



Lam Geotechnics Limited

Ground Investigation & Instrumentation Professionals

華益
土力
有限
公司

Ref : G1938/CS/L247a/HyD
Date : 21 January 2021

3rd Floor
Ho Man Tin Government Offices,
88 Chung Hau Street,
Ho Man Tin,
Hong Kong
Attn: Senior Engineer, Mr. WONG Yee Lok, Enoch

(By Post & Fax: 2714-5289)

Dear Enoch,

Contract No. HY/2019/18
Wanchai Development Phase II and Central-Wanchai Bypass
Sampling, Field Measurement and Testing Works (Stage 4)

Investigation Report on Breakdown of Tunnel Ventilation Fan Nos. MVB-TVF-009 and MVB-TVF-010 at Middle Ventilation Building (MVB) of Central Wanchai Bypass (CWB)

We have reviewed the latest version of the captioned Investigation Report (the IR) dated 21 January 2021 and the responses to comments as per comments given by EPD up to 7 January 2021.

Based on the IR and the above responses to comments, we hereby certify the IR for your onwards submission to EPD as per the Event and Action Plan of the approved AQMP.

Please be reminded our certification does not absolve the EP holder/the project proponent/any person from any requirements or obligations under the Environmental Impact Assessment Ordinance (Cap. 499) or other laws in force in Hong Kong. In addition, please be reminded to ensure all relevant persons without missing the role of the Operator of CWB tunnel to carry out corresponding implementation to ensure normal operation of APS in accordance with the AQMP approved by EPD, and to timely implement all the preventive measures as laid down in Section G iv. of the IR and incorporate these preventive measures into the next revision of the approved AQMP.

Yours faithfully,
For and On Behalf of Lam Geotechnics Limited

Raymond Dai
Environmental Team Leader

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Ref.: AACWBIECEM00_0_12558L.21

21 January 2021

Highways Department
Major Works Project Management Office
Major Works Office (2)
3rd Floor, Ho Man Tin Government Offices
88 Chung Hau Street, Ho Man Tin
Kowloon, Hong Kong

By Post and Fax (2714 5289)

Attention: Mr. WONG Yee Lok, Enoch

Dear Mr. Wong,

Re: Central – Wan Chai Bypass (CWB) including its Road Tunnel and Slip Roads (Environmental Permit: EP-482/2013/C)

Investigation Report on Breakdown of Tunnel Ventilation Fan Nos. MVB-TVF-009 and MVB-TVF-010

Reference is made to the captioned Final Investigation Report on Breakdown of Tunnel Ventilation Fan Nos. MVB-TVF-009 and MVB-TVF-010 received through Project RSS's email and ET's certification letter (ref.: G1938/CS/L247a/HyD) received on 21 January 2021.

We write to verify the captioned final investigation report in accordance with the approved AQMP. By copy of this letter, HyD and relevant parties are reminded to follow the preventive measures stated in Section G (iv) of the captioned report and ET's recommendations.

Thank you very much for your attention and please do not hesitate to contact the undersigned should you have any queries.

Yours sincerely,



David Yeung
Independent Environmental Checker

c.c.	AECOM	Attn: Mr. David Kwan	by fax: 3912 3010
	Lam	Attn: Mr. Raymond Dai	by fax: 2882 3331
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**Central – Wan Chai Bypass
and Island Eastern Corridor Link**

**Investigation Report on Breakdown of
Tunnel Ventilation Fan Nos. MVB-TVF-009
and MVB-TVF-010
(Final Report)**

Prepared by:



Eric Wong / Donald Ip

Date: 21 January 2021

Position:

SRE (S&E) / RE (Env)
AECOM

Endorsed by:


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Date: 21 January 2021

Position:

Chief Resident Engineer
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A. Introduction

Two incidents regarding the damaged of tunnel ventilation fans (TVF) in the Middle Ventilation Building (MVB) of Central – Wan Chai Bypass (CWB) Tunnel were recorded on 28 June 2020 and 5 July 2020 respectively. The two incidents involved the TVFs (i.e. Fan Nos. MVB-TVF-009 and MVB-TVF-010) associated to Air Purification System (APS) No. MVB-APS-002 located in MVB. Please refer to Appendix 1 for schematic Diagram of Tunnel Ventilation System (TVS) and APSs.

Condition 2.9 of the Environmental Permit (EP) No. EP-482/2013/C sets out the requirements for the monitoring of the performance of APSs after the commencement of the operation of the CWB. An Air Quality Monitoring Plan (AQMP) as required in Condition 2.9 of EP No. EP-482/2013/A was approved by the Director of Environmental Protection on 17 January 2019 (See EPD website link : <https://www.epd.gov.hk/eia/register/english/permit/vep5112016/documents/aqmp/pdf/aqmp.pdf>). In the AQMP, there is a provision of Contingency Plan (Clause 3.2) which caters for emergency situations, such as an accidental breakdown of individual component causing malfunction of the TVFs and APSs. The current situation has been handled in accordance with the procedures of the contingency plan. Please refer to the flowchart (in Appendix 2) which summarizes such procedures.

Pursuant to Condition 2.9 of EP No. EP-482/2013/C regarding the incidents on 28 June 2020 and 5 July 2020, HyD is required to submit to the DEP this investigation report. This report provides the chronology of events of breakdown of Fan Nos. MVB-TVF-009 and MVB-TVF-010, comprehensive review on the reason of fan blade failure, short term measures taken / to be taken, proposal on air quality monitoring at Slip Road 3 (SR3) and nearby air sensitive receivers (ASR), in-tunnel air quality monitoring, and action plan / mitigation measures.

B. Chronology of events of breakdown of TVF Nos. MVB-TVF-009 and MVB-TVF-010

Parties Involved

Highways Department (HyD)	The Permit Holder of EP-482/2013/C and the Employer of HyD Contract No. HY/2011/08
AECOM (Resident Site Staff (RSS), The Engineer)	The Consultant of HyD for the CWB project
Chun Wo Tunnel Management Ltd	The Management, Operation and maintenance contractor (MOm) – Operator of the CWB tunnel
LAM Geotechnics Ltd.	Environmental Team (ET) under Environmental Permit No. EP-482/2013/C
Ramboll Hong Kong Ltd.	Independent Environmental Checker (IEC) under Environmental Permit No. EP-482/2013/C
Leighton Joint Venture (LJV)	The Contractor for Contract No. HY/2011/08 which includes the APS and TVS
Zitron	The manufacturer and supplier for the TVFs and a Sub-contractor of LJV
Transport Department/Tunnels and Tsing Ma Section (TD/TTMS)	Management of CWB Tunnel
Electrical and Mechanical Services Department/Government Management Team (EMSD(GMT))	E & M Advisor of TD/TTMS
Ir Dr. Eric C. H. Lim (Dr. Lim)	Consultant, Safety, Accident, and Failure Experts Ltd., independent investigation specialist engaged by HyD
Dr. Zhi Ning (Prof. Ning)	Associate Professor, Division of Environment and Sustainability, Hong Kong University of Science and Technology, team leader for additional

	air quality monitoring
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Chronology

The operation of CWB tunnel traffic was not affected. However, due to the failure of the concerned TVFs, operation of APS at MVB was also partially affected. The chronology of events is listed below:

<u>Date</u>	<u>Site Activities</u>	<u>Communications and Meeting Events</u>
28 June 2020 (Sun)	Fan No. MVB-TVF-009 failed to operate at 7:59am while the operation of APS No. MVB-APS-002 and Fan No. MVB-TVF-010 continued.	
28 June 2020 (Sun)	For investigation, MOM manually stopped APS No. MVB-APS-002 at 4:33pm, and stopped APS No. MVB-APS-001, Fan Nos. MVB-TVF-007 and MVB-TVF-010 at 9:18pm.	<p>MOM notified EPD, HyD, TD, EMSD, ET, IEC and RSS by email at 9:18pm regarding the failure of Fan No. MVB-TVF-009 and that broken fan blades were found (Fault code EM2018).</p> <p>For investigation, the TVFs located in the same fan hall i.e. Fan Nos. MVB-TVF-007 and MVB-TVF-010 were manually stopped by MOM for the inspection of Fan No. MVB-TVF-009. APS Nos. MVB-APS-001 and MVB-APS-002 were also stopped manually by MOM.</p>
29 June 2020 (Mon)	EMSD, RSS, LJV and MOM carried out an on-site investigation of Fan No. MVB-TVF-009 during the maintenance period from 1am to 6am on 29 June 2020.	
29 June 2020 (Mon)	<p>Dr. Lim inspected Fan No. MVB-TVF-009 in the morning.</p> <p>LJV and fan manufacturer's local agent also inspected Fan No. MVB-TVF-009 in the morning, they conveyed the findings to fan</p>	Discussions were made amongst HyD, RSS, TD, MOM and LJV in the morning on site, and it was agreed that the TVFs and the associated APSs at MVB should be suspended for operation for 24 hours in order to facilitate LJV to carry out inspection. LJV and the fan

	<p>manufacturer's office in Spain for their review in the afternoon.</p> <p>All TVFs and APSs at MVB were suspended for LJV's investigation.</p>	<p>manufacturer would also advise whether other TVFs at MVB are still safe to operate by 30 June 2020 morning. ET and IEC were informed of the temporary suspension of TVFs and the associated APSs at MVB accordingly.</p>
29 June 2020 (Mon)		<p>In addition, from safety point of view, RSS notified MOm by email at 9:12pm to suspend the operation of all TVFs and associated APSs at East Ventilation Building (EVB) and West Ventilation Building (WVB) starting from 30 June 2020 at 0:00am until completion of visual inspection of fan blades and fan blade bolts.</p>
30 June 2020 (Tue)	<p>The temporary suspension of all TVFs and APSs at EVB and WVB was started from 1:13am for LJV to conduct inspection. After visual inspection of other TVFs at EVB and WVB, LJV confirmed those TVFs were safe for operation. MOm resumed the all TVFs and APSs at EVB and WVB at 11:43am</p>	
30 June 2020 (Tue)		<p>ET informed HyD and IEC noting the Change of Circumstances of Environmental Permit EP-482/2013/C on the Operation of TVS and APSs in WVB, MVB, and Zero Portal Emission at Slip Roads 1 and 3 of CWB Tunnel respectively.</p>
30 June 2020 (Tue)		<p>IEC issued a letter to EPD notifying the Change of Circumstances for Condition 2.6 of Environmental Permit EP-482/2013/C and the Recommendations of the Approved EIA Report on Zero</p>

		Portal Emission.
30 June 2020 (Tue)		RSS notified HyD, TD, EMSD and MOm by email that LJV had completed the inspection and LJV and the fan manufacturer considered that all APSs and TVFs, except for APS No. MVB-APS- 002 and its associated Fan Nos. MVB-TVF-009 and MVB-TVF-010, could be resumed to operation. All parties had no objection to resume the operation of the TVS, except for APS No. MVB-APS-002 and its associated TVFs.
30 June 2020 (Tue)	MOm reported at 7:45pm that all APSs and its associated TVFs (except APS No. MVB-APS-002 and Fan Nos. MVB-TVF-009 and MVB-TVF-010) at MVB resumed operation.	
2 July 2020 (Thu)		LJV and AECOM suggested that Fan No. MVB-TVF-009 could be blanked off so that the standby Fan No. MVB-TVF-010 serving APS No. MVB-APS-002 could resume operation.
4 July 2020 (Sat)	LJV completed blanking off Fan No. MVB-TVF-009. APS No. MVB-APS-002 with its associated Fan No. MVB-TVF-010 resumed operation at 1:50pm.	RSS notified HyD, TD, EMSD and MOm by email at 10:04am that Fan No. MVB-TVF-009 had been blanked off in the early morning. HyD, TD, EMSD, RSS and LJV agreed that operation of APS No. MVB-APS-002 could be resumed.
5 July 2020 (Sun)	Fan No. MVB-TVF-010 and APS No. MVB-APS-002 failed to operate at 5:48am. Fan Nos. MVB-TVF-007, MVB-TVF-011, MVB-TVF-012 and MVB-TVF-013	MOm notified EPD, HyD, TD, EMSD, ET, IEC and RSS by email at 8:33am regarding the failure of Fan No. MVB-TVF-010 and that its broken fan blades were found (Fault code

	were manually stopped by MOm at 7:15am for investigation.	EM2026). MOm also notified that they manually shut down Fan Nos. MVB-TVF-007, MVB-TVF-011, MVB-TVF-012 and MVB-TVF-013 for investigation.
5 July 2020 (Sun)	HyD, RSS, LJV and Dr. Lim conducted an on-site investigation.	
5 July 2020 (Sun)	RSS and LJV walked through the air path of APS No. MVB-APS-002.	
6 July 2020 (Mon)		A meeting was held amongst HyD, RSS, LJV to discuss the replacement works of the damaged fans and the checking of other fans in the morning.
6 July 2020 (Mon)		An urgent meeting was held amongst EPD, HyD, RSS, ET, IEC and Prof. Ning to discuss the initial findings of the investigation of the incidents, interim measures to restore partial operation of the concerned APS, air quality monitoring and other requirements under the EP in the afternoon.
6 July 2020 (Mon)	MOm resumed the operation of APS Nos. MVB-APS-001, MVB-APS-003 and MVB-APS-004 and their associated TVFs at MVB at 5:45pm.	LJV and RSS confirmed the APS Nos. MVB-APS-001, MVB-APS-003 and MVB-APS-004 could resume operation, hence HyD agreed to resume the operation of APS Nos. MVB-APS-001, MVB-APS-003 and MVB-APS-004.
6 July 2020 (Mon)		RSS provided updates to ET and IEC by email at 8:01pm regarding the stoppage of Fan No. MVB-TVF-010 and APS No. MVB-APS-002 and the resumption of Fan Nos. MVB-TVF-007, MVB-TVF-011, MVB-TVF-012, MVB-TVF-013 and APS Nos. MVB-APS-001, MVB-APS-003 and MVB-APS-004 at MVB.

7 July 2020 (Tue)		ET informed HyD and IEC noting the Change of Circumstances of Environmental Permit EP-482/2013/C on the Operation of MVB and Zero Portal Emission at Slip Roads 1 and 3 of CWB Tunnel respectively.
7 July 2020 (Tue)		IEC issued a letter to EPD notifying the Change of Circumstances for Condition 2.6 of Environmental Permit EP-482/2013/C and the Recommendations of the Approved EIA Report on Zero Portal Emission.
29 Sept 2020 (Tue)	LJV completed the replacement works of Fan Nos. MVB-TVF-009 and MVB-TVF-010. Both TVF and the associated APS No. MVB-APS-002 resumed operation at 4:31pm	

C. Comprehensive review on the reason of fan blade failure

After investigation, Dr. Lim's findings on the reason of fan blade failure of Fan Nos. MVB-TVF-009 and MVB-TVF-010 were summarized as follows:

- 1) The failure mode of the first blade that failed in Fan Nos. MVB-TVF-009 and MVB-TVF-010, respectively, was most likely low cycle fatigue.
- 2) One of the major factors leading to the fatigue failure of the blades was the presence of gas pores in the blades as manufactured which significantly affected the overall strength of the blades.
- 3) Fatigue cracks had developed at surface pores or holes within the blades that were weaker as manufactured as they contained significant amount of gas pores. The surface pores or holes

within the blades acted as stress concentration points to assist fatigue crack initiation.

D. Short term measures taken

i. Resumption of operation of all TVFs except Fan Nos. MVB-TVF-009 and MVB-TVF-010

- a. After the breakdown of Fan No. MVB-TVF-009 on 28 June 2020, RSS and LJV had inspected the fan blades of all TVFs, and later confirmed that all fans (except the damaged Fan No. MVB-TVF-009 and the then affected Fan No. MVB-TVF-010) at the three ventilation buildings were ready for operation. All fans (except Fan Nos. MVB-TVF-009 and MVB-TVF-010) resumed operation on 30 June 2020.
- b. Upon the completion of blank-off of Fan No. MVB-TVF-009, Fan No. MVB-TVF-010 and its associated APS No. MVB-APS-002 resumed operation on 4 July 2020. Shortly after the resumption, Fan No. MVB-TVF-010 failed to operate and APS No. MVB-APS-002 also stopped operating on 5 July 2020.
- c. After the breakdown of Fan No. MVB-TVF-010 on 5 July 2020, Fan Nos. MVB-TVF-007, MVB-TVF-011, MVB-TVF-012, MVB-TVF-013 and their associated APS Nos. MVB-APS-001, MVB-APS-003 and MVB-APS-004 were manually stopped by MOm at 7:15am on the same day for investigation. After checking the X-ray films provided by the supplier in the material submission submitted previously, Dr. Lim advised that the fan blades of all other TVFs in MVB are in better condition comparing to that of Fan Nos. MVB-TVF-009 and MVB-TVF-010. After their inspection, RSS and LJV confirmed that these fans are ready for operation. Fan No. MVB-TVF-007, MVB-TVF-011, MVB-TVF-012, MVB-TVF-013 and their associated APS Nos. MVB-APS-001, MVB-APS-003 and MVB-APS-004 resumed operation at 5:45pm on 6 July 2020.

ii. Resumption of operation of APS No. MVB-APS-002

The contractor worked very hard to speed up the resumption works of Fan Nos. MVB-TVF-009 and MVB-TVF-010 against with the constraints due to COVID-19 since the breakdown. There was no

project related exceedance of air quality nearby the exit of SR3 and inside the CWB tunnel during the breakdown period. The operation of APS No. MVB-APS-002 was resumed on 29 September 2020.

E. Proposal on monitoring of air quality impact

i. Background for additional air quality monitoring

Since the breakdown of Fan No. MVB-TVF-009 on 28 June 2020 at 7:59am, the suspension of operation of APSs and their associated TVFs is as below:

<u>APS No.</u>	<u>Time of Suspension</u>	<u>Time of Resumption</u>
MVB-APS-001	28 June 2020 9:18pm	30 June 2020 7:45pm
MVB-APS-002	28 June 2020 4:33pm	4 July 2020 1:50pm
MVB-APS-003 & 004	29 June 2020 10:00pm	30 June 2020 7:45pm
APS in EVB & WVB	Starting from 30 June 2020 1:13am	All resumed before 30 June 2020 11:43am

After the breakdown of Fan No. MVB-TVF-010 on 5 July 2020 at 5:48am, the suspension of operation of APSs and their associated TVFs is as below:

<u>APS No.</u>	<u>Time of Suspension</u>	<u>Time of Resumption</u>
MVB-APS-001	5 July 2020 7:15am	6 July 2020 5:45pm
MVB-APS-002	5 July 2020 5:48am	29 September 2020 4:31pm
MVB-APS-003 & 004	5 July 2020 7:15am	6 July 2020 5:45pm

While APS Nos. MVB-APS-001, MVB-APS-003, MVB-APS-004 and their associated Fan Nos. MVB-TVF-007, MVB-TVF-011, MVB-TVF-012 and MVB-TVF-013 resumed operation in less than 2 days after checking, APS No. MVB-APS-002 and associated Fan Nos. MVB-TVF-

009 and MVB-TVF-010 would stop operating for a prolonged period. Thus zero portal emission at SR3 might be affected. In this connection, an additional air quality monitoring at SR3 and nearby air sensitive receivers (ASR) were carried out to assess the air quality impacts during the downtime of APS No. MVB-APS-002, Fan Nos. MVB-TVF-009 and MVB-TVF-010 at MVB.

ii. Additional air quality monitoring plan

HyD had engaged Prof. Ning of HKUST and his team (Prof. Ning's monitoring team) to temporarily install air monitoring stations inside the tunnel section of SR3 and at nearby ASR to closely monitor the air quality (NO_x and PM_{10}) in the surrounding areas. The monitoring works consisted of the following tasks:

a. Task 1 – Provision and calibration of mini air stations

The Prof. Ning's monitoring team would use Mini Air Station (MAS) Model MAS-AF300, which had a strong track record in documented data quality performance and local project experience including the demonstration measurement studies conducted in various government projects, for the additional air quality monitoring. The MAS Model MAS-AF300 could be both mounted on walls and portable deployment for flexible arrangement of the air quality measurements. PM_{10} , NO and NO_2 would be monitored with highest time resolution at 1-minute to capture the impact of traffic density on emission pollutants inside the tunnel. The wind speed and wind direction were also measured concurrently by MAS-AF300 system.

To facilitate the fast monitoring status checking and data verification, the air stations would provide wireless data transmission capabilities via 4G network with cloud-based data platform for data storage and visualization and SD card for raw data storage.

The high-performance sensor system MAS-AF300 employed dual sensor principle to track gas measurement baseline and eliminate interference impact from temperature and humidity. The pre-installation calibration followed standard reference analyzer calibration process with zero and multiple point span check for the sensor response linearity and sensitivity. The PM_{10} measurement was based on the forward light scattering photometer with linear response to the PM mass concentration. The multiple calibrations were conducted in factor manufacturer facility and the operational calibration procedure was conducted with the side by side local collocation to the HKEPD Air Quality Monitoring Stations prior to the sensor deployment for calibration.

The routine data quality control and assurance was conducted on weekly basis with two tiers operation with consideration of difficulties in field operation inside the tunnel and desired minimum interruption of the operation time.

Tier 1 – Remote data quality check and quality assurance:

The air quality monitor operation status including flow rate, raw output range, internal signal voltage, temperature and humidity control point, was checked on weekly basis to ensure the operation status falls into manufacturer’s guideline and Prof. Ning’s monitoring team scientific judgment.

Tier 2 – On-site data quality check and quality control:

In case the sensor output from the air quality meter is observed out of range during routine Tier 1 process, ad-hoc maintenance request would be raised by Prof. Ning’s monitoring team for immediate site visit the soonest possible. Manual zero and span check would be conducted for the air quality monitor. Collocation with transfer standard would also be conducted if deemed necessary by Prof. Ning’s monitoring team.

b. Task 2 – Measurements and maintenance of air monitoring equipment

Monitoring stations would be installed inside CWB Westbound Tunnel (Site 1), at SR3 Portal (Site 2), co-located with nearby high volume sampling (HVS) air monitoring location (Site 3). Please see the Appendix 3 for the layout plan.

The measurement parameters for the individual sites are listed below:

<u>Site</u>	<u>Description</u>	<u>Measurement parameters</u>
Site 1	Merging point inside tunnel	NO and NO ₂
Site 2	Portal of SR3	NO, NO ₂ and PM ₁₀ , wind speed* and wind direction*
Site 3	Air Sensitive Point 33 (A33)	NO, NO ₂ and PM ₁₀ , wind speed* and wind direction*

*Wind speed and wind direction collected at Site A would serve to evaluate the air quality monitoring results in case high pollution levels are recorded. It might not warrant other assessment purposes with constraints of installation site and obstacles of nearby structure.

SR3 portal was enclosed by the building structure of Hong Kong Convention and Exhibition Centre (HKCEC) such that the air path towards ASR A32 was enclosed and blocked by the overhead building structure of HKCEC.

A32 was located at behind the SR3 portal and the direction of air flow was towards the proposed monitoring location at Site 3 representing ASR A33. Comparing with ASR A32 being enclosed and blocked by the building structure of HKCEC, Site 3 representing ASR A33 with clearer air path from SR3 portal, was considered to be more representative for capturing the tunnel portal air flow and hence for monitoring of air quality associated with SR3 portal.

The Project ET had existing total suspended particulate monitoring station operating at Site 3 with permission given by the management agent of Pedestrian Plaza, which was adjacent to the Grand Hyatt Hong Kong, so it was considered more feasible to set up additional air quality monitoring station at the Site 3 for similar purpose in short notice.

During the monitoring period, Prof. Ning's monitoring team conducted data calibration and validation with quality control and assurance measures following the supplier's instruction and scientific judgment. Works included:

- Multi point standard gas calibration for MAS-AF300 in laboratory;
- Side by side comparison with reference analyzer or transfer standard;
- Air quality measurements; and
- Data quality control and assurance for routine check and validation.

All the QA/QC activities conducted for the measurement exercise were recorded.

c. Task 3 – Data analysis and interpretation

The multiple point air quality monitoring data inside and outside of the tunnel will be analyzed in terms of diurnal variations, spatial distributions and pattern of peak occurrence. The wind direction and wind speed would be used as supplementary information to support the data analysis. The data collected inside the tunnel would be compared with the relevant pollution

concentration limit provided by Practice Note on Control of Air Pollution in Vehicle Tunnels as below:

<u>Pollutant</u>	<u>Averaging time</u>	<u>Concentration limit ($\mu\text{g}/\text{m}^3$)</u>
Nitrogen dioxide	5-minute	1,800

Data collected near ASR A33 (Site 3) would refer to Hong Kong's Air Quality Objectives (HKAQO) as below:

<u>Pollutant</u>	<u>Averaging time</u>	<u>Concentration limit ($\mu\text{g}/\text{m}^3$)</u>	<u>Number of exceedances allowed per year</u>
Nitrogen dioxide	1-hour	200	18
Respirable suspended particulates (PM ₁₀)	24-hour	100	9

Three routine tasks were done in the monitoring period:

- 1) The raw data analysis and quality assurance were conducted internally by Prof. Ning's monitoring team on daily basis. In addition, comparison would be made between data of MAS and that of EPD's AQMS. Specifically, data obtained from ASR MAS (Site 3) would be compared to data obtained from EPD's ambient AQMS, while data obtained from in-tunnel MAS (Site 1 and 2) would be compared to data obtained from EPD's roadside AQMS. In case abnormality of air monitoring conditions is observed, Prof. Ning's monitoring team would contact the RSS team for immediate corrective actions.
- 2) Formatted data summary and interpretation report were submitted to HyD twice a week on Tuesdays and Fridays. The report summarized the data from period between the report intervals with further analysis.
- 3) A weekly report summarizing the two reports during the week was submitted to EPD for comments and suggestions.

A set of preliminary monitoring results taken from 8 July up to 13 October 2020, together with data analysis and interpretation are enclosed in Appendix 4.

In summary,

- 5-minute NO₂ concentrations inside the CWB Tunnel (Sites 1 and 2) were below the 5-min concentration limit as required in the Practice Note on Control of Air Pollution in Vehicle Tunnels.
- NO₂ concentration measured at Site 3 (Air Sensitive Point 33 (A33)) was within the HKAQO 1-hour NO₂ concentration limit since the start of air quality monitoring except for one exceedance observed on 2 September 2020 due to recent high pollution episode all across Hong Kong. This NO₂ exceedance was not resulted from the fan breakdown. Moreover, Site 3 had NO₂ levels comparable to general ambient AQMS in Central Western and Eastern.
- PM₁₀ concentration measured at Site 3 (Air Sensitive Point 33 (A33)) was within the HKAQO 24-hour PM₁₀ concentration limit since the start of air quality monitoring.

F. In-tunnel air quality monitoring and action plan to fulfill the limit stipulated in EPD's Practice Note

i. In-tunnel air quality monitoring

In-tunnel air quality inside SR3 was closely monitored up to the resumption of TVF/APS operation in MVB.

The in-tunnel air quality results are as below:

<u>Pollutant</u>	<u>Averaging time</u>	<u>Maximum limit as stated in the Practice Note[#]</u>	<u>Near SR3 Portal (Westbound) from 28 June to 13 October 2020</u>

CO	5-min	<100ppm	0.4155ppm to 78.5187ppm
NO ₂	5-min	<1ppm	0.0013ppm to 0.1974ppm
Visibility	5-min	<0.005 m ⁻¹	0.00m ⁻¹ to 0.0022m ⁻¹

Practice Note on Control of Air Pollution in Vehicle Tunnels issued by Air Services Group of Environmental Protection Department in Nov 1995.

Relevant in-tunnel air quality monitoring data were provided to ET and IEC for vetting until the resumption of the concerned TVF and APS.

It was observed from air quality records that the in-tunnel air quality was well below the maximum limit as stated in the Practice Note.

Data collected from in-tunnel air quality monitoring sensors (NO₂) near SR3 was supplemented to those from MAS for the study of air quality impacts. Please refer to the graphical representation in Appendix 5.

For the comparison of in-tunnel air quality (CO, NO₂ and Visibility) near SR3 one week before and one week after the breakdown incidents, please refer to the graphical representation in Appendix 6.

ii. Action plan in case of exceedance of in-tunnel air quality

The current in-tunnel air quality has been well below limits in EPD's Practice Note on the Control of Air Pollution in Vehicle Tunnels. If the in-tunnel air quality deteriorates to 80% of the limit in EPD's Practice Note, in-tunnel ventilation system would be turned on automatically until the in-tunnel air quality is improved to be lower than 40% of the limit in EPD's Practice Note on the Control of Air Pollution in Vehicle Tunnels.

The in-tunnel air monitoring was conducted continuously to give a 5-min average value. The ventilation fan (Fan No. MVB-TVF-001 for CH2885 - CH3770) would be activated automatically when the in-tunnel air quality reach the action level (80% of the limits) to improve

the air quality in Westbound. In case of exceedance of action levels or limit levels, the ventilation level would go up automatically (Fan No. MVB-TVF-002 for CH2885 – CH3770) until the air quality is below the pre-set value.

However, in the event of the extreme breakdown incident of the associated Fan Nos. MVB-TVF-001 and MVB-TVF-002 occurred in the future which might cause the action plan stated in the above paragraph not able to be implemented and the unexpected CWB-related exceedance of the in-tunnel air quality standard, the contingency plan stated in the AQMP would be implemented, the option of noticing/alerting the tunnel users of the situation would be considered subject to the discussion with all relevant parties.

iii. Action plan in case of exceedance of air quality at the ASR

Whilst close monitoring on the 1-hour average concentration of NO₂ will be continued to be provided during the down time of the related fans for SR3, action plan for exceedance case is as follow.

In the event of exceedance of HKAQO 1-hour average concentration of NO₂ at Site 3, detailed investigation and analysis of air monitoring data, including comparison with EPD's general and roadside air quality monitoring stations if considered appropriate, would be carried out as soon as possible to determine whether the exceedance is CWB-related or not. Real time air quality monitoring data on EPD's website would be obtained for comparison and record, if considered necessary, once the corresponding data is available on EPD's website. If it was CWB-related, the contingency plan at AQMP would be followed.

G. Action plan / mitigation measures

i. Independent investigation by HyD specialist

HyD engaged specialist Dr. Lim to carry out independent investigation of the incidents for Fan Nos. MVB-TVF-009 and MVB-TVF-010 and the condition of all the remaining TVFs in the three ventilation buildings of the CWB tunnel. Gamma and X-ray examinations, visual inspection, to check the condition of the fan blade of all the remaining TVFs were conducted.

ii. Replacement arrangement and resumption of Fan Nos. MVB-TVF-009 and MVB-TVF-010

Enormous efforts to reinstate the damaged Fan Nos. MVB-TVF-009 and MVB-TVF-010 had been made.

Immediately after the incidents, LJV has instructed Zitron in Spain to manufacture new fan blades with impellers which were dynamically balanced in Spain for Fan Nos. MVB-TVF-009 and MVB-TVF-010. The impeller blade set of Fan Nos. MVB-TVF-009 and MVB-TVF-010 have been air-freighted to Hong Kong. The two impeller blade sets were checked by X-ray test by an accredited laboratory for their quality prior to re-installation.

It took a considerable amount of time to complete the disassembling, health check and reassembly of fan motors of Fan Nos. MVB-TVF-009 and MVB-TVF-010 due to various difficulties and constraints. These included the difficulty of material delivery to MVB for fan removal due to site constraint, inclement weather problem, setting up temporary works for in-situ dismantling of the fan casing and fan motor; lack of suitable local workshops for health check/rectification; complicated customs and clearance procedures in transporting fan motors to suitable workshop outside Hong Kong; delay in transporting fan motors out of Hong Kong due to inclement weather; difficulty in getting suitable technicians promptly for in-situ fan balancing due to COVID-19, etc. The installation works of the checked fan motors and new impeller blade sets of Fan Nos. MVB-TVF-009 and MVB-TVF-010 were completed by qualified technician appointed by Zitron on 29 September 2020, thus the operation of Fan Nos. MVB-TVF-009, MVB-TVF-010 and the associated APS No. MVB-APS-002 resumed on the same day.

LJV was responsible for the replacement works for the resumption of Fan Nos. MVB-TVF-009 and MVB-TVF-010.

iii. Arrangement for other TVFs in CWB tunnel

As stated in section G(i), Dr. Lim was appointed to carry out investigation of the conditions of other TVFs in the three ventilation buildings of the CWB tunnel. Gamma and X-ray examinations, visual inspection, to check the condition of other TVFs in the three ventilation buildings of the CWB tunnel were completed in end October 2020.

iv. Preventive Measures

Regular maintenance of tunnel ventilation fans will be carried out to prevent reoccurrence of the incident. Non-instruments regular checks will be done monthly. These checks consist of the start-up and a visual and noise check. Regular checks with instruments shall be the ones done every 6 and 12 months, including vibration levels check, cleaning the fan surface, inspection of the motor, inspection of the impeller, inspection of inside and outside of the fan, check of vibration sensor, temperature and heating sensors, inspection of wiring and connection box, and checking of gap between blades and housing.

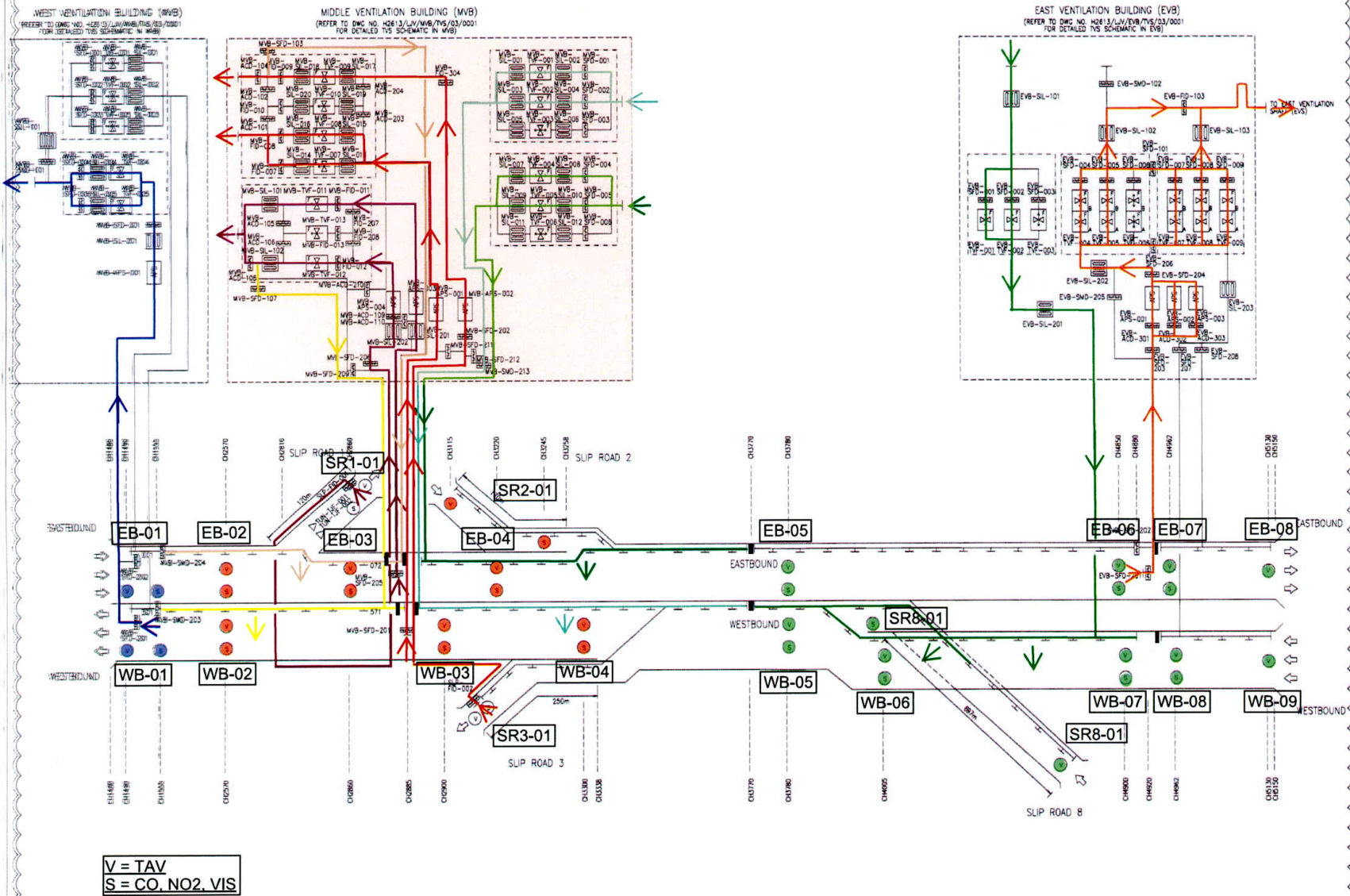
The above preventive measures, which are also specified in the O&M Manual for TVS, are to be carried out by MOm to prevent recurrence of similar incidents in future.

In addition, to facilitate future maintenance, provision of 4 sets of impeller blades as spare part is being arranged.

Appendix 1

Schematic Diagram of TVS and APSs

Normal Operation (Uni-Directional)



- NOTES:**
- FOR LEGEND, GENERAL NOTES AND ABBREVIATIONS, REFER TO DRAWING NO. H2613/LJV/SW/TVS/01/0001
 - THE TUN-SL-001 TO 004 WILL BE INSTALLED IN FRONT AND BEHIND THE TUN-TF-001 AND TUN-TF-002 RESPECTIVELY.

- LEGEND:**
- BI-DIRECTIONAL TWO STAGE TUNNEL VENTILATION FAN (TVF)
 - UNI-DIRECTIONAL SINGLE STAGE TUNNEL VENTILATION FAN (TVF)
 - BI-DIRECTIONAL SINGLE STAGE TUNNEL VENTILATION FAN (TVF)
 - OHVD Separation Wall

E	REVISED AS PER COMMENT	EC	MAR18
D	REVISED AS PER COMMENT	BC	JAN15
C	REVISED AS PER COMMENT	BC	DEC14
B	REVISED AS PER COMMENT	BC	NOV14
A	REVISED AS PER COMMENT	BC	OCT14
-	FOR APPROVAL	BC	JUL14
REV	DESCRIPTION	DATE	BY
BY	DATE		

Highways Department 路政署
Major Works Project Management Office

CENTRAL - WAN CHAI BYPASS AND IEC LINK
CENTRAL - WAN CHAI BYPASS
TUNNEL BUILDINGS, SYSTEMS AND FITTINGS
AND WORKS ASSOCIATED WITH TUNNEL COMMISSIONING

CONSULTANT ENGINEER
AECOM
AECOM Asia Co. Ltd.

CONTRACTOR
LEIGHTON JOINT VENTURE

DRAWING TITLE
TVS OVERALL TVS SCHEMATIC

DRG NO. 圖號	H2613/LJV/SW/TVS/03/0001	E
DESIGN BY 設計	EC	APPROVED BY 校核
DRAWN BY 繪圖	DJC	CW
SCALE 比例	N.T.S	WORKING DRAWING
UNITS 單位	METRES	© COPYRIGHT RESERVED 版權所有

Appendix 2

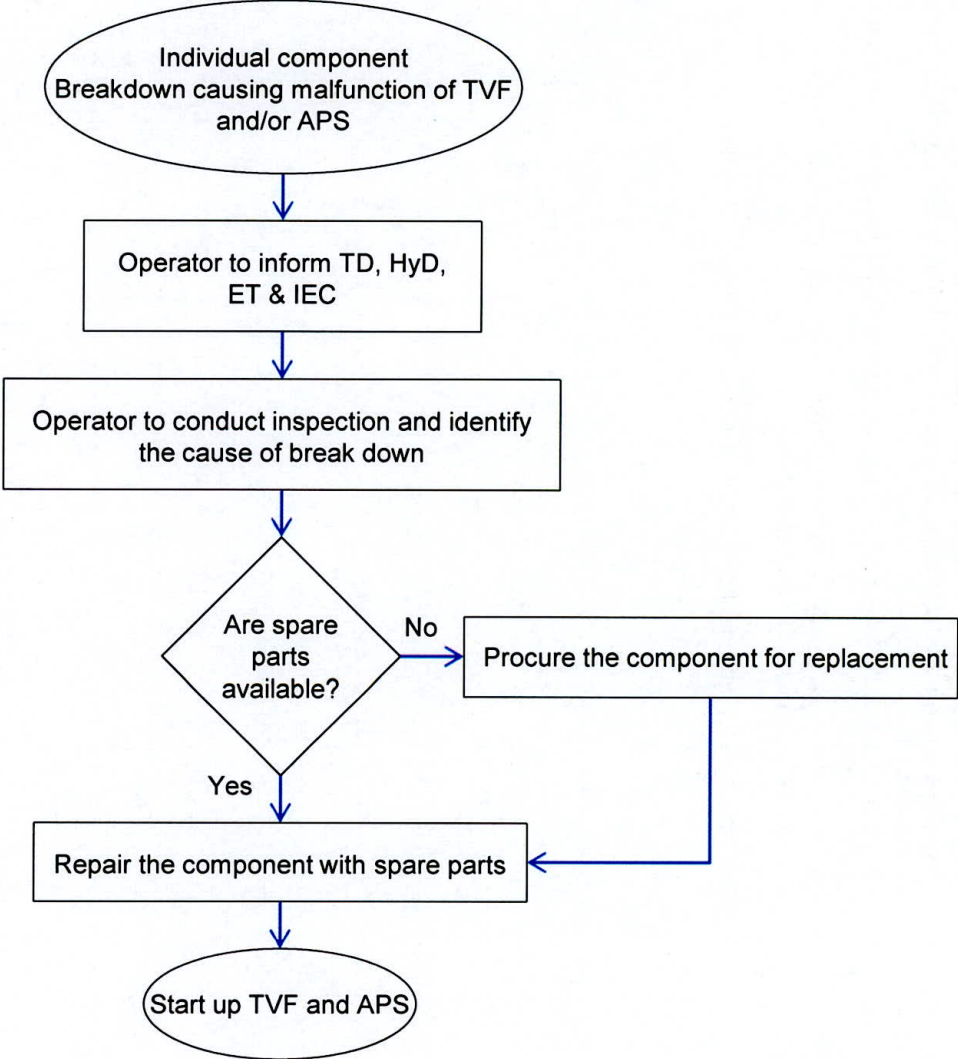
Procedure Flowchart of AQMP Contingency Plan

When there is an accidental breakdown of individual component causing malfunction of TVFs and/or APS, the Operator will follow the procedures below to start up TVFs and APS as soon as practicable.

1. Operator to inform TD, HyD, ET and IEC;
2. Operator to conduct inspection and identify the root cause of the breakdown;
3. Operator to check if there is any spare part available for repair;
4. If there are spare parts available, Operator to repair the broke down component with spare parts;
5. If there is no spare part available, Operator to procure the broke down component for replacement;
6. Operator to start up the APS according to the APS Operational Procedures after finishing repair/replace the broke down component.

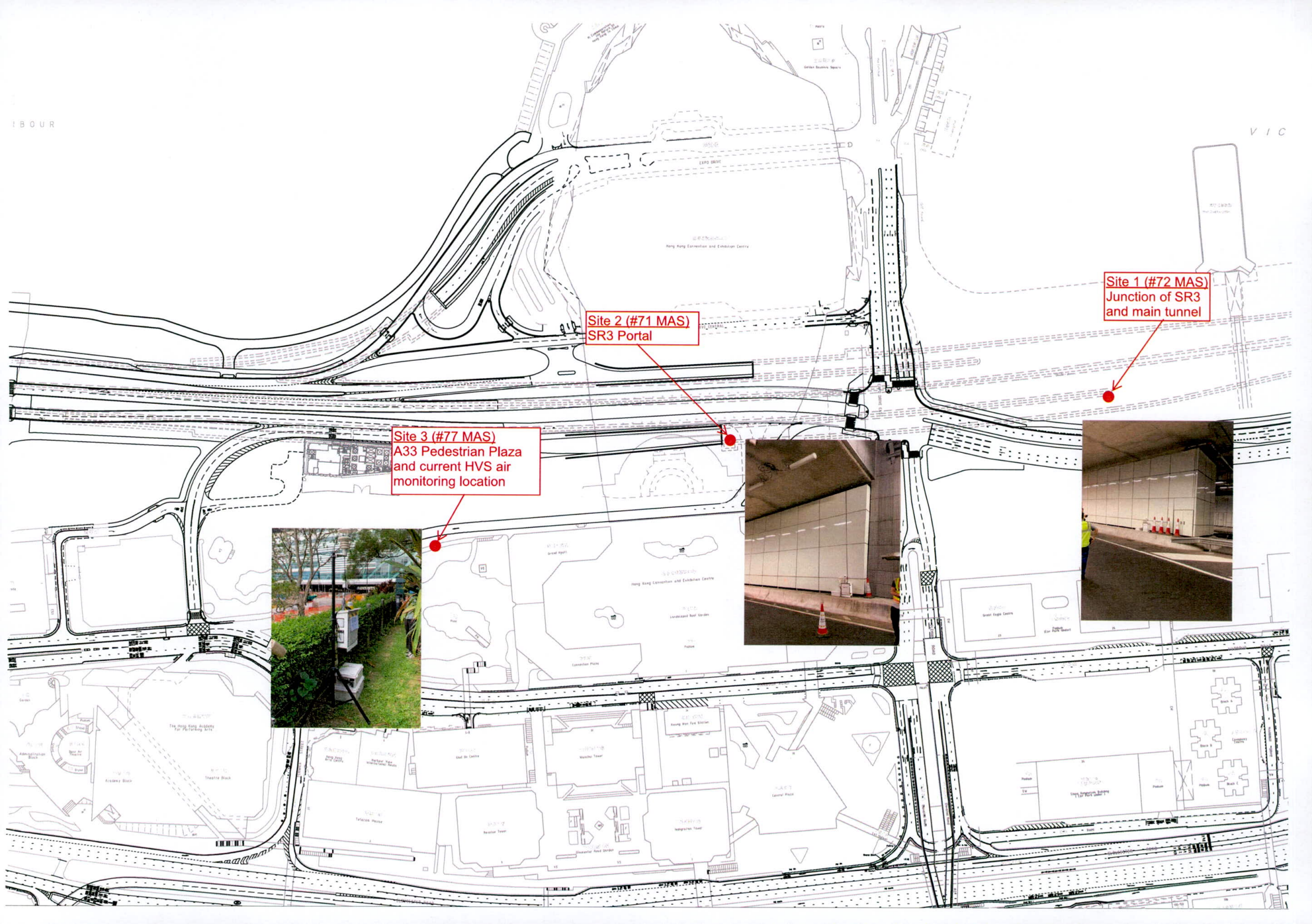
The emergency flowchart for individual component breakdown is attached below.

Component Breakdown



Appendix 3

Layout plan of Additional Air Quality Monitoring Stations



Site 1 (#72 MAS)
Junction of SR3
and main tunnel

Site 2 (#71 MAS)
SR3 Portal

Site 3 (#77 MAS)
A33 Pedestrian Plaza
and current HVS air
monitoring location



Appendix 4

Preliminary Monitoring Results, Data Analysis and Interpretation



Wan Chai Bypass Tunnel Monitoring Data Report

Update 0. 2020 JULY 09, 20:00 PM
Update 1. 2020 JULY 10, 14:00 PM
Update 2. 2020 JULY 14, 14:00 PM
Update 3. 2020 JULY 17, 14:00 PM
Update 4. 2020 JULY 21, 14:00 PM
Update 5. 2020 JULY 24, 14:00 PM
Update 6. 2020 JULY 28, 14:00 PM
Update 7. 2020 JULY 31, 14:00 PM
Update 8. 2020 AUGUST 04, 14:00 PM
Update 9. 2020 AUGUST 07, 13:00 PM
Update 10. 2020 AUGUST 11, 13:00 PM
Update 11. 2020 AUGUST 14, 14:00 PM
Update 12. 2020 AUGUST 18, 13:00 PM
Update 13. 2020 AUGUST 21, 13:00 PM
Update 14. 2020 AUGUST 25, 13:00 PM
Update 15. 2020 AUGUST 28, 13:00 PM
Update 16. 2020 SEPTEMBER 01, 14:00 PM
Update 17. 2020 SEPTEMBER 04, 13:00 PM
Update 18. 2020 SEPTEMBER 08, 14:00 PM
Update 19. 2020 SEPTEMBER 11, 13:00 PM
Update 20. 2020 SEPTEMBER 15, 13:00 PM
Update 21. 2020 SEPTEMBER 18, 13:00 PM
Update 22. 2020 SEPTEMBER 22, 13:00 PM
Update 23. 2020 SEPTEMBER 25, 14:00 PM
Update 24. 2020 SEPTEMBER 29, 13:00 PM
Update 25. 2020 OCTOBER 05, 13:00 PM
Update 26. 2020 OCTOBER 06, 13:00 PM
Update 27. 2020 OCTOBER 09, 13:00 PM
Update 28. 2020 OCTOBER 14, 10:00 AM



MINI AIR STATION INSTALLATION AND SETUP



180UR

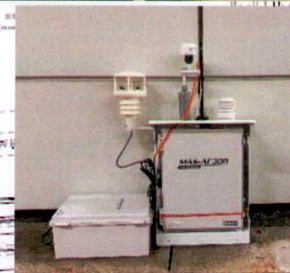
Layout of Slip Road 1



Slip Road 1 Portal

A76 Open Space at West of HKCEC

Slip Road 3 Portal



Tunnel Site 1

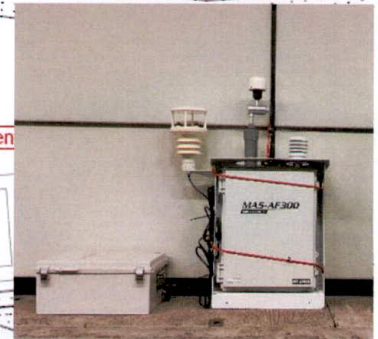
Portal Site 2

A33 Pedestrian Plaza and current HVS air monitoring location

ASR33 Site 3

A29 Servicemen's Guides Association

A35 Great Eagle Cen



A30 HK Academy for Performing Arts (Open Space)

A27 Arts Centre



Monitoring parameters and schedule

Site	Description	Measurement parameters
Site 1	Merging point inside tunnel	NO and NO ₂
Site 2	Portal of Slip Road 3	NO, NO ₂ and PM ₁₀ , wind speed* and wind direction*
Site 3	Air Sensitive Point 33 (A33)	NO, NO ₂ and PM ₁₀ , wind speed* and wind direction*

*Wind speed and wind direction collected at Site 2 and 3 would be used to evaluate the air quality monitoring results in case high pollution levels are recorded. The wind data collected cannot be used for assessment of the performance of TVF with respect to zero portal emission.

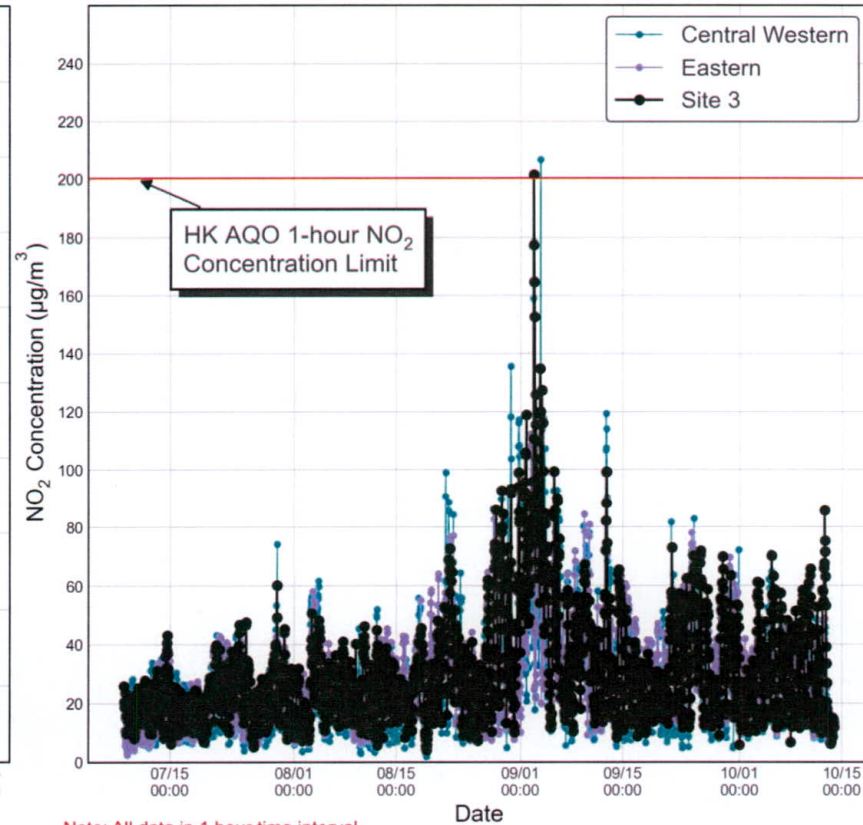
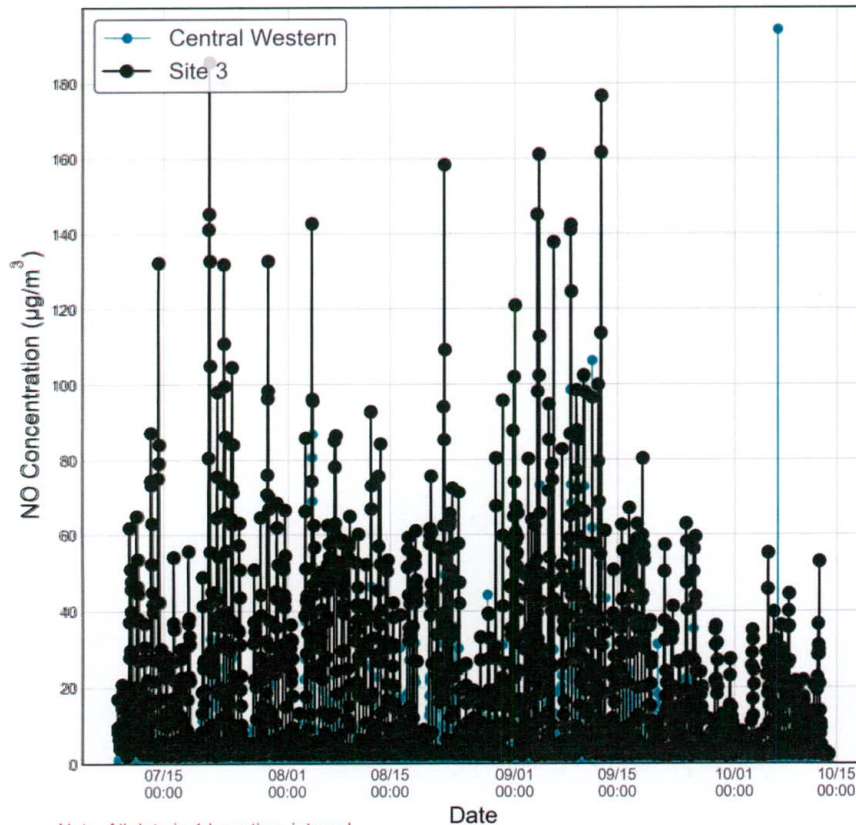
Site visit and installation of MAS at Sites 3	08/07/2020 15:00-17:00
Site visit and installation of MAS at Sites 1 and 2	09/07/2020 01:30 - 05:00
Commencement of air quality monitoring	08/07/2020 for Site 3, 09/07/2020 for Site 1 & 2.



AIR QUALITY MONITORING

Site 3 ASR33

- Monitoring Period: 2020/07/08 18:00 - 2020/10/13 23:59



Site 3:

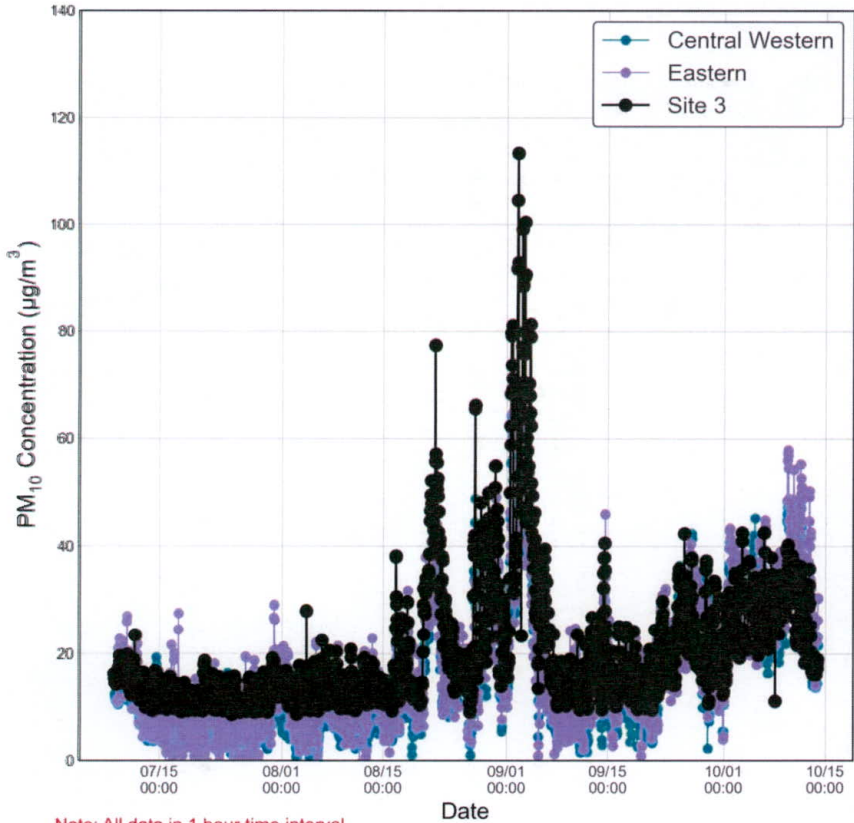
Most of hourly NO₂ concentration is below the 1-hour NO₂ concentration limit in HKAQO. One exceedance was observed on September 2, 2020 due to the recent high pollution episode all across Hong Kong.

No. of NO ₂ exceedances	Date	Time	Concentration (µg/m ³)
1	2020/09/02	19:00	201.5

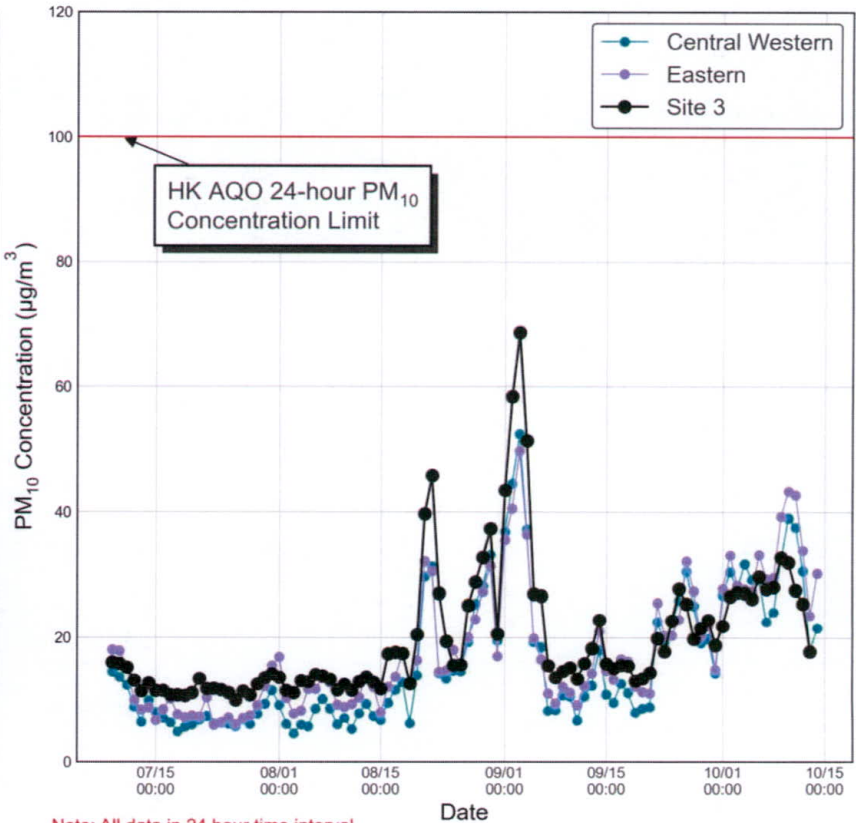


Site 3 ASR33

- Monitoring Period: 2020/07/08 18:00 - 2020/10/13 23:59



Note: All data in 1 hour time interval



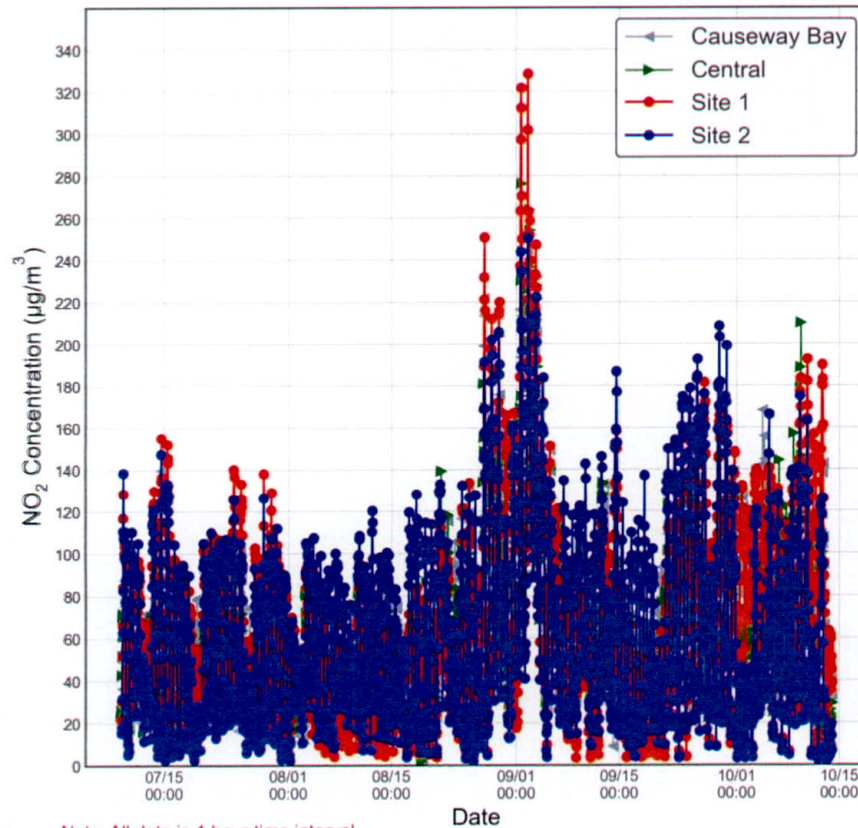
Note: All data in 24 hour time interval

Site 3:

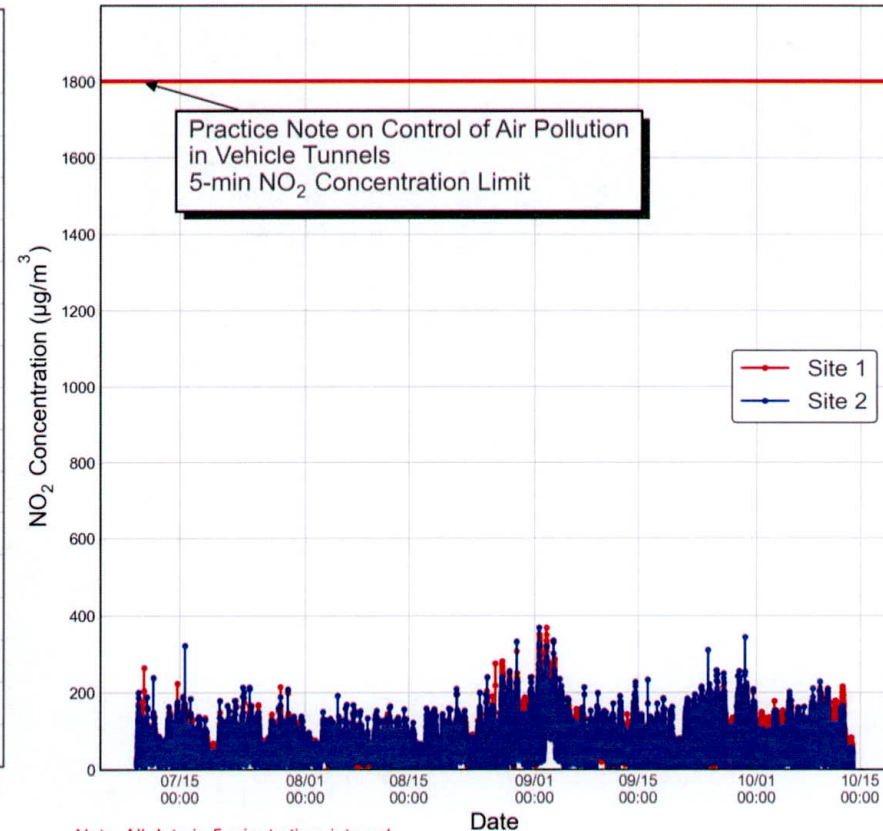
24-h average PM_{10} concentration is below the 24-hour PM_{10} concentration limit in HKAQO.

Site 1 Tunnel and Site 2 Portal

- **Site1:**2020/07/09 04:00 - 2020/10/13 23:59
- **Site2:**2020/07/09 04:00 - 2020/10/13 23:59



Note: All data in 1 hour time interval



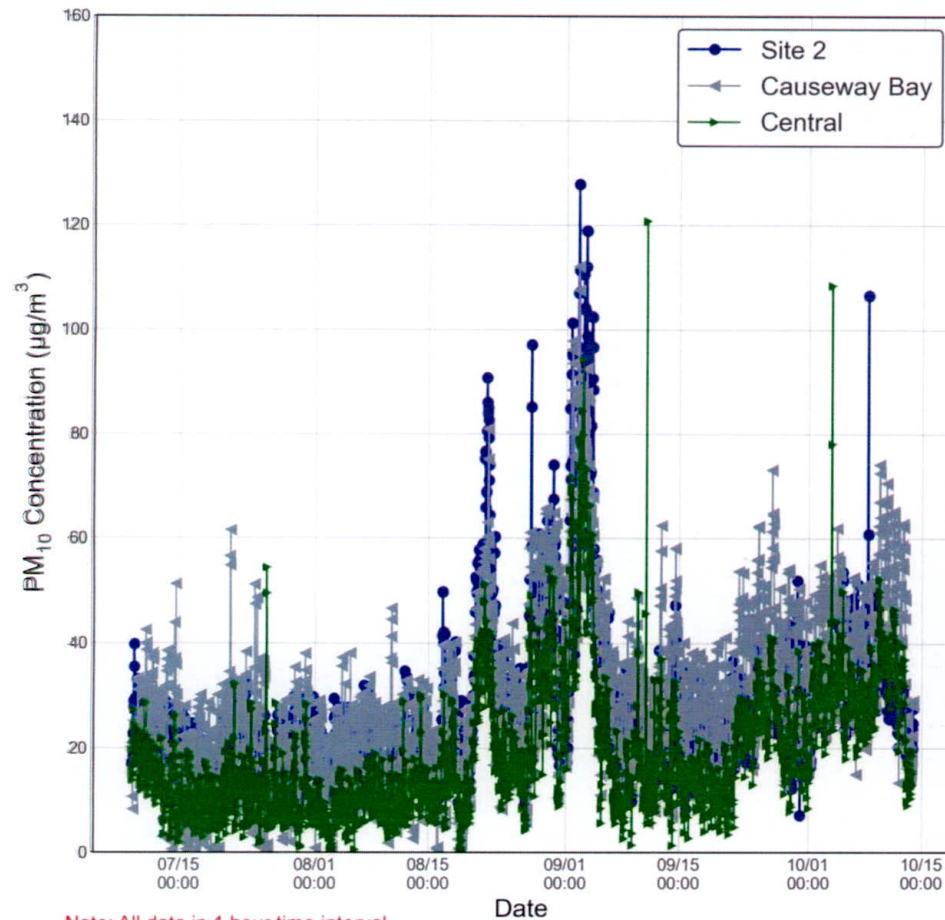
Note: All data in 5 minute time interval

Site 1 and 2:

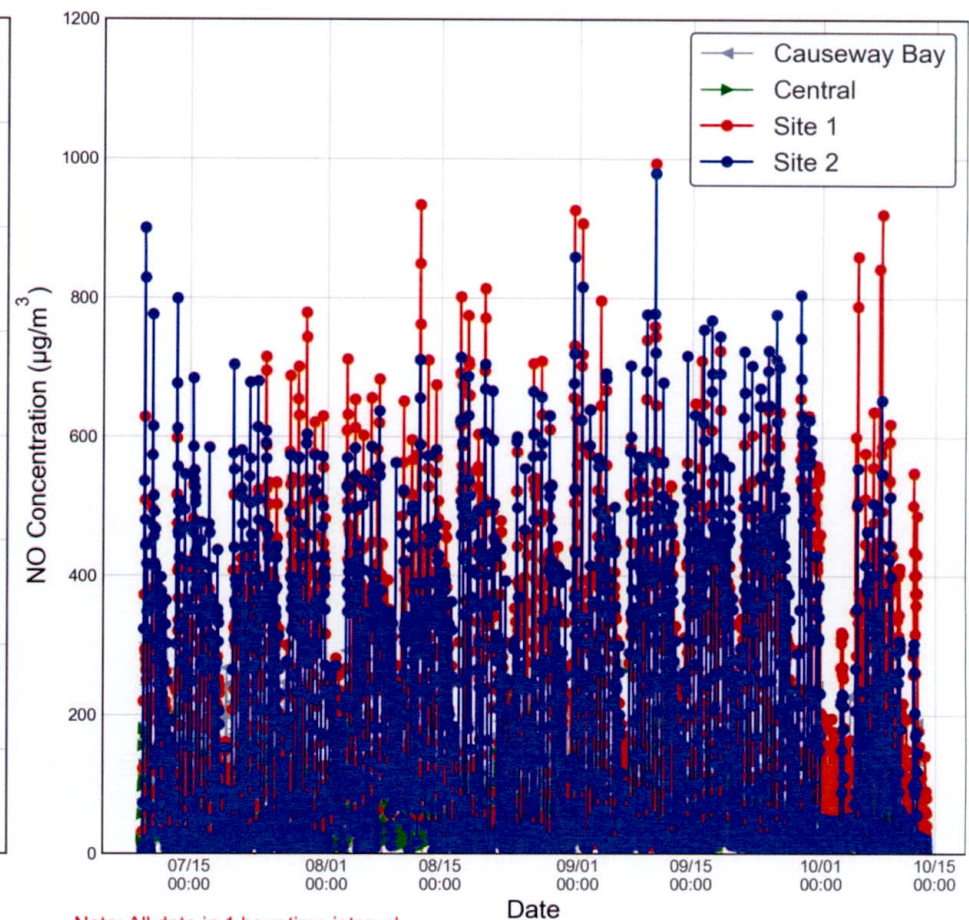
5-min average NO₂ concentration is below the 5-min concentration limit in the Practice Note on Control of Air Pollution in Vehicle Tunnels.

Site 1 Tunnel and Site 2 Portal

- **Site1:**2020/07/09 04:00 - 2020/10/13 23:59
- **Site2:**2020/07/09 04:00 - 2020/10/13 23:59



Note: All data in 1 hour time interval

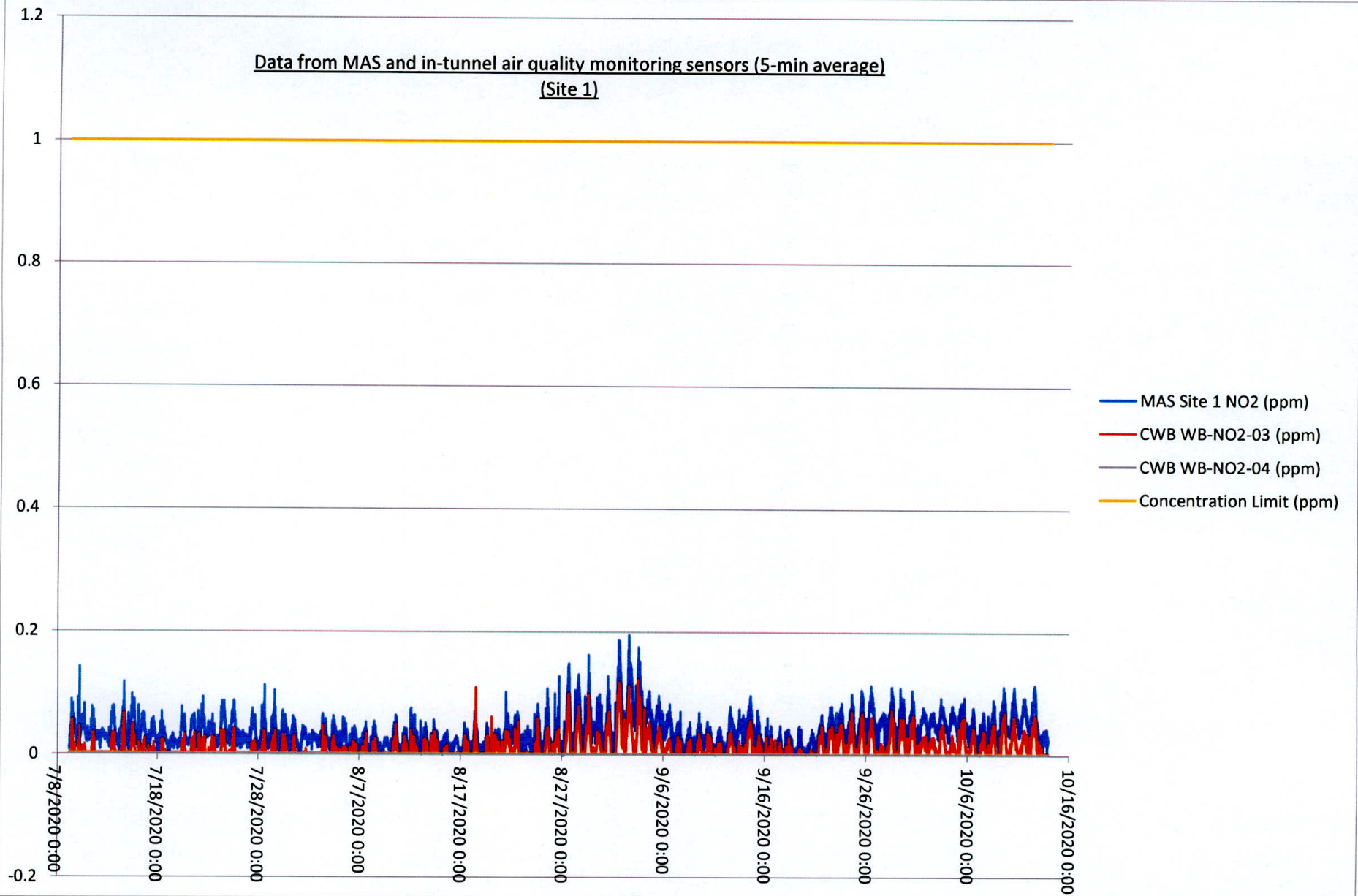


Note: All data in 1 hour time interval

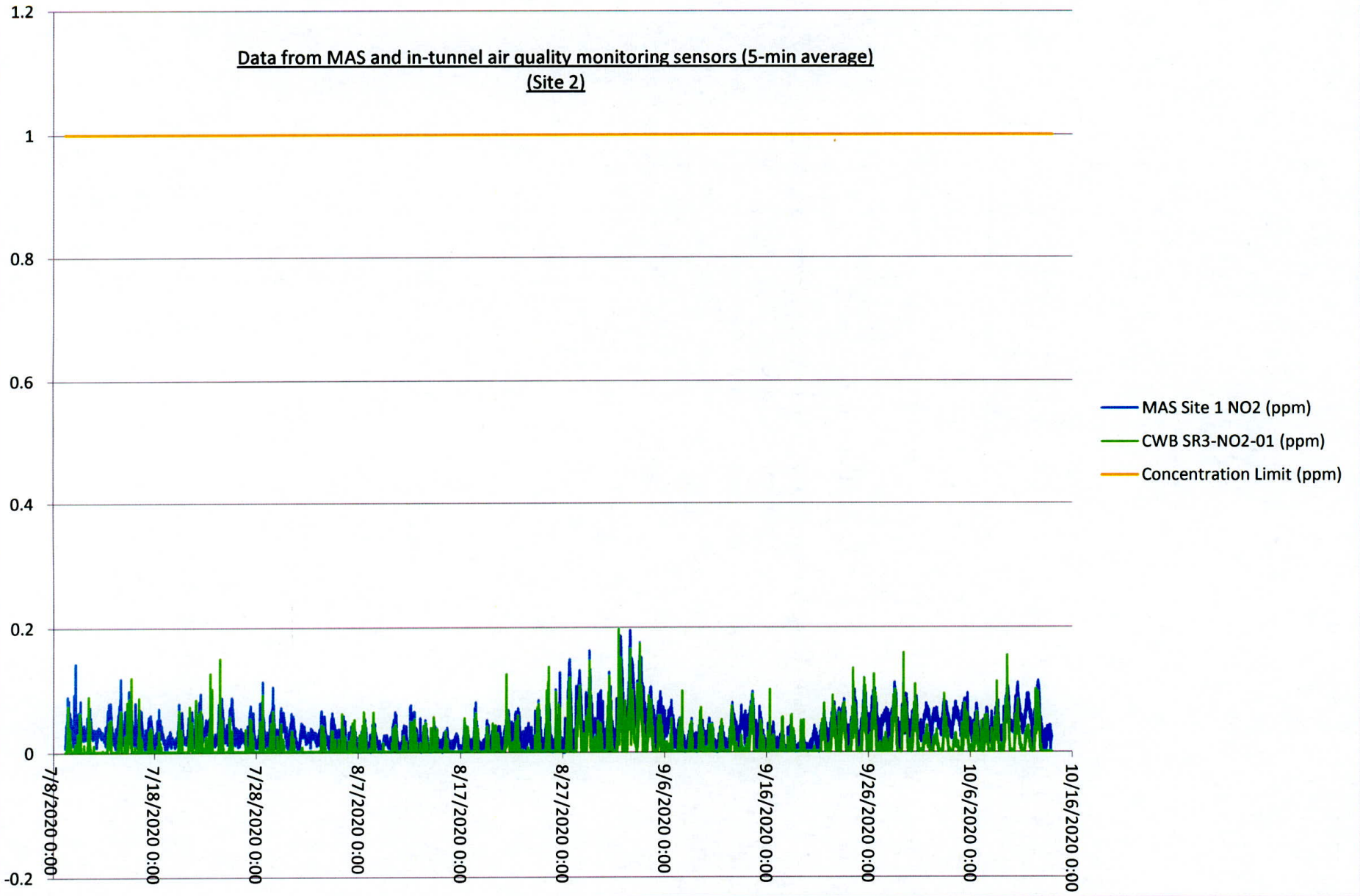
Appendix 5

In-tunnel Air Quality Data (NO₂) and MAS Air Quality Data

Data from MAS and in-tunnel air quality monitoring sensors (5-min average)
(Site 1)

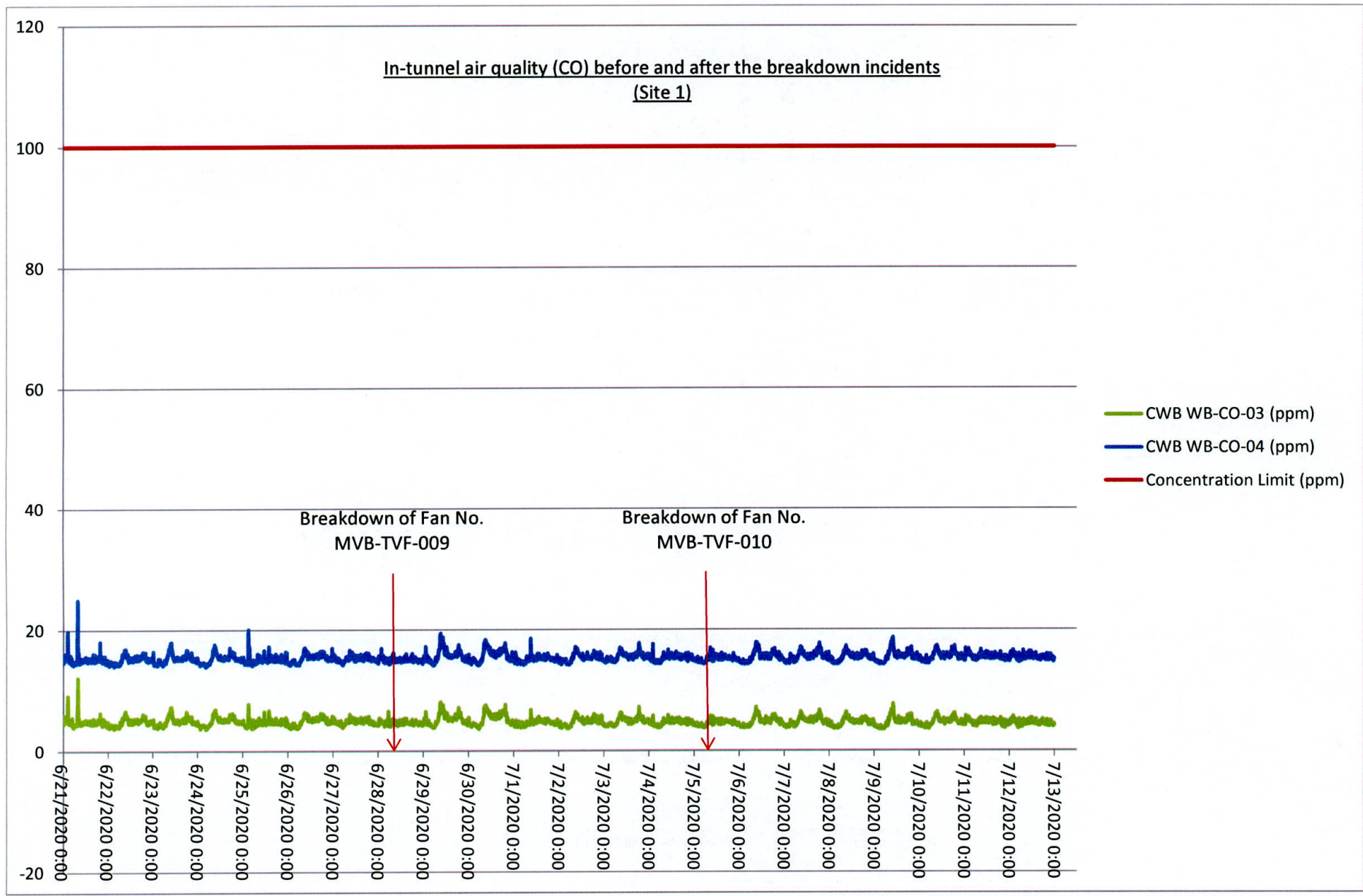


Data from MAS and in-tunnel air quality monitoring sensors (5-min average)
(Site 2)

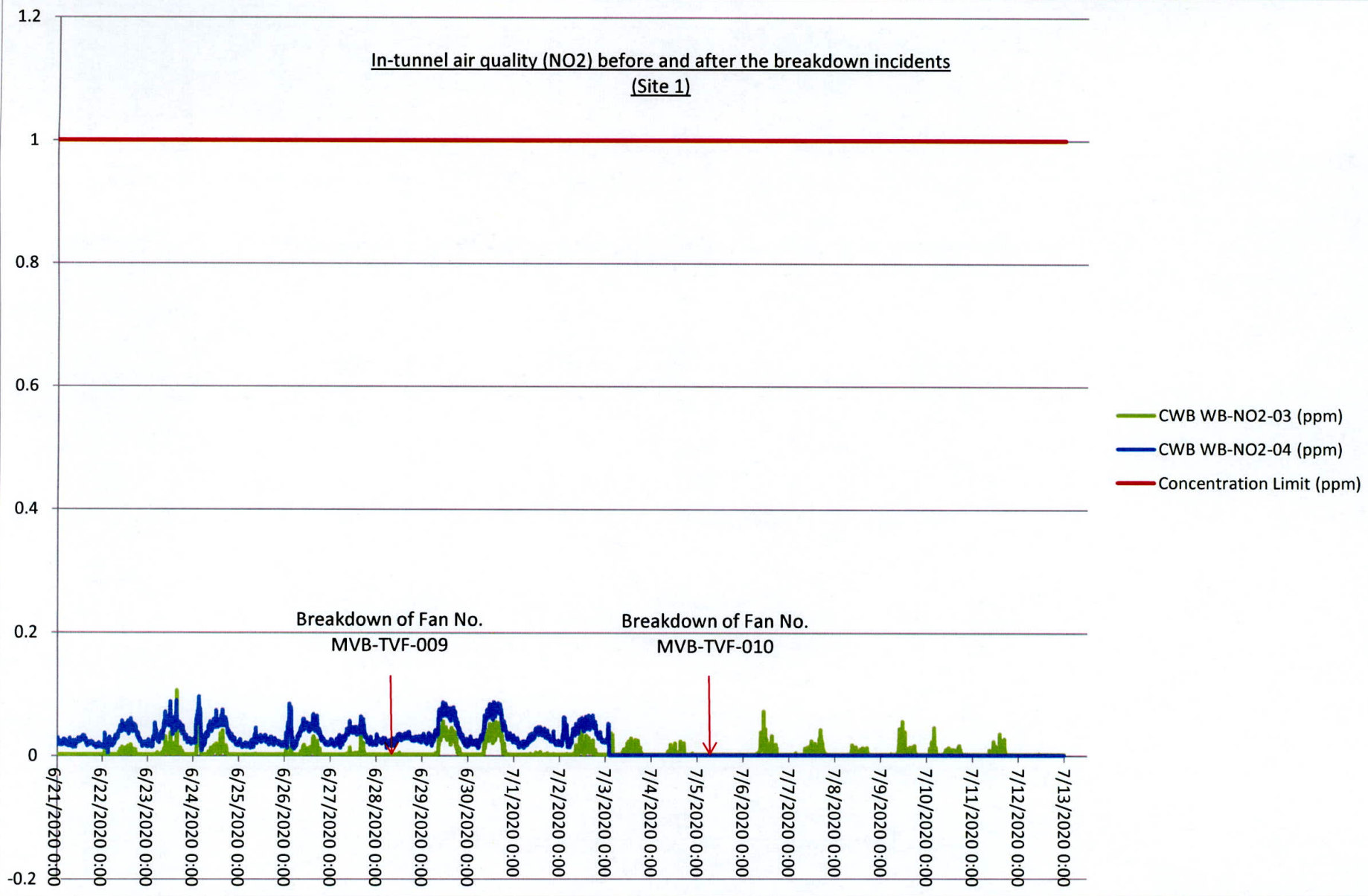


Appendix 6

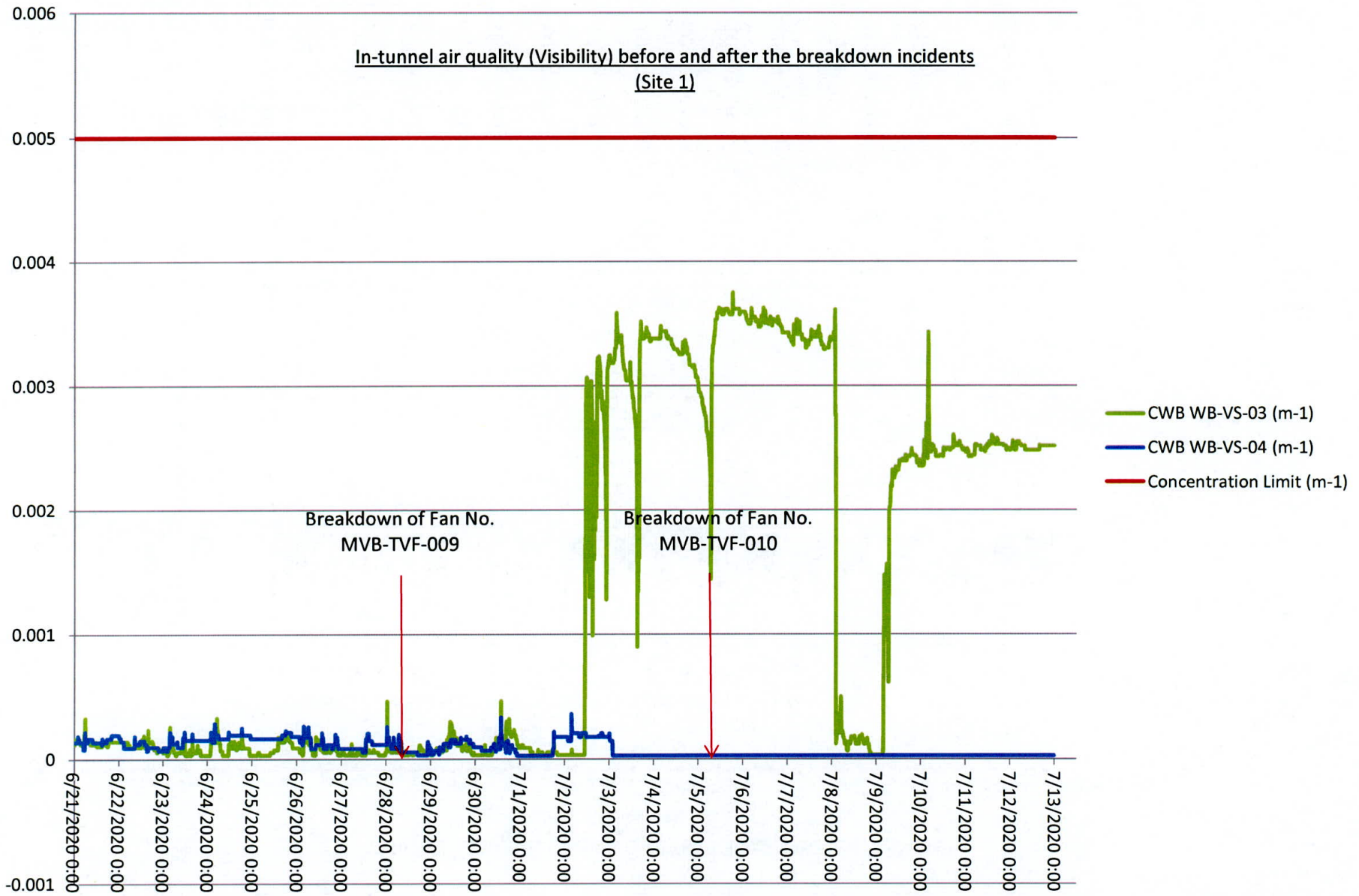
In-tunnel Air Quality Data (CO, NO₂ and Visibility) Before and After the
Breakdown Incidents

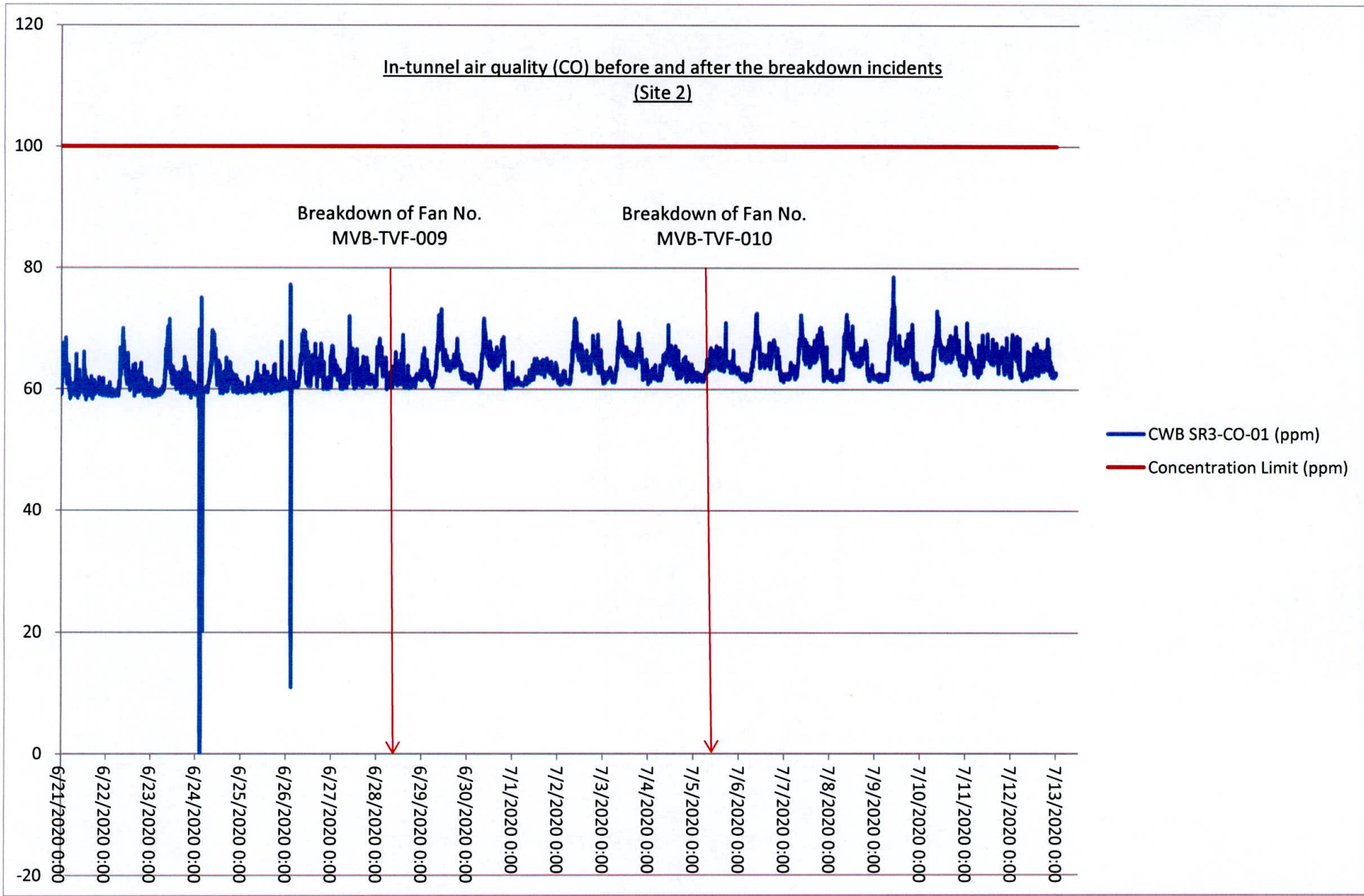


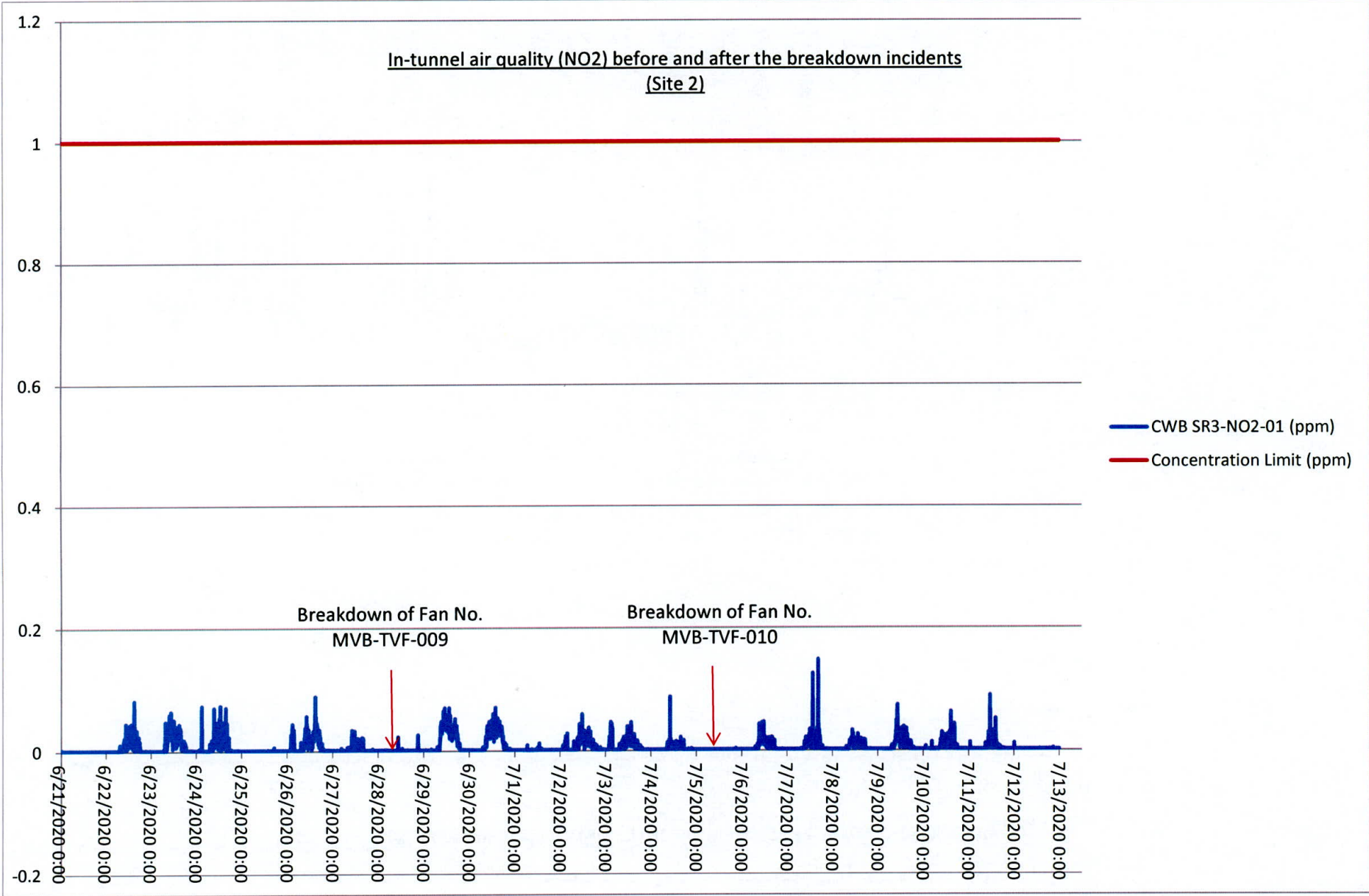
In-tunnel air quality (NO2) before and after the breakdown incidents
(Site 1)



In-tunnel air quality (Visibility) before and after the breakdown incidents
(Site 1)







In-tunnel air quality (Visibility) before and after the breakdown incidents
(Site 2)

