NIWA
Taihoro Nukurangi

Changes in local air quality associated with opening of the M4 East Tunnel

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Executive summary

The M4 East tunnel links the inner-west Sydney suburbs of Homebush and Haberfield. It was opened to traffic on 13th July 2019. It largely provides an underground alternative to Parramatta Road whose route it largely follows. The tunnel's opening was predicted to reduce traffic volumes along Parramatta Road, especially for trucks.

In accordance with planning consent conditions ambient air quality monitoring at six sites close to the tunnel route was begun on 1st January 2018, to be completed on 12th July 2021.

The analysis focusses on oxides of nitrogen (NO_x) which is the most accurate and sensitive measure of road traffic emissions.

During the 8 months following the opening of the M4 East tunnel, and prior to the first restrictions related to COVID-19, air quality related to traffic exhaust emissions (represented by concentrations of oxides of nitrogen) substantially improved in the vicinity of the M4 East tunnel project. The improvement has been estimated for the first 12 months using two methods to disregard the impact of COVID-19 restrictions on emissions.

This estimated improvement varied between locations:

- A ~6% improvement across the whole inner west Sydney area most likely related to ongoing reductions in emissions from the Sydney vehicle fleet, and unrelated to the tunnel, as observed at St Luke's Park and Haberfield Public School monitoring sites,
- An additional improvement of 10 – 15% along the Parramatta Road corridor (with the improvement increasing with proximity to the road), as represented by the Concord Oval and Powells Creek monitoring sites,
- An additional improvement of approximately 20% at the Ramsay Street monitoring site, most likely due to reduction of vehicle volumes and congested vehicle queueing. This effect may have been reproduced at other locations which were not monitored.

These improvements appear to be permanent and have locally accelerated the underlying trend of improving traffic-related air quality across the region by a year. These estimates may also be an under-estimate as the tunnel may have amplified the local positive benefit of COVID-related emission reductions.

No worsening of air quality was observed at any monitoring location. There was no detectable impact of the emissions from the ventilation outlets on local air quality.

Although monitoring continued beyond this initial 8 month period, it is very challenging to disentangle the impact on air quality of traffic changes in and around the project due to COVID-19 restrictions and subsequent changes in local travel from any ongoing or additional impact of the tunnel. However, by the end of July 2021 long-term average NO_x concentrations had reduced by 15 – 30 % across the project monitoring sites relative to 13th July 2019.

1 Introduction

1.1 The M4 East tunnel

The M4 East tunnel links the inner-west Sydney suburbs of Homebush and Haberfield. It was opened to traffic on 13th July 2019. It largely provides an underground alternative to Parramatta Road whose route it largely follows. The tunnel's opening was predicted to reduce traffic volumes along Parramatta Road, especially for trucks. The tunnel is ventilated by a combination of the "piston effect" caused by moving vehicles, and jet fans in the tunnel so that polluted air is collected and emitted through ventilation outlets, one at the end of each tunnel bore (i.e. the Parramatta Road Ventilation Facility in Haberfield and the Underwood Road Ventilation Facility in Homebush).

1.2 Air Quality Monitoring around the M4 East Tunnel

In accordance with planning consent conditions ambient air quality monitoring at six sites close to the tunnel route was begun on 1st January 2018, to be completed on 12th July 2021. Those six sites were located effectively in pairs at the western end (Homebush), eastern end (Haberfield) and mid-section (Canada Bay) of the tunnel (see Table 1 and Figure 1). The sites were chosen to detect changes in air quality close to, and setback from Parramatta Road. They were also chosen to detect changes in air quality due to emissions from the ventilation outlets, even though the outlets were designed to ensure that the change is too small to be detectable.

Table 1: M4 East ambient air quality monitoring sites.

Monitoring site	area	character
Allen Street	Homebush	Setback/outlet
Powells Creek	Homebush	Roadside/outlet
St Lukes Park	Canada Bay	Setback
Concord Oval	Canada Bay	Roadside
Ramsay Street	Haberfield	Minor road/outlet
Haberfield Public School	Haberfield	Setback/outlet

1.3 Scope

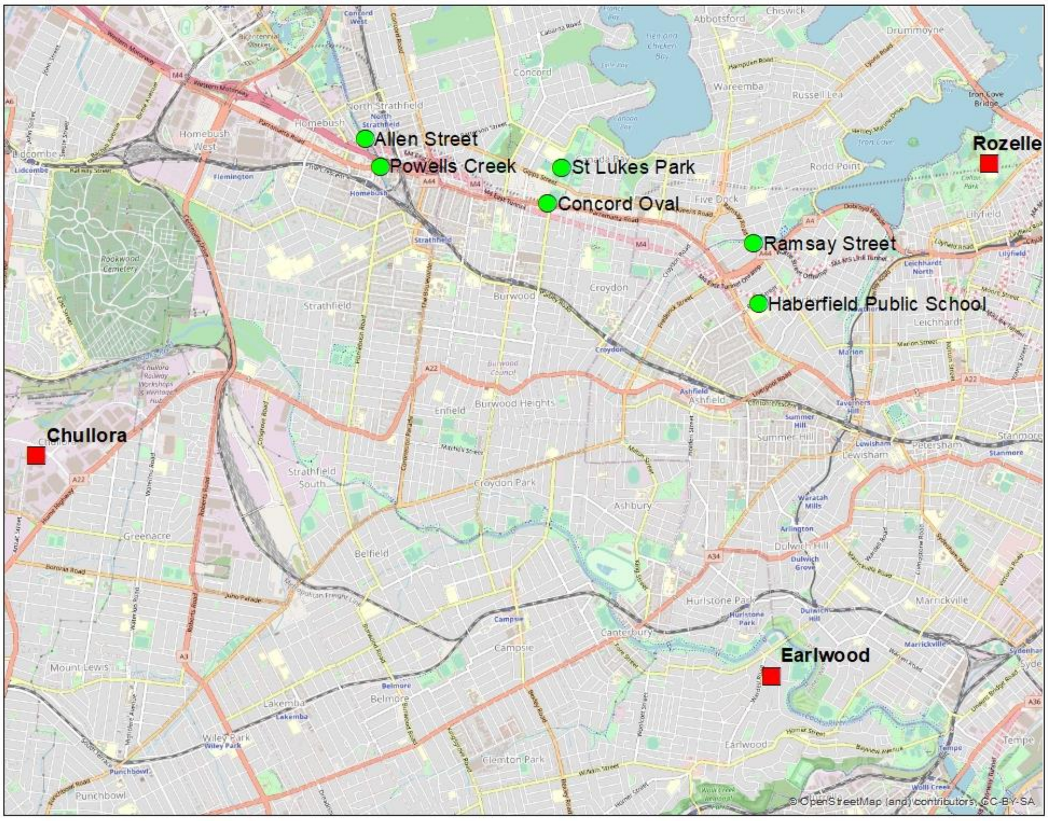
This report is based on data available up to 31st July 2021. It replaces a draft report which covered data up to 31st May 2021.

This analysis of ambient air quality data for the M4 East project has considered two main questions:

- How has air quality in the vicinity of the M4 East tunnel changed since its opening?
- To what degree can the changes be related to the project opening, and to what degree are they related to other factors (i.e. would they have happened anyway?), including the impact of COVID-19 on road traffic.

Analysis focusses on both long-term changes in average air quality (related to chronic health risks arising from living, working or attending education in the project footprint), and additional short-term localised risks arising from emissions from the ventilation outlets.

Figure 1: Locations of air quality monitoring sites mentioned in this Report.



2 Methods

2.1 Data sources:

- This analysis covers data from 1st January 2018 to 31st July 2021 inclusive (43 months). This includes
  - 18½ months pre-opening (1st Jan 2018 – 12th Jul 2019)
  - 8 months post-opening, pre-COVID (13th July 2019 – 15th March[1] 2020)
  - 16½ months post-opening that may be "COVID impacted"[2] (16th March 2020 – 31st July 2021)
- To represent the influences of factors unrelated to the M4 East project, we have created a "background" dataset using data from the NSW Air Quality Monitoring Network monitoring stations at Chullora, Earlwood and Rozelle (see Figure 1). These stations are set back from major roads and are considered representative of general air quality trends across the majority of inner-east Sydney.

2.2 Pollutants

- The analysis focusses mainly on oxides of nitrogen (NO_x). NO_x is the sum of two compounds: nitric oxide (NO) and nitrogen dioxide (NO_2). Amongst the pollutants monitored at project monitoring sites, these are measured to the highest accuracy, whilst having the lowest interference from non-traffic sources making them the most sensitive measures of road traffic emissions.
- NO has relatively low toxicity and NO_2 has higher toxicity. This is why NO_2 is widely used as a measure of health risk and is regulated through a National Environmental Protection Measure (NEPM), World Health Organisation guideline and NSW in-tunnel air quality guideline.
- Total oxides of nitrogen (NO_x) can be used as a sensitive proxy for the complex mixture of other pollutants that is emitted from road vehicle tailpipes. Changes in NO_x concentrations are likely to be replicated in concentrations of other pollutants that are not measured.
- For all these reasons this analysis is therefore based primarily on total oxides of nitrogen (NO_x) as the best indicator of the impact of the project on air quality.
- Particulate matter (PM_{10} and $PM_{2.5}$) is regulated through the National Environmental Protection Measures (NEPM) and monitored at all the M4 East monitoring stations. However, the PM monitoring record is strongly influenced by non-traffic sources, and especially bushfire smoke. Including PM is this analysis using the methods adopted (described below) would likely lead to misleading conclusions, particularly due to the exceptional bushfires of summer 2019/20 occurring shortly after the project opened. A more sophisticated analysis would be required to account for these influences and therefore we do not report PM results at this time.

2.3 Analytical methods

- To explore **long-term changes** in air quality two approaches have been used.

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[1] 16th March 2020 has been taken to be the first day during which the impacts of COVID-19 on traffic volumes were potentially evident.
[2] "COVID impacted" is used to mean any period during which traffic volumes have deviated from the pre-COVID norm as a consequence of travel restrictions or consequent changes in travel patterns.

- In both methods, data were initially checked for validity/suitability and individual data points were excluded if they appeared to significantly deviate from acceptable ranges.
- **Method 1** compares the 8-month average concentration between the tunnel opening and COVID restrictions beginning (July 2019 - March 2020) with the same 8-month period one year earlier (July 2018 – March 2019). By matching data from the same season this method attempts to remove bias that can be introduced by seasonal variation in dispersion conditions which have a major influence on air quality (which is worse in winter). However, this must be traded off with the disadvantage of discarding a significant amount of available data which can slightly increase uncertainty.
- **Method 2** uses a more sophisticated approach in which we compare 12-month averages before and after the tunnel opening. The 4 months of COVID-impacted data is replaced with simulated data that extrapolates the trend to estimate what concentrations might have been from 16th March – 12th July 2020 had COVID restrictions not happened.
- Although method 2 uses more data it also incorporates its own assumptions and uncertainties. We therefore do not consider either method superior to the other, but present results from both methods as a range.

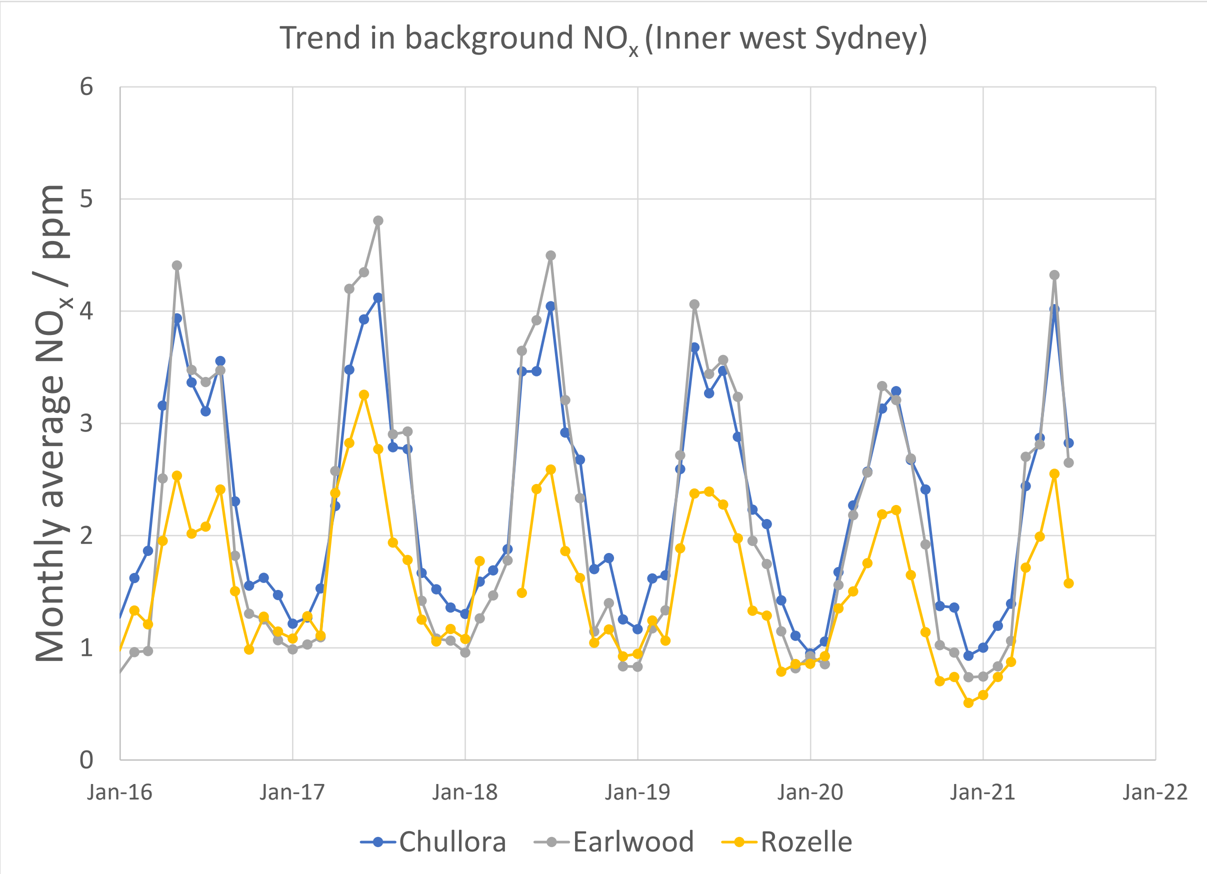
- To explore **short-term changes** in localised air quality related to ventilation facility emissions, the following approach has been used:
    - Examine the changes in average and maximum NO_x concentrations before and after the project opening in each wind direction. A rise (or smaller drop) in concentrations when the ventilation outlet is upwind of the monitoring station, relative to other wind directions, could indicate the detection of emissions from the outlet.
    - Examine changes before and after the project opening in the ratio of 5-minute average NO_x concentration between monitoring station pairs as a function of wind direction.
    - Closer inspection of time series if candidate events were identified.

3 Results:

3.1 Long-term changes in background air quality

- On average, long-term trends in NO_x concentrations in inner-east Sydney between 2011 and early 2020 (i.e. pre-COVID) were slowly falling overall at around 2.5 % per year on average. This is consistent with trends in NO_x concentrations in many similar parts of the world and was most likely due to improvements in fuels and vehicle technology.
- The rate of fall was not consistent, however, with periods of faster reduction alternating with periods of slower reduction or no reduction at all. This is not uncommon and is most likely to due to normal temporary meteorological variation towards conditions more, or less favourable to dispersion, although other factors affecting traffic flow and emissions may also play a role.
- The period from early 2018 until the start of COVID-related restrictions in March 2020 was a period of accelerated reduction in background NO_x of approximately 5 % per year on average.
- NO_x concentrations fell abruptly in May 2020 and were steadily recovering between then and around April 2021. This is almost certainly due to reduced traffic volumes city-wide in this period.

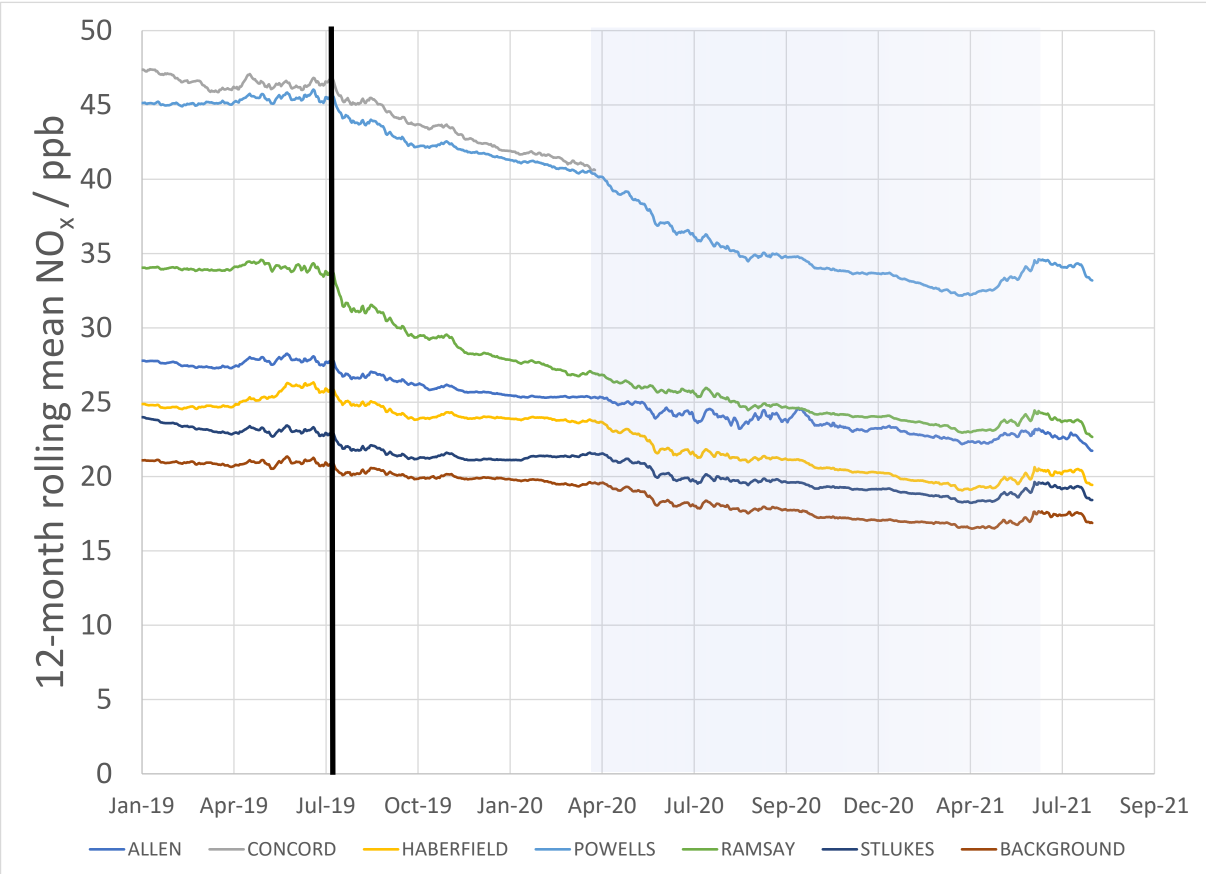
Figure 2: Monthly mean NO_x at background sites in inner west Sydney.



3.2 Long-term changes in project area air quality, 2018 – 2021

- Figure 3 illustrates the long-term trends in traffic-related air quality[3] at the seven project monitoring sites, and in the urban background air. The black vertical line represents the opening of the project. The feint blue background represents the period during which the data is influenced by COVID-related emissions reduction.

Figure 3: 12-month rolling-mean NO_x concentrations. Black line represents project opening and the blue section is data potentially impacted by changes in emissions due to COVID-19.



- From this figure the following features can be observed:
  - Air quality related to traffic has become better at all sites since the tunnel opened indicating a permanent improvement in air quality across the whole study area.
  - Concentrations at the M4 East sites are always higher than the background by an amount representing the degree to which each site is impacted by emissions from nearby roads (within tens to hundreds of metres).
  - There is a weak downward trend at the project background sites, most likely representing the general reductions in emissions from the whole Sydney vehicle fleet described above.
  - There was a stronger reduction in concentrations at the roadside sites (Powells Creek, Concord Oval and Ramsay Street) after the project opened.

[3] Represented by rolling-12 month mean concentrations of oxides of nitrogen (NO_x)

- There were additional reductions in concentrations, especially at Powells Creek, during the COVID-impacted period. These additional reductions were comparable in scale with the reductions that followed the tunnel opening. With lockdowns resuming in June 2021 it is too early, and beyond the scope of this work, to determine if this additional effect is temporary or permanent.

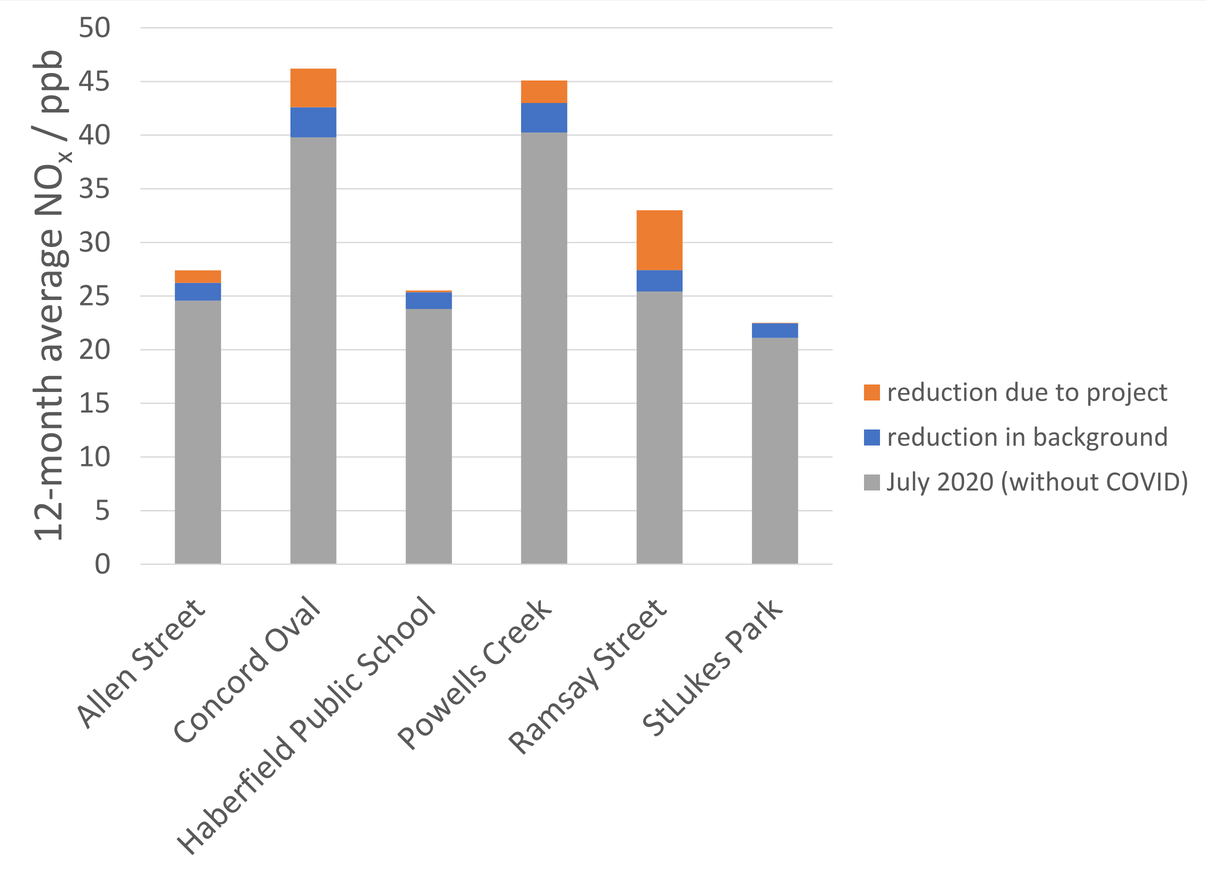
- We have used two methods to calculate the reduction in NO_x concentrations in the first year after the tunnel opening whilst removing the effect of COVID-19 (see above). These estimates combine the contribution of the project and background regional trends. The estimated reductions[4] at each site (in descending order) are:
  - 17 – 23 % at Ramsay Street
  - 14 – 15 % at Concord Oval
  - 11 – 13 % at Powells Creek
  - 7 – 10 % at Allen Street
  - 7 – 8 % at Haberfield Public School
  - 3 – 6 % at St Lukes Park
- By the end of the second year of tunnel operation (i.e. July 2021), and allowing the impact of COVID to be included, those reductions had approximately doubled, ranging from 15 – 28 %.

3.3 Can changes in long-term air quality be attributed to the project?

- Disaggregating the impact of local changes (i.e. the project) and regional changes in emissions, whilst meteorological conditions will also be changing, is a complicated task prone to uncertainty.
- By extrapolating observed trends, we estimate that, in the year following the opening of the project, and in the absence of COVID restrictions, background NO_x concentrations would have improved by approximately 6 %.
- This means we can tentatively attribute the following **additional** improvement to the project:
  - 13 – 17 % at Ramsay Street
  - 8 – 9 % at Concord Oval
  - 5 – 7 % at Powells Creek
  - 1 – 4 % at Allen Street
  - 1 – 2 % at Haberfield Public School
  - -3 – 0 % at St Lukes Park
- Figure 4 summarises these results showing the reductions between July 2019 and July 2020 (with data from 16th March 2020 being simulated to remove the effect of COVID-19).
- It remains a complex problem to extend this analysis through the full COVID-19 period from March 2020 to July 2021. Nevertheless, it appears at the time of writing that some of the improvements in air quality at the more highly trafficked locations during this period have been retained and may be permanent.

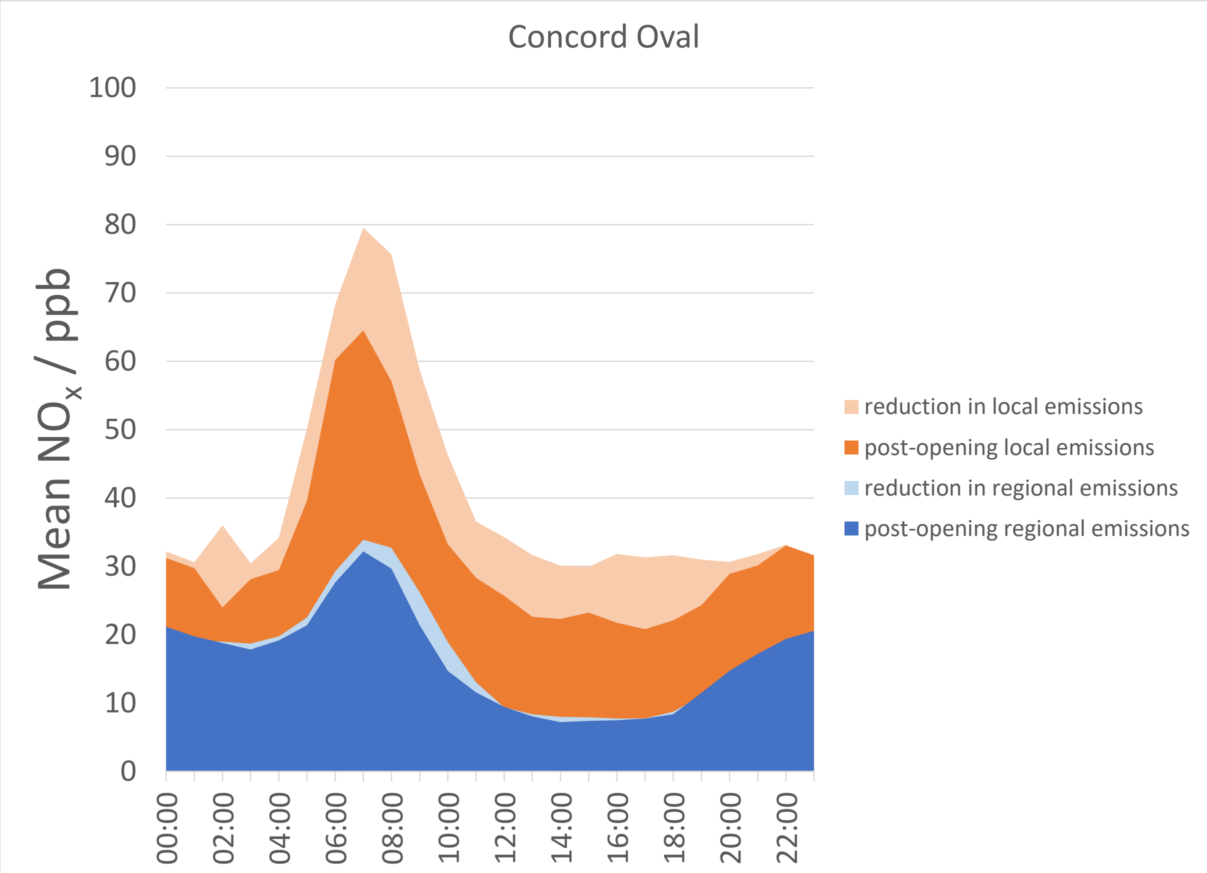
[4] A range is given relating to the two methods used, as described in the Methods section

Figure 4: Changes in long-term NO_x in the 12 months after the tunnel opening in the absence of COVID restrictions.



- Figure 5 provides an additional piece of evidence by showing the average change in NO_x concentrations at the roadside Concord Oval site (alongside Parramatta Road) during the first 8 months post-opening, averaged for each hour of the day. It can be seen that the average reduction in NO_x concentrations changed throughout the day, peaking between 8 and 9 am and broadly corresponding to the variation in traffic volumes. As a percentage the reduction 27 % between 7am and 6pm.

Figure 5: Diurnal average NO_x concentrations at Concord Oval showing changes during the first 8 months of tunnel operation compared to 12 months earlier.



3.4 Changes in air quality attributable to the ventilation outlets

- Four monitoring stations are within close proximity to the ventilation outlets:
    - Allen Street is 250 m east of the Underwood Road outlet
    - Powells Creek is 500 m east-south-east of the Underwood Road outlet
    - Ramsay Street is 500 m north-east of the Parramatta Road outlet
    - Haberfield Public School is 450 m south-east of the Parramatta Road outlet
- At each station we compared mean and maximum NO_x when the outlet was upwind of the station between the post-opening period (13th July 2019 - 15th Match 2020) and the same days 12 months earlier (13th July 2018 – 15th March 2019).
- In all cases mean and maximum NO_x concentrations measured when the monitors were downwind of the outlets were similar or reduced after outlets began operating compared to before. This is illustrated for mean concentrations in figures 6 to 9 in which mean NO_x is plotted for each wind direction (in 10-degree steps). The direction of the outlet relative to each site is illustrated by the blue cylinder and wedge.
- Other investigations failed to detect any impact of emissions from the ventilation outlets on local air quality.

Figure 6: Mean NO_x concentration at Haberfield Public School in each wind direction both before and after the opening of the project. The data potentially impacted by emissions from the Parramatta Road Ventilation Facility is indicated by the wedge.

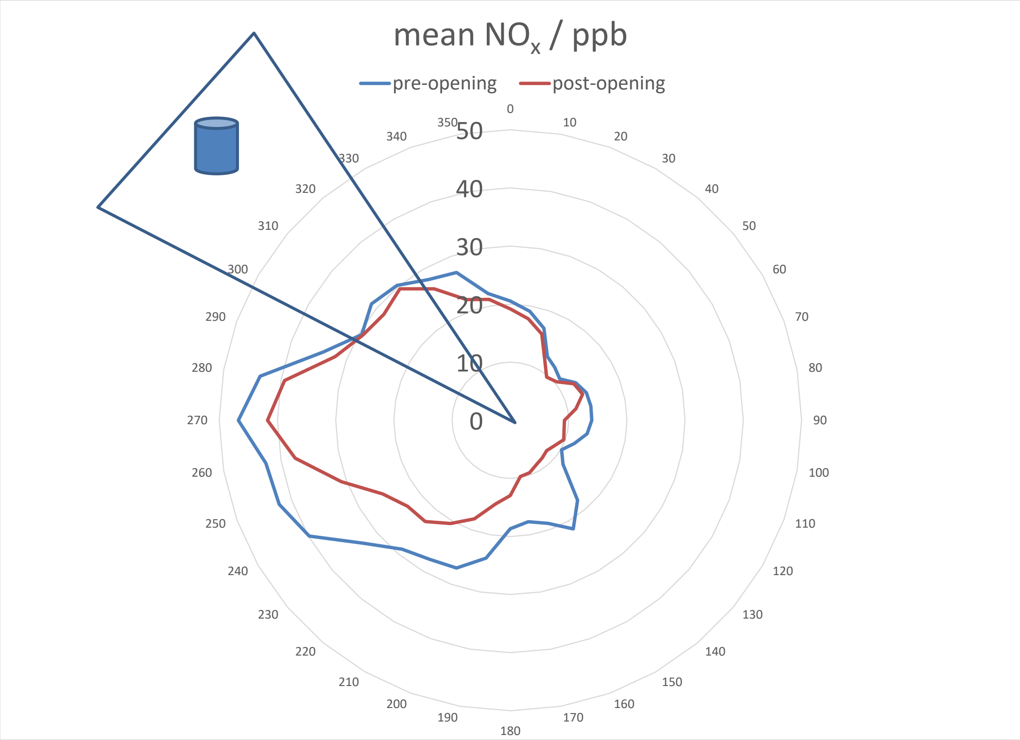


Figure 7: Mean NO_x concentration at Ramsay Street in each wind direction both before and after the opening of the project. The data potentially impacted by emissions from the Parramatta Road Ventilation Facility is indicated by the wedge.

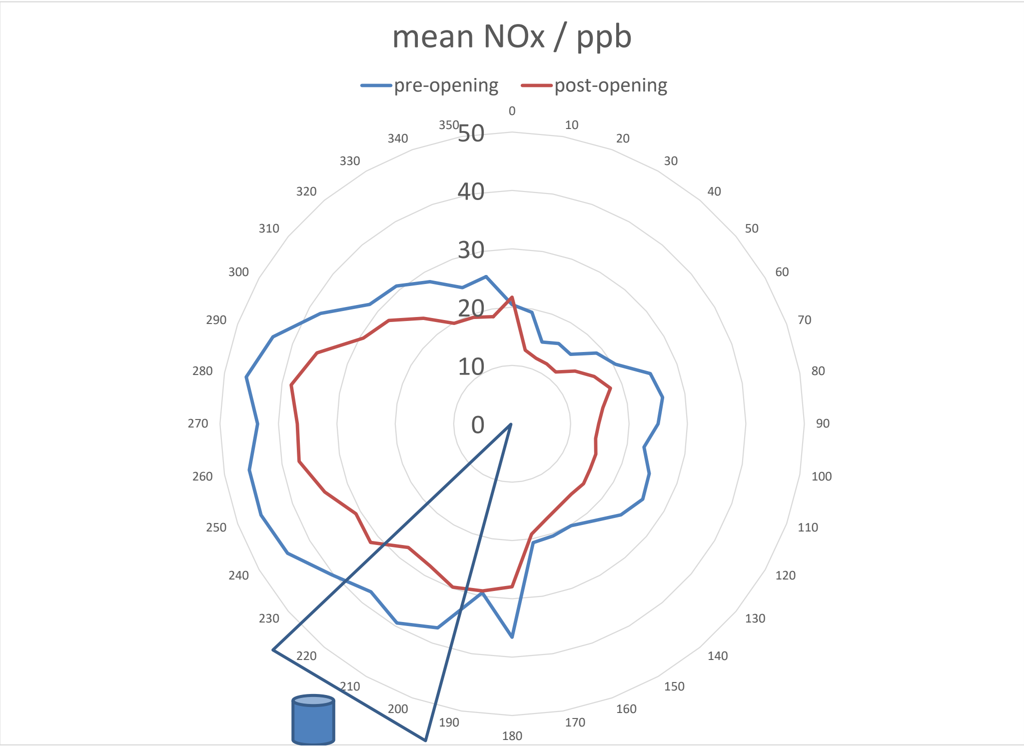


Figure 8: Mean NO_x concentration at Allen Street in each wind direction both before and after the opening of the project. The data potentially impacted by emissions from the Underwood Road Ventilation Facility is indicated by the wedge.

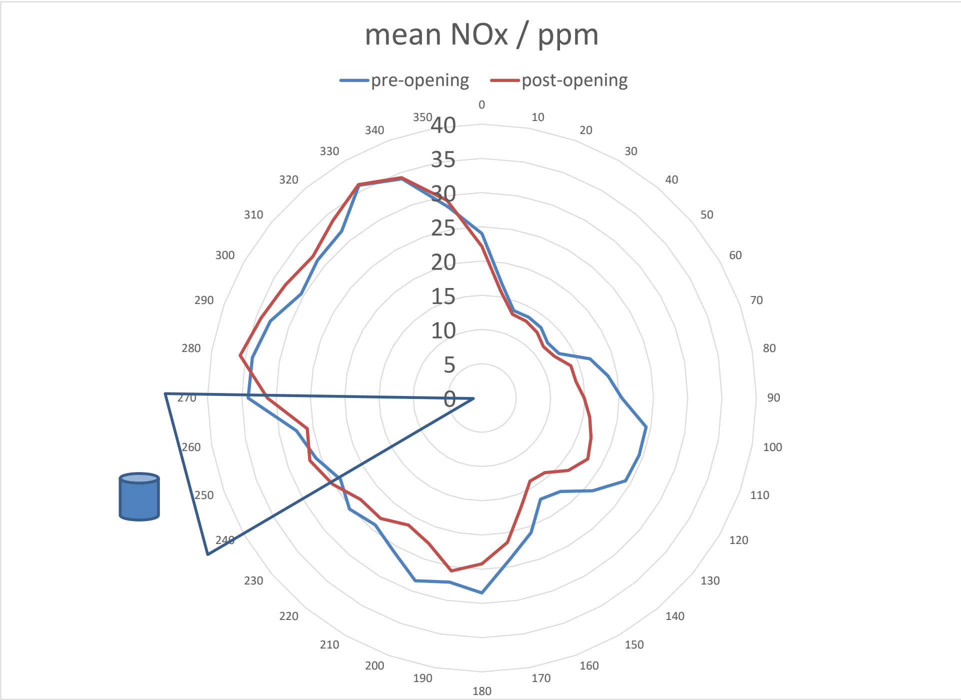
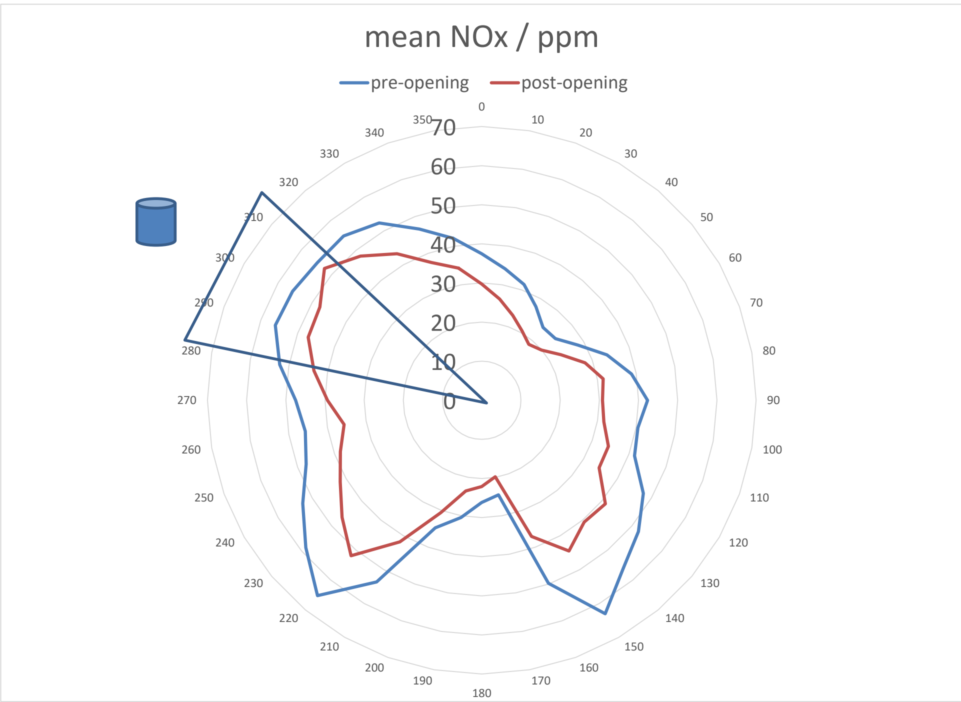


Figure 9: Mean NO_x concentration at Powells Creek in each wind direction both before and after the opening of the project. The data potentially impacted by emissions from the Underwood Road Ventilation Facility is indicated by the wedge.



4 Conclusions and discussion

- During the 8 months following the opening of the M4 East tunnel, and prior to the first restrictions related to COVID-19, air quality related to traffic exhaust emissions (represented by concentrations of oxides of nitrogen) substantially improved in the vicinity of the M4 East tunnel project.
- No worsening of air quality was observed at any monitoring location. There was no detectable impact of the emissions from the ventilation outlets on local air quality.
- Beyond that initial 8 months, analysis has been complicated by reductions in traffic associated with COVID-19 from mid-March 2020, introducing uncertainty into any statistics. We have applied two approaches to compensate for this: 1) comparing the 8-months post-opening with the same 8-month period from a year earlier, and 2) simulating data from mid-March to mid-July 2020 so that 12-month average concentrations can be calculated. Both methods provide slightly different statistics, but the broad patterns are the same.
- Based on these methods the improvement in air quality varied between locations:
    - A ~6% improvement across the whole inner west Sydney area most likely related to ongoing reductions in emissions from the Sydney vehicle fleet, and unrelated to the tunnel, as observed at St Luke's Park and Haberfield Public School monitoring sites,
    - An improvement of up 10 - 15% (i.e. 5 – 9% more than the regional trend) along the Parramatta Road corridor (with the improvement increasing with proximity to the road), as represented by the Concord Oval and Powells Creek monitoring sites, almost certainly due to improved surface traffic flow caused by the opening of the tunnel,
    - An improvement of around 20% at the Ramsay Street monitoring site, most likely due to reduction of vehicle volumes and congested vehicle queueing. This effect is most likely quite localised but may have been reproduced at other locations which were not monitored.
- Although monitoring was conducted for 24 months after the tunnel opened, the degree to which COVID-19 has impacted the data remains difficult to assess. On the second anniversary of the tunnel opening in July 2021, NO_x concentrations were 15 – 30 % lower than when the tunnel opened. Whereas a large proportion of this gain is undoubtedly due to changes in traffic patterns related to COVID-19, some of which may be permanent, the data also suggests that those sites experiencing the greatest positive effect of the tunnel on air quality also experienced a greater and more permanent gain during the COVID-19 period too.
- The data suggest the opening of the tunnel caused the background regional trend of slow improvement in air quality to be locally accelerated by approximately a year. The data also suggest that COVID may have amplified the positive effect of the tunnel causing an even greater acceleration in improving air quality.