Commonwealth of Massachusetts

Central Artery (I-93)/ Tunnel (I-90) Project

Renewal of the Operating Certification of the Project Ventilation System

Technical Support Document

Final Report
September 12, 2016

Prepared For
Massachusetts Department of Transportation

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Table of Contents

Appendices

Appendix A MassDEP Acceptance Letters of the Previous Operating Certification Applications

Appendix A-1 MassDEP Final Acceptance of the 2006 Central Artery/Tunnel Operating Certification (December 22, 2006) – Submitted with 2011 Renewal Application

Appendix A-2 MassDEP Final Acceptance of the 2012 Central Artery/Tunnel Operating Certification (February 14, 2013)

Appendix B 2016 Air Quality Analysis Protocol for the Determination of CO, NO_x, $PM_{2.5}$ and VOC Emission Limits for 2016 Application for the Renewal of the Operating Certification for the Project Ventilation System

Appendix C Air Quality Impact Analysis Supporting Data

Appendix C-1 2016 Air Quality Analysis Supporting Data for CO, NO_x, and $PM_{2.5}$ Emission Limit Demonstration for VB

Appendix C-2 2016 Air Quality Analysis Supporting Data for CO and NO_x Emission Limit Demonstration for longitudinally ventilated ramps and DST

Appendix C-3 Air Quality Supporting Data for CO and NO_x Emission Limit Demonstration for future development of Parcels 6 and 12.

Appendix C-4 Background Monitor Data and Meteorological Data in Support of Air Quality Analyses

Appendix D 2012-2016, 1st Quarter Test Data (Audits, Calibration, Certification)

Appendix E 2012-2016, 1st Quarter CEM Data

Appendix F MassDEP-MassDOT Correspondence

Appendix F-1a MassDEP Approval of Reduction on the Number of CO Monitors, June 30, 2016

Appendix F-1b MassDOT Proposed Technical Memos Requesting the reduction in the number of CO monitors at VBs. March 20 and June 24, 2015

Appendix F-2 Emission Limits Exceedances and ELA Assessments (2006-2011, 1st quarter) – MassDOT submittal letters and MassDEP responses

Appendix F-3 MassDOT Notifications to MassDEP of CEM Equipment Issues

Appendix F-4 2016 Air Quality Analysis Protocols MassDEP approval letter

Appendix F-5 MassDEP Letter on Applicability of 310 CMR 7.38 to Sumner Tunnel Ceiling Reconstruction

Appendix F-6 Mass DOT and MassDEP Correspondence about CA/T Parcels Development Status

Appendix F-7 Mass DOT and MassDEP Correspondence about NOx Monitoring

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS AND ACRONYMS

ACO	Administrative Consent Order
AIS	Air Intake Structure
CA/T	Central Artery/Tunnel
CEM	Continuous Emissions Monitoring
CFM	Cubic Feet Per Minute
CFR	Code of Federal Regulations
CMR	Code of Massachusetts Regulations
CO	Carbon Monoxide
CTPS	Central Transportation Planning Staff
DAHS	Data Acquisition Handling System
DST	Dewey Square Tunnel
ELA	Emission Limit Assessment
EPA	US Environmental Protection Agency
FHWA	Federal Highway Administration
FSEIS/R	Final Supplemental Environmental Impact Statement/Report
g/s	Grams per Second
hp	Horsepower
HOC	Highway Operations Center
MassDEP	Massachusetts Department of Environmental Protection
MBTA	Massachusetts Bay Transportation Authority
MassDOT	Massachusetts Department of Transportation
$\mu g/m^3$	Micrograms Per Cubic Meter
MMIS	Maintenance Management Information System
MPH	Miles Per Hour
MPO	Metropolitan Planning Organization
NAAQS	National Ambient Air Quality Standard
NEMA	National Electric Manufacturers Association
NIST	National Institute of Standards and Technology
NMHC	Non-Methane Hydrocarbon
NO	Nitric Oxide
NO_2	Nitrogen Dioxide
NO_x	Nitrogen Oxide
NPC	Notice of Project Change
OLM	Ozone Limiting Method
PM	Particulate Matter
PM_{10}	Particulate Matter - 10 micron
$PM_{2.5}$	Particulate Matter – 2.5 micron
PPM	Parts Per Million
PPB	Parts Per Billion
QA/QC	Quality Assurance/Quality Control
Ramps	LC-S (Leverett Circle to Central Artery SB); SA-CN (Surface Artery to Central Artery NB); CN-S (Central Artery NB to Storrow Drive); ST-CN (Sumner Tunnel to Central Artery NB); ST-SA (Sumner Tunnel to Surface Artery); CS-SA (Central Artery SB to Surface Artery); CS-P (Central Artery to Purchase Street); F (I-90 WB to Congress Street)
SIP	State Implementation Plan
SOPs	Standard Operating Procedures
TEOM® monitor	Tapered-element oscillating microbalance sensing technology monitor
THC	Total Hydrocarbons
TSD	Technical Support Document
TWT	Ted Williams Tunnel
VB	Ventilation Building
VMT	Vehicle Miles Traveled
VOC	Volatile Organic Compound
VPH	Vehicles Per Hour

Executive Summary

The Central Artery/Tunnel (CA/T) Project depressed and widened I-93 through downtown Boston to Charlestown and constructed (as an extension of I-90) a Seaport Access Highway through South Boston connecting to the Ted Williams Tunnel (TWT) under Boston Harbor to Logan Airport. The Project included approximately 80 lane-miles of tunnels within a 7.5-mile urban corridor. Commercial traffic started flowing through the TWT in 1996, and the remainder of the Project opened to general traffic in March 2005.

The CA/T's ventilation system utilizes a mixture of full transverse and longitudinal ventilation. Most of the tunnels operate with the full-transverse ventilation system in which fresh air enters the tunnels under the roadway and the exhaust air exits through openings in the tunnel ceilings to plenums located above the ceiling. The ventilation fans and auxiliary equipment that provide fresh air and exhaust air are located in six ventilation buildings (VB) designated as VB1, VB3, VB4, VB5, VB6, and VB7. The portion of I-93 called the Dewey Square Tunnel (DST) and eight exit ramps are longitudinally ventilated. In the longitudinally ventilated tunnels, exhaust air moves in the direction of the traffic flow and it is exhausted through the exit portals. Some longitudinally ventilated tunnels include supply air and/or jet fans mounted in the tunnel ceilings or walls. Two additional VBs provide fresh air to two longitudinally ventilated tunnel sections (VB8, and the DST Air Intake Structure (AIS)).

MASSDEP REGULATION 310 CMR 7.38, AND ITS FIVE-YEAR RENEWAL REQUIREMENTS FOR THE OPERATING CERTIFICATION

The CA/T Project's tunnel ventilation system is subject to the regulations set forth by the Massachusetts Department of Environmental Protection (MassDEP) in the Code of Massachusetts Regulations (CMR) at 310 CMR 7.38 entitled "Certification of Tunnel Ventilation Systems in the Metropolitan Boston Air Pollution Control District." Pursuant to 310 CMR 7.38(2), no person shall construct a tunnel ventilation system and project roadway subject to 310 CMR 7.00 without first certifying to MassDEP (and receiving MassDEP written acceptance of that certification) that the operation of any tunnel ventilation system, project roadway, and roadway networks will not cause or exacerbate a violation of certain specified ambient air quality standards, guidelines, and other criteria specified in 310 CMR 7.38.

In compliance with MassDEP Regulation 310 CMR 7.38, the CA/T Project submitted to MassDEP in 2006 an Operating Certification Application for the CA/T Tunnel Ventilation System, which established emission limits for all VBs, the DST, and each longitudinally ventilated exit ramp. The 2006 Operating Certification Application established tunnel emission limits for carbon monoxide (CO), nitrogen oxides (NO_x) and particulate matter equal to or smaller than 10 microns in diameter (PM_{10}). It demonstrated that these emission limits would ensure compliance with National and State Ambient Air Quality Standards (NAAQS) for CO, nitrogen dioxide (NO_2), and PM_{10} and MassDEP guideline values for NO_2. It also established a regional emissions budget for volatile organic compounds (VOC) based on the 2005 CA/T build predictions, which included highway and transit components. MassDEP gave final acceptance to the 2006 CA/T Operating Certification on December 22, 2006 (hereafter referred to as the 2006 CA/T Operating Certification).

On July 1, 2011, MassDOT submitted to MassDEP the Renewal Application for the Operating Certification for the CA/T Tunnel Ventilation System. The renewal application included an air quality compliance demonstration, summaries of air quality and traffic monitoring data, a review of feasible emission control technologies, and updates since the 2006 submittal. The Final document (hereafter referred to as the 2011 CA/T Renewal Operating Certification), which addressed all MassDEP comments, was submitted on September 30, 2011.

The 2011 CA/T Renewal Operating Certification included new emission limits for particulate matter equal to or smaller than 2.5 microns in diameter ($PM_{2.5}$) and demonstrated compliance with the new $PM_{2.5}$ NAAQS. The new $PM_{2.5}$ emission limits replaced the PM_{10} emission limits established as part of the original operation certification approved in 2006. It also demonstrated that the VOC regional emissions for 2010 were below the VOC budget based on the 2005 CA/T build predictions, which included highway and transit components. In addition, it requested to submit a supplemental application to MassDEP on July 1, 2012 to establish revised emission limits for CO and NOx, which are needed to demonstrate compliance with the new 1-hour NAAQS for NO_2.

MassDEP approved the two-part renewal certification approach on May 12, 2011. The need for the two-part certification approach was driven by the US Environmental Protection Agency (EPA) adoption of a new and more stringent one-hour NAAQS for NO_2 effective April 12, 2010. The supplemental application allowed MassDOT to collect a full year of nitric oxide (NO), NO_2 and NO_x data at the DST portal and at the Albany Street sidewalk locations. The purpose of this monitoring was to develop a method for estimating new emission limits for NO_x at all ventilation buildings and longitudinally ventilated tunnels and ramps.

The site-specific monitoring-based methodology replaced the ozone limiting method (OLM) used to demonstrate compliance with MassDEP one-hour NO_2 Policy Guideline. The OLM technique assumes the instantaneous conversion of emitted NO to NO_2 and, in addition, allows this conversion process to continue as long as ambient ozone (O_3) is available in the atmosphere. MassDEP and MassDOT concurred that actual short-distance conversion rates were likely lower, and that a site-specific monitoring-based approach was a more appropriate method to establish the new emission limits for NO_x.

Since NO_x levels were estimated as a function of in-tunnel CO levels in the original 2006 CA/T Operating Certification, the analysis of one full year of NO, NO_2, NO_x and CO data at the DST was used to determine a more appropriate CO-NO_x correlation. Additionally, new emission limits for CO were also established in this supplemental application.

ACCEPTANCE OF 2011/12 CA/T RENEWAL OPERATING CERTIFICATION

MassDOT submitted the Final Supplemental Application for the CA/T Renewal Operating Certification on August 1, 2012.

MassDEP issued a Final acceptance of the 2012 CA/T Renewal Operating Certification Application submitted August 1, 2012 in its letter dated February 14, 2013. The acceptance includes a list of specific requirements and covers the remainder four year operating period from December 19, 2012 to December 19, 2016.

2016 CA/T RENEWAL OPERATING CERTIFICATION

This renewal application covers the five-year period from December 20, 2016 through December 19, 2021.

For consistency, this 2016 document follows the format of the 2011/12 CA/T Renewal Operating Certification TSD, retaining the aspects that remain unchanged and replacing or adding information, as needed. It incorporates new changes, updates the CO, NOx and $PM_{2.5}$ emission limits with their corresponding compliance requirements, and provides updates to the summaries of data collected since 2012. As such, this 2016 TSD document provides most of the information included in the 2012 TSD and all the necessary updates, which form part of this application.

Information contained in the versions prior to the 2011/12 TSD is NOT repeated in this document unless necessary to provide context and/or inputs for the emission limits compliance demonstration. As an example of prior information not repeated here is the detail of Ramps F, L-CS, SA-CN, ST-CN, and ST-SA, which were eliminated from the CEM requirements in the 2012 Submittal approved by MassDEP in February 2013.

The 2016 CA/T Renewal Operating Certification included a Technical Support Document (TSD) divided into four parts:

- Part I – Ventilation System – Operation and Determination of Emission Limits
- Part II – Compliance Monitoring Program
- Part III – Record Keeping and Reporting
- Part IV – Corrective Actions

The 2016 TSD also included several appendices and attachments:

- Appendix A: MassDEP Certification Acceptance Letters (2006 and 2011/12)
- Appendix B: Air Quality Analysis Protocol for Determination of Emission Limits as Part of the Operating Certification of the Project Ventilation Systems
- Appendix C: Air Quality 2016 Impact Analysis Supporting Modeling Data (VBs, DST, Ramps, Development of Parcels 6 & 12)
- Appendix D: CEM 2012-2016 Certification Test Data
- Appendix E: CEM 2012-2016 Data
- Appendix F: MassDEP Correspondence (2012 Certification approval, reduction of number of CO monitors, ELA assessments, AQ Protocol approval letters and other important correspondence)
- Appendix G: Monitoring Equipment Standard Operating Procedures (SOPs); and
- Appendix H: Summary of Findings of DST NOx-NO_2 2011-13 Monitoring Program
- Attachment 1: CEM 2016 Air Emissions Monitoring Protocol

TSD Part I describes in detail the CA/T's ventilation system, and the air quality emission limits established for the exhaust from the ventilation buildings and the longitudinally ventilated tunnel sections (DST and three exit ramps). Emission limits established for the 2011/12-2016 operating certification period apply to day-to-day tunnel operation, except for emergency situations during a tunnel fire. The limits for CO, NO_x and $PM_{2.5}$ were determined as concentration-based emission limits (i.e., measured levels in parts per million [ppm] or micrograms per cubic meter [$\mu g/m^3$] inside the tunnels).

Section 1 of TSD Part I covers the description of the CA/T ventilation system, its physical properties, feasible emission control technologies, and expected operating conditions. Ventilation building emissions control technology reviews were performed in 1991, 1995, 2004, 2011, and are updated in this document. An extensive investigation, conducted as part of these reviews revealed that ventilation was the predominant method of tunnel (inside and outside) air quality control employed in the United States and around the world. All reviews concluded that there are no feasible and effective control techniques available that would result in a net reduction of the tunnel exhaust emissions.

The emissions data collected inside the CA/T tunnel indicate that safe in-tunnel air quality levels were maintained during the past ten years. The results of the monitoring program and corrective actions, indicated that despite a very few instances between 2006 and 2016 when abnormal conditions resulted in measured concentrations exceeding the established emission limits, ambient pollutant levels outside the tunnels have been well below the applicable NAAQS and MassDEP One Hour NO_2 Policy Guideline.

Section 2 of TSD Part I – Determination of Emission Limits – includes the procedures for determining the revised emission limits for CO, NOx, $PM_{2.5}$, and compliance with regional emission budget for VOC.

Section 2 updates the compliance demonstration following the same technical modeling approach used in the 2012 TSD to determine in-tunnel NOx levels as a function of CO levels, and the NO to NO_2 conversion factors based on the 2011-2012 results of the DST Monitoring Program.

This section also provides a summary of the 2011-12 monitoring program that collected one year of CO, NO_x, NO, and NO_2 data inside the DST exit portal and along the Albany Street sidewalk locations. It describes how data gathered from the Albany Street monitoring program were used to develop more accurate NO to NO_2 conversion factors for the new NO_x emission limits to ensure compliance with the new 1-hour NO_2 NAAQS.

The compliance modeling analysis for the ventilation buildings described in this section incorporates the most current background levels, 2012-2015 meteorological data, and receptor locations based on current buildings configuration in each VB surrounding area.

The VB emission impacts were evaluated using the AERMOD analytical model. The maximum predicted emission impacts, when added to the appropriate background pollutant concentrations were compared to the applicable NAAQS and MassDEP policy guideline value for compliance assessment. The entire modeling process was repeated until the maximum allowable emission limits at which ambient standards can still be attained were found. The detailed modeling procedures to determine VB emission impacts and emission limits can be found in section 2.7.1.

The air quality dispersion modeling analyses to determine the emission limits for DST and the three longitudinally ventilated ramps (CN-S, CS-SA and CSP) are based on the dilution coefficients obtained through the 1996 physical simulation study for the longitudinally ventilated ramps and through the 2005 DST physical simulation study described in section 2.7.2. The DST configuration analyzed is based on Scenario #2 which includes development of Parcel 24 building, which is already built. The same NO to NO_2 conversion factors based on the 2011-2012 results of the DST Monitoring Program are applied to both the VB, DST and ramps evaluation process.

This section also includes an evaluation of the future emission limits related to the ongoing MEPA process for the creation of additional parkland features over Parcels 6 and 12, which will cover ramps ST-SA/CN and CS-SA/CN-SA.

Since the 1996 wind tunnel tests did not consider these future parkland scenarios, the analytical modeling of the portal areas of ramps ST-SA and CS-SA was conducted using the AERMOD model, applying a portal jet approach methodology previously applied in the modeling of the DST and other portal impacts in the EIS stage of the CA/T project. The portal area receptor concentrations were estimated from the emissions generated by vehicles traveling inside the tunnel and later pushed and dragged out of the exit portal(s) in the wake of the moving cars. Emission rates carried out from the ramp portals were simulated as area sources and increased by increments to establish emission limit for each ramp. Emission limits for the ramps were established based on the same principles described in section 2.7.2, and are described in detail in section 2.7.3.

Table ES-1 provides the CO and NO_x revised emission limits presented in this document. These emission limits will come into effect in December 2016 and will be valid till 2021.

Section 2 updates the $PM_{2.5}$ compliance demonstration for the VBs following the technical modeling approach used in the 2011 TSD, and explained in more detail in section 2.6, with the incorporation of the most current background levels from MassDEP monitoring stations, the 2012-2015 local meteorological data, and receptor locations based on current buildings configuration in each VB surrounding area. The results of this analysis indicate that a revised $PM_{2.5}$ emission limit of 550 µg/m^3 demonstrates compliance with the current $PM_{2.5}$ annual and 24-hour NAAQS. The annual NAAQS was lowered from 15 µg/m$_3$ to 12 µg/m$_3$ in 2014, which resulted in lowering the $PM_{2.5}$ emission limits to the current value. Table EX-1 below also provides the updated $PM_{2.5}$ emission limits.

TABLE ES-1: SUMMARY OF EMISSION LIMITS FOR 2016 TO 2021 PERIOD

Location*	1-Hour CO Emission Limit (ppm)	8-Hour CO Emission Limit (ppm)	1-Hour NO_X Emission Limit (ppm)	24-Hour $PM_{2.5}$ Emission Limit (µg/m^3)
VB 1	70	70	6.1	550
VB 3	70	70	6.1	550
VB 4	70	70	6.1	550
VB 5	70	70	6.1	550
VB 6	70	70	6.1	550
VB 7	70	70	6.1	550
Ramp CN-S	35	59	3.2	NA
Ramp CS-SA**	35	54	3.2	35***
Ramp CS-P	35	70	3.2	NA
Dewey Sq. Tunnel	22	24	2.1	NA

Notes: Acronyms are defined as: Central Artery Northbound to Storrow Drive (C-NS), Central Artery Southbound to Surface Artery (CS-SA), Central Artery Southbound to Purchase Street (CS-P), part per million (ppm), microgram per cubic meter (µg/m^3).

* For each ventilation building, location includes all associated ventilation zones.

** The ambient $PM_{2.5}$ monitor is located outside ramp CS-SA.

*** Compliance with the 24-hour $PM_{2.5}$ NAAQS is based on the monitoring design value, which is given by the 3-year average of the annual 98th percentile value of daily average concentrations. The form of the standard allows, on average, for the numerical value of the standard (35 µg/m3) to be exceeded on seven calendar days per calendar year without triggering a violation of the NAAQS.

Lastly, Section 2 provides a summary of the VOC regional analysis. The 2012 Operating Certification demonstrated that the VOC regional emissions for 2010 were approximate 35% below the VOC budget based on the 2005 CA/T Build Alternative predictions, which included highway and transit components. Based on the significant decreases in VOC motor vehicle emissions and the current O_3 attainment status of the Boston Metro area the 2016 CA/T renewal certification presents a simplified approach to estimate the reductions in the regional VOC levels. This approach uses MOVES 2014a (EPA s' Motor Vehicle Emission Simulator) VOC emission factors and anticipated traffic increases based on current traffic growth factors.

The result of the 2016 VOC regional emissions approach (described in section 2.7.4) indicated that VOC emissions for the CA/T area would be in the range of 2,000 kg/day, which is close to one third of the 2005 VOC emission budget of 6,095.9 kg/day. The reduction is attributable to fleet turnover and cleaner vehicles and fuels mandated by Federal and State regulations over the past decade.

TSD Part II describes the CA/T's compliance monitoring program, including the Continuous Emissions Monitoring (CEM) system designed, constructed, and installed to demonstrate compliance with established emission limits and used to aid the operators to maintain safe air quality and visibility within the tunnels under normal operations.

The CEM system is a hybrid type of monitoring system. The CEM system incorporates appropriate elements of federal regulations 40 CFR Part 58, 60, and 75 for the ambient air quality monitoring systems and the continuous emission monitoring at power plants. Equipment certification and operations are specifically tailored for use in the CA/T's emission monitoring program. The 2016 CA/T Renewal Operating Certification TSD Attachment 1 (CEM Air Emissions Monitoring Protocol) provides specific information regarding CEM equipment that has been installed and/or revised for the 2016-2021 operating certification at each VB and longitudinally ventilated exit ramp as well as the operational protocol for the CEM equipment.

MassDOT monitors vehicular emissions of CO in the exhaust plenum of each ventilation building prior to discharge up and out the building stacks, and at the exit portal of DST and some longitudinally ventilated exit ramps. MassDOT monitors $PM_{2.5}$ emissions at four representative in-tunnel locations with the highest $PM_{2.5}$ levels and ambient levels the vicinity of Ramp CS-SA. Starting in 2017, a NO_x monitor will measure hourly levels inside the DST (I-93 portal).

TSD Part III describes the record keeping and reporting aspects of the CA/T's Operating Certification, MassDOT process to record CO and $PM_{2.5}$ data continuously at each CEM location and the procedures to download data to a central computer location. MassDOT reviewed the data and generated daily data summaries for each month. Using the daily summaries, MassDOT developed NO_x emission concentrations using a Project-specific CO to NO_x conversion ratio based on the statistical analysis of several thousand hours of monitored data for both pollutants. The conversion equation is based on data collected at the DST during the April 2011-March 2012 monitoring program.

In March 2016, peak hour traffic volumes in vehicles per hour (VPH) using the mainline tunnels were generally in the range of 5,830 to 7,540 VPH in each direction of I-93 and in the range of 3,320 to 3,380 VPH in each direction of the TWT. The average daily volumes were in the range of 83,300 to 102,700 vehicles per day (VPD) in each direction of I-93 and in the range of 41,400 to 42,600 VPD in each direction of the TWT. These traffic levels are still below the 2010 project design projections published in the 1990 FSEIS/R.

The tunnel full transverse ventilation system currently operates at Step 1 (13% of exhaust capacity) for off-peak and Step 3 (32% of exhaust capacity) under peak traffic conditions.

The 2012-2016 (1st quarter) data presented in Section 5 of TSD Part III indicate that measured hourly CO concentrations for the ventilation buildings range from 0.6 to 4.0 ppm on average and as high as 33.6 ppm during peak periods for the ventilation buildings. For the DST and ramps, hourly CO concentrations were in the range of 1.7 to 4.3 ppm on average with maximum levels in the range of 17.9 to 38.5 ppm.

Measured hourly NO_x levels from the ventilation buildings ranged from 0.3 to 0.5 ppm on average with peak values ranging from 1.1 to 3.1 ppm. Measured hourly NO_x levels for the DST and Ramps ranged from 0.4 to 0.6 ppm on average with peaks ranging from 1.8 to 3.5 ppm.

Measured average daily $PM_{2.5}$ concentrations between 2012 and 2016 were between 19 and 39 $\mu g/m^3$, Maximum daily PM_{10} values were in the range of 163 to 414 $\mu g/m^3$. The PM_{10} monitor outside Ramp CS-SA, which measures ambient levels, recorded between 2012 and 2016 annual averages from 9 to 11.4 $\mu g/m^3$, and a maximum 24-hour daily level of 33.5 $\mu g/m^3$.

TSD Part IV describes the procedures and actions that MassDOT implemented in the event of an exceedance of the established emissions limits due to non-emergency traffic conditions. Part IV also describes the notification process; including MassDOT written notification to MassDEP for emission limits exceedances and actions undertaken by MassDOT to restore compliance with limits.

To help ensure compliance with the emission limits at any location, MassDOT established CEM emission action levels generally in the range of 75% to 80% of the emission limit for each of the monitoring locations. Based on operating experience, MassDOT can effectively maintain acceptable in-tunnel CO concentrations by small, step-by-step increases in the ventilation rate.

Based on the Project's abundant ventilation capacity and well-established procedures, the operation of the system has worked well within the established emission limits. Therefore, specific information regarding a long-term mitigation plan was not included as part of the 2006 Operating Certification, 2011 CA/T Renewal Operating Certification, and will not be provided for the 2016-2021 Operating Certification period.

There were four episodes during the period from the beginning of 2012 through the end of the first quarter of 2016 when emission limits were exceeded. These episodes resulted in a total of 7 hours when CO measured levels at the DST exceeded the corresponding emission limit of 23 ppm hourly CO. For these four cases when CO limits were exceeded, the main reasons were emissions from maintenance equipment during nighttime tunnel closing,

Nighttime maintenance activities in the vicinity of the CEM sample probes has been shown to be the primary factor in the majority of CO exceedances from the DST at the times when the system was operating at Step 1. MassDOT in October 2012 initiated a project to use the integrated project control system (IPCS) of the CA/T to raise fan speed to Step 3 upon alarm inputs automatically not only at the DST, but also at the upstream I-93 SB sections of the tunnel. This operational correction resulted in almost three years without any emission limit exceedance proving its effectiveness. A July 2015 exceedance was a result of a temporary mechanical control repair at Air Intake Structure (AIS), which precluded the fans from going above Step 1.

To put these events in perspective, CO concentrations were measured every hour at 24 VB exhaust locations and at five locations in the DST and ramps over the last four calendar years (2012-2015) and during the first quarter of 2016, yielding approximately 1.1 million observations. The 7 hours for which a CO emission limit was exceeded represent an exceedingly infrequent occurrence and shows that the ventilation system nearly always was in compliance with its CO emission limits. Over 99.99% of the hourly CO concentration measurements showed compliance with CO emission limits, and the 7 hours when CO emission limits were exceeded represent only about 0.00009% of the hours during this period.

None of the episodes when an emission limit was exceeded resulted in a violation of the applicable NAAQS or MassDEP NO_2 Policy guideline. The results of each emission limit assessment (ELA) modeling indicated that the maximum predicted ambient concentrations were usually 50% or less of the applicable NAAQS for CO, and less than 70% for NO_2. This shows that the emission limits were established with a considerable margin of safety with regard to the health-related NAAQS, due to the very conservative worst-case assumptions that went into analysis.

There were no exceedances of the new $PM_{2.5}$ emission limit established in 2011.

MassDOT Request to Reduce the Number of CO CEM Monitors at VBs

The full transverse ventilation system includes six ventilation buildings serving 24 ventilation zones with their corresponding supply and exhaust fans. Currently there are 25 CO monitors in operation: one in each ventilation zone, and one at the VB7 air intake. All 24 zones have a CO emission limit of 70 PPM, and a CO action level of 60 PPM.

The tunnel full transverse ventilation system currently operates at Step 1 (13% of exhaust capacity) for off-peak and step 3 (32% of exhaust capacity) for peak traffic conditions. The two million plus hourly CO levels measured during nine years at the 24 VB zones ranged from 0.5 to 10.1 ppm on average, and reached the highest level of 34.4 ppm at VB7, which is below 50% of the emission limit. During the nine years of operation, no full transverse ventilation zone approached the action level.

This request seeks to reduce the number of CO monitoring locations to one per VB, except for VB7, which will have two monitors as part of this 2016 renewal of the Operating Certification. MassDOT will achieve the objective of 310 CMR 7.38 by maintaining the CEM program, and reporting compliance with CO emission limits at each VB by monitoring ventilation zones with the historically highest CO levels.

The reduction in the total number of CO monitors from 25 to seven will allow MassDOT to better maintain the current CO monitors by using the monitors removed from service for spare parts and thus extending the their useful life in the CEM system, and make more feasible a full upgrade in the future.

During March 2015 MassDEP recommended selecting the highest zones by looking at the highest 5% and 10% of hourly data for each zone. The analysis and resulting selection of the seven ventilation zones is presented in section 5.6.

MassDEP concurred with this proposal to reduce the number of CO monitors from 25 today to 7 in the next certification period from 2016 to 2021 in the MassDEP letter dated June 30, 2015 (presented in Appendix F).

The CO monitors at Dewey Square Tunnel (I-93 and I-90 collector) and three longitudinally ventilated ramps (CN-S, CS-SA and CS-P) will continue in accordance with the current CEM program. There will be 12 CO monitors in the CEM system from 2017.

The four $PM_{2.5}$ monitors installed in three VBs, and outside Ramp CS-SA will continue their operation in the 2016-2021 period. In addition, a NO_x monitor inside the DST I-93 longitudinally ventilated ramp will be installed and will start operating in the 2016-2021 certification period.

Introduction

In compliance with MassDEP Regulation 310 CMR 7.38, the CA/T Project filed an application for Operating Certification for the Project's Tunnel Ventilation System during 2006 in which it established emission limits for the exhaust of each Ventilation Building, Dewey Square tunnel, and longitudinally ventilated exit ramps. The 2006 Operating Certification established tunnel emission limits for CO, NO_x and PM_{10} that allowed the tunnel ventilation system to demonstrate compliance with ambient air quality standards for CO, NO_2, and PM_{10} and Massachusetts one-hour Policy Guideline for NO_2. It also established that the CA/T Project was within the regional emissions budget for volatile organic compounds based on the 2005 CA/T build predictions, which included highway and transit components. The 2006 Operating Certification also included: a compliance monitoring program for CO and $PM_{10,}$ record keeping and reporting requirements and procedures, and corrective actions that would be required if any of the established emission limits were exceeded. MassDEP gave final acceptance to the 2006 CA/T Operating Certification in December 22, 2006.

MassDEP Regulation 310 CMR 7.38 requires MassDOT to renew the Operating Certification every five years. On July 1, 2011, MassDOT submitted to MassDEP the Renewal Application for the Operating Certification for the CA/T Tunnel Ventilation System.

The 2011 CA/T Renewal Operating Certification included new emission limits for particulate matter equal to or smaller than 2.5 microns in diameter ($PM_{2.5}$) and demonstrated compliance with the new 2006 $PM_{2.5}$ NAAQS. The new $PM_{2.5}$ emission limits replaced the PM_{10} emission limits established as part of the original operation certification approved in 2006. It also demonstrated that the VOC regional emissions for 2010 were below the VOC budget based on the 2005 CA/T build predictions, which included highway and transit components. In addition, it requested to submit a supplemental application to MassDEP on July 1, 2012 to establish revised emission limits for CO and NOx.

The need for the two-part certification approach (2011/12) was driven by the US EPA adoption of a new and more stringent one-hour NAAQS for NO_2 effective April 12, 2010. The delayed supplemental application allowed MassDOT to collect a full year of NO, NO_2 and NO_x data at the DST portal and at the Albany Street sidewalk locations. The purpose of this monitoring was to develop a data based method for estimating new emission limits for NO_x at all ventilation buildings and longitudinally ventilated tunnels and ramps. MassDEP and MassDOT concurred that a monitoring-based approach was a more appropriate method to establish the new emission limits for NO_x.

Since NO_x levels were estimated as a function of in-tunnel CO levels in the 2006 CA/T Operating Certification, the analysis of one full year of NO, NO_2, NO_x and CO data at the DST was also used to determine a more appropriate CO-NOx correlation that reflected emissions of the motor-vehicle fleet in Massachusetts during the 2012 CA/T Renewal time frame.

MassDOT submitted the Final Supplemental Application for the CA/T Renewal Operating Certification on August 1, 2012.

MassDEP issued a Final acceptance of the 2012 CA/T Renewal Operating Certification Application submitted August 1, 2012 on its letter dated February 14, 2013. The acceptance includes a list of specific requirements described in the February 14, 2013 MassDEP letter, and covers the remainder four year operating period from December 19, 2012 to December 19, 2016.

This renewal application covers the five-year period from the date of MassDEP approval of the 2016 application through December 19, 2021.

For consistency, this application follows the format of the 2011/12 CA/T Renewal Operating Certification TSD, retaining the aspects that remain unchanged and replacing or adding information, as needed, to incorporate new compliance requirements and to update summaries of data collected since 2012. As such, this 2016 TSD document provides most of the information included in the 2012 TSD plus all the necessary updates, which form part of this application.

Information contained in the versions prior to the 2012 Approved TSD is NOT repeated in this document, unless necessary to provide context and/or inputs for the emission limits compliance demonstration. As an example of prior information not repeated here is the elimination of Ramps F, L-CS, SA-CN, ST-CN, and ST-SA from the CEM requirements in the 2012 Submittal, approved by MassDEP in February 2013.

The appendices that appear in this 2016 CA/T Renewal Operating Certification are included as supplements to the electronic files.

Following the same format as the 2012 CA/T Renewal Operating Certification TSD, this document is divided into four parts and several appendices:

- Part I – Ventilation System – Operation and Emission Limits
- Part II – Compliance Monitoring Program
- Part III – Record Keeping and Reporting of 2012-2016 operating levels
- Part IV – Corrective Actions – Procedures implemented during 2012-2016 operations

And several Appendices:

- Appendix A: MassDEP Certification Acceptance Letters (2006 and 2011/12)
- Appendix B: Air Quality Analysis Protocol for Determination of Emission Limits as Part of the Operating Certification of the Project Ventilation Systems
- Appendix C: Air Quality 2016 Impact Analysis Supporting Modeling Data (VBs, DST, Ramps, Development of Parcels 6 & 12)
- Appendix D: CEM 2012-2016 Certification Test Data
- Appendix E: CEM 2012-2016 Data
- Appendix F: MassDEP Correspondence (2012 Certification approval, reduction of number of CO monitors, ELA assessments, AQ Protocol approval letters and other important correspondence)
- Appendix G: Monitoring Equipment Standard Operating Procedures (SOPs); and
- Appendix H: Summary of Findings of DST NOx-NO_2 2011-13 Monitoring Program

Part I – Ventilation System – Operation and Emission Limits

1 DESCRIPTION OF CENTRAL ARTERY/TUNNEL PROJECT VENTILATION SYSTEMS

The Central Artery/Tunnel (CA/T) Project was designed and built to reduce traffic congestion, accidents, and air pollution in the Boston area by replacing the old elevated Central Artery with new aboveground and underground roadways. Figure 1-1 provides the physical limits indicating the above and underground portions of the Project

Approximately 80 lane miles of these new roadways are underground tunnels, including the 7,900-foot-long, four-lane Ted Williams Tunnel (TWT) under the Boston Harbor that connects East Boston to South Boston, the eight to ten lane underground Southeast Expressway (I-93), and the underground portions of the Massachusetts Turnpike (I-90). The TWT opened to commercial and other authorized vehicles on December 15, 1995, and the entire Project was fully operational in March 2005.

As described in the 2012 Renewal of the 2006 TSD of the Operating Certification, in the 1991 Project-wide Final Supplemental Environmental Impact Statement/Report (FSEIS/R), and in the Preferred Alternative in the 1994 FSEIS/R for the Charles River Crossing, the CA/T Project utilizes a full-transverse ventilation system to maintain acceptable in-tunnel air quality set forth by the Federal Highway Administration (FHWA) for motorists traveling in the tunnels.

In response to authorization from the FHWA in November 1995 regarding the use of the longitudinal ventilation system, the Massachusetts Department of Transportation (MassDOT) implemented design refinements to the Project's tunnel ventilation system by using jet fans as a potentially viable alternative for maintaining adequate ventilation. Specifically, the refinements included the replacement of the full-transverse ventilation systems with longitudinal ventilation at the Dewey Square Tunnel (DST) section of I-93 Southbound, and at eight tunnel exit ramps.

1.1 VENTILATION SYSTEM DESIGN CRITERIA

Tunnel ventilation systems servicing the CA/T Project have been designed to provide adequate ventilation capacity during both normal traffic operation and emergency/fire conditions. The urban setting of the Project also imposed significant demands on the tunnel ventilation system design and its allowable impact to the surrounding community. Sensitivity to land use and ambient environmental issues such as noise and air quality weighed heavily in determining the allowable size and locations of the necessary ventilation facilities. Full transverse and longitudinal type ventilation systems were therefore utilized to meet the functional demand of the various road tunnel configurations and the local environmental challenges in the most cost effective and efficient manner.

The design followed the FHWA-Environmental Protection Agency (EPA) in-tunnel air quality criteria, which were established, based on time exposure of the motorists traveling inside the tunnel. Based on these criteria the tunnel operator is required to maintain CO levels below 120 part per million, when the time exposure does not exceed 15 minutes during peak rush hour traffic, 65 ppm for the exposure between 15 and 30 minutes; below 45 ppm for exposure between 30 and 45 minutes; and below 35 ppm when motorists remain inside the tunnels for 60 minutes. The two million plus hourly CO levels measured during nine years at the 24 ventilation building (VB) zones ranged from 0.5 to 10.1 ppm on average, and reached the highest level of 34.4 ppm at VB7, which is below 50% of the emission limit.

FIGURE 1-1: PHYSICAL LIMITS OF CA/T PROJECT

From a tunnel ventilation perspective, the Project was defined as three distinct and separate road tunnel "systems": the Ted Williams Tunnel, the I-90 Tunnel Extension, and the I-93 Central Artery Tunnel. Each of these tunnel systems was divided into multiple "ventilation zones." Each ventilation zone was served by a dedicated and independently controlled set of fans. This concept allowed for significant operational flexibility throughout the Project and provided the means for establishing the most efficient system operation under normal conditions and the most effective system operation in the case of a traffic incident or fire emergency.

The tunnel ventilation system was designed with a supply air capacity of 65 cubic feet per minute (cfm) per lane-foot of tunnel, and an exhaust capacity of 100 cfm per lane-foot of tunnel. The total supply capacity for the full transverse ventilation system (including all six ventilation buildings [VBs]) is approximately 11.4 million cfm serving the 22 ventilation zones. This ventilation system was designed to maintain in-tunnel CO levels between 20 and 60 ppm, and NO_x levels between 1 and 5 ppm, during normal peak hour traffic conditions. Due to advances in motor-vehicle emission control technology and the public's demand for cleaner air, new car emissions have been progressively decreasing. The CO data collected during the first 10 years of operation indicates a significant decrease in tunnel CO levels. Therefore, the CA/T Project ventilation system is expected to provide ample ventilation capacity to accommodate any potential traffic growth.

1.1.1 Full-Transverse Ventilation

In the full-transverse ventilation system, fresh air supply is introduced to the tunnels from under the roadway, and the mixture of vehicle exhaust is extracted through openings in the tunnel ceilings to plenums located above the ceiling before being diverted up through the VB's exhaust stacks. Figure 1-2 provides a schematic of the full transverse ventilation system.

1.1.1.1 System Description

The full transverse ventilation system includes six ventilation buildings (VB1, VB3, VB4, VB5, VB6, and VB7) serving 22 ventilation zones with their supply and exhaust fans. The system includes a total of 73 exhaust stacks, each of which is connected to an exhaust fan. The system also includes VB8, which provides only supply air to Ramp CN-S. Figure 1-3 provides a typical cross section for VB4. Figure 1-4 provides the locations of the ventilation buildings.

The sections of the Project served by each VB are as follows:

- VB 1 serves a section of I-90 Westbound / Eastbound, and Ramps D & L. It has four ventilation zones, 11 exhaust stacks, and a supply capacity of 1.66 million cfm.
- VB 3 serves a section of I-93 Northbound / Southbound. It has three ventilation zones, 14 exhaust stacks, and a supply capacity of 2.44 million cfm.
- VB 4 serves a section of I-93 Northbound / Southbound. It has four ventilation zones, 16 exhaust stacks, and a supply capacity of 2.48 million cfm.
- VB 5 serves a section of I-90 Westbound / Eastbound. It has four ventilation zones, 12 exhaust stacks, and a supply capacity of 1.98 million cfm.
- VB 6 serves a section of the TWT Westbound / Eastbound. It has two ventilation zones, 6 exhaust stacks, and a supply capacity of 1.16 million cfm.
- VB 7 serves a section of the TWT Westbound / Eastbound, and Ramp T-AD. It has five ventilation zones, 14 exhaust stacks, and a supply capacity of 1.68 million cfm.

Figures 1-5 to 1-10 provide the location of each VB.

FIGURE 1-2: SCHEMATIC OF FULL-TRANSVERSE VENTILATION SYSTEM

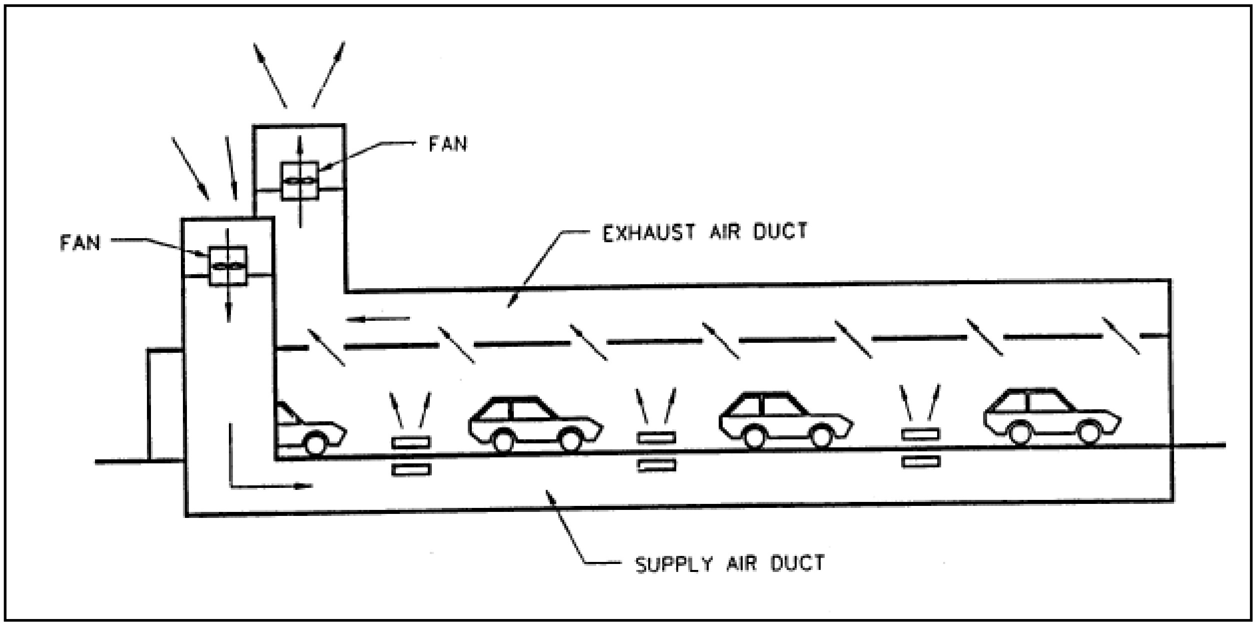


FIGURE 1-3: VENTILATION BUILDING 4 VENTILATION SCHEMATIC DIAGRAM

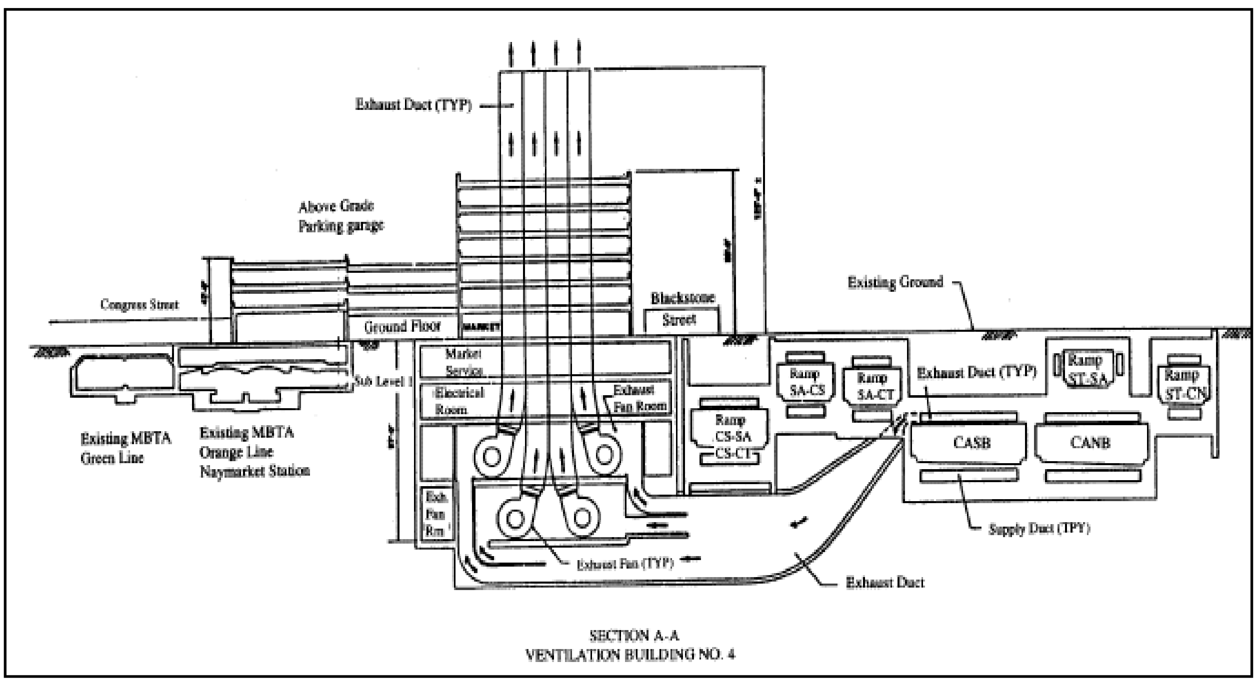


FIGURE 1-4: LOCATION OF VENTILATION BUILDINGS

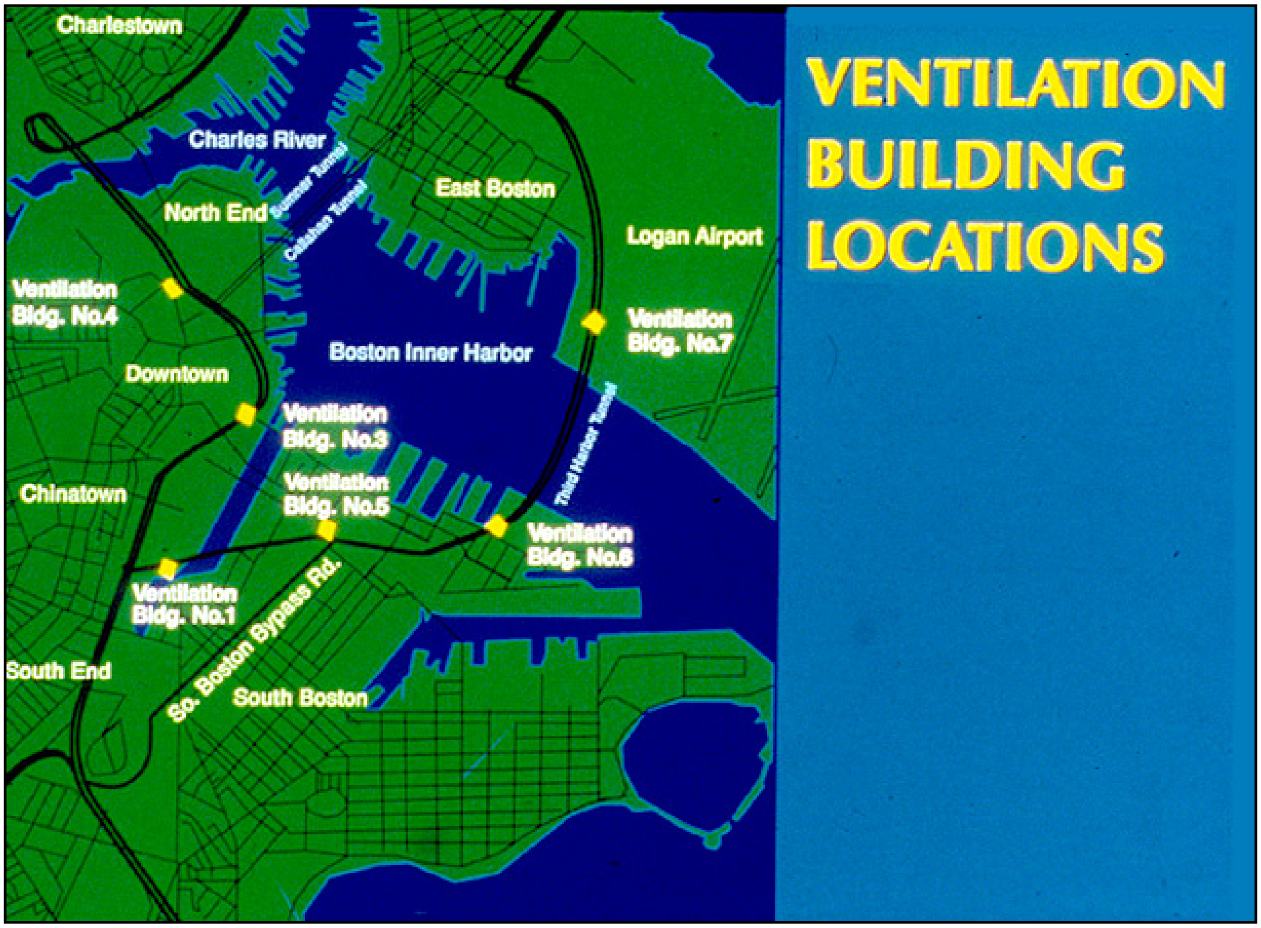


FIGURE 1-5: LOCATION OF VENTILATION BUILDING 1

FIGURE 1-6: LOCATION OF VENTILATION BUILDING 3

FIGURE 1-7: LOCATION OF VENTILATION BUILDING 4

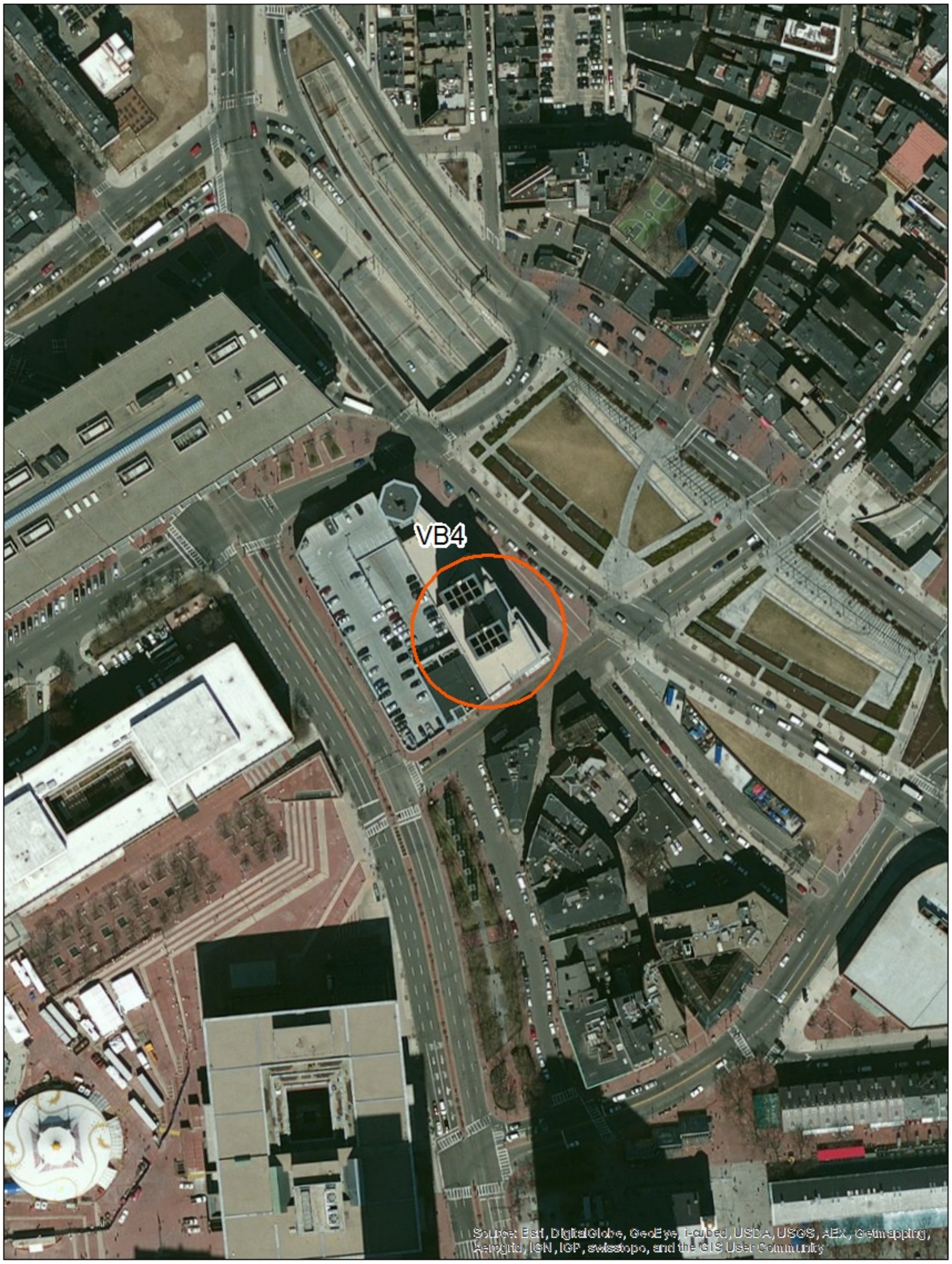
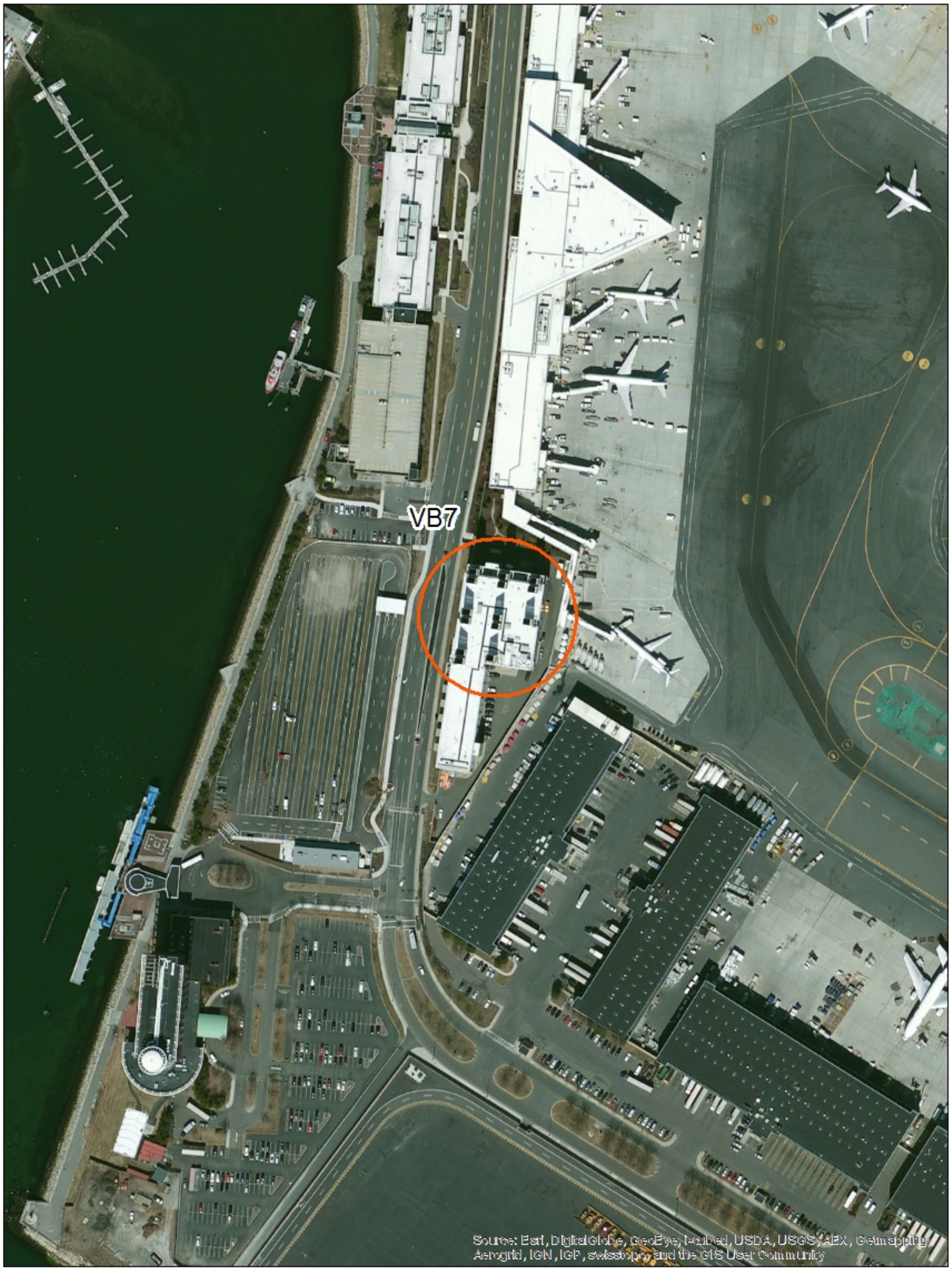


FIGURE 1-8: LOCATION OF VENTILATION BUILDING 5

FIGURE 1-9: LOCATION OF VENTILATION BUILDING 6

FIGURE 1-10: LOCATION OF VENTILATION BUILDING 7



The airflows for the full-transverse system are controlled by the many supply and exhaust fans. Airflows are set from the ventilation control system located in the CA/T Project's Highway Operations Center (HOC) in South Boston, and are determined by the CO levels monitored inside each ventilation zone.

1.1.2 Longitudinal Ventilation

In the longitudinally ventilated tunnels the exhaust air moves in the direction of the traffic flow, and it is pushed through the exit portals by the piston action effect created by the moving vehicles. Longitudinal ventilation applies to the DST section of I-93 Southbound, and at eight tunnel exit ramps.

Some of these tunnel exit ramps are connected to the supply air from the ventilation buildings, and others have supply air in the form of jet fans mounted inside the tunnel ceilings and walls. In all cases, these tunnels are self-ventilated when the traffic flow moves at a speed that ranges from 20 to 45 miles per hour (MPH) (i.e., the traffic movement provides the majority or totality of the ventilation air). In the cases of traffic congestion, stalled conditions or other incidents, the mechanical ventilation (supply air and/or jet fans) supplements and/or replaces the natural self-ventilation system.

The fans that assist the longitudinal ventilation airflows are also controlled from the CA/T Project's HOC in South Boston and they are manually operated according to the CO levels monitored inside each section of these tunnels.

1.1.2.1 Dewey Square Tunnel

The tunnel (which is connected at its northern end to the CA/T I-93 southbound tunnel) includes an Air Intake Structure (AIS) housing two centrifugal fans (300 horsepower (hp) and 300,000 cfm each). The AIS located above the DST alignment slightly south of Congress Street is designed to provide supply air in cases of roadway accidents or congested traffic conditions. These centrifugal fans are automatically set to Step 3 during the peak morning (6-10 AM) and peak afternoon (2-8 PM) hours every weekday.

In addition, to provide operator flexibility with respect to air flow management for normal and emergency operations, three of the four existing DST fan chambers and shafts were retained and rehabilitated with reversible axial fans which typically operate in the supply mode. In the instance of a fire condition, these eight reversible fans (100 hp and 100,000 cfm each) will be operated in exhaust mode to prevent "back layering" (movement of the hot air and combustion gases counter to the desired direction of flow) of the smoke, protecting vehicles and passengers stopped behind the incident location.

The current DST exit portal is located 100 feet south of Kneeland Street (Figure 1-11). The future location of the portal under the full commercial development scenario (Parcel 25 development) may be an additional 300 feet further south, on the South side of the South Station Connector (also identified in Figure 1-11).

1.1.2.2 Exit Ramps with Fresh-Air Supply and/or Jet Fan Ventilation

There are eight longitudinally ventilated ramps. Three of these ramps include supply air and jet fan ventilation, while the other five (which are not connected to the mainline tunnels) only include jet fans.

The longitudinally ventilated ramps are as follows:

- Ramp LC-S (Leverett Circle to Central Artery southbound (SB))
- Ramp SA-CN (Surface Artery to Central Artery northbound (NB))
- Ramp CN-S (Central Artery NB to Storrow Drive)
- Ramp ST-CN (Sumner Tunnel to Central Artery NB)
- Ramp ST-SA (Sumner Tunnel to Surface Artery)
- Ramp CS-SA (Central Artery SB to Surface Artery)
- Ramp CS-P (Central Artery to Purchase Street)
- Ramp F (I-90 westbound (WB) to Congress Street)

The five ramps eliminated from the CEM in the 2012 Renewal Application included: Ramps F, L-CS, SA-CN, ST-CN, and ST-SA.

These five ramps constitute relatively short tunnels (less than 1,200 feet each) that are not connected to the mainline tunnel ventilation system. They are ventilated by the piston action generated by the moving vehicles. All of them have jet fans installed on sidewalls for traffic congestion and emergency situations such as tunnel fire. The average hourly CO levels measured at these ramps during the time when they were part of the CEM system were below 3.0 ppm. Emission limits for these ramps were between 57 and 70 ppm for one hour and 70 ppm for eight hours. It was very unlikely that these limits would be ever exceeded.

The three remaining ramps subject to CEM compliance connected to supply air include:

- Ramp CN-S which has supply air provided by two fans (280,000 cfm) located inside VB 8.
- Ramp CS-SA which is connected to I-93 SB and has supply air from VB 4.
- Ramp CS-P which is also connected to I-93 SB, and has supply air from VB 3.

Due to the future development of a park features above Parcels 6 and 12 and the ongoing MEPA process for these Parcels, emission limits for the covered Parcels 6 and 12 are being considered. The section corresponding to the future development of Parcels 6 and 12 analyze possible future emission limits for ramps CS-SA and ST-SA.

Figures 1-11 to 1-14 identify the location of DST and of each of the three ramps that are still part of the CEM program.

FIGURE 1-11: LOCATION OF EXISTING AND POSSIBLE FUTURE DST EXIT PORTAL

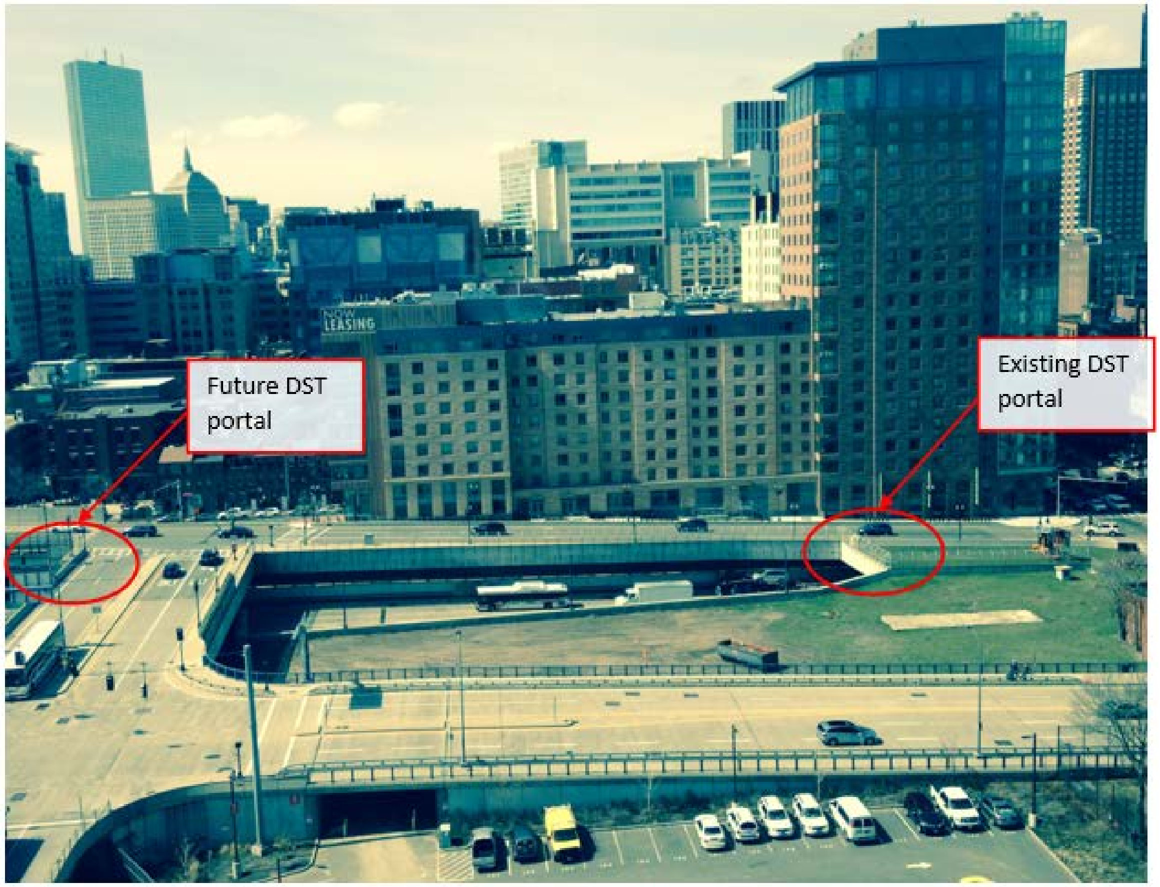


FIGURE 1-12: LOCATIONS OF RAMP PORTAL 2 (CN-S)

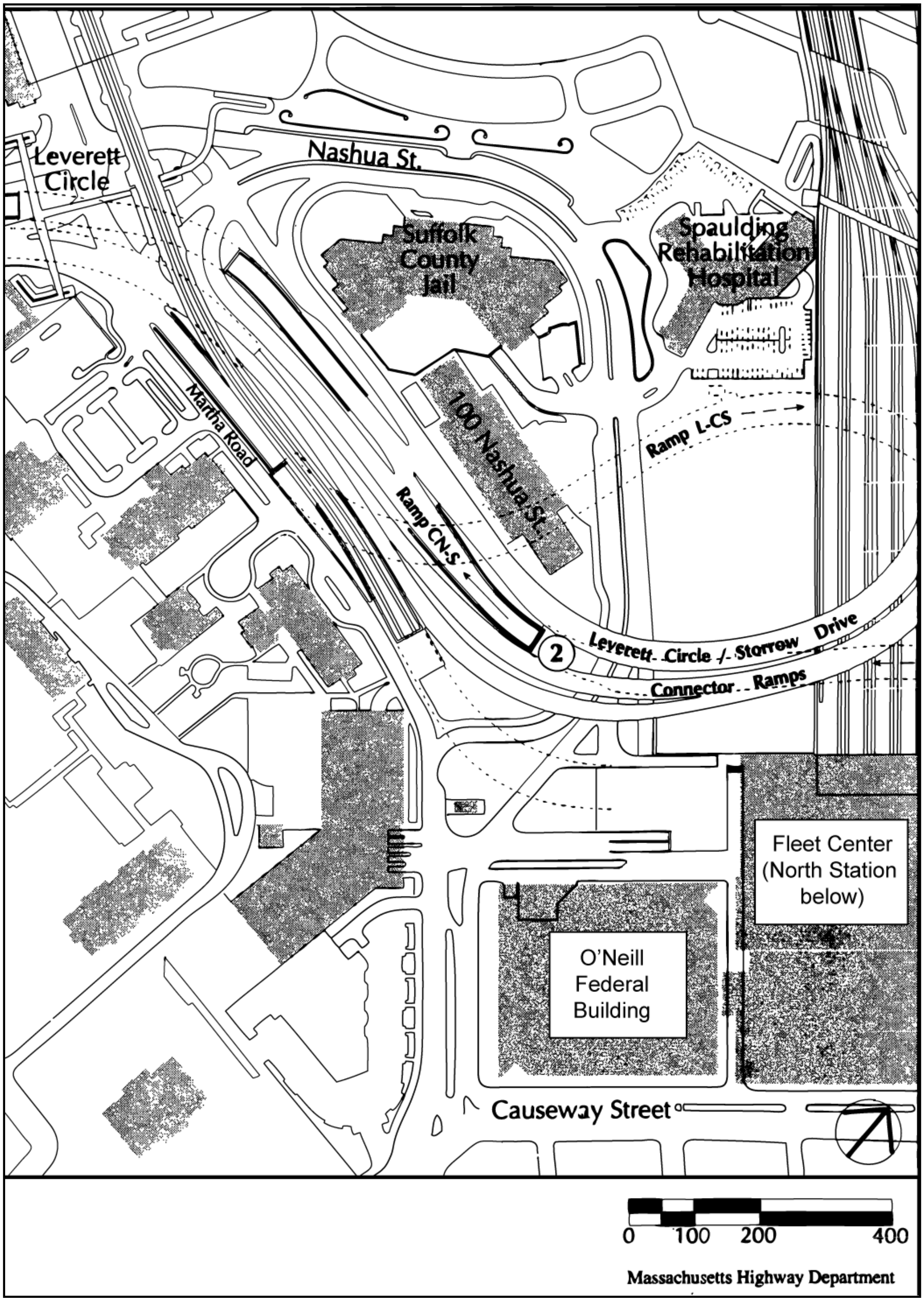


FIGURE 1-13: LOCATIONS OF RAMP PORTAL 6 (CS-SA)

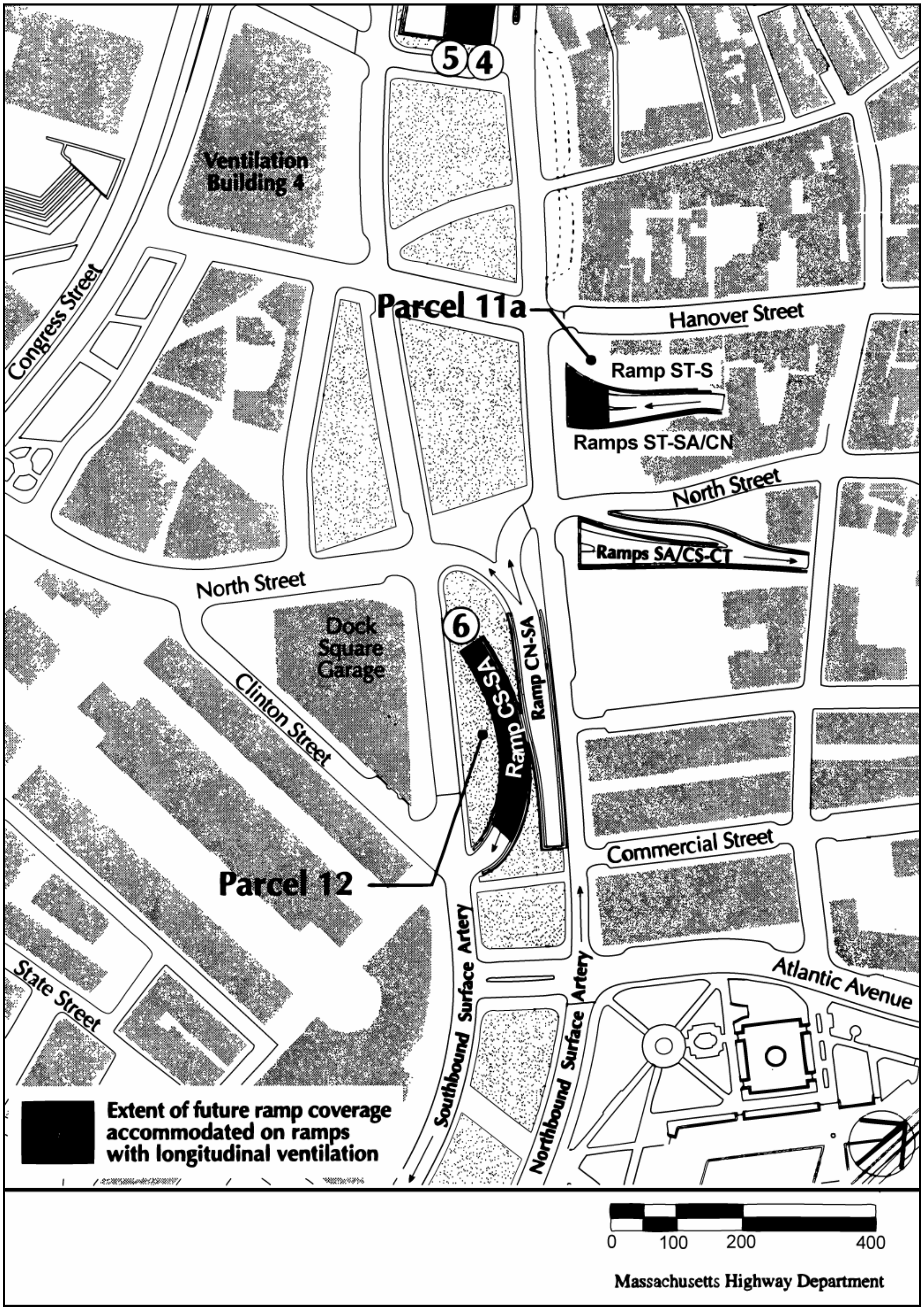
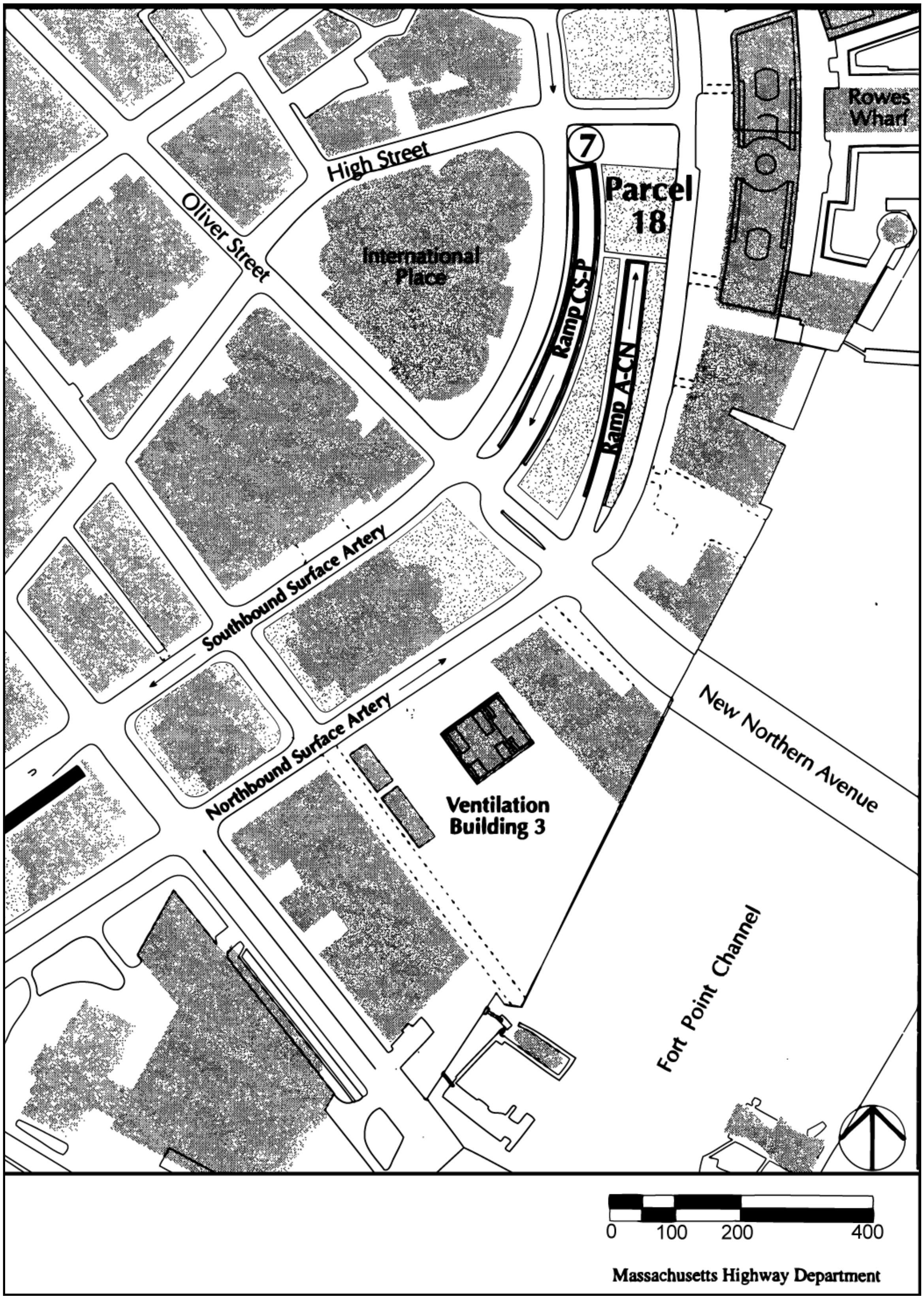


FIGURE 1-14: LOCATION OF RAMP PORTAL 7 (CS-P)



1.2 Feasible Emission Control Technologies

The tunnel exhaust air contains pollutants from motor vehicles including carbon monoxide (CO), nitrogen oxides (NO_x), non-methane hydrocarbons (NMHC) and particulate matter (PM).

NMHC refers to any hydrocarbon species other than methane and is used interchangeably with volatile organic compounds (VOC) and non-methane organic gases (NMOG). The term VOC is used in this document.

The tunnel ventilation systems introduce and circulate fresh ambient air into the tunnels, and remove the mixture of vehicular exhaust and intake air from the tunnels through the exhaust stacks.

Ventilation building emissions control technology reviews were performed in 1991, 1995, 2004, 2011 and subsequently revisited and updated in this document. An extensive investigation, conducted as part of these reviews revealed that ventilation was the predominant method of tunnel (inside and outside) air quality control employed in the United States and around the world. All reviews concluded that there were no feasible control techniques available that would result in a net reduction of the tunnel exhaust emissions.

The use of electrostatic precipitator (ESPs) systems has been an effective method for controlling particulate emissions for long tunnels that have relatively high in-tunnel particulate concentrations. Roadway tunnels equipped with ESPs systems in Europe and Japan are mostly those that are much longer than the CA/T, and have poor in-tunnel visibility caused by heavy-duty diesel truck traffic (i.e., large PM emission sources). In addition, over the last two decades there has been an increased use of ESPs in tunnels for external environmental purposes in Japan. By comparison, the CA/T tunnels are relatively short and have a lower volume of diesel truck traffic. Therefore, the installation of ESPs systems for the CA/T Project would not result in any significant decreases in PM concentrations in the tunnel exhaust air.

Technology for the removal of NO_x from the airstream has been developed and deployed in several tunnels in Japan in recent years. However, it seems that in Japan, the decision to employ air purification for ambient purposes are determined by the politics surrounding the project, and not the technical effectiveness of the systems.

Several methods of controlling gaseous emissions from tunnel exhausts are in various stages of development. However, these methods have not yet been tested or applied to situations with very low concentration levels such as those in the exhaust air of the CA/T tunnels. The extremely high flow and the very low concentration levels of pollutants in the exhaust air have been the greatest impediments to the practical application of these control techniques. Low concentrations and large flow rates would have necessitated unreasonably large control equipment sizes, long treatment times, and the use of large quantities of reagents, catalysts and energy with the consequent generation of large amounts of waste and the need for their disposal. More importantly, the energy (heat and power) requirements of the control techniques would have resulted in fuel combustion and additional emissions of criteria pollutants (e.g., CO, NO_x, PM, SO_2) and non-criteria pollutants (e.g., SO_3 and greenhouse gases such as CO_2) that far exceed the original uncontrolled emission rates due to vehicle exhausts alone.

The tunnel full transverse ventilation system currently operates at Step 1 (13% of exhaust capacity) for off-peak and Step 3 (32% exhaust capacity) for peak traffic conditions.

The 2012-2016 (1st quarter) data presented in Section 5 of TSD Part III indicate that measured hourly CO concentrations for the ventilation buildings range from 0.6 to 4.0 ppm on average and as high as 33.6 ppm during peak periods. For the DST and ramps, hourly CO concentrations were in the range of 1.7 to 4.3 ppm on average with maximum levels in the range of 17.9 to 38.5 ppm.

Measured hourly NO_x levels in the ventilation buildings ranged from 0.3 to 0.5 ppm on average with peak values ranging from 1.1 to 4.4 ppm. Measured hourly NO_x levels for the DST and Ramps ranged from 0.4 to 0.6 ppm on average with peaks ranging from 1.8 to 3.5 ppm.

The 2012-2016 (1st quarter) measured average daily $PM_{2.5}$ concentrations in the ventilation buildings were between 19 and 39µg/m^3, Maximum daily $PM_{2.5}$ values in VB were in the range of 163 to 414µg/m^3. The $PM_{2.5}$ monitor outside Ramp CS-SA, which measures ambient levels, recorded average annual concentrations from 9 to 11.4µg/m^3 and a maximum 24 hour average concentration of 33.5 µg/m^3.

Emissions data collected inside the CA/T tunnel indicate that safe in-tunnel air quality levels were maintained during the past certification period and over the year since the CA/T opening. The results of the monitoring program and corrective actions indicated that despite a very few instances between 2006 and 2016 when abnormal conditions resulted in measured concentrations exceeding the established emission limits, ambient pollutant levels outside the tunnels have been well below the applicable NAAQS and MassDEP One Hour NO_2 Policy Guideline.

These results incidentally indicate that the proper programming of the existing ventilation zones to maintain the pollutant levels inside the tunnel within the emission limits is the most effective way to manage motor vehicle emissions within the tunnel ventilation system.

1.3 TUNNEL OPERATING CONDITIONS

The CA/T Project's tunnel ventilation systems are controlled and monitored at the MassDOT HOC in South Boston. From this facility, tunnel operators are assigned geographical areas of responsibility for oversight of all traffic management and support systems operation. Ventilation system control from this location may be either manual—allowing the operator to make specific adjustments—or automatic via a central computer-based tunnel air quality algorithm or time-of-day histogram. In addition, each of the tunnel ventilation systems can be controlled from the local ventilation facility.

The system at each ventilation zone is normally operated in what is called a balanced mode; in which equal amount of supply and exhaust air are used to keep the system in a neutral pressure state. Only in the case of emergencies will the system be operated in an unbalanced condition (i.e., over exhaust mode).

1.3.1 During Non emergency Operations

During normal daily traffic operating conditions, the tunnel ventilation system is operated to maintain safe air quality and visibility within the tunnels. CO levels resulting from vehicle emissions are continuously monitored throughout all Project tunnels.

Real time values from each CO monitor are averaged by the HOC central computer system and reported on a per ventilation zone basis. Any exceedance of preset alert levels within a ventilation zone triggers an audible alarm to the operator. A banner display on the monitoring console provides specific data regarding actual concentrations, trends and location. The operator is then able to make any necessary adjustments to the ventilation zones in that particular tunnel area in order to restore safe air quality to the tunnel.

1.3.2 During Emergencies

The tunnel ventilation system was pre-programmed to operate in the most effective mode for controlling smoke and heat in the case of a vehicle fire. The programming is based on system simulation modeling of severe fire conditions to determine the most effective way to achieve critical air velocity for smoke dissipation at all locations. If a fire occurs within any of the CA/T tunnels, the HOC operator would bring up the ventilation system emergency operating matrix on his monitor and simply "click" on the column titled "fire location." The central computer will then operate all necessary ventilation systems in their proper modes for securing as safe an environment as possible at the site of the fire.

The criteria specified at 310 CMR 7.38(2)(a) and (b) do not apply during fire emergency situations. The protection of public safety would be the priority during emergencies.

1.4 VENTILATION SYSTEM PHYSICAL PROPERTIES

The Central Artery tunnel ventilation system includes:

- A very large and complex network of supply air ducts located underneath the roadway pavement (or on the side walls in some downtown tunnel sections) to deliver supply air from the supply fans to each segment of the tunnel network.
- Exhaust plenums located over the tunnel ceiling (or on the side walls in the some downtown tunnel sections) to extract the exhaust air to exhaust fans located in the VBs.
- The supply and exhaust fans of each VB, the DST air intake structure and two reversible fan chambers.
- The jets fans on each longitudinally ventilated ramp.
- The HOC building, and extensive ancillary equipment, which provides power and controls to the entire ventilation system.
- The backup power system.

1.4.1 Ventilation Building Dimensions and Ventilation Capacities

The locations of the VBs are provided in Figures 1-5 through 1-10. Each VB is a large structure with its largest part located underground. It includes a group of stacks at a uniform height. Table 1-1 provides the VB and exhaust stack heights above grade.

TABLE 1-1: VENTILATION BUILDING AND EXHAUST STACK HEIGHTS

	Heights of Ventilation Buildings and Stacks Above Grade (feet)	
VB	**Building Roof**	**Stacks**
VB1	82	121
VB3	239	278
VB4	71	131
VB5	117	178
VB6	65	91
VB7	72	108

As stated in Section 1.2, the tunnel ventilation system was designed with a supply air capacity of 65 cfm per lane-foot of tunnel and an exhaust capacity of 100 cfm per lane-foot of tunnel. The variable speed fans can be operated at different steps (depending on the level of air flow delivered). The supply fans vary from step 1 to 6, and the exhaust fans vary from step 1 to 8. Only steps 1 to 6 are required to operate the system in a balanced mode (supply equals exhaust), while steps 7 and 8 are used in cases of emergency and fire conditions. Table 1-2 provides the total exhaust capacity of each ventilation zone and the corresponding capacity at each operating step. Figure 1-15 provides a view of a supply fan at VB7 with the CO and $PM_{2.5}$ monitoring unit.

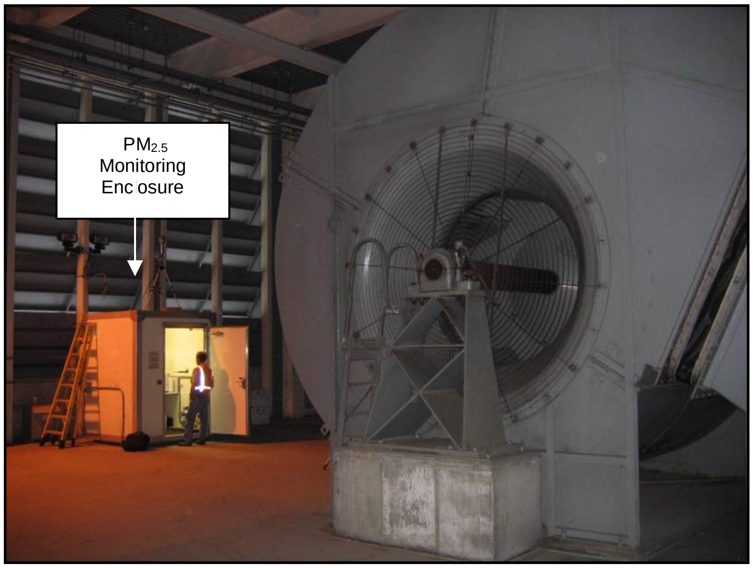
TABLE 1-2: VENTILATION BUILDINGS EXHAUST CAPACITY FOR VARYING STEPS

Ventilation Building	Ventilation Zone	Total Exhaust Capacity (CFM)	Exhaust Capacity Step 1 (CFM)	Exhaust Capacity Step 2 (CFM)	Exhaust Capacity Step 3 (CFM)	Exhaust Capacity Step 4 (CFM)	Exhaust Capacity Step 5 (CFM)	Exhaust Capacity Step 6 (CFM)
3	SB-1	1,070,000	139,100	246,100	342,400	449,400	556,400	695,500
3	NB-1	1,258,150	163,560	289,375	402,608	528,423	654,238	817,798
3	NB-2	1,139,000	148,070	261,970	364,480	478,380	592,280	740,350
4	SB-2	949,000	123,370	218,270	303,680	398,580	493,480	616,850
4	SB-3	1,130,500	146,965	260,015	361,760	474,810	587,860	734,825
4	NB-3	885,000	115,050	203,550	283,200	371,700	460,200	575,250
4	NB-4	809,000	105,170	186,070	258,880	339,780	420,680	525,850
1	SAT-Ramp D-E1	343,000	44,590	78,890	109,760	144,060	178,360	222,950
1	SAT-WB-E1	691,200	89,856	158,976	221,184	290,304	359,424	449,280
1	SAT-EB-E1	563,640	73,273	129,637	180,365	236,729	293,093	366,366
1	SAT-Ramp L/HOV-E1	941,000	122,330	216,430	301,120	395,220	489,320	611,650
5	SAT-WB-E2	1,040,000	135,200	239,200	332,800	436,800	540,800	676,000
5	SAT-WB-E3	393,000	51,090	90,390	125,760	165,060	204,360	255,450
5	SAT-EB-E2	1,112,000	144,560	255,760	355,840	467,040	578,240	722,800
5	SAT-EB-E3	558,000	72,540	128,340	178,560	234,360	290,160	362,700
6	Eastbound Zone 1	900,000	117,000	207,000	288,000	378,000	468,000	585,000
6	Westbound Zone 1	900,000	117,000	207,000	288,000	378,000	468,000	585,000
7	Eastbound Zone 2	822,000	106,860	189,060	263,040	345,240	427,440	534,300
7	Westbound Zone 2	693,000	90,090	159,390	221,760	291,060	360,360	450,450
7	Eastbound Zone 3	452,000	58,760	103,960	144,640	189,840	235,040	293,800
7	Westbound Zone 3	609,000	79,170	140,070	194,880	255,780	316,680	395,850
7	T-A/D	583,000	75,790	134,090	186,560	244,860	303,160	378,950

Notes:

Step 1 = 13% of Exhaust Capacity
Step 2 = 23% of Exhaust Capacity
Step 3 = 32% of Exhaust Capacity
Step 4 = 42% of Exhaust Capacity
Step 5 = 52% of Exhaust Capacity
Step 6 = 65% of Exhaust Capacity
Step 6 is the highest level for supply-exhaust in a balanced mode.
T-A/D - I-90 to Logon International Airport (Terminal -Arrival/Departure)

FIGURE 1-15: SUPPLY FAN AT VB 7 AIR INTAKE FLOOR



1.4.2 Longitudinally Ventilated Tunnels Dimensions and Ventilation Capacities

The plume of exhaust air that comes out of an exit portal in the wake of exiting vehicles maintains its integrity for a distance downstream of the exit portal due to the momentum created by the moving cars. This distance depends on the geometry of the roadway after the tunnel exit, the traffic flow characteristics, such as speed and density, meteorological conditions (wind direction), and other factors affecting the turbulence of the plume.

The dimensions, number of lanes and mechanical ventilation capacities of the DST and the eight longitudinally ventilated ramps exit portals (included in the 2006 Operating Certification) are provided in Table 1-3. Figure 1-16 provides a view of a side-mounted jet fan.

The air flows at the exit portals are very dependent on the traffic characteristics such as vehicle classification, density and speed at any given time.

Table 1-4 summarizes the air flows at each portal in order to provide an indication of the airflows generated by the traffic flows and the available mechanical ventilation that can be delivered by the air supply and jet fans. The air flows at each portal have been estimated in the *Notice of Project Change (NPC)/Environmental Reevaluation (ER) for the Implementation of Longitudinal Ventilation in the Area North of Causeway Street and Central Area, October 1996* (1996 Longitudinal Ventilation NPC/ER), and in the DST final report *Air Quality Study Dewey Square Portal Boston, Massachusetts*, prepared by RWDI, January 2006.

TABLE 1-3: LONGITUDINAL VENTILATION TUNNEL SECTION DIMENSIONS AND MECHANICAL VENTILATION CAPACITIES

Portal No	Ramps/Scenario	Ramp Length (ft)	Number of Lanes	Total Length (lane-ft)	Mechanical Airflow Rates (KCFM)		
					Supply Air	Min Jet Fan	Max Jet Fan
DST I-93a	**DST Existing Portal**	2400	4	9600	400	NA	NA
DST I-93b	**DST Relocated Portal**	2700	4	10800	400	NA	NA
DST I-90	**I-90 Collector**	2700	2	5400	200	NA	NA
1	**LC-S**	1020	2/1	1950	NA	197	393
2	**CN-S**	2000	2	4000	260	NA	NA
3a	**SA-CN**	1130	2	2260	NA	225	318
3b	**SA-CN (with parcel 6)**	2000	2/1	3000	NA	359	508
4	**ST-CN**	600	1	600	NA	232	328
5a	**ST-SA**	600	1	600	NA	232	328
5b	**ST-SA (with parcel 6)**	1000	1	1000	NA	130	260
6a	**CS-SA**	480	1	480	31	NA	NA
6b	**CS-SA (with parcel 12)**	780	1	780	51	NA	NA
7	**CS-P**	740	2	1480	96	NA	NA
8	**F**	700	1	700	NA	130	260

Notes: The relocated DST portal extends the DST tunnel approximately 300 feet south when development of parcel 25 is built. The DST supply capacity does not include the installed ventilation capacity of the three reversible fan chambers, which operate in exhaust mode for emergency conditions.

KCFM – thousands cfm

FIGURE 1-16: JET FAN AT LONGITUDINALLY VENTILATION RAMP

TABLE 1-4: TRAFFIC VOLUMES, SPEEDS AND AIR FLOW RATES FOR DST AND EIGHT LONGITUDINALLY VENTILATED RAMPS

Portal No	Ramps/Scenario	Peak Hour Flow Rate	Peak Hour Traffic Volume	Peak Hour Traffic Speed	Eight Hour Flow Rate	Eight Hour Traffic Volume	Eight Hour Traffic Speed
		cfm	veh/hr	mph	cfm	veh/hr	mph
DST I-93a	**DST Existing Portal**	746,000	4,580	20	1,140,000	3,800	44
DST I-93b	**DST Relocated Portal**	772,000	4,580	20	1,220,000	3,800	44
DST I-90	**I-90 Collector**	592,000	3,140	27	585,000	2,650	28
1	**LC-S**	183,420	2,068	8	248,460	1,839	13
2	**CN-S**	549,440	2,997	20	610,900	2,015	26
3a	**SA-CN**	345,060	2,204	27	339,400	1,756	29
3b	**SA-CN (with parcel 6)**	382,880	2,204	27	402,500	1,756	29
4	**ST-CN**	130,380	166	30	160,920	350	29
5a	**ST-SA**	169,740	1489	20	180,150	1187	26
5b	**ST-SA (with parcel 6)**	208,730	1489	20	208,070	1187	26
6a	**CS-SA**	265,000	1,904	12	273,300	875	16
6b	**CS-SA (with parcel 12)**	241,320	1,904	12	275,700	875	16
7	**CS-P**	136,150	1,559	11	81,400	1,099	15
8	**F**	308,450	1,929	29	281,300	1,440	30

The conditions analyzed in the wind tunnel tests include the partial and full development conditions. The DST airflows provided represent a combination of traffic induced piston effect and the Air Intake Structure (AIS) operating at 50% capacity. The airflows for the ramps represent only the result of piston action. It is worth noting the differences in the airflows between the peak and eight-hour scenarios and the effect of the traffic speeds on such airflows.

The traffic levels monitored during the last ten years indicate that these assumptions remain valid.

2 DETERMINATION OF EMISSION LIMITS

In compliance with MassDEP Regulation 310 CMR 7.38, during 2006 the CA/T Project filed an application for the Operating Certification for the Project's Tunnel Ventilation System in which it established emission limits for the exhaust of each ventilation building, Dewey Square tunnel and longitudinal ventilated exit ramps. MassDEP gave final acceptance to the 2006 CA/T Operating Certification on December 22, 2006.

The 2006 Operating Certification established tunnel emission limits for CO, NOx and PM_{10} to demonstrate compliance with ambient air quality standards for CO, NO_2, and PM_{10} and state guideline value for NO_2. It also established a regional emission budget for volatile organic compounds based on the 2005 CA/T build predictions, which included highway and transit components. MassDEP Regulation 310 CMR 7.38 requires a renewal of the Operating Certification every five years.

On July 1, 2011, MassDOT submitted to MassDEP the renewal application for the operating certification for the CA/T ventilation system. The renewal application included an air quality compliance demonstration, summaries of air quality and traffic monitoring data, a review of feasible emission control technologies and updates from the 2006 submittal. The final 2011 CA/T Renewal Operating Certification, which addressed all MassDEP comments, was submitted on September 30, 2011.

The 2011 CA/T Renewal Operating Certification included new emission limits for $PM_{2.5}$ and demonstrated compliance with the $PM_{2.5}$ NAAQS. The 2011 CA/T Operating Certification also demonstrated that the VOC regional emissions for 2010 were below the VOC budget based on the 2005 CA/T build predictions that included highway and transit components. In addition, it requested to submit a supplemental application to MassDEP on 2012 to establish revised emission limits for CO and NO_x that would demonstrate compliance with the new 1-hour NAAQS for NO_2.

MassDOT submitted the Final Supplemental Application for the CA/T Renewal Operating Certification on August 1, 2012. MassDEP issued a Final acceptance of the 2012 CA/T Renewal Operating Certification Application submitted August 1, 2012 on its letter dated February 14, 2013. The acceptance covers the remainder four year operating period from December 19, 2012 to December 19, 2016.

This renewal application covers the five-year period from the date of MassDEP approval of the 2016 Renewal Operating Certification (December 19, 2016) through December 19, 2021.

2.1 PROJECT PRECONSTRUCTION CERTIFICATION ACCEPTANCE RECORD

MassDEP 310 CMR 7.38(2) "Pre-Construction Certification" states that no person shall construct a tunnel ventilation system and project roadway subject to 310 CMR 7.00 without first certifying to MassDEP (and receiving MassDEP's written acceptance of that certification) that the operation of any tunnel ventilation system, project roadway, and roadway networks will not cause a violation of certain air quality standards, guidelines, and criteria specified in MassDEP Regulation 7.38.

On February 20, 1991, to comply with the provisions of 310 CMR 7.38, the Massachusetts Department of Public Works, now the MassDOT, submitted to MassDEP a Pre-Construction Certification of the Tunnel Ventilation System for the CA/T Project (Pre-Construction Certification). The Pre-Construction Certification was found to be administratively complete by MassDEP on March 27, 1991. On May 7, 1991, MassDEP conducted a public hearing on the Pre-Construction Certification to receive comments pursuant to 310 CMR 7.38(11). After review of the Pre-Construction Certification and consideration of information presented at the public hearing and during the public comment process, MassDEP accepted the Pre-Construction Certification subject to conditions set forth in the decision document dated July 8, 1991 entitled *Conditional Acceptance of Pre-Construction Certification of the Central Artery/Third Harbor Tunnel Project* (Conditional Acceptance). MassDEP determined that the mitigation measures presented in the Conditional Acceptance were necessary to mitigate potential adverse air quality impacts from the CA/T Project and to meet the criteria for project certification in 310 CMR 7.38. The mitigation measures set forth in the Conditional Acceptance included Public Transportation Measures, Measures to Increase Commuter Rail Ridership, Water Transportation Measures, Transportation Management Measures, and a High Occupancy Vehicle (HOV) Program.

On January 7, 1999, the MTA, on behalf of MassDOT, submitted to MassDEP for its review and acceptance pursuant to the 310 CMR 7.38 an amendment to the Pre-Construction Certification.

The Amended Pre-Construction Certification was found to be administratively complete by MassDEP on February 26, 1999. On March 30, 1999 MassDEP conducted a public hearing on the Amended Pre-Construction Certification to receive comments pursuant to 310 CMR 7.38(11). MassDEP issued proposed decision documents on the Amended Pre-Construction Certification on April 29, 1999 and conducted a public hearing on those proposed decisions on May 20, 1999.

A more complete description of the amendments to the Pre-Construction Certification process is detailed in the 2012 CA/T Renewal Operating Certification document and is not repeated here.

2.2 MASSDEP REGULATORY REQUIREMENTS FOR OPERATING CERTIFICATIONS

As discussed in Section 2.1, 310 CMR 7.38 required the issuance by the constructor, MassDOT, of a Pre-Construction Certification; and subsequently by the operator, MassDOT, of an Operating Certification.

As part of the Operating Certification requirements, MassDOT must demonstrate that the tunnel ventilation system when operated in accordance with its design standard operation and maintenance procedures would not:

- Cause or exacerbate a violation of any National Ambient Air Quality Standard (NAAQS), or a Massachusetts Ambient Air Quality Standard (MAAQS);
- Cause or exacerbate a violation of the MassDEP's one hour ambient nitrogen dioxide (NO_2) guideline of 320 $\mu g/m^3$ (170 ppb) or
- Result in an actual or projected increase in the total amount of non-methane hydrocarbons (referred as VOC in this document) measured within the Project area when compared with the No-Build alternative.

The 24-hour NAAQS for particulate matter equal to or smaller than 2.5 microns in diameter ($PM_{2.5}$) was modified several times since its promulgation, and MassDEP required that the 2011 renewal included emission limits for $PM_{2.5}$. The limits for $PM_{2.5}$ replaced the limits for PM_{10}. The annual NAAQS for $PM_{2.5}$ was lowered to 12 $\mu g/m^3$ from 15 $\mu g/m^3$ in December of 2012 during the current certification period.

During the spring of 2010, MassDEP determined that the recertification should also include a demonstration of compliance with the new 1-hour NO_2 NAAQS of 188 $\mu g/m^3$ equivalent to approximately 100 ppb. The 2006 NO_x emission limits were established to comply with the MassDEP 1-hour NO_2 policy guideline of 320 $\mu g/m^3$ equivalent to approximately 170 ppb.

MassDOT is required to demonstrate that the operation of the tunnel ventilation system is in accordance with the criteria set forth in the Pre-Construction Certification accepted by MassDEP. The MassDEP Regulation 310 CMR 7.38 provides that this demonstration shall be based on actual measured emissions and traffic data. [It is worth noting that that the 310 CMR 7.38(2) requirements regarding compliance with the applicable ambient air quality standards and the 1-hour NO_2 MassDEP policy guideline for nitrogen dioxide (NO_2)do not apply during emergency conditions (i.e., tunnel fires).]

MassDOT is required to establish concentration based emission limits for the tunnel ventilation system such that operation of the CA/T ventilation system below these limits would not cause or exacerbate a violation of any applicable ambient standards.

The project compliance monitoring program approved in 2006 included CO continuous emission monitoring (CEM) at the plenum of each ventilation zone and PM_{10} CEM at four ventilation zones that presented the highest potential PM_{10} levels at the mainline tunnel exhaust points. Due to the limited space available and other technical impediments inside the ramps, instead of in-tunnel monitoring, a permanent PM_{10} monitor was installed in 2006 at outside exit Ramp CS-SA to determine if the emissions from the longitudinally ventilated ramps could cause high PM_{10} levels in the adjacent areas. In the end of 2011 all PM_{10} monitors were converted to monitor $PM_{2.5}$. NO_x levels at each CEM monitoring location were determined as a function of the hourly monitored CO levels. The monitoring results and the calculated NO_x levels were compared to their predetermined emission limits for compliance assessment.

For VOC emissions, MassDOT is required to demonstrate that the tunnel ventilation system when operated in accordance with its design, standard operation and maintenance procedures would not result in an actual or projected increase in the total amount of VOC measured within the Project area compared to the No-Build alternative. The 2005 regional VOC emissions for the area affected by the CA/T Project Build scenario was used as a budget limit, not to be exceeded in future years for compliance demonstration purposes.

2.3 ACCEPTANCE OF CONCENTRATION–BASED EMISSION LIMITS

The following section remains unchanged from the 2011 CA/T Renewal Operating Certification and is reprinted here for completeness of this document.

The MassDOT-MassDEP technical working group proposed and received concurrence from MassDEP (see MassDEP letter dated April 16, 2002) that the CA/T emission limits for CO, NO_x and PM_{10} (and now, by extension, for $PM_{2.5}$) should be determined as concentration-based levels (i.e., ppm or $\mu g/m^3$) in lieu of the mass-based (e.g., grams per second (g/s) or pounds per hour (lb/hr)) limits that are usually imposed on stationary sources. The rationale for the concentration-based emission limits, which meet the requirements of 310 CMR 7.38, is briefly discussed as follows.

Vehicular emissions depend on the number, type and conditions of the vehicles and their traveling speeds. Although the MassDOT is the Owner and Operator of the CA/T tunnel ventilation system, the Project tunnels are open for general public use under normal operation conditions without exception. Therefore, the MassDOT has no control regarding the type and conditions of vehicles entering the tunnel and can only manipulate the ventilation rates of the tunnel ventilation system based on traffic conditions to provide acceptable in-tunnel air for the motorists traveling the tunnels. Thus, the emission limits to be set for all applicable pollutants will be the maximum allowable concentrations that will ensure that the applicable ambient standards are not violated.

Since there is no NAAQS for VOC, emission limits for VOC cannot be established based on concentrations measured at a specific receptor location. As such, direct measurement or monitoring of VOC without a benchmark level to guide the operation of the ventilation system may or may not contribute to the protection of the health and welfare of the affected population. A different procedure that is based on the study area VOC budget was developed by the MassDOT-MassDEP air quality working group and accepted by MassDEP on July 30, 2002. The established VOC budget for the CA/T Build condition was then be used as the emission limit, which is not to be exceeded in the future years for compliance demonstration purposes.

2.4 ACCEPTANCE OF EMISSION LIMITS ESTABLISHED IN 2011/2012 APPLICATION

The 2011/2012 Operating Certification established tunnel emission limits for CO, NOx and $PM_{2.5}$ to demonstrate compliance with ambient air quality standards for CO, NO_2, and $PM_{2.5}$ and state guideline values for NO_2.

The final acceptance letter by MassDEP dated February 14, 2013 states that MassDEP issued the final acceptance of the Operation Certification (Final Acceptance) provided that: "Emission Limits shown in the Table 2-1 will ensure that all NAAQS and MassDEP guidelines will not be exceeded in the CA/T Project area."

TABLE 2-1: SUMMARY OF 2012-16 EMISSION LIMITS

Location*	1-Hour CO Emission Limit (ppm)	8-Hour CO Emission Limit (ppm)	1-Hour NO_X Emission Limit (ppm)	24-Hour $PM_{2.5}$ Emission Limit ($\mu g/m^3$)
VB 1	70	70	6.1	900
VB 3	70	70	6.1	900
VB 4	70	70	6.1	900
VB 5	70	70	6.1	900
VB 6	70	70	6.1	900
VB 7	70	70	6.1	900
Ramp CN-S	37	58	3.4	NA
Ramp CS-SA	38	55	3.4	35**
Ramp CS-P	41	70	3.7	NA
Dewey Sq. Tunnel	23	30	2.2	NA

* For VBs, location includes all ventilation zones of this VB.
** The ambient $PM_{2.5}$ monitor is located outside ramp CS-SA.

It also established a regional emission budget for volatile organic compounds (VOCs) based on the 2005 CA/T build predictions, which included highway and transit components setting a limit of 6,095.9 kg/day for the CA/T Project area.

2.5 2016 RENEWAL OF OPERATING CERTIFICATION PROCESS

The 2016 CA/T Renewal Operating Certification includes revised emission limits for CO, NOx, and $PM_{2.5}$ and demonstrated compliance with the CO, NO_2, and $PM_{2.5}$ NAAQS, and one-hour NO_2 MassDEP Policy Guideline.

The 2012 Operating Certification also demonstrated that the VOC regional emissions for 2010 were approximate 35% below the VOC budget based on the 2005 CA/T build predictions, which included highway and transit components.

Based on the significant decreases in VOC motor vehicle emissions and the current O_3 attainment status of the Boston Metro area the 2016 CA/T renewal certification presents a simplified approach to estimate the reductions in the regional VOC levels. This approach uses MOVES 2014a (EPA s' Motor Vehicle Emission Simulator) VOC emission factors and anticipated traffic increases based on current traffic growth factors. This method was agreed with MassDEP at the March 23, 2016 inter-agency meeting.

2.5.1 $PM_{2.5}$ Limits

The results of the analysis in 2011 TSD indicated that a $PM_{2.5}$ emission limit of 900 $\mu g/m^3$ demonstrates compliance with the $PM_{2.5}$ annual and 24-hour NAAQS.

This 2016 document updates the compliance demonstration following the same technical modeling approach used in the 2011 TSD, and explained in more detail in section 2.6, with the incorporation of the most current background levels from MassDEP monitoring stations, the 2012-2015 local meteorological data, and receptor locations based on current buildings configuration in each VB surrounding area. The results of this analysis indicate that a revised $PM_{2.5}$ emission limit of 550 µg/m^3 demonstrates compliance with the current $PM_{2.5}$ annual and 24-hour NAAQS. Note that the annual NAAQS was lowered from 15 µg/m$_3$ to 12 µg/m$_3$ in 2012.

The $PM_{2.5}$ emission limits replaced the PM_{10} emission limits that were established as part of the original operating certification approved in 2006. The CEMs for $PM_{2.5}$ replaced the CEMs for PM_{10} that are located in Vent Buildings 3, 5 and 7 and at the portal area of Ramp CS-SA during 2011.

Since the modeling methodology for the VB $PM_{2.5}$ analysis is integrated into the CO and NOx analysis for VBs, the $PM_{2.5}$ analysis and results are also described in section 2.6.

2.5.2 VOC Compliance

The 2006 Operating Certificate established a regional emission budget for VOC of 6,095.9 kg/day. It was based on the 2005 CA/T build predictions which included highway and transit projects completed by the Commonwealth as of the year 2005.

The 2011 renewal application demonstrated that the VOC emissions in 2010 were 3,906.9 kg/day, far below the budget of 6,095.9 kg/day. The 2006 and 2011 demonstrations calculated the 2010 VOC emissions for each area using the CTPS model area for Eastern Massachusetts including the highway, transit, and commuter rail components.

The result of the 2016 VOC regional emissions approach (described in section 2.7) indicated that VOC emissions for the CA/T area will be in the range of 2,000 kg/day, which is close to one third of the 2005 VOC emission budget of 6,095.9 kg/day.

2.5.3 CO and NO_2 Limits

The 2012 CA/T two-part Renewal Certification approach was driven by the US Environmental Protection Agency (EPA) adoption of a new and more stringent one-hour NAAQS for NO_2 effective April 12, 2010. The 2012 Supplemental Application allowed MassDOT to collect a full year of nitric oxide (NO), NO_2 and NO_x data at the DST portal and Albany street sidewalk locations. The purpose of this monitoring data was to derive a method for estimating new emission limits for NO_x at all ventilation buildings and longitudinally ventilated tunnels and ramps. Compliance with the new NO_2 NAAQS required a more refined analysis and a better understanding of how much NO produced by motor vehicle exhaust is actually converted to NO_2 in the vicinity of the tunnel exhaust points (portals and VBs).

This site-specific monitoring-based methodology replaced the ozone limiting method (OLM) used to demonstrate compliance with MassDEP one-hour NO_2 Policy Guideline in the 2006 CA/T Application. The OLM technique conservatively assumed instantaneous conversion of emitted NO to NO_2 and, in addition, allowed this conversion process to continue as long as ambient ozone (O_3) is available in the atmosphere. While these assumptions may be reasonable at longer transport distances, they grossly over-estimate peak NO_2 concentrations at near-field receptor locations.

Since NOx levels were estimated as a function of in-tunnel CO levels in the original 2006 CA/T Operating Certification; the analysis of one full year of NO, NO_2, NO_x and CO data at the DST was used to determine a more appropriate CO-NOx correlation.

This 2016 document updates the compliance demonstration following the same technical modeling approach used in the 2012 TSD determining in-tunnel NOx levels as a function of CO levels, and determining the NO to NO_2 conversion factors based on the 2011-2012 results of the Dewey Square Tunnel Monitoring Program. This analysis also incorporates the most current background levels, 2012-2015 meteorological data and receptor locations based on current buildings configuration in each VB surrounding area. The Dewey Square Tunnel configuration is based on Scenario #2 that includes Parcel 24 building which is already built. Emission limit demonstration for the longitudinally ventilated ramps is limited to the three ramps that remain part of the approved 2012 Renewal Application.

The document also includes a section to evaluate future emission limits related to the ongoing MEPA process for the creation of park features over Parcels 6 and 12. The results of this analysis are presented in detail in section 2.7 and summarized in section 2.8.

2.5.4 2011-2013 Dewey Square Tunnel (DST) Monitoring Program

The four station NO_x monitoring network was deployed by MassDOT along Albany Street and within the DST. Three of the monitoring locations were south of the DST southbound portal at Kneeland Street along a fence separating Albany Street from the depressed I-93 “boat section.” Monitor Number 1 was located 258 feet from the exit portal. Monitor Number 2 was located 126 feet from the exit portal. Monitor Number 3 was located 6 feet from the exit portal. Monitor Number 4 was located inside the DST approximately 150 feet north of the exit portal, and measured NO, NO_2 and CO concentrations within the tunnel itself. Figure 2-1 provides the location of each monitor. Note that north is at the bottom of the Figure 2-1 photograph.

The network was deployed to assess the concentrations and chemical reaction rates of NO_x associated with the CA/T Project. The network commenced operation on April 2011 and continued to operate through September 2013. NO, NO_2 and NO_x were monitored on an hourly average basis at each monitoring location.

These concentrations have been reported monthly to the MassDEP. The network used EPA certified monitoring equipment and it was subject to routine independent quality assurance (QA) audits performed by MassDEP to ensure the accuracy of the reported concentrations. The first year of data, (April 1, 2011 to March 31, 2012) was used to support the modeling effort for the 2012 compliance demonstration to determine the revised NOx and CO limits at the VBs, DST, and Longitudinally ventilated Ramps. Table 2-2 provides a summary of the data collected between April 2011 and March 2012.

Section 2.6 explains in more detail the use of this data for the NOx levels determine as a function of CO levels within the CEM program, and the NO to NO_2 conversion factor used in the 2012 compliance demonstration to meet the one-hour NO_2 NAAQS. The Final Report titled “Summary and Findings of Dewey Square Tunnel and Albany Street Nitrogen Oxides (NOx – NO_2) Monitoring Data” dated June 20, 2014 is Appendix H.

Table 2-2 shows the maximum, minimum, and average for each parameter at each location for the monitoring period (April 1, 2011 to March 31, 2012). If the instrument measured a negative value, it was recorded as a zero.

FIGURE 2-1: LOCATIONS OF THE THREE AMBIENT MONITORS DEPLOYED AT ALBANY STREET

TABLE 2-2: COLLECTED NO_X, NO AND NO_2 CONCENTRATIONS (PPB)

Pollutant	Parameter	Location 1 Albany St.	Location 2 Albany St.	Location 3 Albany St.	Location 4 Inside DST
NO_x	Average	196	176	94	669
	Max	900	1541	941	6512
	Min	0	0	5.1	0
NO	Average	164	143	64.2	609
	Max	878	1470	870	5779
	Min	0	0	0	0
NO_2	Average	31.8	33.6	29.7	63.5
	Max	131	199	119	733
	Min	0	0	4.2	0
	Hours>100 ppb	1	21	5	n/a
	Days with hours>100 ppb	1	12	4	n/a

2.6 TECHNICAL APPROACH

The technical approach to determine emission limits follows the procedures established in the 2011/12 CA/T Renewal Operating Certification. Appendix B-2 provides updated models, parameters and procedures for the determination of $PM_{2.5}$ emission limits and for the VOC budget compliance analysis. The 2016 air quality analysis protocol contains procedures for the determination of CO and NO_x emission limits, as approved by MassDEP (see Appendix B).

The following sections briefly summarize the methodology employed, which in general terms follows the one employed in the 2012 Renewal Application TSD Report.

Compliance demonstration for ventilation buildings and ramps is based on the modeling analyses at each ramp and each ventilation building. Following approaches are used based on the available data and previously conducted physical simulations (wind-tunnel studies) as described below:

Location/scenario	Approach
Ventilation Buildings	AERMOD modeling
Longitudinally-Ventilated Ramps (CS-P, CN-S, CS-SA and DST)	Modeling based on wind-tunnel results
Ramps ST-SA with parcel 6 and ramp CS-SA with parcel 12	AERMOD modeling

2.6.1 Relevant Pollutants

The relevant vehicular pollutants for which emission limits are developed are those established in 310 CMR 7.38(2) along with the current updates recommended by MassDEP, namely CO, NO_x, $PM_{2.5}$, and VOC.

2.6.2 Averaging Times for Concentration-based Emission Limits for CO, NO_x, and $PM_{2.5}$

The averaging times associated with the concentration-based emission limits for CO, $PM_{2.5}$, and NO_x are determined by their respective NAAQS and MassDEP NO_2 Policy Guideline. Concentration-based emission limits currently apply for the following pollutants and averaging periods at the indicated locations:

Averaging Period	Pollutant	Locations
1-hour and 8-hour	CO	Each VB and longitudinally ventilated ramp
1-hour	NO_X	Each VB and longitudinally ventilated ramp
24-hour	$PM_{2.5}$	Four selected locations at three VBs*

* These four locations represent conditions for mainline tunnels I-93 and I-90 in both directions. The CA/T Project is also performing ambient $PM_{2.5}$ monitoring in the vicinity of Ramp CA-SA.

2.6.3 Predictive Model for NO_x Emission Estimates

The 2006 Operating Certification determined that in-tunnel NO_x levels can be estimated as a function of in-tunnel CO levels. This decision was based on CO and NO_x data collected in the Ted Williams Tunnel monitoring program. The TWT monitoring program measured in-tunnel CO and NO_x levels on a quarterly basis during 1997-1998 at the time when only commercial traffic was permitted inside the TWT. The program was repeated during 2004 when the tunnel was opened to general traffic use. An analysis of the measured levels, and the derived relationship between the two pollutants (based on more than 10,000 hours of collected data) proved that there was a good correlation between the two pollutants, and that NO_x levels can be predicted as a function of CO levels within the TWT.

The results of additional TWT monitoring data collected during the summer of 2010 indicated that levels of both CO and NO_x were lower than in 2004 mostly due to cleaner vehicles, and the use of full transverse ventilation. As a result, the 2010 TWT data clustered at levels closer to background (below 5 ppm CO and 1 ppm NO_x). The low levels at the TWT prompted the use the longitudinally DST 2011/12 monitoring data to better reflect the CO-NO_x relationship at higher CO levels in the 5 – 15 ppm range which are more representative of the in-tunnel CO.

As vehicle emission standards have changed and become more stringent, the relationship between NO_x and CO emissions has been changing. A full year of concurrent NO_x and CO monitoring data (April 2011 through March 2012) collected by MassDOT from the DST monitoring program were used to update the CO-NO_x regression equation to reflect the current vehicle emission profile.

The linear regression equation described below was developed based on the 6,292 pairs of CO and NO_x observations collected inside the DST during April 2011 through March 2012. Figure 2-2 provides the scatter plot of all the data points and the linear regression.

The regression model is of the form:

Y = a + b*X

Where

Y is the unknown concentration of NO_x estimated as a function of ***X*** and

X is the known concentration of CO.

The constant ***"a"*** is the intercept of the regression line and ***"b"*** is the slope, which is the rate at which ***Y*** *(NOx)* changes with unit change of ***X (CO)***.

The equation developed from this data was used in the modeling analysis and will estimate the hourly NO_x levels as a function of CO levels:

NO_x = 0.2956 + 0.0829*CO

Table 2-3 presents calculated NO_x concentrations at selected CO concentrations based on the regression equation.

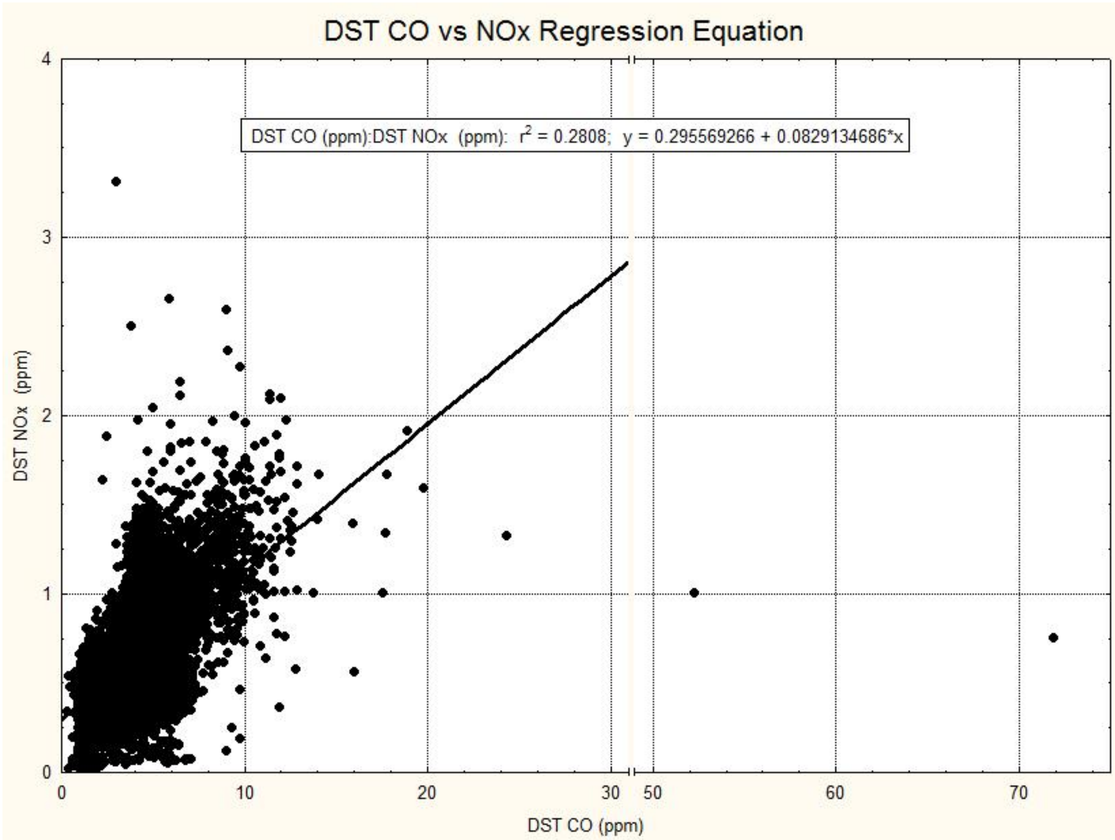
TABLE 2-3: CO/NO_X RELATIONSHIP BASED ON APRIL 2011–MARCH 2012 MEASURED DATA

CO (ppm)	10.0	15.0	20.0	25.0	30.0	35.0	40.0	45.0	50.0	55.0	60.0	65.0	70.0
NO_x (ppm)	1.12	1.54	1.95	2.37	2.78	3.20	3.61	4.03	4.44	4.86	5.27	5.68	6.10

This relationship has an r value of 0.5299 and a p-level of 0.0000, indicating that there is a strong relationship between the monitored CO and NOx concentrations in the tunnel.

Figure 2-2 presents the CO/NOx relationship that is based on monitored levels at the DST from April 2011 hrough March 2012.

FIGURE 2-2: CO/NOX RELATIONSHIP BASED ON MONITORED LEVELS AT THE DST FROM APRIL 2011 THROUGH MARCH 2012



2.6.4 NO to NO_2 Conversion

EPA's and MassDOT's in-tunnel monitoring programs indicated that NO_x emissions inside roadway tunnels consist predominantly of NO (85-95%) with a small fraction of NO_2 (5-15%). This finding is consistent with several monitoring programs performed at different tunnels around the world, and it was verified by the 2011-13 DST monitoring program. In general, ambient NO_2 concentrations could comprise a much higher percentage of NO_x. In the open air several reactions take place that convert NO to NO_2 and back, but the predominant reaction is the oxidation of NO with ozone in the presence of sunlight.

The amount of NO_2 present in the atmosphere within the CA/T Project that affected adjacent areas is a combination of three different sources of NO_2:

- NO_2 directly emitted from the vehicles and released into the atmosphere through the ventilation building and the exit portals. Assumed to be 5 % in 2006 CA/T Operating Certification;
- NO_2 formed from the oxidation of NO that is emitted from the vehicles and released into the atmosphere through the ventilation buildings and the exit portals; and
- NO_2 present as background in the atmosphere.

Determining background concentrations near the monitoring site is somewhat complicated. There are several sources of NO_2 in the close vicinity to the DST portal, including traffic emissions on the local streets, the South Station diesel locomotive idle emissions about 1000 feet to the northeast and the steam generation station emissions not more than 400 feet away. The closest and most representative MassDEP NO_2 background monitor is in Roxbury at Harrison Avenue a few miles away from the site. This monitor does not cover the local sources near the portals and VBs, but represents only the area background concentrations.

The data collected by the DST NOx monitoring project were used to determine the effects of the NO_x emissions generated by the traffic inside the DST (and exhausted through the exit portal) at the Albany Street NOx monitors.

Conversion factors between NO and NO_2 were estimated assuming that the total NO_x exhausted out of the tunnel portal disperses downwind while part of the NO in the plume oxidizes and becomes NO_2, as follows:

$$\mathbf{NO_{x\,(rec)} - NO_{x(bkg)} = (NO_{x\,(src)} - NO_{x(bkg)}) * DR}$$
$$\mathbf{NO_{2(rec)} - NO_{2\,(bkg)} = (NO_{2\,(src)} - NO_{2\,(bkg)}) * DR + (NO_{(src)} - NO_{(bkg)}) * DR * CF}$$

Where DR = dilution ratio
CF = conversion factor

These equations assume that the background concentrations are present in the ambient air, and in the air inside the tunnel at the same level as in the ambient air. The background concentrations were obtained from the hourly MassDEP monitor at the Harrison Avenue monitoring location.

Estimated conversion factors obtained from the monitoring data using the above equations are presented in Table 2-4. As shown in the table, the summer months, the traditional high NO_x season, confirmed the higher conversion factors. Overall, site-specific conversion from NO to NO_2 in close proximity to the source, as studied in this monitoring program, proved to be much lower than it has been reported in the literature for long distances and/or longer time-periods.

TABLE 2-4: NO/NO_2 CONVERSION FACTORS BASED ON DST MONITORING STUDY

Monitoring season	statistics by season	Albany Street Monitors	
		Monitor Number 2	Monitor Number 1
Spring (March – May)	**Average**	**0.08**	**0.05**
	Standard Deviation	0.06	0.06
Summer (June – August)	**Average**	**0.12**	**0.10**
	Standard Deviation	0.11	0.12
Fall (September – November)	**Average**	**0.07**	**0.05**
	Standard Deviation	0.06	0.05
Winter (December – February)	**Average**	**0.07**	**0.07**
	Standard Deviation	0.08	0.08
Full Year Results	**Average**	**0.082**	**0.068**
	Standard Deviation	0.08	0.09

The selected conversion factor for the modeling compliance demonstration is the weighted average based on approximately 4,000 hourly concentrations collected at each of the two Albany Street monitors (Monitor Numbers 1 and 2) and inside the DST at Monitor Number 4. The resulting weighted average conversion factor for the two monitors is **0.075**. The summaries of the data by month, season and yearly totals are included in the last pages of Appendix H.

This factor represents a 7.5% conversion from NO to NO_2.

This 7.5 % conversion factor is used for the compliance of all ventilation buildings, DST and longitudinally ventilated ramps.

2.6.5 Representative Surface and Upper Air Meteorological Data

This demonstration used the most recently available five years (2012–2015) of Automated Surface Observing System (ASOS) meteorological data collected at Boston Logan International Airport (BOS/KBOS) along with concurrent upper air data collected at the National Weather Station in Gray, Maine. These are the closest and most representative sources of meteorological data for the Project. The 2012 supplemental application used the Logan airport surface and Gray, Maine, upper air data from 2007 through 2011 were used for the $PM_{2.5}$, NO_2 and CO compliance demonstrations. This analysis uses the 2012-2015 Logan airport surface and Gray, Maine, upper air data.

2.6.6 Attainment Status of Project Area

At the time of the 2006 application, the Boston area, inclusive of the CA/T Project, was designated as moderate nonattainment for the 8-hour NAAQS for O_3 and as attainment for PM_{10} and NO_2.

In addition, the Boston Metropolitan area, including Boston, Cambridge, Chelsea, Everett, Malden, Quincy, Medford, Revere, and Somerville was designated attainment for CO in April 2016. This ended the 20 year maintenance period designated by EPA in April 1996. The last violation in the state of the CO NAAQS occurred in 1986. With the re-designation to CO attainment status, the entire state acquired attainment status, and is no longer required to demonstrate transportation conformity for CO for the Boston metropolitan area.

In December 2008, EPA designated Massachusetts as “Attainment/Unclassifiable” area statewide for the 2006 24-hour $PM_{2.5}$ standard based on monitoring data. Likewise, in May 2012 EPA designated the Boston area as “Attainment/Unclassifiable” area for the ozone (O_3) standard based on monitoring data.

2.6.7 Background Concentration Levels

Background pollutant concentrations for CO, NO_2 and $PM_{2.5}$ were obtained from several MassDEP air quality monitoring stations in the Boston area. Hourly measurements or the highest recorded levels were used depending on the types of analyses.

Ambient NO_2 concentrations are measured at several air quality monitoring stations in the Boston area, including four sites in Boston. MassDEP operates and maintains Federal Reference Method (FRM) monitors for NO_2 at four sites in Boston: Kenmore Square, Von Hillern Street, Harrison Avenue, and Long Island.

Monitoring sites are located and established for various purposes. Table 2-5 summarizes several characteristics of the NO_2 monitoring sites and their surroundings in Boston as obtained from the EPA AirData website.

The selected conversion factor for the modeling compliance demonstration is the weighted average based on approximately 4,000 hourly concentrations collected at each of the two Albany Street monitors (Monitor Numbers 1 and 2) and inside the DST at Monitor Number 4. The resulting weighted average conversion factor for the two monitors is **0.075**. The summaries of the data by month, season and yearly totals are included in the last pages of Appendix H.

TABLE 2-5: BOSTON NO_2 MONITORING SITES

Parameter	Monitoring Locations			
	Kenmore Square	Von Hillern Street	Harrison Avenue	Long Island
Monitor Type	SLAMS	SLAMS	SLAMS	SLAMS
Site ID	250250002	250250044	250250042	250250041
Measurement Scale	Middle Scale	Middle Scale	Neighborhood	Urban Scale
Dominant Source Type	Mobile	Mobile	Area	N/A
Monitoring Objective	Population Exposure/ Highest Concentration	Near Road	Population Exposure	Population Exposure
Location Type	Commercial	N/A	Commercial	N/A
Monitoring Schedule	1 hour	1 hour	1 hour	1 hour
Number of NO_2 Monitors	1	1	1	1

Notes:
1. SLAMS = State and Local Air Monitoring Stations
2. Long Island station closed as of 10/2014
3. Measurement scale refers to the geographic extent over which measurements are assumed to be representative.
   Microscale = 0 to 100 meters
   Middle scale = 100 to 500 meters
   Neighborhood = 500 meters to 4 kilometers
   Urban Scale = 4 kilometers to 50 kilometers

Given the measurement scale, dominant source type, and monitoring objective of the various sites, measurements at the Harrison Avenue and Kenmore Square sites are the most representative of background concentrations of NO_2 for the Project area. Based on the mixed commercial/residential location of the Harrison Avenue site, the NO_2 monitoring data from the Harrison Avenue monitoring site are used as the primary source of data to establish NO_2 background levels representative of modeling domain. For hours when Harrison Avenue NO_2 data are not available (e.g., calibrations, missing for other reasons), Kenmore Square data is substituted. If there are no observations available from either monitor, the maximum value from the previous or next available hour is used. These background levels are incorporated in the analyses to demonstrate compliance with NAAQS for NO_2 for the ramp and VB NO_x emission limits. The hourly values are added to the hourly model output to obtain the total predicted (model + background) concentration resulting from the CA/T Ventilation System. Consistent with the form of the standards, the design values are compared to the 1-hour and annual NO_2 NAAQS, and MassDEP NO_2 Policy Guideline.

Hourly background monitoring data are also used to demonstrate compliance with the 1-hour and 8-hour CO NAAQS for the ramps and VB CO emission limits. Table 2-6 summarizes characteristics of the CO monitoring sites and their surroundings in Boston as obtained from the EPA AirData website.

As presented in Table 2-6 the CO monitors in Boston are Harrison Avenue, Kenmore Square, and Von Hillern Street. Those monitors are representative with Harrison Avenue being the primary site as discussed above for NO_2. For the modeled years of 2012 through 2015, the hourly Harrison Avenue values will be used. If the observation from Harrison Avenue is missing, then the hourly value from Von Hillern Street was used. If data from both Harrison Avenue and Von Hillern are missing, then data from Kenmore Square was used. CO monitoring at Kenmore Square was discontinued in January of 2015 and Von Hillern Street CO monitoring started in July of 2013; therefore both stations are used for substitutions. If there are no observations available from either monitor, the maximum value from the previous or next available hour was used when only one hour is missing. If there were two or more hours missing, linear interpolation was used. The CO NAAQS for 1-hour and 8-hour periods is not to be exceeded more than once per calendar year. The highest second high 1-hour and 8-hour impact values that include the hourly CO background for the period 2012-2015 was found for comparison to the CO NAAQS.

TABLE 2-6: BOSTON CO MONITORING SITES

Parameter	Monitoring Locations		
	Kenmore Square	Harrison Avenue	Von Hillern
Monitor Type	SLAMS	SLAMS	SLAMS
Site ID	250250002	250250042	250250044
Measurement Scale	Microscale	Neighborhood	Middle Scale
Dominant Source Type	Mobile	Area	Mobile
Monitoring Objective	Population Exposure/Highest Concentration	Population Exposure	Near Road
Location Type	Commercial	Commercial	Commercial
Monitoring Schedule	1 hour	1 hour	1 hour
Number of CO Monitors	1	1	1

Notes:
1. SLAMS = State and Local Air Monitoring Stations
2. Kenmore station closed 12/2014
3. Harrison Avenue and Von Hillern Street transitioned to trace CO analyzers in 2015
3. Measurement scale refers to the geographic extent over which measurements are assumed to be representative.
   Microscale = 0 to 100 meters
   Middle scale = 100 to 500 meters
   Neighborhood = 500 meters to 4 kilometers
   Urban Scale = 4 kilometers to 50 kilometers

Ambient $PM_{2.5}$ concentrations are measured at several air quality monitoring stations in the Boston area, including four sites in Boston. DEP operates and maintains Federal Reference Method (FRM) monitors for $PM_{2.5}$ at four sites in Boston: Kenmore Square, One City Square, Harrison Avenue, and North Street. The North Street Site includes two collocated $PM_{2.5}$ monitors.

Monitoring sites are located and established for various purposes. Table 2-7 summarizes several characteristics of the $PM_{2.5}$ monitoring sites and their surroundings in Boston as obtained from the EPA AirData website.

Given the measurement scale, dominant source type, and monitoring objective of the various sites, measurements at the North Street and Harrison Avenue sites are most representative of background levels of $PM_{2.5}$ for the Project area. Based on the more frequent monitoring at North Street, the presence of two collocated $PM_{2.5}$ monitors at North Street, and the higher $PM_{2.5}$ levels that are generally measured at that site compared to other sites in Boston, it was selected as the primary source of data to establish $PM_{2.5}$ background levels. If the observation from North Street is missing, then the daily value from Harrison Avenue was used. If data from both North Street and Harrison Avenue are missing, then data from Von Hillern Street was used. If data from all of the three previously listed stations are missing, then data from Kenmore Square was used. If there are still daily values missing after substitution then the annual design value data from the North Street site was used to calculate an annual monitoring design value based on the most recent available three years of data (2013-2015) and that design value was used.

TABLE 2-7: BOSTON $PM_{2.5}$ MONITORING SITES

Parameter	Monitoring Locations			
	Kenmore Square	Von Hillern	Harrison Avenue	174 North Street
Monitor Type	SLAMS	SLAMS	SLAMS	SLAMS
Site ID	250250002	250250044	250250042	250250043
Measurement Scale	Neighborhood	Neighborhood	Neighborhood	Neighborhood
Dominant Source Type	Mobile	Mobile	Area	Area
Monitoring Objective	Population Exposure/Highest Concentration	Near Road	Population Exposure	Population Exposure
Location Type	Commercial	Commercial	Commercial	Commercial
Monitoring Schedule	1-in-3 days	1 hour	1-in-3 days	Daily
Number of $PM_{2.5}$ Monitors	1	1	1	2

Notes:
1. SLAMS = State and Local Air Monitoring Stations
2. Measurement scale refers to the geographic extent over which measurements are assumed to be representative.
   Microscale = 0 to 100 meters
   Middle scale = 100 to 500 meters
   Neighborhood = 500 meters to 4 kilometers

These background levels were incorporated in the analyses to demonstrate compliance with NAAQS for $PM_{2.5}$ for the ventilation building $PM_{2.5}$ emission limits that will be proposed for the renewal of the Operating Certification.

Data from both $PM_{2.5}$ monitors at the North Street site will be used and analyzed in accordance with procedures in paragraph 3(d) of Appendix N (Interpretation of the National Ambient Air Quality Standards for $PM_{2.5}$) of 40 CFR Part 50 to determine a daily value. Specifically, if valid daily $PM_{2.5}$ values are available from each monitor, then the values were averaged to obtain a value for that day.

2.6.8 Volatile Organic Compounds (VOC)

Since there are no NAAQS for VOC, concentration-based emission limits for VOC were not established for comparison with measurements at specific receptor locations. Monitoring VOC could not resolve the aspect of how the total amount of VOC generated within the Project area can be compared to the no-build alternative.

Therefore, the following procedure to address the VOC requirements of 310 CMR 7.38 (4) and (2)(c) was developed by the MassDOT-MassDEP air quality working group and accepted by MassDEP on July 30, 2002.

- Prepare an updated emission estimate, which compares the total amount of VOC generated by motor vehicle activity within the Project area for two scenarios including the full operation of the CA/T Project (post opening – year 2005) and a No-Build condition for the same year 2005.
- Establish an emission budget for the Project study area based on the results of the VOC evaluation for year 2005.
- Verify that 2010 total VOC emissions for the study area are below the established emission budget. (2005 Build)

Based on the significant decreases in VOC motor vehicle emissions and the current O_3 attainment status for the Boston Metro area, MassDEP concurred with MassDOT at the February 16 and March 23, 2016 technical meetings, that the 2016 CA/T renewal certification presents a simplified approach to estimate reductions in regional VOC levels.

The CTPS (Boston Metro area MPO) who performed in the past the regional emission analysis as part of their planning and conformity process is not required to do the O_3 conformity analysis at present. The regional VOC demonstration approach is based in MOVES 2014a (EPA s' Motor Vehicle Emission Simulator) emission factors and projected percent increases in regional traffic levels. It is not dependent on the MPO regional conformity analysis used in the past.

The 2016 approach includes:

- A discussion of the previous approach to the VOC Emission Limit assessment and the reasons why it was changed to semi-quantitative.
- A presentation of historical CTPS's travel demand model VOC emission budget for the CA/T and its comparison with the 2005 baseline VOC budget.
- A discussion of Boston's previous nonattainment status for the ozone NAAQS and EPA's designation of Boston as an attainment area in July 2013.
- Measured ozone concentration trends in Suffolk County
- Trend data for nearest non-methane hydrocarbon monitoring station located in Lynn, MA
- Estimate of vehicular VOC emission factors based in MOVES2014a for the Suffolk County fleet based on input parameters obtained from MassDEP.
- MOVES 2014a runs for VOC in emission factor mode for years 2010 (the year of the 2012 TSD analysis), 2016 (Current Op Cert Renewal) and 2021 (to examine the future trend during the five year certification period).
- A description of CA/T average and peak traffic volumes covering the period 2006-2016, with projected increases for the future.
- An evaluation of VOC emission factors from 2010 to 2016 and 2021, which will provide the supporting evidence to demonstrate the VOC reductions when compared to the 2005 baseline emission budget.
- A semi-quantitative assessment of the 2016 and 2021 VOC emission budgets and comparison with the baseline year (2005).

The results of the 2016 VOC analysis are presented in Section 2.7.4.

2.7 EMISSION LIMIT DETERMINATION

The maximum hourly allowable emission limits (in ppm) for the VBs, DST and the specified exit ramps were determined using an iterative modeling process by increasing or decreasing the exhaust concentration in a prescribed interval as described below.

2.7.1 For Full Transverse Ventilation—Ventilation Buildings

2.7.1.1 Determination of Ventilation Building Emission Impacts

The VB emission impacts were evaluated using the AERMOD analytical model. The maximum predicted emission impacts, when added to the appropriate background pollutant concentrations were compared to the applicable ambient air quality standards (NAAQS) and MassDEP policy guideline value for compliance assessment. The entire modeling process was repeated until the maximum allowable emission limits at which ambient standards can still be attained were found. The detailed modeling procedures to determine VB emission impacts and emission limits can be found in Appendix B of this document.

2.7.1.2 Modeling Methodology

The modeling approach to the $PM_{2.5}$, CO and NO_x emission limit determinations was updated to incorporate current models, modeling guidance, treatment of terrain, and more recent meteorological and background data.

The 2006 VB emission impact analysis was performed using the EPA's Industrial Source Complex–Prime Model (ISC-Prime, 2004) in conjunction with the then most recent background air quality data collected in the area and five years of representative hourly meteorological data (see Section 2.6.7). Sensitive receptors such as building air intakes, operable windows, pedestrian walkways and potential receptors on proposed redevelopment projects within 2000 feet of each VB were updated to reflect the existing environment and future commercial development projection.

As discussed in Section 1, there are 22 ventilation zones in the CA/T ventilation system. In general each of these ventilation zones is equipped with more than one exhaust stack and each stack is dedicated to serving one exhaust fan. Fan speeds are controlled by 8 set point steps.

In the modeling, all stacks serving one ventilation zone are grouped together and treated as an individual emission point. The physical center of the stacks serving the same ventilation zone is treated as the center of the source in the modeling runs. The total stack exit area is used in calculation of the equivalent stack diameter. The total flow rate is divided by the total stack exit area to obtain the equivalent stack exit velocity. In 2006 a spectrum of four ventilation scenarios (based on fan steps 2, 3, 4 and 5) were selected to be modeled.

The predicted pollutant concentration consistent with the form of each air quality standard was added to the appropriate background level to estimate their combined impact and to compare to the applicable short or long-term air quality standard.

The 2011/12 $PM_{2.5}$, CO and NOx ventilation building analyses were performed using AERMOD, the currently recommended EPA air quality model. AERMOD is recommended for analyses where building downwash may be an important consideration. AERSURFACE, AERMET, AERMINUTE, AERMAP and the Building Profile Input Program for PRIME (BPIPPRM) were used to process meteorological, terrain information and information relating to building dimensions. These associated preprocessors are discussed in Appendix B the Air Quality Analysis Protocol for the Determination of CO, NOx and PM Emission Limits 2016 Application for the Renewal of the Operating Certification for the Project Ventilation System. AERMOD was run in the urban mode using recommended regulatory default options.

The current analysis was performed using the most recent version of AERMOD, version 15181 and it's pre-processors. Detailed discussion of inputs (meteorological, terrain, building configurations, emission variables, etc.) for AERMOD and its preprocessors are presented in Appendix B.

The 2006 analysis initially considered four ventilation scenarios (based on fan steps listed in Table 2-9). Since emission rates increase linearly with the increase in the exhaust flow rate, and ventilation rates at step 5 or above would only occur in cases of emergency (fire or smoke dissipation).

The VB analysis for the 2011/12 CA/T Renewal Operating Certification was based on step 4 fan speeds, the highest ventilation rate under the normal operations, which corresponds to 42% of ventilation capacity. Step 1 of the tunnel ventilation system, corresponding to the 13% of exhaust capacity, was also selected for modeling in order to analyze the low ventilation flows under the normal peak and off-peak traffic conditions. Those same ventilations steps were modeled for the current 2016 analysis.

TABLE 2-8: VENTILATION BUILDING OPERATING SCENARIOS

Scenario	Zone Step 1	Zone Step 2	Zone Step 3	Zone Step 4	Zone Step 5
Ventilation Rate (% of total exhaust capacity)	13	23	32	42	52

At each receptor location, an average of the eighth highest 24-hour concentrations including the corresponding background concentration for that day for the four modeled years was compared to the 24-hour NAAQS for $PM_{2.5}$. The annual average project impact at each receptor over four modeled years including the daily background concentration was compared to the annual NAAQS for $PM_{2.5}$.

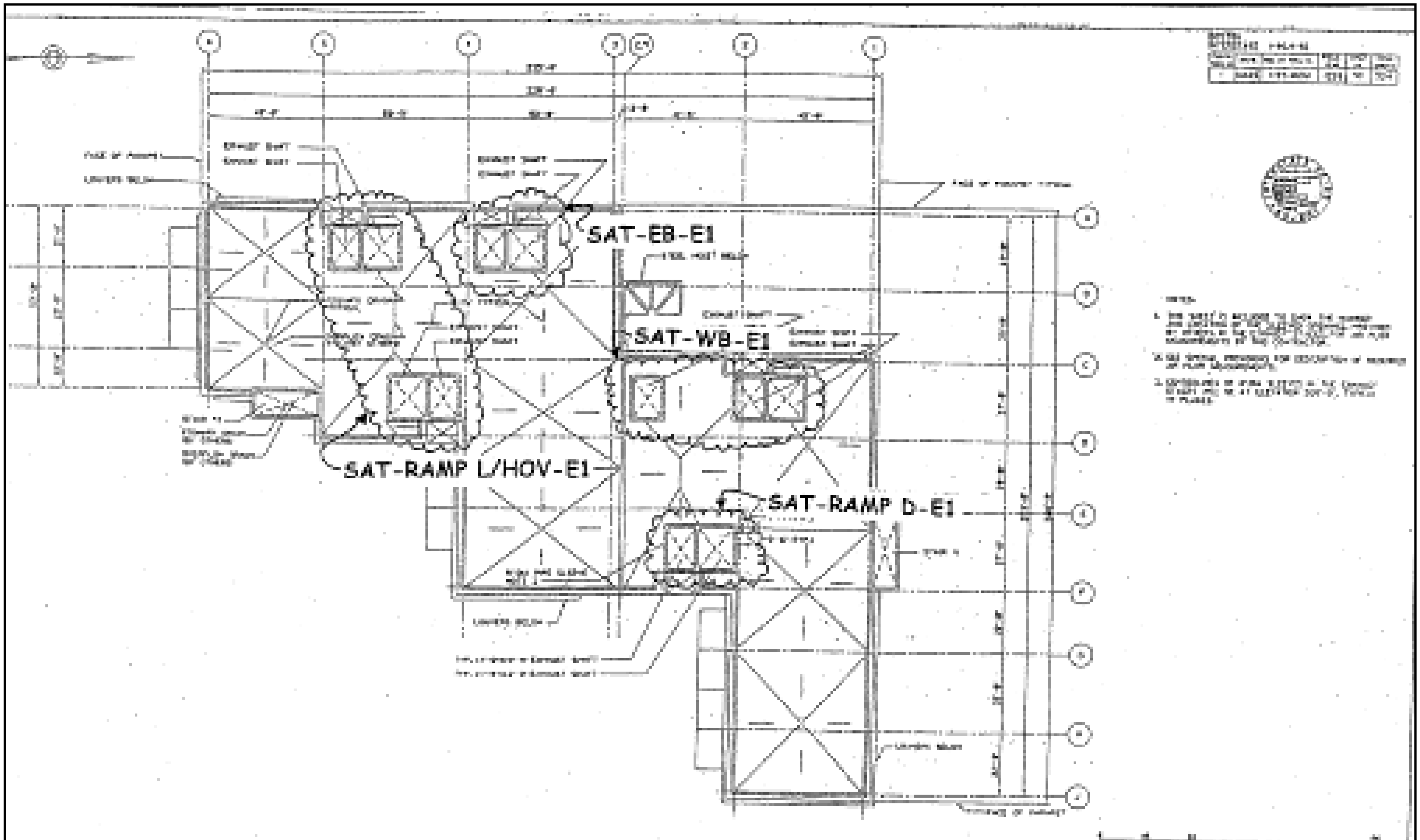
The highest second high 1-hour and 8-hour average CO predicted including hourly monitored background concentrations were compared the NAAQS.

The eighth highest (98th percentile) daily maximum 1-hour predicted including the corresponding hourly monitored background NO_2 concentration averaged over the 4-years at each receptor was compared to the hourly NO_2 NAAQS. The highest second high 1-hour average NO_2 predicted including hourly monitored background concentrations was compared to the MassDEP 1-hour NO_2 policy guideline concentration. The maximum predicted annual average NO_2 concentration plus background was compared to the annual NAAQS.

The maximum hourly allowable emission limits (in ppm for gaseous pollutants and µg/m^3 for particulates) for all VBs are identified using an iterative modeling process by increasing or decreasing the exhaust concentration in a specified interval.

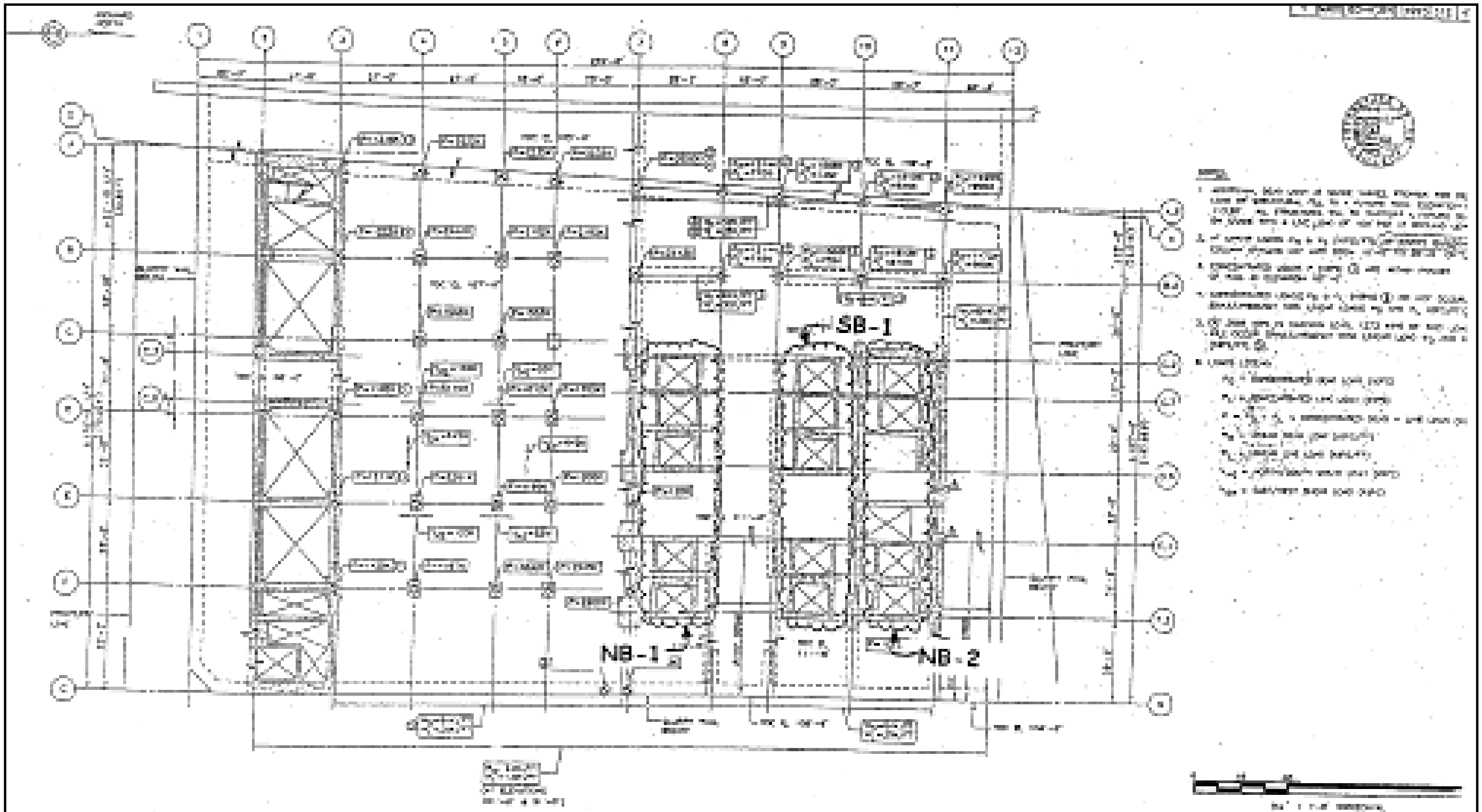
The 2016 model input data, including emission rates, exhaust flow rates, exhaust temperature, and number of fans by ventilation zone are presented in Table 2-10 and 2-11. The stack locations and configurations for all VBs are shown on Figures 2-3 through 2-8. Representative stack locations and sensitive receptors used in the modeling analysis are presented in Appendix B-3 in the 2016 Air Quality Analysis protocols in section 10-6 for 2016 analysis. They sensitive receptors are also presented at Figure 2-9. The 2016 VB modeling analysis input and output data are in Appendix C-1, respectively. Background levels used in this analysis are described in Section 2.6.7.

FIGURE 2-3: STACK CONFIGURATION VENTILATION BUILDING 1



VB #1 Roof Plan

FIGURE 2-4: STACK CONFIGURATION VENTILATION BUILDING 3



VB #3 Roof Plan

FIGURE 2-5: STACK CONFIGURATION VENTILATION BUILDING 4

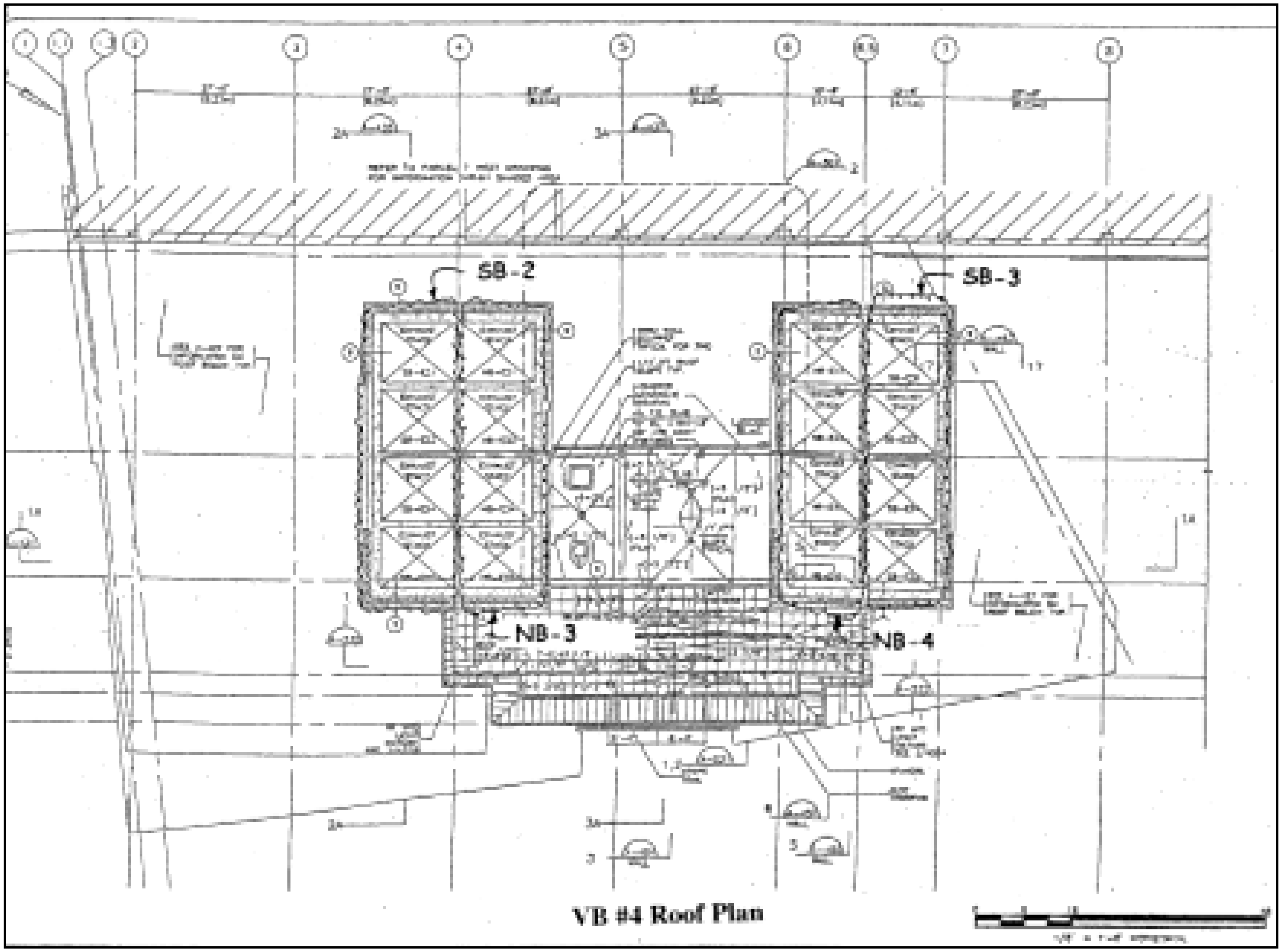
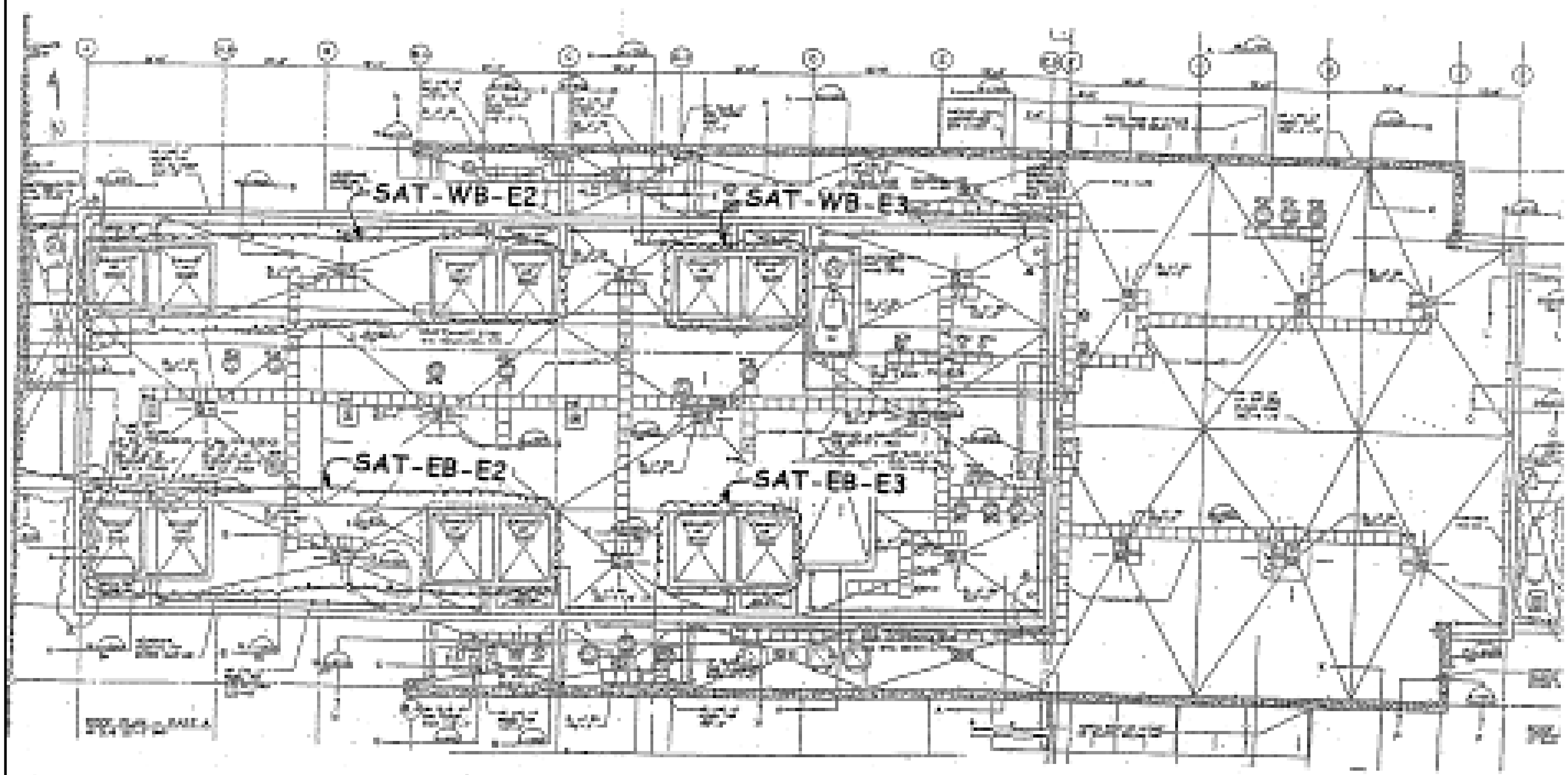
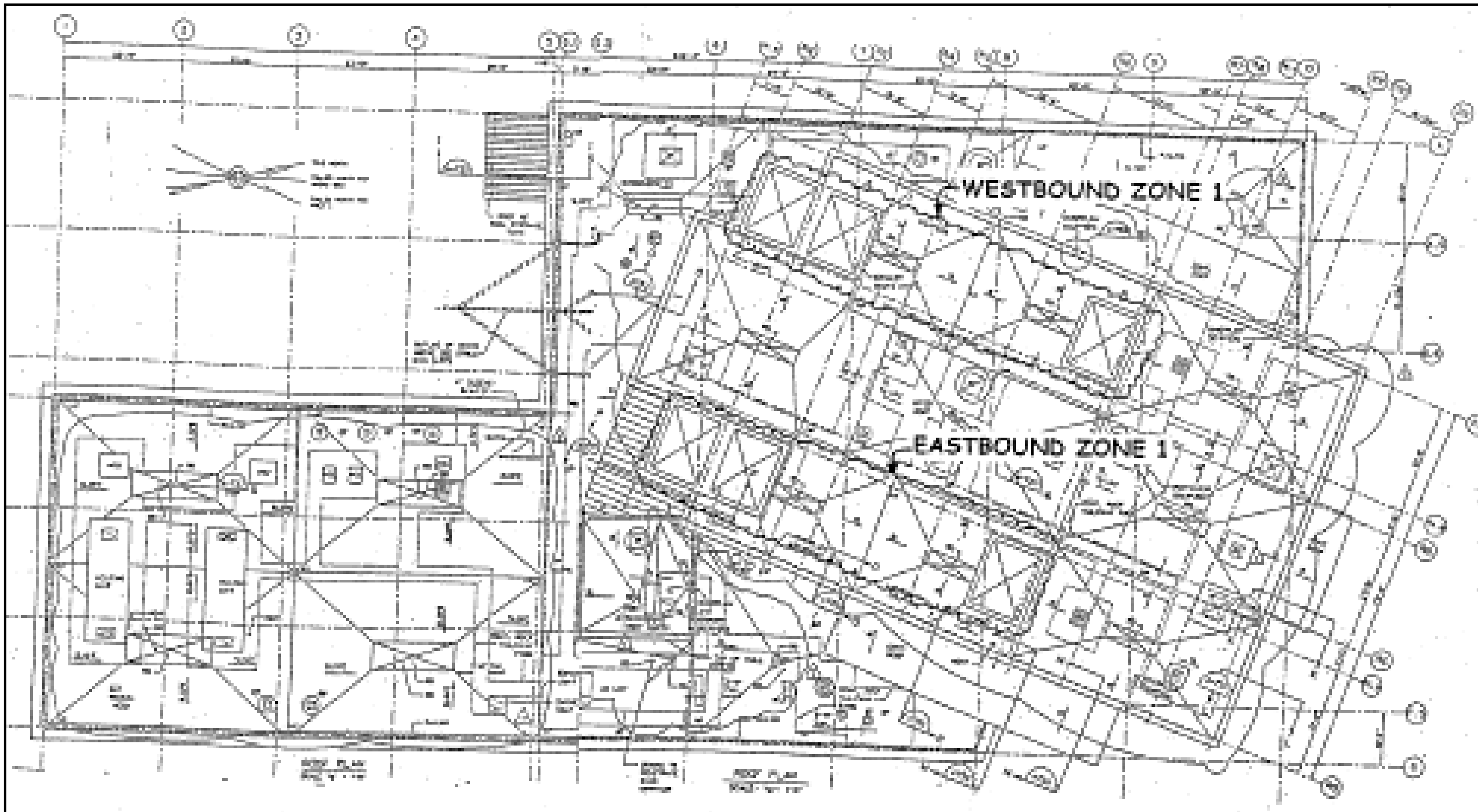


FIGURE 2-6: STACK CONFIGURATION VENTILATION BUILDING 5



VB #5 Roof Plan

FIGURE 2-7: STACK CONFIGURATION VENTILATION BUILDING 6



VB #6 Roof Plan

FIGURE 2-8: STACK CONFIGURATION VENTILATION BUILDING 7

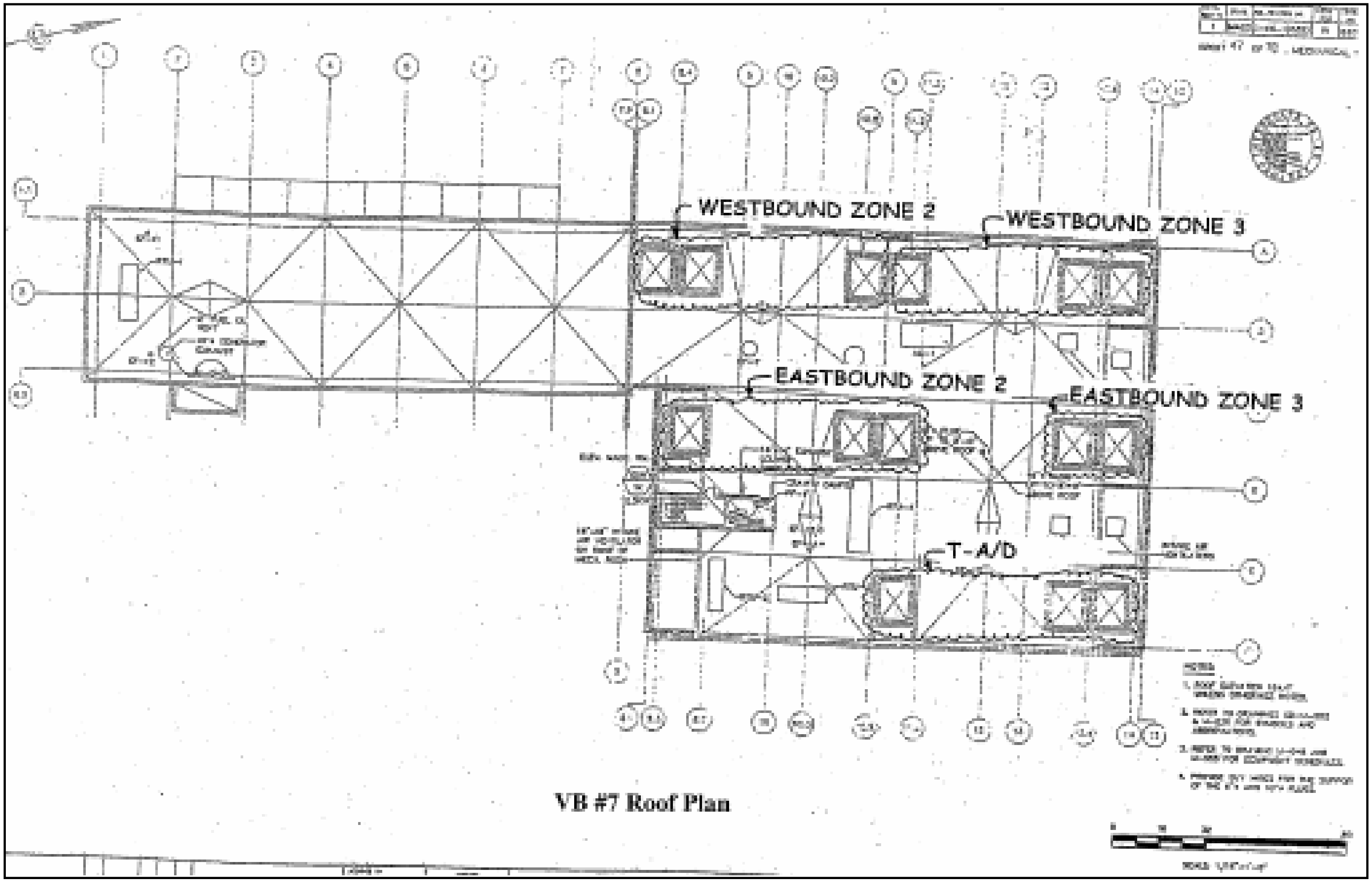


TABLE 2-9: MODEL INPUT PARAMETERS FOR VENTILATION BUILDINGS

Vent Building 3 (I-93 Tunnel)		Temperature		70	°F			Assumed								ISC Input		1 ppm of NOx =		1259.72	ug/m3
Vent Bldg	Zone	# of Fans	Capacity/ Fan (CFM)	Exhaust Capacity (CFM)	Step Used	% Capacity Used	Flow Rate (CFM)	PPM CO	Molecular Weigt CO	CO Density (lb/ft^3)	CFM CO	Total Mass Flow CO (g/sec)	Mass Flow CO/Stack (g/sec)	Area of a single cell (ft^2)	Total Exit Area (ft^2)	Exit Vel. (m/s)	Equ. Dia. (m)	NOx Conc. (ppm)*	NOx Molecular Wt**	NOx Conc. (ug/m3)	NOx Emis. (g/s)
3	SB-1	5	214000	1070000	4	0.42	449400	70	28	0.07238	31.46	17.21	3.44	106.6	533	4.28	7.94	8.876	30.8	11181.3	2.37
3	NB-1	5	251630	1258150	4	0.42	528423	70	28	0.07238	36.99	20.24	4.05	106.6	533	5.04	7.94	8.876	30.8	11181.3	2.79
3	NB-2	4	284750	1139000	4	0.42	478380	70	28	0.07238	33.49	18.32	4.58	106.6	426.4	5.70	7.10	8.876	30.8	11181.3	2.52
Vent Building 4																					
Vent Bldg	Zone	# of Fans	Capacity/ Fan (CFM)	Exhaust Capacity (CFM)	Step Used	% Capacity Used	Flow Rate (CFM)	PPM CO	Molecular Weigt CO	CO Density (lb/ft^3)	CFM CO	Total Mass Flow CO (g/sec)	Mass Flow CO/Stack (g/sec)	Area of a single cell (ft^2)	Total Exit Area (ft^2)	Exit Vel. (m/s)	Equ. Dia. (m)	NOx Conc. (ppm)*	NOx Molecular Wt**	NOx Conc. (ug/m3)	NOx Emis. (g/s)
4	SB-2	4	237250	949000	4	0.42	398580	70	28	0.07238	27.90	15.27	3.82	106.6	426.4	4.75	7.10	8.876	30.8	11181.3	2.10
4	SB-3	4	282625	1130500	4	0.42	474810	70	28	0.07238	33.24	18.19	4.55	106.6	426.4	5.66	7.10	8.876	30.8	11181.3	2.50
4	NB-3	4	221250	885000	4	0.42	371700	70	28	0.07238	26.02	14.24	3.56	106.6	426.4	4.43	7.10	8.876	30.8	11181.3	1.96
4	NB-4	4	202250	809000	4	0.42	339780	70	28	0.07238	23.78	13.01	3.25	106.6	426.4	4.05	7.10	8.876	30.8	11181.3	1.79
Vent Building 1 (I-90 Tunnel)																					
Vent Bldg	Zone	# of Fans	Capacity/ Fan (CFM)	Exhaust Capacity (CFM)	Step Used	% Capacity Used	Flow Rate (CFM)	PPM CO	Molecular Weigt CO	CO Density (lb/ft^3)	CFM CO	Total Mass Flow CO (g/sec)	Mass Flow CO/Stack (g/sec)	Area of a single cell (ft^2)	Total Exit Area (ft^2)	Exit Vel. (m/s)	Equ. Dia. (m)	NOx Conc. (ppm)*	NOx Molecular Wt**	NOx Conc. (ug/m3)	NOx Emis. (g/s)
1	SAT-Ramp D-E1	2	171500	343000	4	0.42	144060	70	28	0.07238	10.08	5.52	2.76	106.6	213.2	3.43	5.02	8.876	30.8	11181.3	0.76
1	SAT-WB-E1	3	230400	691200	4	0.42	290304	70	28	0.07238	20.32	11.12	3.71	106.6	319.8	4.61	6.15	8.876	30.8	11181.3	1.53
1	SAT-EB-E1	2	281820	563640	4	0.42	236729	70	28	0.07238	16.57	9.07	4.53	106.6	213.2	5.64	5.02	8.876	30.8	11181.3	1.25
1	SAT-Ramp L/HOV-E1	4	235250	941000	4	0.42	395220	70	28	0.07238	27.67	15.14	3.78	106.6	426.4	4.71	7.10	8.876	30.8	11181.3	2.08
Vent Building 5																					
Vent Bldg	Zone	# of Fans	Capacity/ Fan (CFM)	Exhaust Capacity (CFM)	Step Used	% Capacity Used	Flow Rate (CFM)	PPM CO	Molecular Weigt CO	CO Density (lb/ft^3)	CFM CO	Total Mass Flow CO (g/sec)	Mass Flow CO/Stack (g/sec)	Area of a single cell (ft^2)	Total Exit Area (ft^2)	Exit Vel. (m/s)	Equ. Dia. (m)	NOx Conc. (ppm)*	NOx Molecular Wt**	NOx Conc. (ug/m3)	NOx Emis. (g/s)
5	SAT-WB-E2	4	260000	1040000	4	0.42	436800	70	28	0.07238	30.58	16.73	4.18	106.6	426.4	5.20	7.10	8.876	30.8	11181.3	2.30
5	SAT-WB-E3	2	196500	393000	4	0.42	165060	70	28	0.07238	11.55	6.32	3.16	106.6	213.2	3.93	5.02	8.876	30.8	11181.3	0.87
5	SAT-EB-E2	4	278000	1112000	4	0.42	467040	70	28	0.07238	32.69	17.89	4.47	106.6	426.4	5.56	7.10	8.876	30.8	11181.3	2.46
5	SAT-EB-E3	2	279000	558000	4	0.42	234360	70	28	0.07238	16.41	8.98	4.49	106.6	213.2	5.58	5.02	8.876	30.8	11181.3	1.24
Vent Building 6 (Ted Wiliam Tunnel)																					
Vent Bldg	Zone	# of Fans	Capacity/ Fan (CFM)	Exhaust Capacity (CFM)	Step Used	% Capacity Used	Flow Rate (CFM)	PPM CO	Molecular Weigt CO	CO Density (lb/ft^3)	CFM CO	Total Mass Flow CO (g/sec)	Mass Flow CO/Stack (g/sec)	Area of a single cell (ft^2)	Total Exit Area (ft^2)	Exit Vel. (m/s)	Equ. Dia. (m)	NOx Conc. (ppm)*	NOx Molecular Wt**	NOx Conc. (ug/m3)	NOx Emis. (g/s)
6	Eastbound Zone 1	3	300000	900000	4	0.42	378000	70	28	0.07238	26.46	14.48	4.83	106.6	319.8	6.00	6.15	8.876	30.8	11181.3	1.99
6	Westbound Zone 1	3	300000	900000	4	0.42	378000	70	28	0.07238	26.46	14.48	4.83	106.6	319.8	6.00	6.15	8.876	30.8	11181.3	1.99
Vent Building 7																					
Vent Bldg	Zone	# of Fans	Capacity/ Fan (CFM)	Exhaust Capacity (CFM)	Step Used	% Capacity Used	Flow Rate (CFM)	PPM CO	Molecular Weigt CO	CO Density (lb/ft^3)	CFM CO	Total Mass Flow CO (g/sec)	Mass Flow CO/Stack (g/sec)	Area of a single cell (ft^2)	Total Exit Area (ft^2)	Exit Vel. (m/s)	Equ. Dia. (m)	NOx Conc. (ppm)*	NOx Molecular Wt**	NOx Conc. (ug/m3)	NOx Emis. (g/s)
7	Eastbound Zone 2	3	274000	822000	4	0.42	345240	70	28	0.07238	24.17	13.22	4.41	106.6	319.8	5.48	6.15	8.876	30.8	11181.3	1.82
7	Westbound Zone 2	3	231000	693000	4	0.42	291060	70	28	0.07238	20.37	11.15	3.72	106.6	319.8	4.62	6.15	8.876	30.8	11181.3	1.54
7	Eastbound Zone 3	2	226000	452000	4	0.42	189840	70	28	0.07238	13.29	7.27	3.64	106.6	213.2	4.52	5.02	8.876	30.8	11181.3	1.00
7	Westbound Zone 3	3	203000	609000	4	0.42	255780	70	28	0.07238	17.90	9.80	3.27	106.6	319.8	4.06	6.15	8.876	30.8	11181.3	1.35
7	T-A/D	3	194333	583000	4	0.42	244860	70	28	0.07238	17.14	9.38	3.13	106.6	319.8	3.89	6.15	8.876	30.8	11181.3	1.29

Notes:

1. Assumes all fans in a given zone are operating simultaneously.
2. Higher bound assumed conditions represent 70 ppm CO and Step 4 (a high ventilation rate for modeling purpose).

* NOx (ppm) = 0.196 + 0.124CO (ppm)

** NO_x molecular weight assumed for 95% NO and 5% NO_2

2.7.1.3 $PM_{2.5}$ Analysis

The $PM_{2.5}$ emission limits for the VBs were identified by starting the modeling process at an assumed concentration of 900 µg/m^3 for each stack in each VB. The modeling was performed using four years of meteorological data (2012 through 2016, described in section 2.6.5) and included daily background air quality data to obtain a total daily (24-hour) $PM_{2.5}$ concentration at each receptor. The 2016 model input data are in Tables 2-11 and 2-12. The 98th percentile daily value (i.e., the 8th highest 24-hour concentration) was determined for each year and at each receptor and these five levels at each receptor were averaged to obtain the 24-hour design value to be compared to the 24-hour NAAQS for $PM_{2.5}$. The annual design value was determined by averaging the annual modeled concentrations at each receptor over four modeled years including the daily background The annual design value was then compared to the annual NAAQS for $PM_{2.5}$. If results showed that an NAAQS was exceeded, the prospective $PM_{2.5}$ emission limit was decreased in intervals of 50 or 100 µg/m^3 and the modeling was repeated until both the 24-hour and annual NAAQS for $PM_{2.5}$ were met.

This process was conducted for Step 4 (Table 2-10) operating conditions and then repeated to verify that the same emission limit showed compliance with the NAAQS for Step 1 (Table 2-11) operating conditions.

TABLE 2-10: VENTILATION BUILDING EXHAUST AND STACK PARAMETERS – STEP 4 OPERATIONS

Ventilation Building	Number of Fans	Zone	Flow Rate (cfm)	Total Exit Area (ft^2)	Exit Velocity (m/s)	Equivalent Diameter (m)
1	2	SAT-Ramp D-E1	144,060	213.2	3.43	5.02
1	3	SAT-WB-E1	290,304	319.8	4.61	6.15
1	2	SAT-EB-E1	236,729	213.2	5.64	5.02
1	4	SAT-Ramp L/HOV-E1	395,220	426.4	4.71	7.10
3	5	SB-1	449,400	533	4.28	7.94
3	5	NB-1	528,423	533	5.04	7.94
3	4	NB-2	478,380	426.4	5.70	7.10
4	4	SB-2	398,580	426.4	4.75	7.10
4	4	SB-3	474,810	426.4	5.66	7.10
4	4	NB-3	371,700	426.4	4.43	7.10
4	4	NB-4	339,780	426.4	4.05	7.10
5	4	SAT-WB-E2	436,800	426.4	5.20	7.10
5	2	SAT-WB-E3	165,060	213.2	3.93	5.02
5	4	SAT-EB-E2	467,040	426.4	5.56	7.10
5	2	SAT-EB-E3	234,360	213.2	5.58	5.02
6	3	EB Zone 1	378,000	319.8	6.00	6.15
6	3	WB Zone 1	378,000	319.8	6.00	6.15
7	3	EB Zone 2	345,240	319.8	5.48	6.15
7	3	WB Zone 2	291,060	319.8	4.62	6.15
7	2	EB Zone 3	189,840	213.2	4.52	5.02
7	3	WB Zone 3	255,780	319.8	4.06	6.15
7	3	T-A/D	244,860	319.8	3.89	6.15

TABLE 2-11: VENTILATION BUILDING EXHAUST AND STACK PARAMETERS – STEP 1 OPERATIONS

Ventilation Building	Number of Fans	Zone	Flow Rate (cfm)	Total Exit Area (ft^2)	Exit Velocity (m/s)	Equivalent Diameter (m)
1	2	SAT-Ramp D-E1	44,590	213.2	1.06	5.02
1	3	SAT-WB-E1	89,856	319.8	1.43	6.15
1	2	SAT-EB-E1	73,273	213.2	1.75	5.02
1	4	SAT-Ramp L/HOV-E1	122,330	426.4	1.46	7.10
3	5	SB-1	139,100	533	1.33	7.94
3	5	NB-1	163,560	533	1.56	7.94
3	4	NB-2	148,070	426.4	1.76	7.10
4	4	SB-2	123,370	426.4	1.47	7.10
4	4	SB-3	146,965	426.4	1.75	7.10
4	4	NB-3	115,050	426.4	1.37	7.10
4	4	NB-4	105,170	426.4	1.25	7.10
5	4	SAT-WB-E2	135,200	426.4	1.61	7.10
5	2	SAT-WB-E3	51,090	213.2	1.22	5.02
5	4	SAT-EB-E2	144,560	426.4	1.72	7.10
5	2	SAT-EB-E3	72,540	213.2	1.73	5.02
6	3	EB Zone 1	117,000	319.8	1.86	6.15
6	3	WB Zone 1	117,000	319.8	1.86	6.15
7	3	EB Zone 2	106,860	319.8	1.70	6.15
7	3	WB Zone 2	90,090	319.8	1.43	6.15
7	2	EB Zone 3	58,760	213.2	1.40	5.02
7	3	WB Zone 3	79,170	319.8	1.26	6.15
7	3	T-A/D	75,790	319.8	1.20	6.15

The 24-hour and annual modeling results for each VB and for the cumulative impact from all are presented in Tables 2-12 and 2-13, respectively. In the cumulative analysis the receptor with the maximum 8th highest 24-hour concentration averaged over five years for Step 4 over a rectangular grid receptor located at ground level immediately adjacent to VB4. The controlling concentration (30.6 µg/m^3) was due entirely to impacts from VB4 and background. The impacts from Step 4 were higher than those for Step 1, the level at which the Project ventilation system normally operates. The receptor with the maximum annual Project impact averaged over five years for Step 4 (11.8 µg/m^3) in the cumulative analysis was a rectangular grid receptor located at ground level immediately adjacent to VB4. Most (approximately 99%) of the controlling impact predicted at this receptor was attributable to emissions from VB4.

TABLE 2-12: MAXIMUM 24-HOUR AND ANNUAL $PM_{2.5}$ CONCENTRATIONS FROM INDIVIDUAL VENTILATION BUILDINGS AT AMBIENT RECEPTORS FOR COMPLIANCE DEMONSTRATION (µG/M^3) BASED ON A SOURCE LEVEL OF 550 (µG/M^3)

VB	Predicted 24 hour Design Value	Predicted Annual Design Value
VB 1	23.4	10.5
VB 3	19.9	9.4
VB 4	31.0	11.8
VB 5	20.8	9.5
VB 6	18.5	8.9
VB 7	21.4	11.5

Notes: $PM_{2.5}$ NAAQS: 24-Hour - 35 µg/m^3; Annual - 12 µg/m^3
Annual $PM_{2.5}$ background level - 10.5 µg/m^3

TABLE 2-13: MAXIMUM CUMULATIVE 24-HOUR AND ANNUAL $PM_{2.5}$ CONCENTRATIONS FROM ALL VENTILATION BUILDINGS FOR COMPLIANCE DEMONSTRATION (μG/M^3) BASED ON A SOURCE LEVEL OF 550 (μG/M^3)

All VB	Predicted 24 hour Design Value	Predicted Annual Design Value
	31.0	11.9

Notes: $PM_{2.5}$ NAAQS: 24-Hour - 35 μg/m^3; Annual - 12 μg/m^3

2.7.1.4 CO and NO_2 Analysis

CO Emission Limits

CO emission limits for the VBs were identified by starting the modeling process at an assumed concentration of 70 ppm CO for each stack in each VB. The AERMOD modeling was performed using four years of meteorological data (2012 through 2016, described in section 2.6.5) and included hourly background air quality data to obtain a total CO concentration (simultaneous predicted plus monitored concentrations) at each receptor. The highest second high 1-hour and 8-hour average concentrations were determined in each year over all four modeling and monitoring years and at each receptor and the highest second high concentration design values were compared to the NAAQS for CO. If the results showed that an NAAQS was exceeded, the prospective CO emission limit would be decreased in intervals of 1 ppm and the modeling was repeated until both the 1-hour and 8-hour average NAAQS for CO were met.

This process was conducted for Step 4 operating conditions and then repeated to verify that the same emission limit showed compliance with the NAAQS for Step 1 operating conditions.

NO_x Emission Limits

As described in Section 2.6.3, the in-tunnel NO_x concentration can be determined from the in-tunnel CO concentration based on the presented regression equation. Thus, beginning at 70 ppm CO for the VBs, a NO_x emission rate was calculated using the regression equation. NO_x emission modeling was conducted using AERMOD with the 2012 to 2016 meteorological input data set. Based on the local, site specific NO_x conversion data from the DST air quality monitoring system, the NO_x emissions were adjusted to account for both direct NO_2 emissions in the tunnels and for the conversion of NO to NO_2 in the ambient air.

As described in Section 2.6.4, 5 percent of the NO_x in the tunnel air was determined to be NO_2 contributing to direct emissions. In addition, 7.5 percent of the NO_x emitted from the VBs and impacting the nearby receptors was modeled as NO_2 to account for NO to NO_2 conversion. Thus, a total of 12.5 percent of the NOx emitted from the VBs was modeled as NO_2.

The modeled NO_2 was combined with the concurrent hourly background NO_2 concentrations to yield the total predicted plus monitored hourly ambient NO_2 concentration at each receptor.

In each modeling year, the 98th percentile (eighth highest) maximum daily 1-hour concentration, the highest second high 1-hour concentration and the annual average concentration were determined. The average of the 98th percentile daily maximum 1-hour concentrations over the four modeling years found using AERMOD model output was compared to the 1-hour NAAQS for NO_2.

The overall highest second high concentration from all four modeling years was compared to the Massachusetts 1-Hour NO_2 Guideline value. Finally, the highest annual average NO_2 concentration from all five modeling years was compared to the annual NO_2 NAAQS.

2.7.1.5 CO and NOx Input Parameters and Modeling Results

Figure 2-9 presents the sensitive receptor locations analyzed during the modeling compliance analysis for all the VBs.

Table 2-14 and 2-15 present the modeling input parameters with the CO and NO_x emission rates for each VB source for Step 1 and Step 4, respectively. These modeling parameters were input into the AERMOD model and resulted in a demonstration of compliance.

Presented in Table 2-16 are the NAAQS comparable predicted concentrations for CO based on a source level of 70 ppm. All VBs meet the CO NAAQS at a 70 ppm source level.

Table 2-17 presents the predicted NO_2 concentrations from the VBs comparable to the NAAQS. Table 2-19 presents the predicted concentrations comparable to the MassDEP 1-hr NO_2 Guideline. The model predicted concentrations plus the concurrent background concentrations at a source level of 6.1 ppm NOx (equivalent of 70 ppm CO) meet the NO_2 NAAQS and the MassDEP 1-hr NO_2 Guideline.

FIGURE 2-9: SENSITIVE RECEPTORS AND VENTILATION BUILDING LOCATIONS

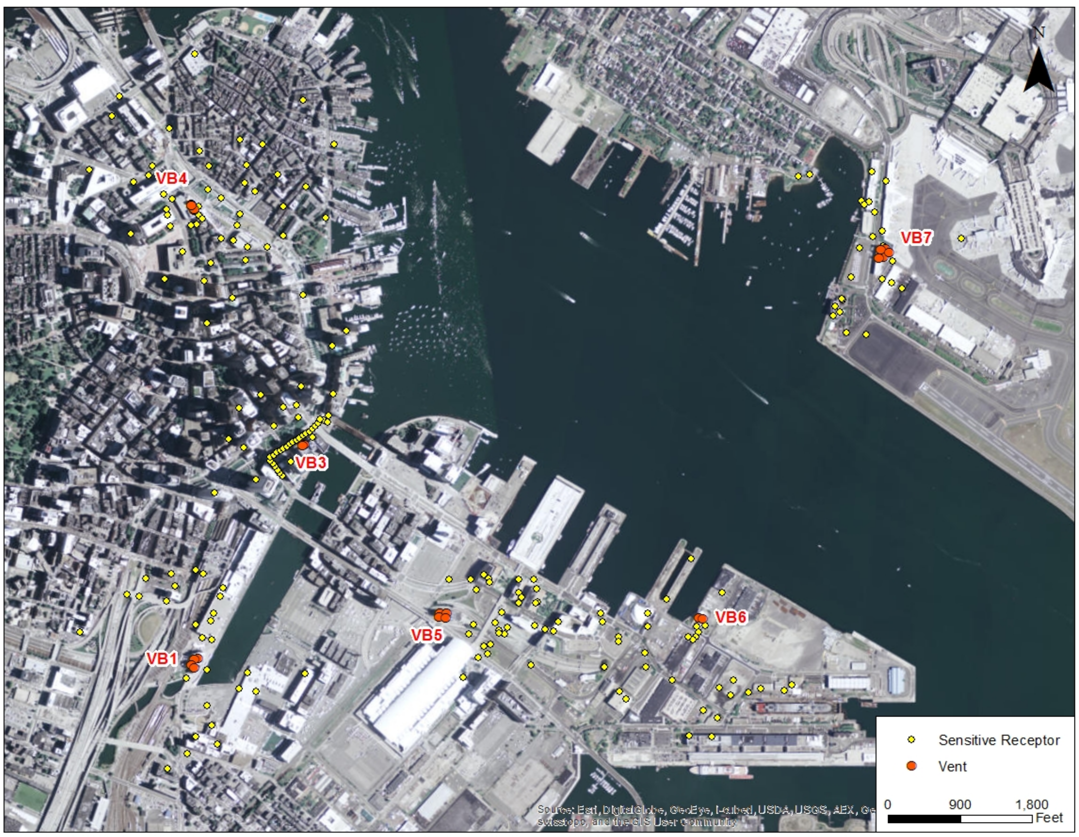


TABLE 2-14: MODELING INPUT PARAMETERS FOR STEP 1

VB	Zone (TSD Table 2-7)	Zone 2006 Modeling	Zone 2011/2012 Modeling	# of Fans	Fan Capacity (cfm)	Zone capacity (cfm)	Step 1 cfm	Fan area (ft^2)	Exit area (ft^2)	Height (m)	vs (ft/sec)	vs (m/s)	Equiv. D (m)	CO Emission Limit (ppm)	CO Emissions (g/s)	NOx Emission Limit (ppm)	NOx Emissions (g/s)
1	SAT-Ramp D-E1	RampD	B1_RampD	2	171,500	343,000	44,590	106.6	213.2	36.9	3.49	1.06	5.02	70.00	1.69	6.10	0.162
1	SAT-WB-E1	WestB	B1_WestB	3	230,400	691,200	89,856	106.6	319.8	36.9	4.68	1.43	6.15	70.00	3.40	6.10	0.327
1	SAT-EB-E1	EastB	B1_EastB	2	281,820	563,640	73,273	106.6	213.2	36.9	5.73	1.75	5.02	70.00	2.77	6.10	0.266
1	SAT-Ramp L/HOV-E1	RampL	B1_RampL	4	235,250	941,000	122,330	106.6	426.4	36.9	4.78	1.46	7.10	70.00	4.63	6.10	0.445
3	SB-1	Vent2	B3_SB1	5	214,000	1,070,000	139,100	106.6	533.0	84.6	4.35	1.33	7.94	70.00	5.26	6.10	0.506
3	NB-1	Vent1	B3_NB1	5	251,630	1,258,150	163,560	106.6	533.0	84.6	5.11	1.56	7.94	70.00	6.19	6.10	0.595
3	NB-2	Vent3	B3_NB2	4	284,750	1,139,000	148,070	106.6	426.4	84.6	5.79	1.76	7.10	70.00	5.60	6.10	0.538
4	SB-2	SB2	B4_SB2	4	237,250	949,000	123,370	106.6	426.4	39.9	4.82	1.47	7.10	70.00	4.67	6.10	0.449
4	SB-3	SB3	B4_SB3	4	282,625	1,130,500	146,965	106.6	426.4	39.9	5.74	1.75	7.10	70.00	5.56	6.10	0.534
4	NB-3	NB3	B4_NB3	4	221,250	885,000	115,050	106.6	426.4	39.9	4.50	1.37	7.10	70.00	4.35	6.10	0.418
4	NB-4	NB4	B4_NB4	4	202,250	809,000	105,170	106.6	426.4	39.9	4.11	1.25	7.10	70.00	3.98	6.10	0.382
5	SAT-WB-E2	WBE2	B5_WBE2	4	260,000	1,040,000	135,200	106.6	426.4	54.3	5.28	1.61	7.10	70.00	5.11	6.10	0.492
5	SAT-WB-E3	WBE3	B5_WBE3	2	196,500	393,000	51,090	106.6	213.2	54.3	3.99	1.22	5.02	70.00	1.93	6.10	0.186
5	SAT-EB-E2	EBE2	B5_EBE2	4	278,000	1,112,000	144,560	106.6	426.4	54.3	5.65	1.72	7.10	70.00	5.47	6.10	0.526
5	SAT-EB-E3	EBE3	B5_EBE3	2	279,000	558,000	72,540	106.6	213.2	54.3	5.67	1.73	5.02	70.00	2.74	6.10	0.264
6	Eastbound Zone 1	WBZ1	B6_WBZ1	3	300,000	900,000	117,000	106.6	319.8	27.6	6.10	1.86	6.15	70.00	4.43	6.10	0.425
6	Westbound Zone 1	EBZ1	B6_EBZ1	3	300,000	900,000	117,000	106.6	319.8	27.6	6.10	1.86	6.15	70.00	4.43	6.10	0.425
7	Eastbound Zone 2	EB2	B7_EB2	3	274,000	822,000	106,860	106.6	319.8	32.9	5.57	1.70	6.15	70.00	4.04	6.10	0.389
7	Westbound Zone 2	WB2	B7_WB2	3	231,000	693,000	90,090	106.6	319.8	32.9	4.70	1.43	6.15	70.00	3.41	6.10	0.328
7	Eastbound Zone 3	EB3	B7_EB3	2	226,000	452,000	58,760	106.6	213.2	32.9	4.59	1.40	5.02	70.00	2.22	6.10	0.214
7	Westbound Zone 3	WB3	B7_WB3	3	203,000	609,000	79,170	106.6	319.8	32.9	4.13	1.26	6.15	70.00	3.00	6.10	0.288
7	T-A/D	TAD	B7_TAD	3	194,333	582,999	75,790	106.6	319.8	32.9	3.95	1.20	6.15	70.00	2.87	6.10	0.276

TABLE 2-15: MODELING INPUT PARAMETERS FOR STEP 4

VB	Zone (TSD Table 2-7)	Zone 2006 Modeling	Zone 2011/2012 Modeling	# of Fans	Fan Capacity (cfm)	Zone capacity (cfm)	Step 4 cfm	Fan area (ft^2)	Exit area (ft^2)	Height (m)	vs (ft/sec)	vs (m/s)	Equiv. D (m)	CO Emission Limit (ppm)	CO Emissions (g/s)	NOx Emission Limit (ppm)	NOx Emissions (g/s)
1	SAT-Ramp D-E1	RampD	B1_RampD	2	171,500	343,000	144,060	106.6	213.2	36.9	11.26	3.43	5.02	70.00	5.45	6.10	0.524
1	SAT-WB-E1	WestB	B1_WestB	3	230,400	691,200	290,304	106.6	319.8	36.9	15.13	4.61	6.15	70.00	10.98	6.10	1.056
1	SAT-EB-E1	EastB	B1_EastB	2	281,820	563,640	236,729	106.6	213.2	36.9	18.51	5.64	5.02	70.00	8.96	6.10	0.861
1	SAT-Ramp L/HOV-E1	RampL	B1_RampL	4	235,250	941,000	395,220	106.6	426.4	36.9	15.45	4.71	7.10	70.00	14.95	6.10	1.437
3	SB-1	Vent2	B3_SB1	5	214,000	1,070,000	449,400	106.6	533.0	84.6	14.05	4.28	7.94	70.00	17.00	6.10	1.634
3	NB-1	Vent1	B3_NB1	5	251,630	1,258,150	528,423	106.6	533.0	84.6	16.52	5.04	7.94	70.00	19.99	6.10	1.921
3	NB-2	Vent3	B3_NB2	4	284,750	1,139,000	478,380	106.6	426.4	84.6	18.70	5.70	7.10	70.00	18.10	6.10	1.739
4	SB-2	SB2	B4_SB2	4	237,250	949,000	398,580	106.6	426.4	39.9	15.58	4.75	7.10	70.00	15.08	6.10	1.449
4	SB-3	SB3	B4_SB3	4	282,625	1,130,500	474,810	106.6	426.4	39.9	18.56	5.66	7.10	70.00	17.96	6.10	1.726
4	NB-3	NB3	B4_NB3	4	221,250	885,000	371,700	106.6	426.4	39.9	14.53	4.43	7.10	70.00	14.06	6.10	1.352
4	NB-4	NB4	B4_NB4	4	202,250	809,000	339,780	106.6	426.4	39.9	13.28	4.05	7.10	70.00	12.85	6.10	1.235
5	SAT-WB-E2	WBE2	B5_WBE2	4	260,000	1,040,000	436,800	106.6	426.4	54.3	17.07	5.20	7.10	70.00	16.53	6.10	1.588
5	SAT-WB-E3	WBE3	B5_WBE3	2	196,500	393,000	165,060	106.6	213.2	54.3	12.90	3.93	5.02	70.00	6.24	6.10	0.600
5	SAT-EB-E2	EBE2	B5_EBE2	4	278,000	1,112,000	467,040	106.6	426.4	54.3	18.26	5.56	7.10	70.00	17.67	6.10	1.698
5	SAT-EB-E3	EBE3	B5_EBE3	2	279,000	558,000	234,360	106.6	213.2	54.3	18.32	5.58	5.02	70.00	8.87	6.10	0.852
6	Eastbound Zone 1	WBZ1	B6_WBZ1	3	300,000	900,000	378,000	106.6	319.8	27.6	19.70	6.00	6.15	70.00	14.30	6.10	1.374
6	Westbound Zone 1	EBZ1	B6_EBZ1	3	300,000	900,000	378,000	106.6	319.8	27.6	19.70	6.00	6.15	70.00	14.30	6.10	1.374
7	Eastbound Zone 2	EB2	B7_EB2	3	274,000	822,000	345,240	106.6	319.8	32.9	17.99	5.48	6.15	70.00	13.06	6.10	1.255
7	Westbound Zone 2	WB2	B7_WB2	3	231,000	693,000	291,060	106.6	319.8	32.9	15.17	4.62	6.15	70.00	11.01	6.10	1.058
7	Eastbound Zone 3	EB3	B7_EB3	2	226,000	452,000	189,840	106.6	213.2	32.9	14.84	4.52	5.02	70.00	7.18	6.10	0.690
7	Westbound Zone 3	WB3	B7_WB3	3	203,000	609,000	255,780	106.6	319.8	32.9	13.33	4.06	6.15	70.00	9.68	6.10	0.930
7	T-A/D	TAD	B7_TAD	3	194,333	582,999	244,860	106.6	319.8	32.9	12.76	3.89	6.15	70.00	9.26	6.10	0.890

TABLE 2-16: HIGHEST 2ND HIGH 1-HOUR AND 8-HOUR PREDICTED CO CONCENTRATIONS FROM VENTILATION BUILDINGS AT AMBIENT RECEPTORS FOR COMPLIANCE DEMONSTRATION

AERMOD Predicted CO Impacts (ppm)
2nd Highest Value including Hourly Background for Comparison to NAAQS
70 ppm Source concentration of CO

Source Description	1-hour Average (ppm)				8-hour Average (ppm)			
	2012	**2013**	**2014**	**2015**	**2012**	**2013**	**2014**	**2015**
Ventilation Step 1								
VB 1	5.65	4.51	4.22	6.19	1.75	1.58	1.59	1.71
VB 3	2.58	2.67	2.88	2.79	1.72	1.11	1.14	1.00
VB 4	5.11	4.35	4.94	4.40	2.93	2.45	2.58	3.19
VB 5	2.46	2.94	2.81	2.98	1.60	1.22	1.01	1.02
VB 6	2.58	2.82	2.39	2.49	1.62	1.22	1.29	1.25
VB 7	3.11	2.80	2.82	2.54	2.12	1.41	1.43	1.28
All VB combined	**5.65**	**4.51**	**4.94**	**6.19**	**2.93**	**2.45**	**2.59**	**3.19**
Ventilation Step 4								
VB 1	12.47	11.84	10.31	12.41	4.33	4.83	3.95	3.93
VB 3	4.66	4.24	5.67	4.98	1.86	1.55	2.25	1.63
VB 4	6.17	6.49	6.50	6.38	4.72	4.27	4.53	5.13
VB 5	6.47	7.19	6.66	7.34	2.97	2.62	2.44	2.14
VB 6	2.77	2.86	2.54	2.59	1.68	1.49	1.76	1.82
VB 7	3.30	3.47	3.27	3.41	2.33	2.22	2.25	2.16
All VB combined	**12.47**	**11.84**	**10.31**	**12.42**	**4.72**	**4.93**	**4.53**	**5.13**
Maximum VB Plus Background Impact	**12.47**	**11.84**	**10.31**	**12.42**	**4.72**	**4.93**	**4.53**	**5.13**
NAAQS	**35**				**9**			

TABLE 2-17: PREDICTED NO_2 DESIGN CONCENTRATIONS FROM VENTILATION BUILDINGS AT AMBIENT RECEPTORS FOR NAAQS COMPLIANCE DEMONSTRATION

AERMOD Predicted NO_2 Impacts (ppm)
One-hour and Annual Concentrations including background for Comparison to NAAQS
6.1 ppm Source concentration of NO_x

Source Description	**Period**	
	1-hr	**Annual**
Ventilation Step 1		
VB 1	0.056	0.019
VB 3	0.051	0.018
VB 4	0.056	0.019
VB 5	0.052	0.018
VB 6	0.051	0.018
VB 7	0.052	0.019
All VB combined	**0.056**	**0.019**
Ventilation Step 4		
VB 1	0.094	0.020
VB 3	0.057	0.018
VB 4	0.068	0.021
VB 5	0.064	0.019
VB 6	0.051	0.018
VB 7	0.055	0.020
All VB combined	**0.094**	**0.021**
Maximum VB Plus Background Impact	**0.094**	**0.021**
NAAQS	**0.100**	**0.053**

* The maximum 4-year average of the 98th percentile (8th Highest) of the daily maximum 1-hour average

TABLE 2-18: PREDICTED NO_2 DESIGN CONCENTRATIONS FROM VENTILATION BUILDINGS AT AMBIENT RECEPTORS FOR MASSDEP GUIDELINE COMPLIANCE DEMONSTRATION

AERMOD Predicted 1-hr NO_2 Impacts (ppm)
2nd Highest Value including Background Comparison to MassDEP 1-hr Standard
6.1 ppm Source concentration of NO_x

	1-hour Average			
Source Description	**2012**	**2013**	**2014**	**2015**
Ventilation Step 1				
VB 1	0.073	0.061	0.062	0.071
VB 3	0.067	0.058	0.061	0.060
VB 4	0.068	0.066	0.062	0.060
VB 5	0.068	0.058	0.062	0.058
VB 6	0.068	0.058	0.062	0.057
VB 7	0.071	0.061	0.063	0.060
All VB combined	**0.073**	**0.066**	**0.063**	**0.071**
Ventilation Step 4				
VB 1	0.114	0.104	0.101	0.108
VB 3	0.068	0.069	0.064	0.078
VB 4	0.080	0.082	0.077	0.072
VB 5	0.071	0.075	0.072	0.075
VB 6	0.070	0.058	0.060	0.060
VB 7	0.074	0.068	0.067	0.062
All VB combined	**0.114**	**0.104**	**0.101**	**0.108**
Maximum VB Plus Background Impact	**0.114**	**0.104**	**0.101**	**0.108**
MassDEP One-hour Policy Guideline	**0.170**			

2.7.2 For Longitudinal Ventilation − Exit Ramps and DST

2.7.2.1 Modeling Procedures to Determine the Impact of Exit Portal Emissions

The plume of exhaust air that comes out of an exit portal in the wake of exiting vehicles has high pollutant concentrations because of the limited dispersion of pollutants within the tunnel. This plume maintains its integrity for a distance downstream of the exit portal due to the momentum created by the moving cars. This distance depends on the geometry of the roadway after the tunnel exit, the traffic flow characteristics, such as speed and density, meteorological conditions (wind direction), and other factors affecting the turbulence and dispersion of the plume. Given the complexity of the air flow patterns and geometries of tunnel portals, physical models were used to analyze the effect of the tunnel emissions.

The air quality dispersion modeling analyses to determine emission limits for the three longitudinally ventilated ramps and the DST are based on the dilution coefficients obtained through the 1996 physical simulation study for the longitudinally ventilated ramps and through the 2005 DST physical simulation study described below.

1996 CA/T Physical Simulation Studies

Physical simulation studies (i.e., wind tunnel tests) were performed in support of the air quality evaluation for the *Notice of Project Change (NPC)/Environmental Reevaluation (ER) for the Implementation of Longitudinal Ventilation in the Area North of Causeway Street and Central Area, October 1996* (1996 Longitudinal Ventilation NPC/ER).

The changes analyzed in the 1996 Longitudinal Ventilation NPC/ER were the direct results of the emissions that previously were vented through the exhaust stacks of VB 8 (eliminated with longitudinal ventilation), and that now are exhausted through the exit portals of ramps CN-S and L-CS. Another change included a small portion of emissions that previously were vented through VB3 and VB4, and which now is vented through the exit portals of the ramps SA-CN, ST-CN, ST-SA, CS-SA and CS-P.

Another physical simulation study was performed for Ramp F as part of the air quality evaluation for the Notice of Project Change (NPC)/Environmental Reevaluation (ER) for the South Bay/South Boston Areas. In order to simplify the ducting system for VB5, the ventilation of exit ramp F was removed from VB5. Exit ramp F now is longitudinally ventilated by the piston action of the vehicles with the addition of jet fans exhausting the air through its exit portal during emergency conditions.

In order to replicate the effects of the air flows created by the moving traffic at these exit ramps, six 1:100 and 1:200 scale models were built at the RWDI wind tunnel testing facility in Guelph, Ontario.

Each model included the individual ramps, and its surrounding buildings within 800 to 1,600 feet from each portal. The scenarios with and without the development of parcels 6 and 12 were also studied. The effects of the moving vehicles were simulated using moving belts, with attached semi spheres representing the aerodynamic characteristics of the predicted traffic speed and density. Specially designed spires and roughness blocks were distributed on the floor upwind of the test section of the wind tunnel to provide a simulation of background turbulence and mean wind speed profiles in the wind flow approaching the modeled area. Urban and suburban profiles were used to simulate the upwind terrain for each area.

Several dimensionless scale parameters are important for the physical model simulation. These parameters were calculated using the full scale information and were then reproduced on the scale model. The parameters included Reynolds numbers, velocity ratios and dimensionless vehicle drag. For the Reynolds numbers, it was necessary to ensure turbulent flow conditions, but not necessary to reproduce the full scale values precisely.

Wind tunnel flow visualization tests were initially performed to determine the most likely locations of the highest impacts, and detailed tracer gas tests were performed at the identified high impact locations, including sensitive public areas, and air intakes of the surrounding buildings. These tests were performed for the peak hour, and the 8-hour traffic scenarios at each ramp.

Tracer gas tests were performed at the wind tunnel facility for each ramp, at each specified traffic and parcel development scenario. Monitoring of the tracer gas concentrations, at all the receptors identified during the flow visualization tests, allowed for the predictions of the concentrations at these locations under a variety of wind direction and speed conditions. The tracer gas concentration measured at each receptor location was recorded as a percentage of the gas concentration measured at the exit portal (this data provides what can be described as a dilution ratio for each location).

In order to cover a full range of meteorological conditions, three wind speeds (at low, medium, and high range) and 24 wind angles (at 15° intervals) were tested for each scenario.

A full description of the study methodology and results was prepared in the report *Physical Simulation Study for the Implementation of Longitudinal Ventilation Systems in the Area North of Causeway and Central Area*, prepared by RWDI, October 1996. The report was submitted to MassDEP as part of the 1996 Longitudinal Ventilation NPC/ER.

Figures 2-10 to 2-12 identify the location of each ramp analyzed, and the most critical receptors in terms of highest potential impacts recorded for each source scenario analyzed.

The receptor locations identified in the in the 1996 Longitudinal Ventilation RWDI report were field checked in order to include only ambient street level, operable windows and air intake locations of existing buildings. Receptor locations from 1996 for non-existent buildings, sidewalks, plazas or areas that do not represent the current condition were removed from the 2012 analysis.

FIGURE 2-10: RAMP CN-S - PORTAL LOCATION AND CRITICAL RECEPTOR

FIGURE 2-11: RAMP CS-SA – PORTAL LOCATION AND CRITICAL RECEPTORS

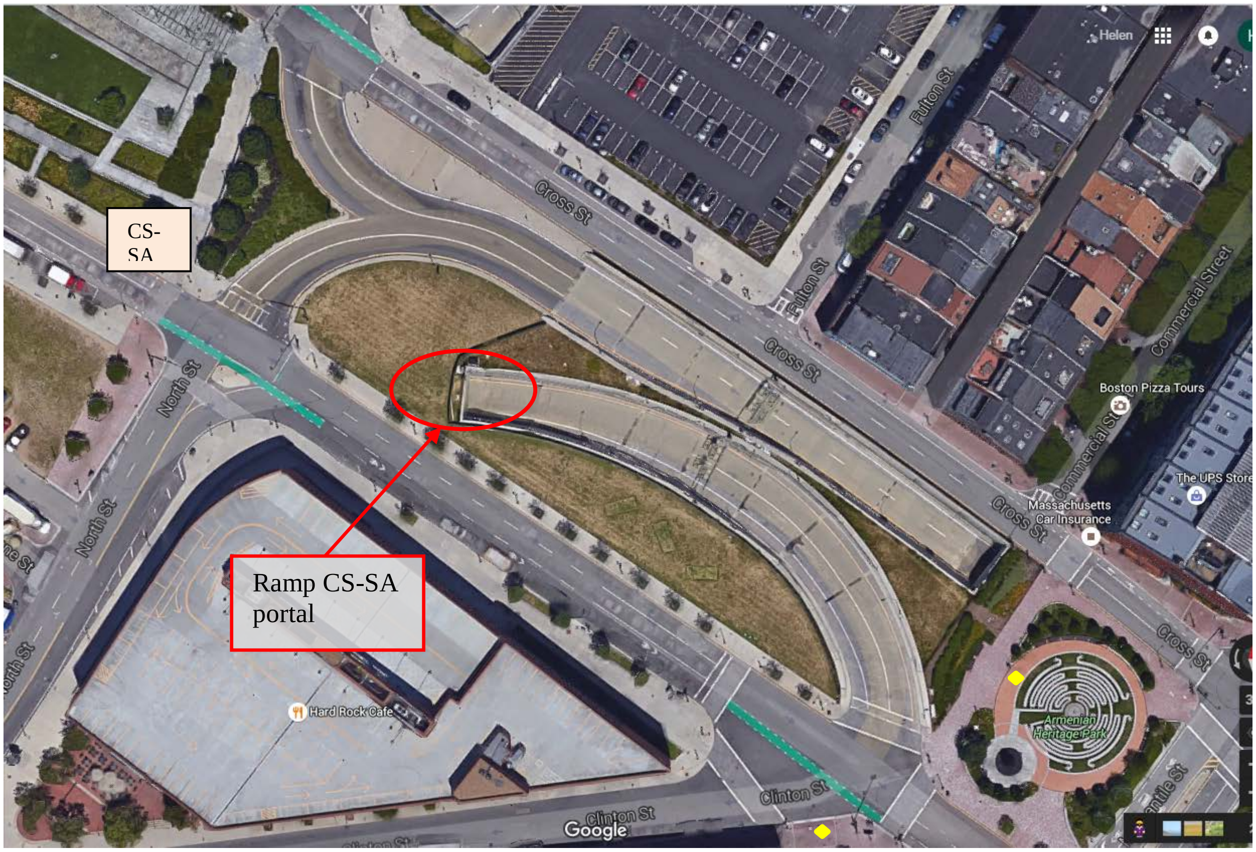


FIGURE 2-12: RAMP CS-P- PORTAL LOCATION AND CRITICAL RECEPTORS

2005 DST Physical Simulation Study

Due to the proposed commercial building development immediately downstream and adjacent to the tunnel portal, a physical simulation study was performed to evaluate the effects of tunnel motor vehicle emissions on the existing environment, the proposed building configurations and the associated sidewalks.

The objective of the 2005 exhaust dispersion study was to evaluate different Build scenarios (from No-Build to fully developed Parcels 24, 25 and 26a), and how these scenarios would affect the dispersion of exhaust from the two vehicle tunnel portals located south of Kneeland Street. These two portals carry the I-93 south-bound mainline traffic (CASB), and the I-90 collector traffic (Ramp H/Slip Ramp). The sources included in this assessment were the exhausts from the CASB and Ramp H/Slip Ramp exit portals.

Three physical configurations evaluated included:

- Configuration 1 – the relocated CASB portal (400 feet south of Kneeland Street) with development at Parcels 24, 25 and 26a (Figure 2-13). Future once Parcel 25 is developed.
- Configuration 2 – the existing CASB portal location with development at Parcels 24 and 26a and low existing retaining wall (Figure 2-14). Current 2016 configuration represents existing conditions.
- Configuration 3 – the existing "No-Build" condition without any development on Parcels 24, 25 and 26a is no longer in existence due to development of Parcel 24.

The exhaust flow from the two portals was simulated using a fan system exhausting through the modeled vehicle tunnels. The pollutants of concern for this assessment were CO, and NO_2.

Flow visualization tests were initially performed to determine the most likely location of the highest impacts, and detailed tracer gas tests were performed at the identified high impact locations, including sensitive public areas, and air intakes of the surrounding buildings.

A full description of the study methodology and results was included in the final report *Air Quality Study Dewey Square Portal Boston, Massachusetts*, prepared by RWDI, January 2006.

The detailed modeling procedures used for determination of the DST emission impacts and emission limits can be found in Appendix B-3 ("2016 Air Quality Analysis Protocol for Determination of CO and NOx Emission Limits for the Renewal of the Operating Certification of the Project Ventilation Systems") of this document.

FIGURE 2-13: DEWEY SQUARE TUNNEL – CONFIGURATION 1 – FUTURE

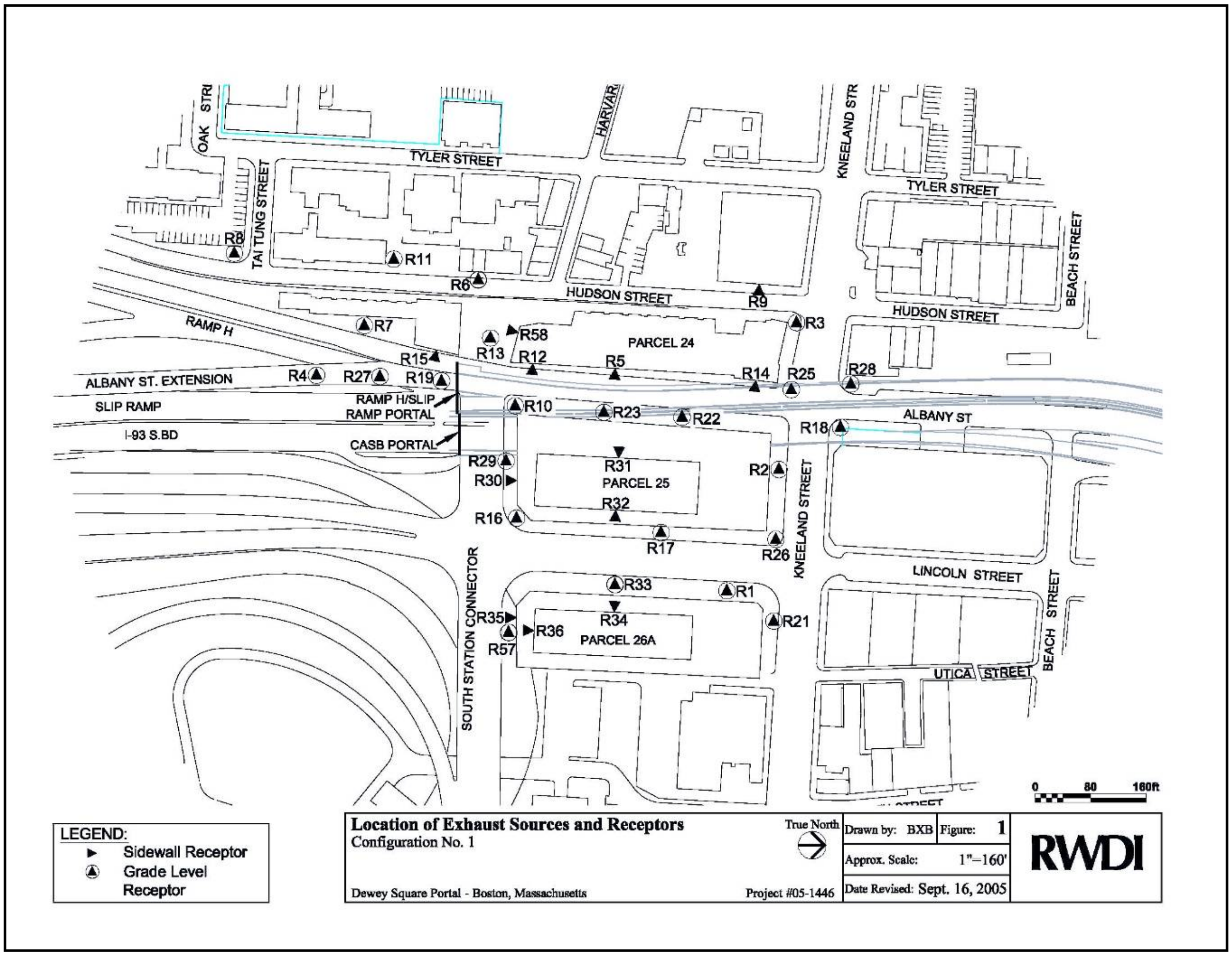
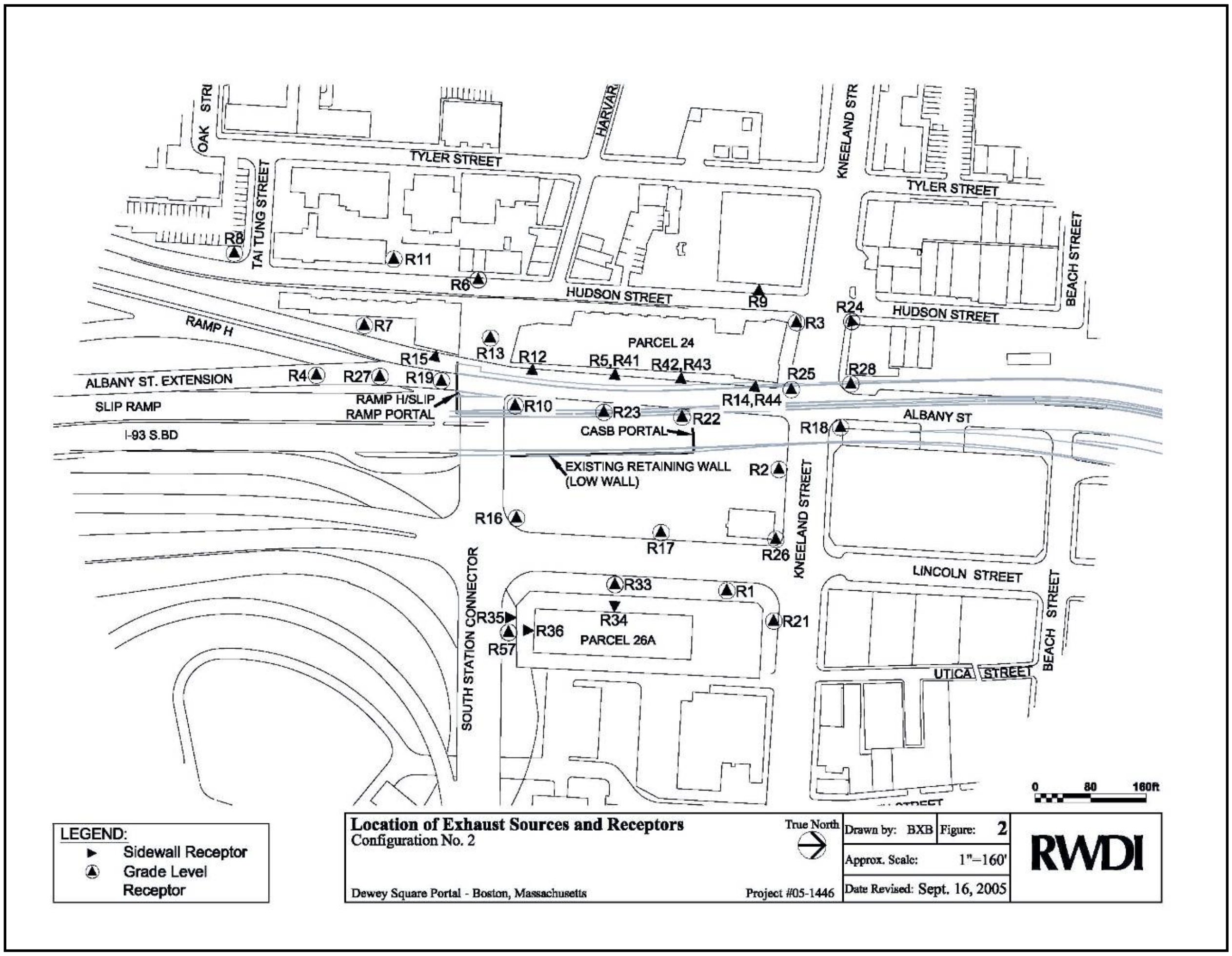


FIGURE 2-14: DEWEY SQUARE TUNNEL – CONFIGURATION 2 - EXISTING 2016



2.7.2.2 Use of Physical Simulation Data

The air quality dispersion modeling analysis to determine the emission limits for the longitudinally ventilated ramps and the DST is based on the dilution coefficients obtained through the 1996 physical simulation study for the longitudinally ventilated ramps and through the 2005 DST physical simulation study.

The dilution factors obtained for the three wind speeds and 24 wind angles for each scenario at each receptor location for the longitudinally ventilated ramps were used to create a series of matrices. These matrices provide the tracer gas concentration measured at each receptor location as a percentage of the full concentration measured at the exit portal (this is the dilution ratio).

This dilution ratio was applied to the full-scale source concentration for each pollutant analyzed, and interpolated using the four years (2012–2016) of meteorological data from Logan Airport in order to obtain pollutant levels corresponding to the NAAQS and MassDEP NO_2 Policy Guideline at each receptor location.

The receptor locations were the ambient locations (public access and buildings windows and/or air intake locations) used in the 1996 and 2005 physical simulation studies corrected to remove locations that do not currently exist, or are not accessible to the public. The site plans and the most critical receptors for the longitudinally ventilated ramps are presented on Figures 2-10 to 2-16.

2.7.2.3 CO Analysis

The CO emission source level for the exit ramps was analyzed in the range from 20 to 70 ppm for each portal. Peak-hour flow conditions (and associated dilution factors) were used for the one-hour analysis, and 8-hour flow conditions (and associated dilution factors) were used for the 8-hour analysis. Five years of actual meteorological observations from the Logan Airport were used to determine the critical source level at which both 1-hour and 8-hour NAAQS would be potentially violated. The critical source level was identified to the nearest ppm. The one and eight-hour emission limit is established as source level 1 ppm lower than the critical level or as the highest level at which both NAAQS would not be potentially violated.

An in-house program was created to multiply the emission source level by the dilution factor (from the physical simulation study matrix). This program also applies bilinear interpolation to the ratios from the dilution matrix to account for the actual wind speed and wind direction at each hour of the year from the meteorological data set of 4 years (2012 to 2016). In addition, the program adds the hourly CO background concentration for the respective hour.

The form of the equation is:

$CO_{\text{(at receptor)}} = CO_{\text{(at source-portal)}} \text{ x Dilution Factor}_{\text{(N hour)}} + CO_{\text{(background N-hour)}}$

$CO_{\text{(at source-portal)}}$ = from 20 to 70 ppm

Dilution Factor $_{\text{(N hour)}}$ = f(Wind Speed, Wind Direction)

N-hour = each hour for the full calendar year

EPA modeling procedures described in Section 9.3.4.2 of the *USEPA Guideline on Air Quality Models (EPA-450/2-78-027R)* were used for calm winds and missing meteorological data. In the case of missing background CO concentration, the program sets the level for that specific hour to zero. This also follows the procedures provided in the reference cited above.

The program output prints the 1st and 2nd highest levels for each source strength for the year indicating the date and hour of occurrence.

The eight-hour analysis procedure is based on the average of eight sequential one-hour results printing the 1st and 2nd non-overlapping highest levels for the year indicating date and the ending hour of the eight-hour period.

Tables 2-19 through 2-23 summarize the compliance demonstrations for the 1-hour and 8-hour NAAQS for CO for each ramp. The tables list 2nd high concentrations, consistent with the form of the CO NAAQS which allow for each short-term standard to be exceeded once per year. Concentrations are listed in units of ppm. The corresponding NAAQS for CO are 9 ppm for the 8-hour standard and 35 ppm for the 1-hour standard.

TABLE 2-19: 1- AND 8-HOUR CO LEVELS FOR COMPLIANCE DEMONSTRATION: RAMP CN-S (PPM)

Ramp CN-S									
	One Hour CO				Eight Hour CO				
Year	Receptor	Source CO	2nd Highest Level	Date Hour	Receptor	Source CO	2nd Highest Level	Date	Ending Hour
2012	22	70	14.42	08/15/12 04	22	59	8.99	03/02/12	21
2013	22	70	14.50	4/6/2013 24	22	61	8.88	12/20/13	11
2014	22	70	14.18	9/10/2014 23	22	65	8.97	01/11/14	8
2015	22	70	13.79	12/09/15 10	22	69	8.98	04/22/15	10

TABLE 2-20: 1- AND 8-HOUR CO LEVELS FOR COMPLIANCE DEMONSTRATION: RAMP CS-SA EXISTING NO PARCEL 12 DEVELOPMENT (PPM)

Ramp CS-SA no Parcel 12									
	One Hour CO				Eight Hour CO				
Year	Receptor	Source CO	2nd Highest Level	Date Hour	Receptor	Source CO	2nd Highest Level	Date	Ending Hour
2012	34	70	15.57	3/19/12 09	33	54	8.93	09/12/12	8
2013	34	70	15.27	9/6/13 10	34	58	8.90	08/21/13	9
2014	34	70	15.10	3/7/14 08	33	66	8.91	09/04/14	9
2015	34	70	14.55	12/01/15 04	34	63	8.92	12/25/15	11

TABLE 2-21: 1- AND 8-HOUR CO LEVELS FOR COMPLIANCE DEMONSTRATION: RAMP CS-P (PPM)

Ramp CS-P									
	One Hour CO				Eight Hour CO				
Year	Receptor	Source CO	2nd Highest Level	Date Hour	Receptor	Source CO	2nd Highest Level	Date	Ending Hour
2012	19	70	14.25	6/23/12 05	19	70	4.90	02/15/12	8
2013	19 &20	70	14.09	11/17/13 01	19	70	4.51	02/23/13	8
2014	19 &20	70	14.72	8/3/2014 02	1	70	4.40	09/24/14	18
2015	19 &20	70	13.56	7/17/15 08	19	70	3.84	06/05/15	8

TABLE 2-22: 1- AND 8-HOUR CO LEVELS FOR COMPLIANCE DEMONSTRATION – DEWEY SQUARE TUNNEL: CONFIGURATION 1 (PPM)

CONFIG 1									
	One Hour CO				Eight Hour CO				
Year	Receptor	Source CO	2nd Highest Level	Date Hour	Receptor	Source CO	2nd Highest Level	Date	Ending Hour
2012	7	70	23.16	11/30/12 05	27	26	8.99	03/04/12	15
2013	27	70	22.98	12/14/13 17	22	26	8.92	10/12/13	19
2014	7	70	22.87	8/17/14 20	27	27	8.83	01/03/14	21
2015	27	70	22.40	3/28/15 02	4	29	8.87	01/15/15	8

TABLE 2-23: 1- AND 8-HOUR CO LEVELS FOR COMPLIANCE DEMONSTRATION – DEWEY SQUARE TUNNEL: CONFIGURATION 2 (PPM)

CONFIG 2									
	One Hour CO				Eight Hour CO				
Year	Receptor	Source CO	2nd Highest Level	Date Hour	Receptor	Source CO	2nd Highest Level	Date	Ending Hour
2012	27	70	23.12	11/30/12 05	4	24	8.99	07/29/12	9
2013	27	70	22.98	12/14/13 03	23	26	8.92	10/12/13	19
2014	4	70	22.71	3/18/14 06	4	25	8.82	12/24/14	15
2015	4	70	22.20	9/30/15 21	23	27	8.88	06/01/15	24

2.7.2.4 NO_2 Analysis

For each ramp multiple runs were performed using a NO_x portal emission source ranging from 1.95 ppm (20 ppm CO equivalent) to 6.10 ppm (70 ppm CO equivalent) at 1 ppm CO equivalent intervals.

A similar to CO ramp analysis in-house program was created to multiply the emission source by the dilution factor (a physical simulation study matrix), interpolate to the closest wind direction and speed for each hour of the year (repeating for four years), and adding the hourly NO_2 background concentrations for the respective hour.

The equations for the relationship between CO and NO_x and between NO_x and NO_2 are presented in sections 2.6.3 and 2.6.4.

The total NO_2 level at each receptor is a combination of NO_2 directly emitted by motor vehicles (5% of the NO_x emitted in the tunnel was considered to be NO_2), the conversion factor of 7.5% from NO to NO_2, and the background NO_2 level for the corresponding hour.

The program outputs the first 10 highest daily concentrations at each modeled receptor for each year modeled. The one-hour NO_2 average of the 8^{th} highest daily concentrations (98^{th} percentile) for the four years (2012 to 2016) was used to determine emission limit.

Emission limits are set for the source concentration at which the highest receptors are below the four year average of 100 ppb (0.1 ppm or 188 $\mu g/m^3$) NO_2 NAAQS.

The highest one-hour level for each one of the five years was used for verifying that the selected emission limits complies with the MassDEP NO_2 Policy Guideline of 170 ppb (0.17 ppm or 320 $\mu g/m^3$). This is conservative, since the MassDEP Policy allows one exceedance per year.

The annual compliance with the NO_2 NAAQS of 53 ppb (0.053 ppm or 100 $\mu g/m^3$) was demonstrated by comparing the annual average results for each year including the hourly background concentrations to the NO_2 annual NAAQS.

Tables 2-24 through 2-28 provide the results of these analyses and identify the highest source level for which all receptor locations analyzed comply with the one-hour and annual NO_2 NAAQS and MassDEP NO_2 Policy Guideline.

TABLE 2-24: 1-HOUR NO_2 LEVELS FOR COMPLIANCE DEMONSTRATION: RAMP CN-S (PPM)

Ramp CN-S																
	MassDEP One Hour Policy Guidance Level						One Hour NO_2 NAAQS						Annual NO_2 NAAQS			
Year	Receptor	Source CO	Source NO_x	1st Highest NO_2	Date	Hour	Receptor	Source CO	Source NO_x	8th Highest NO_2	Date	Hour	Receptor	Source CO	Source NO_x	Annual
2012	22	70	6.10	0.163	5/19/2012	22	22	39	3.50	0.099	01/07/12	11	22	70	6.10	0.045
2013	22	69	6.00	0.169	06/04/13	24	22	35	3.20	0.098	01/09/13	11	22	70	6.10	0.045
2014	30	70	6.10	0.138	03/11/14	21	22	39	3.50	0.0999	11/12/14	17	22	70	6.10	0.043
2015	22	70	6.10	0.163	03/25/15	9	22	35	3.20	0.098	02/12/15	10	22	70	6.10	0.044

TABLE 2-25: 1-HOUR NO_2 LEVELS FOR COMPLIANCE DEMONSTRATION: RAMP CS-SA – EXISTING NO PARCEL 12 (PPM)

Ramp CS-SA no Parcel 12																
	MassDEP One Hour Policy Guidance Level						One Hour NO_2 NAAQS						Annual NO_2 NAAQS			
Year	Receptor	Source CO	Source NO_x	1st Highest NO_2	Date	Hour	Receptor	Source CO	Source NO_x	8th Highest NO_2	Date	Hour	Receptor	Source CO	Source NO_x	Annual
2012	34	65	5.70	0.168	3/28/2012	23	34	37	3.40	0.0986	05/18/12	2	33	70	6.10	0.046
2013	3	70	6.10	0.156	10/04/13	23	34	36	3.30	0.0980	09/20/13	6	33	70	6.10	0.046
2014	34	64	5.60	0.169	03/07/14	8	34	35	3.20	0.098	02/17/14	24	33	70	6.10	0.045
2015	3	66	5.80	0.169	09/08/15	21	34	59	5.20	0.0997	01/29/15	8	33	70	6.10	0.045

TABLE 2-26: 1-HOUR NO_2 LEVELS FOR COMPLIANCE DEMONSTRATION: RAMP CS-P (PPM)

Ramp CS-P																
	MassDEP One Hour Policy Guidance Level						One Hour NO_2 NAAQS						Annual NO_2 NAAQS			
Year	Receptor	Source CO	Source NO_x	1st Highest NO_2	Date	Hour	Receptor	Source CO	Source NO_x	8th Highest NO_2	Date	Hour	Receptor	Source CO	Source NO_x	Annual
2012	19 & 20	70	6.10	0.158	2/29/2012	10	19 & 20	42	3.80	0.0985	03/23/12	6	19	70	6.10	0.029
2013	1	70	6.10	0.132	04/25/13	21	19 & 20	41	3.70	0.0994	10/16/13	19	19	70	6.10	0.029
2014	19 & 20	64	5.60	0.168	03/12/14	4	19 & 20	35	3.20	0.099	02/18/14	9	19	70	6.10	0.027
2015	19 & 20	70	6.10	0.153	04/06/15	7	19 & 20	59	5.20	0.0989	11/25/15	11	19	70	6.10	0.027

TABLE 2-27: 1-HOUR NO_2 LEVELS FOR COMPLIANCE DEMONSTRATION – DST: FUTURE CONFIGURATION 1 (PPM)

Dewey Square Tunnel CONFIG 1																
	MassDEP One Hour Policy Guidance Level						One Hour NO_2 NAAQS						Annual NO_2 NAAQS			
Year	Receptor	Source CO	Source NO_x	1st Highest NO_2	Date	Hour	Receptor	Source CO	Source NO_x	8th Highest NO_2	Date	Hour	Receptor	Source CO	Source NO_x	Annual
2012	4	42	3.80	0.167	11/28/2012	22	4	22	2.10	0.097	11/09/12	20	4	24	2.30	0.0518
2013	4	43	3.90	0.167	01/07/13	7	4	22	2.10	0.098	05/16/13	23	4	23	2.20	0.0523
2014	4	45	4.00	0.169	02/11/14	8	4	39	3.50	0.0975	04/03/14	7	4	23	2.20	0.0513
2015	4	45	4.00	0.169	02/12/15	2	4	22	2.10	0.097	02/05/15	9	4	24	2.30	0.0519

TABLE 2-28: 1-HOUR NO_2 LEVELS FOR COMPLIANCE DEMONSTRATION – DST: EXISTING CONFIGURATION 2 (PPM)

Dewey Square Tunnel CONFIG 2																
	MassDEP One Hour Policy Guidance Level						One Hour NO_2 NAAQS						Annual NO_2 NAAQS			
Year	Receptor	Source CO	Source NO_x	1st Highest NO_2	Date	Hour	Receptor	Source CO	Source NO_x	8th Highest NO_2	Date	Hour	Receptor	Source CO	Source NO_x	Annual
2012	4	46	4.10	0.169	11/19/2012	9	23	23	2.20	0.099	01/23/12	5	4	33	3.00	0.0521
2013	4	46	4.10	0.167	01/16/13	12	23	22	2.10	0.098	10/11/13	18	4	33	3.00	0.0526
2014	4	43	3.90	0.169	03/18/14	6	23	22	2.10	0.0991	02/20/14	24	4	33	3.00	0.0524
2015	4	47	4.20	0.1698	11/30/15	9	23	22	2.10	0.982	03/14/15	15	4	34	3.10	0.0529

2.7.3 For The Longitudinally Ventilated Ramps affected by the Future Development of Parcels 6 and 12

Development of Parcels 6 and 12 is conducted as part of CA/T commitments. The design for the parcel covers is part of the Notice of Project Change (NPC) in the context of MEPA and National Environmental Policy Act (NEPA) regulations. Development of Parcels 6 and 12 was first considered as part of proposal to convert ventilation system for some of the CA/T ramps from full transverse to longitudinal ventilation. The wind-tunnel studies conducted by RWDI for the project in 1996 and later in 2000 used alignments with and without Parcels 6 and 12 development to assess the air quality impacts of the longitudinal ventilation at the sensitive land uses near the exit ramps affected by conversion. The 2012 Renewal of the Operating Certification included compliance demonstration for both existing and possible future scenarios.

The current parcels' development proposal differs from the initial plans in the coverage area and in the plans for the development above the tunnel extensions. While the initial plans were for development of elevated structures (buildings on top of the covers), the current proposal for both parcels include only the park features, paths and lookout points. The wind-tunnel studies conducted for the initial plans do not properly reflect the air quality implications of the current development proposals, mostly due to different public areas adjacent to and on top of the parcels. Therefore, emission limits for the exit ramps associated with these parcels need to be determined based on the modeling of the current proposed designs instead of the wind-tunnel studies done in the past.

These parcels are not covered under the existing condition. Emission limits for CO and NO_x for the ramps in the Parcel 6 area, ramps SA-CN, ST-CN and ST-SA, were determined in the first Operating Certification in 2006. Continuous Emission Monitoring (CEM), conducted inside these ramps in the period 2006-2012, demonstrated that monitored levels were well below the established limits. Based on this finding MassDEP granted MassDOTs' request during the 2012 Operating Certification to discontinue monitoring at these locations. MassDEP concurred with eliminating these ramps from the CEM monitoring system in February 2013.

The modeling described in this section will establish future emission limits for the longitudinally ventilated ramps in the Parcels 6 and 12 areas under the future condition with covers, which is currently expected to occur in 2021 (in the end of this CEM period).

2.7.3.1 The Proposed Design of Parcel Covers

The areas around Parcels 6 and 12 are now open as illustrated on Figures 2-14 and 2-17 for Parcel 6 and 12 respectively. Figures 2-15 and 2-18 present the proposed covers, and Figures 2-16 and 2-19 the Future development scenarios. The ramp covers that are proposed for Parcel 6 are presented in Table 2-29 and for Parcel 12 in Table 2-30.

TABLE 2-29: PROPOSED RAMP COVERAGE FOR PARCEL 6

Parcel 6 Ramp	Description	Allowable Cover
SA-CN	NB-on	75'
ST-CN	NB Thru (Sumner)	Entire ramp
ST-SA	NB-off (Sumner)	265'
SA_CS/CT	SB-on (Callahan)	120'

TABLE 2-30: PROPOSED RAMP COVERAGE FOR PARCEL 12

Parcel 12 Ramp	Description	Allowable Cover
CS-SA	SB-off	300'
CN-SA	NB-off	360'

FIGURE 2-15: PARCEL 6 EXISTING CONDITION

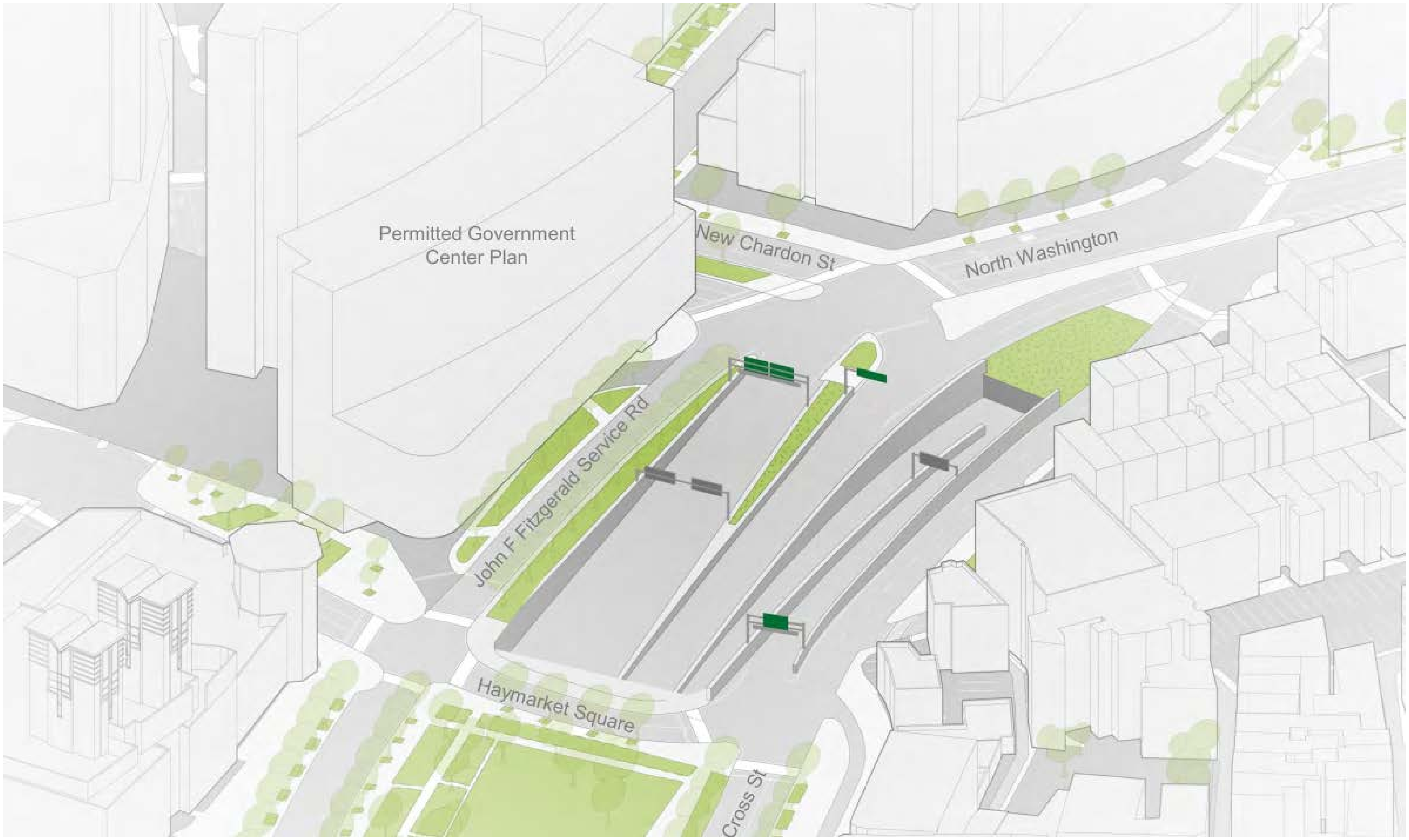


FIGURE 2-16: PARCEL 6 PROPOSED COVER

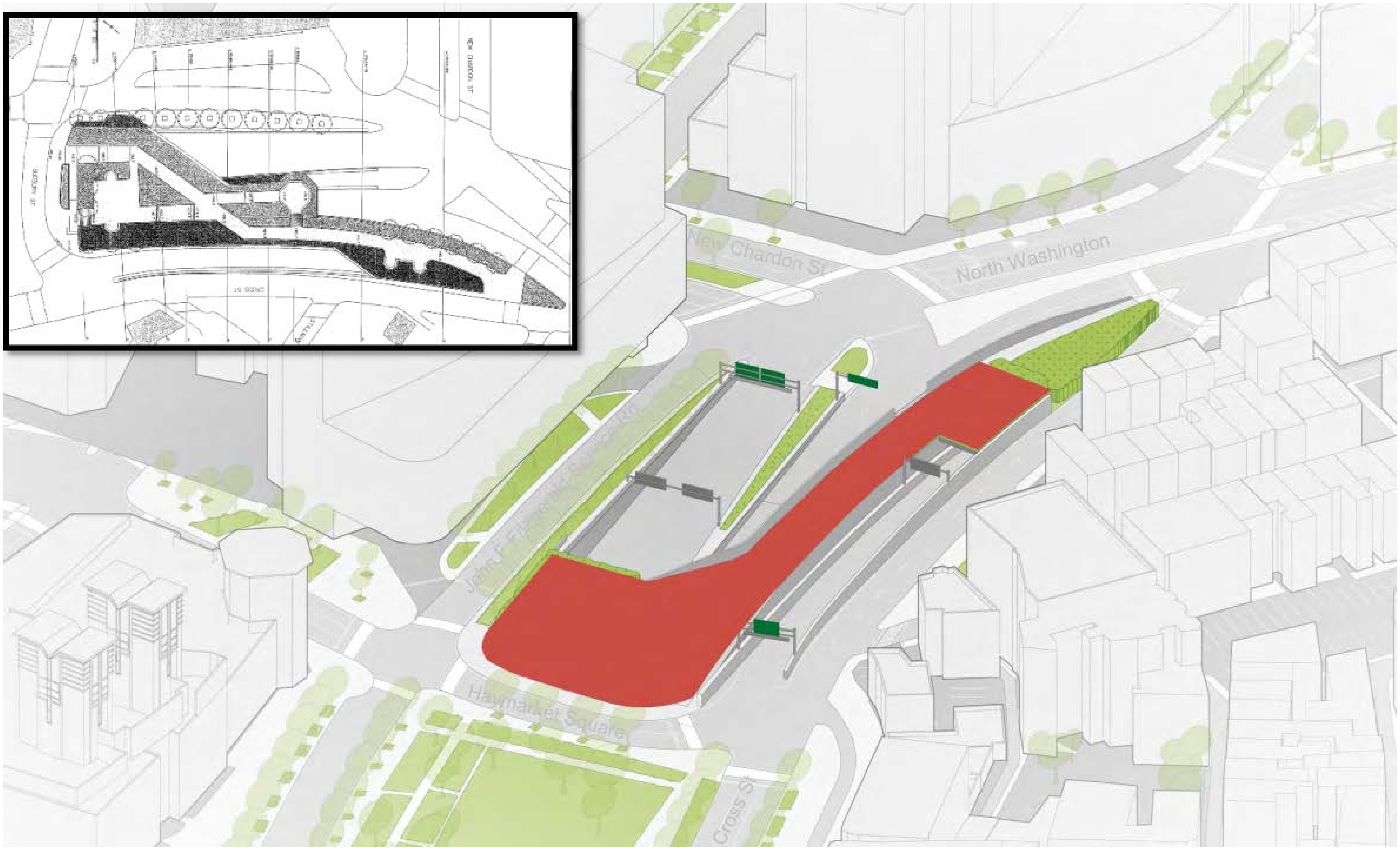


FIGURE 2-17: PARCEL 6 FUTURE BUILD CONDITION

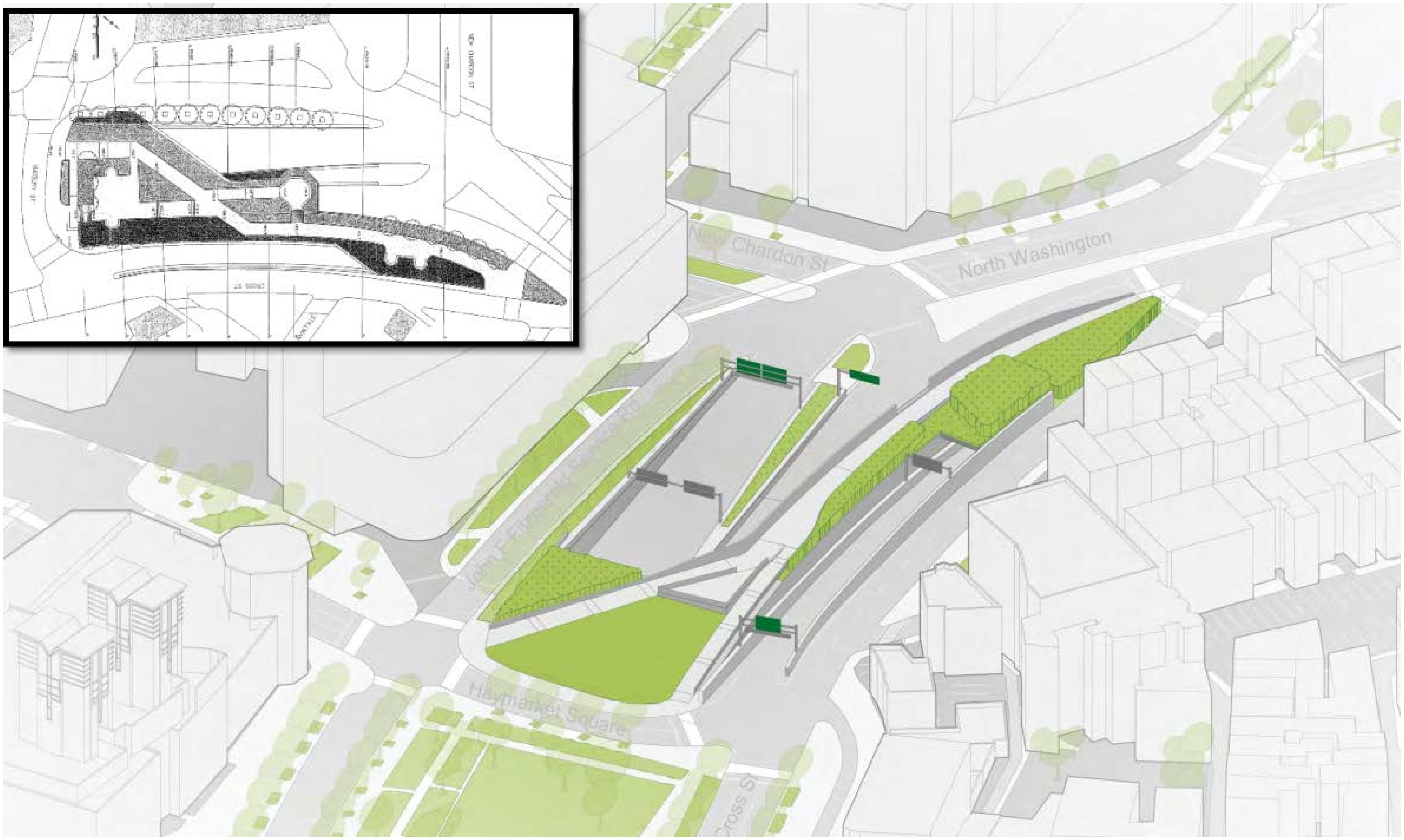


FIGURE 2-18: PARCEL 12 EXISTING CONDITION

FIGURE 2-19: PARCEL 12 PROPOSED COVERS

FIGURE 2-20: PARCEL 12 FUTURE BUILD CONDITION

2.7.3.2 Tunnel Ventilation System near Parcels 6 and 12

Parcel 6: The only exit portal associated with this parcel at this location is ramp ST-SA. Portal-to-portal, this ramp is about 700 feet long. Over the first 550 feet, ramps ST-SA and ST-CN are combined within a single tunnel box, and then they split for the remaining 150 feet. 4 jet fans are installed. However, ventilation is generally handled by the piston action of the moving vehicles. The coverage of ramp ST-CN creates a longer tunnel with the exit at Causeway Street.

Parcel 12: The ramp exit portals associated with this parcel are those for ramp CS-SA and ramp CN-SA. Both ramps are provided with ventilation from Ventilation Building #4 (VB4). Ramp CS-SA has only a supply air duct for normal ventilation and 4 jet fans for emergency ventilation. Ramp CN-SA has both supply and exhaust air ducts, it was never a fully longitudinally ventilated ramp, nor was it ever included in the CEM system.

2.7.3.3 Emission Limits Modeling Approach

The only longitudinally ventilated exit ramp in the Parcel 6 area to be modeled for future compliance demonstration (i.e., to determine emission limit) is ST-SA. The only ramp that will be modeled for the same purpose on the Parcel 12 area is ramp CS-SA. Ramp CS-SA (without cover) is currently part of the CEM system, while monitoring at ramp ST-SA (without cover) was discontinued from 2013 onwards under the current Operating Certification.

The analytical modeling of the portal areas was conducted using the portal jet approach as previously applied in the modeling of the Dewey Square Tunnel and other portal impacts in the EIS stage of the CA/T project. The portal area receptor concentrations were estimated from the emissions generated by vehicles traveling inside the tunnel and later pushed and dragged out of the exit portal(s) in the wake of the moving cars.

Portal jet emissions were modeled using the latest version of the USEPA AERMOD model (version 15181) including detailed procedures described in Appendix B.

Traffic parameters including volume, speed, vehicle types in the tunnels were used to determine the airflow rates (cfm) exhausted from each affected portal to be used in the AERMOD modeling.

Emissions from the ramp portals were increased by increments to determine emission limit for each parcel area. Emission limits for the parcels were established based on the same principles that are described in section 2.7.2. Emission limits were established for CO and NO_x similar to the other longitudinally ventilated ramps.

The same four latest years of meteorological data (2012 through 2015), and hourly CO and NO_2 background concentrations used in compliance modeling for other ramps and VBs were used in this analysis.

Receptors were placed at the ambient areas to where general public has access, and where project impacts are expected to be highest. Figures 2-21 and 2-22 show the placement of receptors and modeled sources at each modeling site.

FIGURE 2-21: RECEPTOR PLACEMENT AT THE PARCEL 6 SITE

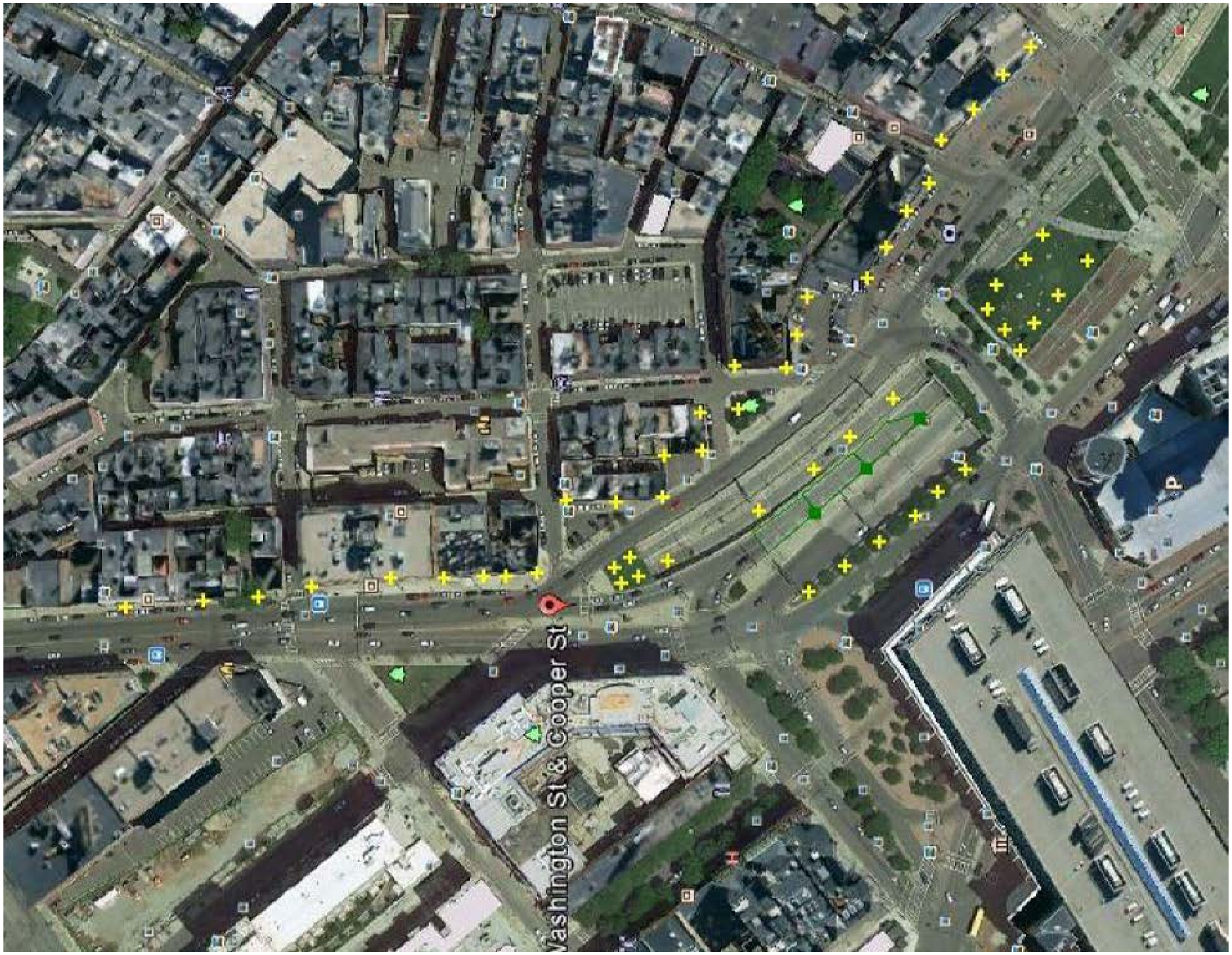
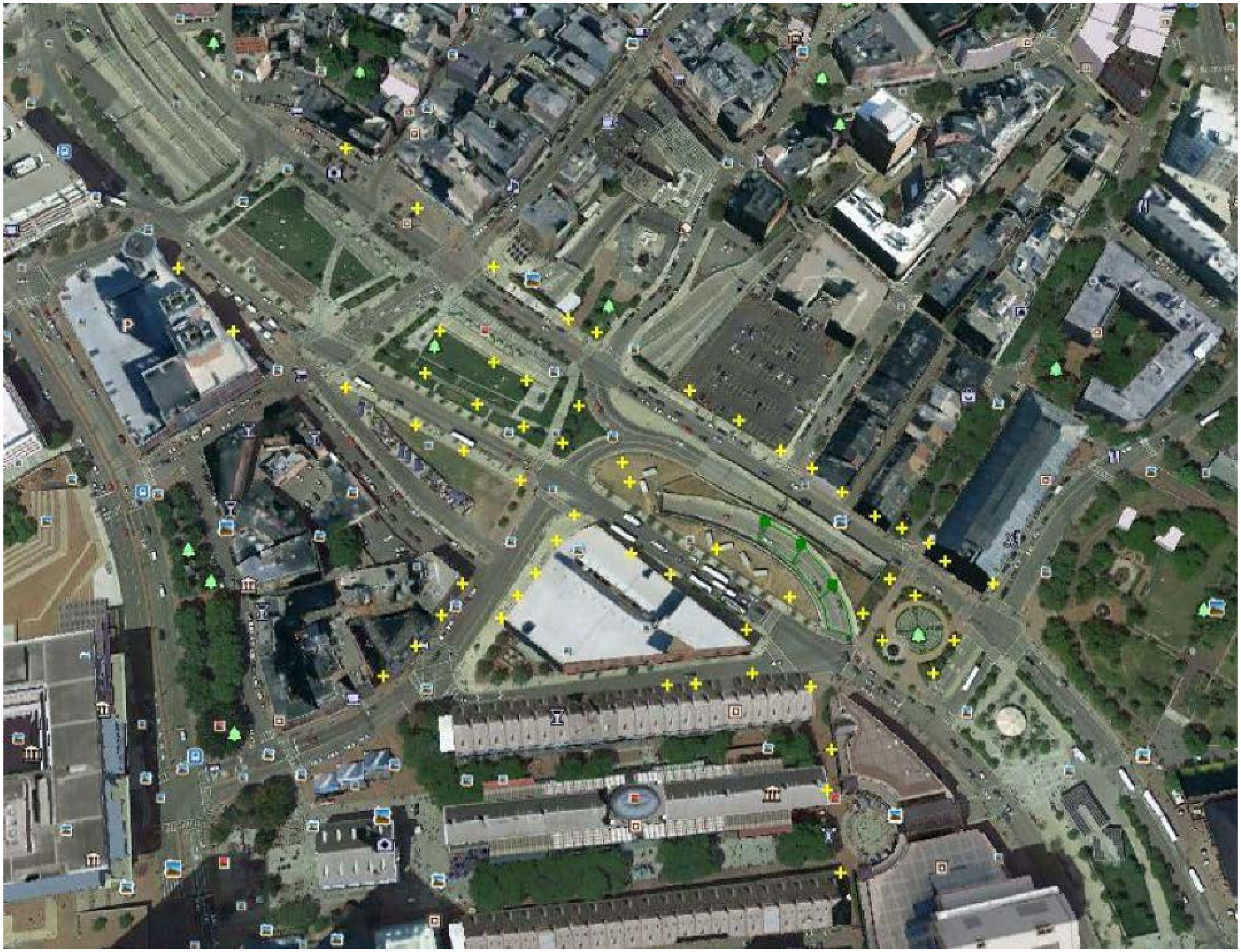


FIGURE 2-22: RECEPTOR PLACEMENT AT THE PARCEL 12 SITE



2.7.3.4 CO Emission Limits for Covered Parcels

CO emission limits for the exit ramps in each parcel area were determined for 1 and 8 hour periods in the range between 20 and 70 ppm in 1 ppm increments following the approach described in section 2.7.2.3. Constant emission rate was used for the portal jet for all hours of the year within each iteration. This emission rate was calculated from the proposed emission limit range in ppm using ventilation flow rates inside the respective tunnels using the daily average airflow rates.

The results presented in Tables 2-31 and 2-32 provide the compliance demonstration for the 1 and 8 hour CO NAAQS determining the emission limits for each respective ramp.

TABLE 2-31: 1- AND 8-HOUR CO LEVELS FOR COMPLIANCE DEMONSTRATION: RAMP ST-SA + PARCEL 6 (PPM) – FUTURE DEVELOPMENT

Ramp ST-SA with Parcel 6				
	One Hour CO		Eight Hour CO	
Year	Source CO	2nd Highest Level	Source CO	2nd Highest Level
2012-2015	64	34.31	55	8.93

TABLE 2-32: 1- AND 8-HOUR CO LEVELS FOR COMPLIANCE DEMONSTRATION: RAMP CS-SA + PARCEL 12 (PPM) –FUTURE DEVELOPMENT

Ramp CS-SA with Parcel 12				
	One Hour CO		Eight Hour CO	
Year	Source CO	2nd Highest Level	Source CO	2nd Highest Level
2012-2015	52	34.67	38	8.80

2.7.3.5 NOx Emission Limits for Covered Parcels

NO_x emission limits for 1 hour period were determined based on compliance with 1 hour NO_2 NAAQS and 1 hour MassDEP Policy Guideline.

NOx emission limits for the exit ramps in each parcel area were determined in the range between 1.95 ppm (20 ppm CO equivalent) to 6.10 ppm (70 ppm CO equivalent) at 1 ppm CO equivalent intervals. Emission rates in grams per second were determined using ventilation airflow rates estimated in respective tunnels.

For compliance with one hour NAAQS 8^{th} highest (98 percentile) daily concentrations obtained from each run were added to the appropriate background levels and averaged over the four years. This value was compared to the NAAQS. If the result showed compliance with the NAAQS, emission rate was increased, modeling and comparison repeated. The highest portal jet emission level that resulted in compliance with one hour NO_2 NAAQS was considered an emission limit for that location following the procedures in section 2.7.2.4.

For compliance with the MassDEP Policy Guideline the highest second highest hourly NO_2 concentration obtained from each run together with the appropriate background level was compared with the Policy Guideline. The highest portal jet emission level that resulted in compliance was considered an emission limit at the respective location.

The lower of the two NO_x emission limits for NO_2 NAAQS and MassDEP Policy Guideline at each location were established as the compliance emission limit for NO_x at the respective ramp.

The results presented in tables 2-33 and 2-34 provide the compliance demonstration for the 1 hour NO_2 determining the emission limit for each respective ramp.

TABLE 2-33: 1-HOUR NO_2 LEVELS FOR COMPLIANCE DEMONSTRATION: RAMP ST-SA + PARCEL 6 (PPM) – FUTURE DEVELOPMENT

Ramp ST-SA with Parcel 6			
	One Hour NO2 NAAQS		
Year	Source CO	Source NO_x	8th Highest NO_2
2012-2015	29	2.70	0.0992

TABLE 2-34: 1-HOUR NO_2 LEVELS FOR COMPLIANCE DEMONSTRATION: RAMP CS-SA + FUTURE PARCEL 12 (PPM) – FUTURE DEVELOPMENT

Ramp CS-SA with Parcel 12			
	One Hour NO2 NAAQS		
Year	Source CO	Source NO_x	8th Highest NO_2
2012-2015	23	2.20	0.0982

2.7.4 VOC Emission Limit Determination

The 2011/12 renewal application demonstrated compliance with 310 CMR 7.38(2)(c) (non-methane hydrocarbon budget – referred here as VOC – volatile organic compounds) established for the year 2005, in the original Operating Certification approved by MassDEP in 2006 (6,095.9 kg/day). The renewal application demonstrated that the VOC emissions in 2010 were 3,906.9 kg/day, 36% below the budget of 6,095.9 kg/day.

Based on the significant decreases in VOC motor vehicle emissions and the current O_3 attainment status of the Boston Metro area, MassDEP concurred with MassDOT that this 2016 CA/T renewal certification would present a simplified approach to estimate the reductions in the regional VOC levels. Since CTPS (Boston Metro area MPO), who performed in the past the regional emission analysis as part of their planning and conformity process, is not required to conduct the conformity analysis at the present time, this regional VOC demonstration is based on MOVES 2014a motor vehicle emission factors and projected percent increases in regional traffic levels.

The 2011 compliance demonstration was based on the 2010 VOC emissions for each area that were calculated using the CTPS model for Eastern Massachusetts area that included highway, transit, and commuter rail components.

2.7.4.1 2011 Travel Demand Estimation Process

The travel model used for the CA/T Project VOC Analysis was based on procedures and data that have evolved over many years. The model set is the same type as those used in most large urban areas in North America. It is based on the traditional four-step urban transportation planning process of trip generation, trip distribution, mode choice, and trip assignment.

The CTPS model area encompasses 164 cities and towns in Eastern Massachusetts, as shown in Figure 2-23. The CA/T Project area is shown in Figure 2-24. The modeled area is divided into 986 internal Traffic

Analysis Zones (TAZ). There are 101 external stations around the periphery of the modeled area that allow for travel between the modeled area and adjacent areas of Massachusetts, New Hampshire and Rhode Island. Population, employment, number of households, auto ownership, highway and transit levels of service, downtown parking costs, auto operating costs, and transit fares are some of the important inputs that are used in applying the model to a real world situation. The model set simulates travel on the entire Eastern Massachusetts transit and highway system. It contains all MBTA rail and bus lines and all private express bus carriers. In the highway system, all express highways and principal arterial roadways and many minor arterial and local roadways are included.

FIGURE 2-23: CTPS MODELED AREA

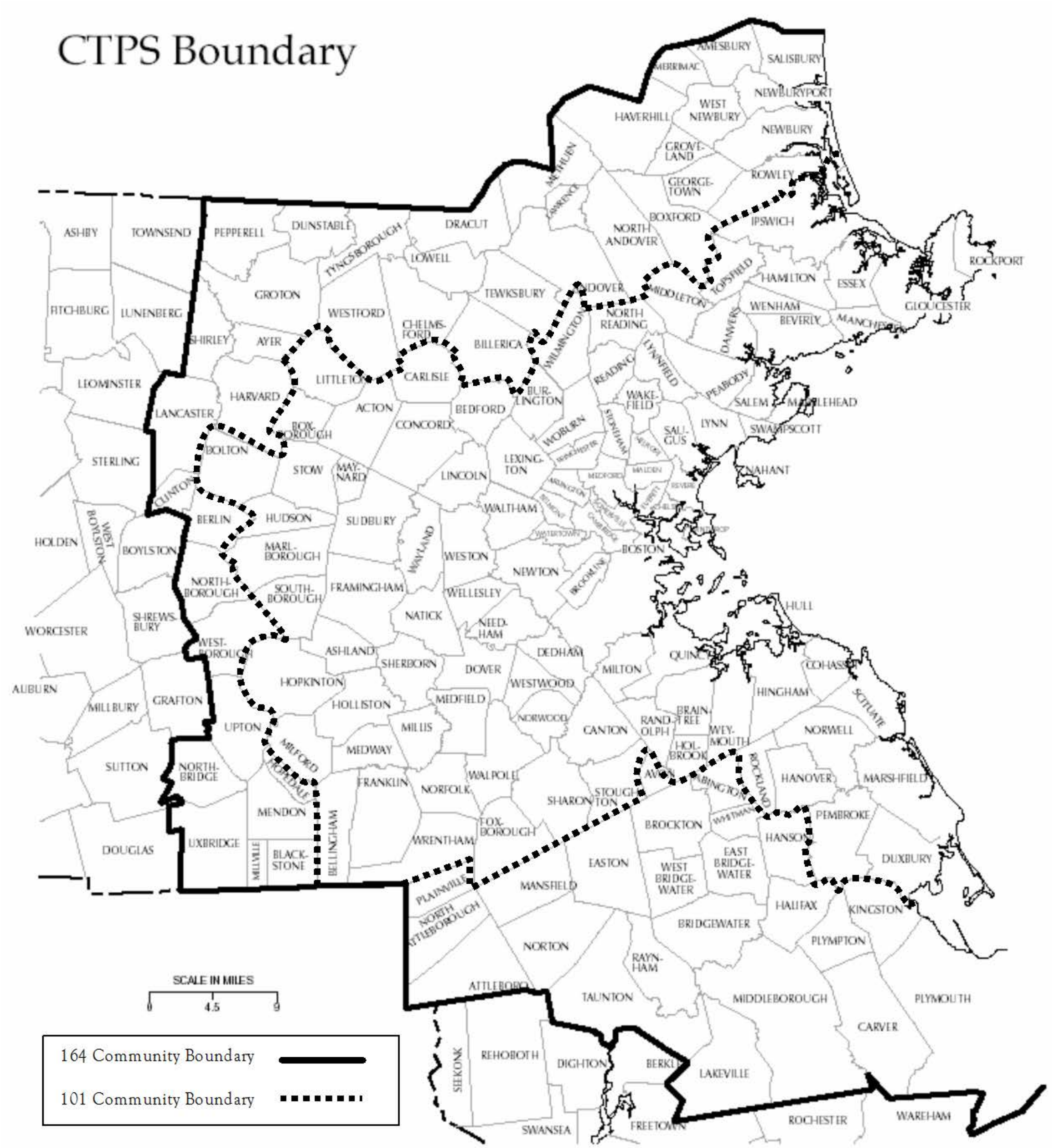


FIGURE 2-24: CA/T PROJECT STUDY AREA

2.7.4.2 Procedures for 2011 VOC Analysis

The air quality effects of regional VOC levels of the two transportation scenarios (2005 CA/T Project Build and 2010 CA/T Project Build) were analyzed using the travel demand model previously described. From the highway assignment component of the model, traffic volumes, average highway speeds, vehicle miles, and vehicle hours traveled were estimated. The amount of VOC emitted by the highway traffic depends on the prevailing highway speeds and vehicle miles traveled on the network. The CTPS model used MOBILE 6.2 emission factors to calculate VOC on a link-by-link basis based on the congested speed and vehicle miles of travel.

The 2010 Build network was defined by CTPS to include additional projects that were constructed between 2005 and 2010. The resulting 2010 Build network was then used to estimate VOC emissions associated with the 2010 Build scenario. VOC emissions associated with the 2010 Build network were compared to the 2005 VOC emissions budget in order to demonstrate that the Project is in compliance with the budget.

There were other transportation related components contributing to VOC emissions, which cannot be handled directly within the model. These were:

- The pollutants emitted by the Diesel Locomotives of the commuter rail system
- The pollutants emitted by the MBTA bus system
- The pollutants emitted by the commuter ferries

The pollutants from the categories above can be estimated outside of the model and included with the vehicular emissions calculated within the model. The following paragraphs describe the general off-model procedure that was used to handle these categories.

2.7.4.3 2011/12 VOC Analysis Results

The results of the VOC regional analyses were presented for three different scales: Eastern Massachusetts Regional Planning Area (EMRPA) 164 community boundary, the MPO 101 community boundary, and the CA/T Project area.

Tables 2-35 to 2-39 provide the daily VMT and VOCs for the vehicular network and the off-network MBTA buses, commuter railroad, and ferries.

TABLE 2-35: NETWORK-BASED DAILY VMT (VEHICLES MILES TRAVELED) AND VOCS (KG/DAY)

Region	2005 CA/T Build		2010		Changes	
	VMT	**VOC**	**VMT**	**VOC**	**VMT**	**VOC**
EMRPA	121,016,208	81,734	122,226,370	50,990	1,210,162	-30,744
MPO	86,877,467	59,499	87,746,242	37,460	868,775	-22,039
CA/T	7,767,266	5,909	7,844,939	3,720	77,673	-2,189

TABLE 2-36: MBTA BUSES DAILY VMT AND VOCS (KG/DAY)

Region	2005 CA/T Build		2010		Changes	
	VMT	**VOC**	**VMT**	**VOC**	**VMT**	**VOC**
EMRPA	88,628	52.1	91,102	53.6	2,474	1.5
MPO	88,588	52.1	91,062	53.6	2,474	1.5
CA/T	10,001	8.2	10,280	8.4	279	0.2

TABLE 2-37: COMMUTER RAILROAD DAILY VMT AND VOCS (KG/DAY)

Region	2005 CA/T Build		2010		Changes	
	VMT	VOC	VMT	VOC	VMT	VOC
EMRPA	15,509	597	15,457	595	-52.0	-2.0
MPO	11,560	445	11,521	443	-39.0	-1.5
CA/T	1,258	48	1,254	47.8	-4.0	-0.2

TABLE 2-38: FERRY DAILY FUEL CONSUMPTION AND VOCS (KG/DAY)

Region	2005 CA/T Build		2010*		Changes	
	Fuel (gallons)	VOC	Fuel (gallons)	VOC	Fuel (gallons)	VOC
EMRPA	4,793	392.2	4,793	392.2	0	0
MPO	4,793	392.2	4,793	392.2	0	0
CA/T	1,598	130.7	1,598	130.7	0	0

* 2010 emission data unavailable; 2005 data reported.

Table 2-48 provides the total cumulative (motor vehicle and transit) VMT and VOC, which results in a net reduction of VOC with the CA/T Project and transit commitments.

TABLE 2-39: TOTAL DAILY VOC EMISSIONS (KG/DAY)

Region	2005 CA/T Build	2010	Changes
EMRPA	82,775.3	52,030.8	-30,744.5
MPO	60,388.3	38,349.3	-22,039.0
CA/T	6,095.9	3,906.9	-2,189.0

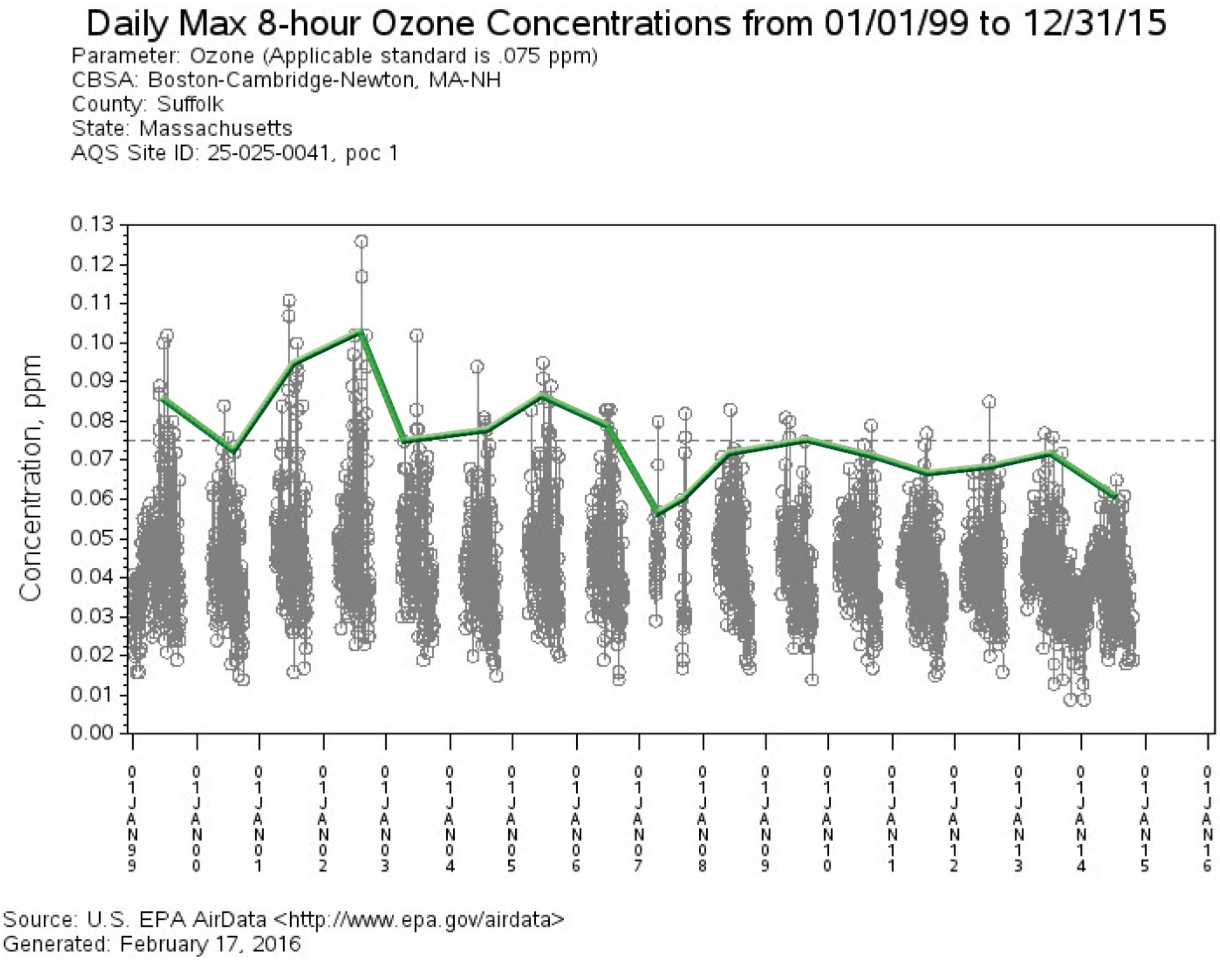
The results (provided in Table 2-51) demonstrated that the 2010 total estimates for the CA/T area resulted in a reduction 2,189 kg/day of VOC with respect of the 2006 established VOC budget of 6,095.9 kg/day. This reduction of approximate 36 % remained very similar for all three regional scales evaluated, despite an increase of approximately 1% in VMT for the five year period.

The emission reductions were the result of cleaner vehicles and fuels mandated by Federal and state regulations over the past decade.

2.7.4.4 Ozone (O_3) and VOC Suffolk County Historical Trends

The Boston area had been designated nonattainment for the 1997 O_3 NAAQS but EPA designated Boston as unclassifiable/attainment for the 2008 8-hour ozone standard (0.075 ppm) in 2012. In October 2015, EPA lowered NAAQS for O_3 to 0.070 ppm for the fourth-highest daily maximum 8-hour concentration, averaged over three years. Massachusetts will file recommended attainment designations in October 2016 with respect to that new standard. The measured ozone concentrations in Suffolk County are shown in Figure 2-25 for the period 1999 through 2015. For reference, the CA/T tunnels fully opened to traffic in early 2006, approximately the time that the monitored ozone concentrations fell below the NAAQS.

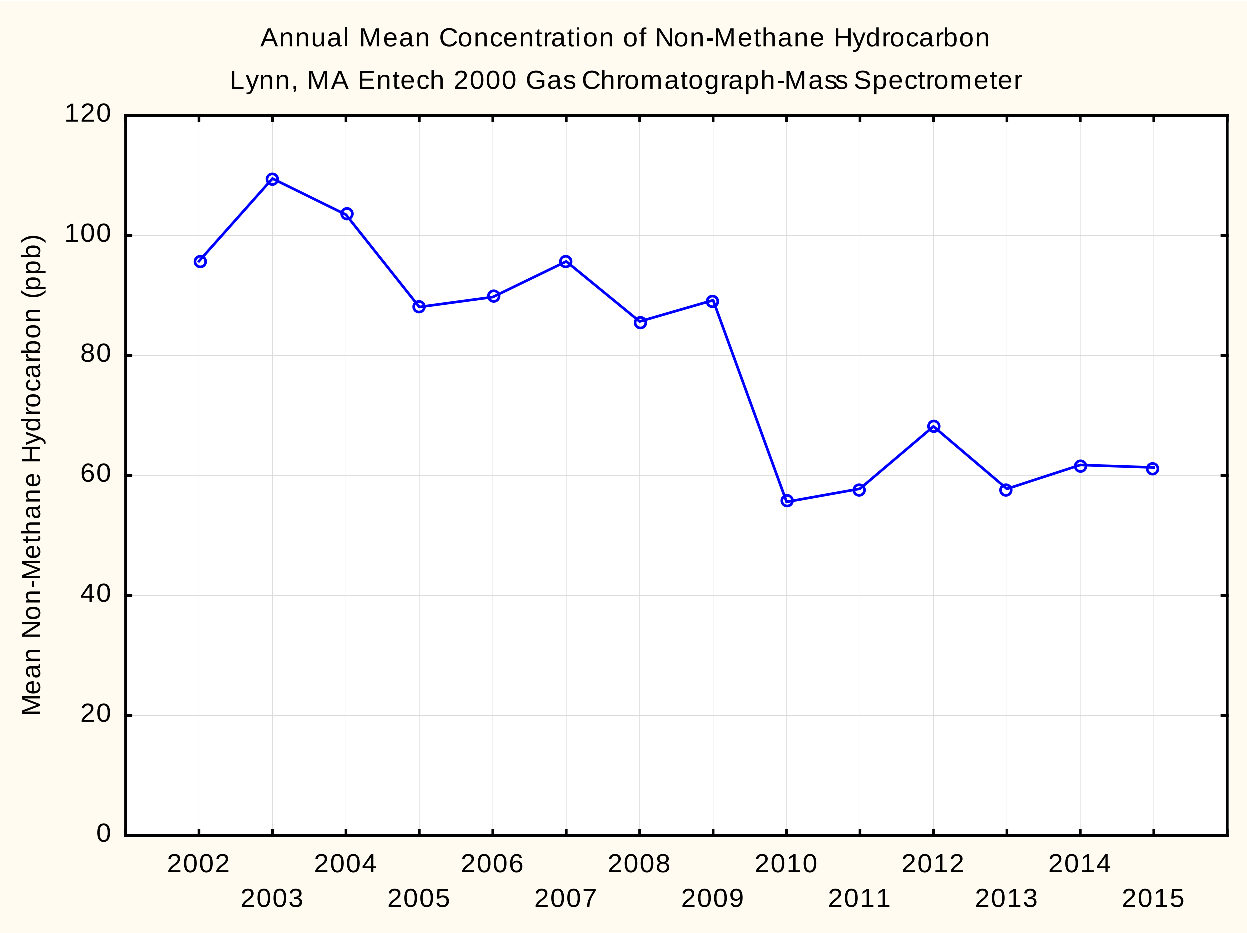
FIGURE 2-25: SUFFOLK COUNTY MEASURED 8-HOUR AVERAGE O_3 CONCENTRATION TREND



Note: Line indicating the 4th high daily maximum value has been added to original EPA figure

The nearest VOC monitoring station is located in Lynn, MA, approximately 9 miles north-northeast of the CA/T. This site monitors regional VOC concentrations. In 2002 an Entech 2000 mass spectrometer was brought on-line at that site and has recorded VOC concentrations since that time. Figure 2-26 presents the non-methane hydrocarbon/VOC annual mean concentration trend recorded at Lynn from 2002 to 2015 as reported in the EPA's AIRS database. Note that regional mean VOC concentrations have decreased approximately 40 percent during this time period.

FIGURE 2-26: LYNN, MA ANNUAL MEAN VOC CONCENTRATION TREND



The results of the monitoring data concurs with the decreasing VOC motor vehicle emission trends, which are estimated for future years using the MOVES2014a (EPA Motor Vehicle Emission Simulator) in the following section.

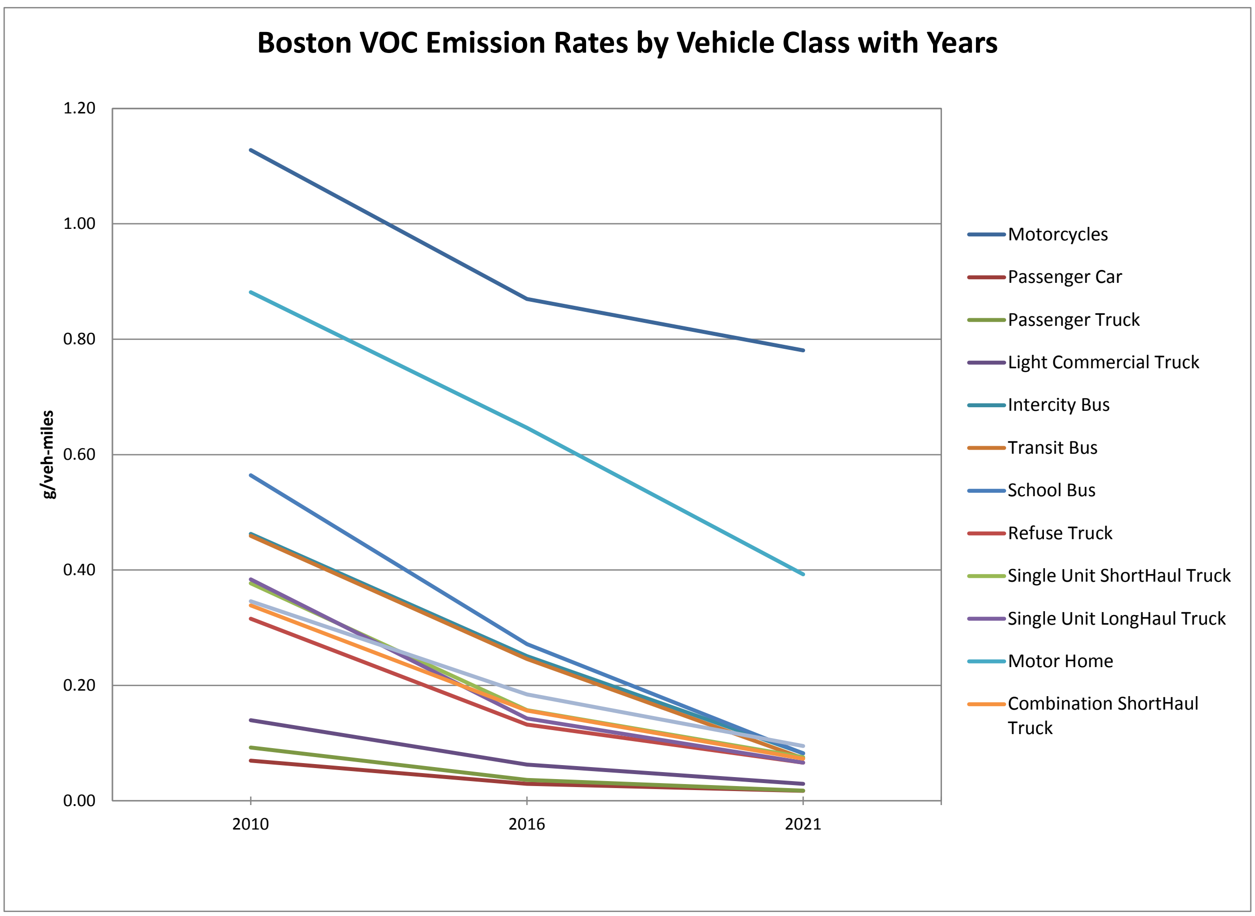
2.7.4.5 MOVES Emission Factors and Future Traffic Changes for Suffolk County Motor Vehicles

MOVES2014a was run using input files obtained from MassDEP for Suffolk County. County scale runs were conducted for years 2010, 2016 and 2021 to determine VOC by vehicle class and the composite for the Suffolk county vehicle fleet. The results are presented in Table 2-40 with the percent reductions from 2010 to 2016 and 2021.

TABLE 2-40: MOVES2014A EMISSION FACTORS BY YEAR AND VEHICLE CLASS (GRAM/VEHICLE-MILE)

MOVES 2014a sourcetypeid	Source Description	2010	2016	2021		2010 to 2016	2010 to 2021
11	Motor Cycle	1.13	0.87	0.78		-23%	-31%
21	Passenger Car	0.07	0.03	0.02		-58%	-75%
31	Passenger Truck	0.09	0.04	0.02		-61%	-81%
32	Light Commercial Truck	0.14	0.06	0.03		-55%	-79%
41	Intercity Bus	0.46	0.25	0.08		-46%	-82%
42	Transit Bus	0.46	0.25	0.07		-46%	-84%
43	School Bus	0.56	0.27	0.08		-52%	-85%
51	Refuse Truck	0.32	0.13	0.07		-58%	-79%
52	Single Unit ShortHaul Truck	0.38	0.16	0.08		-58%	-80%
53	Single Unit LongHaul Truck	0.38	0.14	0.07		-63%	-83%
54	Motor Home	0.88	0.65	0.39		-27%	-55%
61	Combination ShortHaul Truck	0.34	0.16	0.07		-54%	-78%
62	Combination LongHaul Truck	0.35	0.18	0.09		-47%	-73%
	Aggregated Emission Rates	**0.104**	**0.047**	**0.026**		**-55%**	**-75%**

FIGURE 2-27: MOVES2014A EMISSION FACTORS 2010 – 2021 BY VEHICLE CLASS

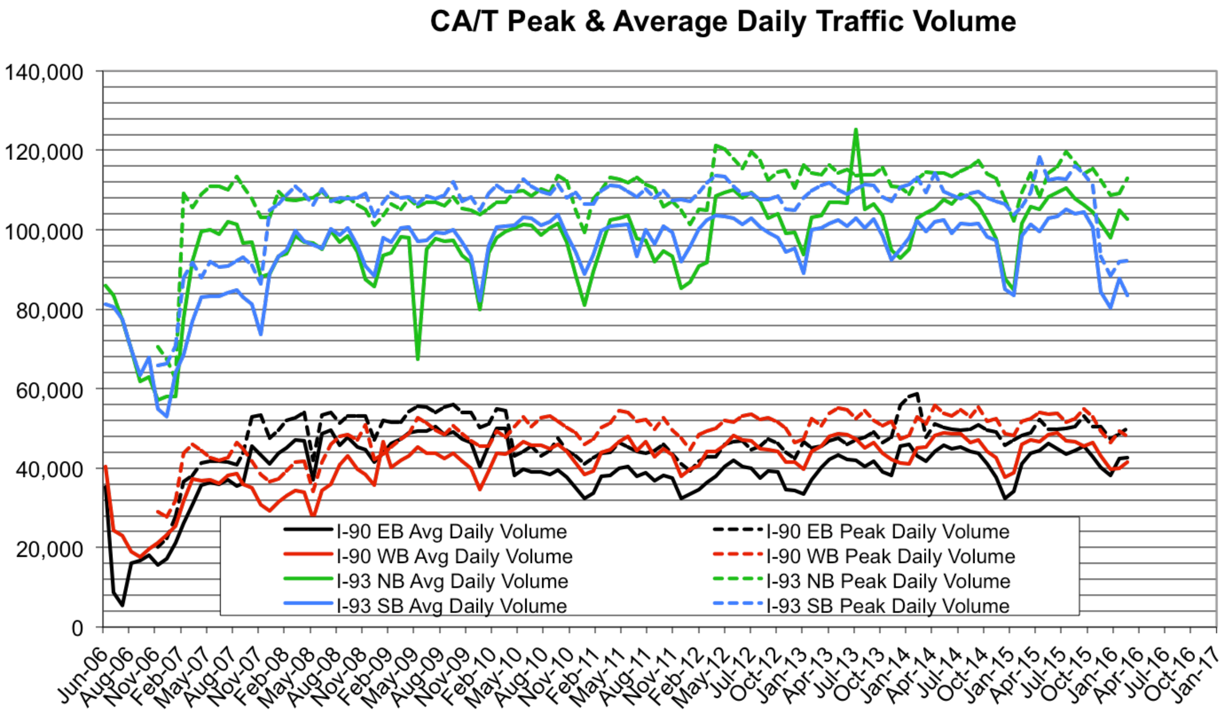


The VOC emission factor reductions from 2010 to 2016 for the Suffolk County composite vehicle fleet is in the order of 55 percent, and between 2010 and 2021 in the order of 75 percent.

The regional traffic projections by CTPS for the Boston Metro Area up to year 2035 represent an annual growth of less than ½ percent per year for the next 20 years. This is consistent with the past decade and results in an approximate traffic VMT growth of 3% from 2010 to 2016.

The CA/T tunnel traffic volumes counted during the past ten years (provided in Figure 2-28) indicate an even lower increase than the regional.

FIGURE 2-28: MONITORED DAILY TRAFFIC IN THE CA/T TUNNELS 2006-2016



2.7.5 VOC Compliance Demonstration

The MOVES2014a trends for VOC described in Table 2-40 indicate a 55% reduction from 2010 to 2016 for the aggregate fleet and a 75% reduction from 2010 to 2021. The regional traffic is expected to increase approximately ½ % per year for the 2010-2021 period. Based on these data, it was estimated that regional VOC emissions from the region's transportation sector should decreased by about 50% between 2010 and 2016 and approximately 70% between 2010 and 2021.

As a result, the 2016 VOC regional emissions in the CA/T area will be in the range of 2,000 kg/day (50% of the 2010 emission levels of 3,906 kg/day), which is close to one third of the 2005 VOC emission budget of 6,095.9 kg/day. The projected 2021 VOC regional emissions are anticipated to be in the order of 1,200 kg/day (30% of the 2010 emission levels).

2.8 PROPOSED 2016-2021 OPERATING EMISSION LIMITS

The proposed operating emission limits are based on the compliance modeling and demonstration of compliance with the applicable standards at the emission limits as described above.

2.8.1 CO, NOx and $PM_{2.5}$

The emission impact modeling results indicated that operation of the CA/T ventilation buildings below these limits would not cause or exacerbate a violation of the applicable NAAQS for CO, NO_2, or $PM_{2.5}$, or the MassDEP Policy Guideline Value for NO_2.

TABLE 2-41: SUMMARY OF 2016-2021 EMISSION LIMITS

Location*	1-Hour CO Emission Limit (ppm)	8-Hour CO Emission Limit (ppm)	1-Hour NOx Emission Limit (ppm)	24-Hour $PM_{2.5}$ Emission Limit ($\mu g/m^3$)
VB 1	70	70	6.1	550
VB 3	70	70	6.1	550
VB 4	70	70	6.1	550
VB 5	70	70	6.1	550
VB 6	70	70	6.1	550
VB 7	70	70	6.1	550
Ramp CN-S	35	59	3.2	NA
Ramp CS-SA**	35	54	3.2	35***
Ramp CS-P	35	70	3.2	NA
Dewey Sq. Tunnel Existing	22	24	2.1	NA

Notes: Acronyms are defined as: Central Artery Northbound to Storrow Drive (C-NS), Sumner Tunnel to Central Artery Northbound (ST-CN), Central Artery Southbound to Surface Artery (CS-SA), Sumner Tunnel to Surface Artery (ST-SA), Central Artery Southbound to Purchase Street (CS-P), part per million (ppm), microgram per cubic meter ($\mu g/m^3$).

* For each ventilation building, location includes all associated ventilation zones.

** The ambient $PM_{2.5}$ monitor is located outside ramp CS-SA.

*** Compliance with the 24-hour $PM_{2.5}$ NAAQS is based on the monitoring design value, which is given by the 3-year average of the annual 98th percentile value of daily average concentrations. The form of the standard allows, on average, for the numerical value of the standard (35 $\mu g/m^3$) to be exceeded on seven calendar days per calendar year without triggering a violation of the NAAQS.

2.8.2 VOC

The results of the regional analysis using MOVES2014a emission factors and traffic growth demonstrate that the 2016 CA/T Project emissions would be in the range of 2,000 kg/day, which are well below the VOC Budget for the 2005 CA/T Build condition of 6,095.9 kg/day.

2.9 OPERATING CERTIFICATION CRITERIA

In summary, the data collected for the Operating Certification to-date demonstrates that the operation of the CA/T Project, as currently constructed and operated, complies with 310 CMR 7.38(2) (a)-(c) in that the CA/T project does not cause or exacerbate a violation of the applicable NAAQS for CO, NO_2 or $PM_{2.5}$ or the MassDEP Policy Guideline Value for NO_2 and does not result in an actual or projected increase in the total amount of non-methane hydrocarbons estimated within the project area when compared with the 2005 emission budget.

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Part II – Compliance Monitoring Program

3 PROJECT COMPLIANCE MONITORING SYSTEM

3.1 MASSDEP 310 CMR 7.38(8) REGULATORY REQUIREMENTS

MassDEP Regulation 310 CMR 7.38(8) states the following requirements for vehicle emissions and vehicle traffic monitoring.

Emissions Monitoring

(a) "Any person who constructs and operates a tunnel ventilation system which is subject to the requirements of 310 CMR 7.38 shall, prior to commencing operation of the tunnel ventilation system or opening the project roadway for public use, develop and submit to the Department for review and approval an "Air Emissions Monitoring Protocol" and shall install and operate emissions monitoring and recording equipment in accordance with the approved protocol. Monitoring as approved by the Department shall be required at the exhaust stacks or exhaust plenums of VBs as well as at exit portals that utilize longitudinal ventilation. The Department will consider for approval hybrid monitoring systems that incorporate elements of the federal regulations for monitoring ambient air pollution, for monitoring stationary source emissions, and for pollutant emission trading (i.e., 40 CFR Parts 58, 60, and 75) as practicable, as well as statistical analysis, computer modeling, and innovative technologies. The "Air Emissions Monitoring Protocol" may also be modified with prior written approval of the Department."

Traffic Monitoring

(b) "Any person who constructs and operates a tunnel ventilation system which is subject to the requirements of 310 CMR 7.38 shall install, operate and maintain traffic monitoring equipment within the project area, the numbers and locations of which shall be determined in consultation with the Department."

3.2 EMISSIONS MEASUREMENT METHODOLOGIES

3.2.1 Applicability of 40 CFR Parts 58, 60 and 75

Unlike emissions from stacks at a power plant, the emissions from the CA/T's ventilation system is unique in that the system contains multiple exhaust stacks and portal emission sources that operate at multiple exhaust flow rates that move extremely large volumes of air. In addition, unlike the emissions from a power plant which emit much higher (i.e., greater) concentrations of pollutants, pollutant emission concentrations from any CA/T VB or longitudinally ventilated exit ramp, are much lower. The CEM system described in this section, is considered a hybrid type of system, which uses elements of both ambient air quality monitoring systems and continuous emission monitoring equipment required at power plants. As such, the CA/T's CEM system incorporates various elements of the federal regulations 40 CFR Parts 58, 60, and 75 as well as statistical analysis, computer modeling, and innovative technologies.

3.3 CONTINUOUS EMISSIONS MONITORING SYSTEMS DESCRIPTION

3.3.1 Monitoring Locations for Ventilation Buildings

The pollutant levels are measured at the discharge points for each ventilation zone. Since each exhaust fan has its own exhaust stack, there are more stacks than ventilation zones for each VB. In general each ventilation zone feeds two or three exhaust fans (depending on air flow to be delivered). As examples: there are six exhaust stacks at VB 6 serving two ventilation zones; and 14 stacks at VB 7 serving five ventilation zones. This duplication provides redundancy and sufficient ventilation capacity during the times when fans have to be taken out of service due to maintenance or repairs.

The number of exhaust fans in operation at a given time depends on the control of airflow to and from various section of the tunnel. This is accomplished by the ventilation control system. The amount of ventilation depends on the in-tunnel CO measurements, which are dependent on the traffic characteristics. As such, the amount of the airflow exhausted through each stack could vary from zero to full exhaust capacity depending on the number of operating fans' ventilation Step setting. Normal operation utilizes Steps 1 (13% exhaust capacity) to 4 (42% exhaust capacity).

In general, there are always some fans in stand-by mode. Therefore, it was not considered cost effective to install equipment to continuously monitor emission levels at each stack, when only some are in simultaneous operation. Instead, vehicular emissions in the tunnel are monitored in the exhaust plenums of each ventilation zone prior to being diverted up and out of the building stacks. This captures the totality of exhaust emissions before they are diverted into a particular stack.

The CO monitoring system employs a "rake probe" to gather the samples. The probe consists of a length of one half inch Teflon or stainless steel tubing. Each of the probes had 8 equal distant holes drilled so that they allowed for sample collection along the entire width of the ventilation plenum. The probe is oriented so that the 8 holes are directed into the direction of flow of the source stream.

The $PM_{2.5}$ (PM_{10} for years 2006-2011) monitoring system also is deployed at the exhaust plenums, but has a single inlet probe at the center of each exhaust plenum. The flow in the plenum is very turbulent (high Reynolds number) and the exhaust stream is expected to be well mixed. This was demonstrated by the results of tests performed during 2003/04 with multiple portable MiniVOL samplers.

There are possible mechanisms that could lead to particle size stratification, but these mechanisms are not significant in the turbulent environment of the ventilation system. PM is affected by gravity, interception (e.g., filtration), inertial separation/ impaction, electrophoresis, thermophoresis and diffusion. Each of these mechanisms could affect different sizes of PM, but as discussed below, it is very unlikely that the turbulent environment of the plenums will change the outcome of the 2003/04 test results.

- Gravitational settling will act more strongly on the heavier PM_{10} particles than on $PM_{2.5}$. if PM_{10} is uniform and well mixed across the plenum, then $PM_{2.5}$ is expected to be likewise uniform.
- Interception is more likely to deplete PM_{10} than $PM_{2.5}$; however, there are no filters or other structures in the plenum that are significant sites for interception, so this mechanism is expected to be insignificant.
- Differential inertial separation/impaction of $PM_{2.5}$ and PM_{10} could occur when there is a sharp bend in the ductwork and the heavier PM_{10} particles are preferentially carried to the outside of the bend by inertia. Since PM_{10} is uniform in the plenum, inertial separation is not occurring for particles of PM_{10} size and smaller.
- Electrophoresis and thermophoresis would affect the smaller $PM_{2.5}$ particles more than PM_{10} , but there are no strong electric fields or temperature gradients across the well mixed plenum to cause these effects.
- Diffusion in the plenum is dominated by turbulence caused by the forced movement of air. The turbulence has resulted in well mixed, uniform distribution of PM_{10} and will also result in a uniform distribution of smaller particles ($PM_{2.5}$) and gases.

3.3.2 Monitoring Locations for Longitudinal Ventilation

The plume of air that escapes from these tunnels in the wake of exiting traffic maintains its integrity for a distance downstream of the exit portal due to the momentum created by the moving cars. Due to the well mixed turbulence of this plume, the pollutant concentrations inside a cross section of these ramps are fairly uniform.

The CO monitoring system employs a similar "rake probe" with eight equal distant holes to gather the samples. Such probe is located across the roadway at the tunnel ceiling level approximately 100 feet inside each exit portal (Figure 3-1). These measurements provide an average of the in-tunnel CO levels before exiting to the atmosphere.

FIGURE 3-1: CO CEILING MONITORING PROBE AT DST

A CEM $PM_{2.5}$ monitoring system is also deployed just outside the east portal of longitudinally ventilated exit ramp CS-SA. This monitor measured ambient $PM_{2.5}$ concentrations in the vicinity of ramp CS-SA, and $PM_{2.5}$ levels as a pilot program for several months during 2009-2010. Since 2011 it has been used to monitor ambient $PM_{2.5}$ ambient levels.

MassDEP presented a request to include a NOx monitor inside the DST at the July 10, 2015 interagency meeting. The MassDEP rationale for this additional monitor is presented in section 5.8 of this document. MassDOT agreed to include this additional NOx monitor, which will be installed and validated prior to the start of the 2016-2021 Operational Period. The NOx and CO analyzers will simultaneously utilize the existing CO sampling probe, currently installed inside the I-93 segment of the DST, as shown in the above figure. The NOx data collected from this new monitor will be reported to MassDEP for compliance with the emission limit for the DST and will be used to refine the CO – NOx regression formula at the end of the 2016-2021 period.

3.3.3 CO Monitoring System

The CEM equipment used to measure and/or record CO levels is described below. The CEM monitoring system is not typically used to control the fan step during normal operations.; this is done by Operators using independent, in-tunnel CO monitors. However, when pre-established alarm limits, determined to insure compliance with CEM emission limits, are exceeded, control of the fans automatically shifts to the integrated project control system (IPCS) until the alarm condition is eliminated, or the system is manually overridden. The tunnel ventilation monitoring system is used to maintain safe air quality and visibility within the tunnels and to control smoke and heat in emergencies.

3.3.3.1 Ventilation Buildings and Longitudinally Ventilated Exit Ramps

The CO CEM systems located at VBs 1, 3, 4, 5, 6 and 7 and longitudinal ventilated exit Ramps CN-S, CS-SA, CS-P, DST-I93, and DST-I-90, consists of the following equipment:

- Non-Dispersive Infrared Continuous CO Gas Analyzer with a detection range of 0 parts per million to 150 parts per million,
- Multi-Gas Calibration System,
- Zero Air Generator,
- System Controller/Data Logger,
- CO Calibration Gas - RATA Class.

MassDOT currently plans to replace all remaining BINOS CAT-100 Infrared Continuous CO gas analyzers with Thermo Environmental Instruments units with the same detection span before July 2017.

3.3.3.2 CEM Equipment Housing

All CEM equipment located at the CA/T VBs are rack mounted in NEMA certified 12 enclosures (Figure 3-2). CEM equipment located in applicable roadway utility rooms for longitudinally ventilated exit ramps are rack mounted in NEMA certified 4x enclosures (Figure 3-3).

FIGURE 3-2: CO AND $PM_{2.5}$ MONITORING UNITS AT VB 7 EXHAUST

FIGURE 3-3: CO MONITORS LONGITUDINALLY FOR VENTILATED TUNNELS

3.3.3.3 Sample Probe / Sample Transport / Sample Conditioning

The sample probe for the CO emissions monitoring system for both VBs and longitudinally ventilated exit ramps are constructed of stainless steel tubing. The sample probe is installed across each applicable VB's exhaust plenum and in the ceiling of longitudinally ventilated exit ramps in a location so that it is positioned in the stream of air being exhausted through the plenum prior to being diverted up each vent building exhaust stack or out the exit portal of a longitudinally ventilated exit ramp. The probe has eight 1/8-inch diameter holes drilled into it at equal distances along the entire length of the probe. There are no sampling holes located within 3 feet of any exhaust plenum or exit ramp wall. Each sample line is positioned in the exhaust plenum perpendicular to the direction of airflow in the plenum, which ensures that the full cross-sectional airflow within an exhaust plenum is being sampled.

The calibration system that is used to calibrate each CO analyzer uses cylinders of CO gas and a “zero” air source. The CO calibration gas used has been certified according to the EPA RATA procedures. The “zero” air source uses a zero air generator. Zero air and CO gas is diluted using a multi-gas calibration system. The calibration system is capable of controlling and mixing the CO calibration gas stream with the zero air stream to produce concentrations over the entire range of the analyzer. The calibration system supplies calibration gas through the calibration line to the sample probe at the calibration flow rates that range between 10 and 15 standard liters per minute (slpm). Calibration gases are injected through the entire sample line so that the sample line pump is constantly drawing an adequate calibration sample to the CO analyzer.

The sample/calibration bundle is comprised of two Teflon lines. The sample lines are connected to each sample probe, through a particulate filter (at the probe end of the line). The sample is drawn from the probe by a positive displacement pump that discharges to a tee. One leg of the tee is connected to an atmospheric vent and the other leg of the tee is connected to a fine particulate filter just prior to entering a CO analyzer. The sample line pump is set to operate so that the velocity in the sample line is sufficient so that sample residence time in the sample line is always less than 20 seconds. The second line in the sample/calibration bundle is a Teflon line that is connected from the calibration system to the sample probe.

3.3.4 $PM_{2.5}$ Monitoring System

$PM_{2.5}$ levels in the full-transverse ventilated section of the CA/T roadway are monitored continuously in key locations in the exhaust plenums before the exhaust air is diverted up through the VB exhaust stacks to the outside atmosphere. There are no continuous $PM_{2.5}$ CEM monitors located inside longitudinally ventilated exit ramps. At longitudinally ventilated exit ramp CS-SA, a CEM $PM_{2.5}$ monitor is located just outside the exit portal above boat-wall section. This location is representative of the ambient $PM_{2.5}$ conditions close to the traffic emerging from the I-93 southbound tunnel and local traffic data in the CA/T surface corridor.

3.3.4.1 VBs and Longitudinally Ventilated Exit Ramp

The $PM_{2.5}$ CEM monitoring system located at VBs 3, 5 and 7 and longitudinally ventilated exit Ramp CS-SA, consists of the following equipment:

- A continuous $PM_{2.5}$ sampler with a detection range of 0 micrograms per cubic meter to 5,000 micrograms per cubic meter;
- System Controller/Data Logger.

$PM_{2.5}$ CEM equipment located at VB 3 is continuously monitoring particulate emissions from vehicles traveling on north and southbound I-93 tunnel sections. $PM_{2.5}$ equipment located at VB 5 and VB 7, continuously monitor $PM_{2.5}$ emissions from vehicles traveling on east and westbound I-90 tunnel sections.

3.3.4.2 Monitoring Locations and Housing

The $PM_{2.5}$ sensor units at VBs 3, 5 and 7 are housed in a NEMA certified 4x enclosure located in the exhaust plenums of each VB. The $PM_{2.5}$ sensor unit located at longitudinally ventilated exit ramp CS-SA samples air outside of the exit portal of the ramp itself. The intent of this monitor was to measure ambient $PM_{2.5}$ levels in the vicinity of the longitudinally ventilated exit ramp. This ramp was selected because of its close proximity to a residential community and because of the highest potential impacts predicted at the sensitive receptors in the wind-tunnel study.

3.3.5 NOx DST Monitoring System

The CEM equipment used to measure and/or record CO and $NO/NO_2/NO_X$ in-tunnel levels at the I-93 Dewey Square Tunnel Exit Portal is described and shown in a photo below:

Monitoring equipment that will be used to collect CO and NO-NO_2-NO_x concentrations inside the DST portal will consist of a Model 48i Infrared (CO) Analyzer and a Model 42i Chemiluminescence NO-NO_2-NO_x (NO_x) analyzer, all manufactured by Thermo Environmental Instruments, Inc. The analyzers, along with one (1) Model 146i dynamic gas calibrator, also manufactured by Thermo Environmental Instruments, Inc., will be housed in an environmentally controlled shelter (i.e., enclosure), located at the top of the DST portal. Along with analyzers and gas calibrator, a data acquisition system (ESC8832) will also be housed in the equipment enclosure. The 8832 will control calibration sequencing, logging of hourly NO_x concentrations, and calibration results. The 8832 is a computer based system connected to MassDOT via modem. The system will allow access to all analyzer operating status, recorded hourly NO_x data and calibration results from current MassDOT monitoring stations. Finally, calibration gas cylinders are also store in the enclosure. (See Figure 3-4 for equipment and enclosure)

FIGURE 3-4: CO-NO-NO2 DST MONITORS ENCLOSURE

3.3.6 Data Acquisition and Handling System

Data from the CO and $PM_{2.5}$ CEM systems located at VBs 1, 3, 4, 5, 6 and 7 and longitudinal ventilated exit Ramps CN-S, CS-SA, CS-P, DST-I93, and DST-I-90, is recorded using a System Controller/Data Logger (data logger) at each location. The data loggers constitute the Data Acquisition Handling System (ESC8832) for each CEM location. The data loggers control the calibration routines for the CO analyzers and records of all CO and $PM_{2.5}$ concentrations on an hourly/daily basis.

3.4 Continuous Emissions Monitoring Systems Initial Certification

The CA/T's ventilation system is unique in many ways. As such, the certification process performed for monitoring the emissions from the ventilation system is also unique in its application to the Project's ventilation system. Equipment certification and operations were specifically tailored for use in the Project's emissions monitoring program and reflect the unique application for which the equipment is being used.

3.4.1 CO Monitoring System

3.4.1.1 CO Analyzer Multi-Point Calibration Test

The CO analyzers that are used to monitor CO concentration in the exhaust plenum and at the longitudinally ventilated exit ramps, were calibrated using the system dilution calibration device at zero (0) concentration and at four (4) calibration points over the range of the instrument. Calibration concentrations were: a high value 100-135 ppm, a mid-range 45–75 ppm, a low-range 20–30 ppm, and a low-low-range 5-10 ppm. Calibration gas was injected directly into each CO analyzer. The instruments were adjusted first at the zero level and then at the high value. After each instrument was adjusted at the high value, the zero level was injected again. If the zero level required re-adjustment, then the high level concentration was injected again. If necessary, several iterations between the zero and high level concentrations were performed to ensure that an analyzer was calibrated. The calibration specification for acceptability was ±1.0 ppm for zero and ±5% of the input concentration for the high level point. All remaining concentrations levels were injected without any further analyzer adjustments. The average Δ% for calibration points were not allowed to exceed ±5% where:

$$\Delta\% = \frac{(\text{Analyzer Response} - \text{Input Concentration})}{\text{Input Concentration}}\, x\, 100$$

Where :

Analyzer Response = Concentration recorded by an analyzer

Input Concentration = Input calibration gas concentration

3.4.1.2 Cycle Time and Linearity Test

For this test, all monitoring systems were operated in their normal sampling mode, including the time sharing mode for the equipment located at VB 7.

Low-level calibration gas with a value of 40 to 50 ppm were input through the entire monitoring system for 30 minutes, or until a stable response was achieved. At the end of the period, a high-level calibration gas with a value of 80 to 90 ppm was input through the entire monitoring system for 30 minutes or until a stable response occurred.

The amount of time it took for 95% of the step change to be achieved between a stable low level and high-level calibration gas response was determined. The cycle time test was successful was the response time achieved was less than 15 minutes.

The linearity of the monitoring system to the low and high scale calibration gases was also tested during the cycle time test. To pass the linearity test, the monitoring system response had to be within ±5% of the low and high-level calibration gas input values using the formula:

$$\text{Linearity } \Delta\% = \frac{(\text{System Response} - \text{Input Concentration})}{\text{Input Concentration}} \, x \, 100$$

Where:

System Response = Concentration recorded by the analyzer when the calibration gas is injected through the entire system

Input Concentration = Input calibration gas concentration

3.4.1.3 Seven-Day Calibration Drift Test

The calibration drift of each monitoring system was measured once a day (approximately 24 hours apart) for seven consecutive days using zero and span gases. No manual or automatic adjustments were made to any analyzer until after recording all responses.

To pass the seven-day drift test for the zero point, each analyzer's zero drift could not be greater than ±1% (1.5 ppm) of the analyzer full-scale range (150 ppm) per day. Drift for the span gas was calculated as follows:

$$\text{Calibration drift} = \frac{(\text{Analyzer Response} - \text{Input Concentration})}{\text{Input Concentration}} \, x \, 100$$

Where :

Analyzer Response = Concentration recorded by the analyzer

Input Concentration = Input span gas concentration

To pass the seven-day drift test for the span gas, each analyzer's span drift could not be greater than ±5% of the span value per day.

3.4.1.4 System Bias Test

After each CO analyzer was calibrated, a system bias check was performed. The high-level calibration concentration was injected through the entire emission monitoring system. The acceptable system bias was ±5% according to the equation:

$$\text{System Bias} = \frac{\text{System Response} - \text{Direct Analyzer Response}}{\text{Direct Analyzer Response}} \quad x \quad 100$$

Where:

System Response = Concentration recorded by the analyzer when the calibration gas was injected through the entire system

Direct Analyzer Response = Concentration recorded by the analyzer when the calibration gas was injected directly into the analyzer

3.4.2 $PM_{2.5}$ Monitoring System

Tests will be performed on each $PM_{2.5}$ unit located at VBs and outside longitudinally ventilated exit Ramp CS-SA and will consist of calibration/certification of each particulate monitoring system, including the calibration of the main and auxiliary flow rate, the on-board temperature sensor, and the barometric pressure sensor by its referenced standard. In addition, verification of the Ko constant of each $PM_{2.5}$ unit mass transducer taper element will be conducted by using five pre-weighed filters.

In all cases, the manufacturer recommended procedures specified in the $PM_{2.5}$ unit's operating manuals were applied for all certifications tests. Reference standards used were either primary standards or working standards traceable to National Institutes of Standards and Technology (NIST).

3.4.2.1 K Factors

% Error of Ko = 100 x (Average Ko – Actual Ko) /Designated Flow

The allowable Ko error ± 2.5%.

3.4.2.2 Flow

% Error of Flow = 100 x (Average Flow – Designated Ko)/Designated Flow

The allowable flow error is ± 7%.

3.4.2.3 Temperature and Barometric Pressure

Error = Display Value – Audit Value

The allowable temperature error is ± 2°C. The allowable barometric pressure error is ± 10 mm Hg.

3.4.3 Continuous Emissions Monitoring Certification Data Submittal

Results for certification tests performed on CO CEM equipment (i.e., multi-point calibration, cycle time/linearity, seven-day drift and system bias) and $PM_{2.5}$ CEM equipment (i.e., K-factor, system flow and temperature/barometric pressure), are presented in Appendix D, "CEM Certification Test Data".

3.5 TRAFFIC MONITORING

The CA/T Project has an extensive array of video cameras to monitor traffic conditions through the entire project. The main function of this centralized system, which is operated by the HOC, is to monitor real time traffic conditions to assist the HOC operations in conducting safe tunnel operation.

There are four locations where hourly traffic volumes are recorded using traffic counting loops under the tunnel pavement, as follows:

- I-93 southbound in the vicinity of Milk Street
- I-93 northbound in the vicinity of Milk Street
- I-90 westbound the vicinity of vent building 6 in South Boston
- I-90 eastbound under Boston Harbor in the vicinity of the South Boston Shoreline

These locations represent the tunnel sections that account for the vast majority of the Project's traffic volumes, and as such, they provide MassDEP with a very good indication of the peak hourly and daily traffic volumes passing thru the CA/T tunnels.

An upgrade of the CA/T Integrated Project Control System (IPCS) will be completed in approximately the next two years, and may not support the existing traffic counting loops, which are embedded in the pavement. These loops are sufficiently old that they may fail in the near future. Thus, alternative traffic counting methods are currently being evaluated by MassDOT.

At this point in time, it is unclear which method will replace, the existing loop detectors.

As this evaluation proceeds, MassDOT will keep MassDEP informed on proposed methods to record and present the traffic data in the future.

4 CONTINUOUS EMISSIONS MONITORING PLAN

4.1 PROJECT-WIDE QUALITY ASSURANCE/QUALITY CONTROL PROGRAM

This section describes the overall quality assurance (QA) and quality control (QC) program for the continuous air emissions monitoring portion of the long-term Compliance Monitoring Program for the CA/T Project. CEM equipment currently in-place for CA/T's Operating Certification, along with specific information regarding the CEM QA/QC program, are described in Attachment 1, "CEM Air Emissions Monitoring Protocol" to this document.

The QA/QC program sets forth, among other things, the procedures to be followed and the criteria to be met, where applicable, for:

- Operating, maintaining and calibrating the CEMS equipment and related components;
- Determining the quality of the measured data; and
- Developing emissions-related parameters or directly reporting the measurement results to the MassDEP in order to demonstrate project compliance status with respect to the ambient concentration limits in 310 CMR 7.38(2)(a).

The QA/QC program has been developed through extensive technical consultation with the MassDEP taking into consideration Federal Regulations 40 CFR Parts 58, 60 and 75. The procedures to be followed also take into account equipment manufacturer's recommendations as well as good engineering practice.

4.1.1 Quality Assurance/Quality Control – Definition and Function

QA, as it relates to the continuous air emissions monitoring program for the CA/T Project, represents those planned or systematic activities, independently performed by personnel external to MassDOT, that are required to ensure that the measurements made and the data reported to regulatory authorities are representative, acceptably accurate, and supported by defendable documentation.

QC, as it is to be implemented for this monitoring program, represents the series of routine and periodic operational activities (based on regulatory requirements, good engineering practice, and the agreed-upon approach for this hybrid monitoring system) that are necessary for maintaining and improving data quality and the instruments and systems that produce that information.

QA checks also serve to ensure that the QC function is not only being implemented properly, but that it is adequate to the task, such that when (or even before) data accuracy or documentation becomes unacceptable, actions are taken to identify and resolve the issues or procedural steps affecting data quality until acceptable performance is once again achieved. Periodic review of implementation and documentation are typically referred to as "Systems Audits".

Corrective action encompasses both internal policies and regulatory requirements. This QA/QC program focuses primarily on the corrective actions required to maintain the system or component back in a status of compliance, but, it also acknowledges the need for periodic review of the CEM Air Emissions Monitoring Protocol and related standard operating procedures (SOPs) based on accumulated operating experience and opportunities for improvement identified as a result of Systems Audits. (**Note:** Recommendations for improvement that are generated during Systems Audits are evaluated by MassDOT staff and are implemented if deemed meritorious **and** adequate resources, e.g. manpower, funding, etc. are available.)

4.1.2 QA/QC Goals and Objectives

The goals of this QA/QC program are to collect measurement data of known and acceptable quality and quantity, and to generate and maintain the records required to demonstrate that the continued operation of the tunnel and exit ramp ventilation systems results in compliance with the air quality criteria set forth in 310 CMR 7.38(2)(a).

In order to do so, MassDOT is committed to installing, certifying, operating, maintaining and calibrating continuous emissions monitoring and related systems in accordance with applicable Commonwealth of Massachusetts regulations at 310 CMR 7.38(8) and 7.38(9), agreed-upon requirements adapted from Federal regulations conditions in the CA/T Project's Operating Certification, the QA/QC program laid out in Attachment 1, and good engineering practice.

4.1.3 Organization and Responsibilities

This section summarizes key personnel, responsibilities and organizational structure for the continuous air emissions monitoring portion of the long-term Compliance Monitoring Program for the CA/T Project which is established pursuant to 310 CMR 7.38 and implemented in accordance with the requirements of the CA/T's Operating Certification.

4.1.3.1 Director of Environmental Engineering

The director of Environmental Engineering is responsible for the overall implementation of the CEM Program described within.

4.1.3.2 Senior Environmental Engineer

The Senior Environmental Engineer is responsible for technical oversight of the continuous air emissions monitoring program and its execution. The Senior Environmental Engineer interfaces with the Director of Environmental Engineering in carrying out the planning and administrative responsibilities of that position and with QA Management (external to MassDOT) to ensure that all program activities affecting data quality are performed and documented in accordance with the CEM Air Emissions Monitoring Protocol and the applicable SOPs. The Senior Environmental Engineer also serves as technical liaison between the MassDOT and representatives of the MassDEP and other regulatory agencies in regards to the monitoring program and the reported results.

Regarding implementation of the monitoring program, the duties of the Senior Environmental Engineer encompass:

- Procurement of equipment, related components and materials[1];
- Training and supervision of air quality staff, participating in the operation, maintenance and calibration of the CEMS equipment and related components, and interpreting CEMS output data[1];
- Ensuring that routine and periodic QC inspections, instrument response checks, calibrations and adjustments are successfully performed and documented as required;
- Verifying that measurement and QC check data are recorded and reviewed on a regular basis, and that measurement data are reduced and validated properly;
- Review, approval and timely submittal of monthly (first year of full operations only) and quarterly (thereafter) reports of CEMS data and QC check results to MassDEP;
- Supporting periodic independent and third-party QA Equipment Performance and Systems Audits in coordination with regulatory agencies (as applicable), and any subcontractor(s) that may conduct such work;
- Review of semi-annual QA Performance Audit and annual Systems Audit reports;
- Resolution of any issues resulting from routine operations, maintenance, QC checks or QA audits, evaluating the need for Monitoring Plan revision in coordination with QA Management and, when required, revising the CAEMP or the accompanying SOPs;

- Daily review of CO and $PM_{2.5}$ measurement data and periodic review of calculated NO_x concentrations for each monitoring location in relation to the corresponding Operating Certification limits, traffic volumes and tunnel operating conditions;
- Regular review of QC check results (i.e., daily CO analyzer response checks) versus applicable acceptance criteria and action limits;
- Routine processing and summarization of measured hourly average CO concentrations, calculated and measured (Dewey Square Tunnel only) hourly average NO_x concentrations, daily (24-hour) average $PM_{2.5}$ measurements, and daily and periodic QC check results;
- Validation of CO and $PM_{2.5}$ measurement data based on operating status of analyzers and related instrumentation, and the results of daily QC response checks (CO only), other periodic QC checks (e.g., multi-point calibrations, flow rate verifications), and periodic QA Equipment Performance Audits;
- Preparation of monthly (first year of full operations only) or quarterly (thereafter) reports of CEMS data, QC check results, and excess emissions (if any) as they occur in accordance with 310 CMR 7.38(9)(a)(2);
- Supporting preparation of semi-annual QA Performance Audit reports and annual QA Systems Audit reports;
- Retaining all measurement data, results of periodic QC checks and QA Performance and Systems Audits, and other related documentation (e.g., records of routine and periodic inspections and preventive maintenance) for a period of at least five years in accordance with 310 CMR 7.38(9)(a)(1);
- The conduct of periodic independent QA Performance Audits - for example, semi-annual multi-point calibration response and bias checks of the CO analyzers, and semi-annual verification of $PM_{2.5}$ mass transducer calibration and flow audit response;
- The performance of annual independent QA Systems Audits of monitoring program implementation and related documentation;
- The scheduling and conduct of any third-party (i.e., regulatory agency) QA Performance or Systems Audits; and
- The preparation and review of the corresponding QA Performance and Systems Audit reports.

[1]Equiment procurement, training and limited data review responsibilities may be integrated with the responsibilities of the Senior Environmental Engineer and/or his designee(s) (e.g., Environmental Engineer, Environmental Technicians).

4.1.3.3 Environmental Engineers

The Environmental Engineer(s), working under the direction of the Senior Environmental Engineer, are responsible for routine operation, maintenance and calibration (collectively referred as QA) of the CEMS and all related components. In this regard, the duties of the Environmental Engineer and Environmental Technicians include:

- Inspection of the CEMS equipment and shelters on a regular basis (e.g., analyzer and equipment settings and readouts, calibration gas bottle pressures and inventory, general housekeeping);
- Completing periodic (e.g., weekly, monthly, semi-annual, annual) preventive maintenance items on the CEMS and related equipment;
- Maintaining an adequate inventory of spare parts and consumable items such that instrument downtime is minimized to the extent practicable;
- Conducting and/or evaluating periodic QC checks – for example, daily, quarterly, annual checks of CO analyzer response and calibration gas dilution system flow meter accuracy, and quarterly, semi-annual

and annual verifications and/or calibrations of $PM_{2.5}$ monitor flow rate and related flow or measurement system components; and

- Supporting independent semi-annual QA Performance Audits and annual QA Systems Audits, or other third-party (e.g., MassDEP) audits.

As indicated at the end of the preceding subsection, the Environmental Engineer(s) may undertake some of the data review, equipment procurement and training duties if deemed qualified by the Senior Environmental Engineer.

4.1.4 Document Distribution and Control

As a matter of practicality, copies of the Continuous Air Emissions Monitoring Plan will not be placed at each continuous emissions monitoring location simply because of the number of sites in the monitoring network. Rather, distribution of the CEM Air Emissions Monitoring Protocol will be via Controlled Copy for those individuals and organizations with a need-to-know function that directly affects the successful implementation, management and/or oversight of the continuous air emissions monitoring program. Each Controlled Copy shall be sequentially numbered.

At a minimum, recipients of Controlled Copies of the CEM Air Emissions Monitoring Protocol (Attachment 1) will include:

- Director of Environmental Engineering
- Senior Environmental Engineer
- Environmental Engineer(s)
- MassDEP

Uncontrolled copies will also be distributed to individuals or organizations on an as-needed basis for informational purposes where casual familiarity with the monitoring program may be beneficial but is not essential. The Senior Environmental Engineer in coordination with the Director of Environmental Engineering shall approve such recipients.

Distribution of Controlled Copies of the CEM Air Emissions Monitoring Protocol, and revisions to it, will be documented on form MTA-ENV-FORM01. Recipients shall sign the distribution form, return the original to the Senior Environmental Engineer or designee, and retain a copy of the signed form. The signed original shall be retained by the Director of Environmental Engineering.

Distribution of Uncontrolled Copies of the CEM Air Emissions Monitoring Protocol shall be by formal transmittal letter or e-mail, as appropriate. Documentation of all such transmittals shall also be retained by the Director of Environmental Engineering.

The CEM Air Emissions Monitoring Protocol may be updated periodically as operational experience with the CEM system is gained, as the effectiveness of the SOPs and the staff's execution of them is demonstrated (as evidenced by the quality of the data and related documentation produced), and as evaluated through the results of periodic QA Equipment Performance and Systems Audits.

At a minimum, the CEM Air Emissions Monitoring Protocol will be reviewed annually by the Senior Environmental Engineer in coordination with QA Management; more frequently, if required (e.g., due to failure of multi-point calibrations or an intervening semi-annual QA Performance Audit during two consecutive calendar quarters, frequently occurring out-of-control periods).

Revisions to any requirement of the CEM Air Emissions Monitoring Protocol (e.g., the frequency of equipment and data inspections, instrument response checks, calibration checks and adjustments) or to SOPs shall be agreed upon by the Senior Environmental Engineer before incorporation. All changes to the CEM Air Emissions Monitoring Protocol shall be clearly marked on each affected page with the Revision

Number, Date and Page Number updated accordingly. Controlled Copies of the affected sections (or subsections), or an individual SOP shall be re-issued by the Senior Environmental Engineer with distribution and receipt to be documented as described above. The Senior Environmental Engineer or designee shall keep a chronological log that summarizes all such revisions.

The Senior Environmental Engineer will identify all parties directly affected by such revisions and will coordinate the necessary training to implement those changes in a timely manner. The appropriate mode of training shall be at the discretion of the Senior Environmental Engineer.

4.2 TRAINING

Training represents an essential element of a successful QA/QC program by identifying the objectives to be accomplished and by providing the basic knowledge required to successfully complete a procedure or task. In this QA/QC program, training takes the form of:

- General training,
- Specialized vendor training,
- Monitoring plan review, and
- Periodic refresher and specialized training

Training and subsequent implementation can also provide a more thorough understanding (over time) of a given task or procedure that enables the individual involved to make more timely and effective decisions while executing the process or improving on the process itself. Therefore, training is the cornerstone of the framework within which activities were performed in a consistent manner regardless of who completes them.

4.2.1 General Training

General training was not intended as much to deliver detailed and specific knowledge, as it is to provide an overall understanding of the goals and objectives of the CA/T Project's continuous air emissions monitoring program within the framework of the CEM Air Emissions Monitoring Protocol. General training is provided to all individuals directly involved with the CEM program.

4.2.2 Specialized Vendor Training

Specialized training in the installation, operation, maintenance and calibration of the various monitoring systems and related components will be provided to the Senior Environmental Engineer, and to the Environmental Engineer(s), as appropriate, by the respective system vendors either at the time of or soon after initial installation of the equipment.

4.2.3 Monitoring Plan Review

All personnel involved in the routine operation, maintenance and calibration of the CEMS, related components and systems, or in the review, processing, validation and reporting of the data produced by those pollutant measurement systems will be required to review:

- The appropriate sections and/or Parts of this document (including the applicable requirements adapted from the regulations under 40 CFR Parts 58, 60 and 75), and
- The CEM Air Emissions Monitoring Protocol, SOPs and corresponding System Manuals.

4.2.4 Periodic Refresher and Specialized Training

Refresher training occurs periodically (e.g., following review of the effectiveness of the CEM Air Emissions Monitoring Protocol and accompanying SOPs).

When changes in personnel or assigned responsibilities take place, the degree of specialized training is tailored to the level of previous experience with the CA/T Project's continuous air emissions monitoring program, specific systems, and tasks to be performed. Specialized training in the operation, maintenance and calibration of the various monitoring systems and components may be conducted by the vendor or by previously trained in-house staff.

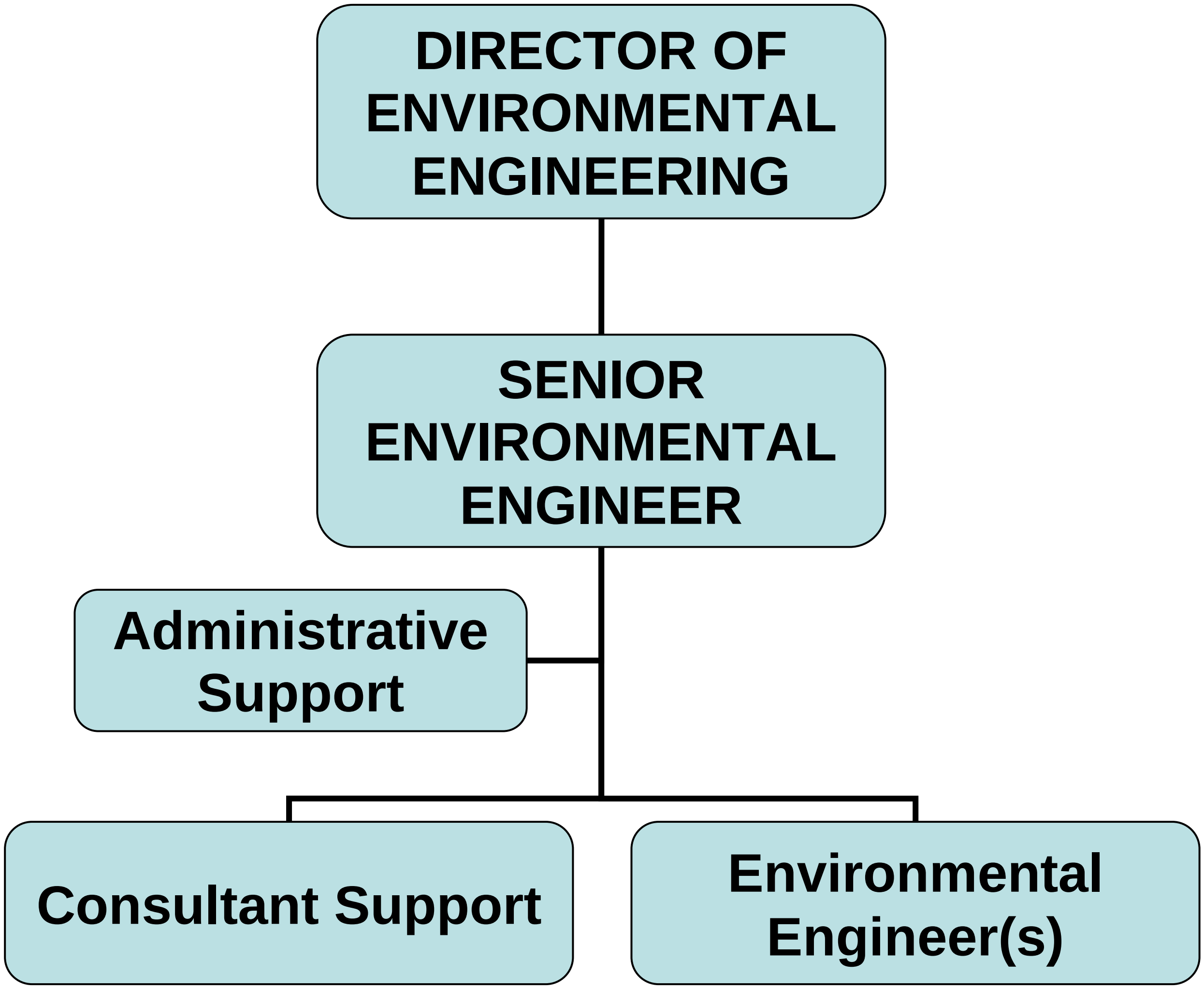
Finally, when system components change (e.g., the replacement of a pollutant monitor with an instrument that bases its measurements on a different analytical method – as opposed to the repair or replacement of a failed part) are made, specialized vendor training takes place for those personnel whose responsibilities or procedures are affected.

TABLE 4-1: KEY PERSONNEL AND RESPONSIBILITIES

Title	Responsibilities
Director of Environmental Engineering	• Overall implementation of the program
Senior Environmental Engineer	• Technical oversight of CEM program • Procure CEMS-related equipment/materials • Determine training needs of AQ staff and, as required, other program participants • Supervise Environmental Engineer and Environmental Technicians and support those responsibilities as needed • CEMS data and QC check report review • QA Performance Audit report review • QA Systems Audit report review/submittal • Revise CAEMP and SOPs (as necessary) and coordinate/conduct associated refresher training • Daily[1] data review • Data processing and validation • Prepare CEMS data and QC check reports • Support preparation of QA Performance and Systems Audit reports • Coordinate conduct of semi-annual/annual QA Performance Audits and annual QA Systems Audits • Coordinate preparation/review of Performance and Systems Audits reports
Environmental Engineer(s)	• CEMS operation, maintenance and calibration • Regular CEMS inspections[2] • Conduct quarterly, semi-annual and annual QC checks • Support independent QA Performance/Systems Audits

Notes:
1 – Data to be reviewed on a daily basis, nominally, during regular work week (Mon/Wed/Fri).
2 – Each site to be visited 2 times, nominally, per regular month.

FIGURE 4-1: ORGANIZATIONAL STRUCTURE FOR THE MASSDOT-CA/T PROJECT CONTINUOUS AIR EMISSIONS MONITORING PROGRAM



MASSDOT-ENV-FORM01
CONTROLLED DOCUMENT DISTRIBUTION FORM

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Title: CENTRAL ARTERY/TUNNEL (CA/T) PROJECT CONTINUOUS AIR EMISSIONS MONITORING PLAN		
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Part III – Record Keeping and Reporting

5 DATA RECORDING AND REPORTING

5.1 MASSDEP 310 CMR 7.38(9) REGULATORY REQUIREMENTS

MassDEP Regulation 310 CMR 7.38(9) states the following requirements for record keeping and reporting:

“(a) Any person who constructs and operates a tunnel ventilation system on or after January 1, 1991 shall comply with the following record keeping and reporting requirements:

1. All records and data from the continuous emissions monitors, recorders and traffic monitors shall be maintained for a period of five years. The most recent two years of data shall be readily available for Department inspection.

2. Emissions Reporting. For the first year of operations monthly reports shall be filed with the Department no later than 30 days following the end of the preceding calendar month. Said monthly reports shall contain a summary of continuous monitoring data showing any excursions from allowable emission limitations contained in the Department's acceptance of the certification. In the event any of the reported data shows an excursion of the emission limitations set forth in the acceptance of certification, a written explanation of any excursion shall be included. Evidence of each calibration event on the monitoring devices shall be included in such monthly reports.

3. Traffic Reporting. For the first year of operation monthly reports shall be filed with the Department no later than 30 days following the end of the preceding calendar month. Said monthly reports shall contain a summary of average daily and peak hour counts of vehicle miles traveled as well as average daily and peak hour vehicle speeds and vehicle hours traveled as identified through the traffic monitoring network established pursuant to 310 CMR 7.38(8).

4. Tunnel Ventilation System Maintenance. For the first year of operations monthly reports shall be filed with the Department no later than 30 days following the end of the preceding calendar month. Said monthly reports shall contain a summary of routine maintenance checks performed, repairs of ventilation equipment, amount of time during which ventilation equipment was not operating in accordance with standard operating procedures and measures taken to remedy this situation.

(b) After the first year of operation, the reports required by 310 CMR 7.38(9) shall be submitted to the Department on a quarterly basis, with the first such quarterly report being due no later than 30 days after the end of the quarter and every three months thereafter.”

5.2 CONTINUOUS EMISSIONS MONITORING MEASUREMENT DATA PROCESSING

As described in Sections 3.3.3 and 3.3.4, all CO and $PM_{2.5}$ CEM data are recorded using data loggers located at each CEM location. Data from each data logger are downloaded via a modem to a central computer. All CO and $PM_{2.5}$ data are reviewed edited as necessary and daily data summaries for each month are generated. Using the edited daily summaries, NO_x emission concentrations are developed using the CO to NO_x ratio described in Section 2.6.3. The reports will be submitted to MassDEP on a quarterly basis.

5.3 TRAFFIC DATA PROCESSING

The HOC will record hourly volumes at the following locations:

- I-93 southbound in the vicinity of Causeway Street
- I-93 northbound in the vicinity of South Station
- I-90 westbound in East Boston
- I-90 eastbound in the vicinity of Fort Point Channel

Peak hourly and average daily traffic volumes at each of the four locations are reported to MassDEP on a quarterly basis. The data will also provide the monthly average daily volumes for each location. Figure 5-1 presents the peak and average daily traffic volumes for I-93 and I-90 in both directions from July 2006 to December 2016. Figure 5-2 presents the peak hourly volumes for the same locations and time periods.

FIGURE 5-1: PEAK AND AVERAGE DAILY TRAFFIC VOLUMES FOR PERIOD 2006-2016

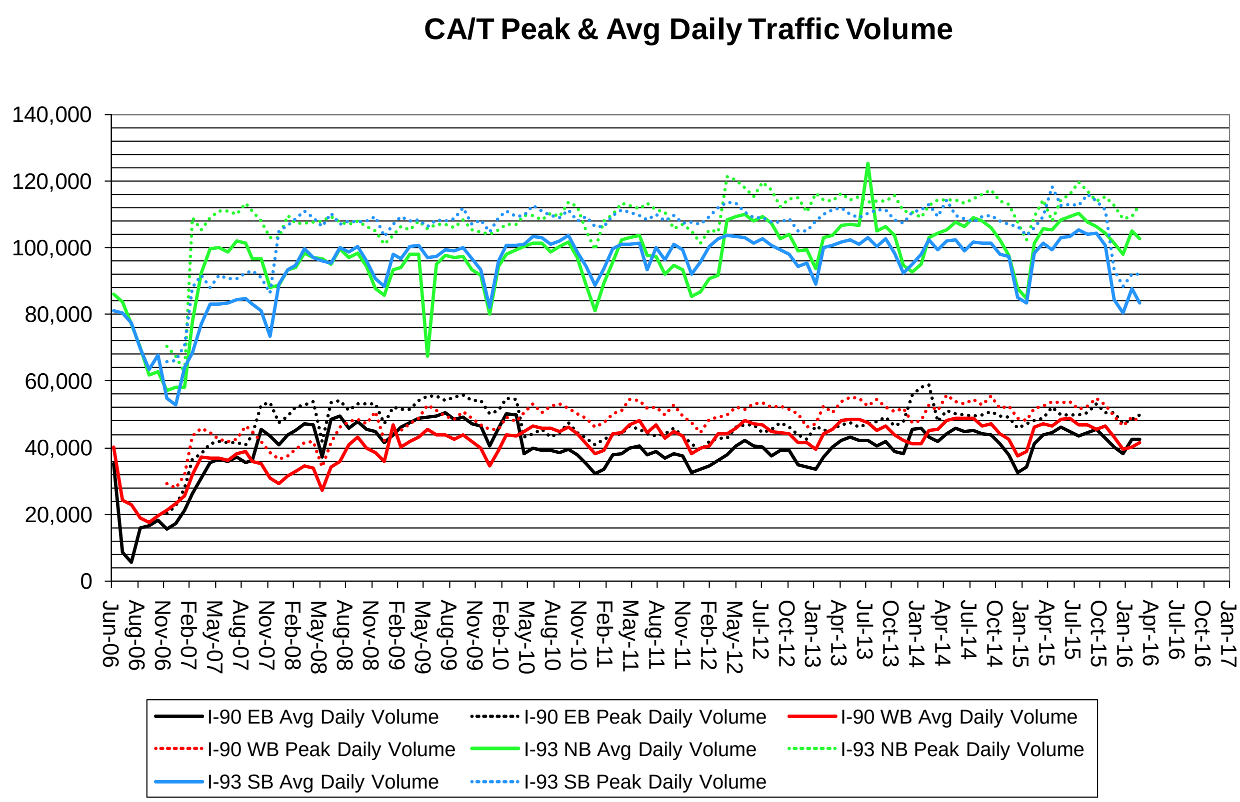
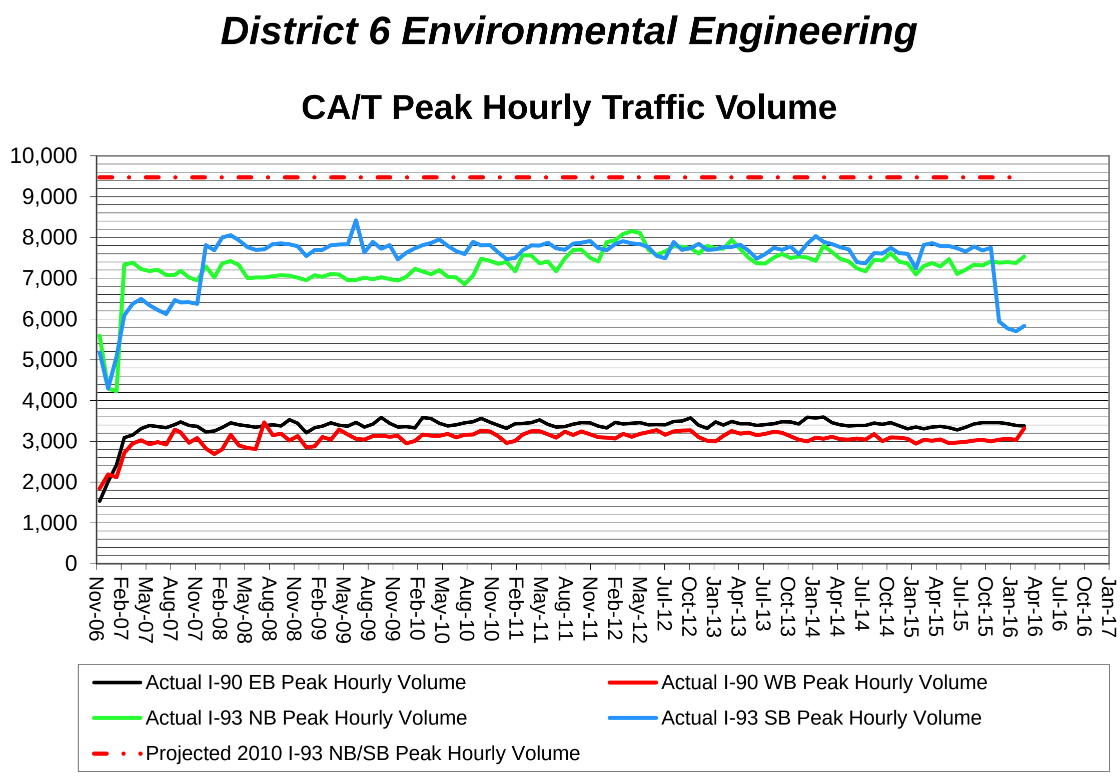


FIGURE 5-2: PEAK HOURLY TRAFFIC VOLUMES FOR PERIOD 2006-2016



5.4 TUNNEL VENTILATION SYSTEM MAINTENANCE RECORDS

Tunnel ventilation records for both routine and non-routine maintenance activities are logged and tracked through the Project's Maintenance Management Information System (MMIS). As described in section 1.2.1 each ventilation zone has multiple exhaust fans that serve that zone. Each zone can operate with one functioning fan. If however, multiple exhaust fans within a ventilation zone are to undergo repair that results in only one operating exhaust fan, MassDOT will notify MassDEP via monthly report as to the extent of the maintenance that will be performed and the duration of the repairs. The reports, if any, will be provided on a monthly basis for the first year of 2011 Operating Certification and on a quarterly basis thereafter.

5.5 CONTINUOUS EMISSIONS MONITORING DATA SUMMARY REPORTS

Annual summaries of the CO, NO_x and $PM_{2.5}$ average and peak levels for each VB (Tables 5-1 to 5-6) and longitudinally ventilated section collected between 2012 and first four months of 2016 are provided in Tables 5-1 to 5-16. The applicable emission limits for CO, NO_x and $PM_{2.5}$ are also set forth in these tables.

The proposed CO, NO_x and $PM_{2.5}$ emission limits after they are approved will come into effect from December 2016.

The collected 2012-2016 data presented in a summary form (Tables 5-1 to 5-16) indicates:

- Measured CO concentrations for the Ventilation Buildings range from 0.6 to 4.0 ppm on average, with maximum 1-hour values as high as 33.6 ppm;

- Measured CO concentrations for the DST and Ramps range from 1.7 to 4.3 ppm on average, with maximum 1-hour average concentrations ranging from 17.9 to 38.5 ppm;
- Measured NO_x levels for the Ventilation Buildings range from 0.3 to 0.5 ppm on average, with maximum 1-hour values ranging from 1.1 to 3.1 ppm;
- Measured NO_x levels for the DST and Ramps range from 0.4 to 0.6 ppm on average, with maximum 1-hour values ranging from 1.8 to 3.5 ppm;
- Measured $PM_{2.5}$ concentrations (2012-2016) were between 19 and 39 $\mu g/m^3$ on average, with maximum daily values ranging from 163 to 414 $\mu g/m^3$;
- The $PM_{2.5}$ monitor outside Ramp CS-SA, which measures ambient levels, recorded annual averages from 9 to 11.4 $\mu g/m^3$, and a maximum daily level of 33.5 $\mu g/m^3$.

The data indicate that the pollutant levels inside the tunnels are generally lower than anticipated, with CO levels decreasing in the latter years. However, as described in detail in Section 6, there were four episodes when emission limits for CO and NOx were exceeded at DST. These four episodes when emission limits were exceeded were related to night-time tunnel closures due to maintenance.

TABLE 5-1: SUMMARY OF CO AND NO_X AVERAGE AND PEAK LEVELS: VENTILATION BUILDING 1

Monitor Location: *VB1 Exhaust 1&2 (Ramp L/HOV for I-90 EB)*

Pollutant	Time Period	Emission Limits	Parameter	Unit	2012	2013	2014	2015	2016 Q1
CO	1 Hour	70 ppm	Maximum	ppm	6.3	9.2	8.4	8.5	5.4
			Average	ppm	1.1	1.1	1.2	1.1	0.9
			Hours exceed EL		0	0	0	0	0
			Hours exceed AL		0	0	0	0	0
	8 Hour	70 ppm	Maximum	ppm	3.1	3.1	3.4	4.3	2.6
			Hours exceed EL		0	0	0	0	0
NO_x	1 Hour	6.1 ppm	Maximum	ppm	0.8	1.1	1.0	1.0	0.7
			Average	ppm	0.4	0.4	0.4	0.4	0.4
			Hours exceed EL		0	0	0	0	0

Monitor Location: *VB1 Exhaust 8&9 (Ramp L/HOV for I-90 EB)*

Pollutant	Time Period	Emission Limits	Parameter	Unit	2012	2013	2014	2015	2016 Q1
CO	1 Hour	70 ppm	Maximum	ppm	5.8	6.1	6.2	6.4	4.4
			Average	ppm	1.0	1.0	1.0	1.0	0.8
			Hours exceed EL		0	0	0	0	0
			Hours exceed AL		0	0	0	0	0
	8 Hour	70 ppm	Maximum	ppm	3.2	2.7	2.9	3.1	2.4
			Hours exceed EL		0	0	0	0	0
NO_x	1 Hour	6.1 ppm	Maximum	ppm	0.9	0.8	0.8	0.8	0.7
			Average	ppm	0.3	0.4	0.4	0.4	0.4
			Hours exceed EL		0	0	0	0	0

Monitor Location: *VB1 I-90 EB*

Pollutant	Time Period	Emission Limits	Parameter	Unit	2012	2013	2014	2015	2016 Q1
CO	1 Hour	70 ppm	Maximum	ppm	4.3	2.7	8.8	5.0	1.6
			Average	ppm	1.0	0.9	0.8	0.6	0.4
			Hours exceed EL		0	0	0	0	0
			Hours exceed AL		0	0	0	0	0
	8 Hour	70 ppm	Maximum	ppm	2.7	2.3	3.0	1.9	1.2
			Hours exceed EL		0	0	0	0	0
NO_x	1 Hour	6.1 ppm	Maximum	ppm	0.7	0.5	1.0	0.7	0.4
			Average	ppm	0.3	0.4	0.4	0.3	0.3
			Hours exceed EL		0	0	0	0	0

Note: EL = Emission Limit

TABLE 5-1: SUMMARY OF CO AND NO_X AVERAGE AND PEAK LEVELS: VENTILATION BUILDING 1 (CONTINUED)

Monitor Location: *VB1 I-90 WB*

Pollutant	Time Period	Emission Limits	Parameter	Unit	2012	2013	2014	2015	2016 Q1
CO	1 Hour	70 ppm	Maximum	ppm	5.1	4.2	7.8	4.8	4.1
			Average	ppm	1.1	1.1	1.3	1.3	1.0
			Hours exceed EL		0	0	0	0	0
			Hours exceed AL		0	0	0	0	0
	8 Hour	70 ppm	Maximum	ppm	2.6	2.7	3.2	2.7	3.1
			Hours exceed EL		0	0	0	0	0
NO_x	1 Hour	6.1 ppm	Maximum	ppm	0.8	0.6	0.9	0.7	0.6
			Average	ppm	0.4	0.4	0.4	0.4	0.4
			Hours exceed EL		0	0	0	0	0

Monitor Location: *VB1 I-90 WB*

Pollutant	Time Period	Emission Limits	Parameter	Unit	2012	2013	2014	2015	2016 Q1
CO	1 Hour	70 ppm	Maximum	ppm	5.2	3.6	8.8	5.9	5.4
			Average	ppm	1.1	1.0	1.0	1.1	0.9
			Hours exceed EL		0	0	0	0	0
			Hours exceed AL		0	0	0	0	0
	8 Hour	70 ppm	Maximum	ppm	2.9	2.5	4.1	2.7	2.2
			Hours exceed EL		0	0	0	0	0
NO_x	1 Hour	6.1 ppm	Maximum	ppm	0.8	0.6	1.0	0.8	0.7
			Average	ppm	0.3	0.4	0.4	0.4	0.4
			Hours exceed EL		0	0	0	0	0

Monitor Location: *VB1 Exhaust 10&11 (Ramp D I-90 WB to I-93 NB)*

Pollutant	Time Period	Emission Limits	Parameter	Unit	2012	2013	2014	2015	2016 Q1
CO	1 Hour	70 ppm	Maximum	ppm	7.7	6.2	4.9	6.0	6.7
			Average	ppm	1.4	1.4	1.4	1.5	1.2
			Hours exceed EL		0	0	0	0	0
			Hours exceed AL		0	0	0	0	0
	8 Hour	70 ppm	Maximum	ppm	3.6	3.8	3.1	3.8	3.4
			Hours exceed EL		0	0	0	0	0
NO_x	1 Hour	6.1 ppm	Maximum	ppm	1.2	0.8	0.7	0.8	0.9
			Average	ppm	0.4	0.4	0.4	0.4	0.4
			Hours exceed EL		0	0	0	0	0

Note: EL = Emission Limit

TABLE 5-2: SUMMARY OF CO, NO_x AND $PM_{2.5}$ AVERAGE AND PEAK LEVELS: VENTILATION BUILDING 3

Monitor Location: *VB3 I-93 NB-1*

Pollutant	Time Period	Emission Limits	Parameter	Unit	2012	2013	2014	2015	2016 Q1
CO	1 Hour	70 ppm	Maximum	ppm	8.1	7.3	4.9	4.1	3.6
			Average	ppm	1.6	1.3	1.5	1.5	1.1
			Hours exceed EL		0	0	0	0	0
			Hours exceed AL		0	0	0	0	0
	8 Hour	70 ppm	Maximum	ppm	3.5	3.9	3.6	3.0	2.6
			Hours exceed EL		0	0	0	0	0
NO_x	1 Hour	6.1 ppm	Maximum	ppm	1.2	0.9	0.7	0.6	0.6
			Average	ppm	0.4	0.4	0.4	0.4	0.4
			Hours exceed EL		0	0	0	0	0
$PM_{2.5}$	24 Hour	900 µg/m3	Maximum	$\mu g/m^3$	74.1	105.7	145.4	157.5	48.4
			Average	$\mu g/m^3$	29.7	34.1	35.3	35.6	30.0
			Days exceed EL		0	0	0	0	0
			Days exceed AL		0	0	0	0	0

Monitor Location: *VB3 I-93 NB-2*

Pollutant	Time Period	Emission Limits	Parameter	Unit	2012	2013	2014	2015	2016 Q1
CO	1 Hour	70 ppm	Maximum	ppm	10.6	8.5	6.0	9.4	4.7
			Average	ppm	1.9	1.6	1.8	1.8	1.5
			Hours exceed EL		0	0	0	0	0
			Hours exceed AL		0	0	0	0	0
	8 Hour	70 ppm	Maximum	ppm	7.6	7.9	4.7	9.0	3.9
			Hours exceed EL		0	0	0	0	0
NO_x	1 Hour	6.1 ppm	Maximum	ppm	1.5	1.0	0.8	1.1	0.7
			Average	ppm	0.5	0.4	0.5	0.4	0.4
			Hours exceed EL		0	0	0	0	0

Note: EL = Emission Limit

TABLE 5-2: SUMMARY OF CO, NO_X, AND $PM_{2.5}$ AVERAGE AND PEAK LEVELS: VENTILATION BUILDING 3 (CONTINUED)

Monitor Location:	VB3 I-93 SB-1								
Pollutant	**Time Period**	**Emission Limits**	**Parameter**	**Unit**	**2012**	**2013**	**2014**	**2015**	**2016 Q1**
CO	1 Hour	70 ppm	Maximum	ppm	8.7	9.2	8.8	7.1	6.3
			Average	ppm	2.7	2.7	2.7	2.5	2.2
			Hours exceed EL		0	0	0	0	0
			Hours exceed AL		0	0	0	0	0
	8 Hour	70 ppm	Maximum	ppm	7.6	6.7	6.4	5.6	4.8
			Hours exceed EL		0	0	0	0	0
NO_x	1 Hour	6.1 ppm	Maximum	1.3	1.0	1.1	1.0	0.9	0.8
			Average	ppm	0.5	0.5	0.5	0.5	0.5
			Hours exceed EL		0	0	0	0	0
$PM_{2.5}$	24 Hour	900 µg/m3	Maximum	µg/m^3	155.0	84.1	123.3	111.9	68.1
			Average	µg/m^3	35.9	34.7	34.1	33.7	31.1
			Days exceed EL		0	0	0	0	0
			Days exceed AL		0	0	0	0	0

Note: EL = Emission Limit

TABLE 5-3: SUMMARY OF CO AND NO_X AVERAGE AND PEAK LEVELS: VENTILATION BUILDING 4

Monitor Location: *VB4 I-93 NB3*

Pollutant	*Time Period*	*Emission Limits*	*Parameter*	*Unit*	*2012*	*2013*	*2014*	*2015*	*2016 Q1*
CO	1 Hour	70 ppm	Maximum	ppm	9.8	8.0	7.0	7.2	5.4
			Average	ppm	2.1	2.1	2.0	2.0	1.4
			Hours exceed EL		0	0	0	0	0
			Hours exceed AL		0	0	0	0	0
	8 Hour	70 ppm	Maximum	ppm	6.2	5.8	4.8	5.9	3.5
			Hours exceed EL		0	0	0	0	0
NO_x	1 Hour	6.1 ppm	Maximum	ppm	1.4	1.1	0.9	0.9	0.7
			Average	ppm	0.5	0.5	0.5	0.5	0.4
			Hours exceed EL		0	0	0	0	0

Monitor Location: *VB4 I-93 NB4*

Pollutant	*Time Period*	*Emission Limits*	*Parameter*	*Unit*	*2012*	*2013*	*2014*	*2015*	*2016 Q1*
CO	1 Hour	70 ppm	Maximum	ppm	9.4	8.2	8.0	7.6	5.6
			Average	ppm	2.7	2.5	2.5	2.6	1.5
			Hours exceed EL		0	0	0	0	0
			Hours exceed AL		0	0	0	0	0
	8 Hour	70 ppm	Maximum	ppm	6.0	5.9	5.4	6.2	3.8
			Hours exceed EL		0	0	0	0	0
NO_x	1 Hour	6.1 ppm	Maximum	ppm	1.4	1.1	1.0	0.9	0.8
			Average	ppm	0.5	0.5	0.5	0.5	0.4
			Hours exceed EL		0	0	0	0	0

Note: EL = Emission Limit

TABLE 5-3: SUMMARY OF CO AND NO_X AVERAGE AND PEAK LEVELS: VENTILATION BUILDING 4 (CONTINUED)

Monitor Location: *VB4 I-93 SB2*

Pollutant	Time Period	Emission Limits	Parameter	Unit	2012	2013	2014	2015	2016 Q1
CO	1 Hour	70 ppm	Maximum	ppm	10.7	6.3	5.4	6.4	4.5
			Average	ppm	1.5	1.5	1.6	1.7	1.4
			Hours exceed EL		0.0	0.0	0.0	0.0	0.0
			Hours exceed AL		0.0	0.0	0.0	0.0	0.0
	8 Hour	70 ppm	Maximum	ppm	5.2	4.9	4.3	4.1	3.6
			Hours exceed EL		0.0	0.0	0.0	0.0	0.0
NO_x	1 Hour	6.1 ppm	Maximum	ppm	1.5	0.8	0.7	0.8	0.7
			Average	ppm	0.4	0.4	0.4	0.4	0.4
			Hours exceed EL		0.0	0.0	0.0	0.0	0.0

Monitor Location: *VB4 I-93 SB3*

Pollutant	Time Period	Emission Limits	Parameter	Unit	2012	2013	2014	2015	2016 Q1
CO	1 Hour	70 ppm	Maximum	ppm	9.4	6.1	4.0	4.7	2.8
			Average	ppm	1.8	1.8	1.3	1.2	0.9
			Hours exceed EL		0.0	0.0	0.0	0.0	0.0
			Hours exceed AL		0.0	0.0	0.0	0.0	0.0
	8 Hour	70 ppm	Maximum	ppm	5.2	5.2	2.9	2.9	2.1
			Hours exceed EL		0.0	0.0	0.0	0.0	0.0
NO_x	1 Hour	6.1 ppm	Maximum	ppm	1.4	0.8	0.6	0.7	0.5
			Average	ppm	0.4	0.5	0.4	0.4	0.4
			Hours exceed EL		0.0	0.0	0.0	0.0	0.0

Note: EL = Emission Limit

TABLE 5-4: SUMMARY OF CO AND NO_X AVERAGE AND PEAK LEVELS: VENTILATION BUILDING 5

Monitor Location: *VB5 I-90 EB2*

Pollutant	Time Period	Emission Limits	Parameter	Unit	2012	2013	2014	2015	2016 Q1
CO	1 Hour	70 ppm	Maximum	ppm	6.9	7.3	7.6	7.4	5.3
			Average	ppm	1.4	1.3	1.5	1.1	0.9
			Hours exceed EL		0	0	0	0	0
			Hours exceed AL		0	0	0	0	0
	8 Hour	70 ppm	Maximum	ppm	3.1	4.0	3.6	3.8	2.7
			Hours exceed EL		0	0	0	0	0
NO_x	1 Hour	6.1 ppm	Maximum	ppm	1.1	0.9	0.9	0.9	0.7
			Average	ppm	0.4	0.4	0.4	0.4	0.4
			Hours exceed EL		0	0	0	0	0

Monitor Location: *VB5 I-90 EB3*

Pollutant	Time Period	Emission Limits	Parameter	Unit	2012	2013	2014	2015	2016 Q1
CO	1 Hour	70 ppm	Maximum	ppm	5.6	5.3	5.6	7.0	3.8
			Average	ppm	1.1	1.1	1.3	1.1	0.9
			Hours exceed EL		0	0	0	0	0
			Hours exceed AL		0	0	0	0	0
	8 Hour	70 ppm	Maximum	ppm	3.1	3.1	3.3	5.5	2.1
			Hours exceed EL		0	0	0	0	0
NO_x	1 Hour	6.1 ppm	Maximum	ppm	0.9	0.7	0.8	0.8	0.6
			Average	ppm	0.3	0.4	0.4	0.4	0.4
			Hours exceed EL		0	0	0	0	0

Note: EL = Emission Limit

Table 5-4: Summary of CO, NO_x, and $PM_{2.5}$ Average and Peak Levels: Ventilation Building 5 (continued)

Monitor Location: VB5 I-90 WB2

Pollutant	Time Period	Emission Limits	Parameter	Unit	2012	2013	2014	2015	2016 Q1
CO	1 Hour	70 ppm	Maximum	ppm	3.5	8.6	3.6	5.7	1.9
			Average	ppm	1.6	0.6	0.6	0.8	0.6
			Hours exceed EL		0	0	0	0	0
			Hours exceed AL		0	0	0	0	0
	8 Hour	70 ppm	Maximum	ppm	2.9	2.3	1.6	2.2	1.4
			Hours exceed EL		0	0	0	0	0
NO_x	1 Hour	6.1 ppm	Maximum	ppm	0.6	1.0	0.6	0.8	0.5
			Average	ppm	0.4	0.4	0.3	0.4	0.3
			Hours exceed EL		0	0	0	0	0
$PM_{2.5}$	24 Hour	900 µg/m3	Maximum	$\mu g/m^3$	39.4	414.8	53.9	184.7	34.6
			Average	$\mu g/m^3$	17.9	21.1	18.7	20.8	16.3
			Days exceed EL		0	0	0	0	0
			Days exceed AL		0	0	0	0	0.0

Monitor Location: VB5 I-90 WB3

Pollutant	Time Period	Emission Limits	Parameter	Unit	2012	2013	2014	2015	2016 Q1
CO	1 Hour	70 ppm	Maximum	ppm	3.3	4.3	3.9	2.8	4.0
			Average	ppm	1.4	0.9	0.8	1.0	0.8
			Hours exceed EL		0	0	0	0	0
			Hours exceed AL		0	0	0	0	0
	8 Hour	70 ppm	Maximum	ppm	2.7	3.0	3.7	2.3	2.1
			Hours exceed EL		0	0	0	0	0
NO_x	1 Hour	6.1 ppm	Maximum	ppm	0.6	0.7	0.6	0.5	0.6
			Average	ppm	0.4	0.4	0.4	0.4	0.4
			Hours exceed EL		0	0	0	0	0

Note: EL = Emission Limit

TABLE 5-5: SUMMARY OF CO AND NO_x AVERAGE AND PEAK LEVELS: VENTILATION BUILDING 6

Monitor Location: *VB6 I-90 EB*

Pollutant	*Time Period*	*Emission Limits*	*Parameter*	*Unit*	*2012*	*2013*	*2014*	*2015*	*2016 Q1*
CO	1 Hour	70 ppm	Maximum	ppm	7.7	9.9	4.6	2.8	2.6
			Average	ppm	0.9	1.3	0.9	0.9	0.9
			Hours exceed EL		0.0	0.0	0.0	0.0	0.0
			Hours exceed AL		0.0	0.0	0.0	0.0	0.0
	8 Hour	70 ppm	Maximum	ppm	3.2	4.1	2.7	2.2	1.6
			Hours exceed EL		0.0	0.0	0.0	0.0	0.0
NO_x	1 Hour	6.1 ppm	Maximum	ppm	1.2	1.1	0.7	0.5	0.5
			Average	ppm	0.3	0.4	0.4	0.4	0.4
			Hours exceed EL		0.0	0.0	0.0	0.0	0.0

Monitor Location: *VB6 I-90 WB*

Pollutant	*Time Period*	*Emission Limits*	*Parameter*	*Unit*	*2012*	*2013*	*2014*	*2015*	*2016 Q1*
CO	1 Hour	70 ppm	Maximum	ppm	8.1	9.6	7.7	8.1	6.5
			Average	ppm	1.6	1.8	1.8	1.9	1.4
			Hours exceed EL		0.0	0.0	0.0	0.0	0.0
			Hours exceed AL		0.0	0.0	0.0	0.0	0.0
	8 Hour	70 ppm	Maximum	ppm	4.5	4.8	4.4	4.5	3.4
			Hours exceed EL		0.0	0.0	0.0	0.0	0.0
NO_x	1 Hour	6.1 ppm	Maximum	ppm	1.2	1.1	0.9	1.0	0.8
			Average	ppm	0.4	0.4	0.4	0.5	0.4
			Hours exceed EL		0.0	0.0	0.0	0.0	0.0

Note: EL = Emission Limit

TABLE 5-6: SUMMARY OF CO, NO_X, AND $PM_{2.5}$ AVERAGE AND PEAK LEVELS: VENTILATION BUILDING 7

Monitor Location: VB7 I-90 EB Ramp TA/D

Pollutant	Time Period	Emission Limits	Parameter	Unit	2012	2013	2014	2015	2016 Q1
CO	1 Hour	70 ppm	Maximum	ppm	8.9	33.6	9.0	17.7	8.1
			Average	ppm	1.5	2.4	2.5	2.5	2.4
			Hours exceed EL		0	0	0	0	0
			Hours exceed AL		0	0	0	0	0
	8 Hour	70 ppm	Maximum	ppm	5.2	6.7	5.8	6.4	5.0
			Hours exceed EL		0	0	0	0	0
NO_x	1 Hour	6.1 ppm	Maximum	ppm	1.3	4.4	1.0	1.8	1.0
			Average	ppm	0.5	0.5	0.5	0.5	0.5
			Hours exceed EL		0	0	0	0	0

Monitor Location: VB7 Fresh Air Intake

Pollutant	Time Period	Emission Limits	Parameter	Unit	2012	2013	2014	2015	2016 Q1
CO	1 Hour	70 ppm	Maximum	ppm	2.2	1.9	1.6	1.9	1.4
			Average	ppm	0.6	0.6	0.6	0.7	0.5
			Hours exceed EL		0	0	0	0	0
			Hours exceed AL		0	0	0	0	0
	8 Hour	70 ppm	Maximum	ppm	2.0	1.6	1.3	1.6	1.3
			Hours exceed EL		0	0	0	0	0
NO_x	1 Hour	6.1 ppm	Maximum	ppm	0.0	0.0	0.0	0.0	0.0
			Average	ppm	0.0	0.0	0.0	0.0	0.0
			Hours exceed EL		0	0	0	0	0
$PM_{2.5}$	24 Hour	900 µg/m3	Maximum	$\mu g/m^3$	24.6	26.2	29.7	21.1	28.2
			Average	$\mu g/m^3$	5.7	7.5	7.6	7.3	6.7
			Days exceed EL		0	0	0	0	0
			Days exceed AL		0	0	0	0	0

Note: EL = Emission Limit

TABLE 5-6: SUMMARY OF CO, NOX, AND PM2.5 AVERAGE AND PEAK LEVELS: VENTILATION BUILDING 7 (CONTINUED)

Monitor Location: *VB7 I-90 WB2*

Pollutant	Time Period	Emission Limits	Parameter	Unit	2012	2013	2014	2015	2016 Q1
CO	1 Hour	70 ppm	Maximum	ppm	7.1	9.8	7.1	6.6	5.3
			Average	ppm	1.1	1.5	1.4	1.5	1.4
			Hours exceed EL		0	0	0	0	0
			Hours exceed AL		0	0	0	0	0
	8 Hour	70 ppm	Maximum	ppm	3.6	4.0	4.2	3.4	2.8
			Hours exceed EL		0	0	0	0	0
NO_x	1 Hour	6.1 ppm	Maximum	ppm	0.7	1.1	0.9	0.8	0.7
			Average	ppm	0.4	0.4	0.4	0.4	0.4
			Hours exceed EL		0	0	0	0	0

Monitor Location: *VB7 I-90 EB2*

Pollutant	Time Period	Emission Limits	Parameter	Unit	2012	2013	2014	2015	2016 Q1
CO	1 Hour	70 ppm	Maximum	ppm	8.8	10.9	8.0	8.9	7.9
			Average	ppm	1.9	2.0	2.0	2.0	1.8
			Hours exceed EL		0	0	0	0	0
			Hours exceed AL		0	0	0	0	0
	8 Hour	70 ppm	Maximum	ppm	4.9	6.7	5.0	5.6	4.3
			Hours exceed EL		0	0	0	0	0
NO_x	1 Hour	6.1 ppm	Maximum	ppm	1.3	1.2	1.0	1.0	1.0
			Average	ppm	0.5	0.5	0.5	0.5	0.4
			Hours exceed EL		0	0	0	0	0
$PM_{2.5}$	24 Hour	900 µg/m3	Maximum	µg/m^3	77.7	126.6	163.1	161.5	140.9
			Average	µg/m^3	39.4	35.3	32.3	34.5	33.8
			Days exceed EL		0	0	0	0	0
			Days exceed AL		0	0	0	0	0

Note: EL = Emission Limit

TABLE 5-6: SUMMARY OF CO AND NO_X AVERAGE AND PEAK LEVELS: VENTILATION BUILDING 7 (CONTINUED)

Monitor Location: *VB7 I-90 WB3*

Pollutant	Time Period	Emission Limits	Parameter	Unit	2012	2013	2014	2015	2016 Q1
CO	1 Hour	70 ppm	Maximum	ppm	6.7	10.6	5.4	4.8	3.7
			Average	ppm	0.8	1.1	1.1	1.0	1.0
			Hours exceed EL		0	0	0	0	0
			Hours exceed AL		0	0	0	0	0
	8 Hour	70 ppm	Maximum	ppm	2.6	3.3	3.1	2.6	2.3
			Hours exceed EL		0	0	0	0	0
NO_x	1 Hour	6.1 ppm	Maximum	ppm	0.6	1.2	0.7	0.7	0.6
			Average	ppm	0.3	0.4	0.4	0.4	0.4
			Hours exceed EL		0	0	0	0	0

Monitor Location: *VB7 I-90 EB3*

Pollutant	Time Period	Emission Limits	Parameter	Unit	2012	2013	2014	2015	2016 Q1
CO	1 Hour	70 ppm	Maximum	ppm	9.9	9.4	9.7	10.4	7.7
			Average	ppm	2.5	2.4	2.5	2.5	2.2
			Hours exceed EL		0	0	0	0	0
			Hours exceed AL		0	0	0	0	0
	8 Hour	70 ppm	Maximum	ppm	6.2	6.1	6.0	6.9	4.8
			Hours exceed EL		0	0	0	0	0
NO_x	1 Hour	6.1 ppm	Maximum	ppm	1.4	1.1	1.1	1.2	0.9
			Average	ppm	0.5	0.5	0.5	0.5	0.5
			Hours exceed EL		0	0	0	0	0

Note: EL = Emission Limit

TABLE 5-7: SUMMARY OF CO AND NO_X AVERAGE AND PEAK LEVELS: RAMP CN-S

Monitor Location: Ramp CN-S									
Pollutant	**Time Period**	**Emission Limits**	**Parameter**	**Unit**	**2012**	**2013**	**2014**	**2015**	**2016 Q1**
CO	1 Hour	37 ppm	Maximum	ppm	23.3	7.1	8.0	10.0	8.5
			Average	ppm	2.7	2.6	2.4	2.4	2.2
			Hours exceed EL		0	0	0	0	0
			Hours exceed AL		0	0	0	0	0
	8 Hour	58 ppm	Maximum	ppm	9.4	5.3	7.1	6.1	4.5
			Hours exceed EL		0	0	0	0	0
NO_x	1 Hour	3.4 ppm	Maximum	ppm	3.1	0.9	1.0	1.1	1.0
			Average	ppm	0.5	0.5	0.5	0.5	0.5
			Hours exceed EL		0	0	0	0	0

Note: EL = Emission Limit

TABLE 5-8: SUMMARY OF CO, NO_X AND $PM_{2.5}$ AVERAGE AND PEAK LEVELS: RAMP CS-SA

Monitor Location: *Ramp CS-SA*									
Pollutant	***Time Period***	***Emission Limits***	***Parameter***	***Unit***	***2012***	***2013***	***2014***	***2015***	***2016 Q1***
CO	**1 Hour**	**38 ppm**	**Maximum**	**ppm**	9.1	6.5	17.9	7.3	4.1
			Average	**ppm**	1.7	1.7	1.5	1.7	1.4
			Hours exceed EL		0	0	0	0	0
			Hours exceed AL		0	0	0	0	0
	8 Hour	**55 ppm**	**Maximum**	**ppm**	4.5	4.3	3.9	4.4	3.4
			Hours exceed EL		0	0	0	0	0
NO_x	**1 Hour**	**3.4 ppm**	**Maximum**	**ppm**	1.3	0.8	1.8	0.9	0.6
			Average	**ppm**	0.4	0.5	0.4	0.4	0.4
			Hours exceed EL		0	0	0	0	0
$PM_{2.5}$	**24 Hour**	**35 µg/m3**	**Maximum**	**$\mu g/m^3$**	30.1	33.5	30.6	26.9	23.4
			Average	**$\mu g/m^3$**	10.1	11.5	9.9	10.0	9.9
			Days exceed EL		0	0	0	0	0
			Days exceed AL		0	0	0	0	0

Notes: EL = Emission Limit

TABLE 5-9: SUMMARY OF CO AND NO_X AVERAGE AND PEAK LEVELS: RAMP CS-P

Monitor Location: *Ramp CS-P*									
Pollutant	***Time Period***	***Emission Limits***	***Parameter***	***Unit***	***2012***	***2013***	***2014***	***2015***	***2016 Q1***
CO	**1 Hour**	**41 ppm**	**Maximum**	**ppm**	29.8	18.3	10.9	8.9	5.9
			Average	**ppm**	1.8	1.7	1.7	1.7	1.3
			Hours exceed EL		0	0	0	0	0
			Hours exceed AL		0	0	0	0	0
	8 Hour	**70 ppm**	**Maximum**	**ppm**	6.0	5.4	5.5	4.6	4.2
			Hours exceed EL		0	0	0	0	0
NO_x	**1 Hour**	**3.7 ppm**	**Maximum**	**ppm**	3.9	1.8	1.2	1.0	0.8
			Average	**ppm**	0.4	0.4	0.4	0.4	0.4
			Hours exceed EL		0	0	0	0	0

Note: EL = Emission Limit

TABLE 5-10: SUMMARY OF CO AND NO_X AVERAGE AND PEAK LEVELS: DST I-93

Monitor Location: *Ramp DST-I-93*

Pollutant	Time Period	Emission Limits	Parameter	Unit	2012	2013	2014	2015	2016 Q1
CO	1 Hour	23 ppm	Maximum	ppm	38.5	16.9	14.0	14.8	10.0
			Average	ppm	4.2	4.0	3.7	3.7	3.1
			Hours exceed EL		3	0	0	0	0
			Hours exceed AL		3	0	0	0	0
	8 Hour	30 ppm	Maximum	ppm	11.4	9.9	8.8	8.7	6.3
			Hours exceed EL		0	0	0	0	0
NO_x	1 Hour	2.2 ppm	Maximum	ppm	5.0	1.7	1.5	1.5	1.1
			Average	ppm	0.7	0.6	0.6	0.6	0.6
			Hours exceed EL		3	0	0	0	0

Notes:
1. EL = Emission Limit
2. An Emission Limit Assessment (ELA) was performed following an EL exceedance. The results of the ELA enabled MassDOT and MassDEP to determine that the EL exceedances did not violate a National Ambient Air Quality Standard (NAAQS). Appendix F provides the results of the ELAs.

TABLE 5-11: SUMMARY OF CO AND NO_X AVERAGE AND PEAK LEVELS: DST I-90

Monitor Location:	Ramp DST-I-90								
Pollutant	*Time Period*	*Emission Limits*	*Parameter*	*Unit*	*2012*	*2013*	*2014*	*2015*	*2016 Q1*
CO	1 Hour	23 ppm	Maximum	ppm	30.5	22.0	17.3	24.4	10.9
			Average	ppm	3.1	3.0	3.3	3.4	2.8
			Hours exceed EL		2	0	0	1	0
			Hours exceed AL		2	1	0	1	0
	8 Hour	30 ppm	Maximum	ppm	8.5	8.3	8.1	9.7	7.2
			Hours exceed EL		0	0	0	0	0
NO_x	1 Hour	2.2 ppm	Maximum	ppm	2.8	2.1	1.7	2.3	1.2
			Average	ppm	0.6	0.6	0.6	0.6	0.5
			Hours exceed EL		2	0	0	1	0

Notes:
1. EL = Emission Limit
2. An Emission Limit Assessment (ELA) was performed following an EL exceedance. The results of the ELA enabled MassDOT and MassDEP to determine that the EL exceedances did not violate a National Ambient Air Quality Standard (NAAQS). Appendix F provides the results of the ELAs.

5.6 REQUEST TO REDUCE THE NUMBER OF CEM CO MONITORS

The CA/T CEM measures CO concentrations in the exhaust plenum of each VB ventilation zone prior to discharge out the VB stacks. The full transverse ventilation system includes six ventilation buildings serving twenty four ventilation zones with their corresponding supply and exhaust fans. Currently there are 25 CO monitors in operation: one in each ventilation zone and one in the VB7 air intake. All twenty four zones have a CO emission limit of 70 PPM and a CO action level of 60 PPM.

An analysis of the peak and average data collected since full opening of the CA/T (nine years) was presented to MassDEP in Technical Memos, dated 3-20-15 and 6-24-2015, and discussed at the interagency meeting.

The tunnel full transverse ventilation system currently operates at Step 1 (13% of exhaust capacity) for off-peak and step 3 (32% of exhaust capacity) for peak traffic conditions. The two million plus hourly CO levels measured during nine years at the 24 VB zones and VB7 air intake, which accounts for the 25th CO monitor, ranged from 0.5 to 10.1 ppm on average, and reached the highest level of 34.4 ppm at VB7. This highest monitored level is less than half of the emission limit concentration. During the nine years of operation, no full transverse ventilation zone approached the action level.

At the meeting on March 20, 2015 MassDEP recommended selecting the highest zones for continuation of monitoring by looking at the highest 5% and 10% of hourly data for each zone.

The request sought to reduce the number of CO monitoring locations to one per VB, except for VB7, which would have two monitors as part of this 2016 renewal of the Operating Certification. MassDOT would achieve the objective of 310 CMR 7.38 by maintaining the CEM program and reporting compliance with CO emission limits at each VB by monitoring ventilation zones with the historically highest CO levels.

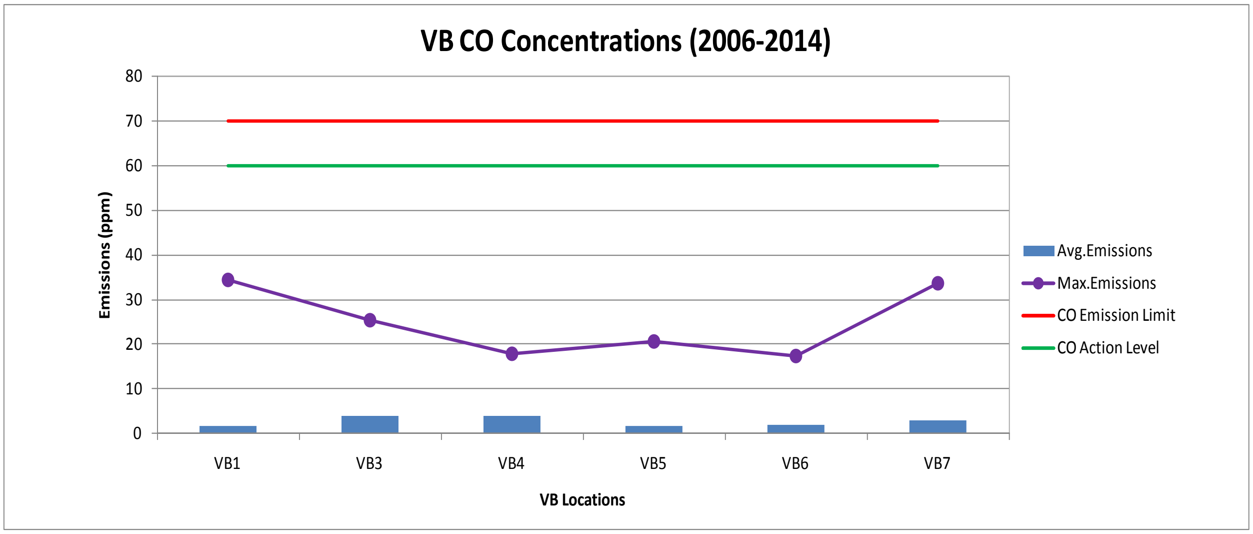
The reduction in the total number of CO monitors from twenty five to seven would allow MassDOT to better maintain the current CO monitors by using the monitors removed from service for spare parts and thus extending the their useful life in the CEM system, and to make more feasible a full upgrade in the future.

MassDEP concurred with this proposal to reduce the number of CO monitors from twenty five today to seven in the next Operating Certification Period from 2016 to 2021 in the MassDEP letter dated June 30, 2015.

5.6.1 Data Supporting the VB CO Monitoring Zones for 2016-2021

The maximum and average hourly CO data is summarized in Figure 5.3 As the data demonstrates, the peak levels have decreased since the monitoring program started in 2006. Only VB7 had higher peak levels in recent years.

FIGURE 5-3: HIGHEST PEAK AND AVERAGE CO LEVELS AT ALL VBS FOR ALL NINE YEARS



The summary of CO measurements conducted by CEM since the last certification is presented in Table 5-12. This table shows the highest 5 and 10 percent concentrations monitored in each zone for each VB. The highest 5 and 10 percent concentration levels for each ventilation building are highlighted in bold.

The maximum CO levels measured since 2010 have been below 13 PPM for the majority of the twenty four ventilation zones. The only VB that recorded maximum levels above 30 PPM was VB7. The peaks above 30 PPM occurred on the uphill I-90 EB3, WB3 mainline and EB T-A/D Ramp, all uphill parts of the Ted Williams Tunnel.

Based on Table 5-12, the remaining monitoring zones for the 2016-2021 period are presented in Table 5-13.

The elimination of these CO monitors from the CEM will result in significant labor savings for MassDOT. More importantly, the equipment that will no longer be needed at the eliminated ventilation buildings will be refurbished and used as spares for the remaining monitoring sites. As all of these instruments have been in continuous service for more than ten years, they require more frequent and extensive maintenance, so the spares will minimize lost data.

The CO monitors at Dewey Square Tunnel (I-93 and I-90 collector), and three longitudinally ventilated ramps (CN-S, CS-SA and CS-P), will continue the current monitoring and reporting process of the current CEM program. The total number of CO monitors in the CEM system from 2017 will be 12.

The four $PM_{2.5}$ monitors installed in three VBs, and the one outside Ramp CS-SA will continue their operation for the 2016-2021 period.

The June 24, 2015 Technical Memo with the supporting yearly data is included in Appendix F.

TABLE 5-12: HIGHEST 5% AND 10% LEVELS MEASURED AT EACH VENTILATION ZONE

Ventilation Building	Location	Highest Levels	
		5%	10%
VB1	Exhaust 1 & 2 (Ramp L/HOV for I-90 EB)	2.5	1.9
	Exhaust 8 & 9 (Ramp L/HOV for I-90 EB)	2.0	1.6
	I-90 EB	1.8	1.6
	I-90 WB1	2.1	1.9
	I-90 WB2	2.1	1.8
	Exhaust 10 & 11 (Ramp D I-90 WB to I-93 NB)	**2.7**	**2.4**
VB3	I-93 NB-1	3.5	2.5
	I-93 NB-2	4.5	3.2
	I-93 SB-1	**5.5**	**4.5**
VB4	I-93 NB-3	4.1	3.5
	I-93 NB-4	**4.6**	**4.1**
	I-93 SB-2	3.5	2.9
	I-93 SB-3	3.4	3.0
VB5	I-90 EB-2	**2.6**	2.2
	I-90 EB-3	2.4	2.2
	I-90 WB-2	2.4	**2.3**
	I-90 WB-3	2.2	2.1
VB6	I-90 EB	2.1	1.8
	I-90 WB	**3.7**	**3.1**
VB7	I-90 WB2	2.4	2.1
	I-90 EB2	4.9	4.2
	I-90 WB3	1.9	1.7
	I-90 EB3	**5.8**	**5.1**
	I-90 EB Ramp TA/D	5.7	5.0
	Fresh Air Intake	1.2	1.1

TABLE 5-13: PROPOSED MONITORING ZONES FOR 2016-2021 PERIOD

Ventilation Building	Location
VB1	Exhaust 10 & 11
VB3	I-93 SB-1
VB4	I-93 NB-4
VB5	I-90 EB-2
VB6	I-90 WB
VB7*	I-90 EB3
	I-90 EB Ramp TA/D

Note: The highest two monitoring VB7 zones are presented

5.7 ADDITION OF NO_X – NO_2 MONITOR AT DEWEY SQUARE TUNNEL

MassDEP presented a request to add a NO_x monitor inside the DST at the July 10, 2015 interagency meeting. The MassDEP rationale for this additional monitor was based on the fact that the DST has the lowest CO emission limits that had been exceeded several times in the past, and on the margin of error in the NOx – CO regression formula that is used to predict NO_x levels based on monitored CO levels. This error can be eliminated by direct monitoring of NO_x.

The NOx – CO linear regression equation developed in the 2012 Renewal Certification was based on the 6,292 pairs of CO and NO_x observations collected at the DST during April 2011 through March 2012. This relationship has an **r** value of 0.5299, and $\mathbf{r^2}$ of 0.2808, and a **p-level** of 0.0000, indicating that there is a fairly good relationship between the monitored CO and NOx concentrations in the tunnel.

MassDOT agreed to include this additional NO_x monitor, which will be installed in 2016. The NO_x probe will be installed inside the I-93 segment of the DST, next to the existing CO monitoring probe. MassDOT is also moving the CO monitoring equipment from the utility room located inside the tunnel to the enclosure located just outside the DST exit portal, which was used in the past for the equipment measuring NO_x-NO_2 as part of the 2011-13 DST - Albany street monitoring program. This new NO_x monitor will be also located in the new CO monitoring enclosure. The rationale for moving the monitoring equipment from the current utility room to the outside enclosure is solely based on the difficulty of accessing this room for maintenance purpose. It requires a closing of a I-93 tunnel lane to walk into this room. The relocation will minimize highway closings in the future.

The NO_x data collected by this new monitor will be directly compared to the emission limit for the DST, and will serve to refine the CO – NOx regression formula at the end of the 2016-2021 period.

All other VB zones and the longitudinally ventilated ramps will continue to predict NO_x levels based on the NO_x–CO regression formula used in the 2012 TSD and described in section 2.6 of this document.

Part IV - Corrective Actions

6 CONTINGENCY PLAN

6.1 GENERAL REQUIREMENTS (310 CMR 7.38(4))

"… the operating certificate submittal shall include a contingency plan consisting of measures which could be implemented in cases of exceedance of the emission limitations in the certificate. Said contingency plan shall identify available contingency measures including, but not limited to, alternative tunnel ventilation system operations and maintenance, and transportation control measures; a commitment for implementing said measures; a schedule for implementing measures on a days-to-full effectiveness basis; and an analysis of the daily air quality impact of the measures on the emissions from the tunnel ventilation system and within the project area."

6.2 COMPLIANCE STATUS DETERMINATION FOR DAY-TO-DAY OPERATIONS

Concentration based emission limits for CO, NO_x and $PM_{2.5}$ were established as discussed in Section 2 of this document for tunnel emission exhaust locations. The limit levels that were established ensure that applicable NAAQS for CO, NO_2 and $PM_{2.5}$ and the MassDEP 1-hour NO_2 Policy Guideline Value for NO_2 will not be exceeded at any ambient (i.e., outside) receptor location.

In order to determine the compliance status of the tunnel emissions, the Project has installed a CO and $PM_{2.5}$ CEM (continuous emission monitoring) system as described in Section 3 and Attachment 1 of this document. Data collected from the CO and $PM_{2.5}$ CEM systems is compared to the emission limits for every emission location.

Based on discussion with MassDEP, MassDOT understands that the 310 CMR 7.38(2) requirements regarding compliance with the applicable ambient air quality standards and the State Policy guideline for nitrogen dioxide do not apply during emergency conditions (i.e., tunnel fires).

As described in Section 2.4.3 of this document, emission limits for NO_x were established using a statistical analysis of actual CO and NO_x emission data collected at the DST portal. The 1-hour CO emission limits listed above were established taking into account 1-hour NO_2 NAAQS and MassDEP Policy Guideline compliance. As a result, if the 1-hour CO emission levels remain below the listed emission limit, then no exceedances of the NAAQS and Massachusetts 1-hour NO_2 Policy Guideline Level should occur.

The established emission limits for each location are listed in the Table 6-1.

TABLE 6-1: SUMMARY OF EMISSION LIMITS (2016-2021)

Location*	1-Hour CO Emission Limit (ppm)	8-Hour CO Emission Limit (ppm)	1-Hour NO_X Emission Limit (ppm)	24-Hour $PM_{2.5}$ Emission Limit (μg/m³)**
VB 1	70	70	6.1	550
VB 3	70	70	6.1	550
VB 4	70	70	6.1	550
VB 5	70	70	6.1	550
VB 6	70	70	6.1	550
VB 7	70	70	6.1	550
Ramp CN-S	35	59	3.2	NA
Ramp CS-SA***	35	54	3.2	35****
Ramp CS-P	35	70	3.2	NA
Dewey Sq. Tunnel	22	24	2.1	NA

Notes: Acronyms are defined as: Central Artery Northbound to Storrow Drive (C-NS), Central Artery Southbound to Surface Artery (CS-SA), Central Artery Southbound to Purchase Street (CS-P), part per million (ppm), microgram per cubic meter ($\mu g/m^3$).

* For each ventilation building, location includes all associated ventilation zones.

** $PM_{2.5}$ emission limits are lower than in the 2011 CA/T Renewal Operating Certification due to the lowering of the $PM_{2.5}$ annual NAAQS from 15 to 12 ug/m^3.

******* The ambient $PM_{2.5}$ monitor is located outside ramp CS-SA.

**** Action level for ramp CS-SA is for 24 hours and is set to 100% of the 24-hour $PM_{2.5}$ NAAQS. Compliance with the 24-hour $PM_{2.5}$ NAAQS is based on the monitoring design value, which is given by the 3-year average of the annual 98th percentile value of daily average concentrations. The form of the standard allows, on average, for the numerical value of the standard (35 $\mu g/m^3$) to be exceeded on seven calendar days per calendar year without triggering a violation of the NAAQS.

6.3 PRE-EMPTIVE ACTIONS

In order to avoid exceedances of the emission limits and ensure compliance with the applicable air quality standards, two tiers of pre-emptive measures are applied.

First, the in-tunnel CO monitoring system that is used to control tunnel ventilation and maintain in-tunnel air quality is set to alarm at a 25 ppm CO level on an hourly basis. In response to an alarm, an HOC operator will lower the in-tunnel CO level to below 25 ppm by increasing the ventilation rate at the affected ventilation zone.

The second tier of pre-emptive measures involves the CEM system. The 1-hour CO CEM emission action levels have been established for each emission location, and actions will be taken (i.e., ventilation of the affected zone or zones increased) to lower the pollutant levels inside the tunnel when these action levels are exceeded. The action level established for each emission location falls within a range between 75% and 85% of its respective emission limit as listed below.

The $PM_{2.5}$ action level is set at 550 $\mu g/m^3$ for an eight hour rolling average, which is one third of the time (24-hour) needed to constitute an exceedance. This provides sufficient time to the operator to take corrective actions.

Real-time CO concentrations for all CO CEM monitoring locations are provided in the HOC for operator use. Procedures were established that would trigger an HOC operator response in the event when a CEM action level (presented in Table 6-2) is reached.

In order to comply with the lowest emission action level (i.e., 18 ppm for DST), the ventilation fans for the Dewey Square Air Intake Structure along with ventilation zone SB-1 from VB 3 are set to step 3 from 6

AM to 10AM each weekday morning and from 2 PM to 8 PM each weekday afternoon. The increase in the ventilation zone settings should prevent hourly CO emission levels from going above 20 ppm for DST. If the emission action level for DST is exceeded because of a non-emergency situation, the ventilation will be stepped up to a higher setting to ensure that emission level remains below the emission action level.

CEM $PM_{2.5}$ emission levels from VB3, VB5, VB7, and ramp CS-SA are also tracked. If $PM_{2.5}$ concentrations at a VB CEM monitor exceeds action level of 550 μg/m^3 for an eight hour rolling average, then $PM_{2.5}$ hourly concentrations will be displayed in the HOC. However, because the 8-hour $PM_{2.5}$ emission action level of 550 μg/m^3 is very high, it is very unlikely that this level will ever be reached.

TABLE 6-2: EMISSION ACTION LEVELS (2016-2021)

Location*	CO Emission Action Levels (ppm)	NOx Emission Action Levels (ppm)	Rolling 8-Hour $PM_{2.5}$ Emission Action Levels (μg/m^3)
VB1	60	NA	NA**
VB3	60	NA	550
VB4	60	NA	NA**
VB5	60	NA	550
VB6	60	NA	NA**
VB7	60	NA	550
Ramp CN-S	28	NA	NA
Ramp CS-SA	28	NA	35***
Ramp CS-P	28	NA	NA
Dewey Square Tunnel	18	1.7****	NA

* For each ventilation building, location includes all associated ventilation zones.

** VB1, VB4, and VB6 do not have $PM_{2.5}$ monitors. Action levels at VB3, VB5, and VB7 will be used as surrogates for these locations.

*** Action level for ramp CS-SA is for 24 hours and is set to 100% of the 24-hour $PM_{2.5}$ NAAQS. Compliance with the 24-hour $PM_{2.5}$ NAAQS is based on the monitoring design value, which is given by the 3-year average of the annual 98th percentile value of daily average concentrations. The form of the standard allows, on average, for the numerical value of the standard (35 μg/m^3) to be exceeded on seven calendar days per calendar year without triggering a violation of the NAAQS.

**** DST monitors CO and NOx, as such the NOx action level is directly compared to the monitored data.

6.4 CORRECTIVE (CONTINGENCY) ACTIONS

6.4.1 Emission Limit Exceedance Notification

The 2012 and this 2016 Renewal Operating Certification includes a two-step procedure whereby if an Emission Limit is exceeded, MassDOT shall verbally notify MassDEP of this exceedance within 12 hours of such an occurrence. This verbal notification shall be followed with a written notification to MassDEP within 48 hours of the Emission Limit exceedance. The written notifications shall be made to MassDEP, Bureau of Air and Waste, Transportation Management Programs Branch, 1 Winter Street, Boston, MA 02108. MassDOT shall verbally notify Transportation Management Programs Branch by calling 617-292-5762, if unable to reach staff directly, then MassDOT shall speak with the front desk at 617-292-5500, and if unable to reach a person should leave a message at MassDEP's Emergency Response phone number, 888-304-1133.

The Emission Limit Assessment shall analyze whether or not an Emission Limit exceedance may cause or contribute to a violation of the relevant NAAQS or MassDEP guideline based on the use of site-specific meteorological and background conditions at the time of the exceedance. Meteorological data collected by the National Weather Service at Boston's Logan International Airport is acceptable. The analysis shall be provided to the above MassDEP address within three business days of MassDOT receipt of background conditions data from MassDEP. If MassDEP determines that a violation of a NAAQS or MassDEP One Hour NO_2 Policy Guideline has occurred, MassDEP will post a notice of the violation on MassDEP's web site within ten business days of notification and in the MEPA Environmental Monitor as a matter of public record.

6.4.2 Emission Limit Assessment (ELA)

When an exceedance of an emission limit occurs at any of the emission locations, an Emission Limit Assessment of the causes and nature of the exceedance will be prepared and sent to MassDEP. The analysis will examine air quality impacts for each designated receptor around the VB or longitudinally ventilated exit ramp where the emission limit was exceeded. Meteorological conditions and pollutant background concentration during the exceedance time period will be used in the analysis.

6.4.3 Additional Contingency Measures

If the ELA determines that an exceedance of an emission limit resulted in an exceedance of a NAAQS for CO or the Massachusetts 1-hour NO_2 Policy Guideline Limit, actions related to a long-term mitigation plan will be discussed with MassDEP for possible implementation. If the ELA determines that an exceedance of emission limit for $PM_{2.5}$ or NO_2 resulted in three exceedances of the level of NAAQS in a single year, MassDOT and MassDEP would meet to discuss the possible mitigation measures to avoid further exceedances.

6.5 MITIGATION PLAN

Pursuant to 310 CMR 7.38(4), the initial operating certificate submittal is not required to include a mitigation plan. Requirements related to the preparation, review, and acceptance of a mitigation plan is instead governed by 310 CMR 7.38(6).

310 CMR 7.38(6) states that if MassDEP finds—based on a review of information submitted by the operator in support of the operating certification, and such information as MassDEP has available to it—that one or more of the air quality limits specified in the regulation are being violated or are likely to be violated, then the operator of the tunnel ventilation system shall take certain identified actions. The trigger to taking those actions is a finding of a violation of air quality standards based on MassDEP review of the operating certification submittal itself.

Sections 6.2 and 6.3 already described the process in place to reduce the possibilities of exceeding emission limits. In summary: First, the tunnel ventilation system is operated to maintain CO levels at or below 25 ppm inside the tunnel which is below all hourly limits. Secondly, the CEM monitoring system warns operators if the action level (typically set in the range of 75% to 85% of the emission limit) is reached. Finally, operators will be notified by an alarm if an emission limit is exceeded. In each case, HOC operators will increase ventilation rates in order to bring emissions in the tunnel below the indicated criteria. If an emission limit is still exceeded at any location, procedures described in section 6.4 above will be followed and an assessment will be performed to analyze air quality impacts for the particular hour/day of when an emission limit was exceeded and to determine whether this caused an NAAQS or a MassDEP Policy Guideline to be exceeded or violated.

The corrective actions regarding the development of a CA/T mitigation plan are required only in the event that MassDEP finds that one or more of the 7.38 criteria are being violated. Unless and until MassDEP makes such a finding, including but not limited to an identification of the nature and severity of the violation, appropriate mitigation measures do not need to be developed.

6.6 COMPLIANCE OF THE VENTILATION SYSTEM FROM 2012 TO 1ST QUARTER OF 2016

The collected data presented in a summary form (Tables 5-1 to 5-11) indicate:

- Measured CO concentrations for the Ventilation Buildings range from 0.6 to 4.0 ppm on average, with maximum 1-hour values as high as 33.6 ppm;
- Measured CO concentrations for the DST and Ramps range from 1.7 to 4.3 ppm on average, with maximum 1-hour average concentrations ranging from 17.9 to 38.5 ppm;
- Measured NO_x levels for the Ventilation Buildings range from 0.3 to 0.5 ppm on average, with maximum 1-hour values ranging from 1.1 to 3.1 ppm;
- Measured NO_x levels for the DST and Ramps range from 0.4 to 0.6 ppm on average, with maximum 1-hour values ranging from 1.8 to 3.5 ppm;
- Measured average daily $PM_{2.5}$ concentrations in each year were between 19 and 39 μg/m^3, Maximum daily $PM_{2.5}$ values were in the range ,of 163 to 414 μg/m^3.
- The $PM_{2.5}$ monitor outside Ramp CS-SA, which measures ambient levels, recorded annual averages from 9 to 11.4 µg/m^3, and a maximum daily level of 33.5 µg/m^3.

The data indicate that the pollutant levels inside the tunnels are generally much lower than anticipated, with CO levels decreasing in the latter years.

There were four episodes recorded over the four and ¼ year period when an emission limit was exceeded. These were the result of abnormal conditions related to nighttime tunnel closures due to maintenance. They were corrected as soon as the cause was identified, and the associated ELA indicated that none of them resulted in a violation of an NAAQS or a MassDEP Policy Guideline.

6.6.1 Exceedances of Emission Limits from 2012 to 1st Quarter of 2016

During the period from the beginning of 2012 through the end of the first quarter of 2016, there were four episodes when an emission limit was exceeded. Table 6-3 provides a summary of these events in chronological order and identifies the location, the emission limit that was exceeded, the maximum level measured, and the associated conditions.

TABLE 6-3: CEM EMISSION LIMIT EXCEEDANCES (2012 – 2016)

No. of Incidents	Date(s)	Time	Location(s)	Pollutant(s)	No. of Hours	Highest Measured Level*	Main Reason
1	21-Jun-12	11:00 PM	DST (I-90)	CO	3	30.5	Tunnel closed for maintenance
2	11-Sep-12	midnight	DST (I-93)	CO	1	31.7	Tunnel closed for maintenance
3	13-Sep-12	2:00 AM	DST (I-93)	CO	1	38.5	Tunnel closed for maintenance
		23:00 PM			1	32.0	Tunnel closed for maintenance
4	20-Jul-15	midnight	DST (I-93)	CO	1	24.4	Tunnel closed for maintenance

* Concentrations are in ppm for CO.

An explanation of the circumstances of each episode and the actions taken to reduce concentration levels is provided below.

The June 21, 2012 exceedance of the CO emission limit occurred at approximately 11 PM , while the I-90 DST was closed to general traffic due to maintenance activities within the tunnel. Recorded levels exceeded the CO limit for three hours. As the MassDOT correspondence to MassDEP (July 13, 2012) indicates, that night there were crews with construction equipment performing maintenance activities. The HOC operators acknowledged the alarm indicating levels above the 25 ppm limit, but, since the DST was closed to traffic, the ventilation rate was not increased as expected during normal heavy traffic conditions. The high levels measured were the combined result of emissions from idling and working construction equipment and the absence of the piston action effect normally created by moving traffic which self-ventilates the DST pushing the tunnel emissions downstream of the exit portal. MassDEP acknowledged the notification, concurred with the MassDOT that the emission limit exceedance did not resulted in an ambient air violation of the NAAQS. The ELA analysis results indicated that predicted ambient levels for this exceedance were 58% of the NAAQS for NO2, and 24% and 42% of the NAAQS for the 1 and 8 hour CO.

The September 11 and 13, 2012, exceedances of the CO emission limit occurred late at night and early morning while the I-93 DST was closed to general traffic due to maintenance activities within the tunnel. As the MassDOT correspondence to MassDEP (September 21, 2012) indicates, the high measured levels were the result of idling equipment in the vicinity of the CO monitor and minimum ventilation rate due to the closing of the DST to general traffic. During this instance the MassDOT implemented corrective actions including a directive to turn off equipment while not in operation (limit idling) and to adjust the DST ventilation rate following the HOC Response Procedure 509 if the CO level approaches 25 ppm. MassDEP acknowledged the notification, concurred with the MassDOT that the emission limit exceedance did not resulted in an ambient air violation of the NAAQS. The ELA analysis results indicated that predicted ambient levels for this exceedances were 65% of the NAAQS for NO2, and 34% and 44% of the NAAQS for the 1 and 8 hour CO.

The July 20, 2015 exceedance of the CO emission limit occurred late at midnight while the I-90 Collector DST was closed to general traffic due to maintenance activities within the tunnel. As the MassDOT correspondence to MassDEP (August 14, 2015) indicates, the high measured levels were the result of equipment intensive maintenance activity (ceiling fireproofing repairs) was being conducted in the vicinity of the DST(I-90) sample probe.

Due to an on-going mechanical/control issue, both Air Intake Structure (AIS) supply fans were unable to achieve higher than Step 1 (where they were running during this event) and thus, had been placed into manual control. The repairs were finished during August.

MassDEP acknowledged the notification, concurred with the MassDOT that the emission limit exceedance did not resulted in an ambient air violation of the NAAQS. The ELA analysis results indicated that predicted ambient levels for this exceedance were 70% of the NAAQS for NO2, and 15% of the NAAQS for the 1 hour CO. The level of the exceedance was below the 8-hour CO emission limit of 30 PPM, as a consequence no ELA analysis was needed for the 8-hour CO.

6.6.2 Summary of Exceedances, Reasons, Lessons Learned, and Corrective Actions

As described in the previous sections, there were four episodes during the period from the beginning of 2012 through the end of the first quarter of 2016 when emission limits were exceeded. These episodes resulted in a total of 7 hours when CO measured levels at the DST exceeded the corresponding emission limit of 23 ppm hourly CO. For these four cases when CO limits were exceeded, the main reasons were emissions from maintenance equipment during night-time tunnel closing, Nighttime maintenance activities in the vicinity of the CEM sample probes has been shown to be the primary factor in the vast majority of CO exceedances from the DST at the times when the system was operating at Step 1 (less than 20% of exhaust capacity). An additional factor has been inconsistent execution of response plans for CO alarms by Highway Operations Center (HOC) staff. As the response plans were based on manual interventions to raise fan speeds upon high CO alarms, MassDOT in October 2012 initiated a project to use the integrated project control system (IPCS) of the CA/T to automatically raise fan speed upon alarm inputs, significantly reducing the probability of human errors.

Although exceedance limits are based on hourly averages, the alarms were based on instantaneous readings. As a result, high CO warnings frequently would go in and out of alarm. This has led to confusion of HOC operators, and delayed response to high CO levels.

In order to eliminate HOC personnel confusion, programming changes were made to use rolling (15) minute averages instead of the instantaneous readings to trigger alarms. Using 15-minute averages provided adequate response time to ensure that hourly average CO emission levels remained below set emission limits. Second, and more significant, the pre 2012 DST response plan called for raising fan speeds only at the air intake structure (AIS) of the DST. However, based on an investigation by MassDOT personnel, it was determined that in addition to raising fan speed at the AIS, the fan speed of all other upstream zones in the I-93 southbound tunnel also had be raised so as to provide additional dilution of in-tunnel exhaust by raising the ventilation to Step (3) which represents 50% of supply capacity at the AIS, VB3 (southbound-1) and VB4 (southbound 2 and 3), providing the necessary dilution to maintain the DST within the emission limits.

This operational correction resulted in almost three years without any emission limit exceedance proving its effectiveness. The July 2015 exceedance was a result of a temporary mechanical control repair at AIS which precluded the fans from going above Step 1.

To put these events in perspective, CO concentrations were measured every hour at 24 VB exhaust locations and at five locations in the DST and ramps over the last four calendar years (2012-2015) and during the first quarter of 2016, yielding approximately 1.1 million observations. The 7 hours for which a CO emission limit was exceeded represent an exceedingly infrequent occurrence and shows that the ventilation system nearly always was in compliance with its CO emission limits. Over 99.99% of the hourly CO concentration measurements showed compliance with CO emission limits, and the 7 hours when CO emission limits were exceeded represent only about 0.00009% of the hours during this period.

It is also important to note that none of the episodes when an emission limit was exceeded resulted in a violation of the applicable NAAQS or MassDEP NO_2 Policy guideline. The results of each ELA indicated that the maximum predicted ambient values were usually 50% or less of the applicable NAAQS for CO, and less than 70% for NO_2. This shows that the emission limits were established with a considerable margin of safety with regard to the health related NAAQS, due to the very conservative worst-case assumptions that went into the analysis, which supported the 2006 Operating Certification process and its 2011-12, and 2016 Renewals of the Operating Certification.

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