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Marine Air Quality and Greenhouse Gas Marine Transportation Technical Report for the Trans Mountain Pipeline ULC Trans Mountain Expansion Project

Final Report

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EXECUTIVE SUMMARY

This air quality assessment addresses operational emissions of air contaminants and greenhouse gases from marine traffic and product loading at the Westridge Marine Terminal. Emissions were estimated and predictive dispersion modelling was completed for operational emissions for two scenarios, namely, existing and application (Project). Several chemicals were modelled and these values were compared to applicable ambient air quality objectives. Although not explicitly part of the marine emissions assessment, for technical completeness in the Westridge/Burnaby study area, emissions from tankers at berth, both fugitives and combustion related, were included in this assessment with other marine traffic for combined effects.

The objectives of the air quality assessment were to:

- identify the assessment indicators and measurement endpoints for air quality and greenhouse gas (GHG);
- establish the spatial boundaries for air quality and GHG indicators, comprising the geographic bounds within which potential air quality effects and GHG emissions are predicted and assessed;
- characterize existing conditions to gain an understanding of existing air quality and to provide context for the predicted air quality effects;
- characterize existing GHG emissions to provide context to estimate the Project contribution;
- predict residual effects of the Project on air quality and GHG emissions; and,
- provide mitigation recommendations for minimizing the air quality effects from the Project.

This report describes the methods of the air quality and GHG assessment, and provides general air quality mitigation recommendations for the construction and operation phases of the Project.

This air quality technical report supports the ESA, and was completed in accordance with the NEB *Filing Manual* (2013), as well as *NEB Filing Requirements Related to the Potential Environmental and Socio Economic Effects of Increased Marine Shipping Activities* (2013c). The air quality assessment was conducted as per the *Guidelines for Air Quality Dispersion Modelling in British Columbia* (2008).

In addition to the dispersion modelling guidelines, ambient air quality criteria are developed by environmental and health authorities. These criteria are based on scientific studies that consider the influence of various air contaminants on such receptors as humans, wildlife, vegetation, as well as aesthetic qualities such as visibility. These criteria were used to provide context for baseline conditions and predicted changes to ambient concentrations of air contaminants due to the Project.

Trans Mountain and its consultants have conducted a number of engagement activities to inform Aboriginal communities, stakeholders, the public and regulatory authorities about the approach to

assessing potential environmental and socio-economic effects of the Project, and to seek input throughout the Project planning process.

While Environment Canada is the lead reviewer for the air quality and GHG portion of the ESA, a number of other regulatory authorities are stakeholders and may provide comments on the ESA. These include BC Ministry of Environment, MV, the Fraser Valley Regional District and PMV. Consultation meetings were held with these regulatory authorities in November, 2012.

The Project will result in the following air emissions:

- criteria air contaminants (CACs), a group of commonly found contaminants typically formed from combustion for which there are ambient air quality criteria, including PM, carbon monoxide (CO), nitrogen dioxide (NO_2), and sulphur dioxide (SO_2);
- volatile organic compounds (VOCs), a group of organic compounds with sufficiently high vapour pressures under ambient conditions to evaporate from the liquid form of the compound and enter the surrounding air; and,
- GHGs, including carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O).

The air quality and GHG assessment comprises three assessment cases:

- The assessment of existing conditions includes all projects in the region at the start of the Project. For the purpose of this assessment, existing include current marine traffic associated with the Trans Mountain Pipeline, all other existing marine traffic, and all existing natural and anthropogenic (i.e., human-caused) sources in the air quality RSA; and,
- The Project effects assessment includes the proposed increase in vessel traffic associated with the Project.

Ambient air quality data for CACs, BTEX, and ozone were collected from BC MOE, MV and Environment Canada's National Air Pollution Surveillance Program (NAPS). Several air quality stations were selected to represent existing ambient concentrations in the major urban areas within the RSA: Vancouver, Nanaimo, Duncan and Victoria. A brief summary of existing air quality conditions in US waters is also provided based on ambient monitoring data from Cheeka Peak and Port Townsend, both located in the Olympic Peninsula.

The 2005 Corbett marine emission inventory, compiled by Dr. J. Corbett at the University of Delaware, was reviewed to establish existing marine emissions in the RSA. Development of the inventory was partially funded by the California Air Resources Board and the Commission for Environmental Cooperation of North America. The intent was to develop an inventory of commercial marine emissions for North America that would support multinational efforts to quantify and evaluate potential air pollution effects from shipping in U.S, Canadian, and Mexican coastal waters.

Emissions of CACs and VOCs were estimated for the 150 km by 150 km marine RSA for input into dispersion modelling. Greenhouse gas emissions were also estimated for the marine RSA. Emission factors were taken from Environment Canada's 2010 National Marine Emission Inventory. Activity based emission factors are based on the engine type with Panamax and Aframax tankers assumed to have 2-stroke main engines and 4-stroke auxiliary engines and both using heavy fuel oil. Emission factors for PM and SO_2 are dependent on fuel sulphur content, and for this assessment, the maximum sulphur content of 0.1% within ECAs, to be implemented starting January 1, 2015, before the anticipated start of the Project, was assumed for all tankers. For NO_x emissions, general emission factors for vessels running on domestic fuel taken from Environment Canada's National Marine Emission Inventory were adopted.

The CALMET/CALPUFF dispersion modelling system was used to estimate ambient concentrations of CACs and VOCs in the marine RSA due to existing and projected future emissions from marine traffic associated with the Trans Mountain pipeline. CALMET is a meteorological model that develops hourly three-dimensional meteorological fields of wind and temperature used to drive pollutant transport within CALPUFF. CALPUFF is a multi-layer, non-steady-state puff dispersion model. It simulates the effects of time- and space-varying meteorological conditions on pollutant transport, transformation and deposition.

The CALMET/CALPUFF modelling approach, and corresponding assumptions and methodology were summarized in a detailed model plan. This model plan was reviewed and updated based on input from MV and the BC MOE and approved on October 10, 2013.

An increase in CACs and VOCs is predicted for the application case due to the Project, but modelled maximum concentrations for the Project only are below MV, BC, and national objectives. For all modelled CACs and VOCs in existing, Project, and application cases, the maximum predicted concentrations are less than the most stringent objectives for all applicable averaging periods, with the exception of maximum predicted 1-hour NO_2 concentrations. For the existing case, maximum predicted 1-hour NO_2 concentration exceeds the MV objective of 200 $\mu g/m^3$ (but not the NAAQO of 400 $\mu g/m^3$) less than 2% of the time based on one year of modelling data. The elevated maximum 1-hour NO_2 concentrations carry over to the application case. The maximum 1-hour NO_2 concentrations modelled for the application case do not differ from the existing case in value or number of exceedances; therefore, the Project's marine contribution to the maximum 1-hour NO_2 concentrations is small. No mitigation measures were considered warranted beyond emission limits mandated for marine vessels as part of the North American Emissions Control Area.

The increase in ambient ground-level concentrations of secondary $PM_{2.5}$ and ozone is small. Related to this, decreases in visibility measured by the increased light extinction are also not significant. All tankers are required to adhere to federal standards and emission limits mandated as part of the North American Emission Control Area. No additional mitigation measures were considered warranted on the basis of modelling results for secondary $PM_{2.5}$ and ozone and visibility.

GHG emissions from the Project will disperse, mix with global emissions, and contribute to global climate change. Although the GHG emissions from any single industrial activity contribute very little to global

emissions and climate change, this contribution is quantifiable. It was demonstrated by Matthew and Weaver (2010) that global temperature increases are proportional to cumulative emissions of GHG. The effect of GHG emissions on climate change can be assessed using the methods discussed in National Research Council Report. In this report, based on the most current modelling results, NRC estimated an approximately linear warming per cumulative emissions ranging from roughly 0.27°C to 0.68°C per 1,000,000 Mt CO_2e, or roughly 20 years of annual global GHG emissions. Assuming that operation emissions will not change over the lifetime of the Project, total estimated emissions over 50 years of Project operation are 3.6 Mt CO_2e, which will result in 1.7×10^{-6} °C increase in Earth's global temperature.

TABLE OF CONTENTS

Tables

Figures

Attachment i: Figures

Appendices

Acronyms

µg/m^3	microgram per cubic metre
AE	Auxiliary Engine
AQMG	Air Quality Monitoring Guidelines
bbl	barrel
BC MOE	British Columbia Ministry of Environment
BC MOF	British Columbia Ministry of Forest & Range
BC	British Columbia
BTEX	benzene, toluene, ethylene and xylene
BPIP-PRIME	Building Profile Input Program Plume Rise Model Enhancement
CAAQS	Canadian Ambient Air Quality Standard
CAC	criteria air contaminant
cc	cubic centimetre
CEA	Cumulative Effects Assessment
CEAA	Canadian Environmental Assessment Act
CH_4	methane
CMAQ	Community Multiscale Air Quality
CO	carbon monoxide
CO_2	carbon dioxide
CO_2e	CO_2 equivalent
COPC	contaminant of potential concern
CPCN	Certificate of Public Convenience and Necessity
EC	Environment Canada
ECA	Emission Control Area
EEDI	Energy Efficiency Design Index
ESA	Environmental and Socio-Economic Assessment

ft	feet
HC	Hydrocarbon
K	Kelvin
KMC	Kinder Morgan Canada
GHG	greenhouse gas
h	hour
H_2S	hydrogen sulphide
HNO_3	nitric acid
LF	Load Factor
LFV	Lower Fraser Valley
LSA	Local Study Area
IMO	International Maritime Organization
m	metre
m^3/h	cubic metre per hour
mg	micrograms
ME	Main Engine
MRA	Movement Restricted Area
MSC	Meteorological Service of Canada
MV	Metro Vancouver
N_2O	nitrous oxide
NAAQS	National Ambient Air Quality Standards
NAPS	National Air Pollution Surveillance
NCDC	National Climatic Data Center
NDBC	National Data Buoy Center
NEB	National Energy Board
NO	nitric oxide

NO_2	nitrogen dioxide
NO_3	nitrates
NOS	National Ocean Service
NO_X	oxides of nitrogen
NPRI	National Pollutant Release Inventory
NRC	National Research Council
OMOE	Ontario Ministry of Environment
ORCAA	Olympic Region Clean Air Agency
PM	particulate matter
PM_{10}	particulate matter less than 10 µm
$PM_{2.5}$	particulate matter less than 2.5 µm
PMV	Port Metro Vancouver
ppb	parts per billion
RSA	Regional Study Area
SEEMP	Ship Energy Efficiency Management Plan
SF_6	sulfur hexafluoride
SO_2	sulphur dioxide
SO_4	sulphates
SO_X	sulphur oxides
STEEM	Ship Traffic, Energy and Environment Model
TMPL system	Trans Mountain pipeline system
Trans Mountain	Trans Mountain Pipeline ULC
TRS	total reduced sulphur
TSP	total suspended particulate
US EPA	United States Environmental Protection Agency
US Gal	United States gallon

VCU	Vapor Combustion Unit
VOC	volatile organic compound
VRI	Vegetation Resources Inventory
VRU	Vapor Recovery Unit
WCMRC	Western Canada Marine Response Corporation
WHO	World Health Organization
WRF	Weather Research and Forecasting
YVR	Vancouver International Airport
the Project	Trans Mountain Expansion Project

1. INTRODUCTION

1.1. Project Overview

Trans Mountain Pipeline ULC (Trans Mountain) is a Canadian corporation with its head office located in Calgary, Alberta. Trans Mountain is a general partner of Trans Mountain Pipeline L.P., which is operated by Kinder Morgan Canada Inc. (KMC), and is fully owned by Kinder Morgan Energy Partners, L.P. Trans Mountain is the holder of the National Energy Board (NEB) certificates for the Trans Mountain pipeline system (TMPL system).

The TMPL system commenced operations 60 years ago and now transports a range of crude oil and petroleum products from Western Canada to locations in central and southwestern British Columbia (BC), Washington State and offshore. The TMPL system currently supplies much of the crude oil and refined products used in BC. The TMPL system is operated and maintained by staff located at Trans Mountain's regional and local offices in Alberta (Edmonton, Edson, and Jasper) and BC (Clearwater, Kamloops, Hope, Abbotsford, and Burnaby).

The TMPL system has an operating capacity of approximately 47,690 m^3/d (300,000 bbl/d) using 23 active pump stations and 40 petroleum storage tanks. The expansion will increase the capacity to 141,500 m^3/d (890,000 bbl/d).

The proposed expansion will comprise the following:

- Pipeline segments that complete a twinning (or "looping") of the pipeline in Alberta and BC with about 987 km of new buried pipeline;
- New and modified facilities, including pump stations and tanks; and,
- Three new berths at the Westridge Marine Terminal in Burnaby, BC, each capable of handling Aframax class vessels.

The expansion has been developed in response to requests for service from Western Canadian oil producers and West Coast refiners for increased pipeline capacity in support of growing oil production and access to growing West Coast and offshore markets. NEB decision RH-001-2012 reinforces market support for the expansion and provides Trans Mountain the necessary economic conditions to proceed with design, consultation, and regulatory applications.

Application is being made pursuant to Section 52 of the *National Energy Board Act* (*NEB Act*) for the proposed Trans Mountain Expansion Project (referred to as "TMEP" or "the Project"). The NEB will undertake a detailed review and hold a Public Hearing to determine if it is in the public interest to recommend a Certificate of Public Convenience and Necessity (CPCN) for construction and operation of the Project. Subject to the outcome of the NEB Hearing process, Trans Mountain plans to begin construction in 2016 and go into service in 2017.

Trans Mountain has embarked on an extensive program to engage Aboriginal communities and to consult with landowners, government agencies (e.g., regulators and municipalities), stakeholders, and the general public. Information on the Project is also available at www.transmountain.com.

While Trans Mountain does not own or operate the vessels calling at the Westridge Marine Terminal, it is responsible for ensuring the safety of the terminal operations. In addition to Trans Mountain's own screening process and terminal procedures, all vessels calling at Westridge must operate according to rules established by the International Maritime Organization, Transport Canada, the Pacific Pilotage Authority, and Port Metro Vancouver (PMV). Although Trans Mountain is not responsible for vessel operations, it is an active member in the maritime community and works with BC maritime agencies to promote best practices and facilitate improvements to ensure the safety and efficiency of tanker traffic in the Salish Sea. Trans Mountain is a member of the Western Canada Marine Response Corporation (WCMRC), and works closely with WCMRC and other members to ensure that WCMRC remains capable of responding to spills from vessels loading or unloading product or transporting it within their area of jurisdiction.

Currently, in a typical month, five vessels are loaded with heavy crude oil (diluted bitumen) or synthetic crude oil at the terminal. The expanded system will be capable of serving 34 Aframax class vessels per month, with actual demand driven by market conditions. The maximum size of vessels (Aframax class) served at the terminal will not change as part of the Project. Similarly, the future cargo will continue to be crude oil, primarily diluted bitumen or synthetic crude oil. Of the 141,500 m^3/d (890,000 bbl/d) capacity of the expanded system, up to 100,200 m^3/d (630,000 bbl/d) may be delivered to the Westridge Marine Terminal for shipment.

In addition to tanker traffic, the terminal typically loads three barges with oil per month and receives one or two barges of jet fuel per month for shipment on a separate pipeline system that serves Vancouver International Airport (YVR). Barge activity is not expected to change as a result of the expansion.

This air quality assessment addresses operational emissions of air contaminants and greenhouse gases from marine traffic and product loading at the Westridge Marine terminal. Emissions were estimated and predictive dispersion modelling was completed for operational emissions for two scenarios, namely, existing and application (Project). Several chemicals were modelled and these values were compared to applicable ambient air quality objectives. Although not explicitly part of the marine emissions assessment, for technical completeness in the Westridge/Burnaby study area, emissions from tankers at berth, both fugitives and combustion related, were included in this assessment with other marine traffic for combined effects.

1.2. Objectives

The objectives of the air quality assessment were to:

- identify the assessment indicators and measurement endpoints for air quality and greenhouse gas (GHG) emissions;

- establish the spatial boundaries for air quality and GHG indicators, comprising the geographic bounds within which potential air quality effects and GHG emissions are predicted and assessed;
- characterize existing conditions to gain an understanding of existing air quality and to provide context for the predicted air quality effects;
- characterize existing GHG emissions to provide context to estimate the Project contribution;
- predict residual effects of the Project on air quality and GHG emissions; and,
- provide mitigation recommendations for minimizing the air quality effects from the Project.

This report describes the methods of the air quality and GHG assessment and provides recommendations for the construction and operation phases of the Project. This report does not identify residual or cumulative environmental or socio-economic effects nor provide conclusions regarding significance. ESA Volume 8A provides the potential residual and cumulative effects of Project-related marine transportation on air quality and GHG emissions, including an evaluation of significance.

1.3. Regulatory Standards

This air quality technical report supports the ESA, and was completed in accordance with the NEB *Filing Manual* (2013), as well as *NEB Filing Requirements Related to the Potential Environmental and Socio Economic Effects of Increased Marine Shipping Activities* (2013c). The air quality assessment was conducted as per the *Guidelines for Air Quality Dispersion Modelling in British Columbia* (British Columbia [BC MOE] 2008).

In addition to the dispersion modelling guidelines, ambient air quality criteria are developed by environmental and health authorities. These criteria are based on scientific studies that consider the influence of various air contaminants on such receptors as humans, wildlife, vegetation, as well as aesthetic qualities such as visibility. These criteria were used to provide context for baseline conditions and predicted changes to ambient concentrations of air contaminants due to the Project.

The North American Emission Control Area (ECA), under the International Convention for the Prevention of Pollution from Ships, came into effect on August 1, 2012. It includes stricter controls on air emissions from ships trading off the coasts of Canada, the United States and the French overseas collectivity of Saint-Pierre and Miquelon (International Maritime Organization [IMO] 2013a).

Mandatory measures to reduce GHG emissions from international shipping have recently been adopted by the IMO and apply to all ships of 400 gross tonnage and above. Under these regulations, all new ships built after June 30, 2013, must comply with the Energy Efficiency Design Index (EEDI) requirements, and all ships must carry a Ship Energy Efficiency Management Plan (SEEMP). The EEDI prescribes energy efficiency levels per capacity mile (e.g., per tonne mile) for different ship types and sizes, but leaves the choice of technologies for ship designers and builders. The SEEMP provides a mechanism for ship operators to improve the energy efficiency onboard their ships, and also provides an approach for shipping companies to improve fleet efficiency performance over time.

1.3.1. National Air Quality Criteria

The Government of Canada (1989) has established national ambient air quality objectives (NAAQO) based on recommendations from the National Advisory Committee and Working Group on Air Quality Objectives and Guidelines. These objectives followed a three-tiered approach as follows:

- The federal maximum desirable objective is a long-term goal for air quality and provides a basis for an anti-degradation policy for unpolluted areas, and for continuing development of control technology;
- The federal maximum acceptable objective is intended to provide adequate protection against effects on soil, water, vegetation, materials, visibility, personal comfort and well-being; and,
- The federal maximum tolerable objective denotes time-based concentrations of air contaminants beyond which, due to a diminishing margin of safety, appropriate action is required without delay to protect the health of the general public.

As of December, 2012, the federal government has issued the Canadian Ambient Air Quality Standards (CAAQS) for particulate matter (PM) less than 2.5 µm ($PM_{2.5}$) and ozone, which are intended to replace the existing Canada-wide standards for $PM_{2.5}$ and ozone, as well as the existing NAAQO for ozone (Government of Canada 2013a). The CAAQS are developed to drive continuous air quality improvement in Canada, and provides a set of metrics to be effective in 2015 and a second set of metrics to be effective in 2020. A review of the 2020 metrics is expected to be conducted in 2015.

Table 1.1 provides the NAAQO and CAAQS for the selected assessment indicators (see Section 3.2), where available.

1.3.2. Provincial Standards in British Columbia

British Columbia (BC) ambient air quality objectives are divided into three categories designated as Levels A, B, and C with Level A being the most stringent (BC MOE 2013a). These levels correspond roughly to the federal levels as defined in Section 1.3.1. In BC, Metro Vancouver (MV) establishes their own ambient air quality objectives for their jurisdiction.

BC and MV ambient air quality objectives are summarized in Table 1.2 (BC MOE 2013a; MV 2011). MV is currently considering adoption of the World Health Organization (WHO) guideline for 24-hour sulphur dioxide (SO_2).

1.3.3. Emission Control Area Regulations (ECA)

The ECA off the Pacific Coast extends approximately 200 nautical miles, as illustrated in Figure 1.1**.**

Within ECAs, the maximum sulphur content in fuel oil is currently 1% by weight, and will decrease to 0.1% starting January 1, 2015. This compares to a maximum sulphur content of 3.5% outside ECAs, falling to 0.5% starting January 1, 2020, or possibly 2025 depending on the outcome of a review as to the

availability of compliant fuel oil. As an alternative to switching fuels as ships enter an ECA, ships may opt to use any control technology that provide equivalent emission reductions.

There are NO_X requirements for all marine diesel engines greater than 130 kW output power, operating in ECAs or outside. These requirements are tiered based on the ship construction date, as shown in Table 1.3. The Tier III standard only applies to the specified ships while operating within an ECA. Tier II standards still apply when operating outside ECAs.

Table 1.1: National Ambient Air Quality Objectives and Canadian Ambient Air Quality Standards (in $\mu g/m^3$)

Contaminant	Averaging Period	Objectives/Standards			
		National Maximum Desirable Objective	National Maximum Acceptable Objective	National Maximum Tolerable Objective	Canadian Ambient Air Quality Standards
Total Suspended Particulate (TSP)	24-Hour	--	120	400	--
	Annual	60	70	--	
Particulate Matter less than 2.5 µm ($PM_{2.5}$)	24-Hour	--			27 to 28[(a)]
	Annual	--			8.8 to 10[(b)]
Carbon Monoxide	1-Hour	15,000	35,000	--	--
	8-Hour	6,000	15,000	20,000	
Nitrogen Dioxide	1-Hour	--	400	1,000	--
	24-Hour	--	200	300	
	Annual	60	100	--	
Sulphur Dioxide	1-Hour	450	900	900	--
	24-Hour	150	300	800	
	Annual	30	60	--	
Ozone	1-Hour	100 (51 ppb)	160 (82 ppb)	300 (153 ppb)	--
	8-Hour	--			62 to 63 ppb[(c)]
	24-Hour	30 (15 ppb)	50 (25 ppb)	--	--
	Annual	--	30 (15 ppb)	--	--

Sources: Government of Canada 1999 and 2013a

Notes: (a) CAAQS is 28 µg/m3 in 2015 and 27 µg/m3 in 2020; compliance based on annual 98th percentile value, averaged over three consecutive years

(b) CAAQS is 10.0 µ/m3 for 2015 and 8.8 µg/m3 for 2020; compliance based on the average over three consecutive years

(c) CAAQS is 63 ppb in 2015 and 62 ppb in 2020; compliance based on 4th highest annual 8-hour daily maximum value, averaged over three consecutive years

Table 1.2: BC and MV Ambient Air Quality Objectives (in µg/m^3)

Contaminant	Averaging Period	Objectives/Standards			
		BC Level A	BC Level B	BC Level C	Metro Vancouver
Total Suspended Particulate (TSP)	24-Hour	120[(a)]	200	260	--
	Annual	60	70	75	
Particulate Matter less than 10 µm (PM_{10})	24-Hour	50			50
	Annual	--			20
Particulate Matter less than 2.5 µm ($PM_{2.5}$)	24-Hour	25[(b)]			25
	Annual	8[(c)]			8[(c)]
Carbon Monoxide	1-Hour	14,300	28,000	35,000	30,000
	8-Hour	5,500	11,000	14,300	10,000
Nitrogen Dioxide	1-Hour	--			200
	Annual	--			40
Sulphur Dioxide	1-Hour	450	900	900	450
	24-Hour	160	260	360	20 to 125[(d)]
	Annual	25	50	80	30
Ozone	1-Hour	--			82 ppb
	8-Hour	--			65 ppb

Sources: BC MOE 2013a, MV 2011

Notes:
(a) Termed as the maximum desirable level as per National Ambient Air Quality Objectives
(b) Compliance based on 98th percentile value
(c) There is also a planning goal of 6 µg/m^3
(d) Current objective is 125 µg/m^3; there is an intention to change the objective to 20 µg/m^3 to match the World Health Organization guideline

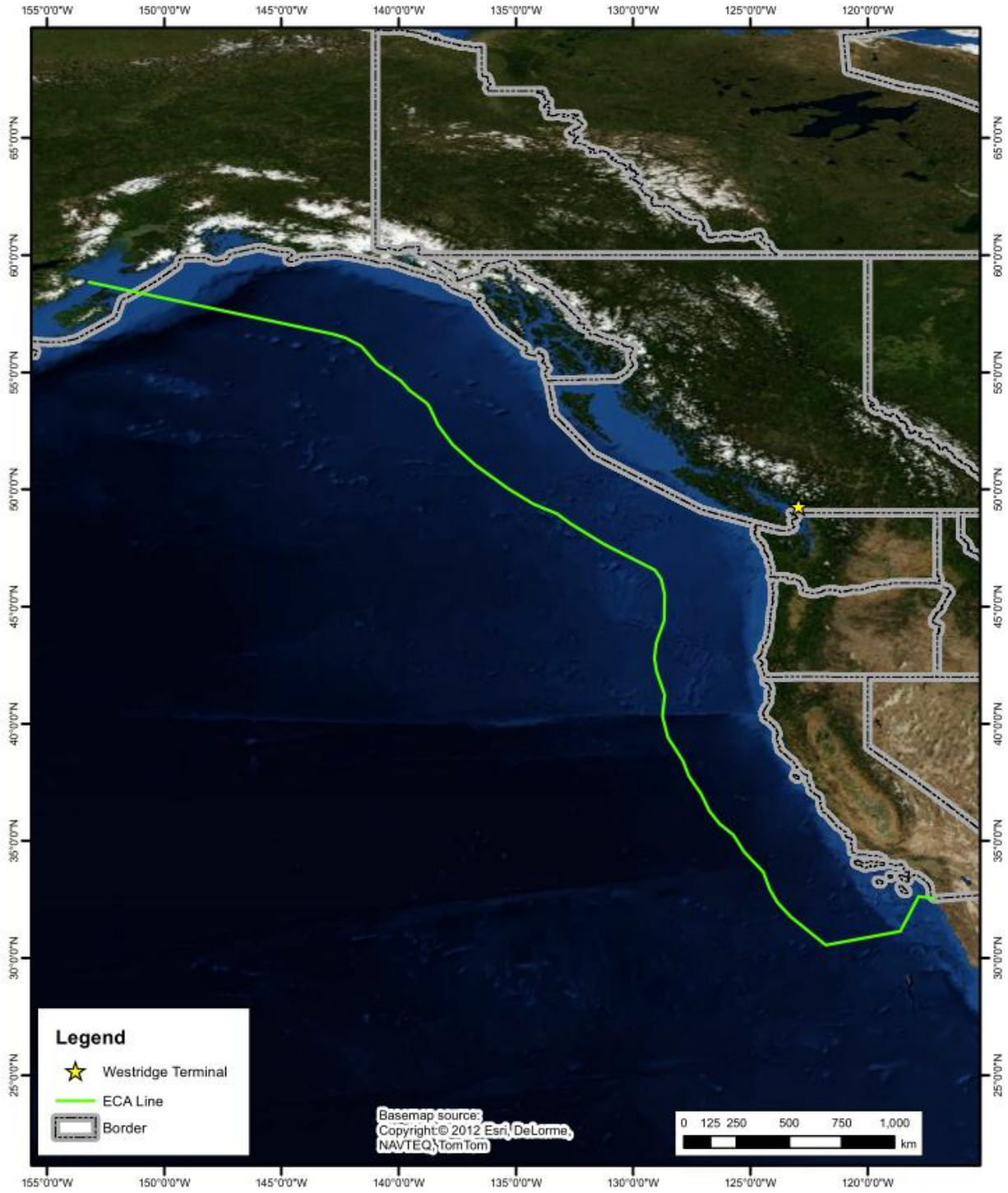


Figure 1.1: North American Emission Control Area off the Pacific Coast

Table 1.3: NO_X Control Requirements for Emission Control Areas (in g/kWh)[a,b]

Tier	Ship Construction Date (on or after)	Emission Limit		
		n < 130	130 ≤ n < 2000	n ≥ 2000
I	January 1, 2000	17.0	45 $n^{-0.2}$	9.8
II	January 1, 2011	14.4	44 $n^{-0.23}$	7.7
III	January 1, 2016[c]	3.4	9 $n^{-0.2}$	2.0

Source: International Maritime Organization 2013b
Notes: (a) Based on the total weighted cycle emissions.
(b) n = engine rated speed (rpm).
(c) Date may be delayed pending technical review to be completed in 2013.

2. CONSULTATION AND ENGAGEMENT

Trans Mountain and its consultants have conducted a number of engagement activities to inform Aboriginal communities, stakeholders, the public and regulatory authorities about the approach to assessing potential environmental and socio-economic effects of the Project, and to seek input throughout the Project planning process.

2.1. Public Consultation and Aboriginal Engagement

Trans Mountain has implemented and continues to conduct open, extensive and thorough public consultation, Aboriginal engagement programs. These programs were designed to reflect the unique nature of the Project as well as the diverse and varied communities along the proposed pipeline and marine corridors. These programs were based on Aboriginal communities, landowner and stakeholder groups' interests and inputs, knowledge levels, time and preferred methods of engagement. In order to build relationships for the long-term, these programs were based on the principles of accountability, communication, local focus, mutual benefit, relationship building, respect, responsiveness, shared process, sustainability, timeliness, and transparency.

Feedback related to marine transportation/the Project that was raised through various Aboriginal engagement and public consultation activities including public open houses, ESA Workshops, and one-on-one meetings, is summarized below and was considered in the development of this technical report, and the assessment of air quality and greenhouse gas emissions in Volume 8A:

- increases in CAC and greenhouse gas emissions as a result of increased vessel traffic;
- increases in odour emissions as a result of increased vessel traffic; and,
- potential for the development of ozone and secondary particulate matter due to the increase in vessel traffic.

In addition, concerns related to the spills in the marine environment (e.g., spill response times and proportion of product that can be cleaned up; WCMRC equipment locations and response capacity; liability regime in Canada in the event of a spill; and ability to fund the cost of a spill) were also raised and detailed information on marine spills is provided in Volume 8A.

The full description of the public consultation, Aboriginal engagement and landowner relations programs are located in Volumes 3A, 3B and 3C, respectively. Section 3.0 of Volume 8A summarizes the consultation and engagement activities that have focused on identifying and assessing potential issues and concerns related to air quality and greenhouse gas emissions which may be affected by the construction and operation of the Project. Information collected through the public consultation, Aboriginal engagement and programs for the Project was considered in the development of this technical report, and the assessment of air quality and greenhouse gas emissions in Volume 8A.

While Environment Canada is the lead reviewer for the air quality and GHG portion of the ESA, a number of other regulatory authorities are stakeholders and may provide comments on the ESA. These include BC Ministry of Environment, MV, the Fraser Valley Regional District and PMV. Consultation meetings were held with these regulatory authorities in November, 2012. Table 2.1 summarizes the consultation activities for air quality and GHG.

A series of ESA Technical Workshops were held in March, 2013. General air quality concerns with regards to the increased marine traffic due to the Project were raised, particularly in terms of PM, NO_X and SO_2 emissions. All concerns have been considered in this assessment.

Table 2.1: Summary of Consultation Activities Related to Air Quality and Greenhouse Gas Assessments

Stakeholder Group/Agency Name	Name and Title of Contact	Method of Contact	Date of Consultation Activity	Reason For Engagement	Issues/Concerns	Commitments/ Follow-up Actions/Comments
FEDERAL CONSULTATION						
Environment Canada	Roxanne Vingarzan, Head (Air Quality Science Unit)	Meeting	November 21, 2012	Project introduction. Air quality and GHG assessment approach.	Requested addition of air quality monitoring stations for inclusion in baseline assessment. Requested model evaluation. Recommended assessment for secondary ozone, particulate matter and visibility.	Air quality monitoring stations added. Model evaluation added Assessment for secondary ozone, particulate matter and visibility added.
PROVINCIAL/LOCAL CONSULTATION – BRITISH COLUMBIA						
BC Ministry of Environment and Metro Vancouver	Ali Ergudenler, Senior Engineer (Air Quality Policy and Management Division)	Meeting	November 20, 2012	Project introduction. Air quality and GHG assessment approach.	Requested assessment for odour as per Odour Management Policy currently being drafted. Requested discussion of Project effects on overall climate change. Recommended assessment for secondary particulate matter and ozone.	Assessments for odour, secondary particulate matter and ozone added. Discussion of Project effects on overall climate change added.
Fraser Valley Regional District	Alison Stewart, Senior Planner (Strategic Planning and Initiatives)	Meeting	November 20, 2012	Project introduction. Air quality and GHG assessment approach.	Requested assessment for secondary ozone and particulate matter.	Assessment for secondary particulate matter and ozone added.
Port Metro Vancouver	Gary Olszewski, Environmental Specialist	Meeting	November 21, 2012	Air quality and GHG assessment approach.	Requested Project assessment approach to be aligned with PMV general approach. Requested minimum study area to include location of pilot pick-up at Victoria with possible extension up to entry point into Juan de Fuca Strait. Requested consideration of detailed vessel time and lane information. Requested consideration of vessel turnover rate.	Project assessment approach discussed and was indicated to be aligned with PMV general approach. Study area for marine transportation defined as recommended. Assessment considers detailed vessel time and lane information, as available.

3. METHODS

3.1. Project Interactions and Identification of Potential Effects

Increased marine vessel traffic has the potential to affect air quality and GHG; therefore, Project interactions with air quality and GHG during the operations phase were assessed.

The Project will result in the following air emissions:

- criteria air contaminants (CACs), a group of commonly found contaminants typically formed from combustion for which there are ambient air quality criteria, including PM, carbon monoxide (CO), nitrogen dioxide (NO_2), and sulphur dioxide (SO_2);
- volatile organic compounds (VOCs)[1], a group of organic compounds with sufficiently high vapour pressures under ambient conditions to evaporate from the liquid form of the compound and enter the surrounding air; and,
- GHGs, including carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O).

PM is often defined in terms of size fractions. Particles less than approximately 10 µm in diameter typically remain suspended in the air for some time. Suspended PM less than 10 µm in diameter is termed PM_{10}, and PM less than 2.5 µm in diameter is termed $PM_{2.5}$. Exposure to fine PM at elevated levels aggravates a number of respiratory illnesses and may even cause premature death in people with existing heart and lung disease. Smaller particles are generally thought to be of greater concern for human health, and therefore, objectives for TSP are not often used as their effect is related to nuisance dust.

CO is produced by incomplete combustion of fossil fuels. Short-term health effects related to CO exposure at elevated levels include headache, dizziness, light-headedness and fainting. Exposure to high CO concentrations can decrease the ability of the blood to carry oxygen and can lead to respiratory failure and death.

Oxides of nitrogen (NO_X), comprised of nitric oxide (NO) and NO_2, are produced when fossil fuels are burned at high temperatures. NO_2 also plays a major role in the secondary formation of ozone. In humans, NO_2 acts as an irritant at elevated levels affecting the mucous membranes of the eyes, nose, throat, and respiratory tract. Continued exposure to NO_2 can irritate the lungs and lower resistance to respiratory infection, especially for people with pre-existing asthma and bronchitis.

Sulphur oxides (SO_X) are produced mostly in the form of SO_2 by the combustion of fossil fuels containing sulphur. SO_2 is irritating to the lungs at elevated levels and is frequently described as smelling of burning sulphur.

[1] For the purposes of this assessment, total VOC is defined as total HC, or TOC, minus CH_4 and ethane, which have negligible photochemical reactivity.

A number of VOCs can adversely affect human health wildlife and vegetation. Typical VOCs found in petroleum derivatives include benzene, toluene, ethylbenzene and xylenes, collectively known as BTEX. At elevated levels, benzene is a known carcinogen and has been linked to chromosomal damage and neural birth defects. Toluene, ethylbenzene and xylenes have harmful effects on the central nervous system at elevated levels.

Greenhouse gases are a group of gases that build up in concentration in the atmosphere and contribute incrementally to climate change. Individual GHGs are typically aggregated into "CO_2 equivalents" (CO_2e) which represent an equivalent quantity of CO_2 that would have the same global warming potential as the combined gases.

Marine vessel traffic is a source of CAC, VOC and GHG emissions from the combustion of fossil fuels in main and auxiliary engines onboard tankers and tugboats. There will also be fugitive emissions released from tanker holds during voyage. CAC and VOC emissions associated with marine vessel traffic were estimated and modelled for the marine air quality regional study area (marine RSA), as defined in Section 3.3. GHG emissions were estimated for all marine transportation within the RSA.

In addition to these direct emissions from the Project, secondary pollutants will be formed from reactions between these primary pollutants in the atmosphere. In the presence of sunlight, precursors such as NO_X and VOCs undergo a complex sequence of reactions to form ozone, a strong oxidizer that can irritate the eyes, nose and throat and decrease athletic performance at high concentrations. Secondary PM can be formed from reactions between NO_X, SO_X and ammonia. Primary and secondary PM can absorb and scatter sunlight, causing haze, obscuring visibility and, at elevated levels, adversely affecting lung performance.

3.2. Assessment Indicators and Measurement Endpoints

The assessment indicators selected for use in the assessment of the Project on air quality are as follows:

- primary emissions of CACs, including PM, CO, NO_2, and SO_2;
- primary emissions of VOCs, including BTEX, as well as other compounds with the potential to cause odour;
- formation of secondary PM and ozone; and,
- visibility.

The measurement endpoints for these indicators and the rationale for their selection are presented in Table 3.1. One or more 'measurement endpoints' are identified for each indicator to allow quantitative or qualitative measurement of potential Project effects. The degree of change in these measurable parameters is used to characterize and evaluate the magnitude of Project-related environmental and socio-economic effects. A selection of the measurement endpoints may also be the focus of monitoring and follow-up programs, where applicable.

The assessment indicators selected for use in the assessment of the Project on GHGs include emissions of CO_2, CH_4, and N_2O, as well as overall climate change. The measurement endpoints for GHG include total CO_2e emissions from the increased vessel traffic, as well as predicted effects on overall climate change. A summary of these indicators are presented in Table 3.2.

A number of other VOCs and other contaminants of potential concerns (COPCs) were also considered for the Screening Level Human Health Risk Assessment of Pipeline and Facilities (see Volume 5D).

Table 3.1: Assessment Indicators and Measurement Endpoints for Air Quality

Assessment Indicators	Measurement Endpoints	Rationale
Primary emissions of criteria air contaminants	Emissions from increased vessel traffic and comparison to emissions from existing marine traffic Predicted levels of ground-level concentrations and comparison to ambient air quality criteria	The selection of indicators and measurement endpoints considered NEB *Filing Manual* requirements and are supported by participants of the ESA engagement workshops and by regulatory authorities (i.e., Environment Canada, BC MOE, MV, Fraser Valley Regional District, PMV).
Primary emissions of volatile organic compounds	Emissions from increased vessel traffic and comparison to emissions from existing marine traffic Predicted levels of ground-level concentrations and comparison to ambient air quality criteria and odour thresholds	
Formation of secondary particulate matter and ozone	Predicted levels of ambient ground-level concentrations and comparison to ambient air quality criteria	
Visibility	Predicted change in light extinction	

Table 3.2: Assessment Indicators and Measurement Endpoints for GHG

Assessment Indicators	Measurement Endpoints	Rationale
Emissions of CO_2, CH_4 and N_2O	Emissions of CO_2e from Project-related marine traffic; comparison to emissions from existing marine vessel traffic and to federal totals	The selection of indicators and measurement endpoints considered NEB *Filing Manual* requirements and are supported by participants of the ESA engagement workshops and by regulatory authoritites (i.e., Environment Canada, BC MOE, MV, Fraser Valley Regional District, PMV).
Effect on overall climate change	Effects of CO_2e emissions from Project-related marine vessel traffic or change in environmental parameters such as global average temperatures.	

3.3. Study Area Boundaries

The marine regional study area (RSA) was selected to be a 150 km by 150 km square, as illustrated in Figure 3.1. This includes the shipping lanes from the Westridge Marine Terminal in Burnaby, through the Burrard Inlet, south through the Strait of Georgia, Boundary Passage and Haro Strait, then westward past Victoria to the end of the Juan de Fuca Strait, close to the 12 nautical mile limit. The RSA includes an area where shipping lanes are relatively defined and can be reasonably represented in dispersion modelling. Beyond this point, shipping lanes diverge into international waters depending on the destination. The marine RSA was specified based on discussions with PMV and has been approved as part of the detailed model plan for BC regulators. Also shown in Figure 3.1 is the RSA for Burnaby and Westridge Marine Terminals Air Quality for pipeline and facilities.

The spatial boundary for the assessment of secondary PM, ozone and visibility was defined as the Lower Fraser Valley (LFV) study area, as shown in Figure 3.2. The Community Multiscale Air Quality (CMAQ) modelling system used for the assessment of secondary PM, ozone and visibility was configured using a nested domain paradigm, in which a larger, parent domain is used to provide boundary conditions for a higher resolution inner domain (or “nest”). The LFV study area in Figure 3.2 represents the spatial boundary of the inner-most 4 km domain, in which all the Project emissions were modelled.

Greenhouse gas emissions have a global effect that cannot easily be measured on a local or regional scale. The spatial boundary for GHG is therefore beyond regional (*i.e.*, international); however, GHG emissions associated with the Project are dependent on final product destinations, which may vary based on market demand; therefore, Project GHG emissions were estimated for the known shipping lanes within the air quality RSA and within Canadian territorial sea. Emissions generated outside this area are considered to be in international territory and thus outside the scope of this assessment.

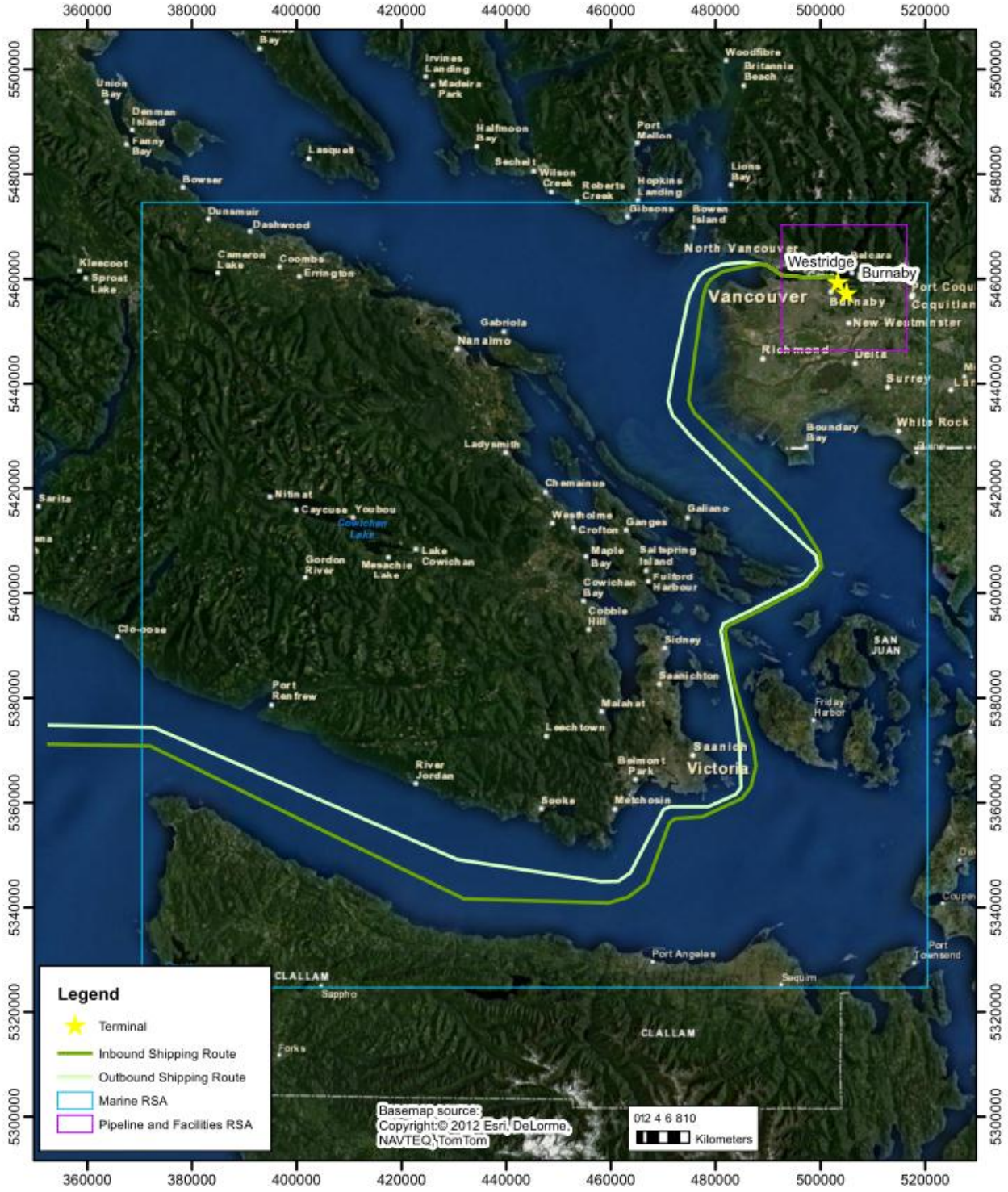


Figure 3.1: Map of Marine Air Quality Regional Study Area

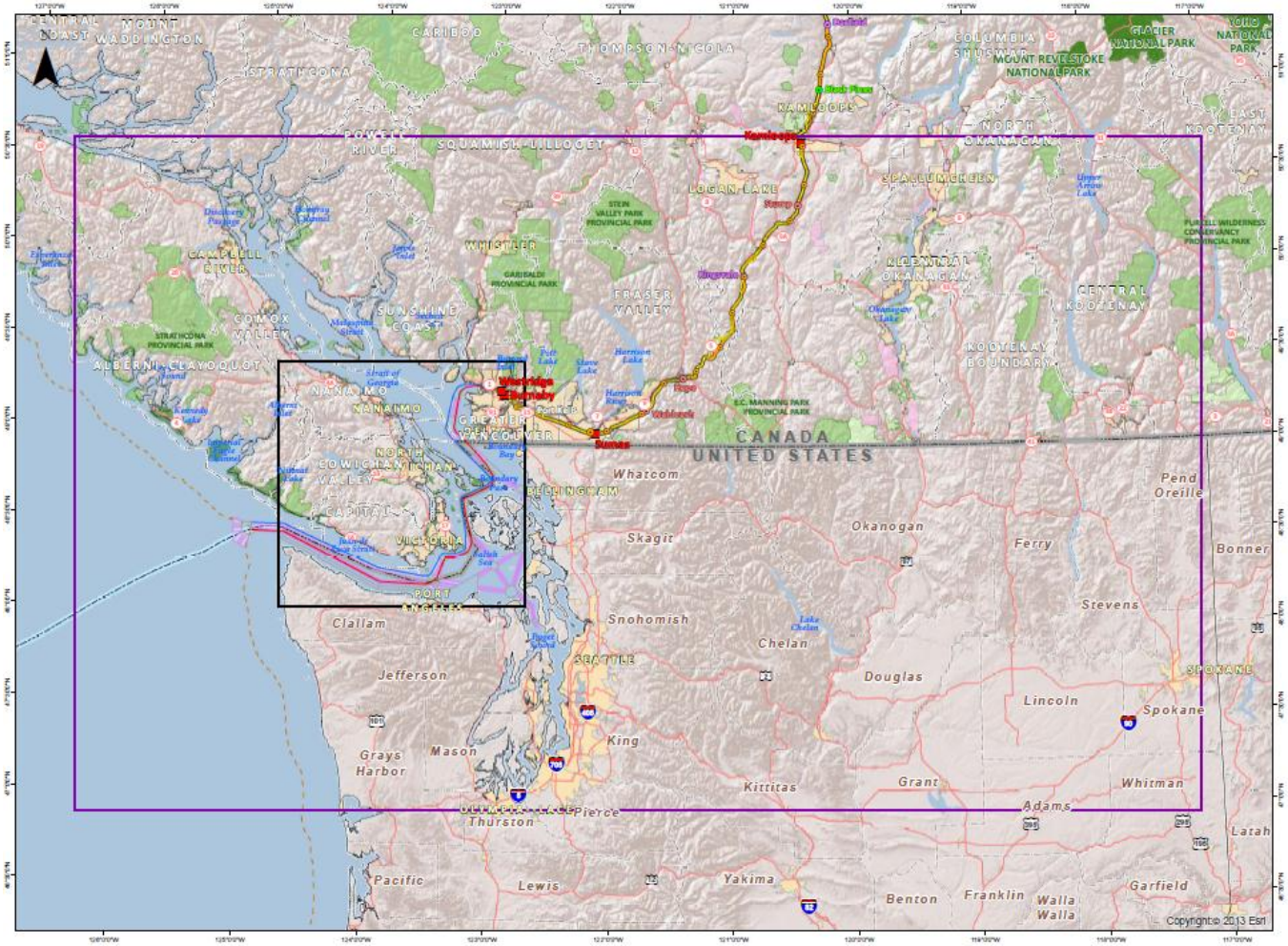


Figure 3.2: Map of Lower Fraser Valley Study Area (with Marine RSA shown in black)

3.4. Assessment Approach and Description of Assessment Cases

The air quality and GHG assessment comprises three assessment cases:

- The assessment of existing conditions includes all projects in the region at the start of the operation of marine vessel traffic. For the purpose of this assessment, existing conditions include current marine traffic associated with KMC operations, all other existing marine traffic, and all existing natural and anthropogenic (i.e., human-caused) sources in the air quality RSA (Section 4.0);
- The Project effects assessment includes the proposed increase in vessel traffic associated with the Project (Sections 5.0 and 6.0); and,
- The cumulative effects assessment includes existing conditions, the Project, and all reasonably foreseeable projects (Section 7.0).

The assessment approach is discussed in the following sub-sections.

3.4.1. Literature and Desktop Review

This section describes the literature and desktop review conducted to characterize the Project setting for air quality and GHG. Results of the literature and desktop review are discussed in Section 4.1.

The Project setting for air quality was characterized based on a review of historical measurements of ambient concentrations within the RSA. Existing marine traffic emissions within the RSA were reviewed to provide context for estimated emissions associated with the Project.

The Project setting for GHG was characterized based on a review of existing marine traffic emissions, as well as national GHG emission inventories.

3.4.1.1. Ambient Concentrations

Ambient air quality data for CACs, BTEX, and ozone were collected from BC MOE (BC MOE 2013b), MV (Reid pers. comm.) and Environment Canada's National Air Pollution Surveillance Program (NAPS) (Environment Canada 2013a). Several air quality stations were selected to represent existing ambient concentrations in the major urban areas within the RSA: Vancouver, Nanaimo, Duncan and Victoria. Since only one station on Saturna Island measures BTEX outside MV in the RSA, this station was also included. A summary of the air quality stations selected and the parameters monitored are shown in Table 3.3. A map of the selected stations is shown in Figure 3.3.

Data from January, 2002, to December, 2011, were reviewed, where available. With the exception of PM, the monitoring data collected were reported in units of parts per billion (ppb). Ambient concentrations in ppb were converted to micrograms per cubic metre ($\mu g/m^3$) for comparison to the ambient air quality criteria (see Section 1.3) using co-located or nearby hourly temperature data. Trends were analyzed based on the full ten-year period; whereas existing air quality conditions were analyzed based on the year 2011, or the most recent year with complete data if 2011 was not available. Where applicable, 8-hour and 24-hour averages were calculated for comparison to the ambient air quality criteria.

Diurnal and seasonal variability is illustrated using box and whisker plots which are simplified representations of frequency distribution data. The box spans the 25^{th} and 75^{th} percentiles while the bar spans the full range of data. Annual trends over the ten-year period are illustrated using time series plots showing the 50^{th} percentile of all observations within each year. Existing air quality conditions are presented as bar charts showing pollutant concentration levels for all averaging periods for which there are ambient air quality criteria. For short-term (i.e., 1-hour to 24-hour) averaging periods, the 99^{th} percentile of observations for the corresponding averaging period are shown. The 99^{th} percentile is selected to consider overall air quality excluding outliers; in addition, this avoids a broad range on the vertical axis that would compress the majority of data to be close to zero and to avoid squeezing longer averaging periods close to zero, making plots visually difficult to compare. The annual averaging period is represented by the 50^{th} percentile of all hourly observations.

A brief summary of existing air quality conditions in US waters is also provided based on ambient monitoring data from Cheeka Peak and Port Townsend, both located in the Olympic Peninsula (ORCCA 2013). Cheeka Peak is part of the US Environmental Protection Agency NCore multi-pollutant monitoring network and is located in a rural setting, while Port Townsend is located in a suburban setting and measures $PM_{2.5}$.

Table 3.3: List of Representative Ambient Air Quality Stations within the Marine RSA

Station ID	Station Name	Data Source	Latitude/Longitude (decimal degrees)	Elevation (m)	Parameters Monitored	Period of Data
1	Vancouver Kitsilano	MV (ID T2)	49.262, -123.164	34	PM_{10}, $PM_{2.5}$, CO, NO_2, SO_2, ozone	2002 to 2011 (PM_{10} until 2009; $PM_{2.5}$ from 2004)
2	Nanaimo Labieux	BC MOE	49.201, -123.994	122	PM_{10}, $PM_{2.5}$, NO_2, SO_2, ozone	PM_{10} from 2002 to 2008 $PM_{2.5}$ and ozone from 2002 to 2011 NO_2 from 2006 to 2011 SO_2 from 2004 to 2011
3	Duncan Cairnsmore	BC MOE	48.785, -123.716	32	$PM_{2.5}$, NO_2, ozone	2009 to 2011
4	Victoria Topaz	BC MOE	48.442, -123.363	31	$PM_{2.5}$, CO, NO_2, SO_2, ozone	2002 to 2011
5	Robson Square	NAPS (ID 100112)	49.282, -123.121	33	BTEX	2002 to 2009
6	Saturna Island	NAPS (ID 102001)	48.783, -123.133	178	BTEX	November, 2002, to 2011
7	Cheeka Peak	ORCAA	49.298, -124.625	478	$PM_{2.5}$, CO, SO_2, ozone, visibility	2011
8	Port Townsend	ORCAA	48.129, -122.779	20	$PM_{2.5}$, visibility	2011

Notes: MV = Metro Vancouver (BC MOE 2013b); BC MOE = British Columbia Ministry of Environment (BC MOE 2013b); NAPS = National Air Pollution Surveillance Program (Environment Canada 2013b); ORCAA = Olympic Region Clean Air Agency (ORCAA 2013)

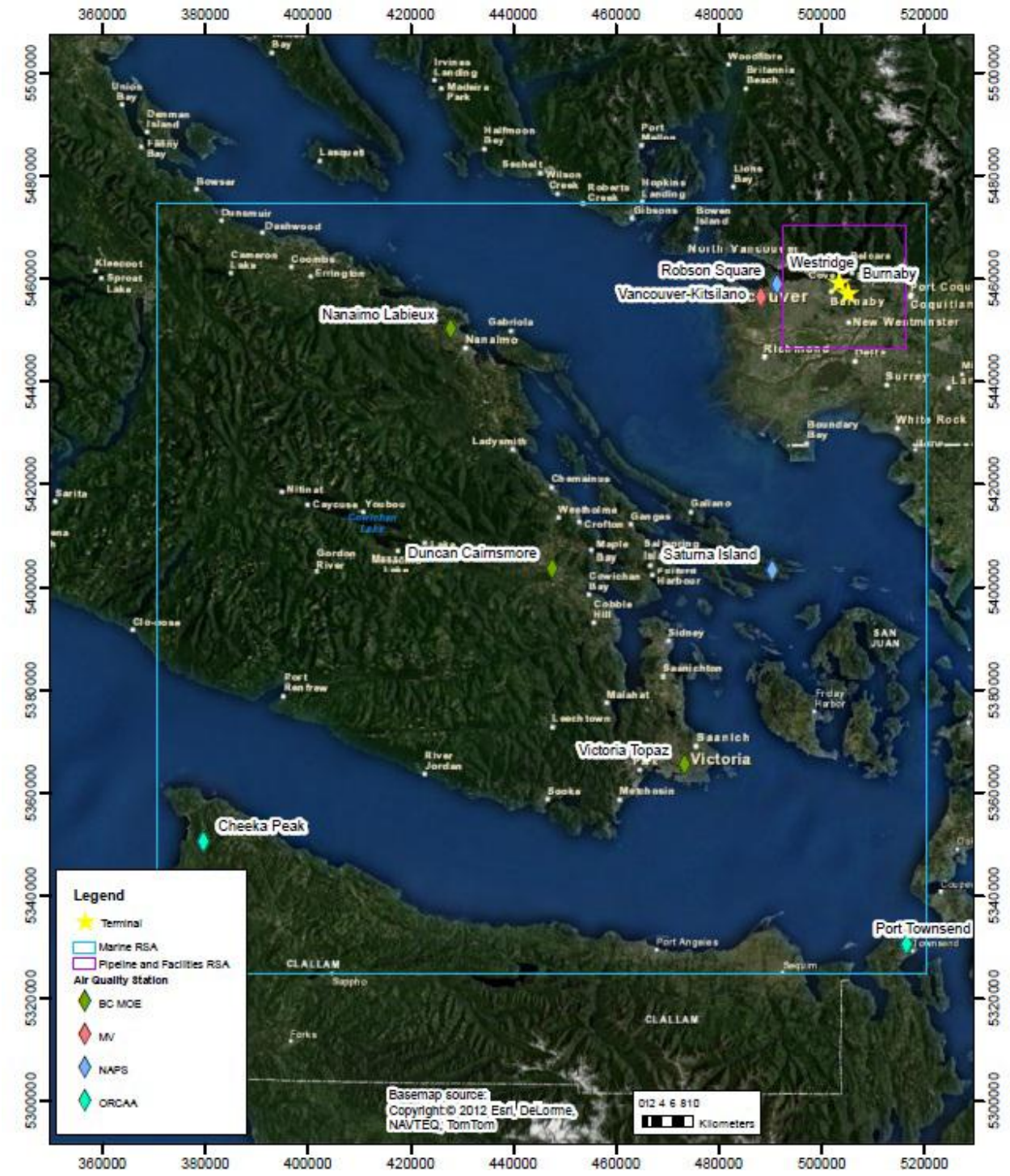


Figure 3.3: Locations of Representative Ambient Air Quality Monitoring Stations in the Marine RSA

3.4.1.2. Emissions

The 2005 Corbett marine emission inventory (Wang et al 2008), compiled by Dr. J. Corbett at the University of Delaware, was reviewed to establish existing marine emissions in the RSA. Development of the inventory was partially funded by the California Air Resources Board and the Commission for Environmental Cooperation of North America. The intent was to develop an inventory of commercial marine emissions for North America that would support multinational efforts to quantify and evaluate potential air pollution effects from shipping in U.S, Canadian, and Mexican coastal waters.

The Corbett inventory was compiled using the Waterway Network Ship Traffic, Energy and Environment Model (STEEM), a system designed to characterize ship traffic, estimate energy use, and assess the environmental impacts of shipping. A ship traffic module within STEEM geographically and temporally allocates ship traffic based on an empirical waterway network, historical ship movement data, and ship attribute data.

The Corbett inventory contains a set of geographically resolved annual gridded emissions for: TSP, CO, NO_X, SO_2, total hydrocarbon (HC), and as CO_2. Gridded emissions within the RSA were summed to represent total existing marine emissions in the RSA. For the purposes of modelling, all TSP emissions were conservatively assumed to be $PM_{2.5}$, and all HC emissions were conservatively assumed to be VOC.

In addition to the Corbett inventory, national and provincial GHG totals were obtained from Environment Canada's National Inventory Report (Environment Canada 2012) to place estimated Project GHG emissions in context. Since GHG emissions have a global effect that cannot easily be measured on a local scale, GHG emissions are typically compared to national and provincial totals.

3.4.1.3. Visibility

Visibility is typically measured at airports and reported by Environment Canada as part of their climate normal data. Climate normals are compiled at the completion of each decade and represent average climatic conditions over the last 30 years of meteorological data. The most recent climate normal data are for 1971 to 2000 (Environment Canada 2013b). Climate normal data from the Vancouver International Airport and Victoria International Airport were compiled to consider existing visibility conditions in the RSA.

Visibility measurements are also available from the Cheeka Peak and Port Townsend air quality monitoring stations (ORCCA 2013). Visibility measurements for 2011 were analyzed for the two stations to consider existing visibility conditions over US waters.

3.4.2. Emissions Estimation

Currently, the Westridge Marine Terminal receives heavy and light/synthetic crude product from the Burnaby Terminal and ships to international destinations, particularly California and Asia. Products are shipped via barges as well as Panamax and Aframax class tankers. In addition, the Westridge Marine Terminal receives jet fuel and delivers it to the Vancouver International Airport via the Trans Mountain Jet Fuel pipeline. The Westridge Marine Terminal currently handles approximately five tankers, two crude

barges and one jet fuel barge per month[2]. With the Project, this is expected to increase to approximately 34 tankers. The number of crude barges and jet fuel barges are not expected to change as a part of the Project.

Emissions were estimated based on the following scenario. Tankers will be escorted by tugs in two areas of the voyage. The first tug assist is in the Vancouver harbour, from Berry Point just east of Second Narrows to English Bay west of First Narrows. The second tug escort area is in Boundary Passage and Haro Strait.

Emissions of CACs, VOCs and GHGs are associated with ship engines onboard tankers and tugboats. There will also be fugitive emissions from tanker holds during voyage. Fugitive emissions associated with vessel loading operations are assessed as part of the pipeline and facilities component at the Westrige Marine Terminal. The emission estimation methodology was obtained from Environment Canada's 2010 National Marine Inventory (SNC-Lavalin Environment 2012) and is described in the following subsections.

3.4.2.1. Combustion Emissions from Marine Engines

Emissions of CACs and VOCs were estimated for the 150 km by 150 km marine RSA for input into dispersion modelling. Greenhouse gas emissions were also estimated for the marine RSA.

The basic equation used to estimate per vessel emissions from tankers and tugboats is:

$$E = (ME \times LF \times T \times EF_{act}) + (AE \times LF \times T \times EF_{act}) + (BO \times T \times EF_{fuel})$$

Where: E = emissions;

ME = main engine capacity, also known as maximum continuous rating (kW);

AE = auxiliary engine capacity, applicable only to tankers (kW);

BO = boiler fuel consumption rate, applicable only to tankers (tonne/hour);

EF_{act} = activity based emission factor (g/kW);

EF_{fuel} = fuel based emission factor (kg/tonne fuel);

LF = load factor; and,

T = time (hours).

Emission factors were taken from Environment Canada's 2010 National Marine Emission Inventory (SNC-Lavalin Environment 2012). Activity based emission factors are listed based on the engine type (main or auxiliary; 2-stroke or 4-stroke) and type of fuel (heavy fuel oil [HFO] or marine diesel oil [MDO]). Panamax and Aframax tankers were assumed to have 2-stroke main engines and 4-stroke auxiliary engines, both

[2] The Project description has been updated to include three crude barges and one to two jet fuel barges per month. However, since the number of crude barges and jet fuel barges are not expected to change as a part of the Project, this update will not affect the Project effects assessment.

using heavy fuel oil. Surveys conducted as part of the Chamber of Shipping's BC Ocean-Going Vessel Emissions Inventory (2007) revealed that tankers currently operating in BC use predominantly HFO in both main and auxiliary engines and do not switch to MDO. A summary of the emission factors used for this assessment is shown in Table 3.4.

Emission factors for PM and SO_2 are dependent on fuel sulphur content, and for this assessment, the maximum sulphur content of 0.1% within ECAs, to be implemented starting January 1, 2015, before the anticipated start of the Project, was assumed for all tankers. For tugboats, MDO will be required to meet stricter federal regulations on marine diesel sulphur content starting in June, 2014. The limit for vessels with small diesel engines (less than or equal to 30,000 cc) is 0.0015% and the limit for vessels with large diesel engines (greater than 30,000 cc) is 0.1%. For this assessment, it was assumed that tugboats will operate as vessels with large diesel engines under the Sulphur in Diesel Fuel Regulations (Government of Canada 2013b), and the sulphur content limit of 0.1% was applied. This represents a conservative estimate as surveys completed as part of both Environment Canada's National Marine Emission Inventory and the Chamber of Shipping's BC Ocean-Going Vessel Emissions Inventory found the sulphur content of MDO currently used by vessels in BC to be 0.05%.

Emission limits for NO_X are dependent on the ship construction date (see Section 1.3.4). For low speed vessels such as tankers, the NO_X limit is 17.0 g/kWh for ships built on or after January 1, 2000, and 14.4 g/kWh for ships built on or after January 1, 2011. For this assessment, all tankers were assumed to meet the NO_X limit of 17.0 g/kW; however, smaller vessels such as tugboats tend to remain in service longer than larger vessels. Furthermore, the emission limit for these vessels is calculated as a function of engine rated speed; therefore, general emission factors for vessels running on domestic fuel taken from Environment Canada's National Marine Emission Inventory were adopted.

Table 3.4: Emission Factors for Main and Auxiliary Engines (in g/kWh)

Vessel Class	Engine Type	Emission Factor										
		TSP	PM_{10}	$PM_{2.5}$	CO	NO_X	SO_2	VOC	CO_2	CH_4	N_2O	CO_2e
Tanker	Main, 2-stroke	0.72	0.69	0.63	1.4	17.0	4.2	0.60	621	0.006	0.017	627.4
	Auxiliary, 4-stroke	0.72	0.69	0.63	1.1	13.9	4.2	0.40	670	0.004	0.017	676.4
Tugboat	Main, 4-stroke	0.30	0.28	0.26	1.1	13.2	0.42	0.50	670	0.004	0.017	676.5

Source: SNC-Lavalin Environment 2012.

Engine and activity profiles were developed for six representative vessels and summarized in Table 3.5: Panamax tanker, Aframax tanker, stern-pull harbour tug, bow-pull harbour tug, Haro Strait tug, and standard ocean-going tug. The stern-pull and bow-pull harbor tugs refer to the first tug assist in the Vancouver harbor, which is located within the Movement Restricted Area (MRA) controlled by the Vancouver Fraser Port Authority and requires three tugs, two at the bow of the vessel and one at the stern. The Haro Strait tug refers to the second tug assist in Boundary Passage and Haro Strait, controlled by the Pacific Pilotage Authority. The standard ocean-going tug refers to the tugboats towing barges to and from the Westridge Marine Terminal. General information sources were used to assign the main engine capacity for the Panamax and Aframax tankers, as well as the standard ocean-going tug. Engine capacities for tugboats used for tug assist were taken from example specifications provided by Moffatt & Nichol. A regression relationship from Environment Canada's National Marine Emission Inventory (SNC-Lavalin Environment 2012) was used to estimate the auxiliary engine capacity (AE) of the tankers:

$$AE = 0.0648 \times ME + 1861$$

Where: AE = auxiliary engine capacity (kW); and,

ME = main engine capacity (kW).

Table 3.5: Main and Auxiliary Engine Rated Capacities (in kW)

Vessel	ME	AE
Panamax tanker	10,800[(a)]	2,561
Aframax tanker	14,914[(b)]	2,827
Stern-pull tug	2,300[(c)]	n/a
Bow-pull tug	4,700[(c)]	n/a
Haro Strait tug	4,290[(c)]	n/a
Standard ocean-going tug	3,183[(d)]	n/a

Sources: (a) MAN Diesel & Turbo 2009.
(b) Kinder Morgan Canada 2013.
(c) Traber pers. comm.
(d) United States Environmental Protection Agency 2000.

Tankers and tugboats travelling to and from Westridge Marine Terminal operate in five different modes: fast underway, slow cruise underway, maneuvering, anchor and berth. The mode of operation determines which engines are used and the load on each engine. A summary of the load factors used for this assessment is shown in Table 3.6.

Table 3.6: Load Factors by Mode of Operation

Engine	Mode	Tanker	Tugboat
Main engine	Fast underway	0.8	0.8
	Slow cruise underway	0.4	0.8
	Maneuvering	0.1	0.8
Auxiliary engine	Underway (fast + slow cruise + maneuvering)	0.24	n/a
	Anchor	0.26	n/a
	Berth	0.26	n/a

Source: The Chamber of Shipping 2007, SNC-Lavalin Environment 2012.

Additional low load factors were applied to the activity based emission factors (Table 3.4) for some contaminants while maneuvering. These low load factors were applied to CO at 2.00, NO_X at 1.22, and VOC at 2.83.

Both Environment Canada's National Marine Emission Inventory and the Chamber of Shipping's BC Ocean-Going Vessels Emissions Inventory used comprehensive databases of actual vessel locations over time to calculate emissions. This detailed information is not available, and therefore for this assessment, the time spent in each mode was estimated based on available information. Typical times at berth were provided by KMC (Kozak pers. comm.). The average time tankers spend at anchor, based on the Chamber of Shipping's BC Ocean-Going Vessels Emissions Inventory, was adopted. While underway and maneuvering, the time-in-mode within the RSA was estimated based on the vessel route distance and the vessel speed. Vessel speeds during maneuvering were set to speed limits from the Vancouver Fraser Port Authority and the Pacific Pilotage Authority for the corresponding tug assist areas. For underway, tankers were assumed to have a maximum design speed of 15 knots (MAN Diesel & Turbo 2009) which is correlated with the actual vessel speed and the engine load factor (LF) via the propeller law (SNC-Lavalin Environment 2012):

$$\mathrm{LF} = \left(\frac{\text{actual speed}}{\text{maximum speed}}\right)^3$$

The route distance, vessel speeds and time-in-mode within the RSA assumed for this assessment are summarized in Table 3.7.

Table 3.7: Route Distance, Vessel Speed, and Time-in-Mode Within the Marine RSA

Vessel	Mode	Round-Trip Distance (km)	Speed (knots)	Time-in-Mode (h)
Tanker	Fast underway	223.6	13.9	8.7
	Slow cruise underway	171.7	11.1	8.4
	Maneuvering	197.5	See tug assist below	11.7
	Anchor	n/a		20.0
	Berth[(a)]	n/a		19.3/24 (Panamax), 25.5/34 (Aframax)
Stern-pull harbor tug		28.2	6.0	2.5
Bow-pull harbor tug		28.2	6.0	2.5
Haro Strait tug		169.3	10.0	9.1
Standard ocean-going tug	Underway	564.6	9.3	32.8
	Maneuvering	28.2	6.0	2.5
	Anchor	n/a		20.0
	Berth	n/a		9.2

Note: (a) Time-in-mode at berth is expected to change as a part of the Project. Time-in-mode will decrease from 24 h (existing conditions) to 19.3 h (with Project) for Panamax vessels, and from 34 h (existing conditions) to 25.5 h (with Project) for Aframax vessels

Boiler fuel consumptions from Environment Canada's National Marine Emission Inventory (SNC-Lavalin Environment 2012) were adopted for this assessment: 0.1 tonne/hour while underway, 0.13 tonne/hour at anchor and 0.11 tonne/hour at berth. The underway fuel consumption rate was applied to the total time-in-mode for fast underway, slow cruise underway, and maneuvering. Fuel based emission factors, taken from Environment Canada's National Marine Emission Inventory, are summarized in Table 3.8.

Table 3.8: Fuel Based Emission Factors (in kg/tonne fuel)

Contaminant	EF_{fuel}
TSP	3.66
PM_{10}	3.51
$PM_{2.5}$	3.23
CO	4.6
NO_X	12.3
SO_2	55.6
VOC	0.4
CO_2	3,188
CH_4	0.29
N_2O	0.081
CO_2e	3,289

Source: SNC-Lavalin Environment 2012.

3.4.2.2. Fugitive Emissions from Tanker Holds

The basic equation for fugitive VOC emissions from marine vessels in transit is:

$E = DWT \times LF \times TF \times EF_{transit}$

Where: E = VOC emissions (mg);

DWT = deadweight tonnage;

LF = load factor;

TF = transit factor; and,

$EF_{transit}$ = transit VOC emission rate (Table 3.9).

The product throughput identified for the Westridge Marine Terminal (see Air Quality and Greenhouse Gas Technical Report [Volume 5C]), outlined in Table 3.9, were used in place of the deadweight tonnage and load factor. The transit factor was set to 0.5 to account for inbound vessels arriving at the Westridge Marine Terminal empty, and outbound vessels leaving the Westridge Marine Terminal loaded, or vice versa for jet fuel barges.

The transit VOC emission rates in Table 3.9, obtained from Environment Canada's National Marine Inventory, are sourced from the United Stated Environmental Protection Agency (US EPA) Compilation of Air Pollutant Emission Factors known as AP-42 (US EPA 1995). In the AP-42 document, it is noted that

the transit VOC emission rates include CH_4 and ethane, and are therefore reflective of total organic compound (TOC) emissions according to the definition employed in this assessment.

Table 3.9: Transit VOC Emission Rates and Associated Product Throughput

Product	Transit VOC Emission Rate (mg/week/litre)	Product Throughput (barrels per day)	
		Baseline Assessment	Project Effects Assessment
Crude	150	63,000	631,900
Jet fuel	0.60	8617	8617

Source: SNC-Lavalin Environment 2012, RWDI 2013.

3.4.2.3. Fugitive Emissions from Marine Vessel Loading

Fugitive emissions associated with marine vessel loading activity at the Westridge Marine Terminal are discussed in the Air Quality and Greenhouse Gas Technical Report (Volume 5C).

Fugitive emissions from marine vessel loading are collected and destroyed by vapour abatement technologies at Westridge Marine Terminal. Westridge Marine Terminal currently operates a vapour combustion unit (VCU). Destruction efficiencies for the existing VCU were estimated based on manufacturer design information. The design destruction efficiency for reduced sulphur compounds of 99% was lowered to 70% to account for the removal of the scrubber upstream of the VCU and resulting higher concentrations in the inlet stream. Based on very preliminary engineering design, the proposed Project design for the new berths includes two new vapour recovery units (VRUs), consisting of a Sulfatreat unit followed by a bed of activated carbon, as well as a new VCU for peak periods and back-up or standby use only when three tankers are berthed. In the absence of specific design information about the new vapour abatement technologies, destruction efficiencies for the proposed VRU were conservatively estimated based on best engineering judgment and it was assumed that the proposed VCU would perform at least as well as the current VCU. Destruction efficiencies associated with the existing and proposed vapour abatement technologies are summarized in Table 3.10. A vapour collection efficiency of 90% was assumed for all technologies. Emissions not collected or destroyed were assumed to be fugitive emissions to atmosphere.

Table 3.10: Destruction Efficiencies Associated with Vapour Abatement Technologies

Contaminant	VCU	VRU
TOC	98%	75%[(a)]
TRS	70%	80%

Note: (a) The 75% destruction efficiency only applies to VOCs other than CH_4 and ethane (C_2H_6)

3.4.2.4. Speciation of VOCs

Emissions of total VOCs and individual COPCs (including individual VOCs, polycyclic aromatic hydrocarbons [PAHs], and heavy metals) were estimated by applying speciation profiles to estimated TOC and PM emissions. The speciation profile for combustion emissions from marine engines were obtained from Environment Canada's National Marine Inventory. The speciation profile for fugitive emissions was developed based on available data for Cold Lake Blend (heavy product) and Peace River Sour (light/synthetic crude product). A more detailed discussion regarding these products and the rationale for selecting these products to represent crude product shipped through Westridge Marine Terminal is provided in the Air Quality and Greenhouse Gas Technical Report (Volume 5C). A summary of the speciation profile sources is provided in Table 3.11.

Table 3.11: Speciation Profile Sources used for VOCs and COPCs

Source Category	Basis of Speciation	Speciation Profile Sources
Combustion from Marine Engines	TOC or TSP	SNC-Lavalin Environment 2012
Cold Lake Blend Vapors	TOC	Flux chamber sampling for TMEP KMC Petroleum Properties 2011 Maxxam Analytics laboratory analysis
Peace River Sour Vapors	TOC	KMC Petroleum Properties 2011 Crude Quality Inc. 2013

Note: RWDI Flux chambers report is provided in TERMPOL Section 3.1 Volume 8C

3.4.3. Dispersion Modelling

The CALMET/CALPUFF dispersion modelling system was used to estimate ambient concentrations of CACs and VOCs in the marine RSA due to existing and projected future emissions from marine traffic associated with the Trans Mountain pipeline. CALMET is a meteorological model that develops hourly three-dimensional meteorological fields of wind and temperature used to drive pollutant transport within CALPUFF. CALPUFF is a multi-layer, non-steady-state puff dispersion model. It simulates the effects of time- and space-varying meteorological conditions on pollutant transport, transformation and deposition.

The CALMET/CALPUFF modelling approach, and corresponding assumptions and methodology were summarized in a detailed model plan. This model plan was reviewed and updated based on input from MV and the BC MOE and approved on October 10, 2013. A copy of the approved and signed final model plan is provided in Appendix A.

In addition to the CALMET/CALPUFF dispersion modelling, photochemical modelling was conducted using the CMAQ modelling system to provide estimates of secondary PM, ozone and visibility. A description of the CMAQ model is provided in Appendix B.

3.4.3.1. CALMET

The development of the CALMET model is described in this section. A detailed list of inputs and model switch settings are included in Appendix C, as well as plots of CALMET model output.

Model Period

The CALMET model period was January to December, 2011. This represents the most recent complete year of data available when TMEP Project work was started.

Model Domain

The CALMET model domain was set to the 150 km by 150 km marine RSA defined in Section 3.3. Domain resolution was set at 2500 m. In the vertical direction, 10 layers were modelled, with the top of each layer set as 20, 40, 80, 160, 320, 500, 1000, 1500, 2200 and 3000 m above ground level. This is consistent with common practice in BC.

Prognostic Meteorology

The CALMET model was initialized using Weather Research and Forecasting (WRF) prognostic model output at 1 km resolution. The WRF model is a mesoscale numerical weather prediction system designed to serve both atmospheric research and operational forecasting needs. It represents the latest numerical weather forecasting model to be adopted by the United States National Weather Service as well as the United States military and private meteorological services.

Surface and Overwater Meteorology

Hourly meteorological data from twelve surface and four overwater buoy stations were included as input to CALMET. The surface stations were selected to provide a reasonable spatial coverage of meteorological observations within the RSA. All overwater buoy stations within the RSA were included. The surface and overwater buoy stations are listed in and shown in Figure 3-4.

Table 3.12: Surface Meteorological and Overwater Buoy Stations Used in CALMET

Station Type	Station Name	Data Provider
Surface	Qualicum Beach	BC MOE[(a)]
Surface	Summit	BC MOF[(b)]
Surface	Entrance Island CS	MSC[(c)]
Surface	Nanaimo Airport	MSC[(c)]
Surface	Sheringham Point	MSC[(c)]
Surface	Victoria International Airport	MSC[(c)]
Surface	Saturna Capmon CS	MSC[(c)]
Surface	Race Rocks CS	MSC[(c)]
Surface	Sand Heads CS	MSC[(c)]
Surface	Vancouver International Airport	MSC[(c)]
Surface	Port Angeles	NCDC[(d)]
Surface	Tatoosh Island	NCDC[(d)]
Overwater Buoy	Halibut Bank	EC [(e)]
Overwater Buoy	Cherry Point	NOS[(f)]
Overwater Buoy	Friday Harbor	NOS[(f)]
Overwater Buoy	New Dungeness	NDBC[(g)]

Notes:
(a) BC MOE = British Columbia Ministry of Environment (2013b)
(b) BC MOF = British Columbia Ministry of Forest & Range (2013)
(c) MSC = Meteorological Service of Canada, a division of Environment Canada (Environment Canada 2013b)
(d) NCDC = National Climatic Data Center, a part of the National Oceanic and Atmospheric Association (NOAA 2013)
(e) EC = Environment Canada (Fisheries and Oceans Canada 2013)
(f) NOS = National Ocean Service, a part of the National Oceanic and Atmospheric Association (NOAA 2013)
(g) NDBC = National Data Buoy Center, a part of the National Oceanic and Atmospheric Association (NOAA 2013)

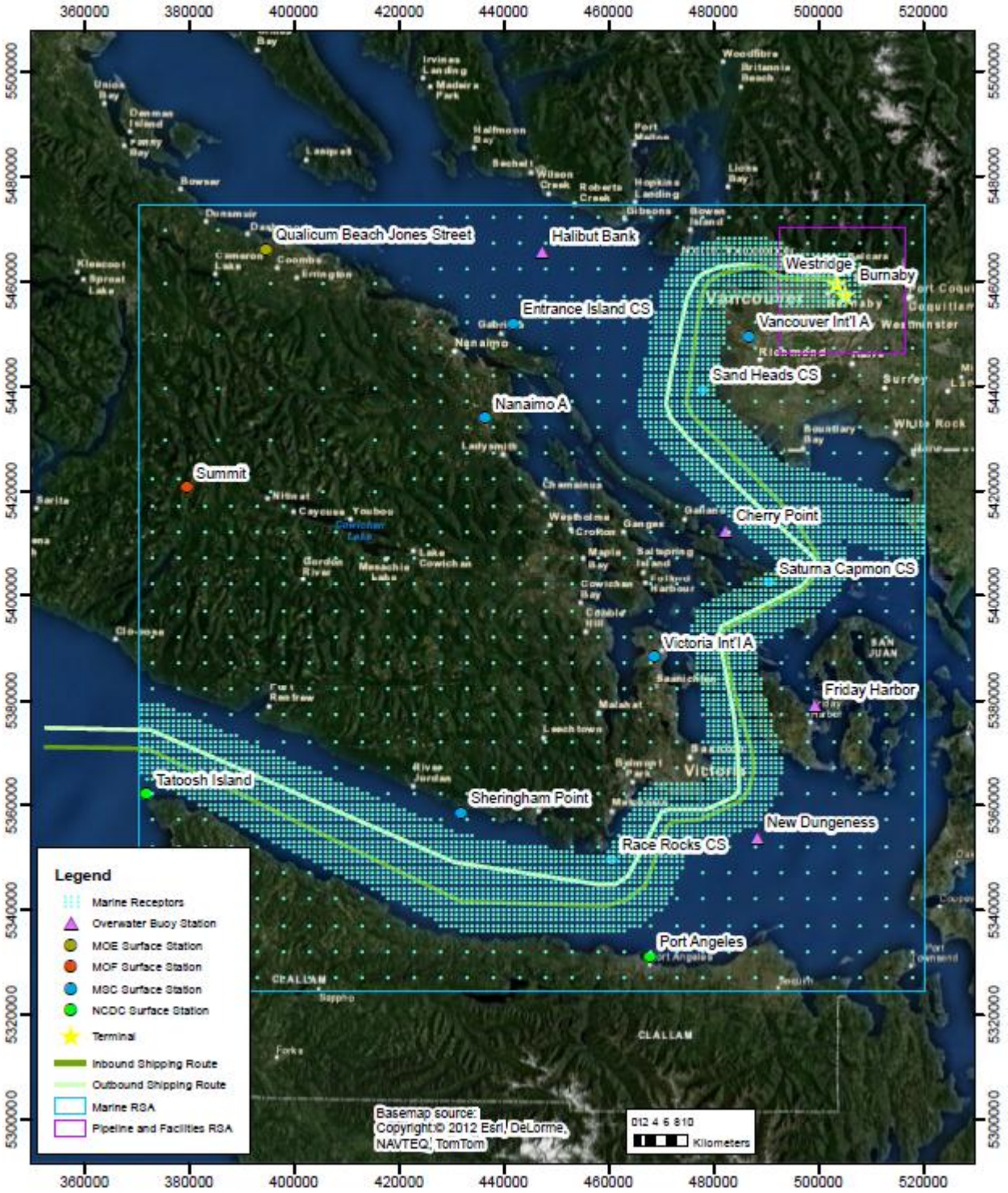


Figure 3.4: Location of Surface Meteorological and Overwater Buoy Stations Used in the CALMET Model

Terrain Elevation and Land Use Characterization

Terrain elevations for the Canadian portion of the model domain were obtained from 1:250,000 scale Canadian Digital Elevation Data available from GeoBase. Terrain elevations for the US portion of the model domain were obtained from 3 arc-second US Geological Survey Shuttle Radar Topography Mission data.

Land use information for the Canadian portion of the model domain was obtained from baseline thematic maps available from GeoBC. Land use information for the US portion of the model domain was obtained from 1:250,000 scale US Geological Survey Composite Theme Grid data.

Model Switch Settings

A list of the switch settings used in the CALMET model is provided in Appendix C. In general, model switch settings were chosen in accordance with the *Guidelines for Air Quality Dispersion Modelling in British Columbia* (BC MOE 2008).

3.4.3.2. CALPUFF

This section outlines the overall CALPUFF methodology. A detailed listing of model switch settings is provided in Appendix C.

The CALPUFF modelling is intended to estimate maximum ambient concentrations of air pollutants due to a realistic worst-case scenario associated with the increased marine vessel traffic due to the Project. As discussed in Section 3.4.2, the Westridge Marine Terminal currently handles approximately five Panamax or Aframax size tankers and two crude barges per month, plus one jet fuel barge per month. A realistic worst-case scenario based on existing marine vessel traffic was therefore developed based on one Aframax vessel travelling in and out along the shipping routes shown in Figure 3.1. The Project will increase marine vessel traffic by approximately 29 tankers per month, for a total of 34 tankers and two crude barges per month and one jet fuel barge per month in the future. On average, this amounts to one or two vessels per day. Since it is highly unlikely for two vessels to traverse the same segment of the shipping route, in the same direction, within the same hour, the1-hour averaging period for projected future conditions with the Project was kept the same as existing conditions.

Also included in the CALPUFF modelling are emissions associated with vessels while at berth and fugitive emissions associated with vessel loading. Modelling of existing conditions consists of one Aframax vessel loading at berth and modelling of Project future conditions with the Project consists of three Aframax vessels loading at berth simultaneously. Emissions associated with the vapour abatement technologies (i.e., vapour combustion unit and vapour recovery units) are considered land-based emissions and were included in the Westridge Marine Terminal modelling, but were not included in the CALPUFF modelling for marine transportation.

The Westridge Marine Terminal receives jet fuel via barges from a refinery in Cherry Point, Washington. Since jet fuel barges travel along a different shipping route that is not expected to considerably overlap spatially with the shipping routes for heavy and light/synthetic crude product, emissions associated with the transport of jet fuel barges were not included in the modelling. Furthermore, the Project is not expected to result in any changes to jet fuel activity and, therefore, effects will cancel out between existing conditions and projected future conditions with the Project.

Model Domain

The CALPUFF model domain was the same as the CALMET 150 km by 150 km marine RSA defined in Section 3.3.

Receptor Locations

A set of discrete receptors was defined for which ground-level concentrations of CACs and VOCs were predicted using the CALPUFF model. A Cartesian grid of receptors was applied with the following receptor spacing:

- 1-km spacing within 5 km of the shipping routes;
- 5-km spacing within 50 km of the shipping routes; and,
- 10-km spacing for the remainder of the RSA.

Gridded receptors are illustrated in Figure 3.4. In addition to the gridded receptors described above, a number of discrete receptors were modelled for the Screening Level Human Health Risk Assessment of Marine Transportation.

Model Switch Settings

A list of the switch settings used in the CALPUFF model is provided in Appendix C. In general, model switch settings were chosen in accordance with the *Guidelines for Air Quality Dispersion Modelling in British Columbia* (BC MOE 2008).

Source Characterization – Combustion Emissions from Marine Engines

Marine vessels in transit along the shipping routes were modelled in CALPUFF as a series of area sources. A series of adjacent area sources were defined along the shipping routes with a maximum length-to-width ratio of 10. The width of the area sources were set to approximately 0.5 km within the Burrard Inlet, and 1.0 km elsewhere.

Area source parameters for modelling combustion emissions from marine engines were selected to represent a typical exhaust stack from an Aframax vessel, estimated based on drawings from KMC, with a release height of 37 m and an initial sigma-z of 10 m.

At berth, combustion emissions from marine engines were modelled as point sources. The point source parameters are summarized in Table 3.13. With the exception of stack height, which is estimated specifically for Aframax vessels calling at the Westridge Marine Terminal, all stack parameters represent a bulk average for all marine vessels, as recommended by the United States Environmental Protection Agency (US EPA), California Air Resources Board, and Environment Canada (Boulton *et al.* 2008).

Table 3.13: Point Source Parameters for Combustion Emissions from Marine Engines at Berth

Parameter	Value
Stack Height (m)	37.0
Stack Diameter (m)	0.80
Exit Velocity (m/s)	25.0
Exit Temperature (K)	555.2

Source Characterization – Fugitive Emissions from Tanker Holds

The series of area sources used to model combustion emissions from marine engines were also used to model fugitive emissions from tanker holds. The release height associated with fugitive emissions from tanker holds was estimated to be 17 m. The initial sigma-z of 10 m used for modelling combustion emissions from marine engines was also used to model fugitive emissions from tanker holds.

Source Characterization – Marine Vessel Loading

Fugitive emissions associated with marine vessel loading activity were modelled as area sources representing vessel tanker holds while at berth. Area source parameters were the same as those used to model fugitive from tanker holds while in transit.

Building Effects

Buildings and other structures located close to point sources may influence the dispersion of emissions. The effect of the marine vessel itself, on the modelled point sources at berth was incorporated using the Building Profile Input Program Plume Rise Model Enhancement (BPIP-PRIME) algorithm. The algorithm explicitly treats the trajectory of the plume near the building, and uses the position of the plume relative to the building to calculate interactions with the building wake. Buildings located near the berth at the Westridge Marine Terminal were deemed too small to influence the dispersion from a 37 m high point source.

Chemistry

The CALPUFF model has the ability to consider the chemical transformation of SO_2 to sulphates (SO_4), and NO_X to nitrates (NO_3) and nitric acid (HNO_3). CALPUFF v6.42, used for this assessment, now includes three chemical reaction schemes. Based on recommendations from the BC MOE, the new RIVAD/ISORROPIA scheme was used, as this module includes a treatment for inorganic gas-particle equilibrium and studies show this new module can avoid over-predictions in nitrate concentrations sometimes seen in the other chemical reaction schemes.

The RIVAD/ISORROPIA chemical reaction scheme requires background concentrations of ozone and ammonia. For this assessment, hourly ozone concentrations concurrent to the meteorological time span were input to the model, along with monthly ammonia concentrations, based on monitoring data in the Pipeline and Facilities Burnaby and Westridge Marine Terminals RSA. A list of the monitoring stations is provided in the Air Quality and Greenhouse Gas Technical Report.

Wet and Dry Deposition

Wet and dry deposition was enabled for all pollutants in CALPUFF.

Deposition of nitrogen and sulphur gases and particles (primary and secondary) was modelled using the parameters shown in Table 3.14 to Table 3.16. These deposition parameters were derived for a Trace Metal and Air Contaminant report (RWDI 2007) based on values provided by ENSOR International from their review of the Design Institute for Physical Properties Data of the American Institute of Chemical Engineers data bank and the US EPA human health risk assessment protocols.

Due to the lack of specific size and reactivity information, dry deposition of PM and VOC was modelled using bulk deposition velocities. A bulk deposition velocity of 1.67 cm/s was used for TSP and PM_{10}, and a bulk deposition velocity of 0.167 mm/s was used for $PM_{2.5}$ (Tombach and Brewer 2005). For VOC, a bulk deposition velocity of 0.5 cm/s was used, based on the US EPA Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities (US EPA 2005).

Table 3.14: CALPUFF Dry Deposition Parameters for Gases

Parameter	SO_2	NO	NO_2	HNO_3
Diffusivity (cm^2/s)	0.1372	0.2203	0.1585	0.1041
Alpha star	1000	1.0	1.0	1.0
Reactivity	8.0	2.0	8.0	18
Mesophyll resistance (s/cm)	0.0	94	5.0	0.0
Henry's Law coefficient	0.033	18	3.5	8×10^{-8}

Table 3.15: CALPUFF Dry Deposition Parameters for Particles (in µm)

Parameter	SO_4^{2-}	NO_3^-
Geometric mass mean diameter	0.48	0.48
Geometric standard deviation	2.0	2.0

Table 3.16: CALPUFF Wet Deposition Parameters (in s^{-1})

Pollutant	Scavenging Coefficient in Liquid Precipitation	Scavenging Coefficient in Frozen Precipitation
SO_2	3.21×10^{-5}	0.0
SO_4^{2-}	1.0×10^{-4}	3.0×10^{-5}
NO	2.85×10^{-5}	0.0
HNO_3	6.0×10^{-5}	0.0
NO_3^-	1.0×10^{-4}	3.0×10^{-5}
TSP	1.0×10^{-4}	3.0×10^{-5}
PM_{10}	1.0×10^{-4}	3.0×10^{-5}
$PM_{2.5}$	1.0×10^{-4}	3.0×10^{-5}

3.4.3.3. Model Output Interpretation

To understand the contribution of various source groups, and to enable scaling of model results to predict maximum concentrations of all individual COPCs, emission sources were grouped into numerous model runs based on the speciation profiles discussed in Section 3.4.2.4. Results for all model runs were summed to determine the combined effects of all sources within the marine RSA.

Determination of Combined Effects for CACs and Total VOC's

The CALSUM post-processing software was used to sum the predicted concentrations at each receptor from each of the model runs to obtain the predicted concentrations from the combined effect of all emission sources within the RSA.

Since the CALPUFF modelling was based on a worst-case scenario of one Aframax vessel travelling in and out along the shipping routes, a direct summation of the results from all model runs yielded maximum expected 1-hour average concentrations. 20-hour average concentrations from the CALPUFF modelling represents a total of 24 Aframax vessels travelling in and out along the shipping routes, and annual average concentrations from the CALPUFF modelling represent a total of 8760 Aframax vessels travelling in and out along the shipping routes for the Project; therefore, 24-hour and annual average concentrations were estimated by applying scaling factors using the CALSUM post-processing software.

The CALPUFF dispersion model simulates and predicts the formation of sulphates and nitrates. Predicted concentrations of sulphates and nitrates were combined using the POSTUTIL post-processing software to estimate secondary $PM_{2.5}$. The POSTUTIL post-processing software was also used to combine predicted concentrations of secondary $PM_{2.5}$ with predicted concentrations of primary PM to estimate total PM.

The CALPOST post-processing software was then used to extract the maximum predicted concentrations of CACs and total VOCs associated with marine transportation.

NO_X to NO_2 Conversion

Emissions of NO_X from marine transportation are comprised of NO and NO_2. The primary emission is in the form of NO with reactions in the atmosphere resulting in the conversion of NO to NO_2. In order to use the RIVAD/ISORROPIA chemical reaction scheme, individual emissions of NO and NO_2 are required. For this assessment, it was assumed that 90% of the NO_X emissions would be in the form of NO, and 10% would be in the form of NO_2.

In light of over-predictions of NO_2 in the higher concentration range seen in previous studies, and to more accurately account for the conversion of total atmospheric NO_X, predicted NO and NO_2 concentrations were combined using the POSUTIL post-processing software, added to background NO_X concentrations (see Section 3.4.3.4), then converted to NO_2.

According to the *Guidelines for Air Quality Dispersion Modelling in British Columbia* (BC MOE 2008), the first and most conservative method of estimating NO_2 is to assume 100% conversion of NO_X into NO_2. If a more accurate estimate is desired, the ambient ratio method or the ozone limiting method may be used. The ambient ratio method is recommended in areas where representative NO_X and NO_2 ambient monitoring data are available. For this assessment, NO_2 concentrations were estimated using the ambient ratio method, based on the ambient monitoring data discussed in Section 3.4.1.1.

The ratio of 1-hour and 24-hour NO_2/NO_X versus total NO_X concentrations are shown in Figure 3.5 and Figure 3.6, respectively. An exponential curve was fitted to the upper-envelope of the scatter plots, as shown in the figures. The maximum NO_2/NO_X ratio was set to 1 and a minimum NO_2/NO_X ratio was set to 0.1, as per the *Guidelines for Air Quality Dispersion Modelling in British Columbia* (BC MOE 2008). For the annual averaging period, a single NO_2/NO_X ratio of 0.70 was used, based on the average of all ambient monitoring data.

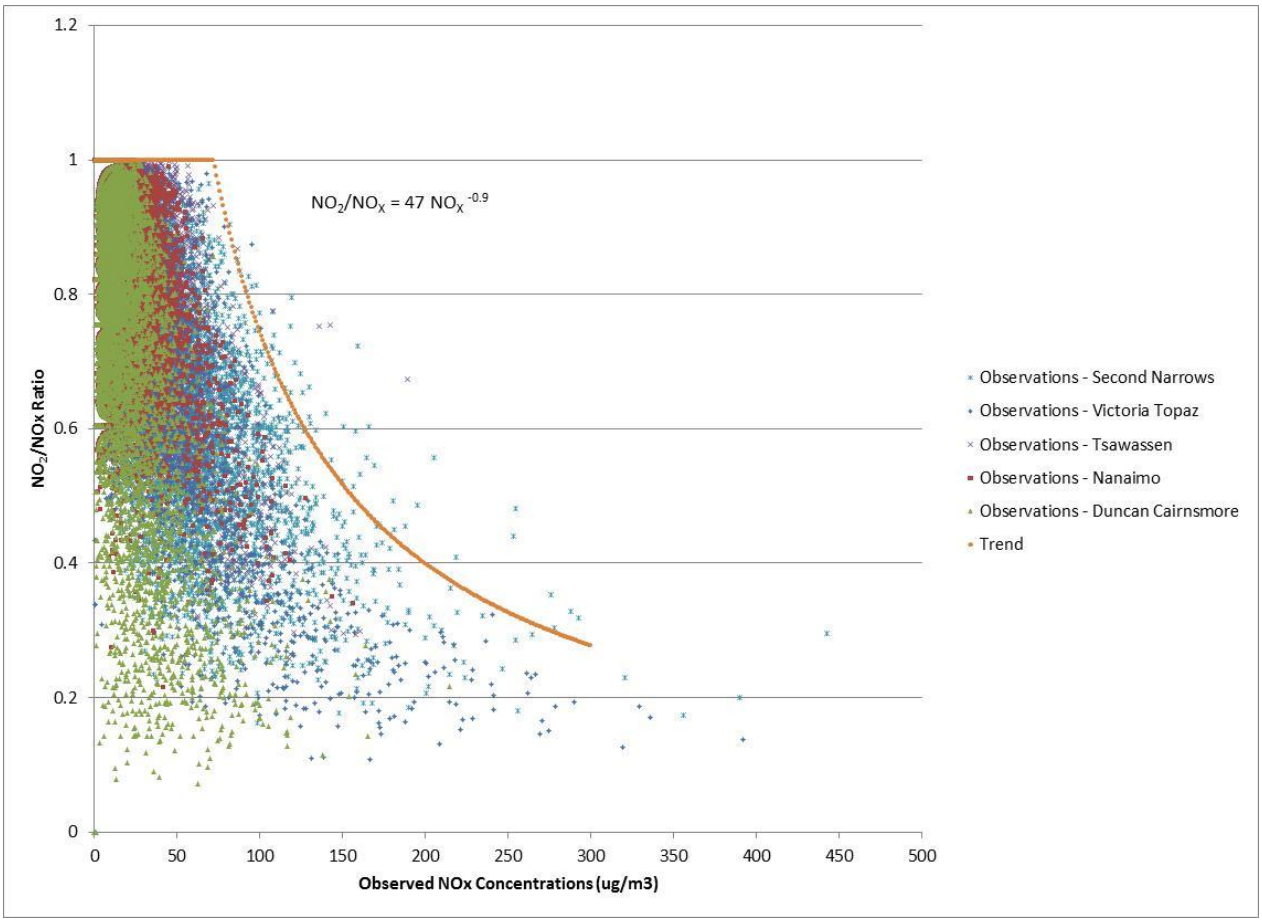


Figure 3.5: Dependence of NO_2/NO_X Ratio on Ambient NO_X Concentrations Based on 1-Hour Observations

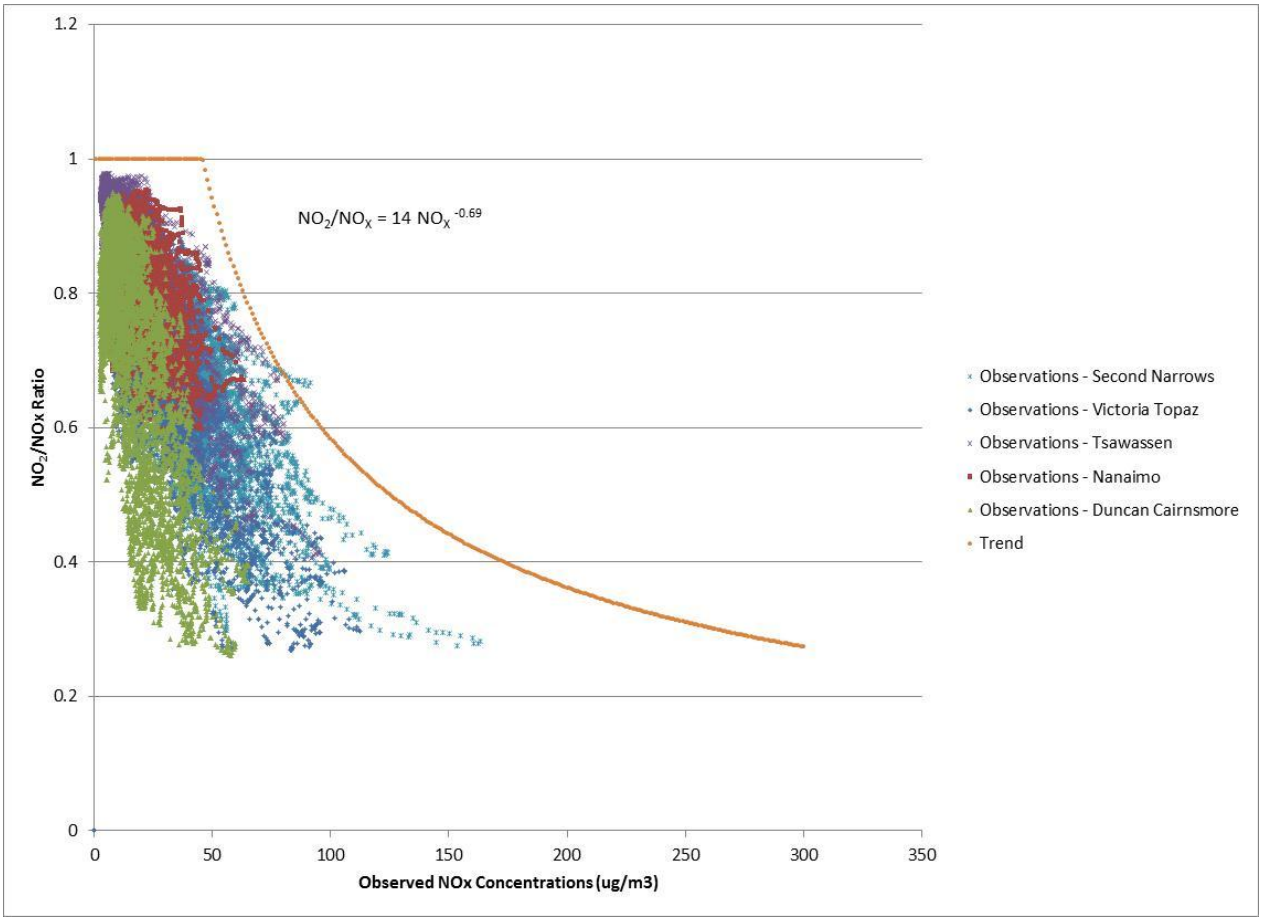


Figure 3.6: Dependence of NO_2/NO_X Ratio on Ambient NO_X Concentrations Based on 24-Hour Observations

Speciation

Due to the number of COPCs required for the Screening Level Human Health Risk Assessment of Marine Transportation, it was impractical to model each of the COPCs directly in CALPUFF. Instead, maximum predicted concentrations of individual COPCs were estimated by scaling the total VOC and total TSP concentrations predicted by CALPUFF for each source category, using the speciation profiles discussed in Section 3.4.2.4.

For each receptor, the maximum concentration of each COPC was calculated using the following equation:

$$\text{Maximum COPC}_i = \sum_{j=1}^{n} \text{Maximum VOC or TSP from } (\text{Source Category}_j \times \text{Speciation Factor}_{i,j})$$

This represents a conservative approach in estimating maximum concentrations of individual COPCs as the maximum VOC or TSP concentration from each source category may occur at different times.

3.4.3.4. Determination of Background

Typically, background concentrations are used to represent the contribution from all other natural and anthropogenic sources in the area, and are added to model results for assessment of cumulative effects (BC MOE 2008). A single value is chosen as background, which is conservatively assumed to apply for every hour of the model period and for every location within the model domain. For this assessment, it was deemed impractical to determine a single value to use as background for the entire 150 km by 150 km marine RSA which encompasses a wide range of land uses including water, urban and agricultural areas; therefore, the background contribution was considered using a multi-step approach.

Contributions from background marine transportation in the marine RSA were considered through the inclusion of the 2005 Corbett marine emission inventory. Model results from the combined effect of marine transportation associated with the TMPL system and background marine transportation were compared to ambient air quality monitoring data discussed in Section 3.4.1.1. For the most part, model results represented only about 2% of observed concentrations; therefore, it was deemed that the addition of background concentrations was required for receptors over land to represent the background contribution of land-based emission sources. Background concentrations were not added for receptors over water as it is expected that observed concentrations over water would be primarily due to marine transportation and would receive little influence from land-based emission sources.

For CACs, background concentrations for the Burrard Inlet area were developed based on Kensington Park station data, as used for the Pipeline and Facilities Burnaby and Westridge Marine Terminals RSA. Background concentrations for the Victoria area were developed based on Victoria Topaz station data. For all other receptors over land, background concentrations based on Cheeka Peak station data were used to represent a regional background.

Background BTEX concentrations were developed based on the Burnaby Burmount NAPS station for the Burrard Inlet area, as discussed in the Air Quality and Greenhouse Gas Technical Report for the Burnaby and Westridge Marine Terminals RSA. For all other receptors over land, background BTEX concentrations based on the Saturna Island NAPS station were used to represent a regional background.

In addition, background metals concentrations for the Burrard Inlet area were obtained from MV's Burrard Inlet Area Local Air Quality Study (Metro Vancouver 2012b) for the Screening Level Human Health Risk Assessment of Marine Transportation. No background metals concentrations were available for receptors outside the Burrard Inlet area.

A summary of the background concentrations used for this assessment is provided in Table 3.17.

Table 3.17: Background Representative Ambient Concentrations (in µg/m^3)

Pollutant	Averaging Period	Burrard Inlet Area	Victoria Area	Regional Background
TSP	24-Hour	36.2	34.7	21.4
	Annual	14.9	15.1	6.3
PM_{10}	24-Hour	20.1	19.3	11.9
	Annual	8.3	8.4	3.5
$PM_{2.5}$	24-Hour	12.5	20.0	6.4
	Annual	3.3	5.2	1.9
CO	1-Hour	605.0	1360.0	259.0
	8-Hour	543.0	1157.0	259.0
NO_X	1-Hour	111.0	118.0	N/A
	24-Hour	88.7	78.8	N/A
	Annual	26.7	20.2	N/A
SO_2	1-Hour	26.3	14.9	2.3
	24-Hour	17.4	12.4	1.9
	Annual	2.7	2.5	0.8
Benzene	1-Hour[(a)]	5.1	N/A	1.4
	Annual	0.6		0.2
Ethylbenzene	1-Hour[(a)]	2.7		0.3
Toluene	1-Hour[(a)]	14.3		3.6
	24-Hour	5.7		1.4
Xylenes	1-Hour[(a)]	13.1		1.1
	24-Hour	5.2		0.4

Notes: (a) Background 1-hour VOC concentrations are calculated as 2.5 times the background 24-hour concentrations (BC MOE 2008)
N/A – Not Available

4. EXISTING CONDITIONS

4.1. Results of Literature/Desktop Review

4.1.1. Existing Air Quality Conditions – Criteria Air Contaminants

Historical monitoring data of CACs are presented in this section. Annual, seasonal and diurnal trends for the ten-year period from 2002 to 2011 were analyzed, along with existing air quality conditions based on 2011 monitoring data. This is followed by a more detailed discussion by location. Historical monitoring data for BTEX and ozone are presented in Sections 4.1.2 and 4.1.3, respectively. The locations of the ambient monitoring stations are shown in Figure 3.4.

4.1.1.1. Overview

Annual time series of observed CAC concentrations for the four monitoring stations selected, based on the 50th percentile of hourly observations for each year (except for PM which is based on the 50th percentile of the 24-hour concentrations), are summarized in Figure 4.1 to Figure 4.4 (BC MOE 2008). For the most part, air quality conditions in the marine RSA, with respect to CAC concentrations, have improved over the last decade. Each area is discussed separately in more detail in the following subsections. Annual time series for SO_2 are not shown because ambient SO_2 concentrations are below the detection threshold much of the time at the four monitoring stations and only occasional spikes are detected by the monitors; therefore, the annual time series based on the 50th percentile generally varied between 0 µg/m^3 and 3 µg/m^3 and did not provide any meaningful information.

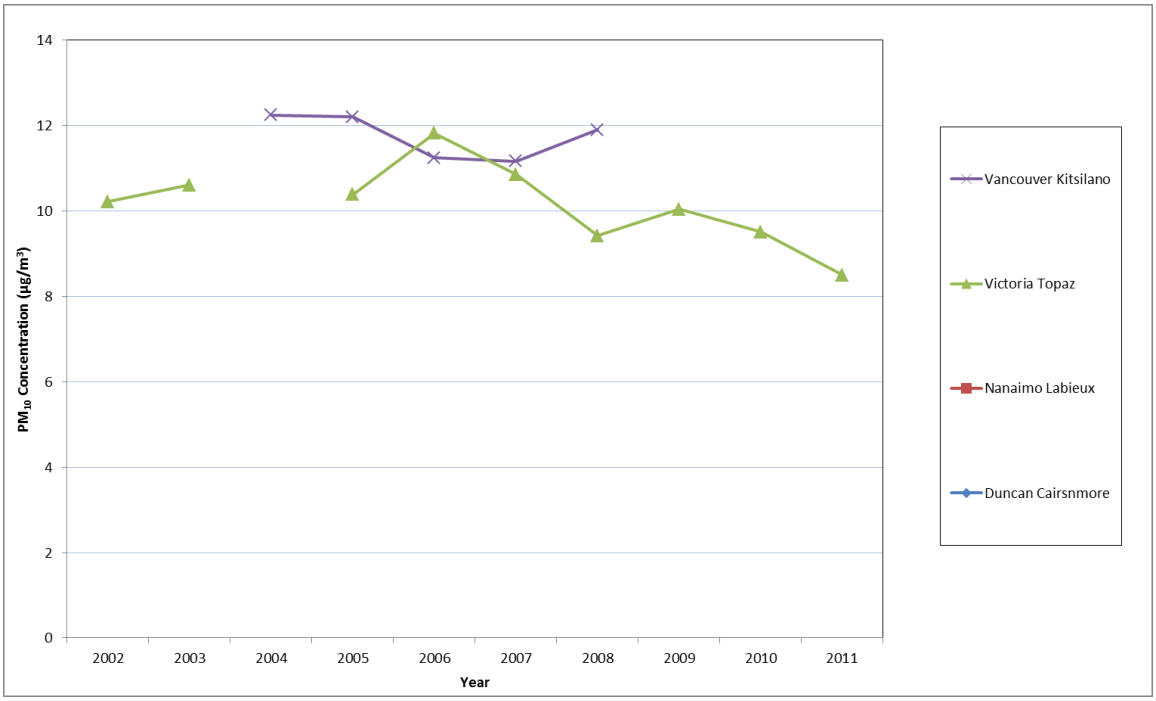


Figure 4.1: Annual Time Series for Ambient PM_{10} Concentrations (in $\mu g/m^3$)

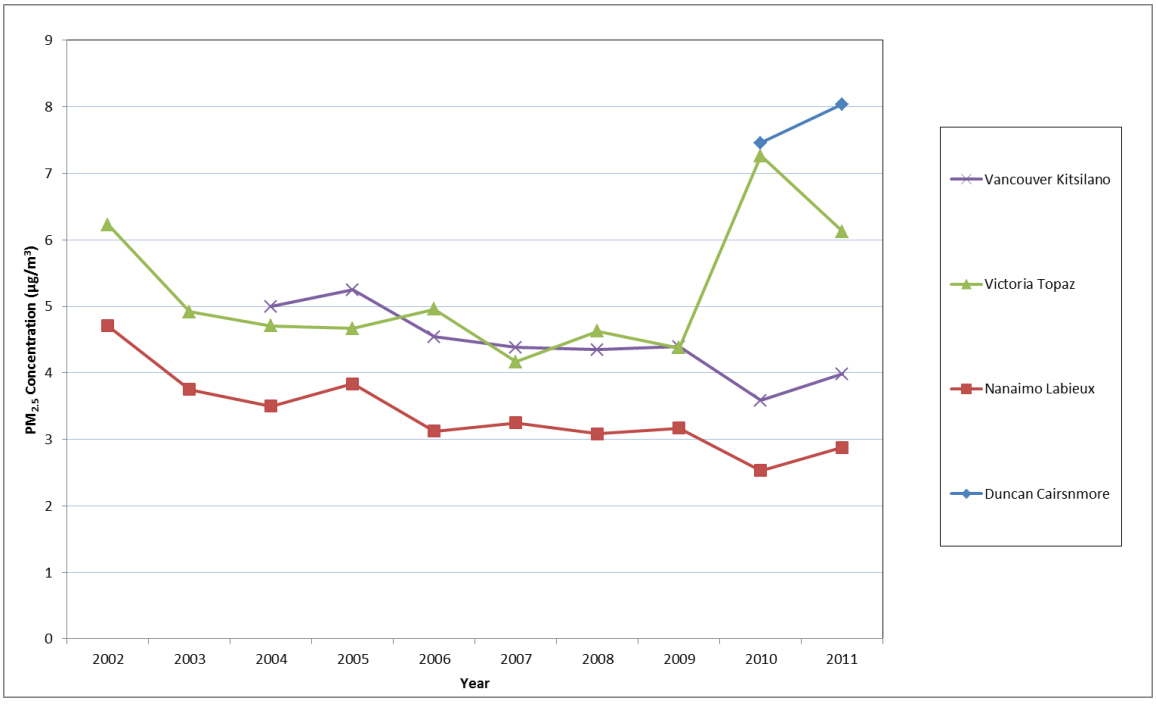


Figure 4.2: Annual Time Series for Ambient $PM_{2.5}$ Concentrations (in $\mu g/m^3$)

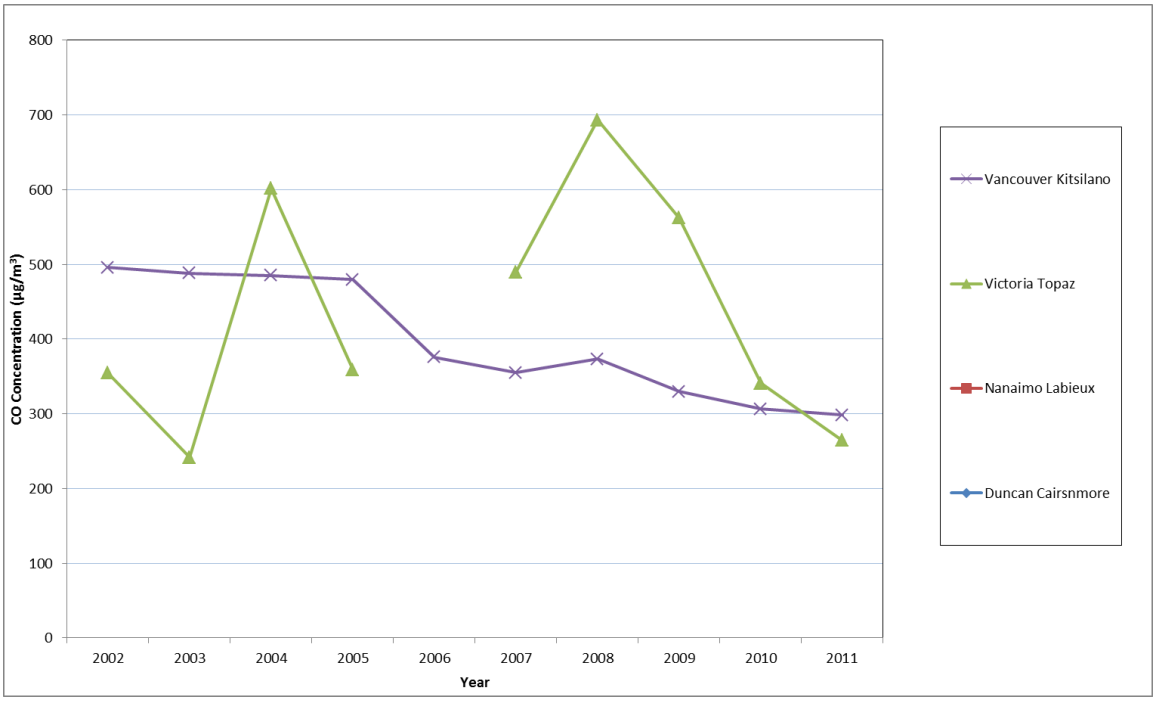


Figure 4.3: Annual Time Series for Ambient CO Concentrations (in µg/m^3)

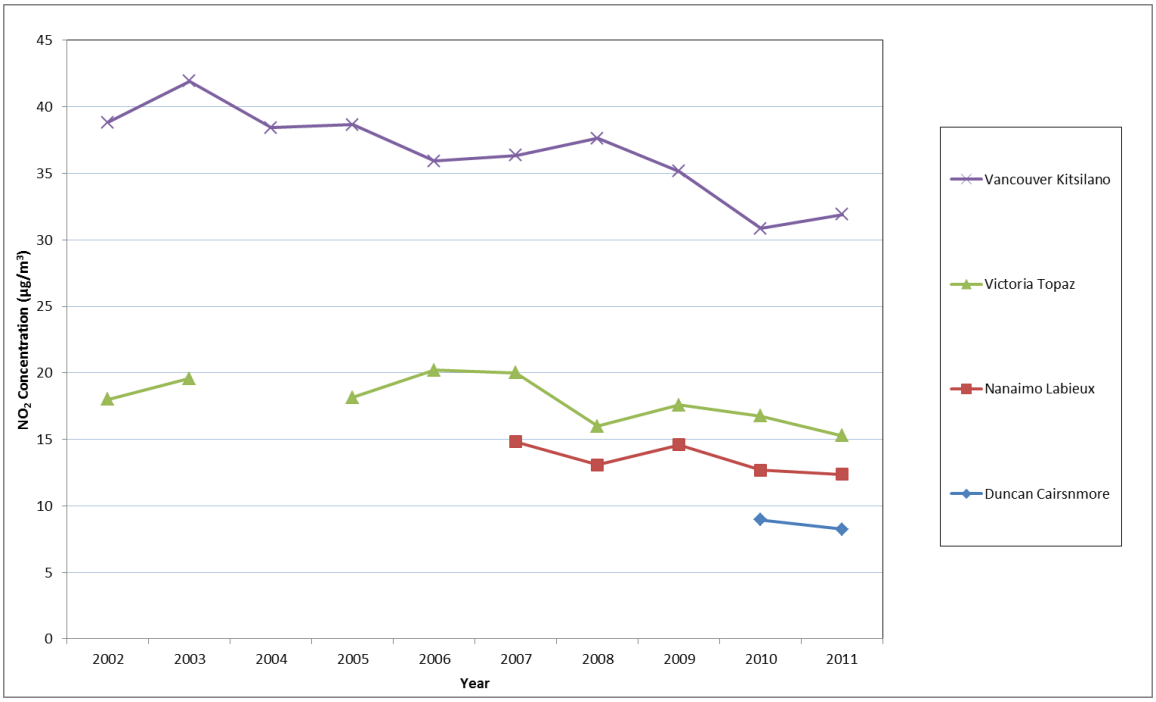


Figure 4.4: Annual Time Series for Ambient NO_2 Concentration (in µg/m^3)

Observed CAC concentrations for 2011, or the most recent year if 2011 was not available, are summarized in Figure 4.5 to Figure 4.9. The frequency of observed $PM_{2.5}$ concentrations exceeding the relevant air quality objectives in 2011, or the most recent year, is shown in Table 4.1. No exceedances of the relevant air quality objectives for PM_{10}, CO, NO_2 or SO_2 were observed in 2011. Overall, existing air quality conditions in the marine RSA, with respect to CAC concentrations, is very good with few exceedances of the relevant ambient air quality objectives only for $PM_{2.5}$. Each area is discussed separately in more detail in the following subsections.

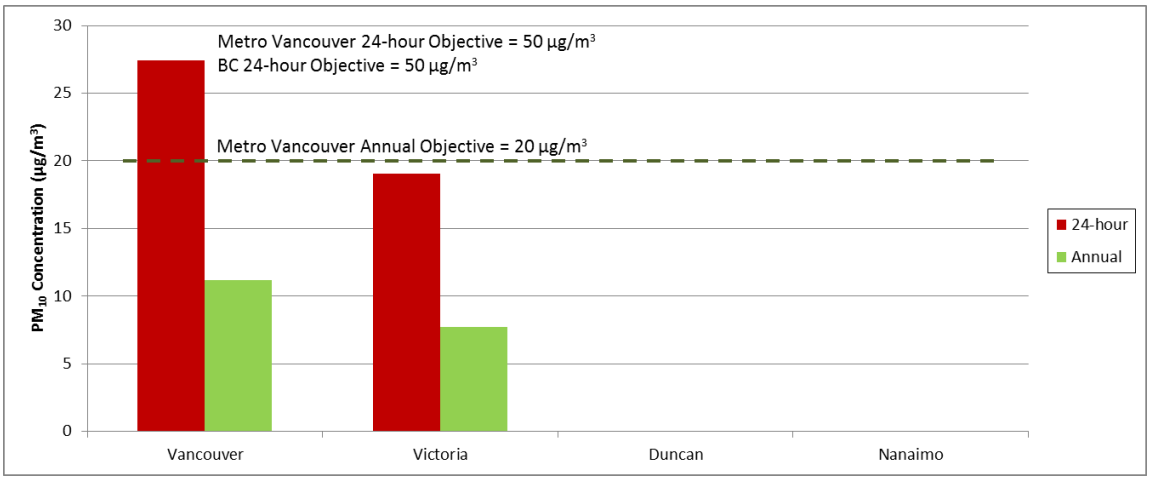
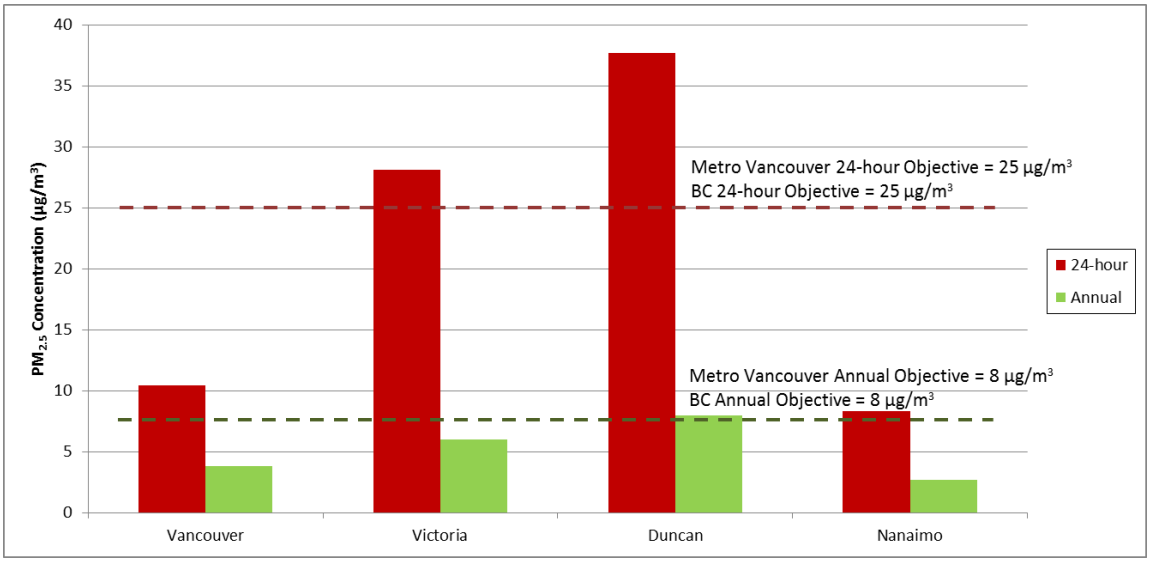


Figure 4.5: Observed PM_{10} Concentrations in 2011 for the Marine RSA (in $\mu g/m^3$)



Note: There was no $PM_{2.5}$ data from the Vancouver-Kitsilano station in 2011. Data from 2008 are presented.

Figure 4.6: Observed $PM_{2.5}$ Concentrations in 2011 for the Marine RSA (in $\mu g/m^3$)

Table 4.1: Frequency of Observed $PM_{2.5}$ Concentrations Exceeding Ambient Objectives In 2011

Area	Jurisdiction	Averaging Period	Objective ($\mu g/m^3$)	Frequency of Exceedance
Vancouver[(a)]	Metro Vancouver	24-hour	25	0%
Victoria	BC	24-hour	25	1.6%
Duncan	BC	24-hour	25	6.5%
Nanaimo	BC	24-hour	25	0%

Note: (a) There was no $PM_{2.5}$ data from the Vancouver-Kitsilano station in 2011. Data from 2008 are presented.

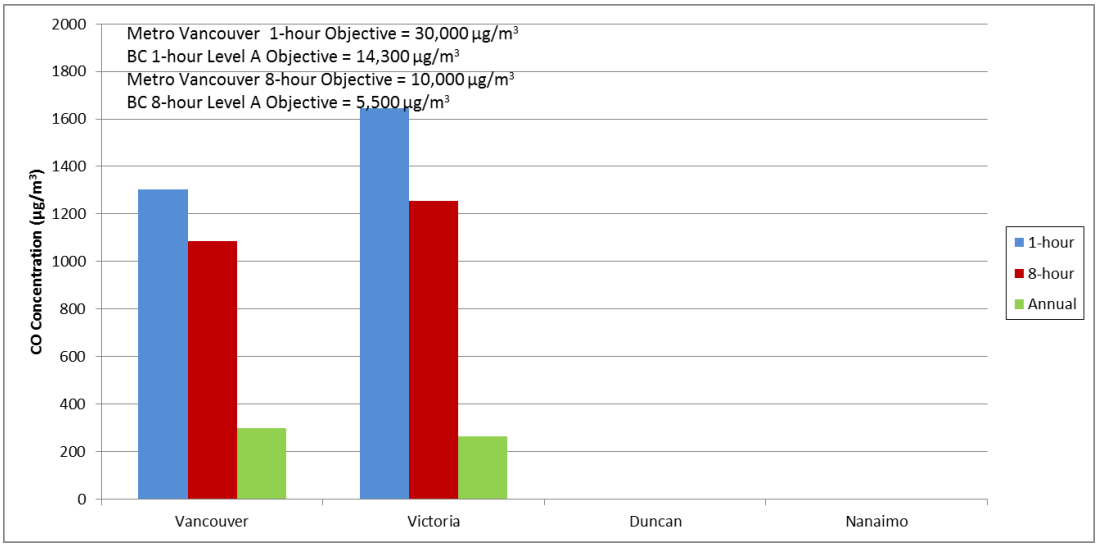


Figure 4.7: Observed CO Concentrations in 2011 for the Marine RSA (in $\mu g/m^3$)

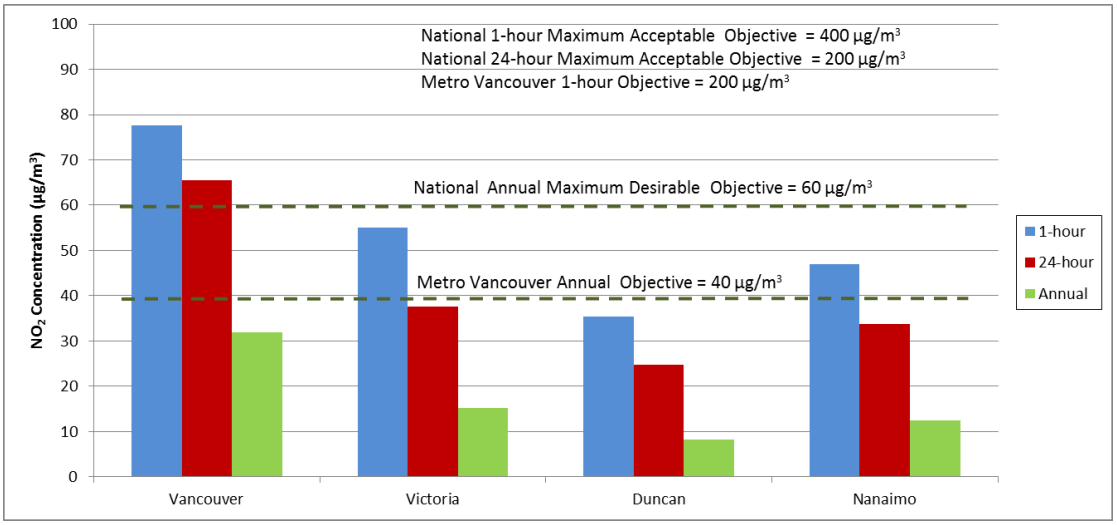


Figure 4.8: Observed NO_2 Concentrations in 2011 for the Marine RSA (in µg/m^3)

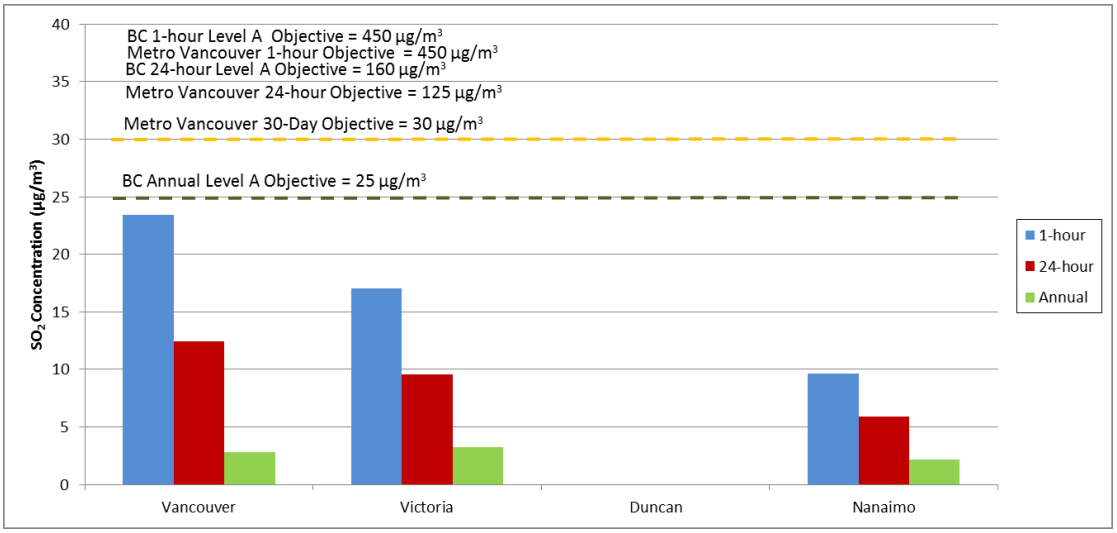


Figure 4.9: Observed SO_2 Concentrations in 2011 for the Marine RSA (in µg/m^3)

4.1.1.2. Vancouver

Vancouver is a city (population 603,502) located on the Burrard Peninsula of BC's mainland, east of Vancouver Island. Burrard Inlet lies to the north and the Fraser River is located to the south. MV's Vancouver-Kitsilano station was selected as the most representative station in the Vancouver area. It is located in a densely populated residential area about 3 km from downtown. The station measured CO,

NO_2 and SO_2 data for the 2002 to 2011 period. $PM_{2.5}$ data are available from 2004 to 2011 and PM_{10} data are available from 2004 to 2009.

Diurnal and seasonal variability for all CACs are illustrated in Appendix D. There is no apparent seasonal trend for $PM_{2.5}$ or PM_{10} in the Vancouver area. PM concentrations are slightly higher in the morning and evening hours, possibly due to rush hour traffic. MV has also noted that sand from the nearby beach volleyball court occasionally influences the PM measurements at the Vancouver-Kitsilano station (Metro Vancouver 2011). CO concentrations are higher in the winter, possibly due to increased residential heating and vehicle cold engine starts in the urban area. The highest CO concentrations occur in the morning and in the evening, and may be representative of rush hour traffic in the area. NO_2 concentrations tend to be highest in the winter months when there are fewest daylight hours, and therefore, less photolysis of NO_2 to NO, shifting the equilibrium towards NO_2. Similar to PM and CO, the highest NO_2 concentrations also occur in the morning and evening. High NO_2 concentrations in the morning reflect the influence of daylight on the NO_2 to NO equilibrium. High NO_2 concentrations in the evening may suggest that local emissions (e.g., traffic) have a stronger diurnal influence on NO_2 concentrations than the presence of sunlight. SO_2 concentrations are slightly higher during the winter months and morning hours, possibly due to more vehicle cold engine starts.

PM concentrations in Vancouver have decreased slightly since 2004. CO and NO_2 have decreased by approximately 25% and 40%, respectively, over the last decade.

The highest NO_2 concentrations in the RSA were observed in Vancouver. There were no exceedances of the relevant ambient air quality objectives for any of the CACs in 2011, or the most recent year. There were also no exceedances of the WHO SO_2 guideline. The 99th percentile concentrations of CO and SO_2 in 2011 were less than 10% of the applicable 1-hour objectives, while the 99th percentile NO_2 concentration in 2011 was approximately one-third of the 1-hour objective.

4.1.1.3. Victoria

Victoria (population 80,017) is located in a delta on the southwest corner of Vancouver Island. Surrounding industries include aggregate facilities and marine shipping ports at the nearby terminals, such as the Victoria Shipyards. The BC MOE operates an ambient air quality station at Victoria-Topaz which measured $PM_{2.5}$, PM_{10}, CO, NO_2 and SO_2 during the 2002 to 2011 period.

There is a slight variation in seasonal and diurnal PM concentrations in Victoria, with concentrations higher in the fall and later winter, and in the morning and evening hours. The seasonal variation may be associated with open burning of waste and wood stove usage; whereas, the diurnal variation may be reflective of traffic patterns. CO concentrations also follow a similar seasonal and diurnal variation. The highest NO_2 concentrations occur in February and September but seasonal trends are not evident. The NO_2 diurnal trend shows the highest NO_2 concentrations occurring in the morning and evening, and may be reflective of local traffic patterns and the development of a lower mixed layer in the evening. SO_2 concentrations, while showing short-term peaks in the summer months, are on average highest in February and October. Maximum SO_2 concentrations are observed in the evening while average SO_2

concentrations tend to be highest in the morning, at 8:00 PST. Given that SO_2 concentrations are below the detection thresholds much of the time, seasonal and diurnal trends may not be significant.

PM concentrations in Victoria have decreased over the last decade, although there has been a significant peak in $PM_{2.5}$ concentrations in 2010 and 2011. NO_2 concentrations have also decreased slightly over the last decade. CO concentrations have fluctuated, remaining relatively steady. Note that PM_{10} and NO_2 data for 2004, as well as CO data for 2006, were not included in the annual trend analysis due to the low data completeness for these years.

In 2011, exceedances of the 24-hour provincial objective for $PM_{2.5}$ of 25 µg/m^3 occurred less than 2% of the time. There were no exceedances of the objectives for PM_{10}, CO, NO_2 or SO_2 in 2011. The 99th percentile concentrations of CO and SO_2 in 2011 were less than 10% of the applicable 1-hour objectives, while the 99th percentile NO_2 concentration in 2011 was less than 15% of the applicable 1-hour objective.

4.1.1.4. Duncan

Duncan (population 4932) is a town located on Vancouver Island with complex terrain to the west and the ocean to the east. It is located 50 km north of Victoria and 50 km south of Nanaimo. Surrounding industries include aggregate, steel recycling and forestry. The BC MOE operates an ambient air quality station at Duncan-Cairnsmore which measured $PM_{2.5}$ and NO_2 from 2010 to 2011.

The highest $PM_{2.5}$ concentrations in Duncan occurred in the winter months, possibly due to increased residential wood heating during this time. NO_2 concentrations tend to be highest in the winter months when there are fewest daylight hours, and therefore, less photolysis of NO_2 to NO, shifting the equilibrium towards NO_2. The highest NO_2 concentrations occurred in the evening, and may be reflective of local emission patterns (e.g., residential wood heating, traffic) as well as the development of a lower mixed layer during this time of day. A smaller peak in NO_2 concentrations was also observed in the morning.

$PM_{2.5}$ concentrations have increased from 2010 to 2011, although the data record is insufficient to indicate trends. NO_2 concentrations have remained relatively consistent from 2009 to 2011.

The $PM_{2.5}$ concentrations in Duncan are the highest in the RSA. Exceedances of the 24-hour provincial objective for $PM_{2.5}$ of 25 µg/m^3 occurred 6.5% of the time in 2011. This may be a result of the industrial contribution to air quality conditions in Duncan. There were no exceedances of the NAAQO for NO_2 in 2011. The 99th percentile NO_2 concentration in 2011 was less than 15% of the applicable 1-hour objective.

4.1.1.5. Nanaimo

Nanaimo (population 83,810) is located in mixed terrain on the east side of Vancouver Island. Surrounding industries include forestry and oil and gas. The BC MOE operates an ambient air quality station at Nanaimo-Labieux which measured $PM_{2.5}$, NO_2 and SO_2 data for the 2002 to 2011 period. NO_2 data are available from 2006 to 2011, and SO_2 data are available from 2004 to 2011. PM_{10} data are also

available from August to September, 2008; however, since two months of data is insufficient to draw conclusions on existing air quality conditions, this data was not analyzed for this assessment.

$PM_{2.5}$ concentrations in Nanaimo tend to be highest in October, November and February, during the evening hours. This is believed to be a result of residential wood burning, as the City of the Nanaimo has received complaints during the winter months regarding poor air quality caused by wood smoke from residential heating (BC MOE 2009). The maximum $PM_{2.5}$ concentration was observed in August, 2010, and is believed to be an effect of several small forest fires at that time. NO_2 concentrations tend to be highest in the winter months when there are fewest daylight hours, and therefore, less photolysis of NO_2 to NO, shifting the equilibrium towards NO_2. The highest NO_2 concentrations occurred in the morning and in the evening. This may suggest that local emissions (e.g., residential heating, traffic) have a stronger diurnal influence on NO_2 concentrations than the presence of sunlight. The maximum SO_2 concentrations occurred in March but seasonal and diurnal trends were not evident.

$PM_{2.5}$ concentrations in Nanaimo have decreased over the last decade. NO_2 concentrations have remained relatively constant.

There were no exceedances of the ambient air quality objectives for $PM_{2.5}$ NO_2, or SO_2 at Nanaimo-Labieux in 2011. The 99th percentile NO_2 concentration in 2011 was approximately 10% of the 1-hour objective.

4.1.1.6. US Waters

A summary of 2011 concentrations of CACs observed at the Cheeka Peak and Port Townsend stations are illustrated in Figure 4-10 to Figure 4-13. There were no exceedances of the US EPA National Ambient Air Quality Standards (NAAQS) (US EPA, 1990). The maximum 24-hour $PM_{2.5}$ concentrations were less than half the standard and the maximum CO, NO_2[3] and SO_2 concentrations were less than 10% of the standards.

[3] Cheeka Peak data were available for NO and NOy (total reactive nitrogen, represents NO_X plus nitric acid and organic nitrates). All NOy concentrations were assumed to be NO_X, and NO_2 was calculated as NO_X minus NO.

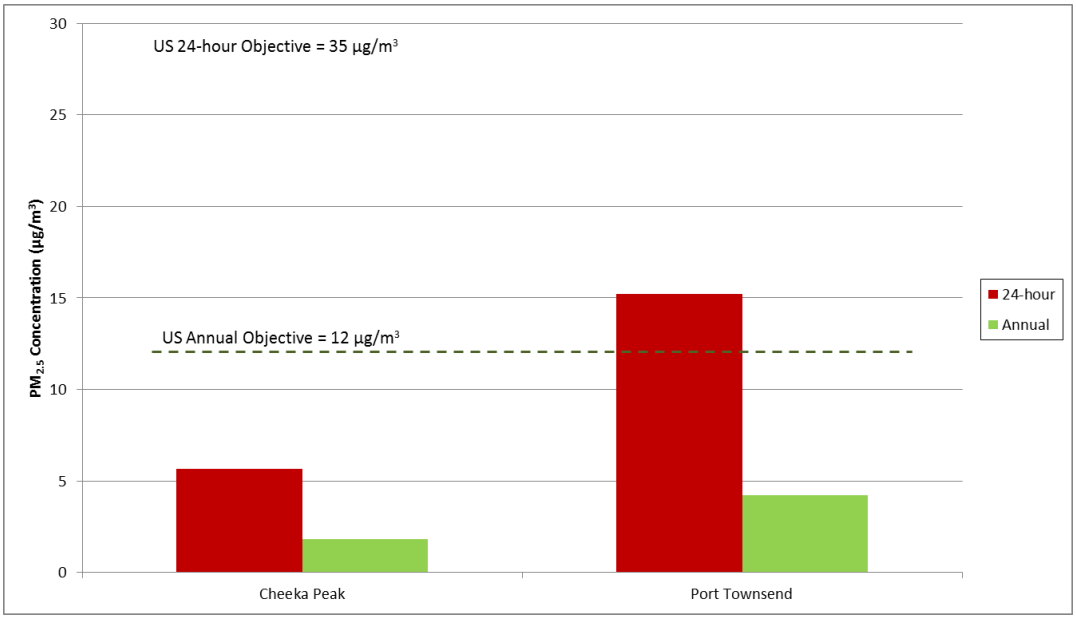


Figure 4.10: Observed $PM_{2.5}$ Concentrations in 2011 for US Waters (in µg/m^3)

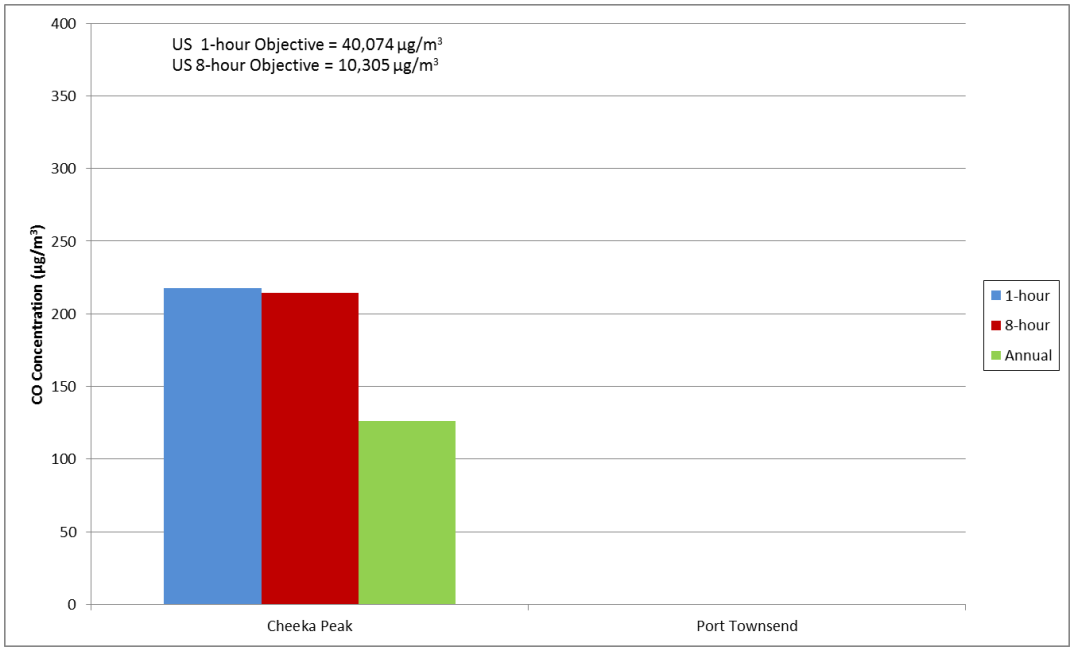


Figure 4.11: Observed CO Concentrations in 2011 for US Waters (in µg/m^3)

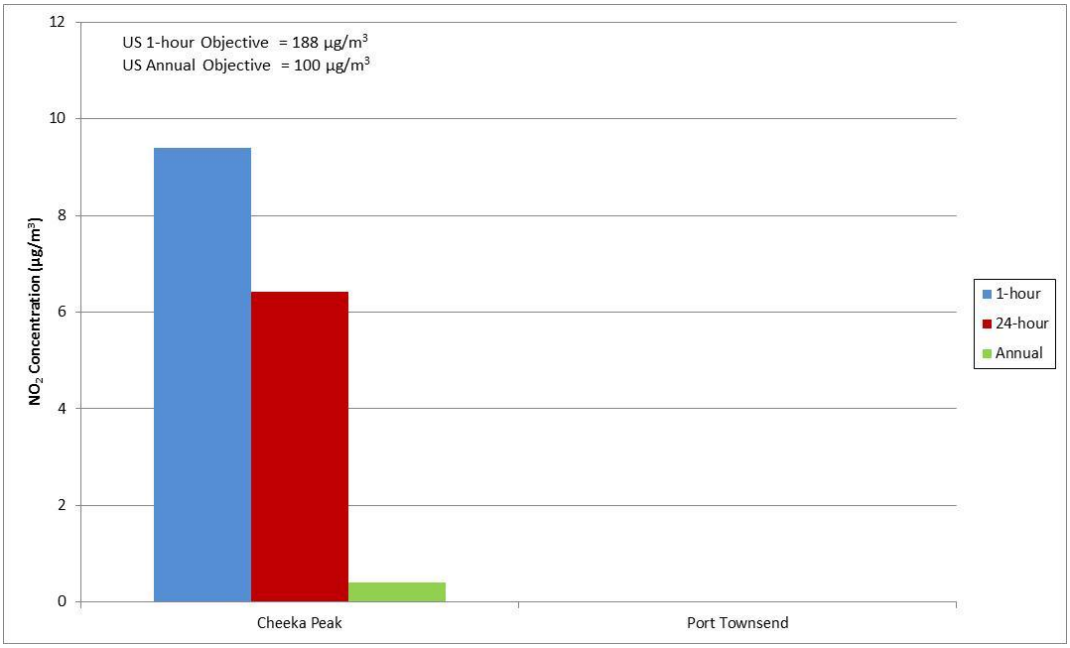


Figure 4.12: Observed NO_2 Concentrations in 2011 for US Waters (in $\mu g/m^3$)

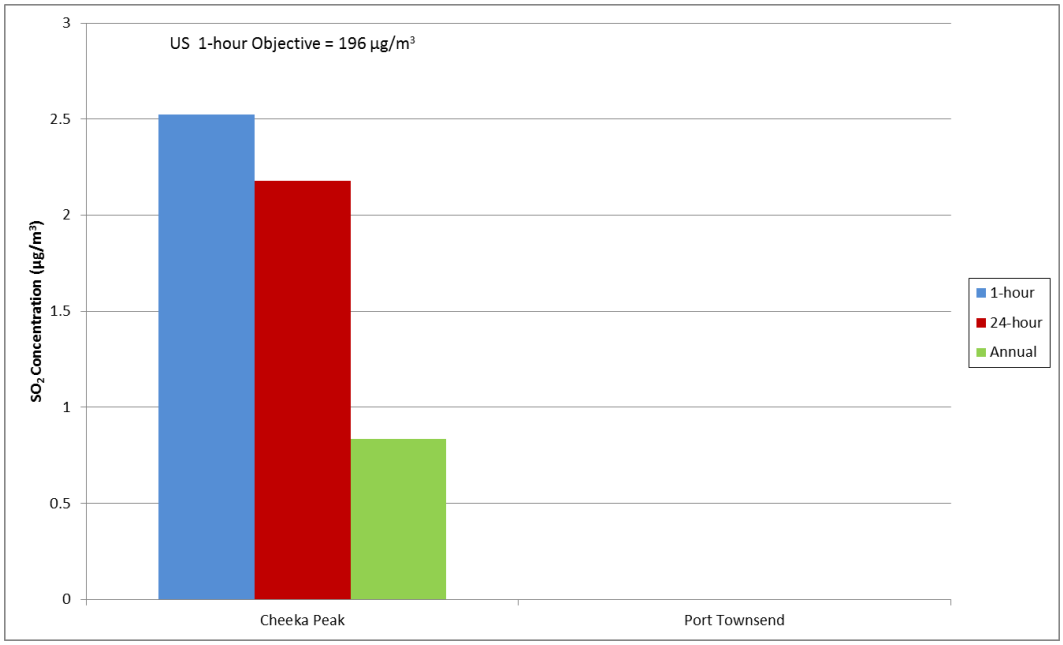


Figure 4.13: Observed SO_2 Concentrations in 2011 for US Waters (in $\mu g/m^3$)

4.1.1.7. Existing Air Quality Conditions – BTEX

Historical monitoring data for BTEX, which is defined as the sum of benzene, toluene, ethyl benzene and xylenes, are presented in this section.

4.1.1.8. Robson Square

The Robson Square NAPS station is located in downtown Vancouver. Measurements were made every two weeks from 2002 to 2009 and are summarized in Figure 4.14. One outlier value of 73.8 µg/m^3 was observed in February, 2007, and excluded from Figure 4.14.

Maximum BTEX concentrations at Robson Square ranged from 10.7 µg/m^3 to 45.5 µg/m^3. Very little to no seasonal variation was observed (see Appendix D) although concentrations tended to be lowest in April. BTEX concentrations have decreased over the last decade, with the annual average concentration in 2009 being less than half of the annual average concentration in 2002.

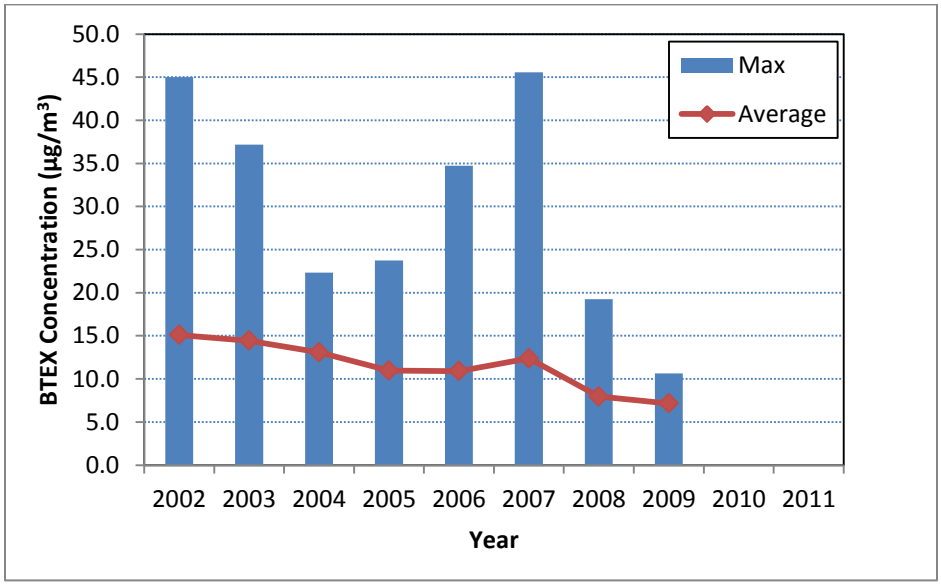


Figure 4.14: Observed BTEX Concentrations at Robson Square (in µg/m^3)

4.1.1.9. Saturna Island

BTEX measurements were made at the Saturna Island NAPS station every three days from November, 2002, to 2011 and are summarized in Figure 4.15. Two outliers have been excluded from the figure: a concentration of 22.5 µg/m^3 in February, 2005, and a concentration of 25.3 µg/m^3 in July, 2009. BTEX concentrations in Saturna Island tend to be lowest in the summer months (May to July) and highest in the winter months (December to February), possibly due to increased oxidation rates and enhanced dispersion in the summer. Due to the low level of surrounding human activity (e.g., vehicle traffic), BTEX observations in Saturna Island were considerably lower than those at Robson Square.

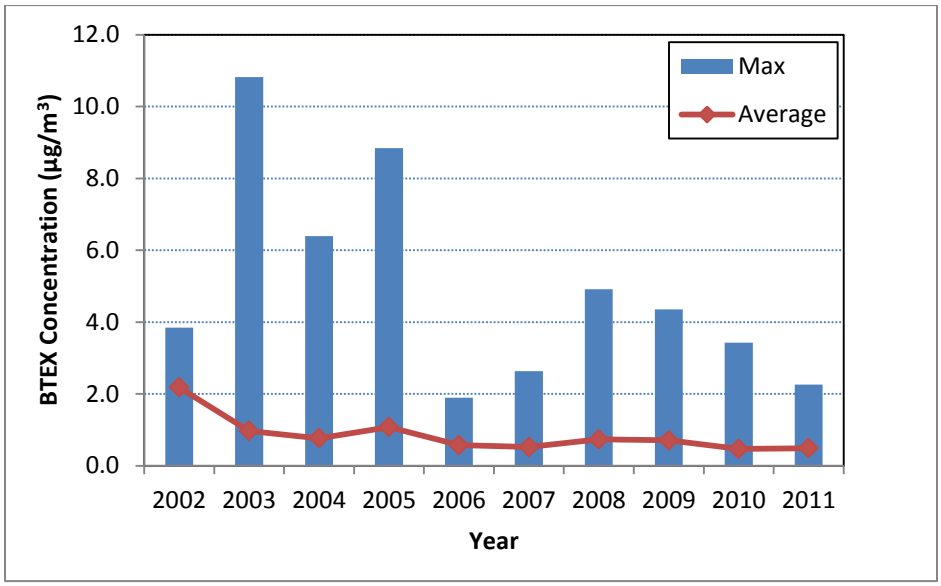


Figure 4.15: Observed BTEX Concentrations at Saturna Island (in µg/m^3)

4.1.1.10. US Waters

There are no known air quality monitoring stations in the Olympic Peninsula region measuring BTEX concentrations representative of US Waters.

4.1.2. Existing Air Quality Conditions – Ozone

Historical monitoring data for ozone are presented in this section. Similar to the analysis performed for CAC concentrations (see Section 4.1.1), annual, seasonal and diurnal trends for ozone for the ten-year period from 2002 to 2011 and existing conditions based on 2011 are presented, followed by a discussion for each location.

4.1.2.1. Overview

Annual time series of observed ozone concentrations are summarized in Figure 4.16. Overall, ozone concentrations within the RSA have increased over the last decade except in Victoria where ozone concentrations have remained relatively constant.

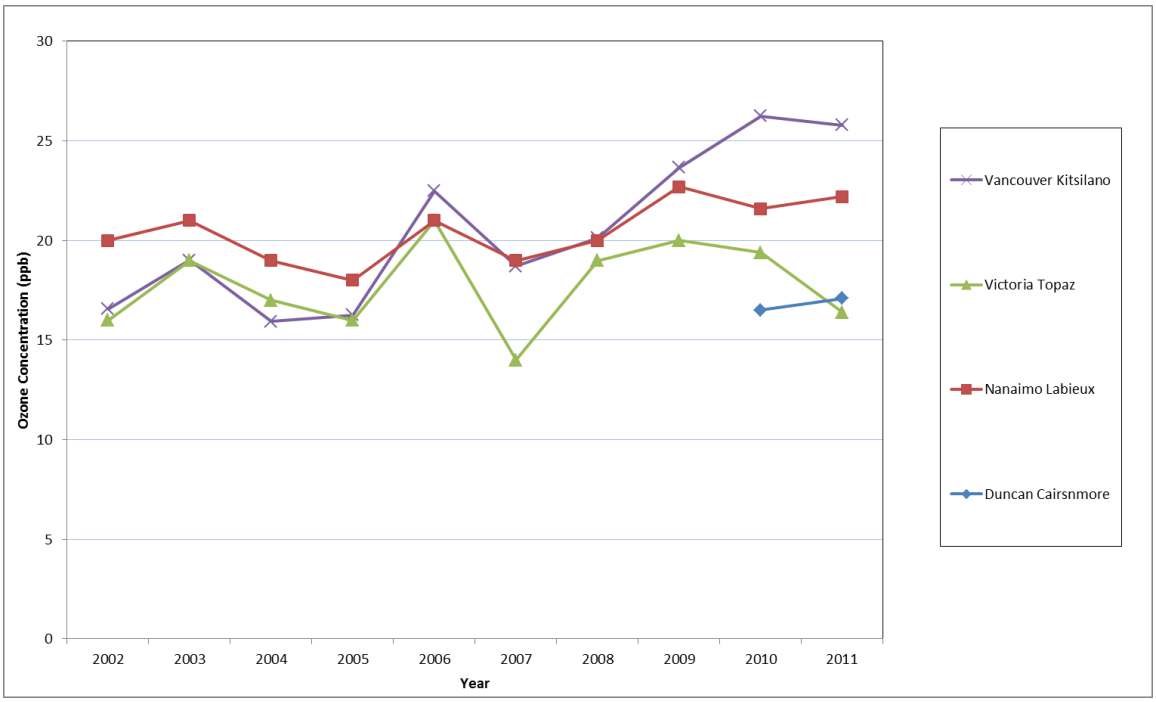


Figure 4.16: Annual Time Series for Ambient Ozone Concentrations (in ppb)

Observed ozone concentrations for 2011 are summarized in Figure 4.17. Ozone concentrations in the RSA were highest in Vancouver. High ozone concentrations in Vancouver may be attributable to large quantities of precursor NO_X and VOC emissions from urban and industrial sources in the region.

Since there are no BC objectives for ozone, areas in BC outside MV are compared to federal ozone objectives which are considerably lower than the MV objectives (see Tables 1.1 and 1.2). Depending on the station's jurisdiction, there were exceedances of the MV 1-hour and 8-hour objectives and the federal 1-hour objective and 8-hour CAAQS. Table 4.2 summarizes the exceedances at each station, based on the relevant objectives.

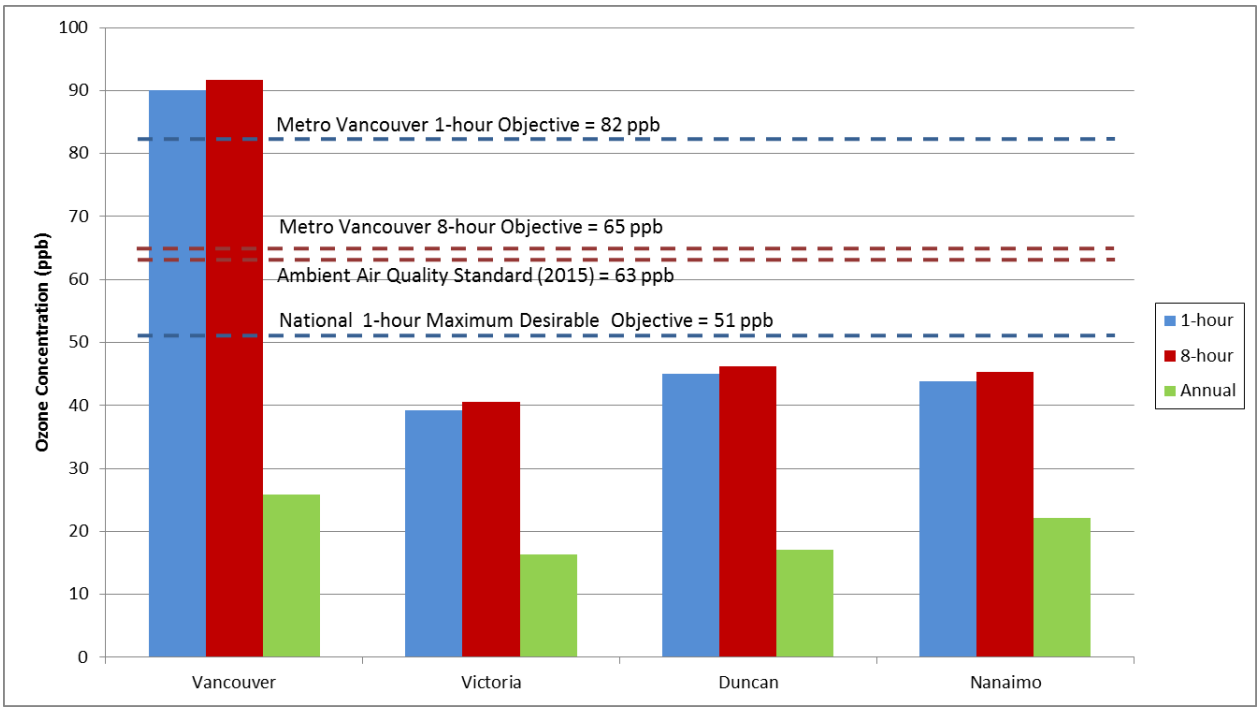


Figure 4.17: Observed Ozone Concentrations in 2011 for the RSA (in ppb)

Table 4.2: Frequency of Observed Ozone Concentrations Exceeding Ambient Objectives In 2011

Area	Jurisdiction	Averaging Period	Ambient Objective (ppb)	Frequency of Exceedance
Vancouver	Metro Vancouver	1-hour	82	3.4%
		8-hour	65	32.9%
Victoria	BC (NAAQO)	1-hour	51	0.0%
		8-hour (MV)	65	0.0%
		24-hour	15	3.6%
Duncan	BC (NAAQO)	1-hour	51	0.1%
		8-hour (MV)	65	0.0%
		24-hour	15	3.5%
Nanaimo	BC (NAAQO)	1-hour	51	0.0%
		8-hour (MV)	65	0.0%
		24-hour	15	3.9%

4.1.2.2. Vancouver

Seasonal and diurnal variations in ambient ozone concentrations are included in Appendix D. The Vancouver-Kitsilano station collected ozone data from 2002 to 2011. Ozone concentrations are highest in the spring and in the afternoon. This reflects the influence of solar radiation and temperature on ozone

formation. Sunlight directly affects the photolysis reactions involved in ozone formation. High temperatures are typically associated with greater solar radiation, low wind speeds and stagnant atmospheric circulation, which suppress mixing and promote build-up of precursor concentrations.

Average ozone concentrations in Vancouver have increased by about 60% over the last decade, the most rapid increase in comparison to the other urban areas within the marine RSA.

Observed ozone concentrations at the Vancouver-Kitsilano station in 2011 exceeded the 1-hour MV objective for ozone 3.4% of the time and the 8-hour MV objective 32.9% of the time. Current ozone concentrations at Vancouver-Kitsilano are about twice those in the other urban areas within the RSA, and about twice those in the Pipeline and Facilities Burnaby and Westridge Marine Terminals RSA (see the Air Quality and Greenhouse Gas Technical Report [Volume 5C]). High ozone concentrations at Vancouver-Kitsilano may be associated with a very localized NO_X titration regime in which upstream NO_X is converted to ozone.

4.1.2.3. Victoria

Similar to Vancouver, ozone concentrations in Victoria were highest in the spring and in the afternoon, reflecting the influence of solar radiation and temperature on ozone formation. Ozone concentrations in Victoria have fluctuated but remained relatively steady over the 2002 to 2011 period.

There were no exceedances of the 1-hour national maximum desirable objective or the 8-hour CAAQS in 2011; however, there were exceedances of the 24-hour national maximum desirable objective 3.6% of the time.

4.1.2.4. Duncan

The Duncan-Cairnsmore station recorded ozone data for the period from 2010 to 2011. Ozone concentrations in the Duncan area were highest in the spring and in the afternoon, reflecting the influence of solar radiation and temperature on ozone formation.

There has been a slight increase in ozone concentrations in Duncan from 2010 to 2011 but there is insufficient data to indicate long-term trends.

In 2011, there were no exceedances of the 8-hour CAAQS at Duncan-Cairnsmore; however, there were exceedances of the 1-hour and 24-hour federal maximum desirable objectives and 24-hour federal maximum desirable objective 0.1% and 3.5% of the time, respectively.

4.1.2.5. Nanaimo

Similar to the other urban areas within the RSA, ozone concentrations in Nanaimo were highest in the spring and in the afternoon, reflecting the influence of solar radiation and temperature on ozone formation. Over the last decade, there has been a slight increase in ozone concentrations in Nanaimo.

There were no exceedances of the 1-hour federal maximum desirable objective or 8-hour CAAQS in 2011; however, there were exceedances of the 24-hour federal maximum desirable objective 3.9% of the time.

4.1.2.6. US Waters

A summary of 2011 concentrations observed in US waters is illustrated in Figure 4-18. There were no exceedances of the 8-hour ozone NAAQS at Cheeka Peak in 2011; however, observed concentrations are relatively high for a rural location. Due to its higher elevation at 478 m elevation, Cheeka Peak may pick up natural background ozone from aloft. Higher ozone concentrations at Cheeka Peak may also be a result of episodic trans-Pacific ozone transport (McKendry 2006).

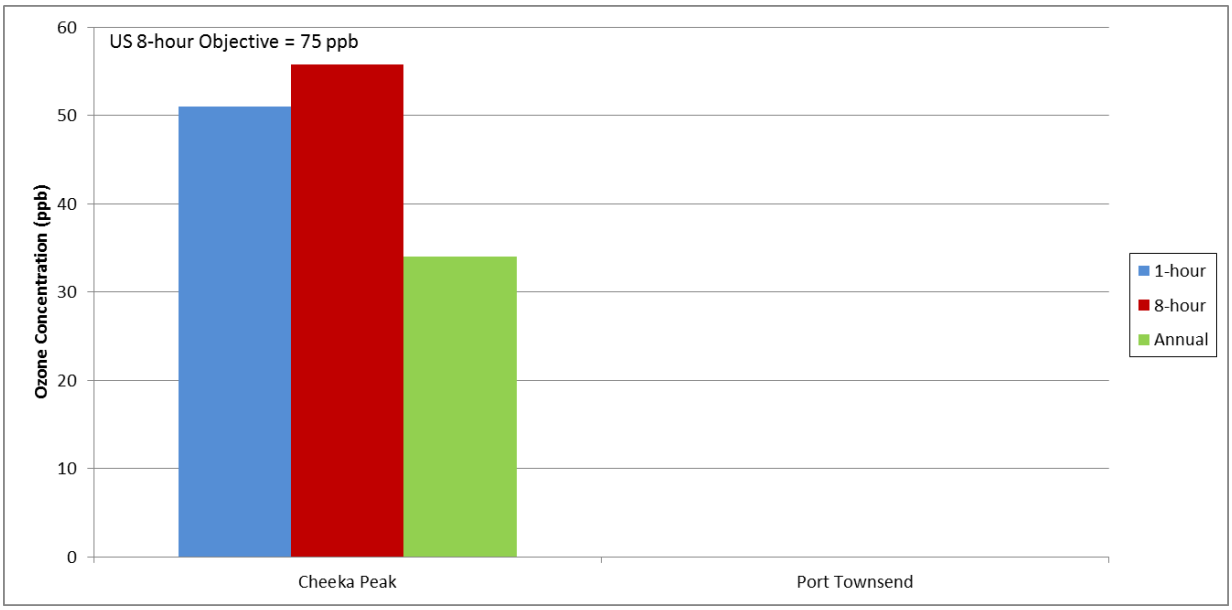


Figure 4.18: Observed Ozone Concentrations in 2011 for US Waters (in ppb)

4.1.3. Existing Emissions

Table 4.3 shows the annual marine emissions within the RSA, based on the 2005 Corbett inventory (Wang et al 2008).

Table 4.3: Existing Emissions from Marine Vessel Traffic in the RSA (in tonnes/y)

Contaminant	Annual Emissions
TSP	66.2
CO	60.1
NO_x	913.5
SO_2	524.6
VOC	31.9
CO_2	35,872.0

Environment Canada's National Inventory Report estimates total GHG emissions from Canada to be 692 Mt in 2010. Of the 692 Mt, 6.7 Mt was estimated to be from domestic marine traffic. In BC alone, the total GHG emissions in 2010 were estimated to be 56.1 Mt, with 2.7 Mt generated from domestic marine traffic (Environment Canada 2012).

4.1.3.1. US Waters

The 2008 National Emissions Inventory (US EPA 2013) estimates total GHG emissions from Washington State to be 39.8 Mt. These include emissions from burning, on-road vehicles and non-road equipment; emissions from marine traffic were not readily available; however, a first-order estimate of GHG emissions from commercial marine vessels can be determined by scaling from CO emissions and was estimated to contribute an additional 2.3 Mt.

4.1.4. Existing Visibility Conditions

Monthly visibility observations from Vancouver International Airport and Victoria International Airport, based on climate normal data, are presented in Table 4.4 and Table 4.5, respectively. Overall, existing visibility conditions in the RSA are good, with visibility greater than 9 km over 90% of the time. The fewest hours with low visibility and the most hours with high visibility tend to be observed in the spring and summer months (March to August).

Table 4.4: Monthly Visibility Observations from Vancouver International Airport for the Period, 1971 to 2000

Parameter	January	February	March	April	May	June	July	August	September	October	November	December	Annual
Visibility (hours with < 1 km)	30.8	11.5	2.8	0.3	0.1	0.2	0.2	0.4	4.7	27.0	14.1	25.0	117.1
Visibility (hours with 1 to 9 km)	134.4	81.0	46.4	26.7	18.0	19.1	13.2	23.4	50.7	111.4	94.5	122.7	741.6
Visibility (hours with > 9 km)	578.8	584.6	694.8	693.0	725.9	700.7	730.6	720.2	664.6	605.7	611.5	596.3	7906.5

Source: Environment Canada 2013b

Table 4.5: Monthly Visibility Observations from Victoria International Airport for the Period, 1971 to 2000

Parameter	January	February	March	April	May	June	July	August	September	October	November	December	Annual
Visibility (hours with < 1 km)	16.6	8.9	3.6	0.6	1.0	0.7	0.8	2.2	5.5	18.8	10.8	14.5	83.9
Visibility (hours with 1 to 9 km)	127.2	91.8	47.3	19.7	14.8	14.2	10.9	20.9	38.3	101.5	99.9	131.6	718.0
Visibility (hours with > 9 km)	600.2	577.3	693.1	699.6	718.3	705.1	732.3	721	676.2	623.8	609.4	597.8	7964.1

Source: Environment Canada 2013b

4.1.4.1. US Waters

Visibility measurements at Cheeka Peak and Port Townsend vary from 13 km to 349 km, with higher visibility observed at Cheeka Peak than at Port Townsend. Visibility measurements over US waters are considerably higher than those in Vancouver and Victoria, possibly due to the better air quality in less urban areas and/or different measurement techniques.

4.2. Existing Marine Emissions Associated With Vessel Loading Operations Associated With Westridge Marine Terminal

4.2.1. Primary Emissions of CACs and VOCs

Total estimated annual marine emissions associated with existing operations of vessels travelling to and from the Westridge Marine are summarized in Table 4.6 and Table 4.7. Combustion emissions are compared to total existing emissions in the marine RSA, based on the 2005 Corbett emission inventory. Annual marine combustion emissions associated with the Westridge Marine Terminal account for up to 44% of existing marine emissions in the marine RSA; however, it is recognized that the Corbett emission inventory is based on 2005 and is intended to consider existing emissions from commercial marine traffic in North America and, therefore, may underestimate total existing marine emissions within the marine RSA only.

Table 4.6: Annual Marine Combustion Emissions Associated with Westridge Marine Terminal – Existing Conditions (in tonnes/y)

Vessel Type	TSP	PM_{10}	$PM_{2.5}$	CO	NO_X	SO_2	VOC
Panamax Tankers	1.7	1.7	1.5	8.0	87.0	2.6	3.3
Aframax Tankers	3.3	3.2	2.9	15.6	168	5.0	6.4
Standard Crude Barge	0.6	0.6	0.6	2.2	26.6	0.8	1.0
Standard Jet Fuel Barge	0.1	0.1	0.1	0.5	5.6	0.2	0.2
Total Combustion Emissions	**5.8**	**5.5**	**5.1**	**26.3**	**287.0**	**8.6**	**10.9**
Total Marine Emissions in RSA	*66.2*	*66.2*	*66.2*	*60.1*	*914.0*	*525.0*	*31.9*
% of Total Marine Emissions in RSA	*8.7*	*8.4*	*7.7*	*43.8*	*31.4*	*1.6*	*34.2*

Table 4.7: Annual Marine Fugitive VOC Emissions Associated with Westridge Marine Terminal – Existing Conditions (in tonnes/y)

Vessel Type	VOC
Panamax Tankers	22.4
Aframax Tankers	51.9
Standard Crude Barge	6.4
Standard Jet Fuel Barge	0.05
Total Fugitive Emissions	**80.7**

4.2.2. Greenhouse Gases

Total estimated marine GHG emissions associated with existing operations at Westridge Marine Terminal are summarized in Table 4.8. Marine transportation associated with existing operations at Westridge Marine Terminal is estimated to represent 37% of marine GHG emissions in the RSA, 0.5% of marine GHG emissions in BC, and 0.2% of marine GHG emissions in Canada. As discussed in Section 4.2.1, it is recognized that the Corbett emission inventory may underestimate existing marine emissions in the RSA. In addition, the Corbett emission inventory only provides emissions of CO_2 and does not provide total CO_2e emissions.

Table 4.8: Annual Marine GHG Emissions Associated with Westridge Marine Terminal – Existing Conditions (in tonnes/y)

Vessel Type	CO_2e
Panamax Tankers	4006
Aframax Tankers	7754
Standard Crude Barge	1365
Standard Jet Fuel Barge	284
Total Combustion Emissions	**13,410**
% of Total Marine Emissions in RSA	*37.4*
% of Total Marine Emissions in BC	*0.5*
% of Total Marine Emissions in Canada	*0.2*

4.3. Model Results

4.3.1. CACs and VOCs

The CALMET/CALPUFF dispersion modelling system was used to estimate ambient concentrations of CACs and VOCs in the marine RSA caused by existing and projected future emissions from marine traffic associated with the Trans Mountain pipeline. The modelling results for the existing case are presented in this section.

The maximum predicted ambient ground-level concentrations over water and over land for CACs, BTEX, H_2S and mercaptans with (over land only) and without background contribution in the RSA of the marine domain are summarized in Table 4.9..

Maximum predicted 24-hour and annual TSP, PM_{10}, and $PM_{2.5}$ concentrations are less than the most stringent objectives among national, provincial, and MV standards. Ambient background contributes more than 95% of the total maximum 24-hour and annual TSP, PM_{10}, and $PM_{2.5}$ concentrations over land. Contours of 24-hour and annual PM_{10} and $PM_{2.5}$ predicted concentrations without ambient background are shown in Figures 4.19 to 4.22, respectively (in the Figures section). Table 4.9 also shows the maximum predicted concentrations of primary and secondary $PM_{2.5}$ as modelled in CALPUFF, in addition to the total $PM_{2.5}$. The maximum modelled primary, secondary, and total $PM_{2.5}$ concentrations might occur at different locations and times; therefore, the primary and secondary concentrations in the table might not add up to the total concentration. At the location where the maximum value occurs for each of TSP, PM_{10}, and $PM_{2.5}$, secondary PMs comprise up to 8.1% and 3.6% of total PM (excluding ambient background) for the 24-hour and annual averaging periods, respectively.

Maximum predicted concentrations for CO and SO_2 for all averaging periods with and without ambient background over land and without ambient background over water are less than the applicable objectives. Predicted maximum 1-hour, 24-hour, and annual SO_2 concentration contour plots without ambient background for the marine RSA existing case are shown in Figures 4.23 to 4.25, respectively.

Maximum predicted NO_2 concentrations, calculated using the ambient ratio method, are less than the air quality objectives for the 24-hour and annual averaging periods, with and without ambient background addition. Maximum predicted 1-hour NO_2 concentrations with and without addition of ambient background concentration over land occur at Burrard Inlet and are greater than the MV objective of 200 µg/m^3. Figure 4.26 presents contours of maximum predicted 1-hour concentrations for NO_2 without addition of ambient background, showing that the maximum concentrations over land and over water occur at Burrard Inlet. The frequency of exceedances of the 1-hour NO_2 MV objective is less than 2% of the time. There are no predicted exceedances of 1-hour NO_2 National Air Quality Criteria of 400 µg/m^3 over land or water. Figures 4.27 and 4.28 show contour plots for the maximum predicted NO_2 concentrations without ambient background for the marine RSA existing case for 24-hour and annual averaging periods, respectively. Table 4.9 also shows predicted NO_x concentrations for 1-hour, 24-hour, and annual averaging periods.

The maximum predicted results for BTEX and H_2S are presented in Table 4.9. The maximum predicted 1-hour and 24-hour H_2S concentrations without ambient background are 0 µg/m^3. There are no National Air Quality Criteria, Provincial or MV Standards for BTEX.

The maximum predicted 10-minute mercaptans concentrations without ambient background over land (no ambient data for mercaptans was available) and over water are presented in Table 4.9. 10-minute average was calculated from 1-hour maximum predicted results in accordance with Ontario Air Quality Modelling Guideline (AQMG) (Ontario Ministry of Environment [OMOE], 2009). The predicted concentration is significantly lower than the odour detection threshold of 13 µg/m^3.

Table 4.9: Marine Base Case Maximum Predicted Concentrations (in µg/m^3)

Pollutant	Ave. Period	Base Case, Over Land (without Background)	Base Case, Over Land (with Background)	Base Case, Over Water	BC Object.	MV Object.	National Object.
TSP (Total)	24-hour	0.96	37.2	1.45	120	n/a	120
	Annual	0.04	15.1	0.09	60	n/a	60
PM_{10} (Total)	24-hour	0.93	21.1	1.45	50	50	n/a
	Annual	0.04	8.42	0.09	n/a	20	n/a
$PM_{2.5}$ (Total)	24-hour	0.88	20.2	1.45	25[(a)]	25	27 to 28[(d)]
	Annual	0.04	5.22	0.09	8	8	8.8 to 10[(e)]
$PM_{2.5}$ (Primary)	24-hour	0.87	20.1	1.44	25	25	27 to 28[(d)]
	Annual	0.03	5.22	0.09	8	8	8.8 to 10[(e)]
$PM_{2.5}$ (Secondary)	24-hour	0.33	20.2	0.35	25	25	27 to 28[(d)]
	Annual	0.01	5.21	0.01	8	8	8.8 to 10[(e)]
CO	1-hour	185	1370.0	141.0	14,300	30,000	15,000
	8-hour	18.6	1160.0	8.27	5500	10,000	6,000
NO_x	1-hour	2920.0	3030.0	2260.0	n/a	n/a	n/a
	24-hour	65.8	154.0	30.0	n/a	n/a	n/a
	Annual	2.40	29.1	1.89	n/a	n/a	n/a
NO_2	1-hour	**292.0**	**303.0**	**226.0**	n/a	200	400
	24-hour	51.3	66.8	30.0	n/a	n/a	200
	Annual	1.67	20.3	1.31	n/a	40	100
SO_2	1-hour	59.4	85.7	45.4	450	450	450
	24-hour	1.70	18.9	11.3	160	125	150
	Annual	0.16	2.77	0.70	25	30	30
Benzene	1-hour	0.63	5.70	0.71	n/a	n/a	n/a
	Annual	<0.005	0.55	<0.005	n/a	n/a	n/a
Ethylbenzene	1-hour	0.10	2.83	0.08	n/a	n/a	n/a
Toluene	1-hour	0.48	14.8	0.53	n/a	n/a	n/a
	24-hour	0.21	5.94	0.16	n/a	n/a	n/a
Xylenes	1-hour	0.30	13.4	0.22	n/a	n/a	n/a
	24-hour	0.07	5.32	0.05	n/a	n/a	n/a

Pollutant	Ave. Period	Base Case, Over Land (without Background)	Base Case, Over Land (with Background)	Base Case, Over Water	BC Object.	MV Object.	National Object.
H_2S	1-hour	0	0	0	7(b)	n/a	n/a
	24-hour	0	0.18	0	3(b)	n/a	n/a
Total Mercaptans(c)	10-minute	0.12	0.12	0.13	13(c)	n/a	n/a

Notes: Exceedance values are highlighted in bold

(a) The BC Provincial $PM_{2.5}$ 24-hour objective is based on 98th percentile values

(b) TRS objectives have been presented for comparison, since there are no H_2S objectives

(c) No background for mercaptans was available, and values do not include background; modelled 1-hour average concentrations were converted to 10-minute average concentrations by multiplying by a factor of 1.65, as per the AQMG for Ontario (OMOE, 2009); the 10-minute Ontario AAQC has been presented for comparison

(d) CAAQS is 28 µg/m^3 in 2015 and 27 µg/m^3 in 2020; compliance based on annual 98th percentile value, averaged over three consecutive years

(e) CAAQS is 10.0 µ/m^3 for 2015 and 8.8 µg/m^3 for 2020; compliance based on the average over three consecutive years

4.3.2. Secondary Smog-Related Products

In addition to the CALMET/CALPUFF dispersion modelling, photochemical modelling was conducted using the CMAQ modelling system to provide estimates of secondary ozone and $PM_{2.5}$ and visibility. Details of the modelling are presented in Appendix B. No results are presented here for the existing case since the CMAQ modelling system was used to estimate differences between current and future secondary formation rather than accurately modelling absolute concentrations.

5. RESULTS OF PROJECT EFFECTS ASSESSMENT – AIR QUALITY

5.1. Emission Estimates

Total estimated annual marine emissions associated with Project Expansion are summarized in Table 5.1 and Table 5.2. Combustion emissions are compared to total existing emissions in the marine RSA, based on the 2005 Corbett emission inventory. Annual marine combustion emissions associated with Project expansion represent only 9% of marine SO_2 emissions in the RSA but over 200% of the marine CO emissions in the RSA. As discussed in Section 4.2.1, it is recognized that the Corbett emission inventory may underestimate existing marine emissions in the RSA. Annual marine fugitive emissions associated with Project expansion are about 12 times the fugitive emissions associated with existing operations at Westridge Marine Terminal.

It was conservatively assumed that all marine vessels associated with Project expansion would be Aframax tankers, and therefore, the main contribution to Project marine emissions is associated with Aframax tankers. As a result of the Project and associated proposed pipelines to the Westridge Marine Terminal, it is expected that berth times may decrease, and therefore, some decreases in Panamax tanker combustion emissions were predicted to occur. No change to combustion emissions associated

with standard crude and jet fuel barges is expected as a result of the Project; however, some increases in fugitive emissions from standard crude barges were predicted as a result of the Project because it is estimated that vessels will be more heavily laden based on the assumed vessel mix and product throughput numbers.

Table 5.1: Changes in Annual Marine Combustion Emissions Associated with Project Expansion (in tonnes/y)

Vessel Type	TSP	PM_{10}	$PM_{2.5}$	CO	NO_X	SO_2	VOC
Panamax Tankers	-0.03	-0.03	-0.03	-0.2	-1.2	-0.06	-0.04
Aframax Tankers	31.1	29.8	27.4	147.0	1584.0	46.6	60.6
Standard Crude Barge	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Standard Jet Fuel Barge	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Combustion Emissions	**31.0**	**29.8**	**27.4**	**147.0**	**1583.0**	**46.6**	**60.6**
Total Marine Emissions in RSA	*66.2*	*66.2*	*66.2*	*60.1*	*914.0*	*525.0*	*31.9*
% Increase due to Project	*46.9*	*45.0*	*41.4*	*244.0*	*173.0*	*8.9*	*190.0*

Note: Some changes in marine emissions are negative because of stricter emission controls for marine vessels in the future.

Table 5.2: Annual Marine Fugitive VOC Emissions Associated with Project Expansion (in tonnes/y)

Vessel Type	VOC
Panamax Tankers	18.3
Aframax Tankers	958
Standard Crude Barge	6.8
Standard Jet Fuel Barge	0.0
Total Fugitive Emissions	**983.1**
Fugitive Emissions Associated with Existing Conditions[(a)]	*80.7*
% Increase due to Project	*1218.0*

Note: (a) A rough estimate of 2012 marine traffic suggests 15,000 to 20,000 tanker, cargo-ship, and ferry transits within the marine RSA. The associated fugitive emissions would be roughly one to two orders of magnitude greater than this estimate from Wang *et al.* (2008).

5.2. Model Results

5.2.1. CACs and VOCs

Predicted maximum concentrations over land with and without ambient background and over water without background contribution in the marine RSA for the application case are presented in Table 5.3 for CACs, BTEX, H_2S, and mercaptans. Modelled concentrations resulting from Project only are also presented in Table 5.3. Maximum predicted 24-hour and annual TSP, PM_{10}, and $PM_{2.5}$ increased slightly between the existing case (see Section 4.3.1) and the application case. Figures 5.1 to 5.4 show contours

of 24-hour and annual PM_{10} and $PM_{2.5}$ predicted concentrations without ambient background for the application case, respectively. All values for modelled PM are below national, provincial, and MV standards. Ambient background contributes more than 90% to the maximum values predicted for the application case. Both primary and secondary PM were modelled in CALPUFF, and the maxima are shown in Table 5.3. Since the maxima do not necessarily occur at the same location or time, the primary and secondary concentrations in the table might not add up to the total concentration. Secondary PM comprises up to 21% of the total PM where the maximum occurs for the 24-hour averaging period for all size fractions (TSP, $PM_{2.5}$, and PM_{10}) before the ambient background is added. The secondary PM contribution at the MPOI is approximately 8% of the total amount of for the TSP, $PM_{2.5}$, and PM_{10} for the annual averaging period before ambient background is added. The increase in the concentration of PM of any size range, caused by the marine component of the Project, is lower than 4% of the most stringent objective.

Table 5.3: Maximum Modelled Concentrations – Application Case and Contribution from Project Only (in µg/m^3)

Pollutant	Ave. Period	Application Case, Over Land (without Background)	Application Case, Over Land (with Background)	Application Case, Over Water	Project, Over Land	Project, Over Water	BC Object.	MV Object.	National Object.
TSP (Total)	24-hour	1.88	38.1	1.46	0.92	0.45	120	n/a	120
	Annual	0.24	15.2	0.10	0.20	0.08	60	n/a	60
PM_{10} (Total)	24-hour	1.83	22.0	1.46	0.90	0.44	50	50	n/a
	Annual	0.23	8.53	0.10	0.19	0.08	n/a	20	n/a
$PM_{2.5}$ (Total)	24-hour	1.73	20.4	1.46	0.85	0.42	25[(a)]	25	27 to 28[(d)]
	Annual	0.22	5.23	0.10	0.18	0.07	8	8	8.8 to 10[(e)]
$PM_{2.5}$ (Primary)	24-hour	1.71	20.1	1.45	0.84	0.39	25	25	27 to 28[(d)]
	Annual	0.20	5.22	0.09	0.17	0.06	8	8	8.8 to 10[(e)]
$PM_{2.5}$ (Secondary)	24-hour	0.64	20.3	0.67	0.32	0.32	25	25	27 to 28[(d)]
	Annual	0.02	5.21	0.02	0.02	0.02	8	8	8.8 to 10[(e)]
CO	1-hour	185.0	1370.0	141	16.2	21.8	14,300	30,000	15,000
	8-hour	37.2	1160.0	16.5	18.6	8.26	5500	10,000	6000
NO_x	1-hour	2920.0	3030.0	2260.0	212.0	285.0	n/a	n/a	n/a
	24-hour	130.0	218.0	48.4	63.9	27.5	n/a	n/a	n/a
	Annual	15.2	41.9	5.74	12.8	4.80	n/a	n/a	n/a
NO_2	1-hour	**292.0**	**303.0**	**226.0**	80.3	82.7	n/a	200	400
	24-hour	63.3	74.3	46.6	50.8	27.5	n/a	n/a	200
	Annual	10.6	29.1	3.99	8.88	3.33	n/a	40	100

Pollutant	Ave. Period	Application Case, Over Land (without Background)	Application Case, Over Land (with Background)	Application Case, Over Water	Project, Over Land	Project, Over Water	BC Object.	MV Object.	National Object.
SO_2	1-hour	59.4	85.7	45.4	6.51	8.78	450	450	450
	24-hour	2.69	20.1	11.3	1.29	0.82	160	125	150
	Annual	0.35	3.04	0.71	0.27	0.10	25	30	30
Benzene	1-hour	1.38	6.44	1.33	1.01	1.11	n/a	n/a	n/a
	Annual	0.01	0.56	0.04	0.01	0.04	n/a	n/a	n/a
Ethylbenzene	1-hour	0.11	2.83	0.08	0.03	0.03	n/a	n/a	n/a
Toluene	1-hour	1.00	15.3	0.97	0.72	0.79	n/a	n/a	n/a
	24-hour	0.31	6.04	0.50	0.12	0.44	n/a	n/a	n/a
Xylenes	1-hour	0.37	13.5	0.38	0.25	0.27	n/a	n/a	n/a
	24-hour	0.11	5.35	0.17	0.04	0.15	n/a	n/a	n/a
H_2S	1-hour	0	0	0	0	0	7[(b)]	n/a	n/a
	24-hour	0	0.18	0	0	0	3[(b)]	n/a	n/a
Total Mercaptans[(c)]	10-minute	0.26	0.26	0.25	0.19	0.21	13[(c)]	n/a	n/a

Notes: Exceedance values are highlighted in bold

(a) The BC Provincial $PM_{2.5}$ 24-hour objective is based on 98th percentile values

(b) TRS objectives have been presented for comparison, since there are no H_2S objectives

(c) No background for mercaptans was available, and values do not include background; modelled 1-hour average concentrations were converted to 10-minute average concentrations by multiplying by a factor of 1.65, as per the Air Quality Modelling Guideline for Ontario (OMOE, 2009); the 10-minute Ontario AAQC has been presented for comparison

(d) CAAQS is 28 µg/m^3 in 2015 and 27 µg/m^3 in 2020; compliance based on annual 98th percentile value, averaged over three consecutive years

(e) CAAQS is 10.0 µ/m^3 for 2015 and 8.8 µg/m^3 for 2020; compliance based on the average over three consecutive years

Maximum modelled CO concentrations for both 1-hour and 8-hour averaging periods were predicted to rise slightly from the existing case, but are well below all the objectives as shown in Table 5.3. Increased concentrations for CO from the Project account for a fraction of a percent of the most stringent objective. Maximum modelled SO_2 concentrations were below all objectives (NAAQO, BC, and MV) for all averaging periods. The maximum contribution from the marine component of the Project is less than 2% of the most stringent objectives. Predicted maximum 1-hour, 24-hour, and annual SO_2 concentration contour plots without ambient background for the marine RSA application case are shown in Figures 5.5 to 5.7, respectively.

For the application case, maximum predicted NO_2 concentrations for the 24-hour and annual averaging periods were lower than the most stringent relevant air quality objectives but exceeded the MV objective for the 1-hour averaging period. These exceedances are collocated with the exceedances predicted for the existing case discussed in Section 4.3.1. The frequency of exceedances of the 1-hour NO_2 objective is less than 2% of the modelled 1-year period and occurs in a very limited area in the Burrard Inlet Region (only 5 receptors modelled exceeded the objective). There were no predicted exceedances of the 1-hour NO_2 NAAQO of 400 µg/m^3. Figures 5.8 to 5.10 show contours of maximum predicted NO_2 concentrations without ambient background for the marine RSA application case for 1-hour, 24-hour, and annual averaging periods, respectively. Maximum predicted NO_2 concentrations for all averaging periods based on the Project only are below the applicable objectives and make little contribute to the maximum predicted NO_2 concentrations and the number of exceedances for the application case in the RSA. Table 5.3 also shows predicted NO_X concentrations for 1-hour, 24-hour and annual averaging periods.

The maximum predicted results for BTEX are presented in Table 5.3 for the application and Project only cases. There are no national, BC, or MV standards for BTEX. Concentrations of BTEX increased with the addition of Project emissions. Of the four contaminants BTEX, benzene's predicted concentrations increase the most from the base case to the application case. H_2S concentrations were modelled to be practically 0 µg/m^3, and background H_2S is considered to be the only contributor of H_2S in the marine RSA.

The maximum predicted 10-minute total mercaptans concentrations without ambient background over land (no ambient data for mercaptans was available) and over water are presented in Table 5.3. 10-minute averages were calculated from 1-hour maximum predicted results in accordance with Ontario AQMG (OMOE, 2009). The maximum predicted 10-minute average mercaptans concentration for the application case is approximately 2% of the odour detection threshold of 13 µg/m^3.

5.2.2. Secondary Smog-Related Products

In addition to the CALMET/CALPUFF dispersion modelling, photochemical modelling was conducted using the CMAQ modelling system to provide estimates of secondary ozone and $PM_{2.5}$ formation and visibility. A brief summary of the modelling results is presented here. Details can be found in Appendix B.

The Project emissions have a relatively minor effects on secondary pollutant formation and visibility in the Lower Fraser Valley. A maximum increase in 8-hour peak ozone concentrations of 0.2 ppb and a maximum increase of peak 24-hour $PM_{2.5}$ concentrations of 0.1 µg/m^3 were predicted over the marine domain for the selected 10-day modelling period. These increases in concentrations represent only a small fraction of the Canada-Wide Standards for ozone and $PM_{2.5}$ concentrations of 65 ppb and 30 µg/m^3, respectively. For visibility, most of the LFV marine area shows a maximum 1-hour 0.3 deciviews (dv) increase of light extinction, corresponding to a decrease in visual range of approximately less than 1 km and, therefore, most likely not noticeable. Although maximum 1-hour increases of greater than 2 dv were predicted over the marine areas, those maxima happened sporadically in space and time.

The projected change in emissions associated with the T2 expansion at Deltaport for years 2014 and 2030 were also modelled as two separate scenarios in combination with the TMEP application emissions. In 2014, the activities associated with Deltaport are expected to emit more NO_X (80 tonnes/year) but less SO_2 (-680 tonnes/year) due to increased shipping and reduced fuel sulphur content, respectively. Overall, this scenario showed results that were comparable to the TMEP application scenario. In 2030, the Deltaport's activities are expected to emit less NO_X and SO_2 (approximately 1000 tonnes/year for both), due to better emission control for marine vessels, and similar amounts of VOC. This scenario showed larger increases of peak ozone and $PM_{2.5}$ concentrations and a wider area of decrease in visual range over parts of the marine areas. The increase in ozone, despite a decrease in NO_X precursor emissions, is likely occurring in areas that are currently experiencing NO_X titration of ozone. These are areas that, because of the titration, do currently not experience high ozone concentrations. It should be noted that this specific scenario did not take into account the growth of population and other industrial activities in the MV area over the same period and, therefore, does not represent future air quality in the region as a whole.

6. RESULTS OF PROJECT EFFECTS ASSESSMENT – GREENHOUSE GASES

6.1. Emission Estimates

Total estimated marine GHG emissions associated with Project expansion are summarized in Table 6.1. Marine transportation associated with Project expansion is estimated to represent an increase of about 200% in marine GHG emissions in the RSA, 2.7% in marine GHG emissions in BC, and 1.1% in marine GHG emissions in Canada. As discussed in Section 4.2.1, it is recognized that the Corbett emission inventory may underestimate existing marine emissions in the RSA. In addition, the Corbett emission inventory only provides emissions of CO_2 and does not provide total CO_2e emissions.

Table 6.1: Annual Marine GHG Emissions Associated with Westridge Marine Terminal – Minus Existing Conditions (in tonnes/y)

Vessel Type	CO_2e
Panamax Tankers	-100
Aframax Tankers	72,181
Standard Crude Barge	0.0
Standard Jet Fuel Barge	0.0
Total Combustion Emissions	**72,081**
% Increase in Marine Emissions in RSA	*201*
% Increase in Marine Emissions in BC	*2.7*
% Increase in Marine Emissions in Canada	*1.1*

6.2. Project Effect on Climate Change

GHG emissions from the Project will disperse, mix with global emissions, and contribute to global climate change. Although the GHG emissions from any single industrial activity contribute very little to global emissions and climate change, this contribution is quantifiable. It was demonstrated by Matthew and Weaver (2010) that global temperature increases are proportional to cumulative emissions of GHG. The effect of GHG emissions on climate change can be assessed using the methods discussed in National Research Council (NRC) (2011). In this report, based on the most current modelling results, NRC estimated an approximately linear warming per cumulative emissions ranging from roughly 0.27°C to 0.68°C per 1,000,000 Mt CO_2e, or roughly 20 years of annual global GHG emissions. NRC further pointed out that other changes in the climate system and physical environment (e.g., precipitation changes and decreases in crop yields) are likewise proportional to cumulative GHG emissions, and global temperature increase. The low and high estimated changes in some of the environmental parameters per 1 °C of global temperature increase are presented in Table 6.2.

Table 6.2: Change in Some Environmental Parameters Per 1 °C of Global Warming

Environmental Parameter	Low Estimate	High Estimate
Change in precipitation	5%	10%
Increase in heavy rainfall	3%	10%
Yield reduction in a number of crops	5%	15%
Changes in streamflows	5%	10%
Decrease in the extent of annually averaged Arctic sea ice	15%	25%
Decrease in the extent of September Arctic sea ice	15%	25%

On the basis of these expected changes per cumulative GHG emissions, the effect of the Project on climate change can be quantified. Assuming that operation emissions will not change over the lifetime of the Project, total estimated emissions over 50 years of Project operation are 3.6 Mt CO_2e, which will result in 1.7×10^{-6} °C increase in Earth's global temperature. Also, the effect of this temperature increase on other environmental parameters can be assessed. The results are summarized in Table 6.3.

Table 6.3: Effect of the Project on Overall Climate Change

Climate Change Effects	Low Estimate	Best Estimate	High Estimate
Precipitation changes	±0.000005%	±0.000015%	±0.000024%
Increase in heavy rainfall	0.000003%	0.000014%	0.000024%
Yield reduction in a number of crops	0.000005%	0.000021%	0.000037%
Changes in streamflows	±0.000005%	±0.000015%	±0.000024%
Decrease in the extent of annually averaged Arctic sea ice	0.000015%	0.000038%	0.000061%
Decrease in the extent of September Arctic sea ice	0.000015%	0.000038%	0.000061%

7. SUPPLEMENTAL STUDIES, MITIGATION, AND MONITORING RECOMMENDATIONS

The following conclusions can be made with respect to recommendations for supplemental studies mitigation measures and monitoring for the proposed marine contribution of the Project. These conclusions are based on the results of the effects assessment summarized in Tables 7.1, and 7.2. The following sub-sections describe additional recommendations beyond those listed in Table 7.1.

7.1. Supplemental Studies

Modelling was conducted for air and GHG emissions for the Project. Trans Mountain is currently evaluating and discussing with the marine community a recommendation for an additional escort tug to support the tankers between English Bay and Boundary Pass as well as from Race Rocks to the 12 Nautical Mile limit (see Section 5.4 Volume 8A). While this additional tug was not included in the initial inventory of emission sources for the Project, and is viewed as an additional safety precaution, this additional escort tug is not likely to change the effects assessment conclusions. Updated marine air emissions modelling results will be provided to the NEB in early 2014 to confirm assessment conclusions, if the commitment for an additional tug is made.

While Trans Mountain can actively enforce its own operating practices and standards on vessels docked at the Westridge Marine Terminal, Trans Mountain has no authority over construction and design of vessels or the operating practices of the vessel, as Project-related vessels are owned and operated by a third party.

7.2. General Mitigations

Mitigation and recommendations are described in Tables 7.1 and 7.2.

7.3. Post-Construction Environmental Monitoring

Post-construction environmental monitoring is not required or recommended based on professional judgement.

Table 7.1: Potential Effects, Mitigation Measures and Residual Effects of Marine Operations on Air Emissions

Potential Effect	Spatial Boundary[a]	Key Recommendations/Mitigation Measures [EPP Reference][b]	Potential Residual Effect(s)
1. Marine Air Emissions Indicator – Primary Emissions of Criteria Air Contaminants			
1.1 Increase in CAC emissions	RSA	• All Project-related tankers are required to adhere to federal standards that may reduce air emissions, including standards for bunker fuel.	• Increase in ambient ground-level concentrations of CACs.
2. Marine Air Emissions Indicator – Primary Emissions of Volatile Organic Compounds			
2.1 Increase in VOC emissions	RSA	• All Project-related tankers are required to adhere to federal standards that may reduce air emissions, including standards for bunker fuel.	• Increase in ambient ground-level concentrations of VOCs.
3. Marine Air Emissions Indicator – Formation of Secondary Particulate Matter and Ozone			
3.1 Increased formation of secondary PM and ozone due to increased ambient concentrations of CACs and VOCs	LFV	• All Project-related tankers are required to adhere to federal standards that may reduce air emissions, including standards for bunker fuel.	• Increase in ambient ground-level concentrations of secondary PM. • Increase in ambient ground-level concentrations of ozone.
4. Marine Air Emissions Indicator – Visibility			
4.1 Increased light extinction	LFV	• All Project-related tankers are required to adhere to federal standards that may reduce air emissions, including standards for bunker fuel.	• Reduced visibility

Notes:
a) RSA = Air Quality RSA.; LFV = Lower Fraser Valley.
b) Detailed mitigation measures are outlined in the Marine EPP (Volume 6A).

Table 7.2:

Potential Effect	Spatial Boundary	Key Recommendations/Mitigation Measures	Potential Residual Effect(s)
1. Marine GHG Indicator –Emissions of CO_2, CH_4, and N_2O			
1.1 Increase in CO_2e emissions	International	• All Project-related tankers are required to adhere to federal standards that may reduce GHG emissions, including standards for bunker fuel.	• Increase in CO_2e emissions.
2. Marine GHG Indicator – Effect on Overall Climate Change			
2.1 Changes in environmental parameters	International	• All Project-related tankers are required to adhere to federal standards that may reduce GHG emissions, including standards for bunker fuel.	• Changes in environmental parameters (global average temperature increase, precipitation events, heavy rainfall, crop yield, etc.).

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