Appendix I: Preliminary Ventilation Analysis (Maunsell: 2006)

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John Betts
Roads and Traffic Authority
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NSW 2010

19 October 2006

Dear John

Effect of Partial Portal Emissions on In-Tunnel Visibility in the M5 East Tunnel

As requested in your fax of 17 October 2006, we have assessed the reduction in extinction coefficient for the two scenarios of partial portal emissions and partial portal emissions with westbound filtration. Details of the analysis methods are the same as for our report "M5 East Motorway – Preliminary Ventilation Analysis, Revision 2" dated 20 September 2006.

Specific to this new assessment, "partial portal emissions" has been taken as the emission of 250m^3/s of tunnel air from each of the main westbound exit portal and the main eastbound exit portal. The filtration is modelled as a bypass system treating 200m^3/s of tunnel air. It is located at chainage 7869 in the westbound tunnel (approximately 673m upstream of the exit portal).

The filtration is assumed to remove 100% of the particulates in the bypass stream. This is not possible of course but it gives an upper bound estimate of the benefits. The flow in the westbound tunnel downstream of Duff Street has been taken as 375m^3/s, while the eastbound flow downstream of Duff Street has been taken as 150m^3/s. These figures are consistent with our earlier report but are slightly different from your current diagram, where the figures are 380m^3/s and 170m^3/s respectively. This variation will not affect indicative conclusions on the effect of portal emissions or filtration.

The attached A3 sheet gives a full set of results of the assessment for critical locations in the tunnel. The summary of effects on visibility is given below.

	Base case (Current operation)	Partial emissions at 250m³/s EB & WB, no filtration		Partial emissions at 250m³/s EB & WB with WB filtration at 200m ³/s		Full portal emissions, no filtration	
	Extinction coefficient (m^{-1})	Extinction coefficient (m^{-1})	Improvement over base case	Extinction coefficient (m^{-1})	Improvement over base case	Extinction coefficient (m^{-1})	Improvement over base case
Section 2 Eastbound just before Turella exhaust	.00566	.00332	41%	.00289	49%	.00222	61%
Section 7 Eastbound just before crossover offtake	.00384	.00236	38%	.00236	38%	.00236	38%
Section 12 Westbound just before Turella exhaust	.00437	.00304	30%	.00304	30%	.00237	46%
Section 13 Westbound just before crossover offtake	.00505	.00505	0%	.00324	36%	.00505	0%

All assumptions and qualifications noted in earlier reports apply generally to these results.

We are not sure that expressing the improvement as a percentage reduction is so clear when reductions are large. You may wish to consider listing the “fraction of haze remaining” or similar wording, such that an “improvement of 61%” becomes “0.39 of the haze remaining.”

We hope the above information satisfies your present needs.

Yours faithfully

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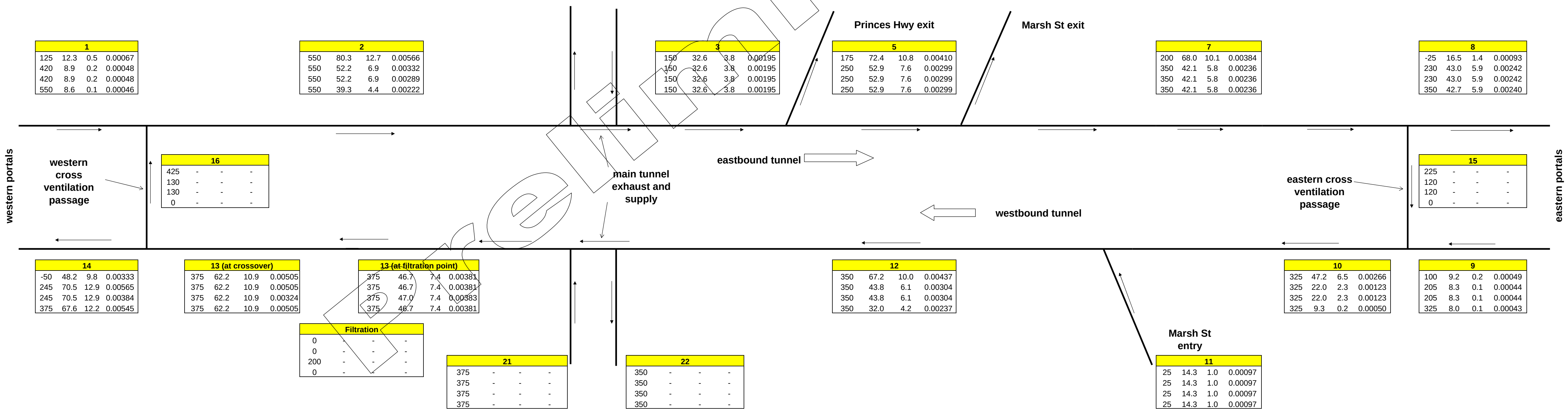
Pollution Levels - Portal Emission and Filtration Scenarios for J. Betts 20061018

congested eastbound and westbound, 20km/h and 3700 vehicles/h

Summary of Key Results - CO (ppm) and Visibility/Extinction Coefficient (1/m)	Critical Locations															
	Section 2 - just before eastbound exhaust				Section 7 - just before crossover take off				Section 12 - just before westbound exhaust				Section 13 - just before crossover take off			
	CO	Improvement	Vis	Improvement	CO	Improvement	Vis	Improvement	CO	Improvement	Vis	Improvement	CO	Improvement	Vis	Improvement
Base case	80.3	0%	0.00566	0%	68.0	0%	0.00384	0%	67.2	0%	0.00437	0%	62.2	0%	0.00505	0%
250m3/s EB&WB Portal Em's	52.2	35%	0.00332	41%	42.1	38%	0.00236	38%	43.8	35%	0.00304	30%	62.2	0%	0.00505	0%
250m3/s EB&WB Portal Em's & 200m3/s WB Filt	52.2	35%	0.00289	49%	42.1	38%	0.00236	38%	43.8	35%	0.00304	30%	62.2	0%	0.00324	36%
Original Case	39.3	51%	0.00222	61%	42.1	38%	0.00236	38%	32.0	52%	0.00237	46%	62.2	0%	0.00505	0%

Key to Results:

Segment Number			
Air Flow Q (m^3/s)	CO (ppm)	NOx (ppm)	extinction (1/m)
Base case			
250m3/s EB&WB Portal Em's			
250m3/s EB&WB Portal Em's & 200m3/s WB Filt			
Original Case			



1			
125	12.3	0.5	0.00067
420	8.9	0.2	0.00048
420	8.9	0.2	0.00048
550	8.6	0.1	0.00046

2			
550	80.3	12.7	0.00566
550	52.2	6.9	0.00332
550	52.2	6.9	0.00289
550	39.3	4.4	0.00222

3			
150	32.6	3.8	0.00195
150	32.6	3.8	0.00195
150	32.6	3.8	0.00195
150	32.6	3.8	0.00195

4			
-25	41.6	6.5	0.00209
-100	16.0	1.6	0.00082
-100	16.0	1.6	0.00082
-100	16.0	1.6	0.00082

5			
175	72.4	10.8	0.00410
250	52.9	7.6	0.00299
250	52.9	7.6	0.00299
250	52.9	7.6	0.00299

6			
-25	19.6	2.3	0.00099
-100	10.5	0.6	0.00055
-100	10.5	0.6	0.00055
-100	10.5	0.6	0.00055

7			
200	68.0	10.1	0.00384
350	42.1	5.8	0.00236
350	42.1	5.8	0.00236
350	42.1	5.8	0.00236

8			
-25	16.5	1.4	0.00093
230	43.0	5.9	0.00242
230	43.0	5.9	0.00242
350	42.7	5.9	0.00240

9			
100	9.2	0.2	0.00049
205	8.3	0.1	0.00044
205	8.3	0.1	0.00044
325	8.0	0.1	0.00043

10			
325	47.2	6.5	0.00266
325	22.0	2.3	0.00123
325	22.0	2.3	0.00123
325	9.3	0.2	0.00050

11			
25	14.3	1.0	0.00097
25	14.3	1.0	0.00097
25	14.3	1.0	0.00097
25	14.3	1.0	0.00097

12			
350	67.2	10.0	0.00437
350	43.8	6.1	0.00304
350	43.8	6.1	0.00304
350	32.0	4.2	0.00237

13 (at crossover)			
375	62.2	10.9	0.00505
375	62.2	10.9	0.00505
375	62.2	10.9	0.00324
375	62.2	10.9	0.00505

13 (at filtration point)			
375	46.7	7.4	0.00381
375	46.7	7.4	0.00381
375	47.0	7.4	0.00383
375	46.7	7.4	0.00381

14			
-50	48.2	9.8	0.00333
245	70.5	12.9	0.00565
245	70.5	12.9	0.00384
375	67.6	12.2	0.00545

15			
225	-	-	-
120	-	-	-
120	-	-	-
0	-	-	-

16			
425	-	-	-
130	-	-	-
130	-	-	-
0	-	-	-

19			
550	-	-	-
550	-	-	-
550	-	-	-
550	-	-	-

20			
150	-	-	-
150	-	-	-
150	-	-	-
150	-	-	-

21			
375	-	-	-
375	-	-	-
375	-	-	-
375	-	-	-

22			
350	-	-	-
350	-	-	-
350	-	-	-
350	-	-	-

Filtration			
0	-	-	-
0	-	-	-
200	-	-	-
0	-	-	-

M5 East Motorway - Preliminary Ventilation Analysis

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Prepared for

Roads and Traffic Authority NSW

Prepared by

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Quality Information

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Prepared by Peter Gehrke / Matthew Bilson

Reviewed by Conrad Stacey

Revision History

Revision	Revision Date	Details	Authorised	
			Name/Position	Signature
1	23/02/2006	Final	Peter Gehrke Principal Engineer	*PJG*
2	20/09/2006	Revised as per Client Request	Peter Gehrke Principal Engineer	

Table of Contents

Executive Summary

This report outlines the results of an assessment to predict potential changes in pollutant concentrations and visibility levels in the M5 East tunnel as a result of changes to the operation of the ventilation system. The assessment involved:

- the development of a Base Case ventilation model for the M5 East tunnel to model air quality levels based upon operational traffic volumes and airflow data including a comparison of the modelled levels with measured carbon monoxide (CO) levels as prescribed in the M5 East Conditions of Approval.;

- prediction of the changes to in-tunnel air quality levels for two alternative ventilation scenarios involving:
    1. increasing the air drawn in through the tunnel entries, the Princes Highway exit portal and the Marsh Street exit portal and releasing the additional air through the main exit portals (portal emissions); and
    2. as per scenario 1 with an assessment of required augmentation of the ventilation system (additional jet fans, supply air redistribution) to redistribute airflows in the tunnel; and

- comparison of the Base Case model with the above ventilation operating scenarios

The introduction of additional air into the tunnels and the use of portal emissions in both scenarios, when compared to the Base Case scenario, are predicted to provide in the following improvements in air quality:

- A reduction in the CO levels, in the order of:
    - 50% at the eastbound tunnel main tunnel exhaust; and:
    - 50% at the westbound tunnel main tunnel exhaust.

- An improvement in visibility, in the order of:
    - 60% in the eastbound tunnel, prior to the eastern main tunnel exhaust; and:
    - 45% in the westbound tunnel, prior to the western main tunnel exhaust.

- An improvement in CO and visibility, in the order of 38%, is predicted to occur in the eastbound tunnel just before the eastern crossover as a result of additional air being drawn in the Princes Highway and Marsh Street portals, which can be released through the main exit portals.

In addition, augmenting the jet fans in the tunnel to redistribute air between the eastbound and westbound tunnels, in conjunction with portal emissions, as in scenario 2, is predicted to improve in-tunnel air quality in the order of 7%, just before the western crossover.

In each of the scenarios, similar relative improvements to the levels of oxides of nitrogen in the tunnel were predicted.

The results of these investigations demonstrated, a potential for improvements in the pollutant concentrations and visibility, at the key locations in the tunnel identified from the Base Case modelling

As this is a preliminary assessment a more detailed analysis of the ventilation system under actual operating conditions by the tunnel operators is required to assess the potential improvements which may be achieved through the use of portal emissions, changes to airflows in the tunnel and augmentation of the in-tunnel ventilation system.

1.0 Introduction

1.1 Scope of Brief

Maunsell Australia were engaged by the RTA (RTA letter JB14MAR041, 14th March 2005) to perform an investigation into the relative merits of portal emissions as an operational procedure to improve in-tunnel air quality.

The brief from the RTA involved:

- the development of a Base Case ventilation model for the M5 East tunnel to model air quality levels based upon operational traffic volumes and airflow data including a comparison of the modelled levels with measured carbon monoxide (CO) levels as prescribed in the M5 East Conditions of Approval.;

- prediction of the changes to in-tunnel air quality levels for two alternative ventilation scenarios involving:
    1. increasing the air drawn in through the tunnel entries, the Princes Highway exit portal and the Marsh Street exit portal and releasing the additional air through the exit portals (portal emissions); and
    2. as per scenario 1 with an assessment of required augmentation of the ventilation system (additional jet fans, supply air redistribution) to redistribute airflows in the tunnel; and

- comparison of the Base Case model with the above ventilation operating scenarios

For the purposes of predicting in-tunnel air quality as requested by RTA, modelling was carried out for CO, oxides of nitrogen (NO_x) and visibility.

Work was also performed on tunnel aerodynamics to determine if extra jet fans were likely to be required to obtain the changes in tunnel flowrates provided by RTA. Details of this analysis are not included in this report, only general findings are given.

1.2 Brief Description of M5 East Tunnel Ventilation

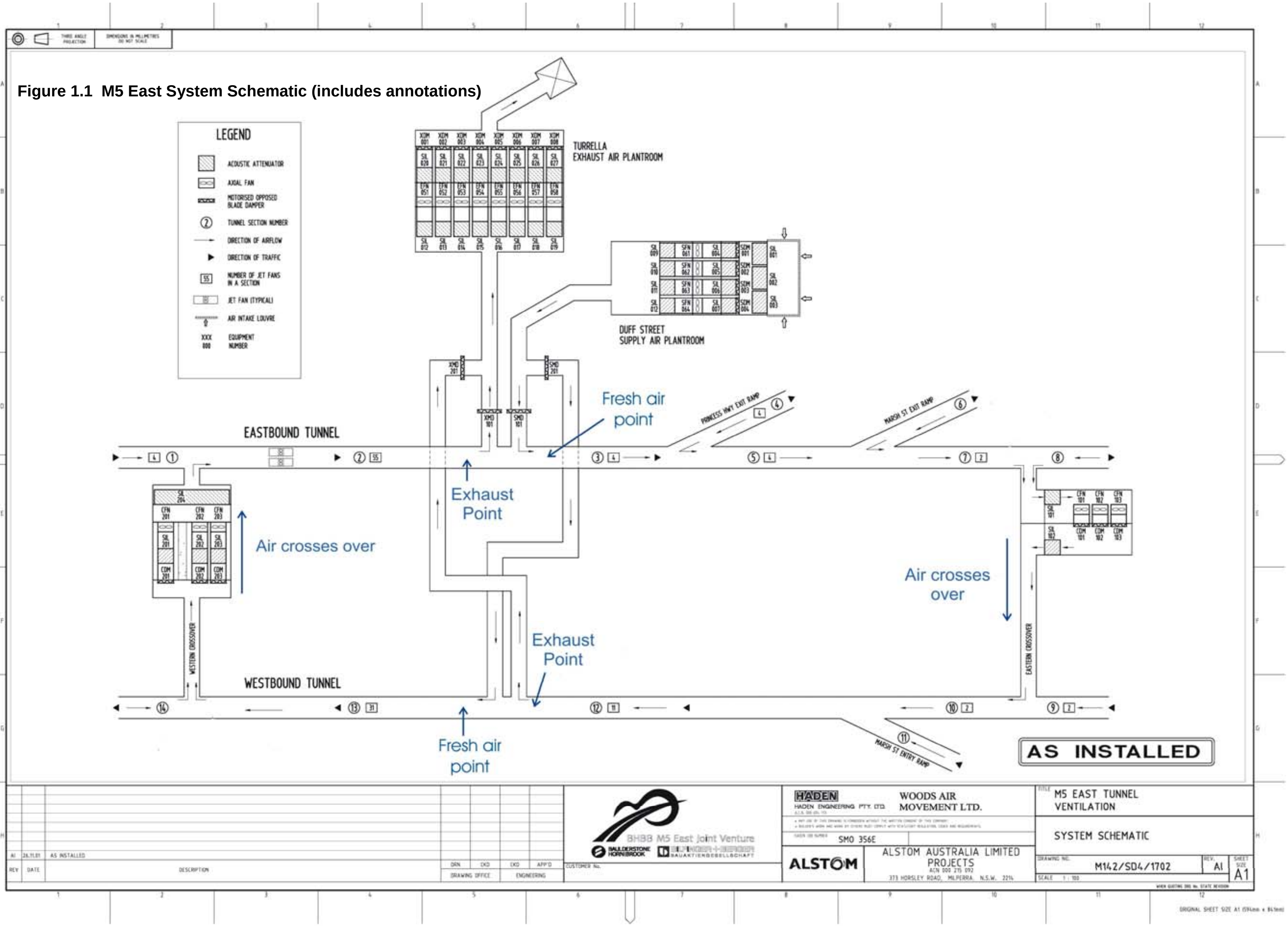
The M5 East road tunnel is a twin bore tunnel system, one bore dedicated to eastbound traffic, and the other to westbound traffic. Both the eastbound and westbound tunnels serve two lanes of traffic, and they each have a total length of approximately 4km. In addition to the main entry and exit portals, the eastbound tunnel has two off-ramps (Princes Highway and Marsh Street) and the westbound tunnel has one on ramp (Marsh Street).

The tunnel ventilation system is a “closed” system which comprises large air exhaust and supply system fans located 600m east of the tunnel mid-point, jet fans to move air throughout the tunnel and cross ventilation passages with fans to circulate the air between the two tunnels. The cross ventilation passages are located near the western and eastern portals. Varying numbers and types of jet fans are installed throughout the tunnel and ramps. Figure 1.1 shows the layout of the tunnel and the ventilation elements.

The ventilation system has been designed to avoid air emissions through the portals, as far as practical. The main tunnel has two cross ventilation passages that move air between the two tunnels. Polluted air is removed by the main exhaust for each tunnel and emitted from the ventilation stack. The air removed is replaced at approximately the same location in the tunnel by the main air supply, which draws air from the intake at Duff Street. Figure 1.1 also illustrates the air movement throughout the tunnels.

Given this arrangement, on a relative scale, the locations of highest pollutant concentrations occur at the exhaust points of both the eastbound and westbound tunnels and at the two locations where tunnel airflows enter the crossovers.

Figure 1.1 M5 East System Schematic (includes annotations)



2.0 Description of Model Used for Analysis

2.1 General

To analyse the in-tunnel effects of the modified operation, an emissions and ventilation model of the M5 East was developed. This model accounted for the following elements:

- Existing tunnel geometry (based on BHBB JV drawings)
- Existing tunnel alignment (based on BHBB JV drawings)
- NSW vehicle fleet age (derived from RTA registration data)
- Vehicle type/distribution (derived from M5 East operational data)
- Vehicle capacity and speed (derived from M5 East operational data)

To maximise the modelling accuracy, operational data from the M5 East were used to calibrate the model. Operational data relating to traffic flows, vehicle speeds, tunnel airflow and in-tunnel pollution levels were used. From the operational traffic information and airflow data, pollution levels in the tunnel were estimated and compared to the recorded operational values. Generally the comparison of pollution levels was favourable, giving confidence in the modelled results.

2.2 Limitations and Exclusions

The modelling work undertaken has the following limitations and exclusions:

- Longitudinal Pollutant Distribution
  The ventilation system for the tunnel is longitudinal (i.e. air is primarily directed along the tunnels in one dimension) hence pollution distribution was only modelled in one dimension. The model does not allow for any vertical or horizontal distribution across a tunnel section. Given the typical level of transverse mixing within a tunnel due to vehicle and jet fan action, this modelling limitation will not affect overall results.

- Aerodynamics
  The modelling work did not assess all aerodynamic effects. Tunnel flowrates as given by RTA were used as model input. In order to determine if it is possible to ventilate with these air quantities given the tunnel section, traffic conditions, and existing jet fan numbers, an aerodynamic model was developed. The model only had sufficient detail to determine bulk airflows in tunnel sections. The east and west tunnels were coupled only by crossover flows, not relative pressure. Full incorporation of fan pressure curves was not included. However, even with these simplifications the model was sufficiently detailed to draw comparative conclusions between the Base Case model and the two ventilation scenarios.

- Null Points
  Pollutant concentrations at possible null points were not assessed. Null points are sections of the tunnel with little or no airflow. This may possibly occur between exhaust and supply points. The pollutant concentrations within a null point is dependent on the transportation of pollutants in and out of the region. More detailed modelling is required to accurately analyse pollution behaviour in a null point. Adequate assessment of the effects of portal emissions does not require modelling of this nature.

- Due to the complex airflow patterns where the tunnel air meets the portal inflows and is directed into the crossover passages, the model is not capable of fully assessing the pollutant and visibility levels due to local recirculation etc at these locations in the eastbound and westbound tunnels. However, the modelled pollutant and visibility levels are considered adequate for this preliminary comparative analysis.

Model parameters used are given in Appendix A.

3.0 Base Case Model – No Portal Emissions ("Base Case")

3.1 General

A base case model was developed to estimate traffic conditions which give peak carbon monoxide concentrations provided by the RTA, given typical operational airflows. The vehicle flow rate, fleet breakdown (split between cars and petrol/diesel trucks) and average speed were adjusted until the worst carbon monoxide level predicted was of the order of 80ppm. The corresponding extinction coefficient (measure of in tunnel visibility) was of the order of $0.005m^{-1}$. The following vehicle parameters were determined:

Table 3.1 Vehicle Parameters

Item	Parameter Adopted	Origin/Comment
Vehicle Speed	EB 20km/hr WB 20km/hr	Speed held constant throughout tunnel (main carriageway and ramps).
Vehicle Flows	EB 3700veh/hr WB 3700veh/hr	Saturation capacity for speeds used (main carriageway and ramps).
Fleet Characteristics	EB Cars 93.46% LCV (P) 2.26% HCV (D) 4.28% WB Cars 90.63% LCV (P) 3% HCV (D) 6.37%	Fleet adjusted to obtain high in-tunnel pollution levels.
In-tunnel Air Quality	CO 87ppm (15 minute) Visibility $0.005m^{-1}$	Based on M5 East Conditions of Approval. 80ppm max. was adopted for the modelling PIARC Guideline

The above assumptions are considered reasonable for the purposes of undertaking a comparative analysis of the different ventilation scenarios.

Additional model parameters are given in Appendix A. Operational airflows for the base case are shown in Figure 3.1. For the base case there are no portal emissions.

3.2 Results

A full summary of airflow and pollution level results is given in Figure B.1 in Appendix B.

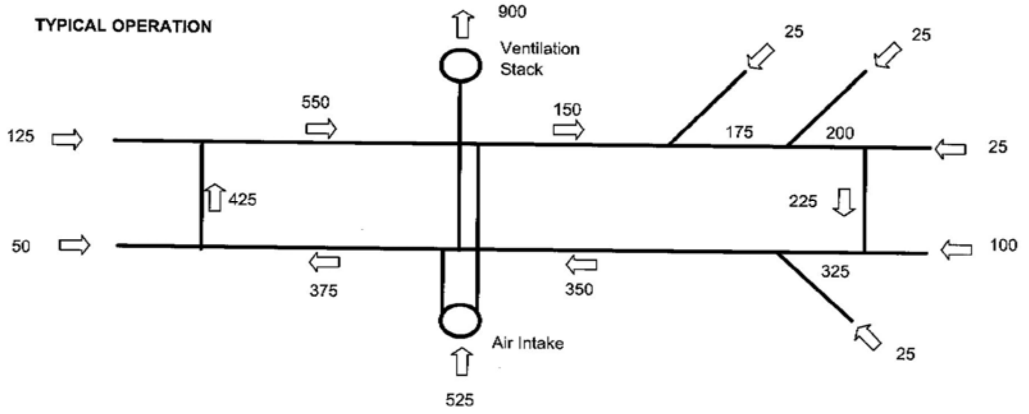
Key results for this scenario are:

- CO concentration maximum of 80ppm at the eastbound tunnel main exhaust, and 72ppm between the Princes Highway and Marsh Street off ramps.
- For the westbound tunnel, the highest carbon monoxide levels occur just before the main exhaust (67ppm) and near the western cross ventilation passage (62ppm).

- Visibility is lowest in the westbound tunnel at the western ventilation crossover (extinction coefficient 0.00505m^{-1}) and at the eastbound exhaust take-off (extinction coefficient 0.00566m^{-1}).

In the following Sections 4.0 and 5.0, the relative improvement in air quality for portal emission airflow scenarios is determined by comparison to the no-portal emission base case determined above.

Figure 3.1 Base Case Operational Air Flow Rates



4.0 Model of In-tunnel Air Quality With Portal Emissions ("Scenario 1")

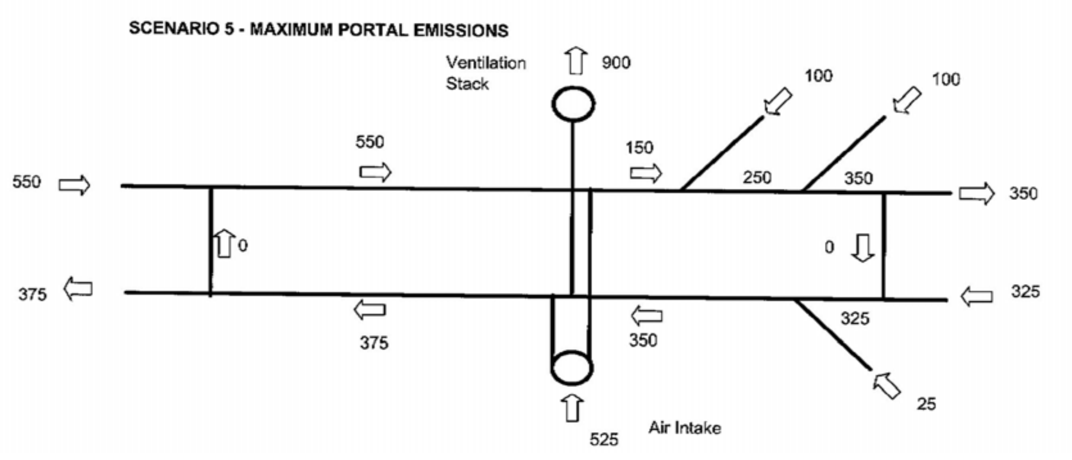
4.1 General

The modelling for this ventilation scenario involves:

- maximum theoretical airflow being released through the eastbound and westbound exit portals
- additional air being drawn in through the tunnel entries and the Princes Highway and Marsh Street exit portals
- no airflow through either the eastern or western crossovers; and
- the exhaust stack and air intake operating at maximum capacity

Figure 4.1 below shows the distribution of air flow in the tunnel for this scenario.

Figure 4.1



This ventilation scenario represents an operating mode which is anticipated to provide the greatest improvement in in-tunnel air quality.

4.2 Results

A full summary of airflow and pollution level results is given in Figure B.1 in Appendix B.

Key results from comparing the portal emission scenario with the Base Case scenario are:

- A reduction in the CO levels were:
    - of up to 51% (max. reduction from 80.3 ppm to 39.3 ppm) at the eastbound tunnel main exhaust; and:
    - 52% (max. reduction 67.2 ppm to 32.0 ppm) in the westbound tunnel at the main tunnel exhaust.

- An improvement in visibility:
    - of up to 46% (max. reduction in level from 0.00437m^{-1} to 0.00237m^{-1}) in the westbound tunnel, prior to the western main tunnel exhaust; and
    - up to 61% (max. reduction in level from 0.00566 to 0.00222) in the eastbound tunnel before the main exhaust.
- An improvement in CO and visibility in the eastbound tunnel just before the eastern crossover of 38% (max. reduction in levels from 68 ppm to 42.1 ppm and 0.00384m^{-1} to 0.00236m^{-1}) as a result of additional air being drawn in the Princes Highway and Marsh Street portals, which can be released through the main portals; and
- Similar relative improvements were predicted for NO_x in the tunnel.
- No improvements were achieved for the westbound tunnel west of the main supply intake because the flow rates remain the same as for the Base Case scenario

It should be noted that tunnel aerodynamics were not assessed for this airflow case. Airflows are based on the stack and supply system fan capacities.

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5.0 Model of In-tunnel Air Quality with Portal Emissions & Altered Airflows (“Scenario 2”)

5.1 General

For the previous section, portal emission airflows of 350m^3/s and 375m^3/s were considered for the eastbound and westbound tunnels respectively. Whilst this scenario provided improvements to the majority of the tunnel, it did not provide improvements in the western end of the westbound tunnel. This is because the westbound flow did not change and hence pollution levels did not improve.

To improve air quality in the westbound tunnel, a scenario was considered where:

- The western supply of air was increased to an optimum level.
- The eastern supply of air was decreased.
- The air drawn in through the Princes Highway and Marsh Street eastbound exit portals was increased.
- Additional fans were identified in the eastern end of the eastbound tunnel and the western end of the westbound tunnel to provide the required airflows.
- Existing airflows through the exhaust vent and air intake were maintained.

An increased supply flowrate of 425m^3/s (increased from 375m^3/s) was considered for the westbound tunnel (the eastbound supply was reduced to 100m^3/s). Aerodynamic effects in the tunnel were considered and from this an estimate of the additional fans that would need to be installed was determined.

5.2 Results

A full summary of airflow and pollution level results is given in Figure B.1 in Appendix B. Figure B.2 in Appendix B shows the estimate of the extra jet fans required and the airflows likely to be achieved.

The analysis of this scenario shows that, when compared with the Base Case Scenario;

- A peak carbon monoxide level of 57.6ppm (a predicted 7% reduction from 62.2ppm) is predicted in the westbound tunnel near the western crossover.
- The maximum visibility level was 0.00467m^{-1} (a predicted 8% reduction from 0.00505m^{-1}) is predicted in the westbound tunnel near the western crossover.
- An estimated 15 additional jet fans would be required to be installed in the western end of the westbound tunnel, with 5 new niches required in the western end of the tunnel. Each niche would accommodate 2 jet fans. An estimated 11 additional jet fans would be required to be installed in the eastbound tunnel.

The analysis of this scenario also confirms the predicted improvements, from scenario 1, to CO levels and visibility at the eastern and western tunnel main exhausts and the eastern end of the eastbound tunnel, when compared with the Base Case Scenario. However, due to the changes in the airflow in the tunnels from scenario 1, the improvements predicted at the two tunnel main exhausts in scenario 2 are approximately 2% less than the improvements predicted at these locations in scenario 1. Minor differences, such as this, are not considered to be significant and are within the accuracy of the ventilation modelling.

Modelling of this scenario shows that with the additional jet fans it may be possible to achieve improvements in the air quality in the eastern end of the eastbound tunnel and in the westbound tunnel west of the supply point.

It should be noted that with the 20km/hr traffic speed modelled, estimated jet fan requirements would be conservative. In reality fewer fans may be required or existing fans may be upgraded.

6.0 Conclusions

With the introduction of additional air through the tunnel entries and release of air through the exit portals, improvements to in-tunnel air quality (CO, NOx and visibility) in two of the four sections of the tunnel are predicted, specifically the levels at the eastbound stack extraction point and levels at the westbound stack extraction point.

Improvements to in-tunnel air quality in the third section of the tunnel (eastern end of the eastbound tunnel) are predicted with increasing the air drawn in through the Princes Highway and/or Marsh Street exits, in conjunction with portal emissions so that the total quantities of air exhausted from the ventilation stack is not increased above the current levels.

The modelling suggests that to improve the in-tunnel air quality in the eastern end of the eastbound tunnel and the western end of the westbound tunnel additional airflows in these sections are required. The increased airflows may be achieved through redistribution of the air supplied to these two sections from the air intake and increasing the jet fans in these sections.

A detailed analysis of the ventilation system by the tunnel operators/ventilation designers is required to assess the potential improvements which may be achieved through the use of portal emissions, changes to airflows in the tunnel and augmentation of the in-tunnel ventilation system.

Appendix A Model Parameters

Item	Parameter Adopted	Origin/Comment
Design Speed - Main Tunnels Free-flowing	 20 to 80km/hr (max)	 For the portal emissions analysed speed and vehicle distribution/fuel type was chosen to give peak CO level of around 80ppm for typical airflow case (refer Section 3.0)
- Ramps Free-flowing	20 to 80km/hr (max)	For the portal emissions analysed speed and vehicle distribution/fuel type was chosen to give peak CO level of around 80ppm for typical airflow case (refer Section 3.0)
Traffic Volumes	WB 3700veh/hr (maximum) EB 3700veh/hr (maximum)	For the portal emissions analysed speed and vehicle distribution/fuel type was chosen to give peak CO level of around 80ppm for typical airflow case (refer Section 3.0) Maunsell estimate.
Traffic distribution between main tunnel and ramps	EB Princes Hwy 13.2% Marsh Street 24.5% WB Marsh Street 36.1%	Typical values derived from M5 East operational data
Fleet characteristics	E/B Cars, LCV 95.72 HCV (P) 0 HCV (D) 4.28 W/B Cars, LCV 93.63 HCV (P) 0 HCV (O) 6.37	Typical values derived from M5 East operational data P – Petrol D – Diesel LCV – Light Commercial Vehicle HCV – Heavy Commercial Vehicle
Vehicle age for cars and light commercial vehicles (Year 2002)	Pre 1982 4.0% 1982 – 1985 4.3% 1986 – 1996 44.1% post 1997 23.4%	Maunsell estimate based on RTA registration data
Vehicle Age for Trucks (European) (Year 2002)	Maunsell Estimates: Pre 1991 45.7% 1991 – 1994 19.3% 1994 – 1996 11.6% 1997- 23.4%	Maunsell estimate based on RTA registration data

Item	Parameter Adopted	Origin/Comment
Vehicle Age for Trucks (US) (Year 2002)	Maunsell Estimates: Pre 1991 45.8% 1991- 54.2%	Maunsell estimate based on RTA registration data
Heavy Vehicle Origin Split European US	 50% 50%	Maunsell Estimate
Tunnel Geometry	Varies – based on BHBB construction drawings	
Passenger and Light Commercial Vehicles (petrol) Pre 1982 1982-1985 1985-1996 1997-	PIARC Tables: ECE 15/00 ECE 15/04 US83 x 4.4 US83	PIARC 05.02.B-1995 Recommendations and Australian Design Rules (ADR)
Light Commercial Vehicles (Diesel) All years	PIARC Tables: ECE 15/04	PIARC 05.02.B-1995 Recommendations and Australian Design Rules (ADR) One table used for all years (conservative)
Heavy Vehicles (European) Pre 1991 1991-1994 1994-1997 1997-	PIARC Tables: Pre Euro Euro 0 Euro 1 Euro 2	PIARC 05.02.B-1995 Recommendations and Australian Design Rules (ADR)
Heavy Vehicles (US) Pre 1991 1991 -	PIARC Tables: Pre Euro Euro 0	PIARC 05.02.B-1995 Recommendations and Australian Design Rules (ADR)
Cold Start Factor	Not Allowed For	Maunsell Assumption – vehicles will be driven over a significant distance before entering the tunnel.
Background Pollution	CO 7.5ppm NO_x 0ppm PM_{10} $0.0004m^{-1}$	Maunsell Estimate for CO. PM_{10} value derived from calibration
Heavy Vehicle Mass	30 tonne	Maunsell Estimate (conservative)

Appendix B Ventilation Modelling Results

Figure B.1 Pollution Levels - Portal Emission Scenarios

congested eastbound and westbound, 20km/hr and 3700 veh/hr

Summary of Key Results - CO (ppm) and Visibility/Extinction Coefficient (1/m)	Critical Locations															
	Section 2 - just before eastbound exhaust				Section 7 - just before crossover take off				Section 12 - just before westbound exhaust				Section 13 - just before crossover take off			
	CO	Improvement	Vis	Improvement	CO	Improvement	Vis	Improvement	CO	Improvement	Vis	Improvement	CO	Improvement	Vis	Improvement
Base Case - No Portal Emissions	80.3	0%	0.00566	0%	68.0	0%	0.00384	0%	67.2	0%	0.00437	0%	62.2	0%	0.00505	0%
Maximum Theoretical Portal Emissions	39.3	51%	0.00222	61%	42.1	38%	0.00236	38%	32.0	52%	0.00237	46%	62.2	0%	0.00505	0%
Optimised Portal Emissions and Altered Airflows	40.9	49%	0.00231	59%	41.8	38%	0.00235	39%	33.1	51%	0.00246	44%	57.6	7%	0.00467	8%

Key to Results:

Segment Number			
Air Flow Q (m^3/s)	CO (ppm)	NOx (ppm)	extinction (1/m)
Base Case - No Portal Emissions			
Maximum Theoretical Portal Emissions			
Optimised Portal Emissions and Altered Airflows			

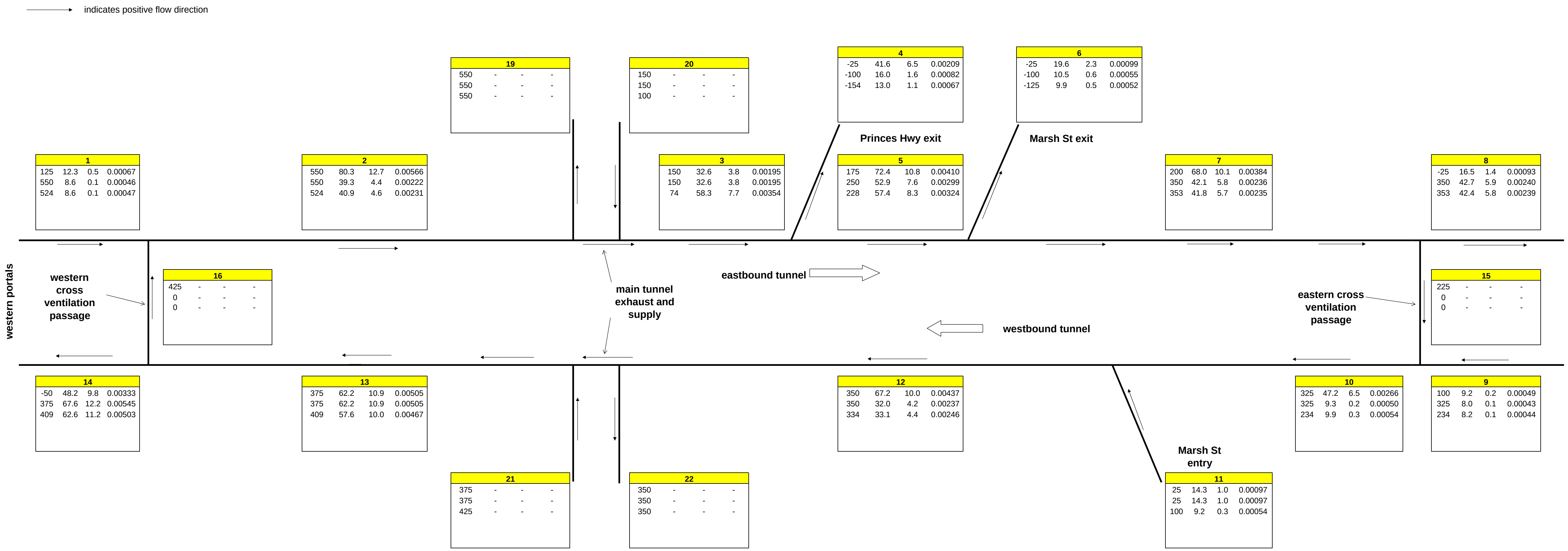

Figure B.2 Jet Fan Requirements - Portal Emission Scenarios

congested eastbound and westbound, 20km/hr and 3700 veh/hr

Summary - Eastbound (additional fans required)	1	2	3	4	5	6	7	8
Available extra jet fan niche capacity	0	7	0	2	4	4	0	4
Maximum Theoretical Portal Emissions	NA	NA	NA	NA	NA	NA	NA	NA
Optimised Portal Emissions and Altered Airflows	0	7	0	0	0	0	0	4
Summary - Westbound (additional fans required)	**9**	**10**	**11**	**12**	**13**	**14**		
Available extra jet fan niche capacity	0	0	0	1	1	4		
Maximum Theoretical Portal Emissions	NA	NA	NA	NA	NA	NA		
Optimised Portal Emissions and Altered Airflows	0	0	0	0	11	4		

Key to Results:

Segment Number			
Air Flow Q (m^3/s)	Jet Fans Installed	Jet Fans Locations Available	Fans Required for Flow
Base Case - No Portal Emissions			
Maximum Theoretical Portal Emissions			
Optimised Portal Emissions and Altered Airflows			

indicates positive flow direction