Initial peer review of

Air Quality Analysis of NSW Tunnel Data — DRAFT, 7 Nov 2024

The aim of the Tunnel Data report is "to consider the impacts of tunnel vents on nearby air quality". The report's conclusion is "Overall, there is very little evidence that tunnel vent stacks have an appreciable impact on nearby air quality …" and "At the Jackson site, the isolation of the signal that is potentially associated with the tunnel vents indicates a contribution to NOx concentrations of only a few percent (<1 µg m^{-3})".

An equally important question not addressed in the report is: what is the maximum possible size of any tunnel-vent signal for it not to be detected in the ambient air quality data.

This is hard to determine in practice because it extends well beyond the accuracy and precision of the monitors used to make the measurements. Over short time periods of hours the variation due to meteorology will easily mask the small signals expected from the vent stacks. This is a principal reason to prefer aggregation techniques (such as polar plots) over trying to detect changes in time series. The work carried out on signal to noise ratio by Dr Hibberd has been referred to and commented on.

The report presents an analysis of vast quantities of air quality data collected around Sydney motorway tunnel projects. It uses several different polar plot formats to show the dependence of concentration on wind direction and speed, some of which would benefit from clearer explanations so that informed community members could understand how to "read" them. (Potential pollution from tunnel vent stacks is an issue that causes a lot of community angst.)

There is a much-expanded section on the main techniques used in the Introduction, which tries to describe these techniques in a straightforward way with examples and also text on the relevance to the tunnel vent stacks.

There is detailed exploration of a potential contribution at the Jackson site (section 2.1). Puzzlingly, the report does not show difference plots for M5 East sites other than Jackson. Although the report notes that because of reductions in vehicle emissions, "it might be expected to be easier to detect tunnel vent impacts for data more than several years ago than data collected in the past few years", a rigorous analysis is warranted for the Gipps site because Hibberd (2019) detected a contribution there in 2009-2013 data.

The analysis has been extended to considering the Gipps sites and a comment made about the earlier analysis using earlier data by Dr Hibberd. The extension of the analysis to Gipps and the background subtraction using the Jackson site does not reveal any evidence of a vent stack effect.

In all other regions, the search for possible tunnel vent contributions is based on differences from a single background site. I suggest a more targeted approach of calculating the difference between pairs of sites close to the tunnel vents. More use of conditional bivariate probability function plots like Figure 9 could also be warranted. If no other signals are detected, these plots would be useful in answering the question about an upper bound on the size of possible tunnel vent impacts in ambient monitoring data. I note that given the very poor siting (from a dispersion point of view) of the M5 East stack in the bottom of a valley, it would not be surprising for any tunnel-vent impact from the newer stacks to be much smaller.

Some consideration should also be given the possible misalignment of directional information from the polar plots due to use of the airport meteorological data at sites that are up to 25 km from the airport.

Much more use has been made of paired site differences based on the suggestions in the Table below. The CPF plots are useful where there is some indication of an effect that is maybe small and can be explored in more depth, as in the M5 East data.

Detailed comments

- *Compare pairs of sites close to the tunnel vents*. For all except one region in the report, a representative background site was selected with polar plot differences from it shown for all other sites. Puzzlingly, the exception was M5 East, where only the Jackson-Wavell difference is shown. Since Hibberd (2019) detected a contribution at the Gipps site, it is important that this report also consider the differences at Gipps.
  Given that the focus of the report is the potential impact of tunnel vent emissions, it could be more effective and relevant to show the differences between pairs of sites near the vents (see Table A below) rather than using a single representative background site. Because these sites are closer to each other than the background site, the differences would tend to be dominated by very local emissions, which could make it easier to interpret these difference plots and give greater confidence in findings of the presence or absence of a tunnel vent signal. See dot point 3 below about also using CBPF plots.

Motorway region	Pairs of sites close to vent stacks
M5 East	Jackson and Wavell (done) Jackson and Gipps – opposite directions from the vent stack, vent stack contribution identified at Gipps by Hibberd (2019)
North Connex	Carden Park and James Park Hornsby Ashley Ave and Larchmont Place
M8	Kingsgrove 1 and Kingsgrove 2 Arncliffe 1 and Arncliffe 2 St Peters 2 and St Peters 3
M4 East	Allen St and Powells Creek (but note very similar downwind directions for both sites) Ramsay St and Haberfield Public School
Rozelle	Chapman Rd and Quirk St
M4-M5 Link	Albert St and Campbell St

Table A Suggested site pairs for investigating tunnel vent contributions

All the combinations above have been considered in each section. In addition to the other analysis in each section it is concluded that by considering differences in concentrations between the site pairs above does not reveal any evidence of vent stack impacts. Note that on the CBPF analysis, this has focused on the M5 East where additional probing of a potential stack source is considered.

- *Choice of meteorological data*. Section 1.2 discusses the reasons for using the meteorological data from Sydney International Airport in all the analyses. It mentions that local on-site data were/could also be used and that "similar conclusions would be drawn using local meteorological data at most sites". Were there sites where the

conclusions were different? As an indication of differences across the Sydney basin, Figure A shows wind roses from three air quality monitoring sites – Randwick (~5 km from the airport), Rozelle (~10 km), and Lindfield (~20 km). An important consideration is whether the wind directions at the airport are representative for sites up to 25 km away, e.g. NorthConnex. If not, then directional information from the polar plots could be misaligned with respect to local sources. Has this been taken into account in assessing the plots for possible tunnel vent signals?

Some of the arguments for using a single met site at the airport are given in the report. It is accepted that more locally that wind direction and speed could be different to that from the airport. This is a complex issue and is best addressed through considering the wind roses across each network to consider their consistency and appropriateness. The reasons for using the airport site are summarised, but overall, I consider it is better to use this site throughout rather than the use of local sites that are often affected by nearby obstacles. It is recognised though that this is a complex problem.

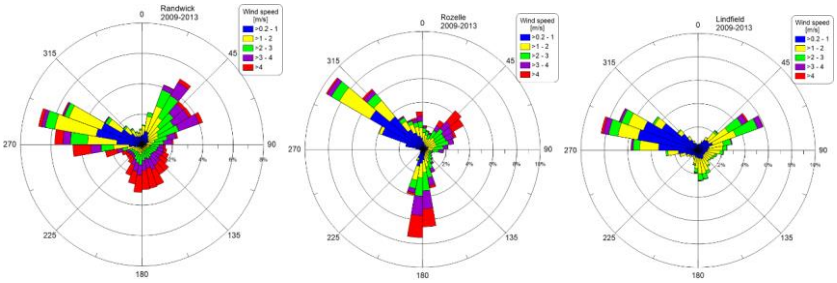

Figure A Wind roses from three air quality monitoring sites across Sydney, from Hibberd (2019)

- *More extensive use of conditional bivariate probability function (CBPF) plots like Figure 9*. Using the example of the Jackson site, Figure B shows that the basic polar plot of concentrations (left) only gives a hint of a tunnel vent signal. How well it stands out is quite sensitive to the colour scale used. In contrast, the middle and right-hand plots clearly show a signal. Uria-Tellaetxe and Carslaw (2014) discuss the sensitivity of CBPF plots and how different concentration ranges can be used to discriminate between potential sources. The right-hand plot shows the differences in concentration between Jackson and Wavell. It is only these difference polar plots that are shown in the rest of the report to assess the presence/absence of a tunnel vent signal. However, the ability of the CBPF plots to distinguish between surface and elevated sources could prove useful for the regions where the tunnel vents are located close to major road emissions. Whether or not they reveal contributions from the tunnel vents, the results would strengthen the conclusions from this report about the impacts of tunnel vents on nearby air quality and assist in setting an upper bound on the size of possible tunnel vent impacts in ambient monitoring data.

  As noted above, the CPF plots were used as an additional way in which to analyse data where there was an indication of a vent stack source in the basic polar plots. In total, for each tunnel air quality network, several methods have been used to determine whether there is a contribution from the vent stacks including:

- *Percentile roses – focused on any evidence of elevated concentrations across a wide range of concentrations from the direction of the vent stacks.*
- Basic polar plots – focused on the nature of important emission sources and especially that of stack sources that are representative of tunnel vent sources.
- Polar plots with background subtraction using the site with the lowest concentrations as a background site. This approach ought most of the time significantly enhance the opportunity for detecting a local vent stack impact.
- Polar plots with paired site differences. Similar to background subtraction but with the benefit of reducing some of the spatial uncertainty in using a background site that is too far way.
- Polar plots comparing before-after tunnel opening. This approach should help reveal a 'new source' in the 'after' data if it is detectable.

- It is my view that applying all these approaches where possible should maximise the opportunities for detecting tunnel vents.

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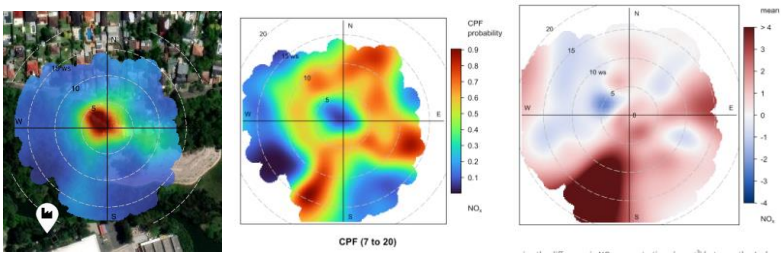

Figure B Polar plots of Jackson site data from Figures 3, 9, 11. The right-hand figure is Jackson-Wavell differences.

- *Better explanations of how to interpret the various polar plots*. Several different types of plots are used in the report. The Percentile Rose is described in section 1.2 and an example given in Figure 1: I suggest adding a sentence to explain what the reader is meant to see in this example. I suggest it would also be useful to describe the concentration polar plots using an example figure, so that specific features can described more easily than using a polar plot in one of the maps. For the probability polar plot, Figure 9 could be used to explain, for example, what does a probability of 0.9 for the dark red region in the SSW mean.
  Agreed – this has been addressed in an expanded introduction that now considers examples of each approach and how to interpret the results..

- *Section 2.1*. It is not clear why the concentration interval of 7 to 20 µg m^{-3} was selected for Figure 9. Was it based on the findings in Uria-Tellaexte and Carslaw (2014) [U&C] about stack impacts? Or was it based on looking at a range of concentration intervals for the Jackson site data in a similar fashion to that done in Figure 4 of the U&C paper?
  The second paragraph presents the conclusion from the cluster analysis, but the cluster approach is barely explained. There is reference to Carslaw and Beevers (2013) but this article is behind a paywall. I suggest adding a sentence or two to explain it.
  I don't understand how you get from a 6.3% to a 3% contribution. I think this paragraph, which includes a key finding of the report, needs reworking – currently the result of the cluster analysis is presented before describing the clustering figure.

Agreed – the explanation has been expanded and also explained in the detection methods section in the Introduction. A more comprehensive description of the cluster analysis and why it has been done has been added.

- *Hourly-average versus annual-average contributions*. Does the analysis in the CBPF plots enable you to estimate the maximum contribution of vent stack emissions to hourly-averaged concentrations at Jackson? The estimates in Table 2 are the contributions of the clusters to annual average NOx concentrations. This question is relevant because both short and long-term air quality averages are important in design criteria for these tunnel projects.
  This is a good question. The maximum concentration by cluster has also been added, which does not provide any indicated that the cluster associated with the stack has especially high maximum concentrations of NO_x.

Other comments/suggestions

- *Wind directions averages*. Tables with the summary site information (Tables 1, 3, 4, 5, 6, 7) list the average wind direction for the meteorology used for analysing each site. This parameter should not be included in these tables. It is not an informative parameter for the analysis undertaken in this report because the wind rarely blows from the "average" direction. This is demonstrated by typical wind roses for the region shown in Figure A.
  Agreed. The summary tables have been changed and a comment made on why wind direction is missing in each caption.

- For all the motorways except M5 East, the available data covers a time span including both before and after opening of the tunnels. These total time periods are listed in Tables 3 to 7. Was all this data used in the main NO_x polar plots (e.g. Figure 13) or just the data after tunnel opening. This needs to be clarified in the report. The report should state the opening dates for regions where After-Before plots are presented. All the data shown in the summary tables is used in the analysis and where a before-after comparison is made, the data is partitioned accordingly. In each section that considers a before-after comparison the date of opening is cited.

- Do seasonal differences in wind directions/speeds have an impact when comparing After and Before concentrations for Rozelle when there are only 5 months of After data compared to 12 months of Before data? It is difficult to answer this with confidence and it is a limitation of the analysis at this location, which has been mentioned in the text.
  Why are there no After-Before difference plots for M4 East even though there are more than 12 months of data for both periods? This has been added together with explanatory text.

- Distance scale missing on most figures (2, 12-19, etc). A distance sacle has now been added to all plots.

- The colours in the NOx concentration colour scales in Figure 3, etc and for nox_inc (increment?) in Figure 14, etc are washed out compared to the colours in the polar plots. This makes it difficult to estimate concentrations from the figures. The plots are semi-transparent so that the base map can still be seen.

- There are no colour scales for concentrations in the polar plots of PM_{10} and CO (Figures 4, 5). Scales have been added.

- Section 1.2, second paragraph. At the end, add a sentence to explain how the reader is meant to interpret the pollution rose example in Figure 1. The Introduction now gives a fuller explanation of how to interpret these (and other) plots.
- Section 2, paragraph 4, The first sentence says "slightly enhanced concentration of NOx from the direction of the vent stack over a range of wind speeds … is the behaviour seen by stack emissions". Add a brief explanation of why this is the case. A cross-reference has been added to the section on polar plots and their interpretation.
- Last sentence before section 2.1 says that the polar plots for CO are "broadly similar" to those for NO_x and do not show clear directional impacts of the vent stacks. The plots are copied in Figure C below; some aspects look quite different. Please be more specific than "broadly similar". Text added to say that the plots are dominated by higher concentrations at low wind speeds.

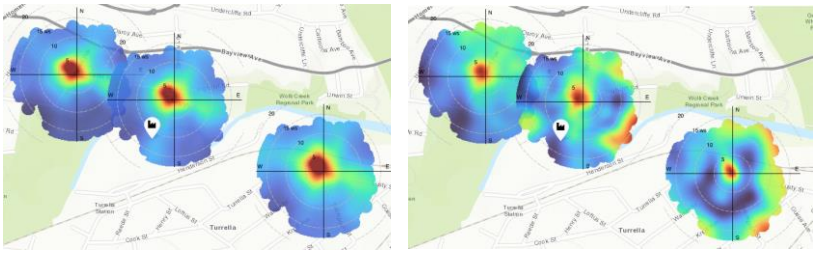

Figure C Extracts from the Report's Figure 3 for NO_x (left) and Figure 5 for CO (right)

- The caption for Table 2 says "The cluster associated with the tunnel vent is highlighted in light blue." This is correct but I found it confusing because this is not the colour of this cluster in Figure 10. Changed to match cluster colour.
- Figure 10. Rather than a legend for the cluster colours, it would be clearer if the cluster numbers were included within the figure written on the coloured regions. Currently the function to produce this plot does not have that flexibility, but it will be considered for the future.
- In Figure 11, the colour scale needs to be adjusted to distinguish concentrations in the saturated dark red/brown region with concentrations >4 µg m^{-3}. Many of the plots of concentrations with the background removed also show colour saturation making it impossible to see any features within these areas. A balance has been struck to use a single scale that can represent changes across a whole network where changes to concentrations cover small to large. In all cases, any indication of a vent stack impact should be clear with the scale used, which is selected to focus mostly on small changes.
- When viewing the html document, the names of the sites can be revealed by clicking on individual polar plots or percentile roses. This is first mentioned in the text in relation to Figure 19. It should be mentioned with the first plot that has this feature. This has been addressed in the introduction and the first plot.
- Scrolling through the html document on a touch-screen device is frustrating because the embedded maps capture the swipe and pan the map instead of scrolling the

document. The same thing happens for a device with a mouse device. Is it possible to implement a feature to require two-finger touch gestures to pan and zoom the maps? I have changes the way the maps display to not take up the full width of the screen. Instead, and explained in the Introduction, readers can click the 'expand' button at the bottom-right of each interactive plot.

- I was unable to produce a useable pdf version of the document – the maps were all small segments of the map without any polar plots. This is a comment from a reviewer who prefers hard copy 😊.

Corrections

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- There are no Figures 6, 7, 8, 15, 20, 25, 28. None of these, except 25, are cited in the text. It looks like they've been deleted but the figure numbering has not been refreshed. Fixed
- Executive Summary, paragraph 5, line 3. Correct "a contributions" to "a contribution". Fixed
- Introduction, 2nd paragraph. Correct "4. M4-M8 link (previously called the M4-M5 link)" to "4. WestConnex M4 East". Fixed
- Section 1, second paragraph. The numbering of the motorway areas from 1 to 6 is slightly confusing because it not consistent with the numbering of the report sections which run from 2 to 7. Fixed
- Table 1. The average CO concentration at Gipps in negative. The mean temperature at Thompson is listed as 36.0°C, almost 20° higher than the other 4 sites. Have the data been checked for anomalous readings? Some data are erroneous and have been removed.
- Figure 2 shows the Flatrock site but no data from this site is presented in the following figures and it's not included in Table 1. Now added but it is noted the meteorological measurements are clearly wrong.
- Section 2.1, second paragraph, line 8. Delete repetition of "would be below". Fixed
- Section 2.1, second last paragraph, line 6. Delete the first "to". The line currently starts "to most likely to be the tunnel stack." Fixed
- In Tables 4, 5, 6, and 7 the average temperatures appear to be in units of Kelvin but the table header says they are °C. Fixed
- St Peters 1 site location listed in Table 4 as NaN. No plots of data from this site are shown in any of the figures. Location was missing in original information provided but has now been added.
- Table 5. Correct the heading in the table from "M5" to "M4". Fixed
- Figure 16, 21, 29. The captions for these figures need to describe that they're After-Before differences. Currently the captions are incomplete, e.g. "Figure 16: Polar difference plots for NO_x (in µg m^{-3}) for North Connex". Fixed

- Include links to the Longley (2018) and Hibberd (2019) reports which are on the chiefscientist.nsw.gov.au website. Fixed