures without generating a vastly higher concentration of NO_2. Almost no inhalation toxicity data are available on N_2O_4 because of this effect, and no information was found on the interactions of nitrogen trioxide (N_2O_3).

Nitrogen Oxides

NO is unstable in air and undergoes spontaneous oxidation to NO_2 making experimental effects difficult to separate and studies difficult to perform (EPA 1993). Studies on the conversion of NO to NO_2 in medicinal applications have found the conversion to be significant at an atmospheric concentration of oxygen (20.9%) at room temperature. NO reacts with oxygen in air to form NO_2 which then reacts with water to form nitric acid (NIOSH 1976). For this reason, careful monitoring of NO_2 concentrations has been suggested when NO is used therapeutically at concentrations ≥80 ppm, especially when coadministered with oxygen (Foubert et al. 1992; Miller et al. 1994). Although closed-system experiments on a laboratory scale clearly indicate the potential for the production of NO_2, the chemical kinetics of NO conversion during a large-scale atmospheric release and dispersion are not well-documented. The estimation of the concentration isopleths following an accidental release would require the use of a finite-element model along with several assumptions about the chemical-rate constants. As a result, the conversion of NO to NO_2 during the atmospheric release is of concern to emergency planners. In photochemical smog, NO_2 absorbs sunlight at wavelengths between 290 and 430 nanometers (nm) and decomposes to NO and oxygen (EPA 1993).

AEGL values were based on studies of NO_2, the predominant form of the nitrogen oxides, and values are considered applicable to all nitrogen oxides. Values for N_2O_4 in units of ppm have been calculated on a molar basis. Because conversion to NO_2 is expected to occur in the atmosphere, and because NO_2 is more toxic than NO, the AEGL values for NO_2 are recommended for use with emergency planning for NO. The National Advisory Committee recognizes, however, that short-term exposures to NO below 80 ppm should not constitute a health hazard.

NO_2 is an irritant to the mucous membranes and might cause coughing and dyspnea during exposure. After less severe exposure, symptoms might persist for several hours before subsiding (NIOSH 1976). With more severe exposure, pulmonary edema ensues with signs of chest pain, cough, dyspnea, cyanosis, and moist rales heard on auscultation (NIOSH 1976; Douglas et al. 1989). Death from NO_2 inhalation is caused by bronchospasm and pulmonary edema in association with hypoxemia and respiratory acidosis, metabolic acidosis, shift of the oxyhemoglobin dissociation curve to the left, and arterial hypotension (Douglas et al. 1989). A characteristic of NO_2 intoxication after the acute phase is a period of apparent recovery followed by late-onset bronchiolar injury that manifests as bronchiolitis fibrosa obliterans (NIOSH 1976; NRC 1977; Hamilton 1983; Douglas et al. 1989). In addition, experiments with laboratory animals indicate that exposure to NO_2 increases susceptibility to infection (Henry et al. 1969; EPA 1993) due, in part, to alterations in host pulmonary defense mechanisms (Gardner et al. 1969).

For AEGL-1, a concentration of 0.5 ppm was adopted for all time points. Although the response of asthmatics to NO_2 is variable, asthmatics were identified as a potentially susceptible population. The evidence indicates that some asthmatics exposed to NO_2 at 0.3-0.5 ppm might respond with either subjective symptoms or slight changes in pulmonary function that are not clinically significant. In contrast, some asthmatics did not respond to NO_2 at concentrations of 0.5-4 ppm. Because of the weight of evidence, the study by Kerr et al. (1978, 1979) was considered the most appropriate for derivation of AEGL-1 values. They reported that 7/13 asthmatics experienced slight burning of the eyes, slight headache, and chest tightness or labored breathing with exercise when exposed at 0.5 ppm for 2 h; at this concentration, the odor of NO_2 was perceptible but the subjects became unaware of it after about 15 min. No changes in any pulmonary function tests were found immediately following the chamber exposure (Kerr et al. 1978, 1979). Therefore, 0.50 ppm was considered a no-adverse-effect level for the asthmatic population. Since asthmatics are potentially the most susceptible population, no uncertainty factor was applied. Time scaling was not performed because adaptation to mild sensory irritation occurs. In addition, animal responses to NO_2 exposure have demonstrated a much greater dependence on concentration than on time; therefore, extending the 2-h concentration to 8 h should not exacerbate the human response.

Supporting studies for AEGL-1 effects report findings similar to the key studies. Significant group mean reductions in forced expiratory volume (FEV1) (-17.3% with NO_2 vs. -10.0% with air) and specific airway conductance (-13.5% with NO_2 vs. -8.5% with air) occurred in asthmatics after exercise when exposed at 0.3 ppm for 4 h and 1/6 individuals experienced chest tightness and wheezing (Bauer et al. 1985). The onset of effects was delayed when exposures were by oral-nasal inhalation as compared with oral inhalation, and might have resulted from scrubbing within the upper airway. In a similar study, asthmatics exposed at 0.3 ppm for 30 min at rest followed by 10 min of exercise had significantly greater reductions in FEV1 (10% with NO_2 = vs. 4% with air) and partial expiratory flow rates at 60% of total lung capacity, but no symptoms were reported (Bauer et al. 1986). In a preliminary study with 13 asthmatic subjects exposed at 0.3 ppm for 110 min, slight cough and dry mouth and throat and significantly greater reduction in FEV1 occurred after exercise (11% vs. 7%); however, in a larger study, no changes in pulmonary function were measured and no symptoms were reported in 21 asthmatic subjects exposed to concentrations up to 0.6 ppm for 75 min (Roger et al. 1990).

The AEGLs values for NO_2 , NO, and N_2O_4 are presented in Tables 4-1 and 4-2.

TABLE 4-1 Summary of AEGL Values for Nitrogen Dioxide and Nitric Oxide

Classification	10 min	30 min	1 h	4 h	8 h	End Point[a] (Reference)
AEGL-1[b] (nondisabling)	0.50 ppm (0.94 mg/m^3)	0.50 ppm (0.94 mg/m^3)	0.50 ppm (0.94 mg/m^3)	0.50 ppm (0.94 mg/m^3)	0.50 ppm (0.94 mg/m^3)	Slight burning of the eyes, slight headache, chest tightness or labored breathing with exercise in 7/13 asthmatics (Kerr et al. 1978, 1979)
AEGL-2 (disabling)	20 ppm (38 mg/m^3)	15 ppm (28 mg/m^3)	12 ppm (23 mg/m^3)	8.2 ppm (15 mg/m^3)	6.7 ppm (13 mg/m^3)	Burning sensation in nose and chest, cough, dyspnea, sputum production in normal volunteers (Henschler et al. 1960)
AEGL-3 (lethal)	34 ppm (64 mg/m^3)	25 ppm (47 mg/m^3)	20 ppm (38 mg/m^3)	14 ppm (26 mg/m^3)	11 ppm (21 mg/m^3)	Marked irritation, histopathologic changes in lungs, fibrosis and edema of cardiac tissue, necrosis in liver, no deaths in monkeys (Henry et al. 1969)

[a]Some effects might be delayed.
[b]The sweet odor of NO, may be perceptible to most individuals at this concentration; however, adaptation occurs rapidly.

Appendix D

Suggestions for Draft Approval Conditions

Aim: The proposal should be developed in general accordance with the EIS, and the final design must deliver equivalent (or better) environmental performance than that set out in the EIS. By limiting the lower stack height and minimum exit velocity, the location of the stacks near the exit portals, and no tangible portal emissions, it can be ensured at equivalent environmental performance is achieved.

It is recommended that DP&E consult with RMS to confirm that the draft conditions are practically deliverable and are consistent with the above aim.

B1 A ventilation stack shall be constructed at each of the following locations:
- (a) the northern ventilation outlet: (Consult with RMS to specify a location near to the ventilation outlet); and
- (b) the southern ventilation outlet: (Consult with RMS to specify a location near to the ventilation outlet);.

B2 The ventilation stacks shall be constructed to achieve a stack exit plane at a height of 20m or more above ground level:

B3 The ventilation stack exit plane must have a minimum exit velocity of:
- (a) 13 metres per second; or
- (b) a velocity, or variable velocity to be determined in the Tunnel Ventilation, Incident Response and Traffic Management Systems Integration Protocol required under condition B9, but only if an equivalent or better environmental outcome than presented in the Proponent's most up to date air assessment can be demonstrated to the satisfaction of the Secretary, in consultation with the EPA.

B4 The tunnel ventilation system shall be designed, constructed and operated to release emissions from the ventilation stacks and to avoid emissions from the portals or the tunnel support facilities at Wilson Road and Trelawney Street except under the special circumstances identified in B5, and emergency situations and/or where emergency personnel are involved.

B5 The following special circumstances apply to the operation of the tunnel:
- (a) accidents and breakdowns inside the tunnel;
- (b) traffic incidents outside of the control of the tunnel operator that have a major effect on tunnel operation;
- (c) major maintenance periods where it can be demonstrated that the in-tunnel CO/NO_2 limits specified in **Table 5a** cannot be met; and
- (d) any other situation approved by the Secretary in consultation with the EPA, Ministry of Health, and the Air Quality Community Consultative Committee.

The special circumstances must be managed so that they do not occur more than 1% of the time in any quarter or annual period.

B6 In the event that any special circumstances identified in B5 occur, they must be notified per E4

In the event that the special circumstances identified in B5 occur more than 1% of the time in any two consecutive quarterly periods, the notification shall be followed up with a detailed report within 20 working days which shall be prepared by an independent person/organisation to the Secretary on the cause and special circumstance and the options available to prevent recurrence. The Secretary shall approve the independent person/organisation.

Where the occurrence of the special circumstance(s) resulted in any recorded exceedance of the limits in E2, **Table 5a**, this report must include consideration of feasible improvements to mitigate air emissions related to the special circumstances. The Proponent shall comply with any requirements arising from the Secretary's review of the Report.

In the event that the special circumstances identified in B5 occur more than 1% of the time in any calendar year, or result in any recorded exceedance of the limits in E2, **Table 5b**, the proponent must immediately limit or modify tunnel operations such that it is certain that the special circumstances do not again occur more than 1% of the time in any calendar year or exceed of the limits in E2, **Table 5b**.

Aim: To ensure the ongoing protection of health to tunnel users and the community from traffic emissions released in the tunnel, for example due to greater vehicle use or higher traffic emissions than anticipated, the tunnel must be designed with a "fall-back" option that would be permit the proponent to quickly and efficiently improve air emissions management (for example if the tunnel performance is poorer than expected, for example where special circumstances occur more than 1% of the time over any two consecutive quarters, or over a full year. .

B7 The tunnel shall be designed and constructed so as to make provision for the future installation of an appropriate system to better manage air emissions from the tunnel as may be required by the Secretary. The Proponent shall provide evidence to this effect during the design and construction phases to the satisfaction of the Secretary.

B8 The Proponent shall install stack emission sampling points and associated safe access thereto, during construction of the ventilation stack. The sampling points shall be designed and located in accordance with the *Approved Methods for the Sampling and Analysis of Air Pollutants in New South Wales* (EPA 2007, or as updated).

B9 Prior to the opening of the tunnel to traffic, the Proponent shall prepare and implement a **Tunnel Ventilation, Incident Response and Traffic Management Systems Integration Protocol** in consultation with the Transport Management Centre. The Protocol must be reviewed by a suitably qualified and experienced independent expert to confirm that, before the tunnel is open to traffic, the ventilation/traffic management systems would operate together to ensure the primary objective of satisfying conditions E1, E2 and E8 are met. The Protocol should include a pre-commissioning procedure to be completed before the tunnel is opened to traffic.

Note:

- *Tunnel ventilation design and operation, incident response triggers and procedures, and traffic management, should be fully integrated in accordance with the primary objective of ensuring the safety of motorists in the tunnel.*

Air Quality Community Consultative Committee

B10 An Air Quality Community Consultative Committee (AQCCC) shall be established by the Proponent. Representatives from relevant Councils and local community representatives with interests in tunnel ventilation shall be invited to participate on the Committee. The AQCCC must be established prior to the commencement of substantial construction.

The terms of reference shall include providing community feedback on air quality monitoring and reporting during the design, construction and operational phases of the SSI, accessing and disseminating monitoring results and other information on air quality issues.

The functions and conduct of the AQCCC shall be in accordance with the terms of reference. The AQCCC shall be established for a period of no less than three years from opening of the complete project.

Construction Environmental Management Plan — Sub plans

D1 As part of the CEMP for the SSI, the Proponent shall prepare and implement (following approval):

(e) a **Construction Air Quality Management Plan** to detail how construction impacts on local air quality will be minimise and managed. The Plan shall be developed in consultation with the AQCCC and the EPA, and shall include, but not necessarily be limited to:

  - (i) identification of sources (including stockpiles and open work areas) and quantification of airborne pollutants;
  - (ii) key performance indicators for local air quality during construction;
  - (iii) details of monitoring methods, including location, frequency and duration of monitoring;

(iv) mitigation measures to minimise impacts on local air quality;
(v) procedures for record keeping and reporting against key performance indicators; and,
(vi) provisions for implementation of additional mitigation measures in response to issues identified during monitoring and reporting.

In-Tunnel Air Quality — Monitoring

E1 Within the tunnel, the Proponent must monitor (by sampling and obtaining results by analysis) the pollutants, specified in **Table 4**. The Proponent must use the sampling method, units of measurement and sample at the frequency specified opposite in the other columns. The number and siting of the monitoring stations inside the tunnel must be; determined to permit an accurate calculation per the requirements of E2; and, be independently verified in general accordance with the *Approved Methods for the Sampling and Analysis of Air Pollutants in New South Wales* (EPA 2007, or as updated). As a minimum there should be monitoring points at the portals, stacks, and exhaust intakes. Each sampling point established under this condition shall be audited prior to its commencement of monitoring for compliance with the requirements set out in **Table 4**. Verification and compliance auditing is to be undertaken by an independent person(s) or organisation(s) approved by the Secretary and paid for by the Proponent.

Table 4 – In-Tunnel monitoring methodology

Pollutant	Units of measure	Frequency	Method[1]
CO	ppm	Continuous	AM-6 or as otherwise agreed by the Secretary in consultation with the EPA
NO_2	ppm	Continuous	AM-12 or as otherwise agreed by the Secretary in consultation with the EPA

Note:

1. *Approved Methods for the Sampling and Analysis of Air Pollutants in New South Wales* (EPA 2007)

In-Tunnel Air Quality — Limits

E2 The tunnel ventilation system must be operated so that the average concentration of carbon-monoxide (CO) and nitrogen dioxide (NO_2) calculated along the length of the tunnel, does not exceed the concentration limit specified for that pollutant in **Table 5a,** except under the special circumstances identified in B5, when the limits in **Table 5b** apply.

Table 5a – In-Tunnel average limits along length of tunnel – normal operation

Pollutant	Concentration Limit	Units of measurement	Averaging period
CO	87	ppm	Rolling 15-minute
CO	50	ppm	Rolling 30–minute
NO_2	0.5	ppm	Rolling 15-minute

Table 2b – In-Tunnel average limits along length of tunnel – special circumstances

Pollutant	Concentration Limit	Units of measurement	Averaging period
NO_2	1	ppm	Rolling 15-minute

The Proponent must justify that the number and location of the measuring points used along the length of the tunnel would permit the calculated average of the pollutant concentration measured at all of the relevant points along the length of the tunnel to serve as an accurate proxy for a motorist's exposure to in-tunnel air pollutants and shall provide data/evidence including appropriate modelling to support its justification. The data/evidence and modelling to support the location of the measuring points/CO/NO_2 profile must be provided to the Secretary on request.

E3 The tunnel ventilation system must be operated so that the concentration of carbon-monoxide (CO) as measured at any single point in the tunnel must not exceed the concentration limit specified for that pollutant in **Table 6** under all conditions (including fully congested conditions).

Table 6 – In-tunnel single point exposure limits

Pollutant	Concentration Limit	Units of measurement	Averaging period
CO	200	ppm	Rolling 3–minute

In-Tunnel Air Quality — Notification

E4 In addition to the general reporting requirements specified in condition E17, the Proponent shall notify the Secretary, EPA and Ministry of Health within 24 hours of the Proponent becoming aware of any of the following;

a. any recording above the limits specified in condition E2 or E3,
b. any special circumstances per where there is a recording above the limits in **Table 5a;**
c. any special circumstances where there is a recording above the limits in **Table 5b;**
d. where the special circumstances identified in B5 occur more than 1% of the time in any quarter, two consecutive quarters or calendar year.

Ambient Air Quality — Monitoring

E5 The Proponent shall monitor (by sampling and obtaining results by analysis) the pollutants and parameters specified in Column 1 of **Table 7** at the following locations:

(a) One ground level location in the vicinity of the northern vent stack;
(b) One ground level location in the vicinity the southern vent stack;
(c) Three locations along Pennant Hills Road, and,
(d) An ambient reference location for background levels away from any of the locations at (a), (b) and (c).

All monitoring stations shall be established subject to the land owner's and occupier's agreement. The Proponent must use the sampling method, units of measure, and sampling frequency specified in **Table 7**.

The Proponent shall commence monitoring for at least twelve continuous months prior to opening of the tunnel to traffic.

The establishment and operation of the stations is to be undertaken in accordance with recognised Australian standards and undertaken by an organisation accredited by NATA for this purpose and approved by the Secretary. The quality of the monitoring results shall be assured through a NATA accredited process prior to the data being considered as a basis for compliance/auditing purposes.

Table 7– Ambient Air Quality Monitoring Methodologies

Pollutant	Units of measurement	Averaging Period	Frequency	Method[1]
NO	pphm	1-hour	Continuous	AM-12
NO_2	pphm	1-hour	Continuous	AM-12
NO_x	pphm	1-hour	Continuous	AM-12
PM10	µg/m3	24-hour	Continuous	AM-18 or AS3580.9.8-2001[2]
PM2.5[4]	$\mu g/m^3$	24-hour	Continuous	AM-18 or AS3580.9.8-2001[2] or as otherwise agreed by the Secretary in

				consultation with the EPA
CO	ppm	1-hour,8-hour	Continuous	AM-2 & AM-6
Parameter[3]	**Units of measurement**	**Averaging Period**	**Frequency**	**Method[1]**
Wind Speed @ 10m	m/s	1-hour	Continuous	AM-2 & AM-4
Wind Direction @ 10 m	°	1-hour	Continuous	AM-2 & AM-4
Sigma Theta @10m	°	1-hour	Continuous	AM-2 & AM-4
Temperature @ 2m	K	1-hour	Continuous	AM-4
Temperature @ 10m	K	1-hour	Continuous	AM-4
Other	**Units of measurement**	**Averaging Period**	**Frequency**	**Method[1]**
Siting	NA	NA	NA	AM-1 & AM-4

Notes:

1. *Approved Methods for the Sampling and Analysis of Air Pollutants in New South Wales (EPA 2007).*
2. *Standards Australia, 2001, AS3580.9.8-2001,* Methods for the Sampling and Analysis of Ambient Air – Determination of Suspended Particulate Matter – PM_{10} Continuous Direct Mass Method using Tapered Element Oscillating Microbalance Analyser.
3. *TBD - location for meteorological monitoring station(s) to be representative of weather conditions likely to occur in the vicinity of the northern and southern stack.*
4. *Appropriately modified to include size selective inlet for $PM_{2.5}$ or as otherwise approved by the Secretary*

Operation Stage Monitoring Stations – Community Based Monitoring Station

E6 The Proponent shall establish one community based monitoring station (CBMS) associated with the northern ventilation stack and one CMBS associated with the southern ventilation stack to monitor ambient air quality consistent with the requirements in **Table 7**, for three years after opening of the complete project or as otherwise extended by the Secretary. The location to be agreed to by the AQCCC. The Proponent shall meet all operating costs associated with the stations.

The CBMS shall be in addition to the monitoring stations identified in E5.

The CBMS shall be operated independently of the Proponent and all other authorities and its establishment and operation shall be overseen by the AQCCC on behalf of the community. The establishment and operation of the stations is to be undertaken in accordance with recognised Australian standards and undertaken by a consultant accredited by NATA for this purpose. The quality of the monitoring results shall be assured through a NATA accredited process prior to the data being considered as a basis for compliance/auditing purposes.

Monitoring results shall be made publicly available and shall be subject to audit at six-monthly intervals or at a longer interval if approved by the Secretary by an independent auditor agreed by the AQCCC, whose report shall be directly provided to the Proponent and the AQCCC. The Secretary shall approve the independent operator.

The Proponent, following consultation with the AQCCC, shall review the need for the continuation of the CBMS after a period of three years after the opening of the complete project. Any recommendation to close the CBMS shall require the approval of the Secretary in consultation with the EPA. The Secretary shall approve the independent auditor.

Ambient Air Quality — Goals

E7 Should ambient monitoring of air pollutants exceed the following goals, the provisions of Condition E8 shall apply:

(a) NO_2 – One hour average of 0.12 ppm (246 µg/m3)(NEPM);
(b) PM_{10} – 24 hour average of 50 µg/m^3 (NEPM); and
(c) $PM_{2.5}$ – 24 hour average of 25 µg/m^3 (proposed NEPM).

Only monitoring station(s) that meet the requirements for ambient monitoring stations in Australian Standard AS2922 – 1987, shall be used for the purposes of assessing compliance with the ambient goals specified in this condition unless otherwise agreed by the Secretary. . A Protocol for the evaluation of a potential measurement that exceeds the criteria shall be developed by the tunnel operator and approved by the Secretary in consultation with the EPA, Ministry of Health and the AQCCC.

E8 Should the results of monitoring required under Condition E5 or E6 show that any of the goals specified in Condition E7 have been exceeded for any given event (excluding extraordinary events such as bushfires, dust storms etc (as to be defined in the Protocol), the Proponent shall immediately notify the Department, EPA and Ministry of Health. The notification shall be followed up with a detailed report within 10 working days which shall be prepared by an independent person/organisation to the Secretary on the cause and major contributor of the exceedance and the options available to prevent recurrence. The Secretary shall approve the independent person/organisation.
Where the operation of the tunnel is identified to be a significant contributor to the recorded exceedance, this report must include consideration of feasible improvements to the installed systems including for example the ventilation system, and traffic management measures to address ambient air. The Proponent shall comply with any requirements arising from the Secretary's review of the Report.

Air Quality — Public Access to Monitoring Results

E9 Results of hourly updated real-time ambient monitoring of PM_{10}, $PM_{2.5}$, NO_2, and CO at the approved ground level monitoring locations, in-tunnel CO/NO_2 and relevant meteorological data shall be provided on an Internet site and be made publicly available each month in hard form in an easy to interpret format. These data shall be preliminary until a quality assurance check has been undertaken by a person or organisation accredited by NATA for this purpose. The availability of these data shall be conveyed to the local community by way of newsletter (including translation into common non-English speaking languages in the area) and newspaper advertisement at least one month prior to the opening of the SSI to traffic.

Ventilation Stacks — Monitoring

E10 The Proponent shall install monitoring equipment to monitor pollutants inside the ventilation stacks. Pollutant monitoring inside the ventilation stacks (by sampling and obtaining results by analysis) shall be for the pollutants and parameters specified in Column 1 of **Table 8**. The Proponent must use the sampling method, units of measures and sample at the frequency specified in the other columns. Monitoring equipment installed under this condition is to be independently audited prior to its commencement of monitoring for compliance with the requirements set out in **Table 8**. Auditing is to be undertaken by an independent person(s) or organisation(s) approved by the Secretary and paid by the Proponent.

Table 8 — Stack Emission Monitoring Methodologies

Pollutant	**Units of measure**	**Frequency**	**Method**[1]
Solid particles	mg/m^3	Continuous	Special Method 1[4]
Solid particles	mg/m^3	Special Frequency 1[5]	TM-15
PM_{10}	mg/m^3	Special Frequency 1[5]	OM-5
$PM_{2.5}$	mg/m^3	Special Frequency 1[5]	OM-5
Nitrogen dioxide (NO_2) or Nitric Oxide (NO) or both, as NO_2 equivalent	mg/m^3	Continuous	CEM-2
NO_2	mg/m^3	Continuous	CEM-2
Carbon monoxide (CO)	mg/m^3	Continuous	CEM-4
Volatile Organic Compounds (VOC)[2]	mg/m^3	Continuous	CEM-8
Speciated VOC	mg/m^3	Annual	TM-34
PAH	$\mu g/m^3$	Annual	OM-6
Parameter	**Units of measure**	**Frequency**	**Method**[1]
Velocity	m/s	Continuous	CEM-6
Volumetric flow rate	m^3/s	Continuous	CEM-6

Moisture	%	Continuous	TM-22
Temperature	°C	Continuous	TM-2
Other	**Units of measure**	**Frequency**	**Method**[1]
Selection of sampling locations	N/A	N/A	TM-1

Notes

1. *Approved Methods for the Sampling and Analysis of Air Pollutants in New South Wales* (EPA 2007) *or an alternative method approved by the Secretary in consultation with the EPA.*
2. *Must include, but not be limited to: Benzene, Toluene, Xylenes, 1,3-Butadiene, Formaldehyde and Acetaldehyde.*
3. *Must include, but not limited to; 16 USEPA priority PAHs, namely; Naphthalene, Phenanthrene, Benz(a)anthracene, Benzo(a)pyrene, Acenapthylene, Anthracene, Chrysene, Indeno(1,2,3-cd)pyrene, Acenaphthene, Fluoranthene, Benzo(b)fluoranthene, Dibenz(a,h)anthracene, Fluorene, Pyrene, Benzo(k)fluoranhtene, Benzo(g,h,i)perylene.*
4. *Special Method 1 means a method approved by the Secretary in consultation with the EPA.*
5. *Special Frequency 1 means quarterly testing for the first 12 months of operation, and if no result (for any pollutant in the Table) exceeds the applicable limits, 6 monthly monitoring for the next 12 months, and if no result (for any pollutant in the Table) exceeds the applicable limit, annual monitoring thereafter.*

Ventilation Stacks — Limits

E11 The concentration of a pollutant discharged from the ventilation stack(s) referred to in **Table 9** and **Table 10** must not exceed the respective limits specified for that pollutant in the respective table.

Table 9 — Mass Pollutant Concentrations — normal operation

Pollutant	100 percentile limit	Units of measurement	Averaging period	Reference conditions
NO_2	2	mg/m^3	1 hour block	Dry, 273K, 101.3kPa

Table 10 — Mass Pollutant Concentrations — special circumstances

Pollutant	100 percentile limit	Units of measurement	Averaging period	Reference conditions
NO_2	4	mg/m^3	1 hour block	Dry, 273K, 101.3kPa

An independent person or organisation, approved by the Secretary shall:

(a) verify that compliance with stack limits detailed in **Table 9** and **Table 10** will not result in air quality impacts greater than predicted in the documents listed in condition A2;

(b) undertake an appropriate assessment to indicate how stack discharge velocities have been optimised in consideration of energy requirements and air quality impacts at all sensitive receivers; and,

(c) validate recorded monitoring data and certify compliance with the stack limits.

The information required in paragraphs (a)-(c) will be made available to the Secretary on request.

The ventilation stack limits detailed in **Table 9** and **Table 10** shall be reviewed on a five-yearly basis and may be lowered (i.e. made more stringent), subject to improvements in vehicle fleet emissions, if the Proponent is directed to do so by the Secretary following consultation with the EPA.

Ventilation Stacks — Exceedence of limits

E12 Should the results of monitoring show that any of the stack limits specified in Condition E11 have been exceeded, the Proponent shall immediately notify the Secretary, EPA and Ministry of Health. This notification shall be followed up with a detailed report within 10 working days to be prepared by an independent person/organisation to the Secretary on the cause and major contributor of the exceedance. The Secretary shall approve the independent person/organisation.

Where the operation of the tunnel is identified to be a significant contributor to the recorded exceedance, this report must include consideration of feasible improvements to the installed systems including for example the ventilation system, and traffic management measures to address compliance. The Proponent shall comply with any requirements arising from the Secretary's review of the Report.

Air Quality Strategy

E13 X

Emergency Discharge

E14 Conditions E2, E3, E7, and E11, do not apply:

(a) in an emergency to prevent damage to life or limb other than an emergency arising from a negligent act or omission from the Proponent. The Proponent shall as soon as reasonably practicable, notify the Secretary and the EPA of any such discharge.

(b) as a result of an incident (not including congestion in the tunnel), which is beyond the control of the Proponent or the tunnel operator and could not have been prevented by taking those steps which a prudent, experienced and competent operator would have taken.

The Proponent shall, as soon as reasonably practicable, notify the Secretary and the EPA of any such discharge.

Note:

- *Any exceedance of the goals or limits in conditions E2, E3, E7, and E11 which result from a negligent act by the Proponent/Company, irrespective of potential damage to life or limb, is a breach of these Conditions of Approval*.

Local and Sub-Regional Air Quality Improvements

E15 X

E16 Prior to the opening of the Tunnel to traffic, the Proponent shall investigate, in consultation with the EPA the measures for smoky vehicle enforcement as related to the operation of the Tunnel, taking into consideration cost effectiveness. Any measures implemented as a result of investigation recommendations shall be in accordance with the Smoky Vehicle Enforcement Program. The Proponent shall report on the effectiveness of the smoky vehicle enforcement.

Air Quality — General Reporting

E17 The Proponent must develop and implement a reporting system for in-tunnel, ambient and ventilation stack limits to the satisfaction of the Secretary in consultation with the EPA. The reporting system must be approved, fully implemented and operational prior to opening of the tunnel to traffic. Minimum analytical reporting requirements for air pollution monitoring stations shall be as specified in the *Approved Methods of Modelling and Assessment of Air Pollutants in NSW* (EPA 2007, or as updated) or as otherwise approved by the Secretary in consultation with the EPA.

Air Quality — Auditing and Quality Assurance

E18 The provision, operation and maintenance (including all auditing and validation of data) of all air quality monitoring and reporting shall be funded by the Proponent.

E19 All continuous emissions monitoring systems installed and operated as a requirement of condition E10 shall undergo relative accuracy test audits at an interval not exceeding 12 months, or as otherwise agreed to by the Department of Planning and Environment in consultation with the EPA.

E20 The Proponent shall appoint an external auditor to conduct an audit of the air quality monitoring (in tunnel and external) at six-monthly intervals or at any longer interval if approved by the Secretary. Air quality audits shall commence six months from opening of the Tunnel to traffic. The auditor shall ensure that the operating procedures and equipment to acquire air monitoring, meteorological data and emission monitoring data and monitoring reporting comply with NATA (or equivalent) requirements and sound laboratory practice. The Proponent must document the results of the audit and make available all audit data for inspection by the Secretary upon request. A copy of the audit report shall also be issued to the Proponent and AQCCC.

E21 The Proponent shall undertake appropriate quality assurance (QA) and quality control (QC) measures for air quality and ventilation stack emission monitoring data. This shall include, but not be limited to: accreditation/quality systems, staff qualifications and training, auditing, monitoring procedures, service and maintenance, equipment or system malfunction and records/reporting. The QA/QC measures shall be approved by an independent expert approved by the Secretary prior to monitoring of air quality and ventilation stack emissions as appropriate.