WESTRIDGE MARINE TERMINAL HUMAN HEALTH RISK ASSESSMENT TECHNICAL REPORT

WESTRIDGE MARINE TERMINAL UPGRADE AND EXPANSION PROJECT APPLICATION TO VANCOUVER FRASER PORT AUTHORITY

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EXECUTIVE SUMMARY

This report describes the assessment of the potential human health risks to people associated with short-term and long-term exposures to the chemical emissions from the Westridge Marine Terminal that was completed on behalf of Trans Mountain Pipeline ULC ("Trans Mountain") for the proposed Trans Mountain Expansion Project (referred to as "TMEP" or "the Project"). The report serves as a supplement to the screening level human health risk assessment (SLHHRA) of the pipeline and facilities for the Project presented in Technical Report 5D-7 in Volume 7 of the Application to the National Energy Board (NEB) on December 16, 2013 ("the Application").

The SLHHRA was performed step-wise following a conventional risk assessment paradigm that is recognized world-wide. The paradigm consists of several steps, highlights of which are outlined below.

- Problem Formulation – This step is concerned with defining the scope and nature of the assessment, and setting practical boundaries on the work such that it is directed at the principal areas of concern. Specifically,
    - the area potentially affected by the chemical releases from the Project;
    - the chemicals of potential concern (COPC) associated with the Project that might contribute to potential health risks;
    - the people who might be exposed to the COPC, with special attention directed at sensitive or susceptible individuals (*e.g.*, infants and children, pregnant women, the elderly, individuals with compromised health); and
    - the potential exposure pathways by which people might be exposed to the COPC.
- Exposure Assessment – This step is concerned with estimating the level of exposure to the COPC that might be received *via* the various exposure pathways. The step often relies on one or more forms of predictive modeling to arrive at the exposure estimates, with specific reliance on air dispersion modelling in the case of chemical emissions to air. Distinction is made between exposures of a short-term (or acute) nature extending over a few minutes to several hours and long-term (or chronic) exposures lasting for several months or years, possibly up to a lifetime.
- Toxicity Assessment – This step is concerned with identifying and understanding the potential health effects that can be caused by each of the COPC (acting either singly or in combination), and the conditions under which the effects can occur. A principal outcome of this step is the determination of the health-based guidelines (or exposure limits) for the COPC, which refer to the levels of exposure that would not be expected to cause adverse health effects. The limits are typically based on guidelines, objectives or standards established by government authorities responsible for the protection of public health, and incorporate a high degree of protection to accommodate vulnerable members of the population.
- Risk Characterization – This step is concerned with quantifying the potential health risks that could be presented to the local residents and the general public who might frequent the area by comparing the exposure estimates determined as part of the Exposure Assessment to the corresponding exposure limits identified as part of the Toxicity Assessment. The risk estimates are calculated as shown below.

$$\text{Risk Estimate} = \frac{\text{Exposure Estimate}}{\text{Exposure Limit}}$$

By convention, the SLHHRA embraced a high degree of conservatism through the use of assumptions intentionally selected to represent worst-case or near worst-case conditions. Using this approach, any health risks that were identified in the SLHHRA are unlikely to be understated, but may be considerably overstated. As a result, where the maximum predicted levels of exposure to the chemical emissions associated with the Project were below the exposure limits, potential health risks were determined to be negligible or low.

The SLHHRA evaluated the potential health risks to people associated with short-term and long-term exposures to the chemical emissions from the additional tanks to be installed at the existing Edmonton, Sumas and Burnaby terminals and the expansion of the Westridge Marine Terminal. Consideration also was given to the potential health risks to people associated with the chemical emissions from the pump stations positioned along the length of the new pipeline. However, the opportunity for exposure to chemical emissions from the pump stations was determined to be limited largely due to the low potential for pump station emissions to disperse off-site, and as a result, these emissions are considered to have negligible, if any, health risk for local residents as well as the general public who might frequent the area.

For the three tank terminals (*i.e.*, Edmonton, Sumas and Burnaby terminals), the chemical emissions inventories were based on the fugitive emissions associated with the working and standing losses from the additional storage tanks to be installed at the existing terminals and consisted principally of lighter-end, volatile and semi-volatile hydrocarbons (C_1 to C_{12}), including both aliphatic and aromatic constituents. The latter constituents included benzene, toluene, ethylbenzene and xylenes (BTEX), as well as polycyclic aromatic hydrocarbons (PAHs). Trace amounts of sulphur-containing compounds made up the remainder of the COPC associated with the additional tanks to be installed at the tank terminals. The results of the SLHHRA for each of the tank terminals revealed that, despite the conservative assumptions employed, the maximum predicted exposures from inhalation and the various secondary pathways to the COPC (acting either singly or in combination) were associated with negligible or low levels of risk. On this basis, it was concluded that adverse health effects would not be expected due to the operations of the Edmonton, Sumas and Burnaby terminals and further assessment was not warranted.

The expanded Westridge Marine Terminal will be a source of combustion-type emissions from the vapour combustion unit (VCU), and the boilers and engines of the Project-related marine vessels while docked at the Westridge Marine Terminal; as well, the expanded terminal will be a source of uncontrolled vapours, including the uncombusted vapours from the VCU and the non-recovered vapours from the VRUs, during loading operations at the expanded Westridge Marine Terminal. The chemical emissions inventory for the expanded Westridge Marine Terminal consisted of more than 100 chemicals, including criteria air contaminants (CACs), metals and metalloids, petroleum hydrocarbon compounds (PHCs), PAHs, sulphur-containing compounds and volatile organic compounds (VOCs), all of which were carried forward for consideration as COPC in the SLHHRA. The results of the SLHHRA for the Westridge Marine Terminal revealed some potential exceedances of the exposure limits. The significance of these exceedances must be balanced against the degree of conservatism incorporated into the assessment. Generally, this requires that the conservative assumptions used in the assessment be reviewed to determine to what extent the predicted health risks may have been overstated. To better understand the potential health risks, a detailed HHRA based on a more refined and balanced set of assumptions having a higher likelihood of occurrence, rather than defaulting to the worst-case or near worst-case conditions described in the SLHHRA, was completed. The methods and findings of the HHRA are presented here.

The HHRA continued to follow the conventional risk assessment paradigm used in the SLHHRA. One of the major refinements made in the current assessment included the assessment of the potential health risks at discrete (or fixed) locations corresponding to actual households, schools, assisted-living complexes, communities, parks and recreation areas found within the Local Study Area (LSA) for the Westridge Marine Terminal. In the earlier assessment, people living in the area were assumed to be found on both a short-term and long-term basis at the location within the LSA corresponding to the maximum point of impingement (MPOI). The MPOI refers to the location at which the highest air concentrations of each of the COPC would be expected to occur, and at which the exposures received by the people within the LSA would be greatest. Use of the MPOI location in the SLHHRA ensured that any potential health effects that could result from exposure to the chemical emissions associated with the expansion of the Westridge Marine Terminal would not be underestimated, regardless of where people might be exposed. With this conservative approach, consideration was not given as to whether or not the MPOI location was suitable for a permanent residence and/or for residents to obtain their entire complement of locally grown or harvested foodstuffs (including home-garden produce, game meat, fish and wild plants).

To better understand the potential health risks of short-term and long-term exposure to chemical emissions originating from the Westridge Marine Terminal, the HHRA assessed the potential health risks

at discrete locations where people are known or anticipated to spend time. Emphasis was given to examining the potential health risks to people living in closest proximity to the Westridge Marine Terminal, where the maximum potential health risks associated with the expansion would be expected to occur.

Apart from the above, the methods followed in the HHRA closely matched that of the SLHHRA. Accordingly, the work included:

- Assessment of both short-term (acute) and long-term (chronic) exposure scenarios.
- Assessment of potential exposures relating to both the primary pathway (*i.e*., inhalation) and secondary pathways (*i.e*., inhalation of dust, food ingestion, and dermal contact).
- Assessment of potential exposures on both a cumulative basis and Project-specific basis.
- Assessment of the potential effects of the chemical emissions on the health of people living in the area (*i.e.,* residents) and people who might visit or frequent the area for recreation or other purposes and theoretically could be found anywhere within the study area at any given time (*i.e*., area users).
- Assessment of the different lifestyle characteristics, such as dietary patterns, of the residents (*i.e*., Aboriginal peoples and urban dwellers) that could influence potential exposure to the chemical emissions.
- Assessment of both non-cancer and cancer health risks.
- Assessment of the potential health risks associated with the COPC acting either singly or in combination (*i.e*., chemical mixtures).

The HHRA revealed that, with very few exceptions, the maximum predicted levels of exposure to the COPC (acting either singly or in combination) were below the corresponding exposure limits. The exceptions were for the short-term inhalation of the respiratory irritants mixture at the MPOI only. Exceedances for respiratory irritants mixture were few in number, low in frequency and modest in magnitude. The conservatism incorporated into both the exposure estimates and the exposure limits must be considered in the interpretation of these exceedances. Specifically, the analysis and interpretation of the short-term exceedances predicted for the respiratory irritants mixture took the following into consideration:

- the potential contribution from the Project to the mixture's exceedances;
- the spatial extent of the exceedances;
- the likelihood of an exceedance occurring; and
- the primary chemical contributors to the mixture's exceedances.

Exceedances were predicted for the respiratory irritants for the area users at the MPOI only. No exceedances were predicted for any of the discrete locations corresponding to actual households, schools, assisted-living complexes, communities, parks and recreation areas identified and assessed within the LSA. The magnitude of the predicted exceedance at the MPOI was modest, with a predicted risk estimate of 1.4. The Base Case risks were not predicted to change at this location under the Application Case or Cumulative Case. This indicates that the incremental changes in risk as a result of the Project are essentially negligible, and that the Project will have very little, if any, impact on the Base Case health risks associated with short-term exposure to the respiratory irritants. The MPOI for the respiratory irritants mixture is predicted to occur within the perimeter of another industrial facility, where public access would be restricted. The acute respiratory irritants mixture was comprised of 12 COPC that were assumed, for the purposes of the HHRA, to have an additive effect on the respiratory tract. Nitrogen dioxide (NO_2) was predicted to contribute more than 73% of the overall mixture risk, with sulphur dioxide (SO_2) predicted to be the next largest contributor at approximately 22% of the risk. However, the modes of action for NO_2 and SO_2 within the respiratory tract can differ, which may result in the mixture risk estimates being overstated. For example, NO_2 is relatively insoluble in water and can be inhaled deeply

into the lungs, acting as a deep-lung irritant; whereas, SO_2 is readily soluble in water and, at the concentrations predicted within the LSA, would be readily absorbed by the moist mucous membranes lining the upper respiratory tract, effectively removing it from the airstream such that it would not penetrate deeply into the lungs and alveolar spaces. For these reasons, it is likely that the combined risks for acute inhalation respiratory irritants mixture are overstated, and adverse health effects would not be expected.

In the chronic exposure assessment, potential health risks that could be presented to the local residents *via* the primary inhalation pathway were assessed. Examination of the findings revealed that in all cases the maximum predicted annual air concentrations of the COPC (acting either singly or in combination) associated with the Project were lower than the corresponding exposure limits, and therefore associated with a negligible or low level of risk. On this basis, long-term inhalation of the COPC associated with the Project are not expected to result in adverse health effects.

The potential health risks that could be presented to the local residents from chronic exposure to the COPC (acting either singly or in combination) associated with the Project *via* the various secondary exposure pathways also were examined. The potential chronic multiple pathway health risks were estimated based on the assumption that residents would be continuously exposed for an assumed lifespan of 80 years. Examination of the findings revealed that in all cases the maximum predicted exposures through the secondary pathways to the COPC (acting either singly or in combination) associated with the Project were lower than the corresponding exposure limits. Long-term health risks associated with the COPC exposures therefore are considered negligible or low, and adverse health effects from the inhalation of dust, consumption of locally-grown or harvested foodstuffs (including home-garden produce, game meat, fish and wild plants) and dermal contact would not expected.

Overall, the HHRA provided additional insight surrounding the potential health risks by incorporating a more refined and balanced set of assumptions. The findings of the HHRA for the expansion of the Westridge Marine Terminal provided here demonstrate that the likelihood of health risks for local residents and the general public who might frequent the area is lower than indicated by the more conservative SLHHRA. The major findings of the HHRA are:

- The contribution from the expansion of the Westridge Marine Terminal to the cumulative exposures to the COPC is negligible. In the majority of instances, the potential health risks remained unchanged between the assessment cases (*i.e.*, Base Case, Application Case and Cumulative Case), signifying that the expansion of the Westridge Marine Terminal and associated increase in marine vessel traffic will have very little, if any, effect on the Base Case health risks.

- With very few exceptions, non-carcinogenic inhalation risks were predicted to be below the benchmark (or target risk estimate) of 1.0, indicating that estimated short-term and long-term inhalation exposures were less than the exposure limits. Risk estimates less than or equal to 1.0 are associated with a negligible or low health risk, and therefore adverse health effects would not be expected. No exceedances were predicted at any of the discrete (or fixed) locations corresponding to actual households, schools, assisted-living complexes, communities, parks and recreation areas found within the LSA. The only exceedances were predicted for the respiratory irritants mixture at the MPOI on a short-term basis. These exceedances were determined to be few in number, low in frequency and modest in magnitude. Further examination of the predicted exceedances indicates that the health risks are low, and that adverse health effects are not predicted to occur.

- In all cases, non-carcinogenic risks associated with the various secondary pathways of exposure (*i.e.*, inhalation of dust, food ingestion, and dermal contact) were predicted to be below the benchmark (or target risk estimate) of 0.2, indicating that estimated exposures were less than 20% of the health-based guidelines (or exposure limits). Risk estimates less than or equal to 0.2 are associated with a negligible or low health risk, and therefore adverse health effects would not be expected.

- In all cases, risks for the carcinogens were predicted to be less than one in 100,000 (*i.e.*, one extra cancer case in a population of 100,000 people), indicating that the incremental cancer risks associated with the expansion of the Westridge Marine Terminal and associated increase in marine vessel traffic are deemed to be “essentially negligible”.

- The findings are consistent with those of the SLHHRA in that they continued to show a low potential for adverse health effects as a result of the Westridge Marine Terminal expansion. However, because of a greater emphasis on more credible exposure circumstances the findings of the HHRA demonstrate that the health risks are lower than indicated by the more conservative SLHHRA.

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DEFINITIONS AND ACRONYM LIST

Definition/Acronym	Full Name
µg	microgram(s)
µg/dL	microgram(s) per decilitre
µg/L	microgram(s) per litre
µg/kg	microgram(s) per kilogram
µg/m^3	microgram(s) per cubic metre
AAQO	Ambient Air Quality Objective
ACCLPP	Advisory Committee for Childhood Lead Poisoning Prevention.
ACGIH	American Conference of Governmental Industrial Hygienists
ARM	Ambient ratio method
atm-m^3/mol	Standard atmosphere cubic metre per mole
ATSDR	Agency for Toxic Substances and Disease Registry
bbl/d	barrel(s) per day
BC	British Columbia
BC MOE	British Columbia Ministry of the Environment
BLL	Blood lead level
BMD	Benchmark dose
BTEX	Benzene, toluene, ethylbenzene and xylenes
bw	Body weight
CAAQS	Canadian Ambient Air Quality Standards
CAC	Criteria air contaminant
Cal EPA	California Environmental Protection Agency
CCME	Canadian Council of Ministers of the Environment
CLWB	Cold Lake Winter Blend
cm^2	Square centimetre
CO	Carbon monoxide
COPC	Chemical of potential concern
COPD	Chronic Obstructive Pulmonary Disease
CPCN	Certificate of Public Convenience and Necessity
DFO	Fisheries and Oceans Canada
e.g.	Latin for “for example”
EBA	EBA, A Tetra Tech Company
EPI	Estimation Program Interface Suite
ESA	Environmental and Socio-economic Assessment
ESRD	Alberta Environment and Sustainable Resource Development
et al.	Latin for “and others”
etc.	Latin for “and more”
FEV_1	Forced expiratory volume in 1 second
FHA	Fraser Health Authority
FNFNES	First Nations Food Nutrition and Environment Survey
FVC	Forced vital capacity
FVRD	Fraser Valley Regional District
g/cm^2/day	gram(s) per square centimetre per day
g/day	gram(s) per day
g/mol	gram(s) per mole
GVRD	Greater Vancouver Regional District
HHRA	Human Health Risk Assessment
HSDB	Hazardous Substance Data Base
i.e.	Latin for “such as"
IEUBK	Integrated Exposure Uptake Biokinetic
ILCR	Incremental lifetime cancer risk
Intrinsik	Intrinsik Environmental Sciences Inc.
IQ	Intelligence quotients
JECFA	Joint Expert Committee on Food Additives
kg	kilogram(s)

Definition/Acronym	Full Name
km	kilometre(s)
KMC	Kinder Morgan Canada Inc.
L/day	Litre per day
Log K_{ow}	Octanol-water partitioning coefficient
LSA	Local study area
m^3/day	cubic metre(s) per day
MA DEP	Massachusetts Department of Environmental Protection
mg/kg	milligram(s) per kilogram
mmHg	millimetre(s) of mercury
MPOI	Maximum point of impingement
n/a	Not applicable
NAAQS	National Ambient Air Quality Standards
NAPS	National Air Pollution Surveillance
NCS	Nutrition Canada Survey
NEB	National Energy Board
NEB Act	*National Energy Board Act*
NHANES	National Health and Nutrition Examination Survey
NIOSH	National Institute of Occupational Safety and Health
No.	number
NO_2	Nitrogen dioxide
NO_X	Nitrogen oxides
NOAEL	No-observed-adverse-effect level
NOEC	No-observed effect concentration
OEHHA	California's Office of Environmental Health Hazard Assessment
OMOE	Ontario Ministry of the Environment
PAH	Polycyclic aromatic hydrocarbon
Pb	Lead
Pb/dL	Lead per decilitre
PBPK	Physiologically Based Pharmacokinetic
PCB	Polychlorinated biphenyl
PEF	Potency equivalency factor
PHC	Petroleum hydrocarbon
PM	Particulate matter
$PM_{2.5}$	Fine particulate matter (less than 2.5 µm in diameter)
PM_{10}	Fine particulate matter (less than 10 µm in diameter)
RADS	Reactive Airway Dysfunction Syndrome
RfC	Reference concentration
RfD	Reference dose
RIVM	Rijksinstituut voor Volksgezondheid en Milieu (Netherlands National Institute of Public Health and the Environment)
RQ	Risk quotient
RSA	Regional study area
RsC	Risk-specific concentration
RsD	Risk-specific dose
RWDI	RWDI Air Inc.
SF	Slope factor
SLHHRA	Screening level human health risk assessment
SO_2	Sulphur dioxide
SRC	Syracuse Research Corporation
TCEQ	Texas Commission of Environmental Quality
TEQ	Total equivalency quotient
the Project	The Trans Mountain Expansion Project
TMEP	Trans Mountain Expansion Project
TMPL	Trans Mountain pipeline
TMPL system	Trans Mountain pipeline system
TPHCWG	Total Petroleum Hydrocarbon Criteria Working Group

Definition/Acronym	Full Name
Trans Mountain	Trans Mountain Pipeline ULC
UR	Unit risk
US	United States
US EPA	United States Environmental Protection Agency
US EPA OSW	United States Environmental Protection Agency Office of Solid Waste
VCHA	Vancouver Coastal Health Authority
VCU	Vapour combustion unit
VOC	Volatile organic compound
VRU	Vapour recovery unit
WA DOE	Washington State Department of Ecology
WHO	World Health Organization

1.0 INTRODUCTION

This report describes the assessment of the potential human health risks to people associated with short-term and long-term exposures to the chemical emissions from the Westridge Marine Terminal that was completed on behalf of Trans Mountain Pipeline ULC (Trans Mountain) for the proposed Trans Mountain Expansion Project (referred to as "TMEP" or "the Project"). The report serves as a supplement to the screening level human health risk assessment (SLHHRA) of the pipeline and facilities of the Project presented in Technical Report 5D-7 in Volume 5D of the Application to the National Energy Board (NEB) on December 16, 2013 (the Application).

The SLHHRA was performed step-wise following a conventional risk assessment paradigm that is recognized world-wide, and endorsed by a number of leading federal, provincial and regional regulatory health authorities, including Health Canada, Environment Canada, the Canadian Council of Ministers of the Environment (CCME), British Columbia Ministry of Environment (BC MOE) and Alberta Environment and Sustainable Resource Development (ESRD). By convention, the SLHHRA embraced a high degree of conservatism through the use of assumptions intentionally selected to represent worst-case or near worst-case conditions. Using this approach, any health risks that were identified in the SLHHRA were unlikely to be understated, but may have been considerably overstated. As a result, where the chemical exposures were below the health-based guidelines (or exposure limits) developed or recommended by regulatory or leading scientific authorities for the protection of human health (*i.e.*, negligible or low level of risk), it was concluded that adverse health effects would not be expected and further assessment was not warranted. However, where the SLHHRA revealed exceedances of the exposure limits, suggesting some prospect for adverse health effects, further assessment was recommended in order to determine the actual extent of the human health risks.

The SLHHRA identified the additional tanks to be installed at the Edmonton, Sumas and Burnaby terminals as Project components that could emit chemicals to the environment in a manner that provides some opportunity for exposure of people. As well, the Westridge Marine Terminal was identified as a Project component of interest in the SLHHRA due to its planned expansion. Consideration was also given to the pump stations positioned along the length of the new pipeline. However, the opportunity for exposure to chemical emissions from the pump stations was determined to be limited largely due to the low potential for pump station emissions to disperse off-site, and as a result, these emissions were determined to present negligible, if any, health risk for local residents as well as the general public who might frequent the area.

For the three tank terminals (*i.e.*, Edmonton, Sumas and Burnaby terminals), the chemical emissions inventories for the additional tanks consisted principally of lighter-end, volatile and semi-volatile hydrocarbons (C_1 to C_{12}), including both aliphatic and aromatic constituents. The latter constituents included benzene, toluene, ethylbenzene and xylenes (BTEX), as well as polycyclic aromatic hydrocarbons (PAHs). Trace amounts of sulphur-containing compounds made up the remainder of the chemicals of potential concern (COPC) associated with the additional tanks to be installed at the terminals. The results of the SLHHRA for each of the tank terminals revealed that, despite the conservative assumptions employed, the maximum predicted exposures from inhalation and secondary pathways to the COPC (acting either singly or in combination) were associated with negligible or low levels of risk. Adverse effects on the health of local residents as well as the general public who might frequent the area therefore would not be expected from exposure to the COPC emissions from the additional tanks at the Edmonton, Sumas and Burnaby terminals. On this basis, the Edmonton, Sumas and Burnaby terminals were not carried forward for further evaluation in the detailed human health risk assessment (HHRA) presented here.

The chemical emissions inventory for the expanded Westridge Marine Terminal consisted of more than 100 chemicals, including criteria air contaminants (CACs), metals and metalloids, PAHs, petroleum hydrocarbon compounds (PHCs), sulphur-containing compounds and volatile organic compounds (VOCs), all of which were carried forward for consideration as COPC in the SLHHRA. The results of the SLHHRA for the Westridge Marine Terminal revealed some potential exceedances of the exposure limits. The significance of these exceedances must be balanced against the degree of conservatism incorporated into the assessment. Generally, this requires that the conservative assumptions used in the assessment be reviewed to determine to what extent the predicted health risks may have been

overstated. In order to permit fuller understanding of the potential health risks, a detailed HHRA based on a more refined and balanced set of assumptions having a higher likelihood of occurrence, rather than defaulting to the worst-case or near worst-case conditions described in the SLHHRA, was completed. The methods and findings of the HHRA are presented here.

1.1 Project Description

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 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.
- 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.

An application is being made pursuant to Section 52 of the *National Energy Board Act* (*NEB Act*) for 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.

1.2 Objectives

The overall objectives of the HHRA remain the same as those described in the SLHHRA:

- To identify and permit understanding of the potential health risks that might be presented to people from exposure to the chemical emissions associated with the Project on both a short-term and long-term basis.

- To address the information requirements outlined in Guide A.2 of the NEB *Filing Manual* for completion of an Environmental and Socio-economic Assessment (ESA) in support of a facilities application (NEB 2014).

- To address concerns held by the various stakeholders, including local residents and landowners, nearby communities and municipalities, and regulatory authorities at the federal, provincial and regional levels, over the potential health effects of the Project, whether voiced publicly or suspected to exist based on the collective experience of the Project team. The intent was to integrate the concerns held by these groups into the design of the HHRA.

- To provide guidance to Trans Mountain by establishing whether or not the chemical releases associated with the Project could potentially contribute to adverse effects on human health, and to provide recommendations, as needed, relating to emission controls or other mitigation measures aimed at eliminating or minimizing any such effects.

In addition, the HHRA embraced a further set of objectives. These objectives relate to the need to use a more refined and balanced set of assumptions that did not automatically default to worst-case or near worst-case conditions. The additional objectives embraced in the HHRA are:

- To provide a fuller, more comprehensive analysis of the potential health risks associated with the Westridge Marine Terminal expansion than was presented in the SLHHRA.

- To allow emphasis to be assigned to those conditions having a higher likelihood of occurrence rather than defaulting to the worst-case or near worst-case conditions, such that a more complete and informed determination can be made as to whether adverse health effects would be expected as a result of the elevated health risks predicted as part of the SLHHRA.

This report provides the methods and findings of the HHRA for the expansion of the Westridge Marine Terminal under routine operating conditions. The HHRA describes the nature and severity of potential short-term and long-term health risks to people associated with exposure to the chemicals that could be emitted from the Westridge Marine Terminal expansion. The HHRA examines the potential health risks attributable to the Project alone, and in combination with existing conditions and all other reasonably foreseeable developments in the region.

In the event of any omissions or inconsistencies in the information presented in this report from that contained in the previously filed report, this report is to prevail. Reference to materials submitted as part of, and contained in, the SLHHRA provided in Technical Report 5D-7 in Volume 5D of the Application form part of the report. The Application should be consulted for complete details respecting these materials.

1.3 Regulatory Guidance

The overall scope of the HHRA considered:

- the information requirements and guidance outlined in Guide A.2 of the NEB *Filing Manual* for completion of an ESA in support of a facilities application (NEB 2014); and

- federal and provincial guidance on HHRA provided by Health Canada (2010a,b,c,d,e,f), the CCME (2008a,b), BC MOE (2012) and Alberta Health and Wellness (2011).

Details with respect to the regulatory requirements and guidance relevant to the HHRA were provided in the SLHHRA as Technical Report 5D-7 in Volume 5D of the Application.

2.0 CONSULTATION

Trans Mountain and its consultants have conducted a number of 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, Aboriginal Engagement and Landowner Relations

Trans Mountain has implemented and continues to conduct open, extensive and thorough public consultation, Aboriginal engagement and landowner relations 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 corridor. 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.

Specific consideration was given to the human health-related concerns identified through the various Aboriginal engagement and stakeholder consultation activities, including public open houses, ESA Workshops, Community Workshops and one-on-one meetings. The human health-related concerns that pertain to the routine operation of the Westridge Marine Terminal of the Project are summarized below and were considered in the development of this technical report.

- Concerns were expressed over the potential health risks associated with chemical emissions from Westridge Marine Terminal.
- Concerns were raised over the potential cancer (carcinogenic) risks associated with the pipeline and facilities for the Project.
- Concerns were raised over the potential health risks to people suffering from asthma.
- Concerns were expressed over the potential health risks associated with dairy consumption due to the pipeline and facilities for the Project.
- Concerns were raised over the potential health risks to children in schools located in close proximity to the pipeline and facilities associated with the Project.
- Concerns were expressed over the potential effects of the Project-related activities on Aboriginal health.
- Concerns were raised over the potential health risks to pregnant women associated with the pipeline and facilities for the Project.

In addition, concerns related to the potential effects of pipeline and facility spills on human health were also raised, and were considered as part of the Qualitative Human Health Risk Assessment of Westridge Marine Terminal Spills Technical Report (Technical Report 7-3 in Volume 7 of the Application), and as part of a supplemental report entitled Human Health Risk Assessment of Facility and Marine Spill Scenarios Technical Report. Concerns relating to odours were addressed in the Air Quality and Greenhouse Gas Technical Report (Technical Report 5C-4 in Volume 5C of the Application); while noise was addressed in the Terrestrial Noise and Vibration Technical Report (Technical Report 5C-3 in Volume 5C of the Application).

A full description of the Public Consultation, Aboriginal Engagement and Landowner Relations, including the consultation and engagement activities that focused on identifying issues and concerns related to the potential effects of the Project on human health and that helped inform the present assessment, is provided elsewhere (see Volumes 3A, 3B and 3C of the Application, and the Consultation Update No. 1 and Errata filed March 20, 2014).

2.2 Regulatory Consultation

Consultation with federal and local regulatory authorities responsible for the protection of public health took place in which the authorities were introduced to the Project and in which the nature and scope of work to be completed to assess the potential Project-related human health risks were shared. Feedback received from the authorities helped inform the work, including the present assessment. The consultative activities are shown in Table 2.1.

TABLE 2.1

SUMMARY OF CONSULTATION ACTIVITIES RELATED TO THE HUMAN HEALTH RISK ASSESSMENT

Stakeholder Group / Authority 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						
Health Canada (BC Region)	Dr. Carl Alleyne, BC Regional Environmental Assessment Coordinator Dr. Gladis Lemus, BC Regional Manager	Meeting	January 28, 2013	Project introduction. Discussion of the planned HHRA approach.	Health Canada advised that they will be directing particular attention to Aboriginal health. Health Canada expressed an interest in knowing the potential health effects associated with any accidents and malfunctions. Health Canada will be interested in knowing the potential short-term as well as long-term health effects associated with the Project, with consideration given to all relevant exposure pathways.	None
LOCAL CONSULTATION						
Fraser Health Authority (FHA)	Dr. Paul Van Buynder, Chief Medical Health Officer Dr. Nadine Loewen, Medical Health Officer Dr. Goran Krstic, Human Health Risk Assessment Specialist, Health Protection Tim Shum, Regional Director	Meeting	January 28, 2013	Project introduction. Discussion of the planned HHRA approach.	FHA and VCHA expressed an interest in knowing whether any long-term monitoring of health is planned. FHA and VCHA expressed an interest in knowing the historical effects of the Legacy Line. FHA and VCHA expressed an interest in knowing the potential health effects associated with a spill to an urban environment. FHA and VCHA is interested in knowing the potential short-term as well as long-term health effects associated with the Project, with consideration given to all relevant exposure pathways.	None
Vancouver Coastal Health Authority (VCHA)	Dr. Patricia Daly, Chief Medical Health Officer Dr. James Lu, Medical Health Officer, Richmond Public Health Dr. Richard Taki, Regional Director, Health Protection					
Fraser Valley Regional District (FVRD)	Alison Stewart, Senior Planner, Strategic Planning and Initiatives	Telephone call	March 20, 2013	Project introduction. Discussion of the planned HHRA approach.	FVRD expressed an interest in knowing the potential effects of the Project on air quality, and subsequently human health, in the FVRD. From a health perspective, Ms. Stewart indicated that the FVRD would be taking their direction from FHA.	None

3.0 METHODS

3.1 Overall Approach

The overall approach that was followed in performing the HHRA was very similar to that described in the SLHHRA (Technical Report 5D-7 in Volume 5D of the Application). The description is meant to introduce the various steps involved and the general principles that apply. Details specific to the design and conduct of the HHRA for the Westridge Marine Terminal are provided in Section 3.2 (Specific Approach).

3.1.1 Guiding Principles

A number of guiding principles that are fundamental to understanding and interpreting the nature and likelihood of occurrence of adverse health effects from chemical exposures were fully respected by the assessment. These principles are:

- All chemicals, regardless of type or source, possess some degree of intrinsic toxicity (*i.e*., all chemicals have the capacity to cause some level of harm or injury).

- The health effects caused by any chemical are dependent not only on the intrinsic toxicity of the chemical (i.e., the capacity to cause harm), but equally on the exposure or dose of the chemical that is received. This principle forms the basis of the so called “dose response relationship” that defines the nature and severity of health effects that can be caused by a chemical as a function of both its intrinsic toxicity and the exposure received. The relationship is fundamental to determining the prospect for health effects to occur in response to exposure to a chemical. In the absence of exposure, health effects will not occur, regardless of the toxicity of the chemical. If exposure takes place, some prospect for the occurrence of health effects will exist, with the likelihood and severity of these effects becoming progressively greater as the exposure increases.

- With very few exceptions, a minimum or “threshold” dose exists below which a chemical’s toxicity is not expressed. In other words, exposure to a chemical must reach a certain level before health effects begin to occur. At exposures below this threshold dose, the body can render the chemical harmless by detoxifying and eliminating it. The body also possesses a certain level of resilience, partly through: i) the physical barriers that are present to prevent or limit the absorption of chemicals, such as the skin and/or other membranes that chemicals must cross in order to reach the target tissues; ii) its ability to self-repair; and, iii) the redundancy of certain organ systems, that allow the body to tolerate low levels of chemical exposure without loss of function. Once the threshold dose is exceeded, health effects will begin to appear, with the response becoming increasingly more pronounced with increasing exposure (*i.e.*, consistent with the dose-response principle). The threshold dose will vary by chemical, by individual (see below), and by the type of response. If the threshold dose is exceeded, health effects may occur. The severity of these effects will depend on the level of exposure received, with more severe effects occurring with higher doses. This is commonly referred to as the ‘dose-response’ principle of toxicology. Possible exceptions to this principle include chemical sensitization responses and certain types of cancer having a genetically-induced basis, for which the existence of a threshold dose may not be obvious. Some scientists contend that no safe dose levels exist for these carcinogens (Health Canada 2010a). Other scientific authorities disagree and argue that the threshold phenomenon applies equally to carcinogens and non-carcinogens; often this approach to carcinogens is chemical dependent (Health Canada 2010a, Klaassen 2008). Debate also surrounds whether or not the threshold phenomenon applies to $PM_{2.5}$ and some other forms of air pollution (US EPA 2004, WHO 2006, WHO 2000).

- The type and nature of health effects that can be produced by a chemical can vary depending on the concentration of the chemical encountered as well as the frequency and duration of exposure (*i.e.*, how much, how often, and how long). Therefore, for any given chemical, health effects that can result from a short-term or “acute” exposure (*i.e.*, an exposure lasting several minutes to several hours, and possibly extending up to several days) may differ from the effects caused by longer-term or “chronic” exposure (*i.e.*, repeated exposure over the course of several weeks or months or longer). Whether this difference applies is very much dependent on the chemical; however, there are many examples of chemicals for which the health effects from acute exposure differ from chronic exposure in terms of

the tissue/organ(s) affected, the mechanism of toxicity, and the severity of the response. Accordingly, in assessing the potential health effects that may result from a chemical exposure, it is important to specify the type of exposure involved *vis-à-vis* its frequency and duration.

- The toxicity of any chemical is largely dependent on its molecular size and structure, with the type of functional groups present having a substantial influence on the manner and extent to which it may interfere with biological tissues and processes. Within limits, chemicals having similar structures and functional groups will produce similar toxic responses. This principle allows the health effects of a chemical of unknown toxicity to be predicted on the basis of the health effects known to be caused by a second surrogate chemical of similar molecular structure. The term 'read across' has been coined to describe the process by which the health effects data for the surrogate chemical are applied to other structurally-related compounds.

- People may respond differently to the same chemical under the same exposure circumstances owing to differences in age, gender, lifestyle, health status and other characteristics affecting an individual's sensitivity and/or susceptibility to chemical exposures. Individuals with a high response threshold will be more tolerant of exposure than most people; whereas, persons having a lower response threshold than normal may be more susceptible to exposure. These differences should be acknowledged and respected as part of the assessment of the potential health effects associated with chemical exposures since they can affect the likelihood and extent to which a person might be affected. Infants, young children, the elderly and people whose health may be compromised as a result of pre-existing medical conditions (*e.g.*, asthma) are generally regarded as being sensitive sub-populations who may show heightened responsiveness to chemical exposures.

3.1.2 The Risk Assessment Paradigm

The overall approach taken in the HHRA continued to follow the conventional risk assessment paradigm, involving four steps: Problem Formulation, Exposure Assessment, Toxicity Assessment, and Risk Characterization (see Figure 3.1 of Appendix A). The paradigm consists of several steps, highlights of which are outlined below.

- Problem Formulation – This step is concerned with defining the scope and nature of the assessment, and setting practical boundaries on the work such that it is directed at the principal areas of concern. It includes the identification of the chemicals that could be released by the Project, the areas and people potentially affected, and the pathways by which these people could be exposed. When characterizing the people who might be exposed, emphasis is placed on sensitive or susceptible individuals.

- Exposure Assessment – This step is concerned with estimating the level of exposure that people could receive to the COPC *via* the various exposure pathways. The step often relies on one or more forms of predictive modelling to arrive at the exposure estimates, with specific reliance on air dispersion modelling in the case of chemical emissions to air. Distinction is made between exposures of a short-term (or acute) nature extending over a few minutes to several hours and long-term (or chronic) exposures lasting for several months or years, possibly up to a lifetime.

- Toxicity Assessment – This step is concerned with identifying and understanding the potential health effects that can be caused by each of the COPC (acting either singly or in combination), and the conditions under which the effects can occur. A principal outcome of this step is the determination of the health-based guidelines (or exposure limits) for the COPC, which refer to the levels of exposure that would not be expected to cause health effects. The limits are typically based on guidelines, objectives or standards established by regulatory and leading scientific authorities responsible for the protection of public health, and incorporate a high degree of protection to accommodate vulnerable members of the population.

- Risk Characterization – This step is concerned with quantifying the potential health risks that could be presented to the local residents or general public by comparing the exposure estimates determined as part of the Exposure Assessment to the corresponding exposure limits identified as part of the Toxicity Assessment.

Details of these steps can be found in Section 3.0 of the SLHHRA (Technical Report 5D-7 in Volume 5D of the Application).

3.2 Specific Approach

3.2.1 Problem Formulation

This step is concerned with defining the scope and nature of the assessment, and setting practical boundaries on the work such that it is directed at the principal areas of concern. The Problem Formulation focuses on four major aspects of the HHRA:

1. Identification of the area potentially affected by the chemical emissions from the Westridge Marine Terminal expansion.
2. Identification of the specific COPC emitted from the Westridge Marine Terminal expansion that might contribute to potential health risks.
3. Characterization of the people who might be exposed to the COPC, with special attention directed at sensitive or susceptible individuals (*e.g.*, infants and children, pregnant women, the elderly, individuals with compromised health).
4. Identification of all potential exposure pathways by which people might be exposed to the COPC.

Details on these four aspects are provided below.

3.2.1.1 Spatial Boundaries

Consistent with the spatial boundaries identified and evaluated in the SLHHRA for the Westridge Marine Terminal, the spatial boundaries in the current assessment were defined in terms of a Local Study Area (LSA) and the Air Quality Regional Study Area (RSA). Specifically, the HHRA evaluated the potential health risks within the:

- LSA: the area in the immediate vicinity of the Westridge Marine Terminal where exposure to the chemical emissions from the terminal might be expected to occur. The LSA represents the predicted spatial extent of the chemical emissions from the expansion of the Westridge Marine Terminal to which people might be exposed. The LSA extends over a 5 km radius centred on the Westridge Marine Terminal.

- Air Quality RSA: the area specified in the Air Quality and Greenhouse Gas Technical Report Technical Report 5C-4 in Volume 5C of the Application) extending beyond the LSA where other activities could directly or indirectly influence air quality within the LSA on a cumulative basis, and potentially contribute to cumulative effects on human health. The Air Quality RSA for the Westridge Marine Terminal is a 24 km by 24 km area.

Figure 3.2 of Appendix A shows the spatial boundaries surrounding the Westridge Marine Terminal.

3.2.1.2 Chemicals of Potential Concern

As indicated earlier, a principal outcome of the Problem Formulation step is the identification of the COPC associated with the Westridge Marine Terminal expansion. The determination of the COPC began with the development of the list of chemicals found in the various emissions associated with the expansion of the Westridge Marine Terminal.

According to the Air Quality and Greenhouse Gas Technical Report provided as Technical Report 5C-4 in Volume 5C of the Application, the Westridge Marine Terminal expansion will emit chemicals to air from the following sources:

- the diesel generators and two diesel-fired water pumps;

- the vapour combustion unit (VCU) and vapour recovery units (VRUs); and

- the engines and boilers of the Project-related marine vessels while docked at the Westridge Marine Terminal.

The chemical emissions inventory for the combustion-type emissions (*i.e.*, generators, water pumps, VCU, and engines and boilers of the Project-related marine vessels) was compiled in Technical Report 5C-4 in Volume 5C, Air Quality and Greenhouse Gas Technical Report. The chemical emissions inventory for the combustion-type emissions are shown in Table 3.1, according to chemical category.

TABLE 3.1

CHEMICAL EMISSIONS INVENTORY FOR THE COMBUSTION-TYPE EMISSIONS ASSOCIATED WITH THE WESTRIDGE MARINE TERMINAL

Criteria Air Contaminants	Metals and Metalloids	Petroleum Hydrocarbon Fractions	Polycyclic Aromatic Hydrocarbons	Volatile Organic Compounds	Other
Carbon monoxide (CO)	Arsenic	Aliphatics C_6-C_8	Acenaphthene	Acetaldehyde	Benzothizole
Nitrogen dioxide (NO_2)	Barium	Aliphatics C_9-C_{16}	Acenaphthylene	Acetylene	Polychlorinated biphenyls (PCBs)[1]
Particulate matter ($PM_{2.5}$ and PM_{10})[2]	Beryllium	Aromatics C_9-C_{16}	Anthracene	Acrolein	Tetramethylthiourea
Sulphur dioxide (SO_2)	Cadmium	Aromatics C_{17}-C_{34}	Benz(a)anthracene	Alkylphenols C_{10}-C_{11}[3]	
	Chromium III		Benzo(a)pyrene	Benzene	
	Chromium VI		Benzo(b)fluoranthene	n-Butane	
	Cobalt		Benzo(g,h,i)perylene	Chlorobenzene	
	Copper		Benzo(k)fluoranthene	Dimethylbenzylalcohol	
	Lead		Chrysene	Dimethyloctyne diol	
	Manganese		Fluoranthene	Ethane	
	Mercury		Fluorene	Ethylbenzene	
	Molybdenum		Indeno(1,2,3-c,d)pyrene	Ethylene	
	Nickel		Naphthalene	Formaldehyde	
	Selenium		Phenanthrene	Hexachlorobenzene	
	Strontium		Pyrene	n-Hexane	
	Titanium			Methane	
	Vanadium			Octanol	
	Zinc			n-Pentane	
				Propylene	
				Propionaldehyde	
				Styrene	
				Tetramethylpentanone	
				Toluene	
				Trimethylbenzenes	
				Trimethylcyclohexanol	
				Trimethylcyclopentanone	
				Xylenes	

Notes:
1 The emissions inventory identifies total PCBs and does not specify the congeners.
2 $PM_{2.5}$ includes both primary (emitted directly into the atmosphere) and secondary (formed in the atmosphere through chemical and physical transformations) particulates.
3 Alkylphenols C_{10}-C_{11} were assumed to represent phenols with alkyl groups containing 10 or 11 carbon atoms (*e.g.*, 2-decylphenol).

The chemical emissions inventory for the uncontrolled vapours, including the uncombusted vapours from the VCU and the non-recovered vapours from the VRUs, associated with loading operations at the Westridge Marine Terminal proceeded step-wise, beginning with the identification of a representative product. Cold Lake Winter Blend (CLWB) diluted bitumen (or dilbit) was chosen to represent the type of oil to be loaded to the docked tanker based, in part, on the fact that CLWB is currently, and is expected to remain a major product carried by the new pipeline (see Section 5.1.1.1 in Volume 7 of the Application). Another factor that contributed to its selection is the fact that the diluent in CLWB is a liquid condensate that is rich in light-end hydrocarbons that are volatile or semi-volatile in nature. These hydrocarbon components could potentially be released as vapours from the tanker during loading operations, which would then disperse in a downwind direction, possibly reaching people who could then inhale the vapours.

As a second step, a sample of CLWB was tested by an accredited third-party laboratory to provide information on its physical and chemical characteristics. A full list of trace elements and organic compounds analyzed in CLWB, including the concentration of individual chemical components, is provided in Table 6.2 of Technical Report 7-1 in Volume 7, Qualitative Ecological Risk Assessment of Pipeline Spills Technical Report. Copies of the original laboratory certificates are provided in Appendix A of Technical Report 7-1 in Volume 7 of the Application. The results of the CLWB analysis were examined, and those individual chemical components identified in the analysis were carried forward in the COPC identification process (see Table 6.2 of Technical Report 7-1 in Volume 7 of the Application).

The third step involved screening the entire list of individual chemical components found in the CLWB based on each component's physical and chemical properties, notably those properties, such as molecular weight and vapour pressure, that determine its tendency to partition into air and the ease with which it might volatilize from the oil's surface. The screening was performed by EBA, a Tetra Tech company (EBA) as described in Section 5.2.6 of Technical Report 8C-12 S9 in Volume 8C of the Application.

Lastly, consideration was given to the findings reported in *Flux Chamber Sampling Program in Support of Spill Modelling for the Trans Mountain Expansion Project completed in Gainford, Alberta* (Appendix I of Technical Report 8C-12 S7 in Volume 8C, A Study of Fate and Behaviour of Diluted Bitumen Oil on Marine Waters, Dilbit Experiments – Gainford Alberta). The aim of the study was to characterize the emissions off the surface of the CLWB in terms of the types and amounts of individual chemical components present. Additional details regarding the study's methods and findings were filed with the NEB on June 18, 2014 in response to an intervenor request (see BROKE IR No. 1.2a).

The chemical emissions inventory for the uncontrolled emissions associated with loading operations at the Westridge Marine Terminal is shown in Table 3.2, according to chemical category.

TABLE 3.2

CHEMICAL EMISSION INVENTORY FOR THE UNCONTROLLED EMISSIONS FROM THE LOADING OPERATIONS AT THE WESTRIDGE MARINE TERMINAL

Petroleum Hydrocarbon Fractions[1]	Polycyclic Aromatic Hydrocarbons	Sulphur-Containing Compounds	Volatile Organic Compounds
Aliphatics C_6-C_8	Acenaphthene	n-Butanethiol	1,2,4-Trimethylbenzene
Aliphatics >C_8-C_{10}	Biphenyl	Dibenzothiophene	Benzene
Aliphatics >C_{10}-C_{12}	Naphthalene	Dimethyl sulphide	iso-Butane
Aromatics >C_8-C_{10}	C1-Naphthalene	Ethanethiol	n-Butane
Aromatics >C_{10}-C_{12}	C2-Naphthalene	n-Hexanethiol	Cyclohexane
		Methyl ethyl sulphide	Ethylbenzene
		iso-Propanethiol	Methylcyclohexane
		Thiophene / sec-Butanethiol	Methylcyclopentane
			iso-Pentane
			n-Pentane
			Propane
			Toluene
			Xylenes

The final step of the COPC identification process involved refining the list of chemicals by combining and re-naming certain of the chemicals to better align with chemical nomenclature and naming conventions in common use by regulatory and leading scientific authorities involved in the development of exposure limits. In some cases, "surrogate" chemicals were used to represent the chemicals, consistent with the "read across" principle mentioned earlier (see Section 3.2 Guiding Principles). The final outcome of the COPC identification process for the Westridge Marine Terminal expansion is the list of COPC shown in Table 3.3.

Chemicals for which sufficient toxicological information could not be identified in the form of a defensible exposure limit, or a representative surrogate chemical could not be evaluated in the HHRA; therefore,

were not carried forward as COPC in the current assessment. These include: alkylphenols C_{10}-C_{11}, benzothiazole, dibenzothiophene, dimethylbenzylalcohol, dimethyloctyne diol, dimethyl sulphide, methyl ethyl sulphide, octanol, tetramethylpentanone, tetramethylthiourea, trimethylcyclohexanol and trimethylcyclopentanone. Many of these compounds contain sulphur, and therefore would be considered odourous. The potential odours associated with these sulphur-containing compounds were addressed in the Air Quality and Greenhouse Gas Technical Report (see Technical Report 5C-4 in Volume 5C of the Application).

TABLE 3.3

CHEMICALS OF POTENTIAL CONCERN FOR THE HUMAN HEALTH RISK ASSESSMENT OF WESTRIDGE MARINE TERMINAL EXPANSION

Criteria Air Contaminants	Metals and Metalloids	Petroleum Hydrocarbon Fractions	Polycyclic Aromatic Hydrocarbons[1]	Sulphur-Containing Compounds	Volatile Organic Compounds	Other
Carbon monoxide (CO)	Arsenic	Aliphatics C_1-C_4[2]	Acenaphthene	Ethanethiol group[3]	Acetaldehyde	PCBs
Nitrogen dioxide (NO_2)	Barium	Aliphatics C_5-C_8	Anthracene		Acrolein	
Particulate matter ($PM_{2.5}$ and PM_{10})	Beryllium	Aliphatics C_9-C_{16}	Benzo(a)pyrene[4] (and equivalents)		Benzene	
Sulphur dioxide (SO_2)	Cadmium	Aromatics C_9-C_{16}	Biphenyl		Chlorobenzene	
	Chromium III	Aromatics C_{17}-C_{34}	Fluoranthene		Cyclohexane	
	Chromium VI		Fluorene		Ethylbenzene	
	Cobalt		Naphthalene		Formaldehyde	
	Copper		Pyrene		Hexachlorobenzene	
	Lead				n-Hexane	
	Manganese				Propionaldehyde	
	Methyl mercury[5]				Styrene	
	Mercury				Toluene	
	Molybdenum				Trimethylbenzenes	
	Nickel				Xylenes	
	Selenium					
	Strontium					
	Titanium					
	Vanadium					
	Zinc					

Notes:
1 Acenaphthylene is assessed in the Aromatics C_9-C_{16}.
2 Aliphatics C_1-C_4 includes acetylene, iso-butane, n-butane, ethane, ethylene, methane, propane and propylene.
3 Ethanethiol group includes n-butanethiol, sec-butanethiol, ethanethiol, n-hexanethiol, iso-propanethiol and thiophene.
4 Benzo(a)pyrene (and equivalents) includes all the carcinogenic PAHs for which a potency equivalency factors (PEF) has been assigned by Health Canada (2010a). This includes benz(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(g,h,i)perylene, benzo(k)fluoranthene, chrysene, fluoranthene, indeno(1,2,3-cd)pyrene, and phenanthrene.
5 Although the Westridge Marine Terminal will not emit methyl mercury directly to the environment, the inorganic mercury emitted to air might deposit to local surface water bodies and bio-transform to methyl mercury. On this basis, methyl mercury, in addition to inorganic mercury, was identified as a COPC in the multiple pathway assessment of the SLHHRA (Technical Report 5D-7 in Volume 5D of the Application), and subsequently the HHRA.

3.2.1.3 People Potentially at Risk

The people potentially at risk represent those people whose health might be adversely affected as a result of exposure to the chemical emissions from the Westridge Marine Terminal expansion. In this regard, consideration was given to:

- The need to assess the potential effects of the chemical emissions on the health of both people living in the area (referred to as residents), and people who might visit or frequent the area for recreation or other purposes and theoretically could be found anywhere within the LSA at any given time (referred to as area users).

- The need to consider the influence of the residents' lifestyle characteristics, such as dietary patterns, on the potential chemical exposures that they might receive from the Westridge Marine Terminal, and the corresponding health risks that could be presented.

- The need to acknowledge that the manner and degree to which people may respond to chemical exposures can vary from one individual to another due to factors like age, sex and/or health status.

The residents and area users were distinguished and represented as outlined below.

Residents

For the purposes of the assessment, it was assumed that the residents would:

- be present at select locations within the LSA 24 hours per day, 365 days per year over an 80-year lifespan; and

- consume a portion of their diet from local sources.

In order to assess the potential health risks that might be presented to the residents within the LSA, it was necessary that all age classes or life stages be considered. The five life stages used to assess potential health risks to the people are consistent with Health Canada guidance for the Canadian general population (Health Canada 2010a):

- Infant – 0 to 6 months (0.5 year span)

- Toddler – 7 months to 4 years (4.5 year span)

- Child – 5 to 11 years (7 year span)

- Teen – 12 to 19 years (8 year span)

- Adult – 20 to 80 years (60 year span)

Similarly, the physical characteristics of the people potentially at risk were obtained from documents published by Health Canada (2010a) and are given in Table 3.4.

TABLE 3.4

ASSUMED PHYSICAL CHARACTERISTICS OF PEOPLE POTENTIALLY AT RISK

Physical Characteristics	Life Stage				
	Infant	Toddler	Child	Teen	Adult
Body weight (kg)	8.2	16.5	32.9	59.7	70.7
Inhalation rate (m^3/day)	2.2	8.3	14.5	15.6	16.6
Soil ingestion rate (g/day)	0.02	0.08	0.02	0.02	0.02
Water ingestion rate (L/day)	0.3	0.6	0.8	1.0	1.5
Surface area (cm^2):					
Hands	320	430	590	800	890
Arms	550	890	1,480	2,230	2,500
Legs	910	1,690	3,070	4,970	5,720
Total body	3,620	6,130	10,140	15,470	17,640
Soil adherence factor (g/cm^2/day):					
Hands	0.0001	0.0001	0.0001	0.0001	0.0001
Surfaces other than hands	0.00001	0.00001	0.00001	0.00001	0.00001

Lifestyle categories were established to represent groups of residents within the LSA that share common behavioural characteristics, such as dietary patterns. Individuals within these groups therefore are assumed to receive similar levels of exposure to the COPC emitted from the Westridge Marine Terminal expansion. Respecting the need to consider the influence of the lifestyle characteristics, the residents

were separated into Aboriginal peoples and non-Aboriginal peoples (hereafter referred to as urban dwellers). Each of these lifestyle categories is described below.

- Aboriginal Peoples - Consideration was given to the people living in Aboriginal communities within the LSA to accommodate the unique opportunities for chemical exposures that might occur among these individuals, some of whom may practice a subsistence lifestyle, including the consumption of traditional foods such as game meat, fish, beach foods and wild plants.

- Urban Dwellers – Consideration was given to the people living in an urban environment within the LSA. For the urban dwellers, allowance was made for potential chemical exposures through the consumption of home-garden produce, fish and beach foods.

One of the major refinements captured in the HHRA relates to the characterization of the people potentially at risk, and ultimately the potential exposures that they might receive as a result of the Project. In the earlier assessment, residents were assumed to be found on both a short-term and long-term basis at the location within the LSA corresponding to the "maximum point of impingement" (MPOI). The MPOI refers to the location at which the highest air concentrations of each of the COPC would be expected to occur, and at which the exposures received by the people within the LSA would be greatest. The choice of the MPOI location was meant to ensure that any potential health effects that could result from exposure to the chemical emissions associated with the Project, regardless of where people might be exposed, would not be underestimated. The decision to use the MPOI to represent the location at which people would be found was made by default; that is, consideration was not given as to whether or not the MPOI location was suitable for a permanent residence and/or for residents to obtain their entire complement of locally grown and/or harvested foodstuffs (including home-garden produce, game meat, fish, beach food and/or wild plants).

To better understand the potential health risks that might be presented to the residents from short-term and long-term exposure to the chemical emissions originating from the Westridge Marine Terminal expansion, residents were represented in the HHRA by discrete (or fixed) locations corresponding to actual households, schools, assisted-living complexes and communities found within the LSA. Emphasis was given to examining the potential health risks to people living in closest proximity to the Project, where the maximum potential health risks associated with the Project would be expected to occur. Over 30 locations were identified within the LSA and assessed as part of the current assessment. These include:

- closest residences,
- closest elementary schools,
- closest assisted-living complexes,
- closest hospitals, and
- all neighbouring communities.

These locations are listed in Table 3.5 and shown in Figure 3.3 of Appendix A.

Area Users

Area users represent people who might frequent the area within the LSA for recreation or other purposes. Unlike the residents, these individuals would not be expected to remain in the area for extended periods of time, thereby precluding any reasonable opportunity for exposure to the chemical emissions on a long-term basis and/or through the consumption of locally grown and/or harvested foodstuffs. In the HHRA, in addition to the MPOI, the area users were represented by discrete (or fixed) locations within the LSA corresponding to:

- closest provincial and municipal parks, and
- closest golf courses.

In total, 15 locations were identified and assessed as part of the current assessment of the area users. These locations are listed in Table 3.5 and shown in Figure 3.3 of Appendix A.

TABLE 3.5

SELECTED LOCATIONS WITHIN THE LOCAL STUDY AREA AT WHICH PEOPLE WOULD RESIDE OR VISIT

Lifestyle Category		Discrete Locations			
		Description	Count	Location Identification No.	Rationale
Residents	Aboriginal peoples	Aboriginal communities	2	10, 37	The nearest Aboriginal community is the Tsleil-Waututh First Nation (Burrard Inlet 3), which is located near Indian Arm on the north shore of Burrard Inlet, approximately 2 km northwest of the Westridge Marine Terminal. Although further removed from the Westridge Marine Terminal at a distance of approximately 5 km, the Aboriginal community of the Squamish Nation (Seymour Creek 2) also is located on the north shore of Burrard Inlet within the LSA.
	Urban dwellers	Closest residences	3	47-49	Includes closest residences identified in the Terrestrial Noise and Vibration Technical Report (Volume 5D of the Application). The nearest residence lies approximately 100 m south of the terminal (see Section 6 in Volume 5B of the Application).
		Closest elementary schools	8	22-24, 29, 31, 40, 41, 45	Includes closest elementary schools identified within the Board of Education Burnaby School District 41 (Burnaby School District 2013) and North Vancouver School District 44 (2013). The nearest elementary school lies approximately 1 km southwest of the terminal.
		Closest assisted-living complexes	2	17, 36	Includes closest assisted-living facilities reported by the Fraser Health Authority (2011).
		Non-Aboriginal communities	22	2, 4, 5, 12, 14-16, 18-20, 25, 27, 28, 30, 34, 35, 39, 42, 43, 46, 51, 52	Includes all communities identified by the Village of Belcarra (2014), City of Burnaby (2014), City of Coquitlam (2013), the District of North Vancouver (2014) and the City of Port Moody (2014) within the LSA.
Area users		Closest provincial and municipal parks	10	1, 3, 6-8, 11, 13, 21, 32, 50	Includes closest parks identified by the City of Burnaby (2013), District of North Vancouver (2013) and BC Parks (2013). The nearest park is the Burnaby Mountain Conservation Area which is located adjacent to the Westridge Marine Terminal.
		Closest recreational areas	5	9, 26, 33, 38, 44	Includes closest recreational areas (*i.e.*, golf courses identified in the Socio-Economic Technical Report (see Volume 5D of the Application).

Notes:
1 The nearest hospital is the Royal Columbian Hospital in New Westminster, which is located approximately 7 km southeast of the terminal and outside the LSA (FHA 2011).

3.2.1.4 Relevant Exposure Pathways

Exposure pathways refer to the various avenues by which the chemical emissions might "travel" from the Westridge Marine Terminal expansion to the people living in and/or frequenting the area (Health Canada 2010a, US EPA OSW 2005). Since the chemicals will be emitted directly into the air, the primary pathway by which people could be exposed is *via* inhalation (*i.e.*, breathing in chemicals). Exposure through less obvious secondary pathways also could occur and were evaluated as part of the current assessment. For example, the chemicals might fall-out or deposit from the air onto the ground and enter the food chain (*i.e.*, deposition of the chemicals directly onto the leafy surfaces of vegetables or other home-garden produce and/or deposition onto soils, with subsequent uptake by plants through the root system). The affected foods could then be eaten by people (*i.e.*, a secondary pathway).

The identification of potential exposure pathways necessarily required consideration of the following:

- The length of exposure (*i.e.*, short-term exposures lasting several hours to a few days versus long-term exposures lasting for several months or years, possibly up to a lifetime). The emissions associated with the Westridge Marine Terminal expansion will be continuous in nature and will extend over the more than 50-year life of the Project, thereby presenting opportunity for both short-term and long-term exposure.

- The lifestyle category (*i.e.*, residents versus area users). Both categories could theoretically be exposed to the emissions associated with the Project *via* inhalation on a short-term basis. However, opportunity also exists for the residents to be exposed to the emissions on a longer-term basis. By convention, consideration of secondary exposure pathways (*e.g.*, inhalation of dust, food ingestion, and dermal contact) is generally reserved for longer-term exposure.

- Any unique lifestyle characteristics of the residents that could influence the amount of exposure received through secondary pathways. For example, the subsistence lifestyle practiced by many Aboriginal communities often includes the regular consumption of game meat, fish, beach food and natural plants, consistent with traditional land uses. Accordingly, allowance was made for the unique exposures that might be received by the Aboriginal people living in the LSA from a subsistence lifestyle. Reliance was placed on the *First Nations Food Nutrition and Environment Survey* (FNFNES) for BC (Chan *et al*. 2011) to describe the lifestyle characteristics such as consumption patterns of the Aboriginal peoples within the LSA. For the purpose of the HHRA, it was assumed that the consumption patterns of the Aboriginal communities located within the LSA for the Westridge Marine Terminal would be most similar to those described for ecozone/cultural area 6 (Pacific Maritime/Subarctic/Northwest Coast) of the FNFNES. For the urban dwellers, guidance provided by Health Canada (2010a) describing the typical lifestyle characteristics of the Canadian general population was assumed.

Table 3.6 offers a summary of the relevant exposure pathways considered for each of the lifestyle categories. Figure 3.4 of Appendix A presents the conceptual model for the residents and area users.

TABLE 3.6

EXPOSURE PATHWAYS FOR THE VARIOUS LIFESTYLE CATEGORIES

Relevant Exposure Pathway	Residents		Area Users
	Aboriginal Peoples	Urban Dwellers	
INHALATION			
Inhalation of air	√	√	√
Inhalation of dust	√	√	x
INGESTION			
Ingestion of soil (inadvertent)	√	√	x
Ingestion of drinking water[1]	x	x	x
Ingestion of surface water while swimming (inadvertent)	√	√	x
Ingestion of wild game (*e.g.*, moose, deer, elk, caribou, beaver, rabbit and grouse)	√	x	x
Ingestion of marine fish[2]	x	x	x
Ingestion of beach food (*e.g.*, clams, mussels, oysters, shrimp, prawns and crabs)	√	√	x
Ingestion of seaweed	√	x	x
Ingestion of wild berries (*e.g.*, soapberries, huckleberries, blueberries, blackberries, raspberries, strawberries and Saskatoon berries)	√	x	x
Ingestion of wild plants (*e.g.*, leaves, bark, roots and mushrooms)	√	x	x
Ingestion of home-garden produce (*e.g.*, fruit and vegetables)	√	√	x
DERMAL CONTACT			
Dermal contact with soil	√	√	x
Dermal contact with surface water while swimming	√	√	x

Notes:

1 It was assumed in the HHRA that people living with the LSA would obtain their drinking water from municipal sources. As the deposition of the chemical emissions associated with the Westridge Marine Terminal expansion is not expected to influence municipal drinking water quality, drinking water was not considered a relevant exposure pathway in the HHRA.

2 Marine fish ingestion was not considered a relevant pathway in the HHRA for the Westridge Marine Terminal because deposition of the chemical emissions associated with the Westridge Marine Terminal expansion is not expected to influence marine surface water quality, and subsequently fish tissue concentrations, in Burrard Inlet.

√ indicates that the exposure pathway will be evaluated in the HHRA for the specified lifestyle category

x indicates that the exposure pathway will *not* be evaluated in the HHRA for the specified lifestyle category

Residents

Aboriginal Peoples

Food consumption patterns, including the types of traditional foods consumed and the frequency and rate of consumption, were taken from those reported for Canadian First Nations in Health Canada's *Guidance on Human Health Preliminary Quantitative Risk Assessment* (Health Canada 2010a), and for Native Canadians in BC in the FNFNES (Chan *et al*. 2011). Unlike the SLHHRA in which the higher of the consumption rates provided by Chan *et al*. (2011) and Health Canada were assumed for the Aboriginal peoples living within the LSA, the current assessment preferentially selected the consumption patterns specified in the FNFNES for the "high consumers" of Native Canadians in BC. This refinement permits a more balanced assessment of the potential health risks that could be presented to Aboriginal peoples within the LSA.

Food consumption patterns in the FNFNES were obtained by 24-hour food recall surveys and a food frequency questionnaire. More than 1,100 interviews of First Nations people were completed province-wide. The FNFNES consumption rates for "high consumers" for such traditional foods as wild game, beach food, seaweed, wild plants and wild berries were assumed in the HHRA, and are described below.

The wild game consumption rates calculated from the FNFNES (Chan *et al*. 2011) for adult high consumers are:

- 155 grams per day for large mammals, including moose, deer, elk, caribou, black bear, and sheep;
- 4 grams per day for small mammals, including rabbit and beaver; and
- 2 grams per day for birds, including grouse, ducks and geese.

A consumption rate for beach food of 26 grams per day was calculated for adult high consumers based on the combined rates for prawn, crab, clam, shrimp, oysters, scallops and mussels (Chan *et al*. 2011). The FNFNES also provides a seaweed consumption rate for adult high consumers of 8 grams per day for First Nations people living in BC, wild root (rat root) consumption rate of less than 1 gram per day, a wild above-ground plant consumption rate of 4 grams per day for mushrooms, rosehips, Labrador tea leaves and balsam tree inner bark. An adult consumption rate of 44 grams per day was derived for wild berries, including soapberries, huckleberries, blueberries, blackberries, raspberries, strawberries and Saskatoon berries (Chan *et al*. 2011).

In addition to the consumption patterns described in the FNFNES (Chan *et al*. 2011), Aboriginal peoples living within the LSA were assumed to maintain a home-garden (Health Canada 2010a). Health Canada provides vegetable (root and other) ingestion rates for the Canadian general population based on 24-hour recall data collected in 1970 and 1972 as part of the Nutrition Canada Survey (Health Canada 1994, 2010a). The dietary survey involved a statistically representative sample of the Canadian population, personal interviews conducted by trained interviewers and 3D models of meal portions to assist in determining food portion sizes for some 180 different foods. Summary data are provided by Health Canada for vegetable (root and other) eaters only, which exclude individuals reporting no vegetable consumption to ensure that the consumption rates of the individuals who consume the majority of the vegetables are not under estimated. The adult ingestion rates provided by Health Canada for root vegetables and other vegetables are 188 grams per day and 137 grams per day, respectively. These consumption rates were adjusted, following CCME (2006) guidance, to reflect the smaller portion of the home-garden produce that a resident living in an urban environment might obtain locally. Specifically, the CCME (2006) suggests that residents may consume as much as 10% of their produce from a home-garden. Using this approach, the adult ingestion rate for root vegetables of 188 grams per day was scaled to 19 grams per day and the adult ingestion rate for above-ground vegetables of 137 grams per day was scaled to 14 grams per day to represent the adult ingestion rates for root and above-ground vegetables, respectively, obtained from a home-garden.

Table 3.7 lists the consumption rates assumed for Aboriginal peoples living within the LSA of the Westridge Marine Terminal.

TABLE 3.7

ASSUMED LOCAL FOOD CONSUMPTION RATES FOR ABORIGINAL PEOPLES

Local Foods	Consumption Rate [g/day]					Reference
	Infant[1]	Toddler	Child	Teen	Adult	
Wild game[2]						Chan *et al*. 2011, Health Canada 2010a
• Large mammal	0	49	72	100	155	
• Small mammal	0	1	2	3	4	
• Bird	0	1	1	1	2	
Beach food[3]	0	13	22	26	26	Chan *et al*. 2011, Health Canada 2007
Seaweed[4]	0	4	6	7	8	Chan *et al*. 2011, Health Canada 2010a
Wild berries[5]	3	19	36	40	44	Chan *et al*. 2011, Health Canada 1994
Wild plants[6]						Chan *et al*. 2011
• Above-ground	4	4	4	4	4	
• Below-ground (roots)	1	1	1	1	1	
Home-garden vegetables[7]						CCME 2006, Health Canada 2010a
• Above-ground	7	7	10	12	14	
• Below-ground (roots)	8	11	16	23	19	

Notes:

1 An infant's diet was assumed to be supplemented with breast milk using a consumption rate of 664 g/day (O'Connor and Richardson 1997).

2 The wild game consumption rates for the other life stages were calculated from the proportions provided in Health Canada's *Guidance on Human Health Preliminary Quantitative Risk Assessment* (Health Canada 2010a). Health Canada (2010a) indicates that teens, children and toddlers consume 65%, 46%, and 32% of the wild game consumed by an adult, respectively.

3 The beach food consumption rates for the other life stages were calculated from the proportions provided in the Food Directorate publication regarding mercury in fish and the health benefits of fish consumption (Health Canada 2007). Health Canada (2007) reported that children and toddlers consume 83% and 50% of the fish consumed by an adult, respectively. No proportion was given for the teen (Health Canada 2007); therefore, for this assessment, it is assumed that the teen and adult consume the same amount. These same proportions were assumed for beach food.

4 The seaweed consumption rates for the other life stages were calculated using the proportions provided in Health Canada (2010a) for other or above-ground vegetables.

5 The wild berry consumption rates for the other life stages were calculated using the proportions provided in Health Canada (1994) for plums, grapes, cherries, strawberries, blueberries and jams combined, which suggests that teens, children, toddlers and infants consume 90%, 82%, 44% and 8% of the wild berries consumed by an adult, respectively.

6 The wild plant consumption rates for the other life stages were assumed to equal to the consumption rates for an adult.

7 Based on the consumption rates for root vegetables and other vegetables provided by Health Canada (2010a), but assumed only 10% of the vegetables would be obtained from their home-garden, as per CCME (2006) guidance.

Urban Dwellers

For the urban dwellers, the consumption patterns assumed in the current assessment were identical to those chosen in the SLHHRA.

Health Canada (2007) provides a maximum daily consumption rate of 11 grams per day for shellfish. This rate was developed using consumption frequency and portion size information for the entire eaters only population surveyed by the Market Facts of Canada (1991) study (*i.e.*, 1 year old and above), and therefore, for the purposes of the HHRA, was assumed for each of the life stages assessed. Health Canada (2007) acknowledges that use of these rates likely overestimates the consumption rates for children (*i.e.*, 13 years and above) since children represent a relatively small percentage of the population surveyed (*i.e.*, 15%) as part of the Market Facts of Canada (1991) study.

Fruit consumption rates assumed for the urban dwellers are based on 24-hour recall data collected in 1970 and 1972 as part of the Nutrition Canada Survey (NCS) (Health Canada 1994). The dietary survey involved a statistically representative sample of the Canadian population, personal interviews conducted by trained interviewers, and 3D models of meal portions to assist in determining food portion sizes for some 180 different foods. Food consumption data for the recommended life stages were compiled by the Food Directorate of the Department of National Health and Welfare into 112 individual food composites. These data were grouped further to estimate the consumption rates that would be representative of the locally grown or harvested fruits that might be consumed by the urban dwellers. For example, the consumption rates reported for apples, applesauce, cherries, strawberries, blueberries, jams and honey

were compiled to estimate the fruit consumption rates. These fruit consumption rates were adjusted, following CCME (2006) guidance, to reflect the smaller portion of the home-garden produce that a resident living in an urban environment might obtain locally. Specifically, the CCME (2006) suggests that residents may consume as much as 10% of their produce (fruits and vegetables) from a home-garden. Using this approach, the adult ingestion rate for fruit of 46 grams per day was scaled to 5 grams per day to represent the adult ingestion rate for fruit obtained from local sources.

Similarly, the vegetable (root and other) ingestion rates recommended for the Canadian general population by Health Canada (2010a) were adjusted, following CCME (2006) guidance, to reflect the smaller portion of the home-garden produce that a resident living in an urban environment might obtain locally. These ingestion rates were discussed earlier for Aboriginal peoples.

Assumed consumption rates for the urban dweller are listed in Table 3.8 for the five life stages.

TABLE 3.8

ASSUMED LOCAL FOOD CONSUMPTION RATES FOR URBAN DWELLERS

Local Foods	Consumption Rate [g/day]					Reference
	Infant[1]	Toddler	Child	Teen	Adult	
Beach food	0	11	11	11	11	Health Canada 2007
Home-garden fruit[2]	0.1	4	7	6	5	CCME 2006, Health Canada 1994
Home-garden vegetables[3]						CCME 2006, Health Canada 2010a
• Above-ground	7	7	10	12	14	
• Below-ground (roots)	8	11	16	23	19	

Notes:
1 Infant's diet was assumed to be supplemented with breast milk using a consumption rate of 664 g/day (O'Connor and Richardson 1997).
2 Based on the sum of consumption rates for apples, applesauce, cherries, strawberries, blueberries, jams and honey provided by Health Canada (1994), but assumed only 10% of the fruit would be obtained from their home-garden, as per CCME (2006) guidance.
3 Based on the consumption rates for root vegetables and other vegetables provided by Health Canada (2010a), but assumed only 10% of the vegetables would be obtained from their home-garden, as per CCME (2006) guidance.

Area Users

The characterization of the area users was identical to the SLHHRA in which it was assumed that area users, unlike the residents, would be situated within the LSA for periods of 24 hours or less. Due to the short-term nature of their potential exposure to the chemical emissions, area users were assessed for effects resulting from acute inhalation only.

In the event that an area user frequents the LSA to swim in the local water bodies and/or harvest locally grown foodstuffs, it was assumed that the potential health risks associated with longer-term exposures such as these would be addressed in the assessment of the residents.

3.2.2 Exposure Assessment

As previously described, the primary objective of the Exposure Assessment is to estimate potential chemical exposures received by the residents and area users. Since the emissions will be released directly into air, people could be exposed *via* the primary exposure pathway of inhalation over both the short-term and long-term. Potential health risks associated with the inhalation of the COPC are evaluated in the inhalation assessment, discussed in detail in Section 3.2.2.1 Inhalation Assessment.

As a principal outcome of the Problem Formulation step of the assessment, it was determined that the residents might also be exposed to the chemical emissions on a long-term basis through secondary pathways of exposure. Potential health risks associated with the secondary pathways of exposure are assessed in the multiple pathway assessment. Details concerning the multiple pathway assessment are provided in Section 3.2.2.2 Multiple Pathway Assessment.

Consistent with the SLHHRA, three assessment cases were evaluated in the HHRA. These are:

- Base Case: includes existing conditions in the Air Quality RSA, including the chemical emissions from the existing Westridge Marine Terminal and existing marine vessel traffic in the Air Quality RSA.

- Application Case: existing conditions in the Air Quality RSA, plus the chemical emissions associated with the Westridge Marine Terminal expansion and the Project-related increase in marine vessel traffic within the Air Quality RSA.

- Cumulative Case: includes Application Case, plus the chemical emissions associated with the reasonably foreseeable increase in all other marine vessel traffic in the Air Quality RSA.

In addition to the above assessment cases, the incremental health risks were evaluated for: i) the Westridge Marine Terminal expansion and the Project-related increase in marine vessel traffic (*i.e.*, Project); and, ii) the reasonably foreseeable increase in all other marine vessel traffic in the region (*i.e.*, Future). Incremental changes in air concentrations associated with the Project were provided as part of Technical Report 5C-4 in Volume 5C (Air Quality and Greenhouse Gas Technical Report), while the incremental changes in air concentrations associated with the Future were calculated by subtracting the Base Case from the Cumulative Case.

3.2.2.1 Inhalation Assessment

Reliance was placed on air dispersion modelling performed by RWDI Air Inc. (RWDI), and described in Air Quality and Greenhouse Gas Technical Report (Technical Report 5C-4 in Volume 5C) and Marine Air Quality and Greenhouse Gas Marine Transportation Technical Report – Supplemental Report. Subsequent to the filing of the Application, the air dispersion modelling relating to the Westridge Marine Terminal and the associated marine vessel traffic was updated to reflect more refined engineering and marine transportation logistics proposed by Trans Mountain. The most noteworthy updates were made to:

- the chemical vapours that will be collected by the VCU and VRUs;

- the collection and destruction efficiencies of the VCU and VRUs;

- the fuel type for the main engines of the marine vessel traffic;

- the number of dedicated tug escorts used by laden tankers along the outbound shipping lane;

- the reasonably foreseeable increase in all non-Project-related marine vessel traffic; and

- the anticipated changes in future marine fuel regulations and more stringent NO_x emission requirements.

Predicted ground-level air concentrations of each of the COPC associated with the Westridge Marine Terminal expansion served as proxies of the inhalation exposures that people living in and/or frequenting the area might experience.

Exposure Estimates

Determination of potential ground-level air concentrations relied on both ambient measurements and predictive exposure modelling. The former approach involved the monitoring of chemicals in the Air Quality RSA. This approach was used in the Air Quality and Greenhouse Gas Technical Report (Technical Report 5C-4 in Volume 5C of the Application) to characterize the background concentrations of the COPC associated with the Westridge Marine Terminal expansion in air. The second approach involved use of predictive models to estimate the concentrations of the COPC emitted from the terminal to air. Further details concerning each approach are provided in Technical Report 5C-4 in Volume 5C of the Application, and summarized below.

Ambient Measurements

Measured ambient air concentrations of the COPC were obtained by RWDI from air quality monitoring stations within Metro Vancouver. Specifically, the measured ambient air concentrations of the CACs, with

the exception of NO_2, were obtained from the Burnaby Kensington Park monitoring station between 2009 and 2011. Burnaby Kensington Park station was selected as it is located in an area described by Metro Vancouver as "*typical of other surrounding areas within the North Burnaby Region*" (Metro Vancouver 2012a). The other monitoring stations in the Burnaby area were thought to be influenced by nearby sources, and therefore would not be representative of overall air quality in the LSA.

Following the *Guidelines for Air Quality Dispersion Modelling in British Columbia* (BC MOE 2008), background air concentrations of NO_2 were estimated by RWDI, from total atmospheric nitrogen oxides (NO_x) using the ambient ratio method (ARM). The primary emission of NO_x from the Westridge Marine Terminal is in the form of NO, which reacts in the atmosphere to form NO_2. The ARM was used by RWDI, in part, to account for the influence of ozone on the conversion of nitrogen oxide (NO) to NO_2. The ratio of one-hour NO_2/NO_x versus total NO_x was shown in Figure 3.15 of the Technical Report 5C-4 in Volume 5C of the Application. The annual background air concentrations of NO_2 were estimated using a single NO_2/NO_x ratio.

The only VOC monitoring station located within the LSA is the Burnaby Burmount National Air Pollution Surveillance (NAPS) station. Measured ambient air concentrations of the VOCs were obtained, when available, from the Burnaby Burmount NAPS station between 2001 and 2009.

The 98th percentile of one-hour, 8-hour or 24-hour ambient air concentrations measured at the aforementioned air quality monitoring stations within Metro Vancouver were used to represent the short-term background air concentrations within the LSA. Annual background air concentrations were based on the 50th percentile of one-hour measured ambient air concentrations.

Ambient air concentrations of the metals were obtained from Metro Vancouver's *Burrard Inlet Area Local Area Quality Study* (Metro Vancouver 2012b). The study provides 1-in-3 day speciation data at Burnaby South station for three distinct sampling periods: fall (October 8 to November 10, 2009), early spring (March 24 to April 14, 2010), and late spring (May 20 to June 18, 2010). As a result, there were 12, eight and 11 daily samples collected during the fall, early spring and late spring, respectively. Metro Vancouver (2012b) provides the distribution of the metal concentrations measured (*i.e.*, median, 25th and 75th percentiles, minimum and maximum) for the three sampling periods at the Burnaby South station. For the metals, the short-term background air concentrations assumed in the air quality assessment are based on the maximum of the 24-hour ambient air concentrations reported at the Burnaby South station. Annual background air concentrations are based on the median of the 24-hour ambient air concentrations.

Further details regarding the ambient measurements used to characterize background air concentrations in the LSA are provided in the Air Quality and Greenhouse Gas Technical Report in Technical Report 5C-4 in Volume 5C of the Application, and Marine Air Quality and Greenhouse Gas Marine Transportation Technical Report – Supplemental Report.

Predictive Modelling

Predicted ground-level air concentrations were evaluated in association with different averaging periods (*i.e.*, 10-minute, one-hour, 8-hour, 24-hour and annual) to allow for the assessment of both short-term and long-term inhalation health risks. On a short-term basis, peak (1st highest) 10-minute, one-hour, 8-hour and 24-hour ground-level air concentrations were used to evaluate the potential acute health risks. The exceptions being:

- The three year average of the 98th percentile (8th highest) of the yearly distribution of one-hour daily maximum NO_2 concentrations was used to evaluate the potential acute health risks (US EPA 2010a).
- The three year average of the 99th percentile (4th highest) of the yearly distribution of one-hour daily maximum SO_2 concentrations was used to evaluate the potential acute health risks (US EPA 2010b).

Long-term health risks were assessed using the maximum annual ground-level air concentrations.

Additional details regarding the predictive air modelling used to estimate the concentrations of the COPC associated with the Westridge Marine Terminal in air are provided in the Air Quality and Greenhouse Gas Technical Report in Technical Report 5C-4 in Volume 5C of the Application.

3.2.2.2 Multiple Pathway Assessment

In order to assess the potential health risks associated with possible secondary pathways, the HHRA identified those chemicals emitted by the Westridge Marine Terminal expansion that, although only emitted into air, may deposit nearby and possibly persist or accumulate in the environment in sufficient quantities for people to be exposed *via* soil, food and water pathways.

For this purpose, two categories were identified:

- Gaseous chemicals, which are unlikely to contribute to human exposure via secondary pathways (i.e., CO, NO2, SO2). In addition, the health effects of these gaseous chemicals are strictly related to inhalation (i.e., these act at the point of contact). Accordingly, the gaseous chemicals were removed from further consideration in the multiple pathway assessment and only evaluated in the inhalation assessment.

- Non-gaseous chemicals, which may deposit in the vicinity of the Project, and persist or accumulate in the environment in sufficient quantities for residents to be exposed via secondary pathways (e.g., metals and metalloids, PHCs, PAHs, sulphur-containing compounds and VOCs). The potential occurrence of these non-gaseous chemicals in the various secondary pathways of exposure required further consideration.

To identify the non-gaseous chemicals that could deposit nearby and possibly persist or accumulate in the environment, consideration was given to the intrinsic properties of the chemicals that influence their fate and persistence in the environment, and subsequently their potential occurrence in the secondary pathways of exposure. This was accomplished *via* the process outlined below. Due to their non-volatile, persistent and accumulative nature, metals and metalloids emitted by the Project were automatically examined in both the inhalation and multiple pathway assessments.

Comparison of Physical-Chemical Properties with Established Criteria for Volatility. The purpose of this step is to identify the chemicals emitted by the Project that are non-volatile and thus have the potential to accumulate in environmental media other than air, in accordance with the following criteria from the US EPA (2003):

- molecular weight ≥200 g/mol (or 2.0E+02 g/mol)
- Henry's Law Constant ≤0.00001 atm-m³/mol (or 1.0E-05 atm-m³/mol)
- vapour pressure ≤0.001 mmHg (or 1.0E-03 mmHg)

Physical-chemical properties (*i.e.*, molecular weight, Henry's Law Constant, vapour pressure, and octanol-water partitioning coefficient) were adopted from Syracuse Research Corporation (SRC 2013). If a property was not available from SRC (2013), the EPI Suite program developed by the US EPA (2011) was searched. For the PHC fractions, however, physical-chemical properties were sourced from CCME (2008a), whenever possible.

Comparison of Physical-Chemical Properties with Established Criteria for Bioaccumulation. The purpose of this step is to identify the chemicals emitted by the Project that have the potential to accumulate in living organisms, in accordance with the following criterion from Environment Canada (2007):

- octanol-water partitioning coefficient (Log K_{ow}) ≥5

Fugacity Modelling. Fugacity modelling was completed to determine the potential relative apportionment of the chemicals emitted by the Project in environmental compartments other than air, and subsequently the chemicals' potential occurrence in the secondary pathways of exposure. Fugacity model results were based on the "Level III" fugacity model developed by the US EPA (2011) that adheres to methods developed by MacKay *et al*. (1992, 1993). If a chemical was found to partition in soil, water or sediment more than 5%, there may be a realistic presence of the chemical in environmental media other than air (Boethling *et al.* 2009; Environment Canada 2003).

The premise of this exercise is that if a chemical emitted to the air does not meet any of these criteria, the potential for the chemical to deposit and persist or accumulate in the environment is negligible, and only limited opportunity exists for exposure *via* secondary pathways. Accordingly, these chemicals were removed from further consideration in the multiple pathway assessment and only evaluated in the inhalation assessment. However, if a chemical meets any one of these criteria, sufficient opportunity could be presented for exposure *via* secondary pathways, and the chemical was evaluated in both the inhalation and multiple pathway assessments.

Table 3.9 summarizes the relevant physical and chemical properties, and fugacity model results for each of the COPC associated with the Westridge Marine Terminal expansion, and identifies those COPC to be included in the multiple pathway assessment.

TABLE 3.9

IDENTIFICATION OF THE CHEMICALS OF POTENTIAL CONCERN FOR THE MULTIPLE PATHWAY ASSESSMENT

Chemical of Potential Concern[1]	Volatility[2]			Bioaccumulation[2]	Fugacity[2]			Included in Multiple Pathway Assessment
	Molecular Weight (g/mol)	Henry's Law Constant (atm m^3/mol)	Vapour Pressure	Log K_{ow}	Soil (%)	Water (%)	Sediment (%)	
CRITERIA:	≥2.0E+02	≤1.0E-05	≤1.0E-03	≥5.0	≥5	≥5	≥5	
PETROLEUM HYDROCARBON FRACTIONS								
Aliphatics C_1-C_4								No
• Acetylene	2.6E+01	2.2E-02	4.0E+04	0.37	0.02	0.1	0.0003	
• iso-Butane	5.8E+01	1.2E+00	2.6E+03	2.8	0.004	0.002	0.000006	
• n-Butane	5.8E+01	9.5E-01	1.8E+03	2.9	0.004	0.002	0.000006	
• Ethane	3.0E+01	5.0E-01	3.2E+04	1.8	0.004	0.005	0.00001	
• Ethylene	2.8E+01	2.3E-01	5.2E+04	1.1	0.005	0.01	0.00002	
• Methane	1.6E+01	6.6E-01	4.7E+05	1.1	0.004	0.004	0.000007	
• Propane	4.4E+01	7.1E-01	7.2E+03	2.4	0.004	0.003	0.000009	
• Propylene	4.2E+01	2.0E-01	8.7E+03	1.8	0.005	0.01	0.00003	
Aliphatics C_5-C_8	9.1E+01	9.9E-01	1.6E+02	3.8	0.005	0.002	0.00001	No
Aliphatics C_9-C_{16}	1.6E+02	5.7E+00	1.8E+00	**5.7**	0.01	0.0003	0.00003	**Yes**
Aromatics C_9-C_{16}	1.3E+02	5.3E-03	1.8E+00	3.6	2	0.5	0.05	No
Aromatics C_{17}-C_{34}	**2.2E+02**	1.6E-04	**4.2E-04**	3.9	**15**	4	**43**	**Yes**
POLYCYCLIC AROMATIC HYDROCARBONS								
Acenaphthene	1.5E+02	1.8E-04	2.2E-03	3.9	**8**	**8**	2	**Yes**
Anthracene	1.8E+02	5.6E-05	**6.5E-06**	4.5	**88**	2	3	**Yes**
Benzo(a)pyrene (and equivalents)								**Yes**
• Benz(a)anthracene	**2.3E+02**	1.2E-05	**2.1E-07**	**5.8**	**80**	1	**16**	
• Benzo(a)pyrene	**2.5E+02**	**4.6E-07**	**5.5E-09**	**6.1**	**82**	0.7	**16**	
• Benzo(b)fluoranthene	**2.5E+02**	**6.6E-07**	**5.0E-07**	**5.8**	**80**	0.7	**18**	
• Benzo(g,h,i)perylene	**2.8E+02**	**3.3E-07**	**1.0E-10**	**6.6**	**80**	0.5	**19**	
• Benzo(k)fluoranthene	**2.5E+02**	**5.8E-07**	**9.7E-10**	**6.1**	**82**	0.7	**16**	
• Chrysene	**2.3E+02**	**5.2E-06**	**6.2E-09**	**5.8**	**87**	1	**11**	
• Fluoranthene	**2.0E+02**	**8.9E-06**	**9.2E-06**	**5.2**	**65**	4	**18**	
• Indeno(1,2,3-c,d)pyrene	**2.8E+02**	**3.5E-07**	**1.3E-10**	**6.7**	**80**	0.5	**19**	
• Phenanthrene	1.8E+02	4.2E-05	**1.2E-04**	4.5	**40**	**9**	**12**	
Biphenyl	1.5E+02	3.1E-04	8.9E-03	4.0	3	**5**	0.7	**Yes**
Fluoranthene	**2.0E+02**	**8.9E-06**	**9.2E-06**	**5.2**	**65**	4	**18**	**Yes**
Fluorene	1.7E+02	9.6E-05	**6.0E-04**	4.2	**6**	**8**	2	**Yes**
Naphthalene	1.3E+02	4.4E-04	8.5E-02	3.3	**5**	**5**	0.4	**Yes**
Pyrene	**2.0E+02**	1.2E-05	**4.5E-06**	4.9	**87**	2	**8**	**Yes**
SULPHUR-CONTAINING COMPOUNDS								
Ethanethiol group								No
• n-Butanethiol	9.0E+01	4.5E-03	4.6E+01	2.3	0.2	0.4	0.002	

TABLE 3.9 Cont'd

Chemical of Potential Concern[1]	Volatility[2]			Bioaccumulation[2]	Fugacity[2]			Included in Multiple Pathway Assessment
	Molecular Weight (g/mol)	Henry's Law Constant (atm m^3/mol)	Vapour Pressure	Log K_{ow}	Soil (%)	Water (%)	Sediment (%)	
• Ethanethiol	6.2E+01	4.5E-03	5.3E+02	1.3	0.08	0.5	0.001	
• n-Hexanethiol	1.2E+02	1.1E-02	4.2E+00	3.2	0.2	0.2	0.002	
• iso-Propanethiol	7.6E+01	4.6E-03	2.8E+02	1.7	0.1	0.5	0.002	
• Thiophene	8.4E+01	2.3E-03	8.0E+01	1.8	0.4	0.9	0.005	
• sec-Butanethiol	9.0E+01	7.3E-03	8.1E+01	2.2	0.1	0.3	0.001	
VOLATILE ORGANIC COMPOUNDS								
Acetaldehyde	4.4E+01	6.7E-05	9.0E+02	-0.34	2	**10**	0.02	**Yes**
Acrolein	5.6E+01	1.2E-04	2.7E+02	-0.010	1	**8**	0.02	**Yes**
Benzene	7.8E+01	5.6E-03	9.5E+01	2.1	0.3	0.5	0.005	No
Chlorobenzene	1.1E+02	3.1E-03	1.2E+01	2.8	0.6	0.7	0.007	No
Cyclohexane	8.4E+01	1.5E-01	9.7E+01	3.4	0.01	0.02	0.0001	No
Ethylbenzene	1.1E+02	7.9E-03	9.6E+00	3.2	0.5	0.3	0.005	No
Formaldehyde	3.0E+01	**3.4E-07**	3.9E+03	0.35	**61**	**23**	0.04	**Yes**
Hexachlorobenzene	**2.8E+02**	1.7E-03	**1.8E-05**	**5.7**	**93**	0.6	0.4	**Yes**
n-Hexane	8.6E+01	1.8E+00	1.5E+02	3.9	0.004	0.001	0.000006	No
Propionaldehyde	5.8E+01	7.3E-05	3.2E+02	0.59	2	**10**	0.02	**Yes**
Styrene	1.0E+02	2.8E-03	6.4E+00	3.0	0.9	0.8	0.01	No
Toluene	9.2E+01	6.6E-03	2.8E+01	2.7	0.3	0.3	0.003	No
Trimethylbenzenes								No
• 1,2,3-Trimethylbenzene	1.2E+02	4.4E-03	1.7E+00	3.7	1	0.6	0.02	
• 1,2,4-Trimethylbenzene	1.2E+02	6.2E-03	2.1E+00	3.6	0.9	0.5	0.02	
• 1,3,5-Trimethylbenzene	1.2E+02	8.8E-03	2.5E+00	3.4	0.6	0.3	0.01	
Xylenes								No
• m-Xylene	1.1E+02	7.2E-03	8.3E+00	3.2	0.4	0.3	0.005	
• o-Xylene	1.1E+02	5.2E-03	6.6E+00	3.1	0.6	0.4	0.007	
• p-Xylene	1.1E+02	6.9E-03	8.8E+00	3.2	0.5	0.3	0.005	
OTHER								
PCBs	**2.9E+02**	4.2E-04	**4.9E-04**	**7.1**	**65**	2	**17**	**Yes**

Notes:

1 CO, NO_2 and SO_2 were not included in the physical-chemical screening as these chemicals predominantly exist in air, and therefore the health effects of these gaseous chemicals are strictly related to inhalation exposures. $PM_{2.5}$ and PM_{10} were excluded from the screening as these COPC represent chemical mixtures for which the physical-chemical properties and fugacity are not known. Metals and metalloids were not included in the physical-chemical screening because they were automatically included in the multiple pathway assessment.

2 With scientific notation, values are expressed either to the negative power (*i.e.*, E-x) or to the positive power *(i.e.*, E+x). For example, the molecular weight for acenaphthene is 1.5E+02 or 150 g/mol. Bold values indicate that the physical-chemical parameter meets or exceeds the pre-established criterion, and the chemical is eligible for inclusion in the multiple pathway assessment, provided that a defensible exposure limit is available. Physical-chemical parameters for all COPC were obtained from the following sources in the order of priority: SRC (2013), US EPA (2011) *(i.e.* EPISuite). The exception is for aliphatic and aromatic hydrocarbons where physical-chemical parameters were obtained from CCME (2008a).

The findings of the exercise indicate that more than 30 chemicals (or chemical groups) are eligible for inclusion in the multiple pathway assessment, provided that defensible exposure limits are available. The final list of chemicals assessed through multiple pathways of exposure is presented in Table 3.10.

TABLE 3.10

CHEMICALS OF POTENTIAL CONCERN TO BE EVALUATED IN THE MULTIPLE PATHWAY ASSESSMENT

Metals and Metalloids[1]	Petroleum Hydrocarbon Fractions	Polycyclic Aromatic Hydrocarbons	Volatile Organic Compounds	Other
Arsenic	Aliphatics C_9-C_{16}	Acenaphthene	Acetaldehyde	PCBs
Barium	Aromatics C_{17}-C_{34}	Anthracene	Acrolein	
Beryllium		Benzo(a)pyrene (and equivalents)	Formaldehyde	
Cadmium		Biphenyl	Hexachlorobenzene	
Chromium III		Fluoranthene	Propionaldehyde	
Chromium VI		Fluorene		
Cobalt		Naphthalene		
Copper		Pyrene		
Lead				
Manganese				
Methyl mercury				
Mercury				
Molybdenum				
Nickel				
Selenium				
Strontium				
Titanium				
Vanadium				
Zinc				

Notes:
1 Metals and metalloids were automatically included in the multiple pathway assessment.

Exposure Estimates

Determination of potential exposures to the COPC through multiple pathways relied on predictive exposure modelling alone.

Predictive Modelling

Determination of potential exposure to the chemicals through the various secondary pathways relied on predictive exposure modelling. Predictive exposure models, in turn, rely on the use of mathematical equations (algorithms) that define the movement of the chemicals from the point of release of the chemicals into the air to the point of contact with humans (Health Canada 2010a, US EPA OSW 2005). The following data were considered as part of the predictive exposure modelling:

- The maximum annual average ground-level air concentrations of a chemical as a result of atmospheric emissions from the Project, in combination with those from other regional sources.
- The various physical-chemical characteristics (*e.g.*, water solubility, volatility, deposition rates) that determine the fate and transport of the chemical in various environmental media and the food chain.
- The concentration of each chemical transported from air to other environmental compartments (*e.g.*, soil, water, vegetation and biota).
- The various exposure pathways identified in the Problem Formulation that could potentially contribute to uptake by humans.
- Absorption characteristics of each chemical once exposure has occurred.
- The activity patterns and characteristics of potentially exposed people (*e.g.*, respiration rate, food consumption rates).

The multiple pathway models predicted concentrations of the chemicals in environmental media under the Base Case, Application Case and Cumulative Case based on atmospheric deposition of the maximum predicted annual average air concentrations for each of the lifestyle categories (*i.e.*, Aboriginal peoples and urban dwellers).

The general approach to predicting chemical concentrations in environmental media is summarized in Table 3.11. Additional detail regarding the predictive exposure models used in the multiple pathway assessment is provided in Appendix B.

TABLE 3.11

APPROACH FOLLOWED TO PREDICT MULTIPLE PATHWAY EXPOSURE TO THE CHEMICALS OF POTENTIAL CONCERN FOR THE RESIDENTS

Environmental Media	Predictive Modelling
Air	Ambient air quality data collected at monitoring stations within the LSA were used to determine background contributions of the chemicals in the region. Air dispersion modelling incorporated meteorological data that represented conditions contributing to maximum predicted ground-level air concentrations of the chemical emissions. The maximum annual average air concentrations were predicted for each of the identified locations at which people are known or anticipated to spend time on a long-term basis, as well as the MPOI of the LSA. Ground-level air concentrations, including ambient measurements, were predicted for the Base Case, Application Case and Cumulative Case. Maximum annual average air concentrations were used in the predictive exposure models to determine: • Inhalation exposure for the residents (when applicable)[1]; • Inhalation exposure for wild game; • Chemical concentrations in soil, sediment, surface water, plants (*i.e.*, wild plants, home-garden vegetables and browse), fruit (*i.e.*, wild berries and home-garden fruits), and seaweed due to direct deposition; and • Chemical concentrations in plants (*i.e.*, wild plants, home-garden vegetables and browse), fruit (*i.e.*, wild berries and home-garden fruits), and seaweed due to direct uptake from the atmosphere.
Soil	Predictive exposure modelling for soil incorporated: • 80 years of deposition of the maximum annual average air concentrations; and • Chemical losses due to degradation and volatilization. Chemical concentrations in soil were predicted for the Base Case, Application Case and Cumulative Case. These soil concentrations were used in the predictive exposure models to determine: • Exposures relating to inhalation of dust, ingestion (inadvertent) of soil, and dermal contact with soil for the residents (*i.e.*, Aboriginal peoples and urban dwellers); • Exposures relating to ingestion of soil and dermal contact with soil for wild game; and • Chemical concentrations in plants (*i.e.*, wild plants, home-garden vegetables and browse) and fruit (*i.e.*, wild berries and home-garden fruit) due to root uptake.
Sediment	Predictive exposure modelling for sediment incorporated: • 80 years of deposition of the maximum annual average air concentrations predicted at locations along the Burrard Inlet; and • Chemical losses due to degradation and volatilization. Chemical concentrations in sediment were used in the predictive exposure model to determine chemical concentrations in beach food consumed by the residents (*i.e.*, Aboriginal peoples and urban dwellers).
Freshwater	Burnaby Lake was determined to be used for recreational purposes, including boating and potentially swimming. Predictive exposure modelling of Burnaby Lake incorporated: • 80 years of direct deposition of the maximum annual average air concentrations predicted over Burnaby Lake; • surface runoff; and • soil erosion loading. Chemical concentrations in surface water were used in the predictive exposure model to determine exposure relating to dermal contact with water and incidental ingestion of surface water while swimming for the residents (*i.e.*, Aboriginal peoples and urban dwellers).
Above-ground plants, including wild above-ground wild plants and home-garden vegetables	Predictive exposure modelling for above-ground plants incorporated: • 80 years of direct deposition of the maximum annual average air concentrations predicted residents (*i.e.*, Aboriginal peoples and urban dwellers); • Direct uptake from the atmosphere; and • Root uptake from soil. Chemical concentrations in above-ground plants were used in the predictive exposure models to determine: • Exposures relating to the ingestion of wild above-ground wild plants for Aboriginal peoples; • Exposure relating to the ingestion of above-ground home-garden vegetables for the residents (*i.e.*, Aboriginal peoples and urban dwellers); and • Exposure relating to the ingestion of forage for wild game.

TABLE 3.11 Cont'd

Environmental Media	Predictive Modelling
Below-ground plants, including wild roots and home-garden root vegetables	Predictive exposure modelling for below-ground plants incorporated root uptake from soil. Chemical concentrations in below-ground plants were used in the predictive exposure model to determine exposure relating to the ingestion of wild roots for Aboriginal peoples, and home-garden root vegetables for Aboriginal peoples and urban dwellers.
Fruit, including wild berries and home-garden fruit	Predictive exposure modelling for fruit incorporated: • 80 years of direct deposition of the maximum annual average air concentrations; • Direct uptake from the atmosphere; and • Root uptake from soil. Chemical concentrations in fruit were used in the predictive exposure model to determine exposures relating to the ingestion of wild berries for Aboriginal peoples, and local fruit for the urban dwellers.
Wild game	Predictive exposure modelling for wild game tissues incorporated: • The maximum annual average air concentrations predicted within the LSA (*i.e.*, MPOI); • Ingestion of invertebrates (if applicable); • Ingestion of soil and forage; • Ingestion of water from a local freshwater body; and • Chemical losses due to metabolism of the chemicals. Chemical concentrations in wild game tissues were used in the predictive exposure model to determine exposures relating to the ingestion of wild game for Aboriginal peoples.
Seaweed	Predictive exposure modelling for seaweed incorporated: • 80 years of direct deposition of the maximum annual average air concentrations predicted at locations along the Burrard Inlet; and • Direct uptake from the atmosphere. Chemical concentrations in seaweed were used in the predictive exposure model to determine exposure relating to the seaweed ingestion by Aboriginal peoples.
Beach food	Predictive exposure modelling for beach food was based on uptake from sediment. Chemical concentrations in beach food were used in the predictive exposure models to determine exposures relating to the ingestion of clams, mussels, oysters, shrimp, prawns and crabs by the residents (*i.e.*, Aboriginal peoples and urban dwellers).

Note:

1 Inhalation risk estimates associated with inhalation exposure were added to the multiple pathway risk estimates for the residents (*i.e.*, Aboriginal peoples and urban dwellers) when the chemical-specific inhalation and oral exposure limits were based on the same critical effect (*e.g.*, the non-carcinogenic inhalation and oral exposure limits for cadmium are both based on renal (*i.e.*, kidney) effects).

3.2.3 Toxicity Assessment

The Toxicity Assessment was concerned with identifying the types of health effects that can be caused by each of the COPC, and with understanding the conditions under which the effects are likely to occur *vis-à-vis* the amount, frequency and duration of exposure. This information can then be compared to the exposures that might be received by people in order to gauge the nature and severity of any health effects that might result. Highlights of which are provided below.

The Toxicity Assessment proceeded step-wise, as outlined below.

- First, the determination of the level of exposure or dose of each of the COPC that is unlikely to produce adverse health effects in humans. As indicated earlier, these levels are commonly referred to as exposure limits.

- Second, for those COPC for which exposure limits are not available, “surrogate” chemicals were identified. The use of surrogate substances is based on the guiding principle that states that the toxicity of any chemical is largely dependent on its molecular structure. Within limits, chemicals having similar structures will produce similar toxic responses. This principle allows the toxicity of a chemical for which health effects data are not available to be forecast on the basis of data that exist for a structurally-similar compound. The second chemical is termed a surrogate. The term ‘read across’ has been coined to describe the process by which the health effects data for the surrogate chemical are applied to other structurally-related compounds.

- Lastly, the determination of the additive interactions of the COPC.

3.2.3.1 Determination of the Exposure Limits

Exposure limits refer to the level of exposure or dose of the chemical that is unlikely to produce adverse health effects in humans. Exposure limits are deliberately intended to be protective of individuals who might be especially vulnerable to chemical exposures. A considerable amount of conservatism is typically embraced in their development.

Exposure limits are often segregated into different categories in recognition of the fact that the appearance and nature of toxic responses are very much dependent on the frequency and duration of exposure. Two categories were assigned:

- Acute Exposure Limit: refers to the amount, concentration or dose of a chemical that can be tolerated without evidence of adverse health effects on a short-term basis. These limits are routinely applied to conditions in which exposures extend over several hours or several days only.

- Chronic Exposure Limit: refers to the dose of a chemical that can be tolerated without evidence of adverse health effects on a long-term basis. These limits are routinely applied to conditions in which exposures extend over several months or years, possibly up to a lifetime.

Acute and chronic exposure limits were utilized in light of the need to address the potential health effects that could result from short-term and long-term exposure to the various chemical emissions associated with the Project. Reliance was placed on exposure limits developed or recommended by regulatory and/or leading scientific authorities as criteria (*e.g.*, objectives, guidelines or standards) for the protection of human health. The use of regulatory limits is a common practice among practitioners of risk assessment. These limits typically embrace a high degree of conservatism, in direct recognition of the mandate of most of the authorities to protect public health, including the health of infants and children, the elderly, and individuals who might be especially vulnerable to chemical exposures.

The sources of the acute and chronic exposure limits are listed below. Emphasis was given to regulatory limits that were health-based, and for which supporting documentation was available.

- Metro Vancouver
- British Columbia Ministry of the Environment (BC MOE)
- Alberta Environment and Sustainable Resource Development (ESRD)
- Agency for Toxic Substances and Disease Registry (ATSDR)
- American Conference of Governmental Industrial Hygienists (ACGIH)
- California's Office of Environmental Health Hazard Assessment (OEHHA)
- Canadian Council of Ministers of the Environment (CCME)
- Health Canada and Environment Canada
- Netherlands National Institute of Public Health and the Environment (RIVM)
- Ontario Ministry of the Environment (OMOE)
- Texas Commission on Environmental Quality (TCEQ)
- United States Environmental Protection Agency (US EPA)
- Washington State Department of Ecology (WA DOE)
- World Health Organization (WHO)

For inclusion in the HHRA, exposure limits were required to be:

- Protective of the health of the general public based on current scientific knowledge of the health effects associated with exposure to the chemical;
- Protective of sensitive individuals (i.e., infants and young children, the elderly, pregnant women, individuals with compromised health) through the incorporation of uncertainty or safety factors;
- Established or recommended by reputable scientific or regulatory authorities; and
- Supported by adequate documentation.

When these criteria were satisfied by more than one objective, guideline or standard, the most scientifically defensible exposure limit was typically selected. The scientific rationale for the selection of each exposure limit is provided in Appendix C of the SLHHRA in Technical Report 5D-7 in Volume 5D of the Application.

Recognizing that, based upon a chemical's mode of action or mechanism of toxicity, there are two general categories of chemicals: threshold and non-threshold.

For threshold chemicals, which are generally non-carcinogenic chemicals, a benchmark or threshold level must be exceeded for toxicity to occur. The degree of toxicity expressed then increases with increasing dose. For these chemicals, a no-observed-adverse-effect level (NOAEL) can be identified. A NOAEL is the dose or amount of the chemical that results in no obvious response in the most sensitive test species and test endpoint. The NOAEL is often used as the starting point for the calculation of these limits. In some cases, a Benchmark Dose (BMD) is derived, which represents the dose associated with a specific magnitude of response (*i.e.*, 5 or 10% incidence within the study population). In the derivation of exposure limits by leading scientific and regulatory authorities, uncertainty factors are then applied to lower the NOAEL or BMD by up to several thousand-fold, in part to accommodate the need to protect sensitive individuals. The limit is calculated as follows:

$$\text{Exposure Limit} = \frac{\text{NOAEL}}{\text{Uncertainty Factor(s)}}$$

It is important to note that in most instances, no empirical evidence exists to suggest that adverse health effects might occur at levels of exposure at or near the exposure limit (*i.e.*, the limits typically embrace sufficient margins-of-safety to accommodate modest excursions without threat of adverse health effects). Moreover, because of the conservatism involved, an exceedance of the exposure limit does not necessarily mean that health effects are certain or imminent.

Carcinogens are capable of producing cancer through one or more of a number of possible mechanisms (*e.g.*, mutagenicity, cytotoxicity, inhibition of programmed cell death, mitogenesis [uncontrolled cell proliferation] and immune suppression) that, in theory, do not require the exceedance of a threshold (US EPA 2005). In general, tumorigenicity data from animals or human epidemiological studies are examined using mathematical models to determine the chemical specific Unit Risks (URs) or Slope Factors (SFs), which are in turn used to develop applicable exposure limits. Regulatory agencies such as Health Canada and the US EPA assume that any level of long-term exposure to carcinogenic chemicals is associated with some "hypothetical cancer risk". As a result, relevant provincial and federal health authorities have specified an incremental (*i.e.*, over and above background) lifetime cancer risk of one extra cancer case in a population of 100,000 people, which these agencies consider acceptable, tolerable or essentially negligible (Alberta Health and Wellness 2011, BC MOE 2009, Health Canada 2010a). The benchmark of an acceptable cancer risk is policy-based, and its interpretation by various regulatory health authorities may differ (CCME 2006).

The exact terminology by which exposure limits are known will depend, in part, on the nature of the chemical, the nature of the exposure (*i.e.*, amount, frequency and duration), and the nature of the exposure pathway(s) involved. Also, terminology often varies between regulatory jurisdictions. The limits for the COPC are described by one of two terms, specifically:

- Reference Concentration (RfC): refers to the safe level of an airborne chemical for which the primary avenue of exposure is inhalation. It is expressed as a concentration of the chemical in air (*i.e.*, µg/m³) and applies only to threshold chemicals.

- Reference Dose (RfD): refers to the safe level or dose of a chemical for which exposure occurs through multiple pathways (*i.e.*, inhalation, ingestion and dermal). It is most commonly expressed in terms of the total intake of the chemical per unit of body weight (*i.e.*, µg/kg bw/day). This term applies only to threshold chemicals.

- Risk-Specific Concentration (RsC): reserved for carcinogens and refers to the level of an airborne carcinogen for which the primary route of exposure is inhalation that results in a regulatory acceptable incremental increase in cancer (typically one in 100,000). It is expressed as a concentration of the chemical in air (*i.e.*, µg/m³).

- Risk-Specific Dose (RsD): reserved for carcinogens and refers to the dose of a carcinogen for which exposure occurs through multiple pathways that results in a regulatory acceptable increased incidence of cancer (typically one in 100,000). It is expressed in terms of the total intake of the chemical (*i.e.*, µg/kg bw/day).

A complete list of the exposure limits identified in the Toxicity Assessment for each of the COPC associated with the expansion of the Westridge Marine Terminal is presented in Table 3.12. Further details are provided in Appendix C of the SLHHRA in Technical Report 5D-7 in Volume 5D of the Application.

3.2.3.2 Chemical Mixtures

Given that chemical exposures rarely occur in isolation, the potential health effects associated with mixtures of the COPC were assessed in the HHRA. The chemicals within a mixture may interact in different ways such that toxicity may be altered, possibly becoming enhanced (*i.e.*, additivity, synergism or potentiation), reduced (*i.e.*, antagonism) or remaining unchanged. The assessment of the health effects of chemical mixtures is challenging by virtue of the infinite number of chemical combinations that are possible. Recent efforts have been taken by several regulatory and leading scientific authorities to better understand the types of interactions involved and to develop methods for assessing mixtures (Boobis *et al.* 2011; European Commission 2012; Meek *et al*. 2011; Price *et al*. 2009; Price and Han 2011). These efforts have led to the following observations:

- Under certain conditions, chemicals can act in combination as a mixture in a manner that affects the overall level of toxicity.

- Chemicals with common modes of action can act jointly to produce combined effects that may be greater than the effects of each of the constituents alone. These effects are additive in nature.

- For chemicals having different modes of action, there is no robust evidence available to indicate that mixtures of such substances are of health or environmental concern provided the individual chemicals are present in amounts at or below their threshold dose levels.

- Interactions (including antagonism, potentiation and synergism) usually occur only at moderate to high dose levels (relative to the lowest effect levels), and are either unlikely to occur or to be of any toxicological significance at low or “environmentally relevant” exposure levels.

- If information is lacking on the mode(s) of action of chemicals in a mixture, it should be assumed by default that they will act in an additive fashion, with the manner and extent to which they may interact act determined on a case-by-case basis using professional judgment.

Based on these observations and in accordance with guidance from Health Canada (2010a), one approach to assessing chemical mixtures is to combine those chemicals which act through a common or similar toxicological mechanism and/or affect the same target tissues and/or organs in the body (*i.e.*, share commonality in effect), and assume that the overall toxicity of the mixture is equivalent to the sum

of the toxicities of the individual chemicals comprising the mixture. In other words, the chemicals are assumed to interact in an additive fashion (Health Canada 2010a).

The critical endpoints of the exposure limits used in the HHRA provided the basis for an individual chemical's inclusion in a chemical mixture. For example, the acute inhalation exposure limit for xylenes is based on its ability to cause respiratory irritation and neurological effects; therefore, xylenes were included in both the acute inhalation respiratory irritants and neurotoxicants mixtures.

The chemical mixtures assumed for the Westridge Marine Terminal expansion are listed in Table 3.13.

TABLE 3.12

SELECTED EXPOSURE LIMITS FOR USE IN THE HUMAN HEALTH RISK ASSESSMENT OF WESTRIDGE MARINE TERMINAL

Chemicals of Potential Concern	Acute Inhalation				Chronic Inhalation				Chronic Multiple Pathway Assessment			
	Duration	Value [µg/m³]	Critical Effect	Authority	Type	Value [µg/m³]	Critical Effect	Authority	Type	Value [µg/kg bw/d]	Critical Effect	Authority
CRITERIA AIR CONTAMINANTS												
CO	1-Hour	40,000	Hypoxia	US EPA	—	—	—	—	n/a	n/a	n/a	n/a
	8-Hour	10,000	Hypoxia	US EPA								
NO_2	1-Hour	200	Respiratory irritation	Metro Vancouver	RfC	40	Respiratory irritation	Metro Vancouver	n/a	n/a	n/a	n/a
		188	Respiratory irritation	US EPA								
$PM_{2.5}$	24-Hour	25	Morbidity and mortality	Metro Vancouver	RfC	8	Morbidity and mortality	BC MOE, Metro Vancouver	n/a	n/a	n/a	n/a
PM_{10}	24-Hour	50	Morbidity and mortality	BC MOE, Metro Vancouver	RfC	20	Morbidity and mortality	Metro Vancouver	n/a	n/a	n/a	n/a
SO_2	10-Minute	500	Respiratory irritation	WHO	—	—	—	—	n/a	n/a	n/a	n/a
	1-Hour	450	Respiratory irritation	BC MOE, Metro Vancouver								
		196	Respiratory irritation	US EPA								
METALS AND METALLOIDS												
Arsenic	1-Hour	0.2	Reproductive and developmental effects	OEHHA	RsC	0.0016	Lung tumours	Health Canada	RfD	0.3	Hyperpigmentation and keratosis	US EPA
									RsD	0.006	Bladder, liver and lung tumours	Health Canada
Barium	—	—	—	—	RfC	1.0	Cardiovascular effects Haematological effects	RIVM	RfD (food/soil)	200	Kidney effects	ATSDR
									RfD (water)	16	Cardiovascular effects	Health Canada
Beryllium	—	—	—	—	RfC	0.007	Respiratory irritation	OEHHA	RfD	2	Gastrointestinal effects	US EPA
					RsC	0.004	Lung tumours	US EPA				
Cadmium	24-Hour	0.03	Nasal and respiratory irritation	ATSDR	RfC	0.01	Kidney effects	ATSDR	RfD (food/soil)	1	Kidney effects	ATSDR
					RsC	0.002	Lung tumours	OEHHA	RfD (water)	0.5	Kidney effects	ATSDR
Chromium III	1-Hour	12	Respiratory irritation	TCEQ	RfC	0.14	Respiratory irritation	TCEQ	RfD	1,500	—	US EPA
Chromium VI	—	—	—	—	RfC	0.1	Respiratory irritation	US EPA	RfD	1.0	Gastrointestinal effects	ATSDR
					RsC	0.00013	Lung tumours	Health Canada				
Cobalt	—	—	—	—	RfC	0.1	Respiratory irritation	US EPA	RfD	1.4	Cardiovascular effects	RIVM
Copper	1-Hour	100	Respiratory irritation	OEHHA	RfC	1	Respiratory irritation Immunological effects	RIVM	RfD (birth to 4 yrs)	90	Liver effects	Health Canada
									RfD (5+ yrs)	100	Liver effects	Health Canada

TABLE 3.12 Cont'd

Chemicals of Potential Concern	Acute Inhalation				Chronic Inhalation				Chronic Multiple Pathway Assessment			
	Duration	Value [µg/m³]	Critical Effect	Authority	Type	Value [µg/m³]	Critical Effect	Authority	Type	Value [µg/kg bw/d]	Critical Effect	Authority
Lead[1]	—	—	—	—	—	—	—	—	—	—	—	—
Manganese	—	—	—	—	RfC	0.09	Neurological effects	OEHHA	RfD (food)	47	Neurological effects	US EPA
									RfD (soil/water)	140	Neurological effects	US EPA
Methyl mercury[2]	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	RfD	0.1	Reproductive and developmental effects Neurological effects	US EPA
Mercury	1-Hour	0.6	Neurological effects Reproductive and developmental effects	OEHHA	RfC	0.03	Neurological effects	OEHHA	RfD	0.57	Kidney effects	WHO
Molybdenum	—	—	—	—	RfC	12	—	RIVM	RfD	5	—	US EPA
Nickel	1-Hour	0.2	Immunological effects	OEHHA	RfC	0.014	Nasal and respiratory irritation	OEHHA	RfD	11	Reproductive and developmental effects	OEHHA
					RsC	0.0077	Lung tumours	Health Canada				
Selenium	—	—	—	—	RfC	20	Liver effects Neurological effects	OEHHA	RfD	5	Liver effects Neurological effects	US EPA
Strontium	—	—	—	—	—	—	—	—	RfD	600	Developmental effects Skeletal effects	US EPA
Titanium	—	—	—	—	RfC	0.1	Nasal and respiratory irritation	ATSDR	—	—	—	—
Vanadium	1-Hour	30	Respiratory irritation	OEHHA	RfC	0.1	Respiratory irritation	ATSDR	RfD	2	Reproductive and developmental effects	RIVM
Zinc	1-Hour	250	Respiratory irritation	ACGIH (adjusted)	—	—	—	—	RfD	300	—	US EPA
PETROLEUM HYDROCARBON FRACTIONS												
Aliphatics C_1-C_4[3]	1-Hour	78,000	Neurological effects	TCEQ	RfC	3,000	Nasal effects Kidney effects	OEHHA	n/a	n/a	n/a	n/a
Aliphatics C_5-C_8	1-Hour	200,000	—	TCEQ	RfC	18,400	Neurological effects	CCME, TPHCWG	n/a	n/a	n/a	n/a
Aliphatics C_{9-16}	—	—	—	—	RfC	200	Neurological effects	MA DEP	RfD	100	Kidney effects Liver effects	TPHCWG
Aromatics C_9-C_{16}	1-Hour	2,000	Eye irritation	ACGIH (adjusted)	RfC	50	Liver effects Kidney effects	MA DEP	n/a	n/a	n/a	n/a

TABLE 3.12 Cont'd

Chemicals of Potential Concern	Acute Inhalation				Chronic Inhalation				Chronic Multiple Pathway Assessment			
	Duration	Value [µg/m³]	Critical Effect	Authority	Type	Value [µg/m³]	Critical Effect	Authority	Type	Value [µg/kg bw/d]	Critical Effect	Authority
Aromatics C_{17}-C_{34}	—	—	—	—	—	—	—	—	RfD	30	Kidney effects	CCME, MA DEP, TPHCWG
POLYCYCLIC AROMATIC HYDROCARBONS												
Acenaphthene	—	—	—	—	—	—	—	—	RfD	60	Liver effects	US EPA
Anthracene	—	—	—	—	—	—	—	—	RfD	300	—	US EPA
Benzo(a)pyrene[4] (and equivalents)	—	—	—	—	RsC – Approach 1	0.00012	Lung tumours	WHO	RsD – Approach 2	0.0014	Gastrointestinal tumours	US EPA
					RsC – Approach 2	0.32	Lung tumours	Health Canada				
Biphenyl	—	—	—	—	—	—	—	—	RfD	500	Kidney effects	US EPA
									RsD	1.25	Liver tumours	US EPA
Fluoranthene	—	—	—	—	—	—	—	—	RfD	40	Kidney effects Liver effects	US EPA
Fluorene	—	—	—	—	—	—	—	—	RfD	40	Kidney effects Liver effects Spleen effects	US EPA
Naphthalene	1-Hour	2,000	Eye irritation	ACGIH (adjusted)	RfC	3	Nasal irritation	US EPA	RfD	20	—	Health Canada, US EPA
Pyrene	—	—	—	—	—	—	—	—	RfD	30	Kidney effects	US EPA
SULPHUR-CONTAINING COMPOUNDS												
Ethanethiol group[5]	1-Hour	2,500	Respiratory irritation	US EPA	—	—	—	—	n/a	n/a	n/a	n/a
VOLATILE ORGANIC COMPOUNDS												
Acetaldehyde	1-Hour	470	Eye, nasal and respiratory irritation	OEHHA	RfC	390	Nasal irritation	Health Canada	—	—	—	—
					RsC	17.2	Nasal tumours	Health Canada				
Acrolein	1-Hour	2.5	Eye, nasal and respiratory irritation	OEHHA	RfC	0.35	Nasal irritation	OEHHA	RfD	0.5	—	US EPA
Benzene	1-Hour	580	Immunological effects	TCEQ	RfC	9.8	Hematological effects Immunological effects	ATSDR	n/a	n/a	n/a	n/a
					RsC	1.3	Leukemia	US EPA				
Chlorobenzene	1-Hour	47,000	Neurological effects	US EPA	RfC	10	Kidney effects	Health Canada	n/a	n/a	n/a	n/a
Cyclohexane	—	—	—	—	RfC	6,000	Reproductive and developmental effects	US EPA	n/a	n/a	n/a	n/a
Ethylbenzene	1-Hour	21,700	Neurological effects	ATSDR	RfC	260	Kidney effects	ATSDR	n/a	n/a	n/a	n/a
Formaldehyde	1-Hour	50	Eye and nasal irritation	ATSDR	RfC	11	Eye, nasal and respiratory irritation	TCEQ	RfD	150	Gastrointestinal effects Kidney effects	Health Canada
					RsC	0.8	Nasal tumours	US EPA				

TABLE 3.12 Cont'd

Chemicals of Potential Concern	Acute Inhalation				Chronic Inhalation				Chronic Multiple Pathway Assessment			
	Duration	Value [µg/m³]	Critical Effect	Authority	Type	Value [µg/m³]	Critical Effect	Authority	Type	Value [µg/kg bw/d]	Critical Effect	Authority
Hexachlorobenzene	—	—	—	—	—	—	—	—	RfD	0.8	Liver effects	US EPA
									RsD	0.006	Adrenal, kidney and liver tumours	OEHHA
n-Hexane	—	—	—	—	RfC	670	Neurological effects	TCEQ	n/a	n/a	n/a	n/a
Propionaldehyde	1-Hour	110,000	Eye, nasal and respiratory irritation	US EPA	RfC	8	Nasal irritation	US EPA	—	—	—	—
Styrene	1-Hour	21,000	Eye and nasal irritation Neurological effects	OEHHA, TCEQ	RfC	470	Neurological effects	TCEQ	n/a	n/a	n/a	n/a
Toluene	1-Hour	15,000	Eye and nasal irritation Neurological effects	TCEQ	RfC	5,000	Neurological	US EPA	n/a	n/a	n/a	n/a
Trimethylbenzenes	1-Hour	690,000	Neurological effects	US EPA	RfC	5	Neurological effects	US EPA	n/a	n/a	n/a	n/a
Xylenes	1-Hour	7,400	Respiratory irritation Neurological effects	TCEQ	RfC	610	Eye and nasal irritation Neurological effects	TCEQ	n/a	n/a	n/a	n/a
OTHER												
PCBs[6]	—	—	—	—	—	—	—	—	RfD	0.13	—	Health Canada

Notes:

— not available

n/a not applicable

1 The current state of the science prevents the use of any of the available exposure limits for lead.

2 Although the Project will not emit methyl mercury directly to the environment, the inorganic mercury emitted to air might deposit to local surface water bodies and bio-transform to methyl mercury. On this basis, methyl mercury, in addition to inorganic mercury, was identified as a COPC in the multiple pathway assessment of the HHRA.

3 Aliphatics C_1-C_4 includes acetylene, iso-butane, n-butane, ethane, ethylene, methane, propane and propylene. An acute inhalation limit for iso-butane and a chronic inhalation limit for propylene were used to assess the potential health risks associated with the aliphatic petroleum hydrocarbon compounds containing fewer than five carbon atoms.

4 Benzo(a)pyrene (and equivalents) includes all the carcinogenic PAHs for which a potency equivalency factors (PEF) has been assigned by Health Canada (2010a). This includes benz(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(g,h,i)perylene, benzo(k)fluoranthene, chrysene, fluoranthene, indeno(1,2,3 cd)pyrene, and phenanthrene. These carcinogenic PAHs were evaluated using two distinct approaches:

- Approach 1: a mixture of carcinogenic PAHs was evaluated based on its benzo(a)pyrene content. The use of benzo(a)pyrene as an indicator of the potency of the mixture is based on the WHO review of air quality guidelines for PAHs (WHO 2000). Benzo(a)pyrene was chosen as the indicator PAH as its toxicity is best characterized out of all the carcinogenic PAH compounds.
- Approach 2: the mixture of carcinogenic PAHs is evaluated by summing each individual PAHs toxic equivalency to benzo(a)pyrene (*i.e.*, the toxic equivalency quotient [TEQ] approach). The toxic equivalencies of the PAH groups were determined using potency equivalency factors that have been adopted by Health Canada (2010a).

5 Ethanethiol group includes n-butanethiol, sec-butanethiol, ethanethiol, n-hexanethiol, iso-propanethiol and thiophene. An acute inhalation limit for ethanethiol was used to assess the potential health risks associated with aliphatic compounds containing a sulfhydryl (–C–SH or R–SH) group.

6 PCBs refers to total PCBs. PCBs often exist as a mixture of congeners; however, the emission factor used in the air quality assessment to predict the ground-level air concentrations of PCBs was for total PCBs and not the individual congeners. As a result, the exposure limit selected for the purpose of the HHRA was based on total PCBs.

TABLE 3.13

ASSUMED CHEMICAL MIXTURES FOR WESTRIDGE MARINE TERMINAL

Exposure Scenario	Critical Effect	Chemical Mixture Designation	Chemical Mixture Constituents
Acute Inhalation	Eye irritation	Eye irritants[1]	Acetaldehyde, Acrolein, Aromatics C_9-C_{16}, Formaldehyde, Propionaldehyde, Styrene, Toluene
	Nasal irritation	Nasal irritants	Acetaldehyde, Acrolein, Cadmium, Formaldehyde, Propionaldehyde, Styrene, Toluene
	Respiratory irritation	Respiratory irritants[2]	Acetaldehyde, Acrolein, Cadmium, Chromium III, Copper, NO_2, Propionaldehyde, SO_2, Ethanethiol group, Vanadium, Xylenes, Zinc
	Reproductive and developmental effects	Reproductive and developmental toxicants	Arsenic, Mercury
	Immunological effects	Immunotoxicants	Benzene, Nickel
	Neurological effects	Neurotoxicants	Aliphatics C_1-C_4, Chlorobenzene, Ethylbenzene, Mercury, Styrene, Toluene, Trimethylbenzenes, Xylenes
Chronic Inhalation	Eye irritation	Eye irritants	Formaldehyde, Xylenes
	Nasal irritation	Nasal irritants	Acetaldehyde, Acrolein, Aliphatics C_1-C_4, Formaldehyde, Propionaldehyde, Nickel, Naphthalene, Titanium, Xylenes
	Respiratory irritation	Respiratory irritants	Beryllium, Chromium III, Chromium VI, Cobalt, Copper, Nickel, NO_2, Titanium, Vanadium, Formaldehyde
	Hematological effects	Hematotoxicants	Barium, Benzene
	Immunological effects	Immunotoxicants	Benzene, Copper
	Kidney effects	Renal toxicants	Aliphatics C_1-C_4, Aromatics C_9-C_{16}, Cadmium, Chlorobenzene, Ethylbenzene
	Liver effects	Hepatotoxicants	Aromatics C_9-C_{16}, Selenium
	Neurological effects	Neurotoxicants[3]	Aliphatic C_5-C_8, Aliphatic C_9-C_{16}, n-Hexane, Manganese, Mercury, Selenium, Styrene, Toluene, Trimethylbenzenes, Xylenes
	Nasal tumours	Nasal carcinogens	Acetaldehyde, Formaldehyde
	Lung tumours	Lung carcinogens[4]	Arsenic, Benzo(a)pyrene (and equivalents), Beryllium, Cadmium, Chromium VI, Nickel
Chronic Multiple Pathway	Cardiovascular effects	Cardiovascular toxicants	Barium, Cobalt
	Reproductive and developmental effects	Reproductive and developmental toxicants	Methyl mercury, Nickel, Strontium, Vanadium
	Gastrointestinal effects	Gastrointestinal toxicants	Beryllium, Chromium VI, Formaldehyde
	Kidney effects	Renal toxicants	Aliphatics C_9-C_{16}, Aromatics C_{17}-C_{34}, Barium, Biphenyl, Cadmium, Fluoranthene, Fluorene, Formaldehyde, Mercury, Pyrene
	Liver effects	Hepatotoxicants	Aliphatics C_9-C_{16}, Acenaphthene, Copper, Fluoranthene, Fluorene, Hexachlorobenzene, Selenium
	Neurological effects	Neurotoxicants	Manganese, Methyl mercury, Selenium
	Liver tumours	Liver carcinogens	Arsenic, Biphenyl, Hexachlorobenzene

Notes:
1 Naphthalene was not added to the acute eye irritants mixture as it was already accounted for as part of the aromatics C_9-C_{16}.
2 The highest risk estimate of the averaging times (10-minute versus 1-hour) for SO_2 and statistics (1st highest versus US EPA percentile) for SO_2 and NO_2 was used in the prediction of the potential health risks for the acute respiratory irritants mixture.
3 Some COPC were assessed both individually and as part of a chemical group. In these cases, the risk estimates are likely to be exaggerated due to the "double counting" of these chemicals in the mixtures. This occurs in the case of n-hexane and the aliphatics C_5-C_8 in the chronic inhalation neurotoxicants mixture.
4 The highest risk estimate of the two approaches used to evaluated benzo(a)pyrene (and equivalents) was used in the prediction of the potential health risks for the chronic lung carcinogens mixture.

3.2.4 Risk Characterization

The Risk Characterization step of the HHRA was concerned with quantifying or otherwise estimating the potential health risks that could be presented to people as a result of exposure to the emissions associated with the Project. This involves the calculation of risk estimates based on comparison of the exposure estimates (determined as part of the Exposure Assessment step) against the corresponding exposure limits (determined as part of the Toxicity Assessment step). For the present HHRA, the risk estimates are expressed as risk quotients (RQs) for the non-carcinogenic COPC, and as incremental lifetime cancer risks (ILCRs) for the carcinogenic COPC.

Details surrounding both types of risk estimates are given below.

3.2.4.1 Calculation of Risk Quotients for Non-Carcinogens

The RQs are calculated as shown below:

$$RQ = \frac{\text{Exposure Estimate (µg/m}^3\text{ or µg/kg/bw/d)}}{\text{Exposure Limit (µg/m}^3\text{ or µg/kg/bw/d)}}$$

For non-carcinogens, interpretation of the RQs varied according to the exposure pathway being assessed, with a different convention followed for inhalation exposures versus multiple pathway exposures. An RQ of 1.0 represents a level of risk that would typically be deemed acceptable by the federal and provincial regulatory health authorities (Alberta Health and Wellness 2011, BC MOE 2009, Health Canada 2010a). A RQ of less than or equal to 1.0 signifies that the estimated exposure is less than or equal to the exposure limit. For comparison to a benchmark (or target RQ) of 1.0, the regulatory health authorities require that the RQ account for background exposures and exposure from multiple media (if applicable). When unable to account for these types of exposures, Health Canada recommends that a target RQ of 0.2 (*i.e.*, five possible exposure pathways, each accounting for 20% of exposure) be employed to ensure that the potential health risks not be understated (Health Canada 2010a).

In the inhalation assessment, background or measure ambient air concentrations were incorporated in the predicted air concentrations under the three assessment cases (*i.e.*, Base, Application and Cumulative cases); therefore, interpretation of the inhalation RQs for non-carcinogenic COPC proceeded assuming the target RQ of 1.0 as follows:

RQ ≤ 1.0 — Signifies that the estimated exposure is less than or equal to the exposure limit. Given the level of conservatism incorporated in the derivation of both the exposure estimate and the exposure limit, risk estimates less than or equal to 1.0 are associated with a negligible or low health risk and no adverse health effects would be expected.

RQ > 1.0 — Signifies that the estimated exposure exceeds the exposure limit. This suggests the possibility of some potential risk, the significance of which must be balanced against degree of conservatism incorporated into the assessment. Generally this requires that the conservative assumptions used in the Exposure Assessment and Toxicity Assessment steps be reviewed to determine to what extent the predicted health risks may have been overstated.

For the multiple pathway assessment, although exposures from multiple media were accommodated, background exposures were not; therefore, interpretation of the multiple pathway RQs for non-carcinogenic COPC proceeded assuming the target RQ of 0.2 as follows:

RQ ≤ 0.2 — Signifies that the estimated exposure is less than or equal to $1/5^{th}$ the exposure limit. Given the level of conservatism incorporated in the derivation of both the exposure estimate and the exposure limit, RQs less than or equal to 0.2 are associated with a negligible or low health risk and no adverse health effects would be expected.

RQ > 0.2 — Signifies that the estimated exposure exceeds $1/5^{th}$ the exposure limit. This suggests the possibility of some potential risk, the significance of which must be balanced against the degree of conservatism incorporated into the assessment. Generally this requires that the conservative assumptions used in the exposure assessment and toxicity assessment be reviewed to determine to what extent the predicted health risks may have been overstated.

3.2.4.2 Calculation of Incremental Lifetime Cancer Risk for Carcinogens

As previously mentioned, regulatory health authorities such as Health Canada, BC MOE and ESRD assume that any level of long-term exposure to carcinogenic chemicals is associated with some hypothetical cancer risk. On this basis, Health Canada, BC MOE and ESRD have specified an incremental (*i.e.*, over and above background) lifetime cancer risk of one in 100,000, which these regulatory health authorities consider acceptable, tolerable or essentially negligible (Alberta Health and Wellness 2011, BC MOE 2009, Health Canada 2010a). Because this assumed acceptable cancer risk

level was specifically developed to address cancer risks over and above background cancer incidence, a portion of which includes background exposure to environmental pollutants, background exposures were not included in the assessment of potential health risks for non-threshold (*i.e.*, carcinogenic) chemicals.

For the purpose of the HHRA, ILCRs were calculated for the carcinogenic COPC by comparing the predicted incremental levels of exposure associated with the expansion of the Westridge Marine Terminal and the Project-related increase in marine vessel traffic (*i.e.*, Project), and all reasonably foreseeable developments in the region (*i.e.*, Future) to their respective exposure limits.

The ILCRs are calculated for the Project and Future as shown below:

$$\text{ILCR} = \frac{\text{Incremental Exposure Estimate (µg/m}^3\text{ or µg/kg/bw/d)}}{\text{Carcinogenic Exposure Limit (µg/m}^3\text{ or µg/kg/bw/d)}}$$

Interpretation of these ILCRs was based on comparison of the ILCR against the *de minimus* risk level of one in 100,000 (*i.e.*, one extra cancer case in a population of 100,000 people) established by the relevant federal and provincial health authorities (Alberta Health and Wellness 2011, BC MOE 2009, Health Canada 2010a). The interpretation proceed as follow:

ILCR ≤ 1.0 Signifies a *de minimus* incremental lifetime cancer risk (*i.e.*, less than one extra cancer case in a population of 100,000 people).

ILCR > 1.0 Signifies an incremental lifetime cancer risk exceeding 1 x 10^{-5} (*i.e.*, one extra cancer case in a population of 100,000 people). The significance of the risk should be evaluated against the conservative assumptions used in the HHRA.

3.2.4.3 Calculation of Risk Estimates for Chemical Mixtures

To evaluate the potential additive effects of COPC with common toxicological endpoints, the combined RQs or ILCRs were calculated for the chemical mixtures as follows, using the respiratory irritants mixture as an example:

$$\text{RQ for the Respiratory Irritants Mixture} = \text{RQ for Respiratory Irritant No. 1} + \text{RQ for Respiratory Irritant No. 2} + \textit{etc.}$$

3.3 Uncertainty and Confidence

Table 3.14 presents a summary of the major assumptions applied in the HHRA and the associated uncertainties, arranged according to the steps of the risk assessment paradigm. Examination of the table shows that conservatism was introduced at virtually every step of the assessment, and extended to both the Exposure Assessment and Toxicity Assessment of the HHRA.

TABLE 3.14

MAJOR ASSUMPTIONS APPLIED AND ASSOCIATED UNCERTAINTY IN THE HUMAN HEALTH RISK ASSESSMENT

Risk Assessment Step	Major Assumptions	Discussion of the Associated Uncertainty
Problem Formulation	Persons might be found anywhere within the LSA, presenting the possibility that they could be exposed to the peak one-hour or maximum 24-hour predicted air concentrations (*i.e.*, MPOI) for the area.	Inclusion of the MPOI is expected to contribute to the overstatement of the exposures that might actually be received by area users as it is unlikely that individuals would be present at the MPOI at the exact time when the meteorological conditions contributing to the peak one-hour or maximum 24-hour air concentrations occur. As a result, this assumption is conservative.
	Residents will be exposed 24 hours per day, 365 days per year for the entire duration of their lives (*i.e.*, 80 years) to the maximum annual average air concentrations.	Chronic inhalation risk estimates for the non-carcinogens were predicted for each lifestyle category based on the assumption that individuals would be exposed 24 hours per day, 365 days per year to the maximum predicted air concentrations of the COPC for the entire duration of their lives (*i.e.*, 80 years). It is not known how long people will live in the area of the Project-related emission sources, nor is it certain how long the Project will be in operation. In light of this uncertainty, the HHRA conservatively assumed that people would be exposed to emissions in the area throughout the duration of their lives. Specifically, that the residents would not leave the area and that the Project would be operating for the entire duration of their lives (*i.e.*, 80 years).
	Aboriginal peoples will obtain 100% of their food from local sources (*e.g.*, fish, beach foods, seaweed, wild game, wild berries, wild plants and home-garden vegetables).	The assumption that Aboriginal peoples obtain all of their food over their lifetime from the area likely contributes to the overstatement of the exposures that might be received under actual circumstances. This assumption is especially conservative with respect to the consumption of beach food as there is a ban on shellfish harvesting from within Burrard Inlet due to elevated coliform levels (DFO 2013). As well, It is therefore unlikely that Aboriginal peoples would harvest all of their beach food from Burrard Inlet.
	Urban dwellers will obtain 10% of their home-garden produce (*e.g.*, fruit and vegetables), and 100% of their fish and beach foods from local sources.	The assumption that urban dwellers obtain all of their fish and beach food over their lifetime from the area likely contributes to the overstatement of the exposures that might be received by these people under actual circumstances. This assumption is especially conservative with respect to the consumption of beach food as there is a ban on shellfish harvesting from within Burrard Inlet due to elevated coliform levels (DFO 2013). It is therefore unlikely that urban dwellers would harvest all of their beach food from Burrard Inlet.
Exposure Assessment	Air dispersion modelling incorporated meteorological data that represented conditions contributing to maximum predicted ground-level air concentrations of the COPC.	This is particularly important in the acute inhalation assessment in which the peak one-hour or maximum 24-hour (*i.e.*, 1st highest) predicted ground-level air concentrations of COPC were used in the prediction of the potential health risks. This assumption likely contributes to the overstatement of the actual short-term exposures that might be received by people residing in or visiting the area under most circumstances. Maximum annual average concentrations were used to represent chronic exposures, providing a reasonably conservative estimate of chronic health risks.
	Wild game will be present and harvested within the LSA.	Meat concentrations were predicted using the maximum predicted ground-level air concentrations within the LSA (*i.e.*, MPOI). It is unlikely that wild game will forage at one fixed location over their entire lifetime. Assuming that wild game will forage at the location where the maximum concentrations are predicted in air, soil, water and vegetation over their lifetime likely overstates the exposures to people who consume wild game.
	Metals and metalloids are 100% bioavailable.	Metals and metalloids are typically less than 100% bioavailable. This assumption therefore likely contributes to the overstatement of the exposures that might be received by the residents under actual circumstances.
Toxicity Assessment	Exposure limits were developed to be protective of sensitive and more susceptible individuals in the general population (*e.g.*, infants and young children, the elderly, individuals with compromised health) (ATSDR 2013, US EPA 2002).	A considerable amount of conservatism is incorporated in the exposure limits. Limits are deliberately set to be protective of sensitive individuals. The use of uncertainty factors is already directed, in part, toward the protection of sensitive individuals.
	The findings from toxicity studies with laboratory rodents can be used to gauge the types of responses and health effects that the chemicals may cause in humans and the findings from the laboratory rodent studies can be used, in part, to determine exposure limits for the chemicals.	Laboratory rodents have traditionally served as suitable surrogate species for humans. The use of uncertainty factors accounts for the possible differences in responses to chemicals that might be observed between laboratory rodents and other species, such as humans (see Appendix C of the SLHHRA in Technical Report 5D-7 in Volume 5D). However, recent evidence suggests that rodents might be more sensitive to nasal effects than humans as a result of higher doses reaching the critical target site or tissue in rodents (Dorman *et al.* 1999, Harkema *et al.* 2006, Kimbell 2006, Reznik 1990, Reznik and Stinson 1983). In some instances, these differences contribute uncertainty to the predicted results with respect to COPC with nasal effects as the critical toxicological effect.

TABLE 3.14 Cont'd

Risk Assessment Step	Major Assumptions	Discussion of the Associated Uncertainty
Toxicity Assessment (cont'd)	The exposure limits for surrogate chemicals adequately represent the toxicity of the chemicals being represented.	In the absence of toxicity data for a number of the individual chemicals in the initial inventory, it was necessary to assume that structural similarity to the surrogate was a sufficient basis for the assumption of toxicological similarity. It is not known if this assumption is more or less conservative.
	Possible interactions of the COPC released by the Project, which might lead to enhanced toxicity, were adequately addressed in the assessment.	Consistent with Health Canada (2010a) guidance, potential health risks associated with the COPC were considered to be additive if the exposure limit for the COPC had the same toxicological endpoint. In some instances, it is possible that components of a mixture may have different mechanisms of effect, contributing some uncertainty in the predicted risk estimates for mixtures.
Risk Characterization	The people with the highest predicted inhalation and multiple pathway exposures in each lifestyle category were used to characterize the potential exposures for all people represented by the lifestyle category.	Predicted inhalation exposures for the remaining fixed locations are lower than those reported in the inhalation assessment results. Potential multiple pathway exposure assumes a large portion of the category's diet is derived from traditional and home-garden foods from the LSA. This contributes to the overstatement of the potential risks other people in the lifestyle category may be presented with.
	Use of a target RQ of 0.2 in the multiple pathway assessment for the non-carcinogenic COPC, which represents an estimated exposure that is only 1/5th the exposure limit (*i.e.*, level at which adverse health effects would not be expected).	When unable to account for these types of exposures, Health Canada recommends that a target risk quotient of 0.2 (i.e., five possible exposure pathways, each accounting for 20% of exposure) be employed to ensure that the potential health risks not be understated (Health Canada 2010a).
	Predicted chronic multiple pathway exposures associated with the non-carcinogens were estimated for all life stages, but only the results of the most sensitive age groups were reported.	Predicted exposures for the other life stages are lower than those reported in the HHRA, resulting in the over-estimation of the risks for each of the other life stages.

4.0 BASELINE CONDITIONS

The current health status of people residing in the Air Quality RSA for Westridge Marine Terminal was described in detail in Section 4.0 of the SLHHRA (Technical Report 5D-7 in Volume 5D of the Application). Population-based health statistics have been compiled by several Canadian health authorities based on healthcare data collected by health authorities in BC. The baseline health status was described in the SLHHRA principally in terms of two endpoints, namely cancer and respiratory health, since these indices have been identified as two of the more commonly-cited health concerns in the region and they are among the most relevant endpoints for assessing the potential effects of exposures to chemical emissions. The information presents an overall picture of the general health of the population residing in the Air Quality RSA, in relation to the two endpoints of interest. No additional baseline health data have been identified by the HHRA team since the Application was filed.

5.0 RESULTS

The results of the HHRA of the Westridge Marine Terminal expansion are presented below, segregated according to:

- exposure duration (i.e., acute versus chronic);
- exposure pathway (i.e., primary inhalation versus secondary exposure pathways); and
- lifestyle category (i.e., residents versus area users).

The findings pertaining to the potential health risks that could be presented to people from exposure to the COPC associated with the expansion of the Westridge Marine Terminal are outlined below. As discussed earlier, the chemical emission inventory for the Westridge Marine Terminal expansion consisted of more than 100 chemicals, including CACs, metals and metalloids, PHCs, PAHs, sulphur-containing compounds and VOCs that were carried forward for consideration as COPC in the HHRA, provided that defensible exposure limits were available.

The potential health risks associated with exposure to the COPC emissions *via* the primary inhalation pathway were assessed on an acute basis for both the residents and area users. In addition, the potential health risks that could result from chronic exposure to the emissions *via* both the primary inhalation and secondary exposure pathways were determined for the residents given the expected operating life of the Project (*i.e.*, more than 50 years).

5.1 Acute Exposure Scenario

The potential health risks (expressed as RQs) that could be presented to residents (*i.e.*, Aboriginal peoples and urban dwellers) and area users from inhaling the COPC associated with the expansion of the Westridge Marine Terminal over the short-term are shown in Table 5.1 to Table 5.4. The tables present the maximum predicted RQs for each of the lifestyle categories; RQs for each of the discrete locations assessed in the HHRA are presented in Appendix C. The potential acute inhalation health risks are based on assumed exposure periods that range from a few minutes to 24 hours.

Examination of the findings revealed that maximum predicted air concentrations of the COPC are lower than the corresponding exposure limits (*i.e.*, RQ < 1.0), indicating that the potential health risks are negligible or low, and adverse health effects would not be expected to result from short-term exposure to the COPC emitted by the Project. The exception is the combined exposures to the respiratory irritants mixture. The nature and severity of the predicted exceedances are discussed in the section that follows.

TABLE 5.1

ACUTE INHALATION RISK QUOTIENTS FOR ABORIGINAL PEOPLES

Chemical of Potential Concern[1]	Averaging Time[2]	Risk Quotients[3]			
		Base Case	Application Case	Cumulative Case	Project[4]
CRITERIA AIR CONTAMINANTS					
CO	1-Hour	1.7E-02	1.7E-02	1.7E-02	1.0E-04
	8-Hour	5.5E-02	5.5E-02	5.5E-02	4.3E-04
NO_2	1-Hour	5.9E-01	6.2E-01	6.2E-01	2.7E-01
$PM_{2.5}$[5]	24-Hour	5.3E-01	5.3E-01	5.3E-01	1.2E-02
PM_{10}	24-Hour	4.2E-01	4.2E-01	4.2E-01	5.9E-03
SO_2	10-Minute	1.6E-01	1.6E-01	1.6E-01	5.4E-03
	1-Hour	1.1E-01	1.1E-01	1.1E-01	3.6E-03
METALS AND METALLOIDS					
Arsenic	1-Hour	8.7E-03	8.8E-03	8.8E-03	2.2E-04
Cadmium	24-Hour	6.8E-03	7.0E-03	7.0E-03	1.5E-04
Chromium III	1-Hour	1.3E-04	1.3E-04	1.3E-04	4.6E-06
Copper	1-Hour	1.2E-04	1.2E-04	1.2E-04	1.1E-07

TABLE 5.1 Cont'd

Chemical of Potential Concern[1]	Averaging Time[2]	Risk Quotients[3]			
		Base Case	Application Case	Cumulative Case	Project[4]
Mercury	1-Hour	1.7E-06	1.8E-06	1.8E-06	8.9E-08
Nickel	1-Hour	2.2E-01	2.3E-01	2.3E-01	1.1E-02
Vanadium	1-Hour	3.8E-04	3.8E-04	3.8E-04	4.1E-06
Zinc	1-Hour	1.7E-04	1.7E-04	1.7E-04	4.9E-07
PETROLEUM HYDROCARBON FRACTIONS					
Aliphatics C_1-C_4	1-Hour	9.5E-04	9.9E-04	9.9E-04	4.4E-05
Aliphatics C_5-C_8	1-Hour	1.0E-03	1.0E-03	1.0E-03	5.0E-05
Aromatics C_9-C_{16}	1-Hour	9.2E-03	9.2E-03	9.2E-03	8.4E-06
POLYCYCLIC AROMATIC HYDROCARBONS					
Naphthalene	1-Hour	7.2E-04	7.2E-04	7.2E-04	4.8E-07
SULPHUR-CONTAINING COMPOUNDS					
Ethanethiol group	1-Hour	5.3E-06	7.2E-06	7.2E-06	2.0E-06
VOLATILE ORGANIC COMPOUNDS					
Acetaldehyde	1-Hour	2.7E-03	2.7E-03	2.7E-03	1.0E-04
Acrolein	1-Hour	2.4E-02	2.4E-02	2.4E-02	9.0E-04
Benzene	1-Hour	1.0E-02	1.1E-02	1.1E-02	3.2E-04
Chlorobenzene	1-Hour	7.8E-07	7.7E-07	7.8E-07	8.1E-11
Ethylbenzene	1-Hour	1.6E-04	1.6E-04	1.6E-04	2.9E-07
Formaldehyde	1-Hour	5.0E-02	5.0E-02	5.0E-02	1.9E-03
Propionaldehyde	1-Hour	9.3E-07	9.3E-07	9.3E-07	3.6E-08
Styrene	1-Hour	3.5E-05	3.5E-05	3.5E-05	6.4E-08
Toluene	1-Hour	1.1E-03	1.1E-03	1.1E-03	9.0E-06
Trimethylbenzenes	1-Hour	6.3E-06	6.3E-06	6.3E-06	6.7E-09
Xylenes	1-Hour	2.0E-03	2.0E-03	2.0E-03	6.4E-06
CHEMICAL MIXTURES[6]					
Eye irritants	n/a	8.2E-02	8.2E-02	8.2E-02	2.9E-03
Nasal irritants	n/a	8.4E-02	8.5E-02	8.5E-02	3.0E-03
Respiratory irritants	n/a	7.8E-01	8.2E-01	8.1E-01	2.8E-01
Reproductive and developmental toxicants	n/a	8.7E-03	8.8E-03	8.8E-03	2.2E-04
Immunotoxicants	n/a	2.3E-01	2.4E-01	2.4E-01	1.1E-02
Neurotoxicants	n/a	4.2E-03	4.3E-03	4.3E-03	6.0E-05

Notes:

n/a not applicable

1 Risk quotients are not presented for 1-hour NO_2 and SO_2 using the US EPA NAAQS as the appropriate statistic was not available for any of the discrete locations.

2 Based on the peak (1st highest) predicted air concentration.

3 With scientific notation, any value expressed to the negative power (*i.e.*, E-x) shows that predicted exposures were less than the exposure limit; whereas, a value expressed to the positive power (*i.e.*, E+x) shows exposure estimates exceeded the exposure limit. Note that addition of the Base Case RQ and the Project RQ provided in the above table might not equate to the Application Case RQ because the values presented in the table are based on the MPOI for each assessment case, the location of which might differ between the cases.

4 The Project RQs are based on the chemicals emissions associated with the Burnaby Terminal (if applicable), Westridge Marine Terminal and the Project-related increase in marine vessel traffic combined.

5 $PM_{2.5}$ includes both primary (emitted directly into the atmosphere) and secondary (formed in the atmosphere through chemical and physical transformations) particulates.

6 Individual constituents of the chemical mixtures are identified in Table 3.13. Note that calculation of the mixture RQs was performed on a location-specific basis; therefore, addition of the RQs provided in the above table for the chemical constituents of the mixture would not necessarily equate to the RQ provided for the mixture because the RQs in the table represent the maximum RQ for each lifestyle category, regardless of the location at which it occurred.

TABLE 5.2

ACUTE INHALATION RISK QUOTIENTS FOR URBAN DWELLERS

Chemical of Potential Concern[1]	Averaging Time[2]	Risk Quotients[3]			
		Base Case	Application Case	Cumulative Case	Project[4]
CRITERIA AIR CONTAMINANTS					
CO	1-Hour	1.7E-02	1.7E-02	1.7E-02	3.6E-04
	8-Hour	5.5E-02	5.6E-02	5.6E-02	6.5E-04
NO_2	1-Hour	7.9E-01	8.0E-01	8.0E-01	4.0E-01
$PM_{2.5}$[5]	24-Hour	6.6E-01	6.8E-01	6.8E-01	2.2E-02
PM_{10}	24-Hour	4.8E-01	4.9E-01	4.9E-01	1.2E-02
SO_2	10-Minute	1.8E-01	1.9E-01	1.9E-01	1.9E-02
	1-Hour	1.2E-01	1.2E-01	1.2E-01	1.3E-02
METALS AND METALLOIDS					
Arsenic	1-Hour	1.6E-02	1.6E-02	1.6E-02	6.0E-04
Cadmium	24-Hour	7.0E-03	7.1E-03	7.1E-03	2.9E-04
Chromium III	1-Hour	2.8E-04	2.8E-04	2.8E-04	1.3E-05
Copper	1-Hour	1.3E-04	1.3E-04	1.3E-04	3.1E-07
Mercury	1-Hour	4.6E-06	4.6E-06	4.6E-06	2.5E-07
Nickel	1-Hour	5.7E-01	5.7E-01	5.7E-01	3.0E-02
Vanadium	1-Hour	5.1E-04	5.1E-04	5.1E-04	1.1E-05
Zinc	1-Hour	1.9E-04	1.9E-04	1.9E-04	1.4E-06
PETROLEUM HYDROCARBON FRACTIONS					
Aliphatics C_1-C_4	1-Hour	1.3E-03	1.9E-03	1.9E-03	6.4E-04
Aliphatics C_5-C_8	1-Hour	1.3E-03	1.3E-03	1.3E-03	2.8E-04
Aromatics C_9-C_{16}	1-Hour	7.9E-02	7.9E-02	7.9E-02	7.2E-05
POLYCYCLIC AROMATIC HYDROCARBONS					
Naphthalene	1-Hour	7.8E-04	7.8E-04	7.8E-04	1.3E-06
SULPHUR-CONTAINING COMPOUNDS					
Ethanethiol group	1-Hour	6.7E-06	1.7E-05	1.7E-05	1.2E-05
VOLATILE ORGANIC COMPOUNDS					
Acetaldehyde	1-Hour	3.3E-03	3.3E-03	3.3E-03	3.6E-04
Acrolein	1-Hour	2.9E-02	2.9E-02	2.9E-02	3.2E-03
Benzene	1-Hour	1.2E-02	1.3E-02	1.3E-02	1.1E-03
Chlorobenzene	1-Hour	7.8E-07	7.8E-07	7.8E-07	2.8E-10
Ethylbenzene	1-Hour	5.0E-04	5.0E-04	5.0E-04	9.0E-07
Formaldehyde	1-Hour	6.3E-02	6.3E-02	6.3E-02	6.8E-03
Propionaldehyde	1-Hour	1.2E-06	1.2E-06	1.2E-06	1.3E-07
Styrene	1-Hour	3.6E-05	3.6E-05	3.6E-05	2.3E-07
Toluene	1-Hour	2.2E-03	2.2E-03	2.2E-03	2.8E-05
Trimethylbenzenes	1-Hour	7.7E-05	7.7E-05	7.7E-05	3.8E-08
Xylenes	1-Hour	3.8E-03	3.9E-03	3.9E-03	2.0E-05
CHEMICAL MIXTURES[6]					
Eye irritants	n/a	1.2E-01	1.2E-01	1.2E-01	1.0E-02
Nasal irritants	n/a	1.0E-01	1.0E-01	1.0E-01	1.0E-02
Respiratory irritants	n/a	1.0E+00	1.0E+00	1.0E+00	4.2E-01
Reproductive and developmental toxicants	n/a	1.6E-02	1.6E-02	1.6E-02	6.0E-04
Immunotoxicants	n/a	5.8E-01	5.9E-01	5.9E-01	3.1E-02
Neurotoxicants	n/a	7.6E-03	7.9E-03	7.9E-03	3.6E-04

Notes:

n/a not applicable

1 Risk quotients are not presented for 1-hour NO_2 and SO_2 using the US EPA NAAQS as the appropriate statistic was not available for any of the discrete locations.

2 Based on the peak (1st highest) predicted air concentration.

3 With scientific notation, any value expressed to the negative power (*i.e.*, E-x) shows that predicted exposures were less than the exposure limit; whereas, a value expressed to the positive power (*i.e.*, E+x) shows exposure estimates exceeded the exposure limit. Note that addition of the Base Case RQ and the Project RQ provided in the above table might not equate to the Application Case RQ because the values presented in the table are based on the MPOI for each assessment case, the location of which might differ between the cases.

TABLE 5.2 Cont'd

4 The Project RQs are based on the chemicals emissions associated with the Burnaby Terminal (if applicable), Westridge Marine Terminal and the Project-related increase in marine vessel traffic combined.
5 $PM_{2.5}$ includes both primary (emitted directly into the atmosphere) and secondary (formed in the atmosphere through chemical and physical transformations) particulates.
6 Individual constituents of the chemical mixtures are identified in Table 3.13. Note that calculation of the mixture RQs was performed on a location-specific basis; therefore, addition of the RQs provided in the above table for the chemical constituents of the mixture would not necessarily equate to the RQ provided for the mixture because the RQs in the table represent the maximum RQ for each lifestyle category, regardless of the location at which it occurred.

TABLE 5.3

ACUTE INHALATION RISK QUOTIENTS FOR AREA USERS

Chemical of Potential Concern[1]	Averaging Time[2]	Risk Quotients[3]			
		Base Case	Application Case	Cumulative Case	Project[4]
CRITERIA AIR CONTAMINANTS					
CO	1-Hour	1.7E-02	1.7E-02	1.7E-02	3.4E-04
	8-Hour	5.5E-02	5.6E-02	5.6E-02	6.2E-04
NO_2	1-Hour	7.1E-01	7.1E-01	7.1E-01	3.9E-01
$PM_{2.5}$[5]	24-Hour	6.1E-01	6.2E-01	6.2E-01	2.9E-02
PM_{10}	24-Hour	4.6E-01	4.6E-01	4.6E-01	1.6E-02
SO_2	10-Minute	1.7E-01	1.7E-01	1.7E-01	1.8E-02
	1-Hour	1.2E-01	1.2E-01	1.2E-01	1.2E-02
METALS AND METALLOIDS					
Arsenic	1-Hour	1.4E-02	1.4E-02	1.4E-02	5.6E-04
Cadmium	24-Hour	6.9E-03	7.3E-03	7.3E-03	4.0E-04
Chromium III	1-Hour	2.5E-04	2.5E-04	2.5E-04	1.2E-05
Copper	1-Hour	1.3E-04	1.3E-04	1.3E-04	2.9E-07
Mercury	1-Hour	4.0E-06	4.0E-06	4.0E-06	2.3E-07
Nickel	1-Hour	4.9E-01	4.9E-01	4.9E-01	2.8E-02
Vanadium	1-Hour	4.8E-04	4.8E-04	4.8E-04	1.1E-05
Zinc	1-Hour	1.8E-04	1.8E-04	1.8E-04	1.3E-06
PETROLEUM HYDROCARBON FRACTIONS					
Aliphatics C_1-C_4	1-Hour	1.3E-03	1.8E-03	1.8E-03	7.9E-04
Aliphatics C_5-C_8	1-Hour	1.2E-03	1.2E-03	1.2E-03	2.2E-04
Aromatics C_9-C_{16}	1-Hour	3.8E-02	3.8E-02	3.8E-02	1.0E-04
POLYCYCLIC AROMATIC HYDROCARBONS					
Naphthalene	1-Hour	7.5E-04	7.5E-04	7.5E-04	1.2E-06
SULPHUR-CONTAINING COMPOUNDS					
Ethanethiol group	1-Hour	8.5E-06	1.4E-05	1.4E-05	8.1E-06
VOLATILE ORGANIC COMPOUNDS					
Acetaldehyde	1-Hour	2.5E-03	2.6E-03	2.6E-03	3.3E-04
Acrolein	1-Hour	2.3E-02	2.3E-02	2.3E-02	2.9E-03
Benzene	1-Hour	1.1E-02	1.2E-02	1.2E-02	8.3E-04
Chlorobenzene	1-Hour	7.8E-07	7.7E-07	7.8E-07	2.6E-10
Ethylbenzene	1-Hour	3.0E-04	3.0E-04	3.0E-04	9.7E-07
Formaldehyde	1-Hour	4.8E-02	4.9E-02	4.9E-02	6.3E-03
Propionaldehyde	1-Hour	8.9E-07	9.0E-07	9.0E-07	1.2E-07
Styrene	1-Hour	3.5E-05	3.5E-05	3.5E-05	2.1E-07
Toluene	1-Hour	1.5E-03	1.6E-03	1.6E-03	2.2E-05
Trimethylbenzenes	1-Hour	3.5E-05	3.5E-05	3.5E-05	2.7E-08
Xylenes	1-Hour	2.7E-03	2.7E-03	2.7E-03	1.6E-05
CHEMICAL MIXTURES[6]					
Eye irritants	n/a	9.5E-02	9.5E-02	9.5E-02	9.6E-03
Nasal irritants	n/a	8.2E-02	8.2E-02	8.2E-02	1.0E-02
Respiratory irritants	n/a	9.2E-01	9.3E-01	9.3E-01	4.2E-01

TABLE 5.3 Cont'd

Chemical of Potential Concern[1]	Averaging Time[2]	Risk Quotients[3]			
		Base Case	Application Case	Cumulative Case	Project[4]
Reproductive and developmental toxicants	n/a	1.4E-02	1.4E-02	1.4E-02	5.6E-04
Immunotoxicants	n/a	5.0E-01	5.1E-01	5.1E-01	2.9E-02
Neurotoxicants	n/a	5.6E-03	5.8E-03	5.8E-03	2.7E-04

Notes:
n/a not applicable
1 Risk quotients are not presented for 1-hour NO_2 and SO_2 using the US EPA NAAQS as the appropriate statistic was not available for any of the discrete locations.
2 Based on the peak (1st highest) predicted air concentration.
3 With scientific notation, any value expressed to the negative power (*i.e.*, E-x) shows that predicted exposures were less than the exposure limit; whereas, a value expressed to the positive power (*i.e.*, E+x) shows exposure estimates exceeded the exposure limit. Note that addition of the Base Case RQ and the Project RQ provided in the above table might not equate to the Application Case RQ because the values presented in the table are based on the MPOI for each assessment case, the location of which might differ between the cases.
4 The Project RQs are based on the chemicals emissions associated with the Burnaby Terminal (if applicable), Westridge Marine Terminal and the Project-related increase in marine vessel traffic combined.
5 $PM_{2.5}$ includes both primary (emitted directly into the atmosphere) and secondary (formed in the atmosphere through chemical and physical transformations) particulates.
6 Individual constituents of the chemical mixtures are identified in Table 3.13. Note that calculation of the mixture RQs was performed on a location-specific basis; therefore, addition of the RQs provided in the above table for the chemical constituents of the mixture would not necessarily equate to the RQ provided for the mixture because the RQs in the table represent the maximum RQ for each lifestyle category, regardless of the location at which it occurred.

TABLE 5.4

ACUTE INHALATION RISK QUOTIENTS FOR AREA USERS AT THE MAXIMUM POINT OF IMPINGEMENT

Chemical of Potential Concern	Averaging Time[1]	Risk Quotients[2]			
		Base Case	Application Case	Cumulative Case	Project[3]
CRITERIA AIR CONTAMINANTS					
CO	1-Hour	1.8E-02	1.8E-02	1.8E-02	1.3E-03
	8-Hour	5.6E-02	5.7E-02	5.7E-02	1.6E-03
NO_2	1-Hour	1.0E+00	1.0E+00	1.0E+00	4.5E-01
	1-Hour (US EPA Statistic)	1.0E+00	1.0E+00	1.0E+00	4.2E-01
$PM_{2.5}$	24-Hour	7.8E-01	7.8E-01	7.8E-01	1.3E-01
PM_{10}	24-Hour	5.4E-01	5.5E-01	5.5E-01	6.5E-02
SO_2	10-Minute	2.2E-01	2.2E-01	2.2E-01	6.7E-02
	1-Hour	1.5E-01	1.5E-01	1.5E-01	4.5E-02
	1-Hour (US EPA Statistic)	3.2E-01	3.2E-01	3.2E-01	3.4E-02
METALS AND METALLOIDS					
Arsenic	1-Hour	1.6E-02	1.6E-02	1.6E-02	2.1E-03
Cadmium	24-Hour	7.4E-03	8.1E-03	8.1E-03	1.3E-03
Chromium III	1-Hour	2.9E-04	2.9E-04	2.9E-04	4.5E-05
Copper	1-Hour	1.3E-04	1.3E-04	1.3E-04	1.1E-06
Mercury	1-Hour	4.8E-06	4.8E-06	4.8E-06	8.6E-07
Nickel	1-Hour	5.9E-01	6.0E-01	5.9E-01	1.0E-01
Vanadium	1-Hour	5.2E-04	5.2E-04	5.2E-04	4.0E-05
Zinc	1-Hour	1.9E-04	1.9E-04	1.9E-04	4.8E-06
PETROLEUM HYDROCARBON FRACTIONS					
Aliphatics C_1-C_4	1-Hour	5.8E-03	5.6E-03	5.6E-03	3.5E-03
Aliphatics C_5-C_8	1-Hour	3.2E-03	4.1E-03	4.1E-03	2.5E-03
Aromatics C_9-C_{16}	1-Hour	4.9E-01	4.9E-01	4.9E-01	3.4E-03
POLYCYCLIC AROMATIC HYDROCARBONS					
Naphthalene	1-Hour	1.1E-03	1.1E-03	1.1E-03	4.6E-06

TABLE 5.4 Cont'd

Chemical of Potential Concern	Averaging Time[1]	Risk Quotients[2]			
		Base Case	Application Case	Cumulative Case	Project[3]
CRITERIA AIR CONTAMINANTS					
SULPHUR-CONTAINING COMPOUNDS					
Ethanethiol group	1-Hour	9.9E-06	7.9E-05	7.9E-05	7.5E-05
VOLATILE ORGANIC COMPOUNDS					
Acetaldehyde	1-Hour	5.1E-03	5.2E-03	5.2E-03	1.2E-03
Acrolein	1-Hour	4.6E-02	4.6E-02	4.6E-02	1.1E-02
Benzene	1-Hour	2.2E-02	2.5E-02	2.5E-02	5.5E-03
Chlorobenzene	1-Hour	7.8E-07	7.8E-07	7.8E-07	1.0E-09
Ethylbenzene	1-Hour	2.6E-03	2.6E-03	2.6E-03	2.3E-05
Formaldehyde	1-Hour	9.7E-02	9.8E-02	9.8E-02	2.4E-02
Propionaldehyde	1-Hour	1.8E-06	1.8E-06	1.8E-06	4.4E-07
Styrene	1-Hour	3.7E-05	3.7E-05	3.7E-05	7.9E-07
Toluene	1-Hour	8.9E-03	9.0E-03	9.0E-03	4.8E-04
Trimethylbenzenes	1-Hour	5.0E-04	5.0E-04	5.0E-04	2.4E-07
Xylenes	1-Hour	1.5E-02	1.5E-02	1.5E-02	3.3E-04
CHEMICAL MIXTURES[4]					
Eye irritants	n/a	6.5E-01	6.5E-01	6.5E-01	4.0E-02
Nasal irritants	n/a	1.6E-01	1.7E-01	1.7E-01	3.8E-02
Respiratory irritants	n/a	**1.4E+00**	**1.4E+00**	**1.4E+00**	5.3E-01
Reproductive and developmental toxicants	n/a	1.6E-02	1.6E-02	1.6E-02	2.1E-03
Immunotoxicants	n/a	6.2E-01	6.2E-01	6.2E-01	1.1E-01
Neurotoxicants	n/a	3.3E-02	3.3E-02	3.3E-02	4.3E-03

Notes:
n/a not applicable
1 Based on the peak (1st highest) predicted air concentration, unless specified.
2 With scientific notation, any value expressed to the negative power (*i.e.*, E-x) shows that predicted exposures were less than the exposure limit; whereas, a value expressed to the positive power (*i.e.*, E+x) shows exposure estimates exceeded the exposure limit. Values indicating predicted exposures exceeding exposure limits are marked in bold font. Note that addition of the Base Case RQ and the Project RQ provided in the above table might not equate to the Application Case RQ because the values presented in the table are based on the MPOI for each assessment case, the location of which might differ between the cases.
3 The Project RQs are based on the chemicals emissions associated with the Burnaby Terminal (if applicable), Westridge Marine Terminal and the Project-related increase in marine vessel traffic combined.
4 Individual constituents of the chemical mixtures are identified in Table 3.13. Note that calculation of the mixture RQs was performed on a location-specific basis; therefore, addition of the RQs provided in the above table for the chemical constituents of the mixture would not necessarily equate to the RQ provided for the mixture because the RQs in the table represent the maximum RQ for each lifestyle category, regardless of the location at which it occurred.

5.1.1 Respiratory Irritants Mixture

The combined RQs for the acute respiratory irritants mixture were predicted to exceed 1.0 for the area users at the MPOI in the Base, Application and Cumulative cases (Table 5.4). The analysis and interpretation of these exceedances took into consideration:

- the potential contribution from the Project to the mixture's exceedance;
- the spatial extent of the exceedance;
- the likelihood of an exceedance occurring; and
- the primary chemical contributors to the mixture's exceedance.

As shown in Figure 5.1 of Appendix A, combined RQs were predicted to be less than or equal to 1.0 for Aboriginal peoples, urban dwellers and area users at the 52 discrete (or fixed) locations within the LSA where people are known or anticipated to spend time. Therefore, acute inhalation health risks associated with the respiratory irritants mixture at these locations are considered negligible or low, and adverse

health effects from the short-term inhalation of the COPC associated with the Westridge Marine Terminal expansion are not expected.

As shown in Table 5.4, the Base Case RQ of 1.4 is not predicted to change under the Application Case or Cumulative Case at the MPOI. This indicates that the incremental changes in RQs as a result of the Project and the reasonably foreseeable increases in all other marine vessel traffic are essentially negligible, and that the Project will have very little, if any, impact on the Base Case health risks associated with short-term exposure to the respiratory irritants mixture at the MPOI. The MPOI refers to the location at which the combined exposures to the respiratory irritants mixture received by the people within the LSA would be greatest. Inclusion of the MPOI location was meant to ensure that any potential health effects that could result from exposure to the chemical emissions associated with the Project, regardless of whether people might be present, would not be underestimated. The location of the MPOI for the respiratory irritants mixture is shown in Figure 5.2 of Appendix A. As shown in this figure, the MPOI is predicted to occur within the perimeter of another industrial facility, where public access would be restricted. The feasibility that a member of the general public would be present at this location should be considered in the interpretation of the exceedance.

As stated previously, it was assumed that there could be an additive interaction among the individual respiratory irritants (Health Canada 2010a). The RQs for the individual respiratory irritants therefore were summed to derive the combined RQs for the mixture. The acute respiratory irritants mixture is comprised of:

- Acetaldehyde
- Acrolein
- Cadmium
- Chromium III
- Copper
- NO_2
- Propionaldehyde
- SO_2
- Ethanethiol group
- Vanadium
- Xylenes
- Zinc

Of these 12 constituents, NO_2 alone contributes about 73% of the overall mixture risk in the Base, Application and Cumulative cases at the MPOI. At 22%, SO_2 is the next largest contributor to the respiratory irritants mixture risk. The relative contribution of the other respiratory irritants is minor (approx. 5%). Combined, NO_2 and SO_2 represent 95% of the predicted respiratory irritant risks. Interpretation of the predicted risks therefore focuses on these COPC. A graphical depiction of the relative contribution of these COPC is provided in Figure 5.3 of Appendix A.

Interpretation of acute inhalation RQs associated with the respiratory irritants mixture must give consideration to the degree of conservatism incorporated into the calculation of the RQs for the individual COPC, particularly the primary contributors (*i.e.*, NO_2 and SO_2), that make up the mixture. The peak (1^{st} highest) predicted hourly concentrations of each of the individual respiratory irritants was used in the mixture calculation. The primary contributors to the peak predicted one-hour NO_2 and SO_2 concentrations are the combustion-type emissions from the existing tugs, and to a lesser extent the emissions from the main engines of the existing tankers. Use of the peak predicted air concentrations likely overstates the actual combined risks as these concentrations are likely to result from rare and unusual meteorological

conditions such that the likelihood of achieving any of these peak concentrations is low, and achieving them simultaneously is even lower (*i.e.*, much less than 0.1%). To allow for more meaningful interpretation of the potential health risks, frequency analysis of one full year of predicted hourly air concentrations was completed. As shown in Table 5.5, the analysis suggests that the respiratory irritants mixture could exceed the target RQ of 1.0 0.90% of the time (*i.e.*, 79 hours per year), and be below the target RQ 99.1% of the time at the MPOI.

TABLE 5.5

FREQUENCY OF RESPIRATORY IRRITANTS MIXTURE EXCEEDANCES AT THE MAXIMUM POINT OF IMPINGEMENT

Location	Frequency of Exceeding [%]			Frequency of Exceeding [hours/year]		
	Base Case	Application Case	Cumulative Case	Base Case	Application Case	Cumulative Case
Maximum Point of Impingement	0.84	0.90	0.90	74	79	79

Despite the use of peak predicted air concentrations, when evaluated on their own, NO_2 and SO_2 were not associated with RQs greater than 1.0. The peak hourly concentration of NO_2 slightly exceeds the one-hour Metro Vancouver AAQO of 200 µg/m³ and the US EPA NAAQS of 188 µg/m³, resulting in an RQ of 1.0 for both the Metro Vancouver AAQO and the US EPA NAAQS under each of the assessment cases. The peak predicted hourly NO_2 concentration at the MPOI is 210 µg/m³. While some studies have reported mild respiratory effects in asthmatics at concentrations below 375 µg/m³ (Cal EPA 2007a), due to the absence of a clear dose-response relationship and statistical uncertainty in these studies, the findings are not considered to reflect the acute effects associated with NO_2 exposure (Cal EPA 2007a, WHO 2000). A recent meta-analysis of NO_2 exposure and airway hyper-responsiveness in asthmatics suggests that there is no evidence that NO_2 causes clinically relevant effects in asthmatics at concentrations up to 1,100 µg/m³ (Goodman *et al*. 2009). The peak predicted one-hour NO_2 concentration at the MPOI is below the concentrations at which adverse effects have been observed in asthmatics and well below the concentrations at which adverse effects have been observed in healthy individuals. Table 5.6 summarizes the relationships between short-term inhalation of NO_2 and health effects reported for humans in the published scientific literature.

TABLE 5.6

POTENTIAL ACUTE HEALTH EFFECTS ASSOCIATED WITH SHORT-TERM NO_2 EXPOSURE

Air Concentrations (µg/m³)	Potential Acute Health Effects[1]
<190	No documented reproducible evidence (consistent and clinically significant) of adverse health effects among healthy individuals or susceptible individuals following short-term exposure. Study results are variable and can be indiscernible from background or control groups
190 to 560	Increased airway responsiveness, detectable by meta-analysis, among asthmatics. Large variability in both protocols and responses.
490	Allergen-induced decrements in lung function and increased allergen-induced airway inflammatory response among asthmatics. Most studies used non-specific airway challenges. No NO_2-induced change in lung function. No documented effects among healthy individuals.
560 to 760	Potential effects on lung function indices, including inconsistent changes FEV_1 (forced expiratory volume in 1 second) and FVC (forced vital capacity) among patients with chronic obstructive pulmonary disease (COPD) during mild exercise.
>1,100	Potentially clinically relevant effects in asthmatics.
1,900 to 3,700	Increased likelihood of inflammatory response and airway responsiveness among healthy individuals during intermittent exercise. Symptoms have not been detected by most investigators among healthy individuals. Asthmatics might experience small decrements in FEV_1.
>3,700	Changes in lung function, such as increased airway resistance, in healthy individuals.

Sources:

Azadniv *et al*. (1998), Beil and Ulmer (1976), Blomberg *et al*. (1997, 1999), Cal EPA (2007a), Devlin *et al*. (1999), Gong *et al*. (2005), Goodman *et al*. (2009), Jorres *et al*. (1995), Morrow *et al*. (1992), Nieding *et al*. (1979, 1980), Nieding and Wagner (1977), Vagaggini *et al*. (1996).

Notes:

1 The descriptions are mostly for the types of health effects that might be experienced among normal, healthy individuals following acute exposure to NO2. Some descriptions refer to the types of symptoms that might occur among individuals with pre-existing eye or breathing disorders, such as asthma, bronchitis or COPD. The exact nature and severity of responses that might occur among individuals with pre-existing conditions will depend on several factors, including: i) the severity of the person's condition; ii) the age of the individual; iii) the level of management of the disorder, including the availability and use of medications; iv) the person's level of physical activity; and, v) external environmental factors such as temperature and humidity. The symptoms that could be experienced by these individuals could be more or less severe that those described because of these factors.

The predicted SO_2 air concentrations were all less than both the one-hour Metro Vancouver AAQO of 450 µg/m³ and the US EPA NAAQS of 196 µg/m³. The peak predicted hourly SO_2 concentration at the MPOI of 66 µg/m³ is well below the range of concentrations at which adverse effects have been observed in asthmatics or other sensitive individuals (*i.e.*, 530 to 1,300 µg/m³). Additional information regarding the dose-response characteristics of inhaled SO_2 on a short-term basis is presented in Table 5.7.

TABLE 5.7

POTENTIAL ACUTE HEALTH EFFECTS ASSOCIATED WITH SHORT-TERM SO_2 EXPOSURE

Air Concentrations (µg/m³)	Potential Acute Health Effects[1]
530 to 1,300	Increased airway resistance and potential bronchoconstriction in asthmatic or sensitive individuals engaged in moderate exercise, but typically no effect on lung function in normal individuals.
1,300 to 2,600	Increased resistance in airways and difficulties breathing may be experienced by normal individuals (in addition to asthmatics and sensitive individuals). Sore throat and the ability to taste and smell SO_2 may also be apparent. Effects in asthmatics and other sensitive individuals may also include wheezing, dyspnea, and bronchoconstriction.
2,600 to 13,000	Odour is detectable. Increased resistance in airways, decreased lung volume, reduced bronchial clearance, and evidence of lung irritation (increased macrophages in lung fluid) were observed at this exposure level. Headache, coughing, throat irritation, nasal congestion, increased salivation may be evident, and some symptoms may persist for several days after exposure. Mucociliary transport in the nasal passages may also be impaired, potentially leading to nasal congestion. Respiratory effects may be more severe in asthmatics and sensitive individuals.
13,000 to 26,000	Increased resistance in airways, decreased respiratory volume, difficulties breathing, and lung irritation were reported at this exposure level. Nasal, throat, and eye irritation, nosebleeds, coughing, potentially accompanied by erythema of trachea and bronchi may occur. Respiratory effects may be more severe in asthmatics and sensitive individuals.
26,000 to 130,000	Symptoms of more severe respiratory irritation may appear, such as burning of nose and throat, sneezing, severe airway obstruction, choking, and dyspnea. Exposure may result in damage to airway epithelium that may progress to epithelial hyperplasia, an increased number of secretory goblet cells, and hypertrophy of the submucousal glands. A condition known as Reactive Airway Dysfunction Syndrome (RADS) may arise in the concentration ranges (as well as above) because of bronchial epithelial damage. Chronic respiratory effects may develop. Eye irritation, watery eyes, and skin eruptions (rashes) may be evident. Respiratory effects may be more severe in asthmatics and sensitive individuals.
130,000 to 260,000	Symptoms of severe respiratory irritation may occur, such as bronchitis, intolerable irritation of mucous membranes in addition to other effects described above, such as decreased lung capacity and breathing difficulties, runny nose, eye and skin irritation.
≥260,000	Immediately dangerous to life and health. Chemical bronchopneumonia and asphyxia were reported at high levels of exposure. Death may result from severe respiratory depression at concentrations of about 2,600,000 µg/m³.

Sources:
ATSDR (1998), Cal EPA (1999), HSDB (2011), NIOSH (1974), WHO (1979, 2000).

Notes:
1 Note that the descriptions pertain largely to the types of health effects that might be experienced among normal, healthy individuals following acute exposure to SO_2. Some descriptions refer to the types of symptoms that might occur among individuals with pre-existing eye and/or breathing disorders, such as asthma, bronchitis or COPD. The exact nature and severity of responses that might occur among these latter individuals will depend on several factors, including: i) the severity of the person's condition; ii) the age of the individual; iii) the level of management of the disorder, including the availability and use of medications; iv) the person's level of physical activity; and/or, v) external environmental factors such as temperature and humidity. The symptoms that could be experienced by these individuals could be more or less severe that those described because of these factors.

Depending on the concentrations of NO_2 and SO_2 to which an individual is exposed, the modes of action for NO_2 and SO_2 within the respiratory tract can differ, which may result in the combined RQs for the respiratory irritants mixture being further overstated. For example, NO_2 is relatively insoluble in water and can be inhaled deeply into the lungs, acting as a deep-lung irritant; whereas, SO_2 is readily soluble in water and, at low concentrations, would be readily absorbed by the moist mucous membranes lining the upper respiratory tract, effectively removing it from the airstream such that it would not penetrate deep into the lungs and alveolar spaces (Calabrese 1991). Clinical studies where both healthy and asthmatic subjects were exposed to both NO_2 and SO_2 in controlled environments have not found evidence that the combination increased respiratory symptoms relative to exposure to either gas on its own (Linn 1980, Rubinstein 1990, Sandstrom 1995). However, if SO_2 concentrations are sufficiently high for it to overwhelm the moist mucous membranes lining the upper respiratory tract, allowing it to penetrate to the lungs and alveolar spaces, then the potential effects of co-exposure to NO_2 and SO_2 on the respiratory tract may be additive. Potential bronchoconstriction has been reported in asthmatic or sensitive individuals engaged in moderate exercise at SO_2 concentrations as low as 530 µg/m³. As such, co-exposure to NO_2 and SO_2 may have additive effects at SO_2 concentrations above this level. The peak predicted hourly SO_2 concentration at the MPOI was 66 µg/m³, which is well below the range of concentrations above which additive effects would be expected (*i.e.*, > 530 µg/m³).

As stated previously, the maximum predicted NO_2 and SO_2 concentrations within the LSA are both below levels or thresholds above which adverse health effects have been reported in the scientific literature. A recent review of mixture toxicity by the European Commission (2012) notes that the potential and type of the interactions between chemicals may vary according to the magnitude of the exposure:

> *"Interactions … usually occur at medium or high dose levels (relative to the lowest effect levels). At low exposure levels they are either unlikely to occur or toxicologically insignificant. According to Boobis et al. (2011), "low dose" is defined as at or near or below doses that do not cause statistically significant effects in experimental studies, such as NOALs, NOECs or benchmark dose levels."*

As a result, the assumption of additivity in the assessment of respiratory irritants, particularly the effects of NO_2 and SO_2, is likely conservative.

Despite predicted combined RQs for the respiratory irritants mixture above 1.0, the overall weight of evidence suggests a low potential for adverse health effects as a result of combined exposure to the respiratory irritants mixture. The evidence is as follows:

- The highly localized nature of the exceedances (*i.e.*, MPOI only) within the perimeter of another industrial facility;
- The use of peak (1st highest) predicted hourly concentrations likely overstates the actual short-term exposures to the mixture at the MPOI;
- The low likelihood of exceedances occurring at the MPOI (*i.e.*, less than 1% of the time);
- The peak predicted one-hour concentrations for each of the individual respiratory irritants are considerably lower than the level at which responses have been observed in most individuals, including asthmatics;
- the assumption of additivity in the assessment of respiratory irritants, particularly the effects of NO_2 and SO_2 at the predicted concentrations, is likely conservative; and
- Any health effects that might be experienced by workers at this location would likely be mild and transient in nature.

5.2 Chronic Exposure Scenario

As discussed earlier, the assessment of the potential health risks that could result from chronic exposure to the COPC associated with the Westridge Marine Terminal was reserved for the residents. Separate assessments were completed for: i) the primary inhalation pathway; and, ii) all exposure pathways combined (*i.e.*, inhalation and applicable secondary exposure pathways. The findings are segregated accordingly.

Area users would not be expected to frequent and/or remain in the area on an extended, long-term basis, thereby precluding any reasonable opportunity for chronic exposure to the emissions from the Westridge Marine Terminal expansion and associated marine vessel traffic. Accordingly, an assessment of the potential health risks that could be presented from chronic exposure to the emissions was not performed for the area users.

5.2.1 Primary Inhalation Pathway

The potential health risks that could be presented to residents (*i.e.*, Aboriginal peoples and urban dwellers) living in the area from chronic exposure to the COPC associated with the Westridge Marine Terminal expansion *via* the primary inhalation pathway are described below. The potential chronic inhalation health risks were estimated based on the assumption that residents would be continuously exposed to maximum predicted annual air concentrations for an assumed lifespan of 80 years (Health Canada 2010a).

Separate assessments were completed for non-carcinogenic and carcinogenic exposures, reflecting the different approaches used in calculating and interpreting the risk estimates.

5.2.1.1 Non-Carcinogenic Exposures

The potential chronic non-carcinogenic health risks (expressed as RQs) associated with the expansion of the Westridge Marine Terminal *via* the primary inhalation pathway are shown in Table 5.8 to Table 5.9. The tables present the maximum predicted RQs for each of the lifestyle categories; RQs for each of the discrete locations assessed in the HHRA are presented in Appendix C.

Examination of the findings revealed that in all cases the maximum predicted annual air concentrations of the COPC are lower than the corresponding exposure limits (*i.e.*, RQ < 1.0). Long-term health risks associated with the COPC exposure are therefore considered negligible or low, and adverse health effects are not expected as a result of long-term inhalation exposures to the COPC associated with the Westridge Marine Terminal expansion.

TABLE 5.8

CHRONIC INHALATION RISK QUOTIENTS FOR ABORIGINAL PEOPLES

Chemical of Potential Concern	Risk Quotients[1]			
	Base Case	Application Case	Cumulative Case	Project[2]
CRITERIA AIR CONTAMINANTS				
NO_2	5.0E-01	5.4E-01	5.4E-01	4.0E-02
$PM_{2.5}$[3]	4.2E-01	4.2E-01	4.2E-01	3.5E-03
PM_{10}	4.2E-01	4.2E-01	4.2E-01	1.5E-03
METALS AND METALLOIDS				
Barium	1.0E-03	1.0E-03	1.0E-03	4.1E-06
Beryllium	8.2E-07	3.6E-06	3.4E-06	2.9E-06
Cadmium	1.0E-02	1.0E-02	1.0E-02	5.7E-05
Chromium III	1.8E-03	1.8E-03	1.8E-03	1.4E-05
Chromium VI	2.5E-03	2.5E-03	2.5E-03	7.9E-06
Cobalt	1.0E-03	1.0E-03	1.0E-03	2.6E-05
Copper	1.0E-03	1.0E-03	1.0E-03	3.9E-07
Manganese	1.1E-02	1.1E-02	1.1E-02	4.9E-06
Mercury	1.8E-08	7.8E-08	7.2E-08	6.2E-08
Molybdenum	8.3E-06	8.3E-06	8.4E-06	3.2E-08
Nickel	4.4E-02	5.0E-02	4.9E-02	5.3E-03
Selenium	1.0E-05	1.0E-05	1.0E-05	2.0E-08
Titanium	2.5E-03	2.5E-03	2.5E-03	3.9E-06
Vanadium	1.5E-02	1.5E-02	1.5E-02	4.3E-05
PETROLEUM HYDROCARBON FRACTIONS				
Aliphatics C_1-C_4	2.8E-03	3.3E-03	3.3E-03	4.4E-04
Aliphatics C_5-C_8	7.8E-04	8.2E-04	8.2E-04	5.0E-05
Aliphatics C_9-C_{16}	9.2E-04	9.7E-04	9.7E-04	6.0E-05
Aromatics C_9-C_{16}	9.4E-03	9.4E-03	9.4E-03	2.7E-06
POLYCYCLIC AROMATIC HYDROCARBONS				
Naphthalene	3.6E-02	3.6E-02	3.6E-02	1.1E-05
VOLATILE ORGANIC COMPOUNDS				
Acetaldehyde	1.1E-06	7.4E-06	7.4E-06	6.2E-06
Acrolein	5.8E-05	3.9E-04	3.9E-04	3.3E-04
Benzene	5.6E-02	5.7E-02	5.7E-02	7.4E-04
Chlorobenzene	7.9E-04	7.9E-04	7.9E-04	1.9E-08
Cyclohexane	3.9E-05	4.1E-05	4.1E-05	2.2E-06
Ethylbenzene	1.0E-03	1.0E-03	1.0E-03	1.1E-06
Formaldehyde	7.9E-05	5.3E-04	5.3E-04	4.5E-04
n-Hexane	5.5E-05	3.6E-04	3.6E-04	3.2E-04
Propionaldehyde	4.4E-06	2.9E-05	3.0E-05	2.5E-05

TABLE 5.8 Cont'd

Chemical of Potential Concern	Risk Quotients[1]			
	Base Case	Application Case	Cumulative Case	Project[2]
Styrene	1.2E-04	1.2E-04	1.2E-04	1.5E-07
Toluene	2.9E-04	3.0E-04	3.0E-04	1.0E-06
Trimethylbenzenes	2.2E-04	2.4E-04	2.4E-04	2.9E-05
Xylenes	1.9E-03	1.9E-03	1.9E-03	3.0E-06
CHEMICAL MIXTURES[4]				
Eye irritants	2.0E-03	2.4E-03	2.4E-03	4.5E-04
Nasal irritants	8.7E-02	9.4E-02	9.3E-02	6.5E-03
Respiratory irritants	5.7E-01	6.1E-01	6.1E-01	4.6E-02
Hematotoxicants	5.7E-02	5.8E-02	5.8E-02	7.4E-04
Immunotoxicants	5.7E-02	5.8E-02	5.8E-02	7.4E-04
Renal toxicants	2.4E-02	2.5E-02	2.5E-02	5.0E-04
Hepatotoxicants	9.4E-03	9.4E-03	9.4E-03	2.7E-06
Neurotoxicants	1.5E-02	1.6E-02	1.6E-02	4.7E-04

Notes:

1 With scientific notation, any value expressed to the negative power (*i.e.*, E-x) shows that predicted exposures were less than the exposure limit; whereas, a value expressed to the positive power (*i.e.*, E+x) shows exposure estimates exceeded the exposure limit. Note that addition of the Base Case RQ and the Project RQ provided in the above table might not equate to the Application Case RQ because the values presented in the table represent the maximum of the two locations assessed for each assessment case, and the location of which might differ between the cases.

2 The Project RQs are based on the chemicals emissions associated with the Burnaby Terminal (if applicable), Westridge Marine Terminal and the Project-related increase in marine vessel traffic combined.

3 $PM_{2.5}$ includes both primary (emitted directly into the atmosphere) and secondary (formed in the atmosphere through chemical and physical transformations) particulates.

4 Individual constituents of the chemical mixtures are identified in Table 3.13. Note that calculation of the mixture RQs was performed on a location-specific basis; therefore, addition of the RQs provided in the above table for the chemical constituents of the mixture might not equate to the RQ provided for the mixture because the RQs in the table represent the maximum RQ for each lifestyle category, regardless of the location at which it occurred.

TABLE 5.9

CHRONIC INHALATION RISK QUOTIENTS FOR URBAN DWELLERS

Chemical of Potential Concern	Risk Quotients[1]			
	Base Case	Application Case	Cumulative Case	Project[2]
CRITERIA AIR CONTAMINANTS				
NO_2	5.0E-01	5.7E-01	5.7E-01	7.1E-02
$PM_{2.5}$[3]	4.2E-01	4.2E-01	4.2E-01	6.0E-03
PM_{10}	4.2E-01	4.2E-01	4.2E-01	2.6E-03
METALS AND METALLOIDS				
Barium	1.0E-03	1.0E-03	1.0E-03	7.1E-06
Beryllium	1.1E-06	6.1E-06	5.8E-06	5.0E-06
Cadmium	1.0E-02	1.0E-02	1.0E-02	9.8E-05
Chromium III	1.8E-03	1.8E-03	1.8E-03	2.4E-05
Chromium VI	2.5E-03	2.5E-03	2.5E-03	1.4E-05
Cobalt	1.0E-03	1.0E-03	1.1E-03	4.5E-05
Copper	1.0E-03	1.0E-03	1.0E-03	6.7E-07
Manganese	1.1E-02	1.1E-02	1.1E-02	8.4E-06
Mercury	2.3E-08	1.3E-07	1.2E-07	1.1E-07
Molybdenum	8.3E-06	8.4E-06	8.4E-06	5.5E-08
Nickel	4.5E-02	5.4E-02	5.3E-02	9.2E-03
Selenium	1.0E-05	1.0E-05	1.0E-05	3.4E-08
Titanium	2.5E-03	2.5E-03	2.5E-03	6.7E-06
Vanadium	1.5E-02	1.5E-02	1.5E-02	7.4E-05
PETROLEUM HYDROCARBON FRACTIONS				
Aliphatics C_1-C_4	3.1E-03	3.5E-03	3.5E-03	6.6E-04
Aliphatics C_5-C_8	8.5E-04	8.5E-04	8.5E-04	7.6E-05
Aliphatics C_9-C_{16}	1.5E-03	1.6E-03	1.6E-03	8.9E-05

TABLE 5.9 Cont'd

Chemical of Potential Concern	Risk Quotients[1]			
	Base Case	Application Case	Cumulative Case	Project[2]
Aromatics C_9-C_{16}	9.8E-03	9.8E-03	9.8E-03	4.1E-06
POLYCYCLIC AROMATIC HYDROCARBONS				
Naphthalene	3.6E-02	3.6E-02	3.6E-02	1.9E-05
VOLATILE ORGANIC COMPOUNDS				
Acetaldehyde	1.5E-06	1.1E-05	1.1E-05	9.4E-06
Acrolein	7.7E-05	5.7E-04	5.7E-04	4.9E-04
Benzene	5.7E-02	5.8E-02	5.8E-02	1.1E-03
Chlorobenzene	7.9E-04	7.9E-04	7.9E-04	2.9E-08
Cyclohexane	4.1E-05	4.2E-05	4.2E-05	3.3E-06
Ethylbenzene	1.0E-03	1.0E-03	1.0E-03	1.6E-06
Formaldehyde	1.0E-04	7.7E-04	7.8E-04	6.7E-04
n-Hexane	2.4E-04	5.4E-04	5.4E-04	4.9E-04
Propionaldehyde	5.8E-06	4.3E-05	4.4E-05	3.8E-05
Styrene	1.2E-04	1.2E-04	1.2E-04	2.2E-07
Toluene	3.0E-04	3.0E-04	3.0E-04	1.5E-06
Trimethylbenzenes	1.7E-03	1.7E-03	1.7E-03	4.4E-05
Xylenes	1.9E-03	1.9E-03	1.9E-03	4.5E-06
CHEMICAL MIXTURES[4]				
Eye irritants	2.0E-03	2.7E-03	2.7E-03	6.7E-04
Nasal irritants	8.8E-02	9.9E-02	9.8E-02	1.1E-02
Respiratory irritants	5.7E-01	6.5E-01	6.5E-01	8.1E-02
Hematotoxicants	5.8E-02	5.9E-02	5.9E-02	1.1E-03
Immunotoxicants	5.8E-02	5.9E-02	5.9E-02	1.1E-03
Renal toxicants	2.4E-02	2.5E-02	2.5E-02	7.3E-04
Hepatotoxicants	9.8E-03	9.8E-03	9.8E-03	4.1E-06
Neurotoxicants	1.7E-02	1.8E-02	1.8E-02	7.1E-04

Notes:
1 With scientific notation, any value expressed to the negative power (*i.e.*, E-x) shows that predicted exposures were less than the exposure limit; whereas, a value expressed to the positive power (*i.e.*, E+x) shows exposure estimates exceeded the exposure limit. Note that addition of the Base Case RQ and the Project RQ provided in the above table might not equate to the Application Case RQ because the values presented in the table represent the maximum of the 35 locations assessed for each assessment case, and the location of which might differ between the cases.
2 The Project RQs are based on the chemicals emissions associated with the Burnaby Terminal (if applicable), Westridge Marine Terminal and the Project-related increase in marine vessel traffic combined.
3 $PM_{2.5}$ includes both primary (emitted directly into the atmosphere) and secondary (formed in the atmosphere through chemical and physical transformations) particulates.
4 Individual constituents of the chemical mixtures are identified in Table 3.13. Note that calculation of the mixture RQs was performed on a location-specific basis; therefore, addition of the RQs provided in the above table for the chemical constituents of the mixture might not equate to the RQ provided for the mixture because the RQs in the table represent the maximum RQ for each lifestyle category, regardless of the location at which it occurred.

5.2.1.2 Carcinogenic Exposures

The potential carcinogenic health risks (expressed as ILCRs) that could be presented to residents (i.e., Aboriginal Peoples and urban dwellers) living in the local area from the increase in chronic exposure to the carcinogenic COPC as a result of the expansion of the Westridge Marine Terminal *via* the primary inhalation pathway are shown in Table 5.10 and Table 5.11. The tables present the maximum predicted ILCRs for each of the lifestyle categories; ILCRs for each of the discrete locations assessed in the HHRA are presented in Appendix C. As previously discussed, the potential carcinogenic risks were calculated on an incremental basis for the Westridge Marine Terminal expansion and associated increase in marine vessel traffic (*i.e.*, Project) and all reasonably foreseeable developments in the region (*i.e.*, Future).

Examination of the findings revealed that the exposure estimates for each of the carcinogenic COPC were less than their corresponding exposure limits, signalling that the incremental lifetime cancer risks are lower than the acceptable benchmark risk of 1×10^{-5} (*i.e.*, one extra cancer case in a population of one hundred thousand people).

TABLE 5.10

CHRONIC INHALATION INCREMENTAL LIFETIME CANCER RISKS FOR ABORIGINAL PEOPLES

Chemical of Potential Concern	Incremental Lifetime Cancer Risks[1] (per 100,000)	
	Project[2]	Future
METALS AND METALLOIDS		
Arsenic	9.4E-04	9.4E-04
Beryllium	5.1E-06	5.1E-06
Cadmium	2.9E-04	2.9E-04
Chromium VI	6.1E-03	6.1E-03
Nickel	9.7E-03	9.7E-03
POLYCYCLIC AROMATIC HYDROCARBONS		
Benzo(a)pyrene (and equivalents)		
• Approach 1	1.6E-03	1.6E-03
• Approach 2	1.2E-06	1.2E-06
VOLATILE ORGANIC COMPOUNDS		
Acetaldehyde	1.4E-04	1.4E-04
Benzene	5.6E-03	5.6E-03
Formaldehyde	6.1E-03	6.2E-03
CHEMICAL MIXTURES[3]		
Nasal carcinogens	6.3E-03	6.3E-03
Lung carcinogens	1.9E-02	1.9E-02

Notes:

1 An ILCR equal to or less than 1.0 signifies an incremental lifetime cancer risk that is below the benchmark ILCR of one in 100,000 (*i.e.*, within the generally accepted limit deemed to be protective of public health). With scientific notation, any value expressed to the negative power (*i.e.*, E-x) shows that predicted exposures were less than the exposure limit; whereas, a value expressed to the positive power (*i.e.*, E+x) shows exposure estimates exceeded the exposure limit.

2 The Project RQs are based on the chemicals emissions associated with the Burnaby Terminal (if applicable), Westridge Marine Terminal and the Project-related increase in marine vessel traffic combined.

3 Individual constituents of the chemical mixtures are identified in Table 3.13.

TABLE 5.11

CHRONIC INHALATION INCREMENTAL LIFETIME CANCER RISKS FOR URBAN DWELLERS

Chemical of Potential Concern	Incremental Lifetime Cancer Risks[1] (per 100,000)	
	Project[2]	Future
METALS AND METALLOIDS		
Arsenic	1.6E-03	1.6E-03
Beryllium	8.8E-06	8.8E-06
Cadmium	4.9E-04	4.9E-04
Chromium VI	1.0E-02	1.0E-02
Nickel	1.7E-02	1.7E-02
POLYCYCLIC AROMATIC HYDROCARBONS		
Benzo(a)pyrene (and equivalents)		
• Approach 1	2.7E-03	2.7E-03
• Approach 2	2.0E-06	2.0E-06
VOLATILE ORGANIC COMPOUNDS		
Acetaldehyde	2.1E-04	2.1E-04
Benzene	8.2E-03	8.3E-03
Formaldehyde	9.2E-03	9.3E-03
CHEMICAL MIXTURES[3]		
Nasal carcinogens	9.4E-03	9.5E-03
Lung carcinogens	3.2E-02	3.2E-02

Notes:

1 An ILCR equal to or less than 1.0 signifies an incremental lifetime cancer risk that is below the benchmark ILCR of one in 100,000 (*i.e.*, within the generally accepted limit deemed to be protective of public health). With scientific notation, any value expressed to the negative power (*i.e.*, E-x) shows that predicted exposures were less than the exposure limit; whereas, a value expressed to the positive power (*i.e.*, E+x) shows exposure estimates exceeded the exposure limit.

2 The Project RQs are based on the chemicals emissions associated with the Burnaby Terminal (if applicable), Westridge Marine Terminal and the Project-related increase in marine vessel traffic combined.

3 Individual constituents of the chemical mixtures are identified in Table 3.13.

5.2.2 Multiple Exposure Pathways

The potential health risks that could be presented to the local residents from chronic exposure to the COPC associated with the expansion of the Westridge Marine Terminal *via* the various secondary pathways that were examined are described below. As indicated previously, the assessment extended only to those COPC that satisfied the environmental fate and persistence criteria that were used to determine the likelihood that exposure might occur through secondary pathways. The potential chronic multiple pathway health risks were estimated based on the assumption that residents would be continuously exposed for an assumed lifespan of 80 years (Health Canada 2010a).

Separate assessments were completed for non-carcinogenic and carcinogenic exposures, reflecting the different approaches used in calculating and interpreting the risk estimates.

5.2.2.1 Non-Carcinogenic Exposures

The potential non-carcinogenic health risks (expressed as RQs) that could be presented to Aboriginal peoples and urban dwellers living in the LSA from chronic exposure to the COPC associated with the Westridge Marine Terminal expansion *via* the relevant secondary pathways are shown in Table 5.12 and Table 5.13, respectively.

Examination of the findings revealed that the maximum predicted health risks for each of the COPC are below the benchmark (or target RQ) of 0.2 used when unable to account for all background exposures. This indicates that long-term exposures *via* the relevant secondary pathways of exposure to the COPC associated with the Westridge Marine Terminal expansion are not anticipated to result in adverse health effects.

TABLE 5.12

CHRONIC MULTIPLE PATHWAY RISK QUOTIENTS FOR ABORIGINAL PEOPLES

Chemical of Potential Concern	Risk Quotients[1,2,3]			
	Base Case	Application Case	Cumulative Case	Project[4]
METALS AND METALLOIDS				
Arsenic	2.0E-02	2.0E-02	2.0E-02	1.0E-04
Barium	2.2E-03	2.2E-03	2.2E-03	9.6E-06
Beryllium	6.1E-07	3.3E-06	3.1E-06	2.7E-06
Cadmium	9.2E-02	9.3E-02	9.3E-02	6.1E-04
Chromium III	1.9E-05	1.9E-05	1.9E-05	1.8E-07
Chromium VI	2.9E-02	2.9E-02	2.9E-02	1.1E-04
Cobalt	1.7E-02	1.8E-02	1.8E-02	5.8E-04
Copper	1.9E-03	1.9E-03	1.9E-03	3.6E-05
Manganese	1.3E-02	1.3E-02	1.3E-02	5.8E-06
Methyl mercury	5.3E-07	2.9E-06	2.8E-06	2.4E-06
Mercury	4.3E-06	1.0E-05	1.0E-05	9.9E-06
Molybdenum	5.1E-03	5.1E-03	5.1E-03	2.3E-05
Nickel	1.3E-02	1.5E-02	1.5E-02	1.9E-03
Selenium	9.4E-03	9.5E-03	9.5E-03	2.2E-05
Strontium	1.8E-04	1.8E-04	1.8E-04	3.0E-07
Vanadium	2.2E-02	2.2E-02	2.2E-02	7.3E-05
Zinc	6.3E-03	6.3E-03	6.3E-03	3.4E-06
PETROLEUM HYDROCARBON FRACTIONS				
Aliphatics C_9-C_{16}	2.0E-03	2.1E-03	2.0E-03	7.9E-09
Aromatics C_{17}-C_{34}	9.9E-06	1.0E-05	9.9E-06	5.7E-08
POLYCYCLIC AROMATIC HYDROCARBONS				
Acenaphthene	1.0E-10	3.0E-10	2.4E-10	2.0E-10
Anthracene	7.4E-11	2.2E-10	1.8E-10	1.5E-10
Biphenyl	4.4E-10	5.6E-09	5.6E-09	5.1E-09
Fluoranthene	2.4E-09	7.6E-09	6.3E-09	5.3E-09

TABLE 5.12 Cont'd

Chemical of Potential Concern	Risk Quotients[1,2,3]			
	Base Case	Application Case	Cumulative Case	Project[4]
Fluorene	1.4E-09	3.9E-09	3.1E-09	2.5E-09
Naphthalene	4.3E-04	4.3E-04	4.3E-04	2.8E-08
Pyrene	4.4E-09	1.4E-08	1.2E-08	9.9E-09
VOLATILE ORGANIC COMPOUNDS				
Acrolein	5.6E-08	2.7E-07	2.7E-07	2.1E-07
Formaldehyde	3.1E-09	1.6E-08	1.6E-08	1.3E-08
Hexachlorobenzene	6.0E-10	1.7E-09	1.3E-09	1.1E-09
OTHER				
PCBs	2.0E-07	5.7E-07	4.6E-07	3.8E-07
CHEMICAL MIXTURES[5]				
Cardiovascular toxicants	2.0E-02	2.0E-02	2.0E-02	5.9E-04
Gastrointestinal toxicants	2.9E-02	2.9E-02	2.9E-02	1.1E-04
Reproductive and developmental toxicants	3.6E-02	3.8E-02	3.8E-02	2.0E-03
Renal toxicants	9.6E-02	9.7E-02	9.6E-02	6.3E-04
Hepatotoxicants	1.3E-02	1.3E-02	1.3E-02	5.8E-05
Neurotoxicants	2.3E-02	2.3E-02	2.3E-02	3.0E-05

Notes:

1 An RQ equal to or less than 0.2 signifies that the predicted exposure is below the benchmark (or target RQ) when unable to account for background exposures. With scientific notation, an RQ of 0.2 would be presented as 2.0E-01.

2 Addition of the Base Case RQ and Project RQ provided in the above table might not equate to the Application Case RQ because the values presented in the table represent the maximum of the two locations assessed for each assessment case, and the location might differ between the cases.

3 Chronic inhalation RQ values were added to the multiple pathway RQ values for those COPC which have the same toxicological endpoint identified for chronic inhalation and chronic oral routes of exposure.

4 The Project RQs are based on the chemicals emissions from the Burnaby Terminal (if applicable), Westridge Marine Terminal and the Project-related increase in marine vessel traffic combined.

5 Individual constituents of the chemical mixtures are identified in Table 3.13. Note that calculation of the mixture RQs was performed on a location-specific basis; therefore, addition of the RQs provided in the above table for the chemical constituents of the mixture might not equate to the RQ provided for the mixture because the RQs in the table represent the maximum RQ for each lifestyle category, regardless of the location at which it occurred.

TABLE 5.13

CHRONIC MULTIPLE PATHWAY RISK QUOTIENTS FOR URBAN DWELLERS

Chemical of Potential Concern	Risk Quotients[1,2,3]			
	Base Case	Application Case	Cumulative Case	Project[4]
METALS AND METALLOIDS				
Arsenic	1.8E-02	1.8E-02	1.8E-02	1.5E-04
Barium	2.0E-03	2.0E-03	2.0E-03	1.2E-05
Beryllium	5.3E-07	2.9E-06	2.8E-06	2.4E-06
Cadmium	7.9E-02	8.0E-02	8.0E-02	5.6E-04
Chromium III	1.6E-05	1.6E-05	1.6E-05	1.5E-07
Chromium VI	2.4E-02	2.4E-02	2.4E-02	9.3E-05
Cobalt	1.4E-02	1.4E-02	1.4E-02	4.3E-04
Copper	1.1E-03	1.1E-03	1.1E-03	5.6E-07
Manganese	1.3E-02	1.3E-02	1.3E-02	9.3E-06
Methyl mercury	4.5E-07	2.5E-06	2.4E-06	2.0E-06
Mercury	3.9E-08	2.2E-07	2.1E-07	1.8E-07
Molybdenum	4.1E-03	4.1E-03	4.1E-03	1.9E-05
Nickel	1.1E-02	1.3E-02	1.2E-02	1.6E-03
Selenium	7.9E-03	7.9E-03	7.9E-03	1.8E-05
Strontium	1.1E-04	1.1E-04	1.1E-04	2.4E-07
Vanadium	1.9E-02	1.9E-02	1.9E-02	7.8E-05
Zinc	5.3E-03	5.3E-03	5.3E-03	3.0E-06
PETROLEUM HYDROCARBON FRACTIONS				
Aliphatics C_9-C_{16}	2.0E-03	2.1E-03	2.0E-03	1.4E-09

TABLE 5.13 Cont'd

Chemical of Potential Concern	Risk Quotients[1,2,3]			
	Base Case	Application Case	Cumulative Case	Project[4]
Aromatics C_{17}-C_{34}	1.8E-05	1.8E-05	1.8E-05	4.4E-08
POLYCYCLIC AROMATIC HYDROCARBONS				
Acenaphthene	1.0E-10	3.1E-10	2.5E-10	2.0E-10
Anthracene	7.5E-11	2.4E-10	2.0E-10	1.6E-10
Biphenyl	2.9E-10	3.6E-09	3.6E-09	3.3E-09
Fluoranthene	2.4E-09	8.6E-09	7.4E-09	6.2E-09
Fluorene	1.4E-09	3.9E-09	3.1E-09	2.6E-09
Naphthalene	4.3E-04	4.3E-04	4.3E-04	2.8E-08
Pyrene	4.5E-09	1.6E-08	1.4E-08	1.2E-08
VOLATILE ORGANIC COMPOUNDS				
Acrolein	5.6E-08	2.7E-07	2.8E-07	2.1E-07
Formaldehyde	2.7E-09	1.4E-08	1.4E-08	1.1E-08
Hexachlorobenzene	6.0E-10	1.7E-09	1.3E-09	1.1E-09
OTHER				
PCBs	2.0E-07	5.6E-07	4.4E-07	3.6E-07
CHEMICAL MIXTURES[5]				
Cardiovascular toxicants	1.6E-02	1.6E-02	1.6E-02	4.5E-04
Gastrointestinal toxicants	2.4E-02	2.4E-02	2.4E-02	9.5E-05
Reproductive and developmental toxicants	3.0E-02	3.2E-02	3.1E-02	1.7E-03
Renal toxicants	8.2E-02	8.3E-02	8.3E-02	5.7E-04
Hepatotoxicants	1.0E-02	1.0E-02	1.0E-02	1.9E-05
Neurotoxicants	2.1E-02	2.1E-02	2.1E-02	3.0E-05

Notes:

1 An RQ equal to or less than 0.2 signifies that the predicted exposure is below the benchmark (or target RQ) when unable to account for background exposures. With scientific notation, an RQ of 0.2 would be presented as 2.0E-01.

2 Addition of the Base Case RQ and Project RQ provided in the above table might not equate to the Application Case RQ because the values presented in the table represent the maximum of the 35 locations assessed for each assessment case, and the location might differ between the cases.

3 Chronic inhalation RQ values were added to the multiple pathway RQ values for those COPC which have the same toxicological endpoint identified for chronic inhalation and chronic oral routes of exposure.

4 The Project RQs are based on the chemicals emissions from the Burnaby Terminal (if applicable), Westridge Marine Terminal and the Project-related increase in marine vessel traffic combined.

5 Individual constituents of the chemical mixtures are identified in Table 3.13. Note that calculation of the mixture RQs was performed on a location-specific basis; therefore, addition of the RQs provided in the above table for the chemical constituents of the mixture might not equate to the RQ provided for the mixture because the RQs in the table represent the maximum RQ for each lifestyle category, regardless of the location at which it occurred.

5.2.2.2 Carcinogenic Exposures

The potential carcinogenic health risks (expressed as ILCRs) that could be presented to residents living in the area from the increase in chronic exposure to the COPC as a result of the Westridge Marine Terminal expansion *via* the secondary exposure pathway are shown in Table 5.14 for the Aboriginal peoples and Table 5.15 for the urban dwellers. As previously discussed, the potential carcinogenic health risks that could result from chronic exposure to the COPC were calculated on an incremental basis for the Project and the reasonably foreseeable increase in all other marine vessel traffic.

Examination of the findings revealed that long-term exposure to the carcinogenic COPC is expected to be less than the corresponding exposure limits in all instances, signalling that incremental lifetime cancer risks are lower than the acceptable benchmark value of one extra cancer case in a population of one hundred thousand people, and deemed to be “essentially negligible” (Alberta Health and Wellness 2011, BC MOE 2009, Health Canada 2010a).

TABLE 5.14

CHRONIC MULTIPLE PATHWAY INCREMENTAL LIFETIME CANCER RISKS FOR ABORIGINAL PEOPLES

Chemical of Potential Concern	Incremental Lifetime Cancer Risks[1,2] (per 100,000)	
	Project[3]	Future
METALS AND METALLOIDS		
Arsenic	2.3E-03	2.3E-03
POLYCYCLIC AROMATIC HYDROCARBONS		
Benzo(a)pyrene (and equivalents)	5.9E-04	5.9E-04
Biphenyl	1.1E-06	1.1E-06
VOLATILE ORGANIC COMPOUNDS		
Hexachlorobenzenes	6.8E-08	6.8E-08
CHEMICAL MIXTURES[4]		
Liver carcinogens	2.3E-03	2.3E-03

Notes:
1 With scientific notation, any value expressed to the negative power (*i.e.*, E-x) shows that predicted exposures were less than the exposure limit; whereas, a value expressed to the positive power (*i.e.*, E+x) shows exposure estimates exceeded the exposure limit.
2 Chronic inhalation ILCR values were added to the multiple pathway ILCR values for those COPC identified to have similar toxicological endpoints for chronic inhalation and chronic oral routes of exposure.
3 The Project ILCRs are based on the chemicals emissions associated with the Burnaby Terminal (if applicable), expansion of the Westridge Marine Terminal, and the Project-related increase in marine vessel traffic combined.
4 Individual constituents of the chemical mixtures are identified in Table 3.13. Note that calculation of the mixture ILCRs was performed on a life stage-specific basis; therefore, addition of the ILCRs provided in the above table for the chemical constituents of the mixture might not equate to the ILCR provided for the mixture because the ILCRs in the table represent the maximum ILCR for each lifestyle category, regardless of the life stage.

TABLE 5.15

CHRONIC MULTIPLE PATHWAY INCREMENTAL LIFETIME CANCER RISKS FOR URBAN DWELLERS

Chemical of Potential Concern	Incremental Lifetime Cancer Risks[1,2] (per 100,000)	
	Project[3]	Future
METALS AND METALLOIDS		
Arsenic	2.8E-03	2.8E-03
POLYCYCLIC AROMATIC HYDROCARBONS		
Benzo(a)pyrene (and equivalents)	5.1E-04	5.1E-04
Biphenyl	4.5E-07	4.6E-07
VOLATILE ORGANIC COMPOUNDS		
Hexachlorobenzenes	6.7E-08	6.7E-08
CHEMICAL MIXTURES[4]		
Liver carcinogens	2.8E-03	2.8E-03

Notes:
1 With scientific notation, any value expressed to the negative power (*i.e.*, E-x) shows that predicted exposures were less than the exposure limit; whereas, a value expressed to the positive power (*i.e.*, E+x) shows exposure estimates exceeded the exposure limit.
2 Chronic inhalation ILCR values were added to the multiple pathway ILCR values for those COPC identified to have similar toxicological endpoints for chronic inhalation and chronic oral routes of exposure.
3 The Project ILCRs are based on the chemicals emissions associated with the Burnaby Terminal (if applicable), expansion of the Westridge Marine Terminal, and the Project-related increase in marine vessel traffic combined.
4 Individual constituents of the chemical mixtures are identified in Table 3.13. Note that calculation of the mixture ILCRs was performed on a life stage-specific basis; therefore, addition of the ILCRs provided in the above table for the chemical constituents of the mixture might not equate to the ILCR provided for the mixture because the ILCRs in the table represent the maximum ILCR for each lifestyle category, regardless of the life stage.

5.3 Other Considerations – Lead

Based on the current weight of evidence, Health Canada and other regulatory health authorities (ACCLPP 2012, Cal EPA 2009, JECFA 2011, US EPA 2006, WHO 2009) no longer support the premise that lead is a threshold toxicant. Health Canada (2011) has concluded that lead should be considered a non-threshold substance. Accordingly, threshold-based exposure limits are no longer recommended for

use. Currently, there is no exposure limit available to evaluate risks from inhalation or oral lead exposures due the uncertainty in identifying a level without adverse effect. In light of the uncertainty regarding regulatory guidance and the lack of an inhalation or oral exposure limit, an alternative method of evaluation was used to assess lead risks from inhalation and oral exposures in this HHRA.

As suggested by Wilson and Richardson (2013), toxicokinetic approaches or physiologically based pharmacokinetic (PBPK) models can be used to predict the blood lead level (BLL) of children due to lead exposures from multiple exposure pathways (*i.e.*, air, soil, water and food). PBPK models provide a scientifically sound means to predict the target tissue dose of chemicals in humans who are exposed to environmental levels (ATSDR 2007). The Integrated Exposure Uptake Biokinetic (IEUBK) model for lead in children (IEUBKwinv1.1 build 11; US EPA 2010c) was used to predict the incremental changes in BLL from exposure to the COPC associated with the Project through relevant secondary pathways. The IEUBK model was assumed to address inhalation exposures because the IEUBK model incorporates both inhalation and oral exposures to lead, and addresses the most sensitive endpoint (*i.e.*, IQ deficits in children).

Increasing BLLs are associated with neurological impairment, which is characterized as the most sensitive endpoint in children (Cal EPA 2009, Health Canada 2011, JECFA 2011). Some evidence suggests that a 1 to 2 µg/dL increase in BLL may be associated with a decrease of one IQ point on a population basis (Cal EPA 2009, Health Canada 2011). In the case of IQ, a one point decrement is a subtle effect that, in all likelihood, could not be reliably measured, detected, or attributed on an individual basis (Wilson and Richardson 2013). The HHRA used the 1 to 2 µg/dL BLL increase as a point of reference. The OEHHA also uses a threshold blood concentration with a source-specific "benchmark change" of 1 µg/dL (Cal EPA 2007b). The change in BLL is intended to be used as the "benchmark" increase in BLL resulting from exposure to environmental lead (Cal EPA 2007b).

Background lead levels in Canada are available as an alternative point of reference. Canadian levels of lead in blood and urine were measured in participants aged 6 to 79 years in the Canadian health measures survey between 2007 to 2009. The BLL for children aged 6 to 11 years are presented as µg/dL in whole blood in Table 5.16 (Health Canada 2010g). The data provide reference ranges for blood levels of lead in the Canadian population. Since the Canadian Health Measures Study (Health Canada 2010g) failed to collect data from 1 to 6 year old children, the sensitive population group for lead exposure, standard practice is to use data from the US population *National Health and Nutrition Examination Survey* (NHANES) as a surrogate (Table 5.16).

TABLE 5.16

ARITHMETIC AND GEOMETRIC MEANS AND 95TH PERCENTILE BLOOD LEAD CONCENTRATIONS

Sex	Age	Arithmetic Mean (95% Confidence Interval)	Geometric Mean (95% Confidence Interval)	95th Percentile (95% Confidence Interval)
Male and Female[1]	1 to 5	1.66 (unavailable)	1.33 (1.20 to 1.39)	3.83 (3.39 to 4.40)
Male and Female[2]	6 to 11	1.02 (0.91 to 1.13)	0.90 (0.81 to 0.99)	1.95 (1.65 to 2.26)
Female[2]	20 to 39	1.02 (0.91 to 1.12)	0.89 (0.81 to 0.98)	2.05 (1.78 to 2.32)

Notes:
1 Based on 2007-2010 NHANES dataset (ACCLPP 2012, CDC 2013).
2 Health Canada (2010g).

The IEUBK model for lead in children (IEUBKwinv1.1 build 11; US EPA 2010c) was used to predict the incremental changes in BLL from the relevant secondary pathways of exposure associated with the expansion of the Westridge Marine Terminal and associated increase in marine vessel traffic (*i.e.*, Project). The input values that were used in the IEUBK model to predict BLL in children are presented in Table 5.17 for Aboriginal peoples and urban dwellers. All remaining input values in the IEUBK model were unchanged or remained at default values.

As shown in Table 5.18, the geometric mean BLL in children is predicted to be 0.027 µg/dL for Aboriginal peoples and 0.026 µg/dL for urban dwellers as a result of the increase in lead exposures associated with the Project. The risk of adverse effects from lead exposures in air, soil and diet due to the Project is low based on the following:

- The predicted BLLs of are lower than the expected background levels in children (Table 5.16).
- The probability of exceeding the point of reference values of 1 µg/dL and 2 µg/dL is very low (*i.e.*, less than 0.00%) (Table 5.18).

For the reasons stated, emissions of lead from the Project are not expected to result in adverse health effects in the region.

TABLE 5.17

INPUT PARAMETERS USED IN THE IEUBK MODEL TO PREDICT PROJECT-RELATED BLOOD LEAD LEVELS IN CHILDREN

Parameter	Units	Life Stage	Project[1]	
			Aboriginal Peoples	Urban Dwellers
Air Concentration	µg/m^3	All ages	0.000006	0.00001
Dietary Exposure[2]	µg/day	Toddler[3]	0.017	0.014
		Child[4]	0.029	0.015
Soil concentration	mg/kg	All ages	0.018	0.030
Drinking water concentration[5]	µg/L	All ages	0	0
Mother's blood lead concentration at childbirth[6]	µg Pb/dL	Adult	1.02	1.02

Notes:
1 The Project includes the chemical emissions associated with the expansion of the Westridge Marine Terminal and the associated increase in marine vessel traffic combined. The Burnaby Terminal was not a source of metal emissions.
2 Sum of the following dietary items: plant, root, berries, wild game, beach foods and seaweed, depending on the lifestyle category under consideration.
3 Toddler dietary exposure assumed constant for the following age groups in the IEUBK model: 1 to 2, 2 to 3, and 3 to 4.
4 Child dietary exposure assumed constant for the following age groups in the IEUBK model: 4 to 5, 5 to 6, and 6 to 7.
5 It was assumed in the HHRA that Aboriginal peoples and urban dwellers would rely on a municipal water supply for their drinking water, and that municipal water would not be impacted by the Project; therefore, the incremental change in lead concentrations in drinking water was zero.
6 Provided Table 5.16.

TABLE 5.18

PREDICTED PROJECT-RELATED IEUBK LEAD CONCENTRATIONS FOR CHILDREN

Parameter	Units	Life Stage	Project[1]	
			Aboriginal Peoples	Urban Dwellers
Predicted geometric mean BLL in children aged 0 to 84 months	µg/m^3	All ages	0.027	0.026
Probability of blood lead concentrations above cut-off value of 1 µg/dL	mg/kg	All ages	0	0
Probability of blood lead concentrations above cut-off value of 2 µg/dL	µg/L	All ages	0	0

Notes:
1 The Project includes the chemical emissions associated with the expansion of the Westridge Marine Terminal and the associated increase in marine vessel traffic combined. The Burnaby Terminal was not a source of metal emissions.

6.0 DISCUSSION

The HHRA represents an extension and refinement of the previously filed SLHHRA (Technical Report 5D-7 in Volume 5D of the Application) aimed at identifying and understanding the potential health risks that chemical emissions from the Westridge Marine Terminal expansion might present to people living in the area and to people who might frequent the area for recreational or other purposes. The recommendation for the detailed HHRA was prompted by the results of the SLHHRA for the pipeline and facilities, which revealed exceedances of the health-based guidelines (or exposure limits) for certain of the COPC (acting either singly or in combination) associated with the Westridge Marine Terminal expansion. Although the exceedances were determined to be few in number and in virtually all cases were modest in magnitude, a detailed HHRA was conducted to provide a more comprehensive analysis of the potential health risks associated with the terminal. The HHRA allowed emphasis to be assigned to those conditions having a higher likelihood of occurrence rather than defaulting to the worst-case or near worst-case conditions, such that a more complete and informed determination can be made as to whether adverse health effects would be expected as a result of the exceedances predicted in the SLHHRA.

The HHRA for the Westridge Marine Terminal expansion continued to follow the conventional risk assessment paradigm used in the SLHHRA. The paradigm involved four steps: Problem Formulation, Exposure Assessment, Toxicity Assessment, and Risk Characterization. The major differences between the two risk assessments related to the Exposure Assessment step of the paradigm. Unlike the SLHHRA, which defaulted to conservative assumptions of worst-case or near worst-case conditions, the HHRA relied on a more refined set of assumptions that represented more credible conditions.

One of the major refinements captured in the HHRA relates to the characterization of the people potentially at risk, and ultimately the potential exposures that they might receive as a result of the expansion of the Westridge Marine Terminal. In the earlier assessment, people living in the area were assumed to be found on both a short-term and long-term basis at the location within the LSA corresponding to the MPOI. The MPOI refers to the location at which the highest air concentrations of each of the COPC would be expected to occur, and at which the exposures received by the people within the LSA would be greatest. Use of the MPOI location in the SLHHRA was meant to ensure that any potential health effects that could result from exposure to the chemical emissions associated with the Westridge Marine Terminal expansion would not be underestimated, regardless of where people might be exposed. With this conservative approach, consideration was not given as to whether or not the MPOI location was suitable for a permanent residence and/or for residents to obtain their entire complement of locally grown or harvested foodstuffs (including home-garden produce, beach food, game meat and wild plants). To better understand the potential health risks of short-term and long-term exposure to the chemical emissions associated with the expansion of the Westridge Marine Terminal, the HHRA assessed potential health risks at discrete (or fixed) locations corresponding to actual households, schools, assisted-living complexes, communities, parks and recreation areas found within the LSA. Emphasis was given to examining the potential health risks to people living in closest proximity to the Westridge Marine Terminal, where the maximum potential exposures to the COPC associated with the expansion would be expected to occur.

Apart from the above refinement, the methods followed in the HHRA closely matched that of the SLHHRA. Accordingly, the work included:

- Assessment of both short-term (or acute) and long-term (or chronic) exposure scenarios.
- Assessment of potential exposures relating to both the primary pathway (*i.e.*, inhalation) and secondary pathways (*i.e.*, inhalation of dust, food ingestion, and dermal contact).
- Assessment of potential exposures on both a cumulative basis and Project-specific basis.
- Assessment of the potential effects of the chemical emissions on the health of people living in the area (*i.e.*, residents), and people who might visit or frequent the area for recreation or other purposes and theoretically could be found anywhere within the LSA at any given time (*i.e.*, area users).

- Assessment of the different lifestyle characteristics, such as dietary patterns, of the residents (*i.e.*, Aboriginal peoples and urban dwellers) that could influence potential exposure to the chemical emissions.

- Assessment of both cancer and non-cancer health risks.

- Assessment of the potential health risks associated with the COPC acting either singly or in combination (*i.e.*, chemical mixtures).

The HHRA revealed that the maximum predicted levels of exposure to the COPC (acting either singly or in combination) were below the health-based guidelines (or exposure limits). The only exception was for the short-term inhalation of the respiratory irritants mixture at the MPOI. No exceedances were predicted at any of the discrete locations corresponding to actual households, schools, assisted-living complexes, communities, parks and recreation areas found within the LSA. The conservatism incorporated into both the exposure estimates and the exposure limits must be considered in the interpretation of these exceedances.

Specifically, the analysis and interpretation of the short-term exceedances predicted for the respiratory irritants mixture took the following into consideration:

- the potential contribution from the Project to the mixture's exceedance;

- the spatial extent of the exceedances;

- the likelihood of an exceedance occurring; and

- the primary chemical contributors to the mixture's exceedances.

Exceedances were predicted for the respiratory irritants for the area users at the MPOI only. The magnitude of the predicted exceedance at the MPOI was modest, with a predicted risk estimate of 1.4. The Base Case risks were not predicted to change at this location under the Application Case or Cumulative Case. This indicates that the incremental changes in risk as a result of the Project are essentially negligible, and that the Project will have very little, if any, impact on the Base Case health risks associated with short-term exposure to the respiratory irritants. The MPOI for the respiratory irritants is predicted to occur within the perimeter of another industrial facility, where public access would be restricted.

The acute respiratory irritants mixture was comprised of 12 COPC that were assumed, for the purposes of the HHRA, to have an additive effect on the respiratory tract. NO_2 was predicted to contribute more than 73% of the overall mixture risk, with SO_2 predicted to be the next largest contributor at approximately 22% of the risk. However, the modes of action for NO_2 and SO_2 within the respiratory tract can differ, which may result in the mixture risk estimates being overstated. For example, NO_2 is relatively insoluble in water and can be inhaled deeply into the lungs, acting as a deep-lung irritant; whereas, SO_2 is readily soluble in water and, at the concentrations predicted within the LSA, would be readily absorbed by the moist mucous membranes lining the upper respiratory tract, effectively removing it from the airstream such that it would not penetrate deep into the lungs and alveolar spaces. For these reasons, it is likely that the combined RQs for acute inhalation respiratory irritants mixture are overstated, and adverse health effects would not be expected.

In the chronic exposure assessment, potential health risks that could be presented to the local residents *via* the primary inhalation pathway were assessed. Examination of the findings revealed that in all cases the maximum predicted annual air concentrations of the COPC (acting either singly or in combination) associated with the Project were lower than the corresponding exposure limits. Long-term health risks associated with the COPC exposures therefore are considered negligible or low, and adverse health effects from the long-term inhalation of the COPC associated with the Project are not expected.

The potential health risks that could be presented to the local residents from chronic exposure to the COPC (acting either singly or in combination) associated with the Project *via* the relevant secondary exposure pathways also were examined. The potential chronic multiple pathway health risks were

estimated based on the assumption that residents would be continuously exposed for an assumed lifespan of 80 years. Examination of the findings revealed that in all cases the maximum predicted exposures through the secondary pathways of the COPC (acting either singly or in combination) associated with the Project were lower than the corresponding exposure limits. Long-term health risks associated with the COPC exposures therefore are considered negligible or low, and adverse health effects from the inhalation of dust, food ingestion, and dermal contact are not expected.

The above findings provide no obvious indication that the health of people living in the area surrounding the Westridge Marine Terminal and who might frequent the area for recreational or other purposes would be adversely affected from exposure to the COPC associated with the Project. Similarly, the changes between the Base Case and Application Case health risks are generally small, suggesting that the expansion of the Westridge Marine Terminal and associated increase in marine vessel traffic is not expected to contribute significantly to local health risks.

7.0 SUMMARY

The HHRA represents an extension and refinement of the earlier SLHHRA (Technical Report 5D-7 in Volume 5D of the Application) aimed at identifying and understanding the potential health risks that the chemical emissions from the Project might present to people living in the area and to people who might frequent the area for recreational or other purposes. The need for the detailed HHRA was prompted by the results of the SLHHRA for the Westridge Marine Terminal, which revealed exceedances of the health-based guidelines (or exposure limits) for certain of the COPC (acting either singly or in combination). Although the exceedances were determined to be few in number and in virtually all cases were modest in magnitude, a detailed HHRA was conducted to provide a more comprehensive analysis of the potential health risks associated with the Westridge Marine Terminal expansion. The HHRA allowed emphasis to be assigned to those conditions having a higher likelihood of occurrence rather than defaulting to the worst-case or near worst-case conditions, such that a more complete and informed determination can be made as to whether adverse health effects would be expected as a result of the modest health risks predicted in the SLHHRA.

The HHRA examined both short-term (acute) and long-term (chronic) health risks associated with the expansion of the Westridge Marine Terminal. The potential health risks relating to both the primary pathway (*i.e.*, inhalation) and secondary pathways (*i.e.*, inhalation of dust, food ingestion, and dermal contact) were assessed. Health risks were evaluated in the HHRA by comparing predicted exposures with health-based guidelines (or exposure limits) considered protective of the most sensitive individuals. The approach used for the HHRA has been accepted in the past by regulatory agencies such as Health Canada, the CCME, BC MOE and ESRD.

Overall, the major findings of the HHRA are:

- The contribution from the expansion of the Westridge Marine Terminal to the cumulative exposures to the COPC is negligible. In the majority of instances, the potential health risks remained unchanged between the assessment cases (*i.e.*, Base Case, Application Case and Cumulative Case), signifying that the expansion of the Westridge Marine Terminal and associated increase in marine vessel traffic will have very little, if any, effect on the Base Case health risks.

- With very few exceptions, non-carcinogenic inhalation risks were predicted to be below the benchmark (or target risk estimate) of 1.0, indicating that estimated short-term and long-term inhalation exposures were less than the health-based guidelines (or exposure limits). Risk estimates less than or equal to 1.0 are associated with a negligible or low health risk, and therefore adverse health effects would not be expected. No exceedances were predicted at any of the discrete (or fixed) locations corresponding to actual households, schools, assisted-living complexes, communities, parks and recreation areas found within the LSA. The only exceedances were predicted for the respiratory irritants mixture at the MPOI on a short-term basis. These exceedances were determined to be few in number, low in frequency and modest in magnitude. Further examination of the predicted exceedances indicates that the health risks are considered low, and that adverse health effects are not predicted to occur.

- In all cases, non-carcinogenic risks associated with the various secondary pathways of exposure (*i.e.*, inhalation of dust, food ingestion, and dermal contact) were predicted to be below the benchmark (or target risk estimate) of 0.2, indicating that estimated exposures were less than 20% of the health-based guidelines (or exposure limits). Risk estimates less than or equal to 0.2 are associated with a negligible or low health risk, and therefore adverse health effects would not be expected.

- In all cases, risks for the carcinogens were predicted to be less than one in 100,000 (*i.e.*, one extra cancer case in a population of 100,000 people), indicating that the incremental cancer risks associated with the expansion of the Westridge Marine Terminal and associated increase in marine vessel traffic are deemed to be “essentially negligible”.

- The findings are consistent with those of the SLHHRA in that they continued to show a low potential for adverse health effects as a result of the Westridge Marine Terminal expansion. However, because

of a greater emphasis on more credible exposure circumstances the findings of the HHRA demonstrate that the health risks are even lower than those indicated by the SLHHRA.

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9.0 REFERENCES

9.1 Literature Cited

Advisory Committee for Childhood Lead Poisoning Prevention. 2012. Low Level Lead Exposure Harms Children: A Renewed Call for Primary Prevention. Centers for Disease Control and Prevention. Available at http://www.cdc.gov/nceh/lead/ACCLPP/Final_Document_030712.pdf

Agency for Toxic Substances and Disease Registry. 1998. Toxicological Profile for Sulphur Dioxide. Prepared by Sciences International, Inc. under subcontract to: Research Triangle Institute under contract No. 205-93-0606. Prepared for US Department of Health and Human Services. Public Health Service. Agency for Toxic Substances and Disease Registry. Atlanta, GA. December 1998.

Agency for Toxic Substances and Disease Registry. 2007. Toxicological Profile for Lead. US Department of Health and Human Services. Public Health Service. Agency for Toxic Substances and Disease Registry. Atlanta, GA. August 2007.

Agency for Toxic Substances and Disease Registry. 2013. Minimal Risk Levels (MRLs). Available at: http://www.atsdr.cdc.gov/mrls/index.asp

Alberta Health and Wellness. 2011. Guidance on Human Health Risk Assessment for Environmental Impact Assessment in Alberta. Government of Alberta. August 2011.

Azadniv, M., Utell, M.J., Morrow, P.E., Gibb, F.R., Nichols, J., Roberts, N.J. Jr., Speers, D.M., Torres, A., Tsai, Y., Abraham, M.K., Voter, K.Z. and Frampton, M.W. 1998. Effects of nitrogen dioxide exposure on human host defense. Inhal Toxicol 10(6): 585-601.

Beil, M. and Ulmer, W.T. 1976. Wirkung von NO2 im MAK-Bereich auf Atemmechanik und bronchiale Acetylcholinempfindlichkeit bei Normalpersonen [Effect of NO2 in workroom concentrations on respiratory mechanics and bronchial susceptibility to acetylcholine in normal persons]. Int. Arch. Occup. Environ. Health 38: 31-44.

Blomberg, A., Krishna, M.T., Bocchino, V., Biscione, G.L., Shute, J.K., Kelly, F.J., Frew, A.J., Holgate S.T. and Sandstrom. T. 1997. The inflammatory effects of 2 ppm NO2 on the airways of healthy subjects. Am J Respir Crit Care Med 156: 418-424.

Blomberg, A., Krishna, M.T., Helleday, R., Söderberg, M., Ledin, M.C., Kelly, F.J., Frew, A.J., Holgate, S.T. and Sandström. T. 1999. Persistent airway inflammation but accommodated antioxidant and lung function responses after repeated daily exposure to nitrogen dioxide. Am. J. Respir. Crit. Care Med. 159: 536-543.

Boethling, R., Fenner, K., Howard, P., Klečka, G., Madsen, T., Snape, J.R., and Whelan, M.J. 2009. Environmental persistence of organic pollutants: guidance for development and review of POP risk profiles. Integr Environ Assess Manag 5(4):539-556.

Boobis, A., Budinsky, R., Collie, S., Crofton, K., Embry, M., Felter, S., Hertzberg, R., Kropp, D., Mihlan, G., Mumtaz, M., Price, P., Solomon, K., Teuschler, L., Yang, R., Zaleski, R. 2001. Critical analysis of literature on low-dose synergy for use in screening chemical mixtures for risk assessment. Critical Reviews in Toxicology, 2011; 41(5): 369–383

British Columbia Ministry of Environment. 2008. Guidelines for Air Quality Dispersion Modelling in British Columbia. Environmental Protection Division, Environmental Quality Branch, Air Protection Section. Victoria, B.C. http://www.env.gov.bc.ca/epd/bcairquality/reports/pdfs/air_disp_model_08.pdf

British Columbia Ministry of Environment. 2009. Technical Guidance on Contaminated Sites. Environmental Quality Standards. February, 2009.

British Columbia Ministry of Environment. 2012. Supplemental Guidance for Risk Assessments. Technical Guidance on Contaminated Sites. Version 2. July 2012. British Columbia Ministry of Environment, Government of British Columbia. Victoria, BC.

British Columbia Parks. 2013. Available at: www.env.gov.bc.ca/bcparks/

Bureau of Chemical Safety, Health Canada. 2004. Fish Consumption: Review and Recommendation of Current Intake Figures for Canadian Consumers. Cited in: Health Canada 2007

Burnaby School District. 2013. Elementary Schools. Available at: http://sd41.bc.ca/schools/elementary/

Calabrese, E.J. 1991. Multiple Chemical Interactions. Toxicology and Environmental Health Series. Chelsea, MI: Lewis Publishers Inc.

California Environmental Protection Agency. 1999. Air Toxics Hot Spots Program Risk Assessment Guidelines Part I: Determination of Acute Reference Exposure Levels for Airborne Toxicants. Air Toxicology and Epidemiology Section, Office of Environmental Health Hazard Assessment, California Environmental Protection Agency. March 1999.

California Environmental Protection Agency. 2007a. Review of the California Ambient Air Quality Standard For Nitrogen Dioxide: Technical Support Document. California Environmental Protection Agency Air Resources Board and Office of Environmental Health and Hazard Assessment. Available at: http://www.arb.ca.gov/research/aaqs/no2-rs/no2tech.pdf

California Environmental Protection Agency. 2007b. Development of Health Criteria for School Site Risk Assessment Pursuant to Health and Safety Code Section 901(G): Child-Specific Benchmark Change in Blood Lead Concentration for School Site Risk Assessment Integrated Risk Assessment Branch Office of Environmental Health Hazard Assessment California Environmental Protection Agency. Final Report. April 2007.

California Environmental Protection Agency. 2009. Revised California Human Health Screening Level for Lead (Review Draft). Office of Environmental Health Hazard Assessment, Sacramento, CA, USA. Available at http://www.oehha.ca.gov/risk/pdf/LeadCHHSL51809.pdf

California Office of Environmental Health Hazard Assessment. 2012. Acute, 8-hour and Chronic Reference Exposure Level (REL) Summary. California Environmental Protection Agency, Office of Environmental Health Hazard Assessment. Sacramento, CA. Available at: http://www.oehha.ca.gov/air/allrels.html

Canadian Cancer Society. 2010. General cancer statistics for 2010. Available at: http://www.cancer.ca/canada-wide/about%20cancer/cancer%20statistics/stats%20at%20a%20glance/general%20cancer%20stats.aspx

Canadian Council of Ministers of the Environment. 2006. A Protocol for the Derivation of Environmental and Human Health Soil Quality Guidelines. Winnipeg, MB. ISBN – 10 1-896997-45-7 PDF.

Canadian Council of Ministers of the Environment. 2008a. Canada-Wide Standard for Petroleum Hydrocarbons (PHC) in Soil: Scientific Rationale – Supporting Technical Document. January 2008.

Canadian Council of Ministers of the Environment. 2008b. Canada-Wide Standard for Petroleum Hydrocarbons (PHC) in Soil: User Guidance. January 2008.

Canadian Council of Ministers of the Environment. 2012. Canadian Ambient Air Quality Standards (CAAQS) for Fine Particulate Matter (PM2.5) and Ozone. http://www.ccme.ca/assets/pdf/caaqs_and_azmf.pdf

Centre for Disease Control. 2013. Fourth National Report on Human Exposure to Environmental Chemicals Updated Tables, September 2012. Updated February 2013.

Chan, L., O. Receveur, D. Sharp, H. Schwartz, A. Ing and C. Tikhonov. 2011. First Nations Food, Nutrition and Environment Study: Results from British Columbia (2008/2009). University of Northern British Columbia. Prince George, BC.

City of Burnaby. 2014. Available at: http://www.burnaby.ca/home.html

City of Coquitlam. 2013. Available at: http://www.coquitlam.ca/

City of Port Moody. 2014. Available at: http://www.portmoody.ca/

Devlin, R.B., Horstman, D.P., Gerrity, T.R., Becker S. and Madden, M.C. 1999. Inflammatory response in humans exposed to 2.0 ppm nitrogen dioxide. Inhalation Toxicol. 11: 89-109.

Department of Fisheries and Oceans. 2013. Bivalve Shellfish Sanitary Contamination Closures – Pacific Region. Government of Canada. Fisheries and Oceans Canada. http://www.pac.dfo-mpo.gc.ca/fm-gp/contamination/sani/index-eng.html

District of North Vancouver. 2014. Available at: Available at: http://www.district.north-van.bc.ca/

Dorman DC, Brenneman KA, Struve MF. 1999. Experimental investigations into the neurotoxicity and nasal toxicity of hydrogen sulfide in rats. Environ Epidemiol Toxicol; 1: 249 255.

Environment Canada. 2003. Guidance Manual for the Categorization of Organic and Inorganic Substances on Canada's Domestic Substances List. Determining persistence, bioaccumulation potential, and inherent toxicity to non-human organisms. Existing Substances Branch, Environment Canada. June 2003.

Environment Canada. 2007. Use of Environmental Fate and Effects Criteria to Determine the Alternate Threshold of a Substance for the National Pollutant Release Inventory. September 2007. Website: https://www.ec.gc.ca/inrp-npri/default.asp?lang=en&n=889870FD-1

European Commission. 2012. Scientific Committee on Health and Environmental Risks (SCHER), Scientific Committee on Emerging and Newly Identified Health Risks (SCENIHR), and Scientific Committee on Consumer Safety (SCCS). Toxicity and Assessment of Chemical Mixtures. European Commission DG Health & Consumers Directorate D: Health Systems and Products Unit D3 - Risk Assessment Office: B232 B-1049 Brussels. November 2011.

Fraser Health Authority. 2011. Search for Locations. Available at: http://www.fraserhealth.ca/find_us/locations/

Gong, H., Jr., Linn, W.S., Clark, K.W., Anderson, K.R., Geller, M.D. and Sioutas, C. 2005. Respiratory responses to exposures with fine particulates and nitrogen dioxide in the elderly with and without COPD. Inhalation Toxicol. 17: 123-132.

Goodman, J.E., Chandalia, J.K., Thakali, S. and Seeley, M. 2009. Meta-analysis of nitrogen dioxide exposure and airway hyper-responsiveness in asthmatics. Critical Reviews in Toxicology 39(9):719-742.

Harkema JR, Carey SA, Wagner JG. 2006. The nose revisited: a brief review of the comparative structure, function and toxicologic pathology of the nasal epithelium. Tox Pathol 34: 252 269.

Hazardous Substances Data Bank. 2011. Database on-line search for Sulfur dioxide. Available at http://toxnet.nlm.nih.gov/cgi-bin/sis/htmlgen?HSDB

Health Canada. 1994. Human Health Risk Assessment for Priority Substances. Canadian Environmental Protection Act: Priority Substances List Assessment Report No. 41. Ottawa, ON: Health Canada. PSL-41E EN40-215/41E.

Health Canada. 2007. Human Health Risk Assessment of Mercury in Fish and Health Benefits of Fish Consumption. Bureau of Chemical Safety, Food Directorate, Health Products and Food Branch. Cat.: H164-54/2007E-PDF, ISBN: 978-0-662-47023-6. http://www.hc-sc.gc.ca/fn-an/pubs/mercur/merc_fish_poisson-eng.php

Health Canada. 2010a. Federal Contaminated Site Risk Assessment in Canada, Part I: Guidance on Human Health Preliminary Quantitative Risk Assessment (PQRA), Version 2.0. September 2010. Contaminated Sites Division, Safe Environments Directorate, Health Canada. Ottawa, ON.

Health Canada. 2010b. Federal Contaminated Site Risk Assessment in Canada, Part II: Health Canada Toxicological Reference Values (TRVs) and Chemical-Specific Factors, Version 2.0. September 2010. Contaminated Sites Division, Safe Environments Directorate, Health Canada. Ottawa, ON.

Health Canada. 2010c. Federal Contaminated Site Risk Assessment in Canada, Part III: Guidance on Peer Review of Human Health Risk Assessments for Federal Contaminated Sites in Canada, Version 2.0. September 2010. Contaminated Sites Division, Safe Environments Directorate, Health Canada. Ottawa, ON.

Health Canada. 2010d. Federal Contaminated Site Risk Assessment in Canada, Part V: Guidance on Human Health Detailed Quantitative Risk Assessment for Chemicals (DQRAChem), Version 2.0. September 2010. Contaminated Sites Division, Safe Environments Directorate, Health Canada. Ottawa, ON.

Health Canada. 2010e. Federal Contaminated Site Risk Assessment in Canada, Supplemental Guidance on Human Health Risk Assessment for Country Foods (SLHHRAFoods). October, 2012. Contaminated Sites Division, Safe Environments Directorate, Health Canada. Ottawa, ON.

Health Canada. 2010f. Federal Contaminated Site Risk Assessment in Canada, Supplemental Guidance: Checklist for Peer Review of Detailed Human Health Risk Assessments (SLHHRAs) for Federal Contaminated Sites in Canada. Contaminated Sites Division, Safe Environments Directorate, Health Canada. Ottawa, ON.

Health Canada. 2010g. Report on Human Biomonitoring of Environmental Chemicals in Canada Results of the Canadian Health Measures Survey Cycle (2007–2009). August 2010.

Health Canada. 2011. [DRAFT] Human Health State of the Science Report on Lead. Ottawa, ON, Canada. Available at http://www.hc-sc.gc.ca/ewh-semt/pubs/contaminants/dhhssrlrpecscepsh/index-eng.php

Joint FAO/WHO Expert Committee on Food Additives. 2011. WHO Food Additive Series: 64 – Safety Evaluation of Certain Food Additives and Contaminants. Prepared by the seventy-third meeting of JECFA, Joint FAO/WHO Expert Committee on Food Additives, ISBN 978 924 166064 8. Geneva, Switzerland.

Jorres, R., Nowak, D., Grimminger, F., Seeger, W., Oldigs, M. and Magnussen, H. 1995. The effect of 1 ppm nitrogen dioxide on bronchoalveolar lavage cells and inflammatory mediators in normal and asthmatic subjects. Eur. Respir. J. 8: 416-424.

Kimbell JS. 2006. Nasal Dosimetry of inhaled gases and particles: where do inhaled agents go in the nose? Tox Pathol; 34: 270 273.

Klaassen, C.D. 2008. Casarett and Doull's Toxicology – the Basic Science of Poisons. 7th ed. McGraw Hill New York: 2008.

Linn, W.S., Jones, M.P., Bailey, R.M., Kleinman, M.T., Spier, C.E., Fischer, D.A., Hackney, J.D. 1980. Respiratory effects of mixed nitrogen dioxide and sulfur dioxide in human volunteers under simulated ambient exposure conditions. Environ Res, 1980 Aug; 22(2): 431-8

Mackay, D., Shiu, W. and Ma, K. 1992. Illustrated Handbook of Physical-Chemical Properties and Environmental Fate for Organic Chemicals: Volume II.: Lewis Publishers. Chelsea, Michigan.

Mackay, D., Shiu, W. and Ma, K. 1993. Illustrated Handbook of Physical-Chemical Properties and Environmental Fate for Organic Chemicals: Volumes III.: Lewis Publishers. Chelsea, Michigan.

Market Facts of Canada. 1991. Research Report: National Seafood Consumption Study. Conducted for: Health and Welfare Canada. #C388/JdeB. Cited in: Health Canada 2007

Meek, M.E., Boobis, A.R., Crofton, K.M., Heinemeyer, G., Van Raaij, M. and Vickers, C. 2011. Risk assessment of combined exposure to multiple chemicals: A WHO/IPCS framework. Regulatory Toxicology and Pharmacology 60:S1-S14.

Metro Vancouver. 2012a. Station Information: Lower Fraser Valley Air Quality Monitoring Network. Burnaby, BC. 115 pp.

Metro Vancouver. 2012b Burrard Inlet Area Local Area Quality Study – Monitoring Program Results. December 2012. Air Quality Policy and Management Division of Metro Vancouver. http://www.metrovancouver.org/about/publications/Publications/BIALAQS_Monitoring_ProgramFinal_ReportDec2012.pdf

Morrow, P.E., Utell, M.J., Bauer, M.A., Smeglin, A.M., Frampton, M.W., Cox, C., Speers D.M. and Gibb, F.R. 1992. Pulmonary performance of elderly normal subjects and subjects with chronic obstructive pulmonary disease exposed to 0.3 ppm nitrogen dioxide. Am Rev Respir Dis 145: 291-300.

National Energy Board. 2014. Filing Manual. Inclusive of Release 2014-01 (January 2014). Calgary, AB.

National Institute of Occupational Safety and Health. 1974. Criteria for a Recommended Standard - Occupational Exposure to Sulphur Dioxide. US Department of Health, Education and Welfare, Public Health Service, Center for Disease Control, National Institute of Occupational Safety and Health. DHHS (NIOSH) Publication No. 74-111.

Nieding, G. von and Wagner, H.M. 1977. Experimental studies on the short-term effect of air pollutants on pulmonary function in man: two-hour exposure to NO2, O3 and SO2 alone and in combination. In: Kasuga, S., N. Suzuki, T. Yamada, G. Kimura, K. Inagaki and K. Onoe (eds.). Proceedings of the fourth international clean air congress, May, Tokyo, Japan. Tokyo, Japan: Japanese Union of Air Pollution Prevention Associations. P.p. 5-8.

Nieding, G. von, H.M. Wagner, H. Casper, A. Beuthan and U. Smidt. 1980. Effect of experimental and occupational exposure to NO2 in sensitive and normal subjects. In: Lee, S. D. (ed.). Nitrogen oxides and their effects on health. Ann Arbor, MI: Ann Arbor Science Publishers, Inc. P.p. 315-331.

Nieding, G. von, Wagner, H.M., Krekeler, H., Loellgen, H., Fries, W. and Beuthan, A. 1979. Controlled studies of human exposure to single and combined action of NO2, O3 and SO2. Int. Arch. Occup. Environ. Health 43: 195-210.

North Vancouver School District. 2013. District Map. Accessed at: http://www.nvsd44.bc.ca/Schools/DistrictMap/Pages/default.aspx

O'Connor Associates Environmental Inc. and G. Mark Richardson. 1997. Compendium of Canadian Human Exposure Factors for Risk Assessment. Ottawa, Ontario.

Price, P.S. and Han, X. 2011. Maximum cumulative ratio (MCR) as a tool for assessing the value of performing a cumulative risk assessment. Int J Environ Res Public Health 8:2212-2225; doi:10.3390/ijerph8062212

Price, P.S., Hollnagel, H.M. and Zabik, J.M. 2009. Characterizing the noncancer toxicity of mixtures using concepts from the TTC and quantitative models of uncertainty in mixture toxicity. Risk Analysis, 29(11):1534-1548. DOI: 10.1111/j.1539-6924.2009.01300.x

Reznik, G. and Stinson, S.F. (eds). 1983. Nasal Tumours in Animals and Man. Volumes 1 and 2. CRC Press, Boca Raton.

Reznik, G.K. 1990. Comparative anatomy, physiology, and function of the upper respiratory tract. Environ Health Perspect; 85:171 6.

Rubinstein, I., Bigby, B.G., Reiss, T.F., Boushey JR, H.A. 1990. Short-term exposure to 0.3 ppm nitrogen dioxide does not potentiate airway responsiveness to sulfur dioxide in asthmatic subjects. Am. Rev. Respir. Dis. 1990; 141:381-385

Sandstrom, T., 1995. Respiratory effects of air pollution: experimental studies in humans. Eur. Respir J, 1995, 8, 976-995

Syracuse Research Corporation. 2013. Interactive PhysProp Database Demo. SRC Inc. Available at: http://www.syrres.com/what-we-do/databaseforms.aspx?id=386

Texas Commission on Environmental Quality. 2011. Nickel and Inorganic Nickel Compounds. (CAS Registry Numbers: Nickel: 7440-02-0, Nickel Sulfate: 7786-81-4, Nickel Subsulfide: 12035-72-2, Nickel Oxide: 1313-99-1, Nickel Chloride: 7718-54-9). Development Support Document Final, June 01, 2011. Prepared by McCant, D.D., Haney, J.T. Jr. and Grant, R.L. , Toxicology Division, Chief Engineer's Office, Texas Commission on Environmental Quality. Available at: http://www.tceq.state.tx.us/assets/public/implementation/tox/dsd/final/june11/nickel_&_compounds.pdf

United States Environmental Protection Agency Office of Solid Waste. 2005. Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities, Final. US EPA Region VI. Multimedia Planning and Permitting Division. Center for Combustion Science and Engineering. Office of Solid Waste.

United States Environmental Protection Agency. 2002. A Review of the Reference Dose and Reference Concentration Processes. US EPA Risk Assessment Forum, Washington, DC. EPA/630/P 02/002F, December 2002. Final Report.

United States Environmental Protection Agency. 2003. Attachment 1-3 Guidance for Developing Ecological Soil Screening Levels (Eco-SSLs) Evaluation of Dermal Contact and Inhalation Exposure Pathways for the Purpose of Setting Eco-SSLs. OSWER Directive 92857-55. November 2003.

United States Environmental Protection Agency. 2004. Air Quality Criteria for Particulate Matter, Volume I. October 2004. EPA/600/P 99/002aF. National Centre for Environmental Assessment-RTP Office, Office of Research and Development, U.S. Environmental Protection Agency. Triangle Park, North Carolina.

United States Environmental Protection Agency. 2005. Guidelines for Carcinogen Risk Assessment. United States Environmental Protection Agency. Risk Assessment Forum, Washington, DC. EPA/630/P-03/001F. March 2005.

United States Environmental Protection Agency. 2006. National Ambient Air Quality Standards: Air Quality Criteria for Lead. Available at http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=158823

United States Environmental Protection Agency. 2010a. 40 CFR Parts 50 and 58. Primary National Ambient Air Quality Standards for Nitrogen Dioxide. file:///E:/NO2/US%20EPA%202010.htm

United States Environmental Protection Agency. 2010b. Code of the Federal Register. Environmental Protection Agency. 40 CFR Parts 50, 53 and 58. Primary National Ambient Air Quality Standard for Sulfur Dioxide: Final Rule.

United States Environmental Protection Agency. 2010c. Integrated Exposure Uptake Biokinetic Model for Lead in Children, Windows® version (IEUBKwin v1.1 build 11). February 2010 32-bit version.

United States Environmental Protection Agency. 2011. Estimation Programs Interface Suite™ for Microsoft® Windows, v 4.10. United States Environmental Protection Agency, Washington, DC, USA.

Vagaggini, B., Paggiaro, P.L., Giannini, D., Di Franco, A., Cianchetti, S., Carnevali, S., Taccola, M., Bacci, E., Bancalari, L., Dente, F.L. and Giuntini, C. 1996. Effect of short-term NO2 exposure on induced sputum in normal, asthmatic and COPD subjects. Eur Respir J 9: 1852-1857.

Village of Belcarra. 2014. Available at: http://www.belcarra.ca/index.htm.

Wilson, R. and G.M. Richardson. 2013. Lead (Pb) is now a non-threshold substance: How does this affect soil quality guidelines? Human and Ecological Risk Assessment: An International Journal, Doi:10.1080/10807039.2013.771534.

World Health Organization. 1979. Environmental Health Criteria 8 Sulfur oxides and suspended particulate matter. International Programme on Chemical Safety. ISBN 92 4 154068 0.

World Health Organization. 2000. Air Quality Guidelines for Europe, Second Edition. World Health Organization, Regional Office for Europe, Copenhagen. WHO Regional Publications, European Series, No. 91. ISBN 92 890 1358 3 ISSN 0378-2255

World Health Organization. 2006. Air Quality Guidelines: Global Update. 2005. Particulate matter, ozone, nitrogen dioxide and sulphur dioxide. ISBN 92 890 2192 6.

World Health Organization. 2009. Blood Lead Levels in Children. Factsheet 4.5, European Environment and Health Information System. Available at http://www.euro.who.int/__data/assets/pdf_file/0003/97050/4.5.-Levels-of-lead-inchildrens-blood-EDITING_layouted.pdf

9.2 Figure and Mapping References

BC Forests, Lands and Natural Resource Operations. 2008. BC Freshwater Atlas Stream Network (digital file). Victoria, BC. Available: https://apps.gov.bc.ca/pub/dwds/home.so. Acquired: July 2011. Last Update Check: January 20, 2014.

BC Forests, Lands and Natural Resource Operations. 2008. BC Freshwater Atlas Rivers (digital file). Victoria, BC. Available: https://apps.gov.bc.ca/pub/dwds/home.so. Acquired: July 2011. Last Update Check: January 20, 2014.

BC Forests, Lands and Natural Resource Operations. 2008. Freshwater Atlas Lakes (digital file). Victoria, BC. Available: https://apps.gov.bc.ca/pub/dwds/home.so. Acquired: August 2011. Last Update Check: January 20, 2014.

BC Forests, Lands and Natural Resource Operations. 2008. Freshwater Atlas Bays and Channels (digital file). Victoria, BC. Available: https://apps.gov.bc.ca/pub/dwds/home.so. Acquired: July 2012. Last Update Check: January 20, 2014.

BC Forests, Lands and Natural Resource Operations. 2008. Tantalis Parks, Ecological Reserves and Protected Areas (digital file). Victoria, BC. Available:https://apps.gov.bc.ca/pub/dwds/home.so. Acquired: August 2013. Last Update Check: August 1, 2013.

BC Forests, Lands and Natural Resource Operations. 2008. Tantalis Conservancy Areas (digital file). Victoria, BC. Available: https://apps.gov.bc.ca/pub/dwds/home.so. Acquired: May 2013. Last Update Check: May 21, 2013.

BC Forests, Lands and Natural Resource Operations. 2008. Tantalis Parks, Ecological Reserves and Protected Areas (digital file). Victoria, BC. Available: https://apps.gov.bc.ca/pub/dwds/home.so. Acquired: March 2014. Last Update Check: March 17, 2014.

BC Forests, Lands and Natural Resource Operations. 2012. Digital Road Atlas (DRA) - Master Partially Attributed Road Data (digital file). Victoria, BC. Available: https://apps.gov.bc.ca/pub/dwds/home.so. Acquired: December 2012. Last Update Check: December 17, 2012.

Esri, Inc. 2014. World Imagery map service (digital file). Redlands, CA. Available: via ArcGIS Online, visit http://www.arcgis.com/home/item.html?id=10df2279f9684e4a9f6a7f08febac2a9. Acquired: June 2013. Last Accessed: March 31, 2014.

IHS Inc. 2013. IHS Cities and Towns (digital file). Calgary, AB. Available: http://energy.ihs.com/Solutions/Regions/Canada/. Acquired: October 2013. Last Update Check: January 21, 2014.

Kinder Morgan Canada. 2006-12. 0.5cm - 1m B/W & Colour Orthophotography (digital file). Calgary, AB. Received via FTP. Acquired: 2012-13. Last Update Check: N/A.

Kinder Morgan Canada. 2012. Baseline Routing (digital file). Calgary, AB. Received via FTP. Acquired: May 9, 2012. Last Update Check: N/A.

Natural Resources Canada. 2003. Canadian Geographical Names (digital file). Ottawa, ON. Available: http://geobase.ca/geobase/en/data/cgn/index.html. Acquired: December 2013. Last Update Check: December 16, 2013.

Natural Resources Canada. 2012. CanVec -Transportation - 1020009 Railway (digital file). Sherbrooke, QC. Available: http://geogratis.cgdi.gc.ca/geogratis/en/download/topographic.html. Acquired: June 2012. Last Update Check: November 2012.

Natural Resources Canada. 2014. Canada Lands Administrative Boundaries Level 1 (digital file). Ottawa, ON. Available: http://geogratis.gc.ca/api/en/nrcan-rncan/ess-sst/eb3757cc-d08b-5e62-9a44-3a8534ff3249.html. Acquired: January 2014. Last Update Check: March 11, 2014.

UniversalPegasus International. 2013. Rev 9 Routing (digital file). Calgary, AB. Received via FTP. Acquired: March 19, 2014. Last Update Check: N/A.

APPENDIX A FIGURES

LIST OF FIGURES

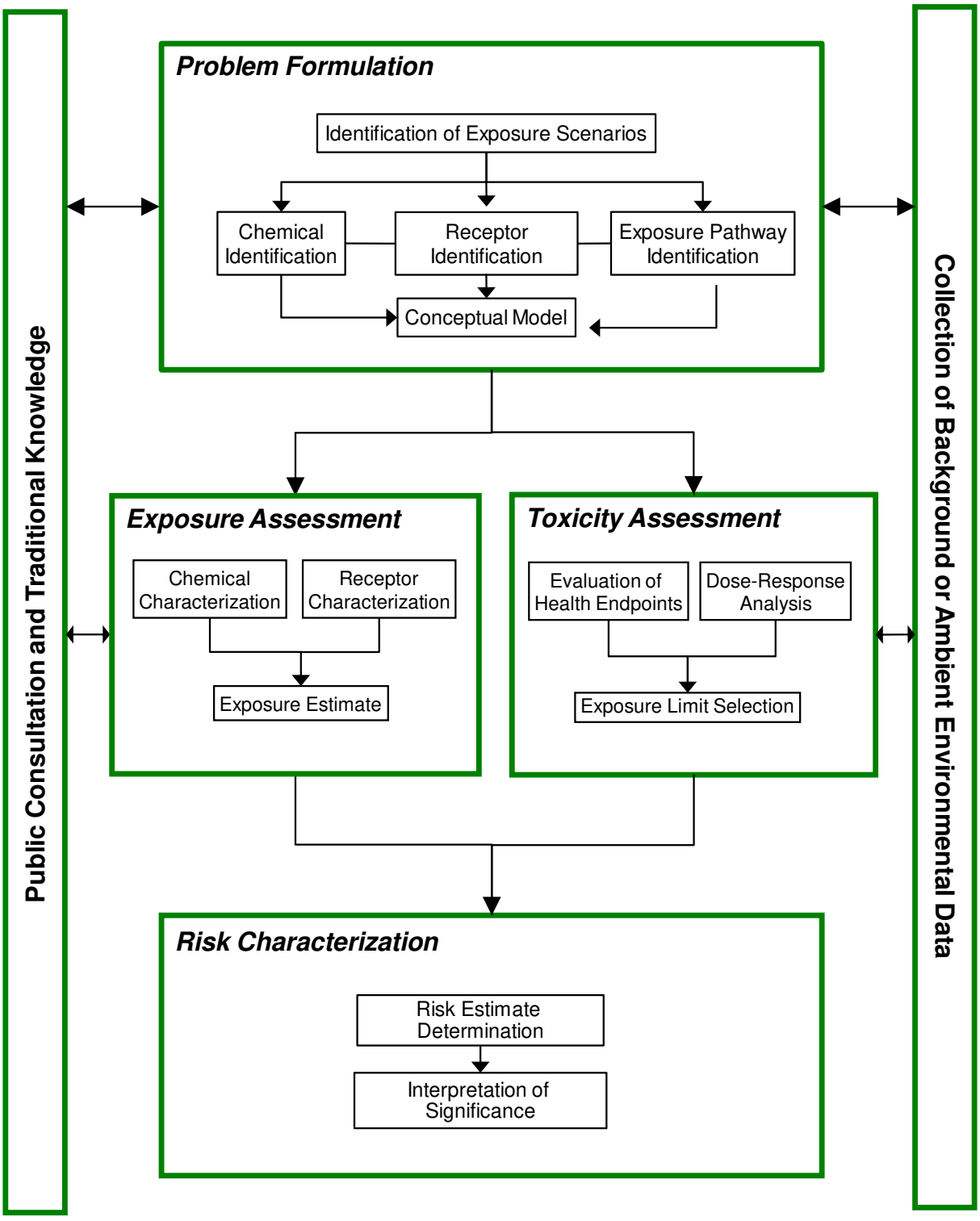
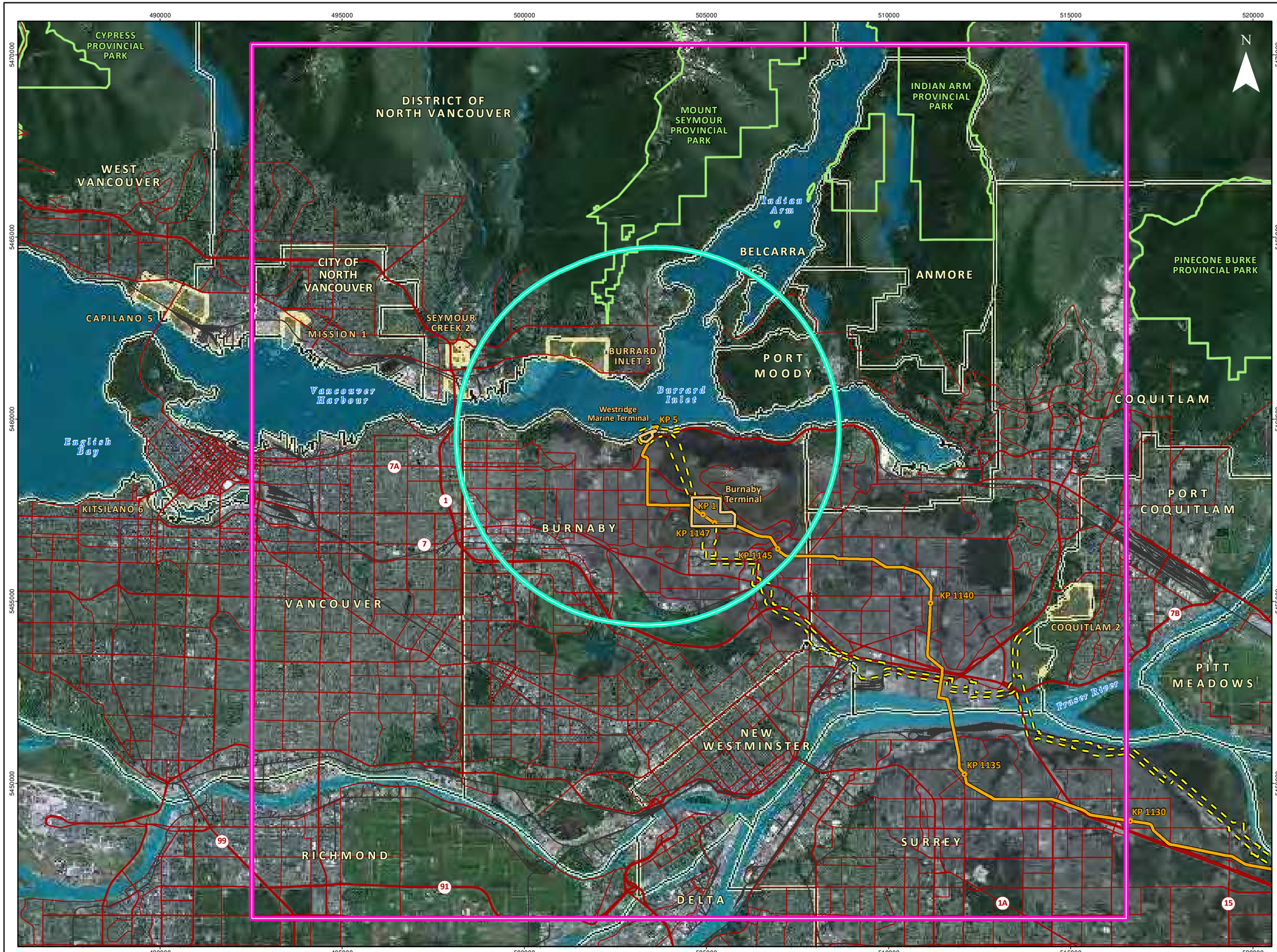


Figure 3.1 Risk Assessment Paradigm



TRANS MOUNTAIN

FIGURE 3.2

HUMAN HEALTH STUDY AREA BOUNDARIES FOR WESTRIDGE MARINE TERMINAL

TRANS MOUNTAIN EXPANSION PROJECT

- Kilometre Post (KP)
- Trans Mountain Pipeline (TMPL)
- Trans Mountain Expansion Project Proposed Pipeline Corridor
- Terminal Property Boundary
- Air Quality RSA
- Westridge Marine Terminal HHRA Local Study Area (5 km Buffer)
- Highway
- Paved Road
- Railway
- City / Town / District Municipality
- Indian Reserve / Métis Settlement
- National Park / Provincial Park / Protected Area

Projection: NAD 1983 UTM Zone 10N. Routing: Baseline TMPL & Facilities: provided by KMC, 2012; Proposed Pipeline Corridor V9: provided by UPI, March 19, 2014; B/W & Colour Imagery: 2005-2011 provided by KMC, 2012, ESRI, 2014 (Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community); Transportation: BC FLNRO, 2012, Natural Resources Canada, 2012; Geopolitical Boundaries: Natural Resources Canada 2003, IHS Inc., 2013; First Nation Lands: Government of Canada, 2014; Hydrology: BC FLNRO, 2008; Parks and Protected Areas: Natural Resources Canada, 2014, BC FLNRO, 2008.

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DRAWN: AJS	CHECKED: TGG	DESIGN: TGG

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ALL LOCATIONS APPROXIMATE

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TRANS MOUNTAIN

FIGURE 3.3

DISCRETE LOCATIONS WITHIN THE LOCAL STUDY AREA FOR WESTRIDGE MARINE TERMINAL

TRANS MOUNTAIN EXPANSION PROJECT

- Kilometre Post (KP)
- Trans Mountain Pipeline (TMPL)
- Trans Mountain Expansion Project Proposed Pipeline Corridor
- Terminal Property Boundary
- Westridge Marine Terminal HHRA Local Study Area (5 km Buffer)
- Highway
- Paved Road
- Railway
- Village / Hamlet / Community
- City / Town / District Municipality
- Indian Reserve / Métis Settlement
- National Park / Provincial Park / Protected Area

HHRA Sensitive Receptors

- Aboriginal Community
- Assisted Living Facility
- Community
- Elementary School
- Recreational Area
- Residence

Projection: NAD 1983 UTM Zone 10N. Routing: Baseline TMPL & Facilities: provided by KMC, 2012; Proposed Pipeline Corridor V9: provided by UPI, Mar. 19, 2014; B/W & Colour Imagery: 2005-2012 provided by KMC, 2012-13, ESRI, 2014 (Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community); Transportation: BC FLNRO, 2012, Natural Resources Canada, 2012; Geopolitical Boundaries: Natural Resources Canada 2003, IHS Inc., 2013; First Nation Lands: Natural Resources Canada, 2014; Hydrology: BC FLNRO, 2008; Parks and Protected Areas: Natural Resources Canada, 2014, BC FLNRO, 2008.

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Although there is no reason to believe that there are any errors associated with the data used to generate this product or in the product itself, users of these data are advised that errors in the data may be present.

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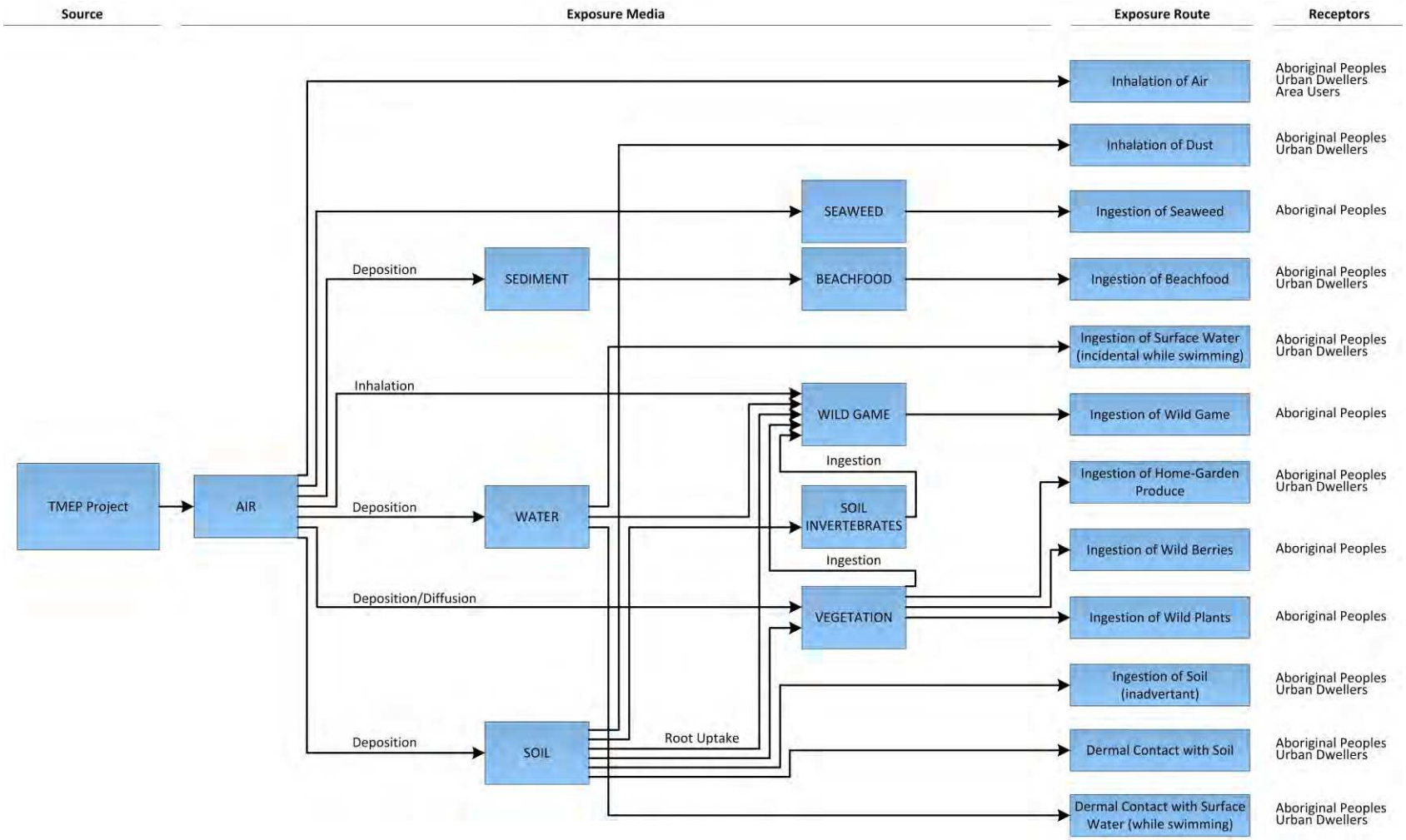

Figure 3.4 Conceptual Model of Exposure Pathways

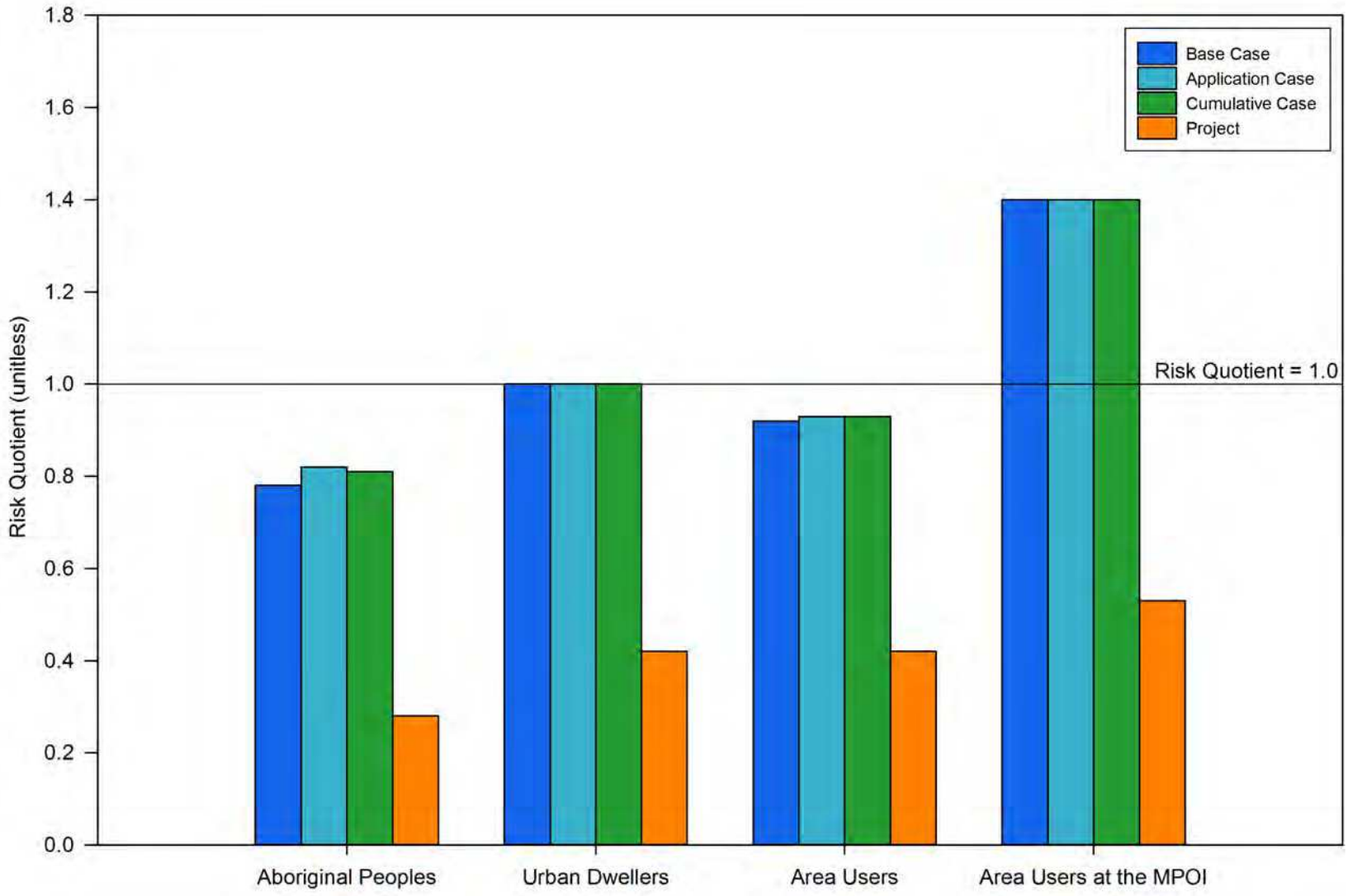

Figure 5.1 Acute Inhalation Risk Quotients for the Respiratory Irritants Mixture

- Maximum Point of Impingement
- Kilometre Post (KP)
- Village / Hamlet / Community

HHRA Sensitive Receptors

- Aboriginal Community
- Assisted Living Facility
- Community
- Elementary School
- Recreational Area
- Residence

- Existing Trans Mountain Pipeline
- Highway
- Road
- Trans Mountain Expansion Proposed Pipeline Corridor
- Westridge Marine Terminal HHRA Local Study Area (5 km Buffer)
- Terminal Boundary
- City / Town / District Municipality
- Indian Reserve / Métis Settlement
- National Park / Provincial Park / Protected Area

Map Notes:
Projection: NAD 1983 UTM 10N.
Routing: Baseline TMPL provided by KMC, May 2012; Study Corridor V9 provided by UPI, March 19, 2014.; Facilities: Provided by KMC, 2012;
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Location of Maximum Point of Impingement for the Acute Inhalation Respiratory Irritants Mixture

Trans Mountain Expansion Project - Alberta and British Columbia, Canada

True North

Drawn by: NBN	Figure: 5.2	RWDI
Approx. Scale:	1:50,000	
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Project #1202006

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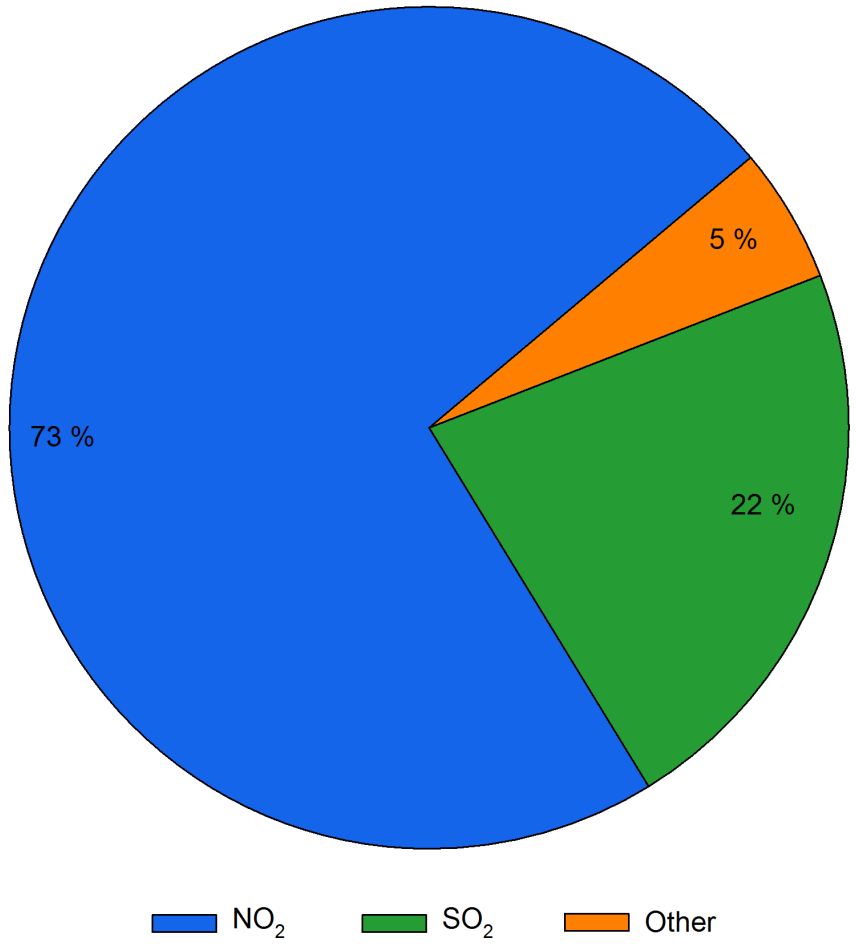

Figure 5.3 Percent Contribution of the Primary Chemical Constituents to the Predicted Exceedances for the Acute Inhalation Respiratory Irritants Mixture