NATIONAL ENERGY BOARD

IN THE MATTER OF

the *National Energy Board Act*,
R.S.C. 1985, c. N-7, as amended, ("*NEB Act*")
and the Regulations made thereunder;

AND IN THE MATTER OF

the *Canadian Environmental Assessment Act*, 2012,
S.C. 2012, c. 37, as amended,
and the Regulations made thereunder;

AND IN THE MATTER OF

an application by Trans Mountain Pipeline ULC
as General Partner of Trans Mountain Pipeline L.P.
(collectively "Trans Mountain")
for a Certificate of Public Convenience and Necessity and
other related approvals pursuant to Part III of the *NEB Act*

VARIOUS FILINGS

June 2014

To: The Secretary
The National Energy Board
444 — 7th Avenue SW
Calgary, AB T2P 0X8

HUMAN HEALTH RISK ASSESSMENT OF FACILITY AND MARINE SPILL SCENARIOS TECHNICAL REPORT FOR THE TRANS MOUNTAIN PIPELINE ULC TRANS MOUNTAIN EXPANSION PROJECT

June 2014

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Prepared for:

TRANSMOUNTAIN

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EXECUTIVE SUMMARY

E1.0 Introduction

This report describes the assessment of the potential human health effects associated with a series of simulated facility and marine oil spill scenarios that was completed on behalf of Trans Mountain Pipeline ULC ("Trans Mountain") in support of the proposed Trans Mountain Expansion Project (referred to as "TMEP" or "the Project"). This single report serves as a supplement to two previously separate reports presented in the Application to the National Energy Board (NEB) on December 16, 2013. The Qualitative Human Health Risk Assessment of Westridge Marine Terminal Spills in Volume 7 included a set of simulated and unmitigated spill scenarios involving different sized spills resulting from an incident while loading a tanker at berth at the Westridge Marine Terminal. The Qualitative Human Health Risk Assessment of Marine Transportation Spills in Volume 8B included a second set of simulated and unmitigated spill scenarios of different sized spills resulting from the grounding of a laden tanker on Arachne Reef.

This report provides a more detailed analysis of the potential health effects that might occur in relation to each of the simulated oil spill scenarios than the earlier qualitative assessments in order to further enhance awareness and understanding of the nature and extent of such effects. Scenario spill volumes represent a credible worst-case (CWC) and a smaller-sized spill. Emphasis is given to the types of health effects that people could potentially experience from exposure to hydrocarbon vapours released during the early stages of a spill, before the arrival of first responders and the implementation of emergency and spill response measures aimed at quickly isolating, containing and recovering the spilled oil.

E2.0 Methods

The general methodology adopted for the present assessment matched that used for the earlier assessments (Volumes 7 and 8B) insofar as it involved identifying the potential health effects that could be experienced by people under each of the different spill scenarios on a qualitative basis, with emphasis placed on assessing the possible health-related consequences of such spills, without consideration of the low likelihood or probability of occurrence of such incidents. In this regard, it was assumed *a priori* that the oil spill events had taken place despite their low probability of occurrence, and without regard for the multitude of design, engineering, operational, administrative and other types of safeguards described in Volumes 7 and 8A that will be in place as part of the Project to limit the prospect for oil spills to occur, whether along the pipeline corridor, at the Westridge Marine Terminal or along the marine shipping route. In addition, the spill scenarios were assessed assuming neither Trans Mountain (in the case of the Westridge Marine Terminal) nor the Western Canada Marine Response Corporation (WCMRC) (in the case of a spill from a tanker en route) would immediately execute their emergency response plans, despite Trans Mountain's and the WCMRC's commitments to emergency response as outlined in Volumes 7 and 8A. The net result is that the spill scenarios represent hypothetical, simulated events that embrace a high degree of conservatism that must necessarily be respected as part of the interpretation of the findings of the assessment.

The overall approach used for the assessment followed a paradigm adapted from that used for conventional human health risk assessments (HHRAs) to reflect the emphasis on identifying the potential health consequences that could occur under the different simulated oil spill scenarios based on the premise that the spills had taken place. The paradigm is illustrated in Figure 3.1 of Appendix A of the report. It consists of a series of steps in which consideration is given to both the toxicological properties of the chemicals of interest as well as the opportunities for exposure to these chemicals that might exist to arrive at an understanding of the types of health effects that people might experience. A brief description of the various steps is provided below. Complete details can be found in the main report.

Problem Formulation – This step is concerned with defining the overall scope and boundaries of the assessment, and is meant to focus the work on the areas of principal interest and concern. It focuses on five major areas:

- Identification of the Project components to be examined, with a specific focus on identifying components that might reasonably be anticipated to contribute to chemical exposures through the emission, discharge or release of chemicals into the environment.
- Identification of the exposure scenarios under which humans might reasonably be anticipated to be exposed to the chemicals emitted, discharged or released from the various Project components.
- Identification of the chemicals of potential concern (COPC) found in the emissions, discharges and/or releases to which people could be exposed.
- Identification and characterization of the human "receptors" that could potentially be exposed to the COPC.
- Identification of the exposure routes and pathways by which people the receptors might be exposed to the COPC.

The principal outcomes of the Problem Formulation step completed for the present assessment are summarized in Table E1.

TABLE E1

SUMMARY OF THE PROBLEM FORMULATION STEP FOR THE ASSESSMENT

Project Component		Exposure Scenario	COPC	Receptors	Exposure Pathway
Spill Type	Spill Size				
Westridge Marine Terminal Spill Scenarios – Spill during loading of tanker at berth.	CWC – 160 m^3 of oil spilled; 20% (*i.e.*, 32 m^3) presumed to escape containment boom.[1]	Exposures received during the early stages of the spill before the arrival of first responders and implementation of emergency and spill response measures.	Consisted principally of lighter-end, volatile and semi-volatile hydrocarbons (C_1 to C_{16}), including both aliphatic and aromatic constituents. The latter constituents included BTEX (benzene, toluene, ethylbenzene and xylenes), alkyl substituted benzenes, and polycyclic aromatic hydrocarbon (PAHs). The remaining COPC consisted of various combinations of sulphur-containing chemicals.	Members of the general public found near the Terminal, specifically: i) people on the water in fishing boats, kayaks, and other pleasure craft; ii) people on shore; iii) people living in adjacent communities; and, iv) first responders.	Inhalation
	Smaller – 10 m^3 of oil spilled and completely contained within containment boom.				
Marine Transportation Spill Scenarios – Spill from powered grounding of laden tanker on Arachne Reef.	CWC – 16,500 m^3 of oil spilled.	Same as above.	Same as above.	Members of the general public found in the area, specifically: i) people on the water in fishing boats, tour boats, sail boats, motorboats, and other pleasure craft; ii) people living on or frequenting nearby island communities; and, iv) first responders.	Same as above.
	Smaller – 8,250 m^3 of oil spilled.				

Notes:

1 At 160 m³, this spill is larger than the CWC spill resulting from a rupture of a loading arm. It is also substantially smaller than the over 1,500 m³ capacity of the precautionary boom that will be deployed around each berth while any cargo transfer activities are taking place and it is reasonable to expect that the spill would be entirely contained within the boom.

Exposure Assessment – This step involves estimating the level of exposure to the COPC that might be received by the receptor(s) via different 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. A sub-part of this step often involves defining the areal extent or size of the area that might be affected by the chemical emissions associated with the Project component(s) under each of the exposure scenarios of interest, with an aim to focus the assessment on those areas where exposure to the COPC might be expected to be greatest and/or where particularly sensitive receptors may be located. For the purposes of the present assessment, reliance was placed on the results of spill modelling simulations performed by EBA, A Tetra Tech Company (EBA) of the fate and behaviour of the spilled oil under each of the simulated spill scenarios. Consideration was given to the manner in which the components of the spilled oil would partition between the water column and the air in order to develop estimates of the airborne concentrations that could occur as a function of elapsed time. For the purposes of the assessment, the model outputs were ultimately used to derive hour-by-hour estimates of the one-hour average vapour concentrations of the COPC at progressively increasing distances from the site of the oil spill for each spill scenario. These hourly estimates were used to determine the extent to which people in the area could be exposed to the vapours during the early stages of the oil spill.

Toxicity Assessment – This step involves identifying and understanding the potential health effects that can be caused by each of the COPC (acting either singly or in combination), and the exposure conditions under which the effects can occur. The step revolves around the principle that the dose of a chemical largely dictates the nature and extent of any health effects that might be observed. Consideration is given to understanding the influence of the amount, duration and frequency of exposure on the types and severity of the health effects. The principal outcomes of this step are:

- The determination of Exposure Limits for the COPC, which refer to the levels of exposure that would not be expected to cause adverse health outcomes. The Exposure Limits are often based on guidelines, objectives or standards established by leading scientific and regulatory authorities charged with the protection of public health, with the level of protection afforded by the Limits set so as to be protective of even sub-populations who may show heightened responsiveness to chemical exposures. For the purposes of the present assessment, emphasis was placed on Exposure Limits intended to be protective against health effects resulting from short-term exposures (referred to as “acute Exposure Limits”) since the focus of the work was on determining the nature and extent of health effects that could occur among people from short-term inhalation exposure to the COPC vapours released from the surface of the oil slick during the early stages of the oil spill before the arrival of first responders and the implementation of emergency and spill response measures. The Exposure Limits were used to gauge the prospect for health effects to occur as an initial screening step in a multi-step process in which the nature and extent of any health effects were characterized (see Characterization of Health Effects below).

- The identification of benchmarks other than conventional Exposure Limits, which may be better suited for health effects assessment purposes because of the particular exposure circumstances involved. For example, situations in which there can be rare, atypical accidental exposure of the general public to a chemical(s), such as during spills, fires or explosions, may be better addressed using benchmarks such as the Acute Exposure Guideline Levels (AEGLs) developed by the United States Environmental Protection Agency (US EPA) or the Emergency Response Planning Guidelines (ERPGs) developed by the American Industrial Hygiene Association (AIHA). These guidelines are specifically intended for use in determining the potential risks to the health of the general public from rare exposures to high concentrations of airborne chemicals for short durations. For the purposes of the present assessment, the one-hour AEGLs and ERPGs developed for the COPC provide added perspective *vis-à-vis* the prospect for people’s health to be adversely affected from exposure to the chemical vapours released from the surface of the oil slick during the early stages of the spill(s).

- The determination of the relevant chemical mixtures given the fact that people are rarely exposed to chemicals in isolation, but rather exposure most commonly occurs to mixtures of chemicals. The latter situation applies to the oil spill scenarios in that the vapours released during the spill will consist of a mix of hydrocarbons and other chemicals emitted simultaneously from the surface of the oil slick. Accordingly, it was necessary that the assessment consider the health effects that might be experienced by people in the area at the time of the spill not only from exposure to the COPC acting singly, but also in combination.

Characterization of Health Effects – This step involves comparing the estimates of the exposures to the COPC that might be experienced by the receptor(s) against the corresponding Exposure Limits and/or other comparison benchmarks to determine whether health effects might occur, and if so, to assess the nature and extent of these effects across each of the Project components and exposure scenarios of interest. For the present assessment, the potential health effects were characterized using a multi-step approach: (i) screening against Exposure Limits; (ii) determination of the areal extent of the exceedances; (iii) determination of duration of exceedances; and, (iv) comparison against AEGLs and ERPGs.

Uncertainty Analysis – This step is concerned with acknowledging and understanding the uncertainties that can surround the assessment, with consideration given to the assumptions made to accommodate the uncertainties, which typically embrace a high degree of conservatism so as to avoid health effects being overlooked or understated. The analysis forms part of the interpretation of the findings of the assessment, especially in terms of gauging their meaning and relevance. Care must be taken to distinguish health effects for which the prospect for occurrence is tangible from effects that represent hypothetical constructs only because of the conservatism incorporated into the assessment. The present assessment represents a more in-depth analysis of the potential health effects that could be experienced by people under the different simulated spill scenarios compared to the earlier qualitative assessments, providing better definition of the types of effects that could occur, the time course of these effects, and the populations that might be affected, By providing better definition of the nature and extent of potential effects, the present assessment further increases awareness and understanding of the possible health-related consequences of the spills.

E3.0 Results

The results of the assessment are summarized below.

Westridge Marine Terminal Spill Scenarios

- The initial screening-level comparison of the predicted maximum one-hour average concentrations of the COPC to the corresponding acute inhalation Exposure Limits revealed some exceedances for certain chemicals at certain times for both the CWC spill scenario (160 m^3 of oil) and smaller size spill scenario (10 m^3 of oil). These initial findings suggested that human health could possibly be affected by exposure to the vapours released from the surface of the oil slick during the early stages of the spill incident. The findings signaled the need for further analysis to define the nature and extent of any effects, including comparison against the relevant AEGLs and ERPGs as well as consideration of the conservatism incorporated into the assessment.

- The exceedances of the Exposure Limits revealed by the initial screening-level analysis were predicted to occur over water only, with the spatial extent either confined to an area within the Westridge containment boom (*i.e.*, smaller size spill) or an area in close proximity to the tanker berths (*i.e.*, CWC spill).

- The exceedances of the Exposure Limits were only predicted to occur over the first one-to-two hours following the start of the smaller spill scenario. For some COPC, the exceedances were predicted to occur for up to 12 hours after the start of the spill under the CWC spill scenario.

- Comparison of the predicted maximum one-hour average airborne concentrations of the COPC against the corresponding one-hour AEGL and ERPG guidelines revealed no exceedances of even the Tier-1 values, indicating that people who might be in the area at the time of the spill would not be expected to experience health effects other than mild, transient sensory and/or non-sensory effects, examples of which could include: discomfort and/or irritability, mild irritation of the eyes, nose and/or throat, mild cough, and symptoms consistent with nominal central nervous system (CNS) involvement such as mild headache, light headedness, minor vertigo, dizziness, and/or nausea. Odours could be apparent to some individuals, especially those with a keen sense of smell. The odours would be dominated by a hydrocarbon-like smell, with some potential for other distinct odours due to the presence of sulphur-containing chemicals in the vapour mix. The odours could contribute to added discomfort and irritability among these people.

- The absence of substantial adverse health effects applied whether the COPC were assessed on an individual chemical basis or as part of mixtures, with the mixtures defined on the basis of commonality of effects and the individual chemical constituents interacting in an additive manner.

Marine Transportation Spill Scenarios

- The initial screening-level comparison of the predicted maximum one-hour average concentrations of the COPC to corresponding acute inhalation Exposure Limits revealed some exceedances for certain chemicals at certain times for both the CWC spill scenario (16,500 m^3 of oil) and smaller size spill scenario (8,250 m^3 of oil), again suggesting that human health could possibly be affected by exposure to the vapours released from the surface of the oil slick during the early stages of the spill incident. The findings signalled the need for further analysis to define the nature and extent of any effects, including comparison against the relevant AEGLs and ERPGs as well as consideration of the conservatism incorporated into the assessment.

- The exceedances were predicted to occur predominantly over water, but in some instances, extended over land, including island communities along the marine shipping route. The areal extent of the exceedances was similar for the two sized spills; albeit, overall the spatial coverage of the exceedances predicted for the CWC spill was greater than that predicted for the smaller spill. The spatial coverage was such that appreciable numbers of people could be found within the affected area under either size spill scenario.

- The temporal extent of the exceedances followed a biphasic pattern, with the second phase extending out to approximately 20 to 30 hours after the start of the spill event, regardless of the spill size. It is conceivable that these exceedances could occur before the arrival of first responders and the implementation of emergency and spill response measures, albeit with improvements in emergency and spill response planning standards and expected response times, the prospect for the occurrence of such exceedances would likely be diminished.

- Comparison of the predicted maximum one-hour average airborne concentrations of the COPC against the corresponding one-hour AEGL and ERPG guidelines revealed no exceedances of even the Tier-1 values, indicating that people who might be in the area at the time of the spill would not be expected to experience health effects other than mild, transient sensory and/or non-sensory effects. Odours might be noticeable and could contribute to added discomfort and irritability among these people. The specific types of effects that might be experienced would be similar to those described above for the Westridge Marine Terminal spill scenarios; however, the intensity of the effects would be expected to be greater because of the higher concentrations of the COPC vapours that people could encounter under the marine transportation spill scenarios.

- Again, the absence of substantial adverse health effects applied whether the COPC were assessed on an individual chemical basis or as part of mixtures, with the mixtures defined on the basis of commonality of effects and the individual chemical constituents interacting in an additive manner.

E4.0 Conclusions

The principal conclusions of the assessment are:

- Based on the weight-of-evidence, there is no obvious indication that human health would be seriously adversely affected by acute inhalation exposure to the chemical vapours released during the early stages of a spill under any of the simulated and unmitigated oil spill scenarios examined.

- The evidence suggests the health effects that could be experienced by people in the area would likely be confined to mild, transient sensory and/or non-sensory effects, attributable largely to the irritant and CNS depressant properties of the chemicals. Odours also might be noticed, which could contribute to added discomfort and irritability.

- The evidence indicates that these mild, transient health effects could be experienced under all of the simulated and unmitigated oil spill scenarios examined; however, the intensity of the effects would be greatest for the larger-sized spills because of the higher concentrations of the chemical vapours that could be encountered and the longer durations of exposure.

- Although mild and transient, the effects would still be annoying and discomforting, indicating the need for and importance of the spill prevention programs described in Volumes 7 and 8A. Planning and preparedness around emergency and spill response also are critical to ensure timely and adequate response to any spill events to limit opportunities for chemical exposures such that public health is not threatened or compromised, again highlighting the need for and importance of the emergency and spill response programs described in Volumes 7 and 8A.

- The absence of any serious adverse health effects from exposure to the chemical vapours released from the surface of the oil slick during the early stages of the spill scenarios applies to people in general, including the general public as well as first responders arriving on scene. However, because the first responders could remain on scene for some time while working to isolate, contain and recover the spilled oil, and could face the prospect of direct physical contact with the oil and/or more prolonged exposure to the vapours, it is important that they be trained in emergency and spill response procedures, be equipped with personal protective equipment, and be alert to potential exposure opportunities so as to minimize any exposures they might receive.

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DEFINITIONS AND ACRONYM LIST

Definition/Acronym	Full Name
$\mu g/m^3$	microgram(s) per cubic metre
ACGIH	American Conference of Governmental Industrial Hygienists
AEGL	Acute Exposure Guideline Level(s)
AIHA	American Industrial Hygiene Association
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
BTEX	benzene, toluene, ethylbenzene and xylenes
CCME	Canadian Council of Ministers of the Environment
CFIA	Canadian Food Inspection Agency
CLWB	Cold Lake Winter Blend
CNS	central nervous system
COPC	chemical of potential concern
CPCN	Certificate of Public Convenience and Necessity
CWC	credible worst-case
DFO	Fisheries and Oceans Canada
e.g.	Latin for “for example”
EBA	EBA, A Tetra Tech Company
ECB	European Chemicals Bureau
ERPG	Emergency Response Planning Guidelines
ESA	Environmental and Socio-economic Assessment
ESRD	Alberta Environment and Sustainable Resource Development
et al.	Latin for “and others”
etc.	Latin for “and more”
FHA	Fraser Health Authority
FVRD	Fraser Valley Regional District
HHRA	Human Health Risk Assessment
i.e.	Latin for “such as”
Intrinsik	Intrinsik Environmental Sciences Inc.
km	kilometre(s)
KMC	Kinder Morgan Canada Inc.
LOAEL	Lowest-observed-adverse-effect level
LSA	Local Study Area
m	metre
m^3	cubic metres
m^3/day	cubic metres per day
NEB	National Energy Board
NEB Act	*National Energy Board Act*
NOAEL	No-observed-adverse-effect level
NRC	National Research Council
OEHHA	California’s Office of Environmental Health Hazard Assessment
OMOE	Ontario Ministry of the Environment
OSRP	Oil Spill Response Plan
PAH	polycyclic aromatic hydrocarbon
PAR	Primary Area of Response
PPE	personal protective equipment
RIVM	Rijksinstituut voor Volksgezondheid en Milieu (Netherlands National Institute of Public Health and the Environment)
RSA	Regional Study Area
RWDI	RWDI Air Inc.
TCEQ	Texas Commission of Environmental Quality
the Project	The Trans Mountain Expansion Project
TMEP	Trans Mountain Expansion Project
TMPL	Trans Mountain pipeline

Definition/Acronym	Full Name
TMPL system	Trans Mountain pipeline system
Trans Mountain	Trans Mountain Pipeline ULC
US	United States
US EPA	United States Environmental Protection Agency
UTM	Universal Transverse Mercator
VCHA	Vancouver Coastal Health Authority
vs.	versus
WA DOE	Washington State Department of Ecology
WCMRC	Western Canada Marine Response Corporation
WHO	World Health Organization

1.0 INTRODUCTION

This report describes the assessment of the potential human health effects associated with a series of simulated facility and marine oil spill scenarios that was completed on behalf of Trans Mountain Pipeline ULC ("Trans Mountain") in support of the proposed Trans Mountain Expansion Project (referred to as "TMEP" or "the Project"). The report serves as a supplement to two previously separate reports presented in the Application to the National Energy Board (NEB) on December 16, 2013 ("the Application"). The Qualitative Human Health Risk Assessment of Westridge Marine Terminal Spills in Volume 7 included a set of simulated spill scenarios involving different sized spills resulting from an incident while loading a tanker at berth at the Westridge Marine Terminal. The Qualitative Human Health Risk Assessment of Marine Transportation Spills in Volume 8B included a second set of simulated spill scenarios of different sized spills resulting from the grounding of a laden tanker on Arachne Reef. This report provides a more detailed analysis of the potential health effects that might occur in relation to each of the simulated oil spill scenarios aimed at further increasing awareness and understanding of the nature and extent of any such effects, with the information meant, in part, to help further inform emergency and spill response programs and other programs aimed at the protection of public health and safety. Emphasis is given to the types of health effects that people could potentially experience from exposure to hydrocarbon vapours released during the early stages of a spill, before the arrival of first responders and the implementation of emergency and spill response measures aimed at quickly isolating, containing and recovering the spilled oil.

The focus of the assessment was on the potential health-related consequences of the spills, with the assumption made that the spills had taken place despite their low probability of occurrence and without regard for the numerous design, engineering, operational, administrative and other types of safeguards described in Volumes 7 and 8A of the Application that will be in place as part of the Project to limit the prospect for oil spills to occur, whether along the pipeline corridor, at the Westridge Marine Terminal or along the marine shipping route. In addition, the spill scenarios were assessed assuming neither Trans Mountain (in the case of the Westridge Marine Terminal) nor the Western Canada Marine Response Corporation (WCMRC) (in the case of a spill from a tanker en route) would quickly execute their emergency response plans, with no allowance made for the various emergency and spill response actions that will be taken during the early stages of the incident to isolate, contain and recover the spilled oil as well as to protect public health and safety. These response measures are outlined in Volumes 7 and 8A. The net result is that the spill scenarios represent hypothetical, simulated events that embrace a high degree of conservatism that must necessarily be respected as part of the interpretation of the findings of the assessment.

Both the present and earlier assessments were completed in partial fulfillment of 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) as well as the requirements outlined in NEB's (2013) *Filing Requirements Related to the Potential Environmental and Socio-Economic Effects of Increased Marine Shipping Activities, Trans Mountain Expansion Project* (September 10, 2013).

This report combines the assessment of the potential human health effects associated with the full complement of simulated oil spill scenarios that were described and assessed in the previously filed reports. As noted above, these scenarios consisted of a set of spill scenarios involving the spillage of oil while loading a tanker vessel at berth at the Westridge Marine Terminal (hereafter referred to as "the Westridge Marine Terminal spill scenarios") as well as second set of scenarios involving the spillage of oil from the powered grounding of a laden tanker vessel on Arachne Reef in the northern portion of the Haro Strait (hereafter referred to as "the marine transportation spill scenarios"). In both cases, the scenarios included a spill under conditions corresponding to credible worst-case (CWC) circumstances and a similar, but smaller-sized spill.

This report begins with background information on the Project relevant to the assessment. It continues with a description of the overall approach used for the assessment, including discussion of a number of guiding principles that were respected as part of the work. It then proceeds to describe the specific methodology that was followed for the assessment, and continues with discussion of the results that emerged. It concludes with a discussion of the findings, which includes a summary of the conclusions that were reached.

In the event of any omissions or inconsistencies in the information presented in this report from that contained in the previously filed reports, this report is to prevail. Reference to materials submitted as part of, and contained in, the Application (Volumes 7 and 8B) forms part of the report. The Application should be consulted for complete details respecting these materials.

1.1 Project Overview

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

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

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

The proposed expansion will comprise the following:

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

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

Application is being made pursuant to Section 52 of the *National Energy Board Act* (*NEB Act*) for the proposed 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 primary objectives of the present assessment are to:

- Expand on the analyses completed as part of the previously filed assessments (Volumes 7 and Volume 8B of the Application) in order to provide further definition of the potential health effects that might be experienced by people under each of the simulated and unmitigated oil spill scenarios.

Emphasis was directed toward identifying and understanding the health effects that could potentially occur from short-term exposure to the hydrocarbon vapours that might be released from the surface of the oil slick during the early stages of a spill before the arrival of first responders and the implementation of emergency and spill response measures.

- Further address the information requirements outlined in Guide A.2 of the NEB *Filing Manual* for completion of an ESA in support of the Project (NEB 2014), specifically the requirements relating to the assessment of the potential socio-economic and environmental effects that could result from Project-related accidents and malfunctions.
- Further address the information requirements outlined in NEB's (2013) *Filing Requirements Related to the Potential Environmental and Socio-Economic Effects of Increased Marine Shipping Activities, Trans Mountain Expansion Project* (September 10, 2013), notably the requirements related to the assessment of the potential socio-economic and environmental effects from accidents and malfunctions at the Westridge Marine Terminal and along the marine shipping routes, including the need to examine the effects for both CWC spill scenarios and smaller spill scenarios.
- Further address concerns expressed by Aboriginal communities and stakeholders, including the general public, emergency responders and regulatory authorities at the federal, provincial and regional levels, over the potential health effects of accidents and malfunctions associated with the Project. These concerns include the possible effects of oil spills on people's health.
- Provide further information to Trans Mountain, the Project team and spill response authorities on the nature and extent of potential human health effects that could result from oil spills under the simulated spill scenarios in order to help inform emergency and spill preparedness and response programs aimed at the protection of public health and safety.

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 corridor and marine shipping routes. These programs were based on Aboriginal communities, landowner and stakeholder groups' interests and inputs, knowledge levels, time and preferred methods of engagement. In order to build relationships for the long-term, these programs were based on the principles of accountability, communication, local focus, mutual benefit, relationship building, respect, responsiveness, shared process, sustainability, timeliness, and transparency.

Feedback, related to the Project that was raised through various Aboriginal engagement and public consultation activities, including public open houses, ESA Workshops, Community Workshops and one-on-one meetings, is summarized below and was considered in the development of this technical report:

- potential human health effects associated with the inhalation of chemical vapours that could result from accidents or malfunctions, including a spill to the marine environment;
- potential human health effects that could occur if an accidental oil spill was to occur on water as a result of the Project;
- potential effects of a spill on the health of Aboriginal peoples, including the potential effects of spills on traditional activities; and.
- potential effects of a pipeline spill on the health of emergency responders.

Full descriptions of the Public Consultation, Aboriginal Engagement and Landowner Relations programs, 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, are provided elsewhere (see Volumes 3A, 3B and 3C of the Application filed December 2013, 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 effects 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 ASSESSMENT

Stakeholder Group / Agency Name	Name and Title of Contact	Method of Contact	Date of Consultation Activity	Reason For Engagement	Issues / Concerns	Commitments / Follow-up Actions / Comments
FEDERAL CONSULTATION						
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 methodology.	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 human health risk assessment (HHRA) methodology.	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 methodology.	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 GENERAL METHODS

3.1 Overall Approach

The general methodology adopted for the present assessment is discussed below. The overall approach followed that used for the previously filed assessments (Volumes 7 and 8B) insofar as it involved identifying the potential health effects that could be experienced by people under each of the different spill scenarios on a qualitative basis, with emphasis placed on assessing the possible health-related consequences of such spills, without consideration of the low likelihood or probability of occurrence of such incidents. In this regard, the assessment differed from a conventional human health risk assessment (HHRA) in which some measure of the prospect for health effects to occur typically forms part of the analysis and the results are expressed in quantitative terms (*i.e.*, the results consist of numerical estimates of the likelihood that health effects will occur). The difference in approach is due principally to the fact that, unlike HHRAs that tend to focus on routine operations consisting of planned activities for which chemical exposures and any corresponding health risks can be anticipated and assessed on the basis of known or reasonably well-defined exposure scenarios, spills represent low probability, unpredictable events for which the exposures and any associated risks must necessarily be assessed on the basis of strictly hypothetical scenarios. For the purposes of the present assessment, rather than attempting to combine the probability of occurrence of these unpredictable events with the consequences of exposure to arrive at quantitative risk estimates, it was assumed *a priori* that the oil spill events had taken place, leaving the assessment to focus on the potential health effects that could occur under each simulated spill scenario. In this respect, the approach was very conservative in nature since it did not allow for the multitude of design, engineering, operational, administrative and other types of safeguards that will be in place as part of the Project to limit the prospect for oil spills to occur, whether along the proposed pipeline corridor, at the Westridge Marine Terminal or along the marine shipping route. These safeguards are described in Volumes 7 and 8A of the Application. For added conservatism, the spill scenarios were assessed assuming neither Trans Mountain (in the case of the Westridge Marine Terminal) and the WCMRC (in the case of a spill from a tanker en route) would execute their emergency response plans, with no allowance made for the various emergency and spill response actions that will be taken during the early stages of the incident to isolate, contain and recover the spilled oil as well as to protect public health and safety. Details surrounding the emergency and spill response measures that will be implemented in the unlikely event of an oil spill at the Westridge Marine Terminal contained in Sections 4.0 and 2.0 of Volume 7 of the Application. For marine transportation, the emergency and spill response measures are described in Section 5.5 of Volume 8A of the Application.

The overall approach aligned with the objectives of the assessment as outlined above insofar as it not only allowed for the identification of the potential health effects that might be experienced by people in the event of an oil spill under the various simulated spill scenarios, but also served to inform Trans Mountain, the Project team and spill response authorities of the potential human health consequences that could result from such oil spills in order to assist in Project planning around emergency and spill response programs aimed at the protection of public health and safety.

Having distinguished the overall approach used in the present assessment from that followed in conventional HHRAs, it is important to note that some similarities remain. In this regard, the assessment fully respected a number of guiding principles and incorporated a number of design features that are central to the conduct of any assessment of the human health consequences that can result from chemical exposures, be it qualitative or quantitative in nature. These items are introduced and discussed below.

3.2 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, can be considered toxic since they all have the capacity to cause health effects. This principle applies to every chemical, including the various hydrocarbons and other chemical constituents of oil that could be released as vapours in the event of an oil spill. Each of these chemicals is potentially capable of causing health effects.

- Whether or not a chemical's potential to cause health effects will be realized depends on the amount or "dose" of the chemical received. The dose, in turn, depends 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). This principle forms the basis of the so-called "dose-response relationship" that defines the nature and extent 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. This principle, sometimes coined "the dose makes the difference", is important since it points to the fact that, simply because a chemical is known to be toxic, does not necessarily mean that it will cause health effects. It is the combination of toxicity and exposure that will ultimately determine whether or not health effects will occur.

- With 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. The exceptions 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.

- For any given chemical, the type and nature of 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 very much 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 often share a similar mechanism of toxic action and produce similar types of toxic responses. This principle allows the health effects of a chemical of unknown toxicity to be predicted on the basis of the toxicological properties of a second "surrogate" chemical having similar molecular characteristics. The term "read across" has been coined to describe the process by which the properties of the surrogate chemical are applied to other structurally-related compounds to predict the types of health effects the latter substances might cause.

- 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 (see above) 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.

3.3 The Health Effects Assessment Paradigm

The overall approach used for the assessment followed a paradigm adapted from that used for conventional HHRAs to reflect the emphasis on identifying the potential health consequences that could occur under the different simulated and unmitigated oil spill scenarios based on the premise that the spills had taken place (*i.e.*, without regard for the low probability of occurrence of such spill events). The paradigm is shown in Figure 3.1 of Appendix A. It consists of a series of steps in which consideration is given to both the toxicological properties of the chemicals of interest as well as the opportunities for exposure to these chemicals that might exist to arrive at an understanding of the types of health effects that people might experience. A brief introduction to the paradigm and the steps involved is provided below. The manner in which the paradigm was applied for the purposes of the present assessment is described in Section 4.0 Specific Methods.

3.3.1 Problem Formulation

This step is concerned with defining the overall scope and boundaries of the assessment, and is meant to focus the work on the areas of principal interest and concern. In terms of the present assessment, the intent was to strike an appropriate balance between the need to avoid overlooking any health effects that could potentially occur under the simulated spill scenarios and the need to acknowledge and appreciate the various emergency and spill response measures that will be implemented in the event of a spill, with the understanding that these measures will contribute to limiting any chemical exposures and corresponding health effects that people might experience. The step focuses on five major areas:

- Identification of the Project components to be examined, with a specific focus on identifying components that might reasonably be anticipated to contribute to chemical exposures through the emission, discharge or release of chemicals into the environment.

- Identification of the exposure scenarios under which humans might reasonably be anticipated to be exposed to the chemicals emitted, discharged or released from the various Project components. In selecting the exposure scenarios, consideration is given to the overall exposure circumstances and exposure opportunities that could exist taking into account the quantities of chemicals that might be emitted or released, the expected manner in which the chemicals would behave in the environment, the expected duration of exposure, and other factors governing the extent to which exposures might occur. The aim is to focus the assessment on the exposure scenarios that best represent the conditions under which people might be exposed to the chemicals.

- Identification of the chemicals of potential concern (COPC) based on consideration of their toxic properties, their environmental fate and behavior, and the opportunities for exposure that might exist taking into consideration the amounts and the rates at which the chemicals might be released into the environment.

- Identification and characterization of the human "receptors" that could potentially be exposed to the COPC.

- Identification of the exposure routes and pathways by which the receptors might be exposed to the COPC, with the most common routes being inhalation, ingestion and/or dermal contact, and the pathways consisting of either direct (or primary) and/or indirect (or secondary) avenues of exposure. As the name suggests, the former pathways are direct in nature with no intermediate steps. An example is inhaling chemicals that are emitted into the air. Secondary pathways involve one or more intermediate steps taking place before the chemical(s) reaches the receptor(s). For example, chemicals that are emitted into the air may deposit onto the ground, where they may be taken up by plants and other organisms to become part of the "food chain", with the chemicals eventually being ingested by humans.

3.3.2 Exposure Assessment

This step is concerned with estimating the level of exposure to the COPC that might be received by the receptor(s) *via* different 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. Factors that can influence the amount of exposure received, such as the fate and behaviour of the COPC in the environment and the characteristics of the receptors (*e.g.*, age, body weight, breathing rate) are integrated into the assessment. Distinction is made between exposures received on a short-term basis and those that could be experienced on a longer-term basis to accommodate the fact that the health effects caused by the COPC from acute versus chronic exposure may differ (see Section 3.2 Guiding Principles). The distinction is needed to allow the exposure estimates to align with the health effects information and Exposure Limits revealed by the Toxicity Assessment (see below) such that the health effects and corresponding exposure circumstances (*i.e.*, acute *vs.* chronic) are kept separate and not confused.

A sub-part of this step often involves defining the areal extent or size of the area that might be affected by the chemical emissions or discharges associated with the Project component(s) under each of the exposure scenarios of interest, with an aim to focus the assessment on those areas where exposure to the COPC might be expected to be greatest and/or where particularly sensitive receptors may be located. The scale involved may be local and/or regional in nature. This added step is often needed when relying on environmental quality datasets having large grid spacing and extending over large distances as proxies for the chemical exposures that people might experience, with the data becoming less relevant as the distances involved become further removed from the potentially affected population(s).

3.3.3 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 exposure conditions under which the effects can occur. The step revolves around the guiding principle that the dose of a chemical largely dictates the nature and extent of any health effects that might be observed (*i.e.*, "the dose makes the difference" – see Section 3.2 Guiding Principles). Careful consideration is given to understanding the influence of the amount, duration and frequency of exposure on the types and severity of the health effects (*i.e.*, the dose-response relationship). Much of the information is sourced from case studies involving accidental or deliberate exposure of people to the COPC, clinical investigations involving controlled exposure of human subjects to the chemicals in laboratory settings, and/or non-clinical studies involving controlled exposure of laboratory animals. By design, the latter studies often involve exposure to the chemicals at dosages much greater than those that might be encountered in the environment, with the experimental protocols very often involving exposure at the maximum tolerated dose.

A principal outcome of this step is the determination of Exposure Limits for the COPC, which refer to the levels of exposure that would not be expected to cause adverse health outcomes. The development of the Limits typically follows a standard protocol wherein the level of exposure that causes either no effects or minimal effects only on the most sensitive health endpoint in the most sensitive species is identified (*i.e.*, the no-observed-adverse-effect level [NOAEL] or lowest-observed-adverse-effect level [LOAEL]), and then the NOAEL or LOAEL is adjusted to a lower value using uncertainty factors[1] to accommodate possible differences in responsiveness to the chemical that may exist within and between species to arrive at the Exposure Limit. Additional uncertainty factors may be applied to allow for limitations in the extent to which health effects information exists for the chemical. Examples of the use of uncertainty factors are provided in Table 3.1. Typically, the use of uncertainty factors results in at least a 100-fold downward adjustment of the NOAEL or LOAEL. The net result is that the Exposure Limit is often set at a level well below the levels at which health effects have been observed.

[1] Also referred to as "modifying factors" or "safety factors" by some scientific and regulatory authorities.

The Exposure Limits chosen for use in human health effects/risk assessments often correspond to guidelines, objectives or standards developed by leading scientific authorities and/or regulatory agencies charged with the protection of public health. The level of protection afforded by the Exposure Limits is set so as to be protective of even sub-populations who may show heightened responsiveness to chemical exposures, such as infants, young children, the elderly and individuals who may be especially sensitive because of medical conditions. Distinction is made between Exposure Limits intended to be protective against health effects resulting from short-term exposures (referred to as "acute Exposure Limits") and health effects caused by longer-term exposure (referred to as "chronic Exposure Limits"). More specifically, the acute Exposure Limits are meant to provide protection against the occurrence of adverse health effects from exposures lasting for a few minutes to a few hours or longer (*i.e.*, for as long as 14 days); the chronic Exposure Limits are intended to be protective against the occurrence of effects from exposures lasting from several months to several years or longer (*i.e.*, up to a lifetime).

TABLE 3.1

EXAMPLES OF COMMONLY-USED UNCERTAINTY FACTORS

Nature of Uncertainty	Magnitude of Factor	Comments
Differences in sensitivity between species	3 to10-fold	Used to accommodate the uncertainty surrounding the use of laboratory animal data to predict potential human responses. For example, an uncertainty factor of 10 assumes that humans are 10 times more sensitive to the chemical than the laboratory animal species studied.
Differences in sensitivity within a species	3 to10-fold	Used to account for individuals within the human population that may be more sensitive to a chemical than the average person. For example, an uncertainty factor of 10 assumes that the sensitive individual is 10 times more responsive than the average person.
LOAEL to a NOAEL	3 to10-fold	Used to account for the uncertainty surrounding the use of a LOAEL when a NOAEL is not available for the critical health endpoint in the most sensitive test species. For example, an uncertainty factor of 10 assumes that, at a dose 10 times lower than the lowest dose used in the most definitive toxicity study, no responses would be observed in the test species.
Duration of exposure	3 to 10-fold	Used to account for the uncertainty surrounding the use of data involving shorter exposure periods to predict the responses that might occur over longer periods of exposure.
Adequacy of database	3 to 10-fold	Used to account for a lack of toxicological information for one or more endpoints.

In some cases, benchmarks other than conventional Exposure Limits may be better suited for health effects assessment purposes because of the particular exposure circumstances involved. For example, situations in which there can be rare, atypical accidental exposure of the general public to a chemical(s), such as spills, fires or explosions, may be better addressed using benchmarks such as the Acute Exposure Guideline Levels (AEGLs) developed by the US Environmental Protection Agency (US EPA) or the Emergency Response Planning Guidelines (ERPGs) developed by the American Industrial Hygiene Association (AIHA) since these guidelines are specifically intended for use in determining the potential risks to the health of the general public from rare exposures to high concentrations of airborne chemicals for short durations. (Further description of the AEGLs and ERPGs is provided in Section 4.0 Specific Methods).

As part of the Toxicity Assessment step, consideration is given to the fact that people are rarely exposed to chemicals in isolation, but rather exposure occurs to mixtures of chemicals. The chemicals within a mixture may interact in different ways such that toxicity may be altered, possibly becoming enhanced (*i.e.*, additivity, potentiation or synergism) or reduced (*i.e.*, antagonism). 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 leading scientific and regulatory 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 relevance 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 judgement.

Based on these observations and in accordance with Health Canada (2010) guidance, one approach to assessing chemicals 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 as a group, and assume that the overall toxicity of the group is equivalent to the sum of the toxicities of the individual chemicals comprising the group. In other words, consistent with the above observations, the chemicals are assumed to interact in an additive fashion, with the net result being an enhancement of toxicity when assessed at the mixture level.

3.3.4 Characterization of Potential Health Effects

This step involves comparing the estimates of the exposures to the COPC that might be experienced by the receptor(s) on either a short-term and/or longer-term basis (as revealed by the Exposure Assessment) against the corresponding Exposure Limits and health effects information (revealed by the Toxicity Assessment) to determine whether health effects might occur, and if so, to assess the nature and extent of these effects across each of the Project components and exposure scenarios of interest. Unlike a conventional HHRA, for the purposes of the present assessment, the prospect for health effects to occur under each simulated oil spill scenario was not quantified *per se* since the occurrence of such incidents is unpredictable, and to generate numerical risk estimates could be misleading since they would infer a higher degree of precision and certainty than actually surrounds such low probability, unpredictable events. Instead, the focus was placed on describing the types of health effects that might occur under the spill scenarios, assuming the spills had taken place without regard for their low probability and unpredictability.

3.3.5 Uncertainty Analysis

This step is concerned with acknowledging and understanding the uncertainties that can surround the assessment, with consideration given to the assumptions made to accommodate the uncertainties, which typically embrace a high degree of conservatism so as to avoid health effects being overlooked or understated. The analysis forms part of the interpretation of the findings of the assessment, especially in terms of gauging their relevance and meaning. Care must be taken to distinguish health effects for which the prospect for occurrence is tangible from effects that represent hypothetical constructs only because of the conservatism incorporated into the assessment.

4.0 SPECIFIC METHODS

The methodology followed for the present assessment was based on the health effects assessment paradigm discussed above, with some unique design features introduced to address elements specific to the various simulated oil spill scenarios of interest. The specific methodology used is outlined below, with the topics arranged according to the steps of the paradigm.

Among the items that were considered in developing the specific approach to be followed were:

- the type and volume of oil spilled;
- the types of chemicals contained in the spilled oil to which people could be exposed;
- the extent to which people could be exposed based on predictions of how the spilled oil and the chemicals would likely behave in the environment;
- the manner and pathways by which people might be exposed to the chemicals;
- the types of health effects that can be caused by the chemicals as a function of the amount, frequency and duration of exposure;
- the types of health effects that might be experienced by people exposed to the chemicals contained in the spilled oil, including individuals who may show heightened responsiveness to chemical exposures; and
- the actions that can be taken by government authorities charged with the protection of human health and/or the environment, including coastal resources, to safeguard people's health in the event of an emergency or unplanned event, such as an oil spill.

4.1 Problem Formulation

The specific design features of the assessment related to the Problem Formulation step of the paradigm are discussed below. The information is summarized at the end of this subsection in Table 4.4.

4.1.1 Identification of Project Components

Two types of simulated and unmitigated oil spill scenarios were assessed:

- the Westridge Marine Terminal spill scenarios, involving the spillage of oil during the loading of a tanker vessel at berth at the Terminal; and
- the marine transportation spill scenarios, involving the spillage of oil as a result of the powered grounding of a laden tanker vessel on Arachne Reef in the northern part of Haro Strait.

As indicated below, for each type of spill, two different sized spills were assessed: one representing the volume of oil that potentially could be spilled under CWC conditions, and the second involving the spillage of a smaller amount of oil.

The rationale surrounding the selection of the spill scenarios *vis-à-vis* spill location, spill circumstances, and spill volumes is presented in Section 8.0 of Volume 7 of the Application for the Westridge Marine Terminal spill scenarios, and Section 5.7 of Volume 8A of the Application for the marine transportation spill scenarios.

Common design features that applied across both types of spill scenarios included:

- In all cases, the scenarios represented hypothetical events and were based strictly on simulated conditions. For the purposes of the assessment, it was assumed that the spills had taken place despite a low probability of occurrence and without regard for the numerous spill prevention measures that will be implemented as part of the Project as outlined for the Westridge Marine Terminal in Section 2.0 of Volume 7 of the Application, and for marine transportation in Section 5.3 of

Volume 8A of the Application. Also, for the purposes of the assessment, it was assumed that the spills would go unattended, without regard for the various emergency and spill response measures and other mitigation measures that will be quickly taken to isolate, contain and recover the spilled oil in the event of a spill incident. The emergency and spill response measures and mitigation measures specific to the Westridge Marine Terminal are described in Sections 4.0 and 2.0 of Volume 7 of the Application, respectively. For marine transportation, the emergency and spill response measures are described in Section 5.5 of Volume 8A of the Application.

- In all cases, Cold Lake Winter Blend (CLWB) diluted bitumen was chosen to represent the type of oil spilled. The selection of the CLWB was based, in part, on the fact that CLWB is currently, and is expected to remain, a major product carried by the TMEP. Accordingly, in the unlikely event of a spill occurring, there is a strong possibility that the spilled product will be CLWB.

- For each type of spill scenario, two different-sized spills were assessed, one reflecting the spill volume that potentially could occur under CWC conditions, and the second corresponding to a smaller-sized spill. Details concerning the specific circumstances surrounding each of the spill scenarios, including the spill volumes, are provided below.

- The decision to examine different-sized spills under each type of spill scenario was based on instruction received from the NEB in its letter of September 10, 2013 outlining *Filing Requirements Related to the Potential Environmental and Socio-Economic Effects of Increased Marine Shipping Activities, Trans Mountain Expansion Project* (NEB 2013). These instructions included specific requirements related to the assessment of accidents and malfunctions associated with the Project, encompassing both the Westridge Marine Terminal and marine shipping routes, and specifying the need for the assessment to include a description of the human health risks that could occur from exposure to hydrocarbons under CWC and smaller spill scenarios.

- Each of the spill scenarios was examined on a regional and local scale, with the assessment of the potential human health effects focused principally on localized areas where effects might reasonably be expected to occur from exposure to hydrocarbon vapours during the early stages of the spill (*i.e.*, within the first few hours to days) before the arrival of first responders and the implementation of emergency and spill response measures. More specifically, for the purposes of the assessment, emphasis was given to a local study area (LSA), representing a portion of the overall areal extent of the spilled oil, where it was expected the prospect for health effects to be experienced by people from exposure to the chemical vapours released from the surface of the oil slick would be greatest. The LSA for the Westridge Marine Terminal spill scenarios is shown in Figure 4.1 of Appendix A; the LSA for the marine transportation spill scenarios is shown in Figure 4.2 of Appendix A. The manner by which the LSAs were determined is outlined in Section 4.2 Exposure Assessment

- In all cases, the spill was assumed to occur during the summer months when the warmer water and air temperatures would facilitate more rapid dissolution and volatilization of the lighter hydrocarbon components of the spilled oil into the ocean water column and overlying air, respectively. In addition, the generally lower wind speeds that mark the summer months would result in less wave action, and hence, less vertical mixing of the water column contributing to higher concentrations of dissolved hydrocarbons in the surface water layer as well as less dilution of hydrocarbon vapours in air. Under these conditions, a heightened prospect exists for the occurrence of effects on the marine environment and resources and human health.

4.1.1.1 Westridge Marine Terminal Spill Scenarios

Descriptions of each of the two simulated oil spill scenarios involving the different-sized spills at Westridge Marine Terminal are presented below. Additional details surrounding each scenario can be found in Section 8.0 of Volume 7 of the Application. Each scenario involved a spill during loading of a tanker at berth at the Terminal, with the principal differences between the scenarios being:

- The CWC spill was assessed assuming a volume of 160 m³ of CLWB diluted bitumen. At 160 m³, this spill is substantially smaller than the over 1,500 m³ capacity of the precautionary boom that will be deployed around each berth while any cargo transfer activities are taking place, and it is reasonable to expect that the spill would be entirely contained within the boom. In addition, observed weak currents (*Modelling the Fate and Behaviour of Marine Oil Spills for the Trans Mountain Expansion Project* in Volume 8B) at the Terminal support the full containment of the spilled oil within the pre-deployed boom. However, as a conservative approach to this scenario, it was deemed that, for oil spill modelling and health effects assessment purposes, 20% of the oil released (*i.e.*, 32 m³) would escape the containment boom. This condition was chosen to ensure a conservative approach to spill response requirements at the site and does not reflect Trans Mountain's expectation for performance of the precautionary boom which will be in place to fully contain such a release at the Terminal. For the reader's information, the CWC oil spill volume resulting from this scenario has been calculated by DNV as 103 m³ and deemed as a low probability event with a likelihood of occurring once every 234 years.

- A smaller release of 10 m³ of CLWB diluted bitumen also was evaluated, consistent with the NEB's (2013) letter of September 10, 2013 *Filing Requirements Related to the Potential Environmental and Socio-Economic Effects of Increased Marine Shipping Activities, Trans Mountain Expansion Project*. This smaller release was assumed to result from a loading arm leak, and be totally contained within the boom placed around all tankers during loading.

4.1.1.2 Marine Transportation Spill Scenarios

Descriptions of each of the two simulated oil spill scenarios involving the different-sized spills along the marine shipping route are presented below. Additional details surrounding each scenario can be found in Section 5.7 of Volume 8A of the Application.

The simulated CWC oil spill scenario and the similar but smaller spill scenario that were assessed involve the spillage of 16,500 m³ and 8,250 m³, respectively, of CLWB diluted bitumen into the northern portion of the Haro Strait from the powered grounding of a laden tanker on Arachne Reef. Complete details of the scenarios, including the specific circumstances surrounding each spill, its exact location, the basis of its selection, and the manner in which the spilled oil would be expected to behave based on ocean currents, tidal effects, wave action, weather patterns and other influences can be found elsewhere (Section 5.7.1 of Volume 8A). Both scenarios shared a number of common features with respect to the various criteria that governed their selection in terms of the spill location, including:

- The northern entrance to the Haro Strait has the greatest level of navigation complexity for the entire passage that would be taken by the tanker, due in part to the numerous vessels that transit the Strait.
- The tanker was assumed to strike the reef while under its own power; whereas, it has been proposed that the tanker be tethered to a tug through this part of the passage.
- The spill location has a very high environmental and socio-economic value, with several distinct areas and habitats present including Boundary Bay, the Gulf Islands, the San Juan Islands, the Salish Sea and the Juan de Fuca Strait.

4.1.2 Identification of Exposure Scenarios

The choice of exposure scenarios to be examined principally revolved around identifying the circumstances under which reasonable opportunity for exposure of people in the area to the chemicals contained in the spilled oil would be expected to exist. Consistent with a screening-level approach, the choice necessarily weighed the need to ensure that any major opportunities for possible exposure were not overlooked against extending the assessment to include examination of all possibilities, whether reasonable or not, without regard or appreciation for the fact that certain opportunities may be strictly hypothetical and isolated in nature and of questionable relevance. After considering the various possible exposure opportunities that could exist, it was determined that the assessment would focus on the chemical exposures that people might experience during the early stages of the oil spill incident, when they could be unaware of its occurrence and before the arrival of first responders and the implementation of emergency and spill response measures. Some reasonable opportunity exists for people in the area to be exposed to the chemicals during the early stages of the spill event because some time will elapse between the first reporting of the spill, the arrival of first responders on scene, and the implementation of the response measures. Further analysis suggested that the most likely avenue of exposure during this time would be *via* inhalation of the chemical vapours released from the surface of the oil slick (*i.e.*, breathing in the chemicals – see Section 4.1.5 Identification of Exposure Pathways).

The nature and extent of the emergency and spill response measures were important considerations in arriving at the choice of exposure scenarios to be assessed since they represent important determinants governing the chemical exposures that people might receive, not only in terms of amount, but also with respect to frequency and duration (which in turn, will govern the prospect for people's health to be affected – see Section 3.2 Guiding Principles). Details concerning the measures can be found in Volumes 7 and 8A of the Application. Some key features of the measures are presented below, arranged by spill type. As mentioned above, for the purposes of the assessment, it was assumed that neither Trans Mountain (in the case of the Westridge Marine Terminal) and the WCMRC (in the case of a spill from a tanker en route) would quickly execute their emergency response plans, with no allowance made for the various emergency and spill response actions that will be taken during the early stages of the incident to isolate, contain and recover the spilled oil as well as to protect public health and safety.

4.1.2.1 Westridge Marine Terminal Spill Scenarios

In the event of an accidental oil spill at the Westridge Marine Terminal with the prospect for the spilled oil to escape into the Burrard Inlet, emergency and spill response measures would be implemented by Trans Mountain, Coast Guard authorities, the WCMRC and other spill response agencies to protect people's health, the marine environment and resources, and the coastal shoreline. The measures would include securing the area as well as the isolation, surveillance, monitoring, containment, and clean-up and recovery of the spilled oil. Local, provincial and federal authorities responsible for the protection of public health, fisheries, and the marine environment and resources would be notified so that additional resources can be deployed and any further needed response measures can be implemented. Other measures would include notifying the public to avoid the spill area, restricting access to the spill area, and possibly evacuating people from the area if public health and safety was deemed to be threatened. The exact emergency and spill response measures to be implemented would be dictated, in part, by the circumstances and real-time events surrounding the spill, including the size, behaviour and immediate hazards presented by the oil slick.

These and other emergency and spill response measures described in Volumes 7 and 8A of the Application would act to limit the opportunities for the general public to experience any chemical exposures as a result of an oil spill at the Westridge Marine Terminal on both a short and long-term basis.

4.1.2.2 Marine Transportation Spill Scenarios

In the event of an oil spill into the marine environment along the marine shipping route, emergency response measures would be implemented by a number of different authorities and organizations, including the ship owner, the WCMRC, Coast Guard authorities, and other spill response agencies, again to protect people's health, the marine environment and resources, and the coastal shoreline. Examples of these are provided below. As noted above for the Westridge Marine Terminal spill scenarios, the actual emergency and spill response measures to be implemented would be dictated, in part, by the circumstances and real-time events surrounding the spill, including the size, behaviour and immediate hazards presented by the oil slick.

- In the event of a spill, the WCMRC would be responsible for carrying out spill response activities within the vicinity of Arachne Reef as it falls within the Corporation's Primary Area of Response (PAR) for the Port of Vancouver. Currently, for Tier 3 (2,500 tonnes) and Tier 4 (10,000 tonnes) spills inside the PAR, response times for equipment deployed on-scene are 18 and 72 hours, respectively (WCMRC 2012). As noted in Table 5.5.3, Section 5.5, Volume 8A of the Application (December 2013), Trans Mountain has been working with WCMRC to propose improved planning standards for response times to Transport Canada.

- Following a spill, the *Oil Spill Response Plan* (OSRP) submitted to Transport Canada by WCMRC would be activated and this includes information on geographical area of response, call-out procedures, and health and safety programs (WCMRC 2012). The OSRP is designed to work within the framework of other federal, provincial and local emergency response plans, including the BC

Ministry of Environment's (BC MOE) Environmental Emergency Management Program, which has an essential role in protecting human health (BC MOE 2013a, WCMRC 2012).

- The BC MOE recently prepared a *Marine Oil Spill Response Plan* (BC MOE 2013b). This response plan provides details of the provincial response strategy, including incident notification, escalation and support, response organization, Ministry roles and services, and provincial support. The province of BC has a 24-hour reporting number for marine oil spills. If specific human safety and welfare conditions (*e.g.*, contamination of water or food sources and/or supply, presence of toxic fumes or explosive conditions, need for evacuation) or specific environmental conditions are met, a marine oil spill becomes an "incident" which warrants consideration of invoking part or all of the response plan and whether to declare an environmental emergency. The Technical Specialist Unit falls under the Planning Section of the BC Marine Oil Spill Incident Management Team which, among other things, monitors air quality for hydrocarbons to measure risks to human health.

These and other emergency and spill response measures described in Volumes 7 and 8A would act to limit any opportunities for people in the area to experience chemical exposures on either a short or long-term basis from an oil spill along the marine shipping route.

4.1.3 Identification of Chemicals of Potential Concern

For the purposes of the assessment, CLWB diluted bitumen was chosen to represent the type of oil spilled, with its selection based, in part, on the fact that CLWB is currently, and is expected to remain a major product carried by the TMEP. 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 surface of the oil slick, which would then disperse in a downwind direction, possibly reaching humans who could inhale them. This step of the paradigm was directed at identifying the specific hydrocarbon components to be assessed as COPC. It proceeded step-wise, as outlined below, beginning with the development of an inventory of the chemical components comprising the CLWB diluted bitumen:

- As a first step, reliance was placed on the results of a bulk liquid analysis of CLWB to determine its chemical make-up. The results are summarized in Table 4.1, arranged by chemical family.

- The second step involved screening the entire list of chemicals shown in Table 4.1 based on each component's physico-chemical properties, notably those properties, such as vapour pressure and Henry's Law Constant, that determine its tendency to partition into air and the ease with which it might volatilize from the surface of the oil slick. The screening was performed by EBA, a Tetra Tech company (EBA) as described in Volume 8C of the Application. Due to their non-volatile nature, the metals/metalloids/minerals components were removed from further consideration. A listing of the components that were carried forward to the next step of the chemical selection process based on the screening performed by EBA is provided in Table 4.2.

- The final step of the selection process involved refining the list of chemicals by combining and re-naming certain of the components to better align with chemical nomenclature and naming conventions in common use by health authorities and regulatory agencies involved in the development of Exposure Limits. In some cases, "surrogate" chemicals were used to represent the CLWB components, consistent with the "read across" principle mentioned earlier (see Section 3.2 Guiding Principles). The final outcome of the screening process was the list of COPC shown in Table 4.3. Examination of the list reveals that the COPC consisted principally of lighter-end, volatile and semi-volatile hydrocarbons (C_1 to C_{16}), including both aliphatic and aromatic constituents. The latter constituents included BTEX (benzene, toluene, ethylbenzene and xylenes), alkyl substituted benzenes, and polycyclic aromatic hydrocarbons (PAHs). The remaining COPC consisted of various groups of sulphur-containing chemicals.

TABLE 4.1

STEP 1: FULL LIST OF CHEMICAL COMPONENTS OF CLWB DILUTED BITUMEN

Metals/Metalloids /Minerals	Petroleum Hydrocarbons	Polycyclic Aromatic Hydrocarbons	Sulphur-Containing Compounds	Volatile Organic Compounds	Other
Boron	Aliphatics C_6-C_8	Acenaphthene	n-Butanethiol	1,2,4-Trimethylbenzene	2,4-Dimethylphenol
Calcium	Aliphatics >C_8-C_{10}	Acridine	Dibenzothiophene	Benzene	3 & 4-Methylphenol
Iron	Aliphatics >C_{10}-C_{12}	Anthracene	C1-Dibenzothiophene	*iso*-Butane	Asphaltenes
Mercury	Aliphatics >C_{12}-C_{16}	Benz(a)anthracene	C2-Dibenzothiophene	n-Butane	Polars
Molybdenum	Aliphatics >C_{16}-C_{21}	C1-Benzo(a)anthracene / chrysene	C3-Dibenzothiophene	Cyclohexane	Saturates
Nickel	Aliphatics >C_{21}-C_{34}	C2-Benzo(a)anthracene / chrysene	C4-Dibenzothiophene	Ethylbenzene	
Phosphorus	Aliphatics >C_{34}-C_{50}	C3-Benzo(a)anthracene / chrysene	Dimethyl sulphide	Methylcyclohexane	
Potassium	Aromatics >C_8-C_{10}	C4-Benzo(a)anthracene / chrysene	Ethanethiol	Methylcyclopentane	
Silicon	Aromatics >C_{10}-C_{12}	Benzo(a)pyrene	n-Hexanethiol	*iso*-Pentane	
Sodium	Aromatics >C_{12}-C_{16}	Benzo(b&j)fluoranthene	*iso*-Propanethiol	n-Pentane	
Sulphur	Aromatics >C_{16}-C_{21}	C1-Benzo(b,j,k)fluoranthene / benzo(a)pyrene	Methyl ethyl sulphide	Propane	
Titanium	Aromatics >C_{21}-C_{34}	C2-Benzo(b,j,k)fluoranthene / benzo(a)pyrene	Thiophene / sec-Butanethiol	Toluene	
Vanadium	Aromatics >C_{34}-C_{50}	Benzo(e)pyrene		Xylenes	
		Benzo(g,h,i)perylene			
		Biphenyl			
		C1-Biphenyl			
		C2-Biphenyl			
		Chrysene			
		Fluoranthene			
		C1-Fluoranthene / pyrene			
		C2-Fluoranthene / pyrene			
		C3-Fluoranthene / pyrene			
		C4-Fluoranthene / pyrene			
		Fluorene			
		C1-Fluorene			
		C2-Fluorene			
		C3-Fluorene			
		Naphthalene			
		C1-Naphthalene			
		C2-Naphthalene			
		C3-Naphthalene			
		C4-Naphthalene			
		Perylene			
		Phenanthrene			
		C1-Phenanthrene / anthracene			
		C2-Phenanthrene / anthracene			
		C3-Phenanthrene / anthracene			
		C4-Phenanthrene / anthracene			
		Retene			

TABLE 4.2

STEP 2: LIST OF CHEMICAL COMPONENTS OF CLWB REMAINING AFTER SCREENING BASED ON VOLATILITY

Petroleum Hydrocarbons	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}	Acridine	Dibenzothiophene	Benzene
Aliphatics >C_{10}-C_{12}	Anthracene	C1-Dibenzothiophene	*iso*-Butane
Aliphatics >C_{12}-C_{16}	Biphenyl	C2-Dibenzothiophene	n-Butane
Aliphatics >C_{16}-C_{21}	C1-Biphenyl	C3-Dibenzothiophene	Cyclohexane
Aromatics >C_8-C_{10}	C2-Biphenyl	C4-Dibenzothiophene	Ethylbenzene
Aromatics >C_{10}-C_{12}	Fluoranthene	Dimethyl sulphide	Methylcyclohexane
Aromatics >C_{12}-C_{16}	Fluorene	Ethanethiol	Methylcyclopentane
	C1-Fluorene	n-Hexanethiol	*iso*-Pentane
	C2-Fluorene	Methyl ethyl sulphide	n-Pentane
	C3-Fluorene	*iso*-Propanethiol	Propane
	Naphthalene	Thiophene / sec-Butanethiol	Toluene
	C1-Naphthalene		Xylenes
	C2-Naphthalene		
	C3-Naphthalene		
	C4-Naphthalene		
	Phenanthrene		
	C1-Phenanthrene / anthracene		
	C2-Phenanthrene / anthracene		

TABLE 4.3

STEP 3: LIST OF COPC EXAMINED AS PART OF THE ASSESSMENT

COPC	CLWB Chemical Components
Aliphatic C_1-C_4 group	*iso*-Butane, *n*-Butane, Propane
Aliphatic C_5-C_8 group	*iso*-Pentane, *n*-Pentane, Aliphatics C_6-C_8[1]
Aliphatic C_9-C_{16} group	Aliphatics >C_8-C_{10}, Aliphatics >C_{10}-C_{12}, Aliphatics >C_{12}-C_{16}
Aromatic C_9-C_{16} group	Aromatics >C_8-C_{10}[2], Aromatics >C_{10}-C_{12}[3], Aromatics >C_{12}-C_{16}
Benzene	Benzene
Dibenzothiophenes	Dibenzothiophene, C1-Dibenzothiophene, C2-Dibenzothiophene, C3-Dibenzothiophene, C4-Dibenzothiophene
Dimethyl sulphide group	Dimethyl sulphide, Methyl ethyl sulphide
Ethanethiol group	Ethanethiol, *iso*-Propanethiol, Thiophene/*sec*-Butanethiol, *n*-Butanethiol, *n*-Hexanethiol
Ethylbenzene	Ethylbenzene
Toluene	Toluene
Trimethylbenzenes	1,2,4-Trimethylbenzene
Xylenes	Xylenes

Notes:

1. Cyclohexane, methylcyclohexane and methylcyclopentane were assessed as part of the aliphatic C_6-C_8 group since health-based Exposure Limits intended to be protective against the occurrence of health effects from acute inhalation exposure are not currently available for these chemicals.
2. Acenaphthene, biphenyl, naphthalene, C1-naphthalene and C2-naphthalene were assigned to the aromatic C_8-C_{10} group, and ultimately assessed as part of the aromatic C_9-C_{16} group since health-based Exposure Limits intended to be protective against the occurrence of health effects from acute inhalation exposure are not currently available for these chemicals.
3. Acridine, anthracene, C1-biphenyl, C2-biphenyl, fluoranthene, fluorene, C1-fluorene, C2-fluorene, C3-fluorene, C3-naphthalene, C4-naphthalene, phenanthrene, C1-phenanthrene / anthracene and C2-phenanthrene / anthracene were assigned to the aromatic C_{12}-C_{16} group, and ultimately assessed as part of the aromatic C_9-C_{16} group since health-based Exposure Limits intended to be protective against the occurrence of health effects from acute inhalation exposure are not currently available for these chemicals.

4.1.4 Identification of Receptors

The assessment was directed at identifying and understanding the nature and extent of health effects that humans might experience from exposure to the COPC under each of the simulated and unmitigated oil spill scenarios. The selection of the specific human receptors to be assessed was based on consideration of the following:

- It is reasonable to assume that members of the general public, including Aboriginal communities, could be in the area at the time of a spill and unaware of its occurrence, at least in the short-term before the arrival of first responders and the implementation of emergency and spill response measures. These people could include individuals who might be frequenting the area for work, recreation or other reasons. Examples include people who might be on the water in pleasure craft (*e.g.*, power boats, sail boats, kayaks) or commercial vessels (*e.g.*, tour boats, fishing boats), fishermen, people on-shore, and people living in communities along Burrard Inlet adjacent to the Westridge Marine Terminal and/or island communities along the marine shipping route. Given that opportunity could exist for these people to be exposed to chemical vapours released from the spilled oil during the early stages of an incident, they were chosen as the human receptors to be assessed. It was recognized that, as members of the general public, these human receptors could include people who may be especially responsive to chemical exposures, including young children, the elderly, people with compromised health, and other sensitive sub-populations. The assessment necessarily allowed for the fact that these types of individuals could be among people found in the area at the time of the spill.
- In the event of a spill, emergency and spill response personnel will be dispatched to the scene. These personnel will be trained in emergency preparedness and response, will be equipped with appropriate personal protective equipment (PPE), will be trained and prepared for such situations, and will take appropriate precautions to avoid physical contact with the spilled oil itself as well as to limit exposure to any chemical vapours that might be present. These measures will act to limit any chemical exposures and corresponding health effects that might be experienced by first responders and other response personnel. Provided these individuals take appropriate measures to minimize any exposures, no obvious opportunity will exist for their health to be adversely affected by the chemicals released as a result of a spill.

4.1.5 Identification of Exposure Pathways

The assessment focused on the potential health effects that could occur among people found in the area at the time of the spill from inhalation exposure to the hydrocarbon and other chemical vapours released from the surface of the spilled oil, with a specific focus on exposures that could be received on a short-term basis during the early stages of the incident. The choice of this exposure pathway is explained below:

- Opportunity exists for people located downwind of the oil spill to be exposed to chemical vapours released from the surface of the oil slick during the early stages of the incident because some time will elapse between the first reporting of a spill, the arrival of first responders and the implementation of the emergency response measures. Exposure to the vapours would be *via* inhalation on a short-term basis, with the likelihood and extent of exposure declining as responders arrive on scene and emergency response measures are implemented. With respect to a spill at the Westridge Marine Terminal, Trans Mountain would execute its emergency response plan immediately to contain the spill, with other response personnel, such as the WCMRC and Coast Guard authorities arriving on-scene within as little as one hour. The WCMRC, Coast Guard authorities and other response personnel would arrive on-scene within as little as 18 hours in the case of the marine transportation spill scenarios. Improvements to these planning standards for response times proposed by Trans Mountain and the WCMRC would further limit the extent to which people might be exposed to the chemical vapours. See Table 5.5.3 in Section 5.5 of Volume 8A for additional details on improvements to emergency response.
- Direct physical contact with the spilled oil was considered unlikely. The actions taken by first responders will include securing the area, restricting access, and containing the oil slick. Appropriate

regulatory authorities will be immediately notified and the public will be advised to avoid the area. In the event that oiling of the shoreline occurs, beach and shoreline closures will be announced, if conditions warrant. These actions will limit opportunity for the general public to be exposed to the spilled oil through direct physical contact with the chemicals. Although some prospect may exist for first responders to experience direct physical contact with the spilled oil, exposure of these individuals to the oil via skin contact will be minimized through their training and knowledge of protocols to be followed to reduce exposures, use of personal protective equipment, and high state of awareness and attention to avoid exposure.

- In addition to the implementation of the emergency and spill response measures discussed above (see Section 4.1.2 Identification of Exposure Scenarios) and described in Volumes 7 and 8A of the Application, if conditions warrant, local, provincial and/or federal authorities can implement controls or issue advisories to protect public health. Examples of such controls include closure of commercial and recreational fisheries, beach closures, forced evacuation of people off-shore and/or on-shore if public health and safety are threatened, and the issuance of fish, shellfish or other seafood consumption advisories. In this regard, once a spill has occurred, the Fisheries and Oceans Canada (DFO) is notified. DFO along with other regulatory authorities such as Environment Canada and the Canadian Food Inspection Agency (CFIA) will assess the spill and, based on its location, size and the potential opportunities for people to be exposed to the oil through different exposure pathways, will determine the types of added control measures, if any, that may be necessary. These measures will further reduce the potential opportunities for exposure of people to the chemicals released during a spill not only *via* inhalation, but also through secondary pathways on both a short and long-term basis.

- As part of the spill response measures, chemical, biological and taint monitoring programs will be initiated to track both the movement of the oil slick itself as well as the presence of any spill-related chemical residues in different environmental media, including the water column, air, soils and/or sediment, and extending to fish, shellfish and other possible foodstuffs if necessary to protect public health. The results of the monitoring program(s) will be used, in part, to guide decision-making opposite the need for control measures such as fisheries closures, beach closures and/or food advisories. These controls will remain in place until the results of the monitoring program(s) indicate that public health and safety is no longer threatened and that baseline conditions are restored. The implementation of the monitoring programs and introduction of such control measures will serve to reduce the opportunities for exposure of the public to the chemicals, especially any exposures that could be received through secondary pathways on a longer-term basis.

- Further justification for focusing the assessment on the chemical exposures that people might experience *via* inhalation during the early stages of the oil spill incident was provided by the fact that exposure of people might reasonably be expected to be self-limiting owing to the irritant properties of a number of the hydrocarbon components of the spilled oil as well as the odours that might be noticed. Both of these properties would provide warning of the presence of the chemicals such that individuals could take action to remove and/or distance themselves from the source, thereby limiting the amount and duration of any inhalation exposure that might be experienced.

TABLE 4.4

SUMMARY OF THE PROBLEM FORMULATION STEP FOR THE ASSESSMENT

Project Component		Exposure Scenario	COPC	Receptors	Exposure Pathway(s)
Spill Type	**Spill Size**				
Westridge Marine Terminal Spill Scenarios – Spill during loading of tanker at berth.	CWC – 160 m^3 oil spilled; 20% (*i.e.,* 32 m^3) presumed to escape containment boom.[1]	Exposures received during the early stages of the spill before the arrival of first responders and implementation of emergency and spill response measures.	Consisted principally of lighter-end, volatile and semi-volatile hydrocarbons (C_1 to C_{16}), including both aliphatic and aromatic constituents found in CLWB diluted bitumen (see Table 4.3). The latter constituents included BTEX (benzene, toluene, ethylbenzene and xylenes), alkyl substituted benzenes, and PAHs. The remaining COPC consisted of various combinations of sulphur containing chemicals.	Members of the general public found near the Terminal, specifically: i) people on the water in fishing boats, kayaks, and other pleasure craft; ii) people on shore; iii) people living in adjacent communities; and, iv) first responders..	Inhalation
	Smaller – 10 m^3 oil spilled and completely contained within containment boom.				
Marine Transportation Spill Scenarios – Spill from powered grounding of laden tanker on Arachne Reef.	CWC – 16,500 m^3 of oil spilled.	Same as above.	Same as above.	Members of the general public found in the area, specifically: i) people on the water in fishing boats, tour boats, sail boats, motorboats, and other pleasure craft; ii) people living on or frequenting nearby island communities; and, iii) first responders .	Same as above.
	Smaller – 8,250 m^3 of oil spilled.				

Notes: 1 At 160 m³, this spill is larger than the CWC spill resulting from a rupture of a loading arm. It is also substantially smaller than the over 1,500 m³ capacity of the precautionary boom that will be deployed around each berth while any cargo transfer activities are taking place and it is reasonable to expect that the spill would be entirely contained within the boom.

4.2 Exposure Assessment

The Exposure Assessment proceeded step-wise. Reliance was placed on the results of stochastic modelling performed by EBA (2013, 2014) of the fate and behavior of the spilled oil under each of the simulated spill scenarios, with the findings ultimately used to derive estimates of the exposures to the COPC that people might experience during the early stages of each incident. The modelling accounted for a number of different parameters affecting the fate and movement of the oil slick, including time of year, weather patterns, ocean currents and tides, and wave action. As the modelling evolved, refinements were introduced, with additional input parameters included, such as the thickness of the oil slick, the time the oil would be expected to remain on the water surface, the time to first contact with the shoreline, and the extent of shoreline oiling. Consideration also was given to the manner in which the components of the spilled oil would partition between the water column and the air in order to develop estimates of the airborne concentrations that could occur as a function of elapsed time. For modelling purposes, the components were initially grouped and defined as "pseudo-components", representing different hydrocarbon groups and chemical families comprising CLWB diluted bitumen. Highlights of the general modelling approach used by EBA to predict the fate of the spilled oil are presented below. The highlights apply to each of the simulated oil spill scenarios examined. Full details concerning the spill modelling can be found in Modelling the Fate and Behaviour of Marine Oil Spills for the Trans Mountain Expansion Project in Volume 8C of the Application. Details surrounding the air dispersion modelling used to estimate the airborne concentrations of the COPC can be found in the addendum to Volume 8C. The discussion of the modelling highlights is followed by an explanation of the steps that were then taken to translate the model outputs into estimates of the exposures to the COPC vapours that people might experience.

4.2.1 Oil Spill Modelling

The oil spill modelling proceeded step-wise:

First, a number of stochastic model simulations were completed for each of four seasons: winter (January–March); spring (April–June); summer (July–September); and fall (October–December). The combined simulations for any given season tracked the behaviour and fate of the spilled oil over a 15-day period, beginning from moment the spill occurred. Each simulation comprised a three-hour snapshot of the movement of the oil slick, with the movement forecast on the basis of weather, ocean currents and tide data drawn from records compiled for 2011 and 2012. The mass balance of the spilled oil also was forecasted, with the distribution of the hydrocarbon components of the oil between the ocean water column, the overlying air and the shoreline determined for each three-hour interval. The simulations served to represent the behaviour and fate of the spilled oil as a function of time across the four seasons of the year.

Next, one of the independent model simulations from the stochastic dataset was selected for more comprehensive deterministic modelling in order to compute the fate of the individual pseudo-components of the spilled oil. The selection process proceeded as follows:

- As a first step, consideration was given to the four seasons that were modelled stochastically. Selection centered on the summer season as warmer water and air temperatures facilitate more rapid dissolution and volatilization of lighter hydrocarbons into water and air, respectively. At the same time, generally lower wind speeds during the summer months result in less wave action (and hence, less vertical mixing of the water column and higher concentrations of dissolved hydrocarbons in the surface water layer) as well as less dilution of any hydrocarbon vapours released from the surface of the oil slick into the air. The combination of these factors will contribute to greater opportunity during the summer months for people in the area at the time of the oil spill to be exposed to the hydrocarbon vapours compared to other times of the year. In addition, more people are likely to be outdoors during the summer months compared to other seasons (*e.g.*, on the water in pleasure craft, at beaches, on the shoreline), again contributing to greater opportunity for people to be exposed to the hydrocarbon vapours. Thus, a simulation chosen from the summer season was considered most appropriate for the purposes of the assessment.
- As a second step, consideration was given to the predicted length of shoreline oiled since oil spill effects on shorelines are among the more obvious and profound environmental effects of spills. The median length of shoreline oiled was identified as a selection criterion in order to balance the need to address the potential effects that could be experienced by:
  - aquatic organisms, for which effects are primarily driven by the amount of oil remaining in water;
  - terrestrial organisms, for which effects are primarily driven by the length of shoreline oiled; and
  - people who might be on the water close to the oil slick itself and potentially at risk of exposure versus people who might be on-shore at or near the oiled shoreline at the time of the spill.

  The median length of shoreline oiled as a result of the spill was determined based on the summer stochastic simulations. The specific simulations resulting in a length of oiled shoreline corresponding to this median value were then identified and examined. The following additional criteria were then factored into the selection of the single simulation to be used for deterministic modelling from among the candidate simulations identified:

  - the maximum thickness of the oil modelled on water during the simulation;
  - the time elapsed to first contact with the shoreline;
  - the exposure duration for the oil on water; and
  - the distribution of total hydrocarbons between water, shore and air (*i.e.*, the mass balance).

  As part of this step, each of the candidate stochastic simulations was ranked (high, moderate or low) according to how well the final four selection criteria were satisfied. Higher weighting was given to those simulations that demonstrated greater thickness of the oil reaching the shoreline, shorter time to first contact with the shoreline, longer exposure time on water, and higher percentage of hydrocarbons in air. On this basis, the list of candidates was narrowed further.

- As the final step of the selection process, the outputs for the candidate simulations that remained as well as the outputs for the entire summer season stochastic modelling were visually examined to determine the single most appropriate simulation to be used for the more detailed deterministic modelling.

As indicated above, the deterministic modelling was used to compute the fate of the individual pseudo-components of the spilled oil. For the purposes of the assessment, the model outputs were ultimately used to derive hour-by-hour estimates of the vapour concentrations of the COPC (expressed as one-hour average values) at progressively increasing distances from the site of the oil spill for each spill scenario, with these estimates serving as proxies for the exposures to the COPC that people in the area might experience during the early stages of the incident. As part of the development of these estimates, the pseudo-components of the spilled oil that were modelled by EBA were re-assigned to components better fitted for assessment purposes based on speciation performed by Stantec (Detailed Quantitative Ecological Risk Assessment for Loading Accidents and Marine Spills Technical Report in Volume 8B). The latter components were better aligned with chemical naming conventions and nomenclature used by regulatory agencies in the development of Exposure Limits and/or other guidelines for the protection of human health and the environment. More specifically, these components were aligned with the COPC such that comparison of the predicted one-hour average concentrations against the corresponding Exposure Limits, AEGLs and/or ERPGs (see Section 4.2.2 below) could be made in order to determine the extent to which people's health might be affected. The manner in which the predicted concentrations were collated for the purposes of the assessment and used to estimate the concentrations of the COPC vapours that people might encounter under each of the spill scenarios is described below.

4.2.2 Determination of Exposure Estimates

The hourly estimates of the COPC vapour concentrations derived as part of the deterministic model simulations were used to determine the extent to which people in the area could be exposed to the vapours during the early stages of the oil spill. Again, the work proceeded step-wise. Because of subtle differences in the nature of the model outputs produced for the Westridge Marine Terminal spill scenarios versus the marine transportation spill scenarios, discussion of the steps is presented separately for each type of spill scenario. Further distinction according to the size of the spill was not necessary since the model outputs were similar in character for both the CWC and smaller-sized spills.

4.2.2.1 Westridge Marine Terminal Spill Scenarios

The deterministic air modelling simulation outputs for the Westridge Marine Terminal CWC spill scenario consisted of hour-by-hour estimates of the one-hour average airborne concentrations of the COPC vapours at progressively increasing distances from the oil slick that people in the area might encounter over a 61-hour period beginning from the time of occurrence of the spill. These predicted vapour concentrations were modelled at 100 metre (m) grid intervals within the modelling domain. For the purposes of the assessment, the entire modelling domain was used to represent the overall Regional Study Area (RSA) of interest. The predicted concentrations were used to generate a series of concentration-contour maps and concentration-time plots, which were then used to help estimate the potential exposures to the COPC vapours and any associated health effects that people in the area might experience on an acute basis during the early stages of the oil spill. The exact manner in which the predicted vapour concentration data were used is outlined below.

First, the vapour concentrations predicted to occur within the RSA were screened against the corresponding acute inhalation Exposure Limits developed for the COPC (see Table 4.5 in Section 4.3 Toxicity Assessment) in order to identify UTM coordinates for each grid-point within the modelling domain where the concentrations were found to exceed the Exposure Limits, independent of the hour post-spill in which the exceedance occurred. In addition, grid-points where adverse health effects might be experienced as a result of the additive interaction of the COPC when combined as chemical mixtures (see Table 4.6 in Section 4.3 Toxicity Assessment) were identified. The information was used to establish a Local Study Area (LSA), defined as the maximum east-west and north-south areal extent of the predicted exceedances, to which a 200 m (two grid-point) "buffer" was added to establish the LSA's outer perimeter (*i.e.*, 200 m was added to the maximum northern, eastern, southern, and western distances to which exceedances extended). The LSA served as the focus of the assessment in terms of identifying and understanding the nature and extent of health effects that people might experience from exposure to the COPC vapours since it represents the area within which exposure to the vapours would be greatest, possibly reaching levels at which effects could occur. For simplicity, and as a conservative measure, the LSA determined for the CWC spill was applied to the smaller-sized spill (*i.e.*, the LSA was common to both sized spills even though the areal extent of the exceedances predicted for the smaller-sized spill was less than that of the CWC spill).

Second, for the purpose of assessing the change in the COPC vapour levels during the course of the spill, the maximum one-hour average airborne concentrations of the COPC predicted for each hour post-spill, independent of location, were retrieved from the deterministic air dispersion modelling dataset and plotted as a function of time to permit visualization of the flux in concentrations as well as the pattern of exceedances as time elapsed during the early stages of the spill event. These concentration-time plots were constructed for each COPC for which exceedances of the Exposure Limit were predicted to occur over the 61-hour time interval examined. The plots were used to help understand and delineate the time course over which people in the area might experience health effects from exposure to the COPC. Separate plots were constructed for the CWC spill and smaller-size spill.

Finally, the entire deterministic model simulations dataset was provided to RWDI Air Inc. (RWDI) to generate raster layers for the creation of vapour concentration contour maps for the COPC for which exceedances of the Exposure Limits were noted. RWDI resampled the raster data to 10% of the original grid spacing (10 m grid) using bilinear interpolation. Contours were generated based on the resultant resampled raster data, with the individual concentration contours assigned by the modelling software. The contours extended outward from the spill source to distances corresponding to the maximum areal extent of the predicted exceedances of the Exposure Limits. The maps were used to help delineate the area within which people might experience health effects from acute inhalation exposure to the COPC. Separate maps were created for the chemical mixtures, again depicting the maximum areal extent to which potential health effects might be experienced by people found in the area at the time of the oil spill from the additive interaction of the COPC comprising the mixture. Maps were created for both the CWC spill and smaller-size spill.

4.2.2.2 Marine Transportation Spill Scenarios

The approach followed for estimating the exposures to the COPC vapours that people in the area might experience during the early stages of the oil spill under the marine transportation oil spill scenarios resembled that described above for the Westridge Marine Terminal spill scenarios, with the following exceptions:

- Due to the differences in the spill dynamics, including the larger spill volumes involved, the deterministic model simulation outputs consisted of hour-by-hour estimates of the one-hour average airborne concentrations of the COPC vapours at progressively increasing distances from the oil slick, with the concentrations modelled at 1 km grid intervals within the modelling domain as opposed to the 100 m intervals used for the Westridge Marine Terminal spills. As a result, the boundaries of the LSA were configured differently, with the LSA defined as the maximum east-west and north-south areal extent of the predicted exceedances, to which a 2 km (two grid-point) "buffer" was added to establish the area's outer perimeter (*i.e.*, 2 km was added to the maximum northern, eastern, southern, and western distances to which exceedances extended).

- For the same reason, the grid spacing used to generate the vapour concentration contour maps differed for the marine transportation spill scenarios, with the RWDI raster data that were resampled using bilinear interpretation to 10% of the original grid spacing representing a 100 m grid as opposed the resampled 10 m spacing for the Westridge Marine Terminal spill scenarios.

Apart from the above differences, the approach used to estimates the exposures to the COPC vapours that might be experienced by people under the marine transportation spill scenarios matched that followed for the Westridge Marine Terminal scenarios. Comparable vapour-concentration time plots and concentration contour maps were created for both the CWC oil spill and smaller-sized spill.

Figures 4.1 and 4.2 of Appendix A show the RSA and corresponding LSA for the Westridge Marine Terminal spill scenarios and the marine transportation spill scenarios, respectively.

4.3 Toxicity Assessment

4.3.1 Selection of Exposure Limits

As indicated earlier, this step of the paradigm is concerned with identifying and understanding the potential health effects that can be caused by the COPC (acting either singly or in combination) as a function of the amount, frequency and duration of exposure, with a principal outcome of the step being the determination of Exposure Limits for the COPC, which refer to the levels of exposure that would not be expected to cause adverse health outcomes. As mentioned already, the Exposure Limits are typically based on guidelines, objectives or standards established by reputable government authorities charged with the protection of public health, with the level of protection afforded by the Exposure Limits set so as to be protective of even sub-populations who may show heightened responsiveness to chemical exposures, such as infants, young children, the elderly and individuals who may be especially sensitive because of medical conditions. In order to achieve the level of protection demanded, the Limits are derived on the basis of the most sensitive health endpoint affected in the most sensitive species, with uncertainty factors then applied to account for possible differences in sensitivity to the chemical(s) between and within species. Distinction is made between Exposure Limits intended to be protective against health effects resulting from short-term exposures (referred to as “acute Exposure Limits”) and health effects caused by longer-term exposure (referred to as “chronic Exposure Limits”). For the purposes of the present assessment, emphasis was placed on the acute Exposure Limits since the focus of the work was on determining the nature and extent of health effects that could occur among people from short-term inhalation exposure to the COPC during the early stages of the oil spill before the arrival of first responders and the implementation of emergency and spill response measures. The manner by which the acute inhalation Exposure Limits were selected is described below. The description applies across all of the simulated oil spill scenarios examined assessed since the COPC were common to all cases. More complete details surrounding the basis of selection of the individual COPC are presented in the “Toxicity Profiles” found in Appendix B.

Key features surrounding the choice of Exposure Limits were:

- The Exposure Limits were chosen on the basis of a pre-defined series of selection criteria to ensure consistency, relevance and technical defensibility. The criteria specified that the Exposure Limits be:
  - health-based (as opposed to being based on a non-health endpoint, such as odour perception or damage to physical materials);
  - protective of the health of the general population, including the health of sub-populations who may be especially responsive to chemical exposures, such as infants and young children, the elderly, and people with compromised health because of medical conditions);
  - established by leading scientific authorities or government agencies whose primary mandate includes the protection of public health; and
  - supported by documentation outlining the manner by which the Exposure Limit was developed.
- A search and comparison of Exposure Limits established by a number of scientific and regulatory authorities was completed, the supporting documentation was reviewed, and a choice was made of the Exposure Limit to be used based on relevance, scientific robustness and technical defensibility. The search extended to the following authorities:
  - 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)
- Canadian Council of Ministers of the Environment (CCME)
- Health Canada
- Environment Canada
- Netherlands National Institute of Public Health and the Environment (RIVM)
- California's Office of Environmental Health Hazard Assessment (OEHHA)
- Ontario Ministry of the Environment (OMOE)
- Texas Commission of Environmental Quality (TCEQ)
- United States Environmental Protection Agency (US EPA)
- Washington State Department of Ecology (WA DOE)
- World Health Organization (WHO)

- Certain COPC were discrete chemical substances (e.g., benzene, toluene); whereas, other COPC consisted of families of structurally-similar chemicals (e.g., aliphatic C1-C4 hydrocarbons, dibenzothiophenes). For the former COPC, Exposure Limits developed for the specific chemicals were chosen. For the latter COPC, a "surrogate" chemical was used to represent the group as a whole, and the Exposure Limits chosen were those developed for the surrogate substance. In all cases, the surrogate chemicals were members of the chemical families being represented. For example, iso-butane was identified as one of the chemicals comprising the aliphatic C1-C4 group based on the bulk analysis of the crude CLWB, and was used to represent the group. Similarly, n-pentane was identified as a constituent of the aliphatic C5-C8 group, and was chosen to represent the group as a whole. The use of surrogate chemicals was dictated, in part, by the fact that Exposure Limits were unavailable for the chemical families per se, but did exist for one or more of the chemical constituents of the group. The use of such surrogate chemicals to represent the latter-type COPC is consistent with the "read across" principle that was mentioned earlier (Section 3.2 Guiding Principles). The principle is accepted by leading scientific and regulatory authorities as a means to accommodate the absence of health effects information and/or lack of availability of Exposure Limits that may apply to some chemicals or chemical groups, with the understanding that because of the structural similarities involved, the toxicity of the surrogate chemical is likely to be representative of the toxicity of the group as a whole. As a conservative measure, the surrogate chemicals chosen to represent the group-based COPC were the most acutely toxic of the chemical constituents comprising the group for which health effects data were available.
- In some cases, Exposure Limits satisfying the above selection criteria could not be located, nor was sufficient health effects information available to develop *bona fide* "provisional" Limits on a *de novo* basis. In these instances, the COPC was removed from further consideration.

A list of the Exposure Limits chosen for use in the assessment is provided in Table 4.5. The basis of each Exposure Limit (*i.e.*, the critical health endpoint affected), together with the identity of the scientific/regulatory authority responsible for its development are shown. More complete details concerning the Limits and the manner in which they were developed are available in Appendix B. It is important to note that a high degree of conservatism is incorporated into the Exposure Limits by virtue of reliance on the most sensitive endpoint in the most sensitive species as the primary determinant, coupled with the use of uncertainty factors to arrive at the value. Due to this conservatism, the Exposure Limits represent exposure levels that are well below those known to cause adverse health effects.

4.3.2 Assessment of Chemical Mixtures

As stated earlier, people are rarely exposed to chemicals in isolation, but rather exposure most commonly occurs to mixtures of chemicals. The latter situation applies to the oil spill scenarios in that the vapours released during the spill will consist of a mix of hydrocarbons and other chemicals emitted simultaneously from the surface of the oil slick. Accordingly, it was necessary that the assessment consider the health effects that might be experienced by people in the area at the time of the spill not only from exposure to the COPC acting singly, but also in combination. In accordance with the approach outlined earlier (Section 3.2.1.2 Toxicity Assessment) and recommended by Health Canada (2010), the COPC acting through a similar mechanism of toxicity and/or affecting the same target tissues/organs (*i.e.*, sharing a so-called "commonality of effect") were combined and assumed to act in an additive fashion. A series of different chemical mixtures were developed. Each mixture was assigned a specific designation (*e.g.*, eye irritants, neurotoxicants) based on the common critical health endpoint affected by the COPC comprising the mixture that served as the basis for the development of their Exposure Limits. The specific mixtures examined as part of the assessment are listed in Table 4.6.

TABLE 4.5

SUMMARY OF ACUTE INHALATION EXPOSURE LIMITS

COPC	Duration	Value (µg/m³)	Critical Health Endpoint	Authority
Aliphatic C_1-C_4 group[1] (surrogate: *iso*-butane)	1-Hour	78,000	Neurological effects	TCEQ (2012)
Aliphatic C_5-C_8 group[1] (surrogate: *n*-pentane)	1-Hour	200,000	—	TCEQ (2011)
Aliphatic C_9-C_{16} group	—	—	—	—
Aromatic C_9-C_{16} group[1] (surrogate: naphthalene)	1-Hour	2,000 (adjusted)	Eye irritation	ACGIH (2013)
Benzene	1-Hour	580	Immunological effects	TCEQ (2007)
Dibenzothiophene[1]	—	—	—	—
Dimethyl sulphide group[1]	—	—	—	—
Ethanethiol group[1] (surrogate: ethanethiol)	1-Hour	2,500	Respiratory irritation	US EPA (2013)
Ethylbenzene	1-Hour	21,700	Neurological effects	ATSDR (2010)
Toluene	1-Hour	15,000	Eye and nasal irritation Neurological effects	TCEQ (2008)
Trimethylbenzenes[2]	1-Hour	690,000	Neurological effects	US EPA (2007)
Xylenes	1-Hour	7,400	Respiratory irritation Neurological effects	TCEQ (2009)

Notes: — not available
1 Refer to Table 4.3 for the chemical components comprising the chemical groups.
2 Trimethylbenzenes was assessed as an individual COPC as well as part of the aromatic C_9-C_{16} group.

TABLE 4.6

CHEMICAL MIXTURES EXAMINED

Chemical Mixture Designation	Critical Health Endpoint	COPC Comprising Mixture
Eye irritants	Eye irritation	Aromatic C_9-C_{16} group, Toluene
Respiratory irritants	Respiratory irritation	Ethanethiol group, Xylenes
Neurotoxicants	Neurological effects	Trimethylbenzenes, Aliphatic C_1-C_4 group, Ethylbenzene, Toluene, Xylenes

4.4 Characterization of Potential Health Effects

A step-wise approach was taken to characterize the potential health effects that might be experienced by people in the area from exposure to the COPC vapours during the early stages of the oil spill across all of the spill scenarios examined. The steps were:

Step 1: Comparison Against Exposure Limits

As an initial screening-level exercise, the predicted maximum one-hour average airborne concentrations of the COPC that people in the area might encounter during the early stages of the spill were compared to the corresponding acute inhalation Exposure Limits, and any exceedances of the Limits were noted. These exceedances indicated the possibility of occurrence of adverse health effects. Any COPC for which exceedances were noted were carried forward for further evaluation aimed, in part, at understanding the exact nature and extent of the health effects, the population(s) that potentially could be affected, and the actual prospect for the effects to occur. Any COPC for which exceedances of the Exposure Limits were not revealed by the comparison were removed from further consideration, with the understanding that even the maximum levels of these COPC that people might encounter were below those associated with adverse health outcomes. Because of the high degree of conservatism incorporated into both the exposure estimates (*i.e.*, use of the predicted maximum airborne concentrations for comparison) and the Exposure Limits (*i.e.*, deliberately set to afford a high degree of protection against the occurrence of adverse health effects), the decision to remove the latter COPC from further evaluation was made with confidence.

Step 2: Determination of the Areal Extent of the Exceedances

As discussed earlier (see Section 3.2 Exposure Assessment), vapour concentration contour maps were constructed for each of the COPC for which exceedances of the Exposure Limits were revealed by the first step. The locations at which the predicted maximum one-hour average concentrations of these COPC exceeded the Exposure Limits were plotted on the maps, providing a visual representation of the areal extent of the exceedances, which in turn, provided an indication of the area surrounding the oil slick where the airborne concentrations of the COPC could reach levels potentially capable of causing health effects among people. The information gathered from the maps was used to help interpret the exceedances *vis-à-vis* assessing the actual prospect for people's health to be affected, with consideration given to the actual location(s) at which the exceedances were predicted to occur and the features of these locations in terms of whether they would likely qualify as places where people might be found. With respect to the latter item, consideration was given to whether the exceedances occurred over water and/or over land, in areas with restricted *vs.* unrestricted public access, on vacant *vs.* occupied lands, on industrial/commercial lands *vs.* residential properties, *etc*. The aim was to identify the populations potentially at risk of experiencing health effects from exposure to the COPC vapours during the early stages of the spill incident.

Step 3: Determination of Duration of Exceedances

Vapour concentration-time plots were constructed for the COPC for which exceedances were noted in order to determine the period of time during the early stages of the spill event over which some prospect for people in the area to experience health effects would exist. The maximum hourly airborne concentrations of the COPC predicted to occur within the LSA were plotted at hourly intervals from the start of the spill event until 40 to 60 hours had elapsed, and the times at which the Exposure Limits were exceeded were identified. The plots provided a visual representation of the pattern of flux of the vapour concentrations as a function of time, and allowed determination of the times at which people's health could be affected as well as the length of the exposures involved. The exact manner by which the concentration-time plots were constructed was described earlier in Section 3.2 Exposure Assessment.

Step 4: Comparison Against Other Health-Based Benchmarks

Finally, in order to provide additional perspective opposite the prospect for adverse health effects to occur from acute inhalation exposure to the COPC for which exceedances were noted, additional health-based comparison "benchmarks" apart from the Exposure Limits were introduced for assessment purposes. Two sets of additional benchmarks were used: i) Acute Exposure Guideline Levels (AEGLs) developed by the US Environmental Protection Agency (US EPA); and, ii) Emergency Response Planning Guidelines (ERPGs) developed by the American Industrial Hygiene Association (AIHA). Both types of benchmarks correspond to guideline levels for use in situations where rare, unintended exposure of the general public to hazardous chemicals may occur for short durations, such as accidents involving chemical spills, industrial explosions or fires. In this respect, the AEGLs and ERPGs are particularly well suited for use in the present assessment for which the focus is on identifying and understanding the nature and extent of health effects that could occur among people from exposure to the chemical vapours released from the surface of the oil slick during the early stages of an accidental oil spill, with the accident having a low probability of occurrence qualifying it as a rare event. The AEGLs and ERPGs differ from conventional Exposure Limits insofar as they apply to rare, unpredictable situations in which some prospect exists for short-term exposures to relatively high airborne concentrations of chemicals; whereas, Exposure Limits are intended to provide protection against more commonly encountered exposures associated with more routine circumstances quite apart from accidents or malfunctions.

Both the AEGLs and ERPGs are constructed around three “tiers” distinguished by varying degrees of severity of health effects, with each tier representing a short-term exposure value corresponding to a threshold concentration below which specific categories or types of effects would not be expected to occur among members of the general public. With progressively increasing airborne concentrations above each tier, the prospect for occurrence of the particular effects becomes greater. The definitions of the various tiers are similar between the AEGLs and the ERPGs, as evidenced by the descriptions provided below. The AEGLs differ from the ERPGs in at least two respects: i) although both benchmarks are geared toward rare, accidental exposures of short-term duration, the ERPGs are based on a one-hour averaging period only; whereas, the AEGLs are often developed for a range of exposure times, from 10 minutes to eight hours; and, ii) although both benchmarks are intended to be protective of the health of the general public, the protection afforded by the AEGLs extends to sub-populations that may be especially sensitive to chemical exposures, such as infants, young children, the elderly and the infirm; whereas, the ERPGs are developed without specific consideration of these sensitive individuals. Complete details concerning the AEGLs and ERPGs, including their meaning, derivation and use can be found elsewhere (AIHA 2013, NRC 2001, US EPA 2013).

The AEGLs are defined as follows:

- **AEGL-1** is the airborne concentration of a substance above which it is predicted that the general population, including susceptible individuals, could experience notable discomfort, irritation, or certain asymptomatic non-sensory effects. However, the effects are not disabling and are transient and reversible upon cessation of exposure.
- **AEGL-2** is the airborne concentration of a substance above which it is predicted that the general population, including susceptible individuals, could experience irreversible or other serious, long-lasting adverse health effects or an impaired ability to escape.
- **AEGL-3** is the airborne concentration of a substance above which it is predicted that the general population, including susceptible individuals, could experience life-threatening health effects or death.

The ERPGs are defined as follows:

- **ERPG-1** is the maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing other than mild, transient health effects or perceiving a clearly defined, objectionable odor.
- **ERPG-2** is the maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing or developing irreversible or other serious health effects or symptoms which could impair an individual's ability to take protective action.
- **ERPG-3** is the maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing or developing life-threatening health effects.

As part of the characterization of the potential health effects that people might experience from exposure to the chemical vapours released during the early stages of the simulated oil spills, the predicted maximum one-hour average airborne concentrations of the COPC were compared to the corresponding AEGLs and ERPGs to determine if any of the tiered guideline values were exceeded, and if so, to identify the potential health implications involved. Comparison of the predicted concentrations against the AEGLs and ERPGs was meant to provide added perspective beyond the comparisons based on the acute

Exposure Limits in those instances in which exceedances of the Exposure Limits were noted. In this regard, the use of the Exposure Limits as the initial comparison benchmarks was performed by default as part of the screening-level approach used for the assessment, with the premise being that, because of the high degree of conservatism incorporated into the Exposure Limits, comparisons showing no exceedances could be accepted with confidence as indicating that very little, if any, prospect for the occurrence of health effects exists, effectively ruling out any need for further assessment. However, for cases in which exceedances were noted, reliance also was placed on the AEGLs and/or ERPGs as the comparison benchmarks since, unlike the Exposure Limits which are meant to provide protection against exposures received on a routine basis, the AEGLs and ERPGs are meant to be applied to rare, unpredictable exposure circumstances, such as accidents or malfunctions, that better match the simulated oil spill scenarios. AEGLs and ERPGs were only identified for COPC for which exceedances of the Exposure Limits were noted. A listing of the AEGLs and ERPGs that were used for comparison purposes is provided in Table 4.7.

TABLE 4.7

SUMMARY OF 1-HOUR AEGLS AND ERPGS

COPC	1-Hour AEGL (µg/m³)			1-Hour ERPG (µg/m³)		
	1	2	3	1	2	3
Aliphatic C_1-C_4 group	13,074,703	—	—	—	—	—
Aliphatic C_5-C_8 group	—	—	—	—	—	—
Aromatic C_9-C_{16} group	—	—	—	—	—	—
Benzene	166,131	2,555,858	12,779,288	159,741	479,223	3,194,822
Toluene	753,703	4,522,218	16,958,319	188,426	1,130,555	3,768,515
Xylenes	569,847	4,032,761	10,958,589	—	—	—

For certain of the COPC for which exceedances of the Exposure Limits were noted, neither AEGLs nor ERPGs were available. In these instances, added perspective was provided by comparison of the predicted airborne concentrations against concentrations reported to cause adverse effects in case studies and/or controlled exposure studies in humans, with the outcomes serving as another means to gauge the conservatism built into the Exposure Limits and to assess the relevance and meaning of the exceedances. Again, these comparisons enabled better understanding of the actual nature, extent and likelihood of occurrence of any health effects among people who might be in the area at the time of an oil spill.

4.5 Uncertainty Analysis

Uncertainties surrounded some of the information that was relied upon as part of the assessment as might be expected for the analysis of low probability events of a rare and unpredictable nature. The uncertainty was accommodated, in part, by the use of conservative assumptions aimed at ensuring that the assessment would not overlook or understate any health effects that people might experience in the event that a spill was to occur. The use of the conservative assumptions can present challenges when interpreting the relevance and meaning of the assessment findings insofar as the assumptions may be needed to rule out the possibility that the prospect for the occurrence of health effects has been underestimated, but the assumptions, especially when compounded, may lead to the creation of “phantom” effects that represent hypothetical constructs only that are of little, if any, practical meaning. As a result, the interpretation of the findings must necessarily consider not only the uncertainties surrounding the assessment, but also the conservatism incorporated into the work, with some measure of professional judgement included. To facilitate the interpretation of the results, the major conservative assumptions that formed part of the assessment are listed below, followed by a list of the principal uncertainties that remained.

For the purposes of the assessment, it was conservatively assumed that:

- The oil spills had occurred despite being rare, unpredictable events, and without regard for the multitude of design, engineering, construction, inspection, maintenance and other spill prevention programs described in Volumes 7 and 8A of the Application that will be in place to minimize the prospect for spills to occur.

- The spills would go unattended for at least two-to-three days, without regard for the various emergency and spill response measures described in Volumes 7 and 8A that will be implemented quickly following a spill incident, within as little as one hour and 18 hours of the spill being reported in the case of the Westridge Marine Terminal and marine transportation spills, respectively. The measures will include not only isolating, containing and recovering the spilled oil (*i.e.*, removing the hazard from the people), but also notifying the public, restricting public access to the affected area(s), and possibly evacuating people if public health and safety is threatened (*i.e.*, removing people from the hazard).

- Humans may be especially responsive to chemical exposures, including the COPC vapours that could be released from the surface of the oil slick. In this regard, reliance was placed on the use of health-based Exposure Limits developed by reputable scientific and regulatory authorities as comparison benchmarks to determine the nature and extent of any health effects that might be experienced by people from exposure to the vapours. As mentioned already, the Exposure Limits are deliberately set to afford a high degree of protection to the general public, including protection of sub-populations who may be particularly responsive to chemical exposures such as infants, young children, the elderly and individuals with compromised health. Due to the protection demanded, the Exposure Limits correspond to levels of exposure that are well below those known to cause health effects.

- People in the area at the time of the oil spill would be exposed to the maximum one-hour average concentrations of the COPC vapours predicted to occur anywhere within the LSAs at any given hour for 40 to 60 hours from the start of the spill incident, without regard for the time of day or locations at which the maximum concentrations were predicted to occur. Distinction was not made as to whether the predictions applied to relatively remote locations over water or inhabited areas on land.

The principal uncertainties that remained were:

- The simulated oil spill scenarios that were examined reflected specific circumstances *vis-à-vis* spill location and size, as well as water movement, water temperature, wave action, meteorological conditions and other physical parameters affecting the fate and behavior of the spilled oil and/or the dispersion of the chemical vapours released from the surface of the oil slick. The results of the assessment necessarily apply to the specific scenarios that were chosen. In defense of the choice of spill scenarios, it is important to acknowledge that: i) the scenarios included CWC conditions in terms of the spills themselves; and, ii) the deterministic model simulations that the assessment extensively relied upon were founded on the basis of selection criteria capturing a number of important parameters from a human health perspective (*e.g.*, thickness of the oil on the water surface, extent of shoreline oiling). The combination of these items with the conservatism incorporated into the assessment, as outlined above, provide some measure of assurance that the results of the assessment are unlikely to underestimate the nature and extent of any health effects that people might experience under each simulated spill scenario. However, uncertainty remains as to how well the results reflect the potential exposures to the COPC vapours and associated health effects that could be experienced by people under different spills scenarios because of differences in circumstances.

- Certain of the COPC comprising the vapours that could be released from the surface of the oil slick were absent acute inhalation Exposure Limits, AEGLs, ERPGs and/or health effects information on which to predict the types of health effects that could result from short-term exposure to them under the simulated oil spill scenarios. Surrogate chemicals could not be identified to represent these COPC. As a result, they were removed from further consideration and not assessed. Other COPC required grouping on the basis of molecular/structural similarities to create a chemical group that could be represented by a surrogate chemical. These groups were assessed, but with some uncertainty surrounding how well their toxicity was reflected in the toxicological properties of the surrogate chemical. Some uncertainty remained even in cases in which the most toxic chemical in the group was chosen as the surrogate to represent the toxicity of the group as a whole.

5.0 RESULTS

The results that emerged from the assessment are presented below. They are arranged by the type of simulated oil spill scenario examined, beginning with the findings for the assessment of the Westridge Marine Terminal spill scenarios, followed by those for the marine transportation spill scenarios. The results for each type of spill scenario are then further segregated according to spill size, with the findings for the CWC spill presented first, followed by those for the smaller size spill. The latter sets of results are further differentiated between the findings that apply to the individual COPC and those pertaining to the chemical mixtures.

The presentation of the results for the individual COPC follows the sequence described earlier in Section 4.4 Characterization of Potential Health Effects, beginning with the comparison of the predicted one-hour average COPC vapour concentrations against the corresponding acute inhalation Exposure Limits; proceeding to the assessment of the areal extent of the exceedances as well as the duration of the exceedances; and ending with the comparison of the vapour concentrations against the corresponding AEGL and ERPG guidelines. The results presented for the chemical mixtures consist primarily of discussion of the areal extent within the LSAs where people’s health potentially could be affected by exposure to the combined vapours of the COPC comprising the mixtures.

5.1 Westridge Marine Terminal Spill Scenarios

5.1.1 CWC Spill Scenario

5.1.1.1 Individual COPC

5.1.1.1.1 Comparison Against Exposure Limits

The predicted maximum one-hour average airborne concentrations of the COPC predicted to occur within the LSA together with the corresponding acute inhalation Exposure Limits are provided in Table 5.1 for the CWC spill scenario (160 m^3 of oil). Examination reveals that exceedances of the Exposure Limits were predicted to occur for the following COPC: aliphatic C_1-C_4, aliphatic C_5-C_8, and aromatic C_9-C_{16} groups, benzene, toluene, and xylenes. The exceedances indicate the possibility that people exposed to each of these COPC during the early stages of the spill incident could potentially experience adverse health effects. The nature, extent and relevance of the exceedances are examined in the following subsections. The predicted concentrations for the remaining COPC were consistently lower than the corresponding Exposure Limits, indicating no obvious prospect for people’s health to be affected by exposures to these chemicals. As a result, these COPC were removed from further consideration.

TABLE 5.1

WESTRIDGE MARINE TERMINAL CWC SIMULATED SPILL SCENARIO 1-HOUR AVERAGE COPC VAPOUR CONCENTRATIONS AND CORRESPONDING EXPOSURE LIMITS

COPC[1]	Maximum Predicted 1-Hour Average Vapour Concentration (µg/m³)	Acute Inhalation Exposure Limit (µg/m³)
Aliphatic C_1-C_4 group	109,823	78,000
Aliphatic C_5-C_8 group	1,452,300	200,000
Aromatic C_9-C_{16} group	14,598	2,000
Benzene	11,860	580
Ethanethiol group	111	2,500
Ethylbenzene	2,845	21,700
Toluene	23,610	15,000
Trimethylbenzenes	1,452	690,000
Xylenes	21,180	7,400

Note: 1 COPC for which the maximum predicted one-hour average vapour concentrations exceeded the Exposure Limits are shown in bold font.

5.1.1.1.2 Areal Extent of Exceedances

Contour maps showing the predicted one-hour average concentrations of the COPC within the LSA for which exceedances of the Exposure Limits were identified are provided as Figures 5.1 to 5.6 of Appendix A. The figures also show the location at which the maximum predicted one-hour average concentration of each COPC was predicted to occur. Examination of the figures revealed the following:

- In all cases, the predicted one-hour average concentrations of the COPC were only seen to exceed the corresponding Exposure Limits over water, suggesting that individuals on land would not experience any health effects as a result of the spill.
- Exceedances were generally predicted to occur in close proximity to the berth, where the general public would not reasonably be expected to spend time. In some cases, the exceedances occurred in areas where public access would be limited and/or restricted. In the case of the aliphatic C_5-C_8 and aromatic C_9-C_{16} groups, and benzene, the exceedances extended beyond the area immediately surrounding the berths by up to approximately 300 m.

5.1.1.1.3 Duration of Exceedances

Vapour concentration-time plots showing the hour-by-hour maximum predicted one-hour average concentrations of the COPC as a function of time during the early stages of a spill event are provided as Figures 5.7 to 5.12 of Appendix A. These plots illustrate the predicted change in these maximum airborne concentrations over time, independent of the location within the LSA at which they occurred. Examination of the figures revealed the following:

- With a few exceptions, the maximum predicted one-hour average concentrations of the COPC were only seen to exceed the corresponding Exposure Limits within the first six hours following the occurrence of the spill. In some cases, there were no exceedances beyond the first hour.
- The two exceptions were the aromatic C_9-C_{16} group and benzene for which exceedances were predicted to occur for up to 13 hours; however, it should be noted that the assessment did not allow for any emergency and spill response or other mitigative measures aimed at quickly isolating, containing and recovering the spilled oil. These measures would be expected to reduce the time over which these exceedances might occur.

5.1.1.1.4 Comparison Against Other Health-Based Benchmarks

The predicted maximum one-hour average airborne concentrations of the COPC predicted to occur within the LSA together with the corresponding AEGL and ERPG guidelines are provided in Table 5.2. Examination reveals that the predicted concentrations were consistently lower than these guidelines, including the Tier-1 values, indicating that people in the area would not be expected to experience health effects other than mild, transient sensory and/or non-sensory effects. Examples of these effects are: discomfort, irritability, mild irritation of the eyes, nose and/or throat, mild cough, and symptoms consistent with nominal central nervous system (CNS) involvement such as mild headache, light headedness, minor vertigo, dizziness, and/or nausea. These effects would likely resolve quickly upon cessation of exposure, with no lingering after-effects. Odours could be apparent to some individuals, especially those with a keen sense of smell. The odours would be dominated by a hydrocarbon-like smell, with some potential for other distinct odours due to the presence of sulphur containing chemicals in the vapour mix. The odours could contribute to added discomfort and irritability among these people.

TABLE 5.2

WESTRIDGE MARINE TERMINAL CWC SIMULATED SPILL SCENARIO - MAXIMUM PREDICTED 1-HOUR AVERAGE COPC VAPOUR CONCENTRATIONS AND CORRESPONDING AEGLS AND ERPGS

COPC	Predicted Maximum 1-Hour Average Vapour Concentration (µg/m³)	1-Hour AEGL (µg/m³)			1-Hour ERPG (µg/m³)		
		1	2	3	1	2	3
Aliphatic C_1-C_4 group	109,823	13,074,703	—	—	—	—	—
Aliphatic C_5-C_8 group	1,452,300	—	—	—	—	—	—
Aromatic C_9-C_{16} group	14,598	—	—	—	—	—	—
Benzene	11,860	166,131	2,555,858	12,779,288	159,741	479,223	3,194,822
Toluene	23,610	753,703	4,522,218	16,958,319	188,426	1,130,555	3,768,515
Xylenes	21,180	569,847	4,032,761	10,958,589	—	—	—

For some COPC, AEGLs and ERPGs have not been developed, namely the aliphatic C_5-C_8 and aromatic C_9-C_{16} groups. In the case of the aliphatic C_5-C_8 group, evidence indicates that substantial adverse health effects from exposure to this COPC would not be expected to occur, even at the maximum predicted concentrations that people in the area may experience during the early stages of the spill. More specifically, acute inhalation exposure of human subjects to a mixture of *n*-pentane, *iso*-pentane, hexane, and butane at concentrations up to 15,000,000 µg/m³ (*i.e.*, approximately 10-fold higher than the maximum concentration for this group predicted to occur from the spill) resulted in no observed effects (ECB 2003). In the case of the aromatic C_9-C_{16} group, based on a review of available scientific literature, there is no evidence to indicate that people would experience health effects from exposure to this group at the concentrations predicted to occur during the early stages of a spill event. However, information on the health effects that can follow acute inhalation exposure to the aromatic C_9-C_{16} group is quite limited.

5.1.1.2 Chemical Mixtures

As outlined in Section 4.0 Specific Methods, the intent of the chemical mixtures assessment was to allow for the fact that the COPC could possibly interact in an additive fashion, potentially increasing the prospect for people's health to be adversely affected by exposure to the vapours released from the oil slick during the early stages of a spill event. A series of chemical mixtures were defined based on commonality of effects, namely eye irritants, respiratory irritants and neurotoxicants. Each of these mixtures was examined as part of the assessment of the Westridge Marine Terminal CWC spill scenario. The examination focussed on establishing the area within the LSA in which people's health could potentially be affected by exposure to these mixtures. Maps showing the predicted maximum areal extent from the spill source where people's health could potentially be affected from the combined vapour concentrations of the COPC comprising each of these mixtures are provided as Figures 5.13, 5.14, and 5.15 of Appendix A for the eye irritants, respiratory irritants, and neurotoxicant mixtures, respectively. Examination of the figures reveals the following:

- The areal extent was greatest for the eye irritants mixture, less for the neurotoxicants, and least for the respiratory irritants.
- For the respiratory irritant and neurotoxicant mixtures, the maximum areas that could be potentially affected were predicted to occur in close proximity to the berths, where public access would be limited and/or restricted. The maximum area predicted to be affected by the eye irritant mixture extended beyond the berths by up to approximately 100 m, introducing the possibility that people in this area at the time of the spill could potentially experience health effects.
- The prospect for health-effects to occur from exposure to the chemical mixtures did not materially differ in terms of areal extent from that predicted for the individual COPC.
- People in the area exposed to the mixtures would not be expected to experience health effects other than the mild, transient sensory and non-sensory effects described above for the individual COPC.

The maximum predicted one-hour average concentrations of the individual COPC comprising the mixtures remained well below the corresponding acute inhalation Exposure Limits or the Tier-1 AEGL and/or ERPG guidelines. Because of this, even combining the COPC and assuming they would interact in an additive fashion would not materially change the manner and extent to which people would be affected.

5.1.2 Smaller Spill Scenario

As already indicated in Section 4.0 Specific Methods, the smaller spill scenario (10 m^3 of oil) was assumed to result from a loading arm leak, with the spilled oil totally contained within the boom placed around all tankers during loading. Due to the lesser amount of spilled oil, the predicted maximum one-hour average vapour concentrations released from the oil slick would be expected to be lower than those identified in the CWC spill scenario. The areal and temporal extent of exceedances also would be limited. The predicted COPC vapour concentrations were examined following the same step-wise approach used for the CWC spill scenario, and are discussed in the subsections below.

5.1.2.1 Individual COPC

5.1.2.1.1 Comparison Against Exposure Limits

The maximum one-hour average airborne concentrations of the COPC predicted to occur within the LSA together with the corresponding acute inhalation Exposure Limits are provided in Table 5.3 for the smaller spill scenario. As might be expected, fewer exceedances of the Exposure Limits were predicted as compared to the CWC spill scenario, with exceedances only occurring for the following COPC: aliphatic C_5-C_8 and aromatic C_9-C_{16} groups, and benzene. Again, the exceedances indicate the possibility that people exposed to each of these COPC during the early stages of the spill incident potentially could experience adverse health effects. The nature, extent and relevance of the exceedances are discussed in the following subsections. The predicted concentrations for the remaining COPC were consistently lower than the corresponding Exposure Limits, indicating no obvious prospect for people's health to be affected by exposures to these chemicals. As a result, these COPC were removed from further consideration.

TABLE 5.3

WESTRIDGE MARINE TERMINAL SMALLER SIMULATED SPILL SCENARIO 1-HOUR AVERAGE COPC VAPOUR CONCENTRATIONS AND CORRESPONDING EXPOSURE LIMITS

COPC[1]	Maximum Predicted 1-Hour Average Vapour Concentration (µg/m³)	Acute Inhalation Exposure Limit (µg/m³)
Aliphatic C_1-C_4 group	12,794	78,000
Aliphatic C_5-C_8 group	234,190	200,000
Aromatic C_9-C_{16} group	5,594	2,000
Benzene	3,389	580
Ethanethiol group	14	2,500
Ethylbenzene	806	21,700
Toluene	6,685	15,000
Trimethylbenzenes	552	690,000
Xylenes	5,999	7,400

Note: 1 COPC for which the maximum predicted one-hour average vapour concentrations exceeded the Exposure Limits are shown in bold font.

5.1.2.1.2 Areal Extent of Exceedances

Contour maps showing the predicted one-hour average concentrations of the COPC within the LSA for which exceedances of the Exposure Limits were identified are provided as Figures 5.16 to 5.18 of Appendix A. The figures also show the location at which the maximum predicted one-hour average concentration of each COPC was predicted to occur. Examination of the figures revealed the following:

- Similar to the CWC spill scenario, the predicted one-hour average concentrations of the COPC were only seen to exceed the corresponding Exposure Limits over water, suggesting that individuals on land would not experience any health effects from the smaller-sized spill.
- Exceedances were not predicted to extend beyond the area immediately surrounding the berths where access by the general public would be limited and/or restricted.

5.1.2.1.3 Duration of Exceedances

Vapour concentration-time plots showing the hour-by-hour maximum predicted one-hour average concentrations of the COPC as a function of time during the early stages of the spill event are provided as Figures 5.19 to 5.21 of Appendix A. These plots illustrate the predicted change in these maximum airborne concentrations over time, independent of the location within the LSA at which they occurred. Examination of the figures revealed the following:

- The maximum predicted one-hour average concentration of benzene was only seen to exceed the Exposure Limit within the two hours following the start of the spill. In the case of the aliphatic C_5-C_8 and aromatic C_9-C_{16} groups, there were no exceedances beyond the first hour.

5.1.2.1.4 Comparison Against Other Health-Based Benchmarks

The predicted maximum one-hour average airborne concentrations of the COPC predicted to occur within the LSA together with the corresponding AEGL and ERPG guidelines are provided in Table 5.4. Examination reveals that the predicted maximum one-hour average vapour concentration of benzene was substantially lower than the Tier-1 AEGL and ERPG guideline values, indicating that people in the area would not be expected to experience health effects other than mild, transient sensory and/or non-sensory effects. The effects would consist of lesser variants of those described above for the CWC spill scenario. Odours could be apparent to some individuals, especially those with a keen sense of smell. The odours would be continue to be dominated by a hydrocarbon-like smell, with some potential for other distinct odours due to the presence of sulphur containing chemicals in the vapour mix. The odours could contribute to added discomfort and irritability among these people.

TABLE 5.4

WESTRIDGE MARINE TERMINAL SMALLER SIMULATED SPILL SCENARIO - MAXIMUM PREDICTED 1-HOUR AVERAGE COPC VAPOUR CONCENTRATIONS AND CORRESPONDING AEGLS AND ERPGS

COPC	Predicted Maximum 1-Hour Average Vapour Concentration (µg/m³)	1-Hour AEGL (µg/m³)			1-Hour ERPG (µg/m³)		
		1	2	3	1	2	3
Aliphatic C_5-C_8 group	234,190	—	—	—	—	—	—
Aromatic C_9-C_{16} group	5,594	—	—	—	—	—	—
Benzene	3,389	166,131	2,555,858	12,779,288	159,741	479,223	3,194,822

As previously stated, AEGLs and ERPGs have not been developed for the aliphatic C_5-C_8 and aromatic C_9-C_{16} groups. In the case of the aliphatic C_5-C_8 group, evidence indicates that substantial adverse health effects from exposure to this COPC would not be expected to occur for the same reasons outlined above for the CWC scenario. In the case of the aromatic C_9-C_{16} group, based on a review of available scientific literature, there is no evidence to indicate that people would experience health effects from exposure to this group at the concentrations predicted to occur during the early stages of a spill event. However, information on the health effects that can follow acute inhalation exposure to the aromatic C_9-C_{16} group is quite limited.

5.1.2.2 Chemical Mixtures

The chemical mixtures that were examined as part of the smaller spill scenario were the eye irritant, respiratory irritation and neurotoxicant mixtures. Respiratory irritation would not be expected to occur as the maximum predicted vapour concentrations for the individual COPC comprising the mixture were predicted to be below the corresponding Exposure Limits. Maps showing the predicted maximum areal extent from the spill source where people's health could potentially be affected from the combined vapour concentrations of the COPC comprising the eye irritant and neurotoxicant mixtures are provided as Figures 5.22 and 5.23 of Appendix A, respectively. Examination of the figures reveals the following:

- The maximum areal extent for both mixtures did not extend beyond the area immediately surrounding the berths where public access would be limited and/or restricted.
- The prospect for health-effects to occur from exposure to the chemical mixtures did not materially differ in terms of areal extent from that predicted for the individual COPC.
- As described above for the CWC spill scenario, people in the area exposed to the mixtures would not be expected to experience health effects other than the mild, transient sensory and non-sensory effects.

5.2 Marine Transportation Spill Scenarios

5.2.1 CWC Spill Scenario

5.2.1.1 Individual COPC

5.2.1.1.1 Comparison Against Exposure Limits

The predicted maximum one-hour average airborne concentrations of the COPC predicted to occur within the LSA together with the corresponding acute inhalation Exposure Limits are provided in Table 5.5 for the CWC spill scenario (16,500m^3 of oil). Examination reveals that exceedances of the Exposure Limits were predicted to occur for the following COPC: aliphatic C_1-C_4, aliphatic C_5-C_8, and aromatic C_9-C_{16} groups, benzene, toluene, and xylenes. The exceedances indicate the possibility that people exposed to each of these COPC during the early stages of the spill incident could potentially experience adverse health effects. The nature, extent and relevance of the exceedances are examined in the following subsections. The predicted concentrations for the remaining COPC were consistently lower than the corresponding Exposure Limits, indicating that no obvious prospect for people's health to be affected by exposures to these chemicals exists. As a result, these COPC were removed from further consideration.

TABLE 5.5

MARINE TRANSPORTATION CWC SIMULATED SPILL SCENARIO 1-HOUR AVERAGE COPC VAPOUR CONCENTRATIONS AND CORRESPONDING EXPOSURE LIMITS

COPC[1]	Maximum Predicted 1-Hour Average Vapour Concentration (µg/m^3)	Acute Inhalation Exposure Limit (µg/m^3)
Aliphatic C_1-C_4 group	113,384	78,000
Aliphatic C_5-C_8 group	1,801,900	200,000
Aromatic C_9-C_{16} group	21,443	2,000
Benzene	17,510	580
Ethanethiol group	40	2,500
Ethylbenzene	4,273	21,700
Toluene	35,460	15,000
Trimethylbenzenes	1,939	690,000
Xylenes	31,820	7,400

Note: 1 COPC for which the maximum predicted one-hour average vapour concentrations exceeded the Exposure Limits are shown in bold font.

5.2.1.1.2 Areal Extent of Exceedances

Contour maps showing the predicted one-hour average concentrations of the COPC within the LSA for which exceedances of the Exposure Limits were identified are provided as Figures 5.24 to 5.29 of

Appendix A. The figures also show the location at which the maximum predicted one-hour average concentration of each COPC was predicted to occur. Examination of the figures revealed the following:

- In virtually all cases, the predicted one-hour average concentrations of the COPC were seen to exceed the corresponding Exposure Limits over both water and land. The only exception was the aliphatic C_1-C_4 group for which exceedances were only predicted to occur over water.

- There were substantial differences in the areal extent and coverage of the exceedances of the individual COPC within the LSA. The areal extent and coverage was greatest for the aromatic C_9-C_{16} group and benzene, with exceedances extending up to approximately 20 km from the spill source. Coverage across this area was nearly complete with a number of island communities located within the affected area. In the case of the aliphatic C_5-C_8 group, toluene, and xylenes, the areal extent of the exceedances was similar to that of the aromatic C_9-C_{16} group and benzene; however, coverage was much sparser and confined predominantly to areas over water, with fewer island communities likely to be affected. In the case of the aliphatic C_1-C_4 group, the predicted areal extent of exceedances did not extend beyond 3 km from the spill source. As already indicated, these exceedances occurred over water only.

5.2.1.1.3 Duration of Exceedances

Vapour concentration-time plots showing the hour-by-hour maximum predicted one-hour average concentrations of the COPC as a function of time during the early stages of a spill event are provided as Figures 5.30 to 5.35 of Appendix A. These plots illustrate the predicted change in these maximum airborne concentrations over time, independent of the location within the LSA at which they occurred. Examination of the figures revealed the following:

- In all cases, the maximum predicted one-hour average concentrations of the COPC followed a biphasic pattern characterized by an initial phase occurring within the first several hours of the spill and a second phase occurring approximately 20 hours later during which these maximum concentrations peaked.

- In all but one case, the data revealed that exceedances of acute inhalation Exposure Limits could occur for up to 30 hours following the start of the CWC spill event. The only exception was the aromatic C_9-C_{16} group for which exceedances were predicted to occur for up to approximately 50 hours following the start of the spill. However, the majority of exceedances occurred within the first 30 hours, and only two isolated exceedances occurred thereafter.

- The overall pattern of temporal exceedances aligned with the spatial extent of exceedances discussed above insofar as the largest number of exceedances were revealed for the aromatic C_9-C_{16} group and benzene, with fewer exceedances seen for aliphatic C_5-C_8 group, toluene, and xylenes, and the fewest exceedances revealed for aliphatic C_1-C_4 group. The number and pattern of exceedances for the different COPC are obvious from examination of Figures 5.30 to 5.35 of Appendix A.

5.2.1.1.4 Comparison Against Other Health-Based Benchmarks

The predicted maximum one-hour average airborne concentrations of the COPC predicted to occur within the LSA together with the corresponding AEGL and ERPG guidelines are provided in Table 5.6. Examination reveals that the predicted concentrations were consistently lower than these guidelines, including the Tier-1 values, indicating that people in the area would not be expected to experience health effects other than mild, transient sensory and/or non-sensory effects. The effects could consist of somewhat more pronounced variants of those described above for the Westridge Marine Terminal CWC spill scenario, continuing to be dominated by irritation of the eyes and breathing passages and symptoms consistent with nominal CNS involvement. These effects would likely resolve shortly after cessation of exposure, with no lingering after-effects. Odours could be apparent to some individuals, especially those with a keen sense of smell. The odours would be dominated by a hydrocarbon-like smell, with some potential for other distinct odours due to the presence of sulphur containing chemicals in the vapour mix. The odours could contribute to added discomfort and irritability among these people.

TABLE 5.6

MARINE TRANSPORTATION CWC SIMULATED SPILL SCENARIO - MAXIMUM PREDICTED 1-HOUR AVERAGE COPC VAPOUR CONCENTRATIONS AND CORRESPONDING AEGLS AND ERPGS

COPC	Predicted Maximum 1-Hour Average Vapour Concentration (µg/m³)	1-Hour AEGL (µg/m³)			1-Hour ERPG (µg/m³)		
		1	2	3	1	2	3
Aliphatic C_1-C_4 group	113,384	13,074,703	—	—	—	—	—
Aliphatic C_5-C_8 group	1,801,900	—	—	—	—	—	—
Aromatic C_9-C_{16} group	21,443	—	—	—	—	—	—
Benzene	17,510	166,131	2,555,858	12,779,288	159,741	479,223	3,194,822
Toluene	35,460	753,703	4,522,218	16,958,319	188,426	1,130,555	3,768,515
Xylenes	31,820	569,847	4,032,761	10,958,589	—	—	—

As stated earlier, AEGLs and ERPGs have not been developed the aliphatic C_5-C_8 and aromatic C_9-C_{16} groups. In the case of the aliphatic C_5-C_8 group, evidence indicates that substantial adverse health effects from exposure to this COPC would not be expected to occur, even at the maximum predicted concentrations that people in the area may experience during the early stages of the spill. More specifically, acute inhalation exposure of human subjects to a mixture of *n*-pentane, *iso*-pentane, hexane, and butane at concentrations up to 15,000,000 µg/m³ (*i.e.*, approximately 8-fold higher than the maximum concentration for this group predicted to occur from the spill) resulted in no observed effects (ECB 2003). In the case of the aromatic C_9-C_{16} group, based on a review of available scientific literature, there is no evidence to indicate that people would experience health effects from exposure to this group at the concentrations predicted to occur during the early stages of a spill event. However, information on the health effects that can follow acute inhalation exposure to the aromatic C_9-C_{16} group is quite limited.

5.2.1.2 Chemical Mixtures

The chemical mixtures that were examined as part of the smaller spill scenario were the eye irritant, respiratory irritant, and neurotoxicant mixtures. Maps showing the predicted maximum areal extent from the spill source where people's health could potentially be affected from the combined vapour concentrations of the COPC comprising each of these mixtures are provided as Figures 5.36, 5.37, and 5.38 of Appendix A for the eye irritant, respiratory irritant, and neurotoxicant mixtures, respectively. Examination of the figures reveals the following:

- The areal extent and coverage was greatest for the eye irritants mixture while the extent and coverage for the remaining mixtures were comparable.
- For the respiratory irritant and neurotoxicant mixtures, the coverage was predominantly over water; whereas the eye irritant mixture coverage extended over both land and water. The areal extent of the mixtures did not differ substantially from the maximum extent of the individual COPC comprising the mixtures.
- As previously described for the Westridge Marine Terminal CWC spill scenario, people in the area exposed to the mixtures would not be expected to experience health effects other than the mild, transient sensory and non-sensory effects described above for the individual COPC. Again, the maximum predicted one-hour average concentrations of the individual COPC comprising the mixtures remained well below the corresponding acute inhalation Exposure Limits or the Tier-1 AEGL and/or ERPG guidelines. Because of this, even combining the COPC and assuming they would interact in an additive fashion would not materially change the manner and extent to which people would be affected.

5.2.2 Smaller Spill Scenario

The smaller marine transportation spill scenario (8,250 m^3 of oil) was similar to the CWC scenario except that a lesser amount of oil was assumed to have escaped from the grounded vessel. The maximum one-hour vapour concentrations predicted to occur following the smaller spill event were typically lower than those predicted for the CWC spill scenario. However, the spatial extent and duration of exceedances were not substantially different between the two scenarios. The predicted COPC vapour concentrations were examined following the same step-wise approach used for the CWC spill scenario, and are discussed in the subsections below.

5.2.2.1 Individual COPC

5.2.2.1.1 Comparison Against Exposure Limits

The predicted maximum one-hour average airborne concentrations of the COPC predicted to occur within the LSA together with the corresponding acute inhalation Exposure Limits are provided in Table 5.7 for the smaller spill scenario. Examination reveals that exceedances of the Exposure Limits were predicted to occur for the following COPC: aliphatic C_5-C_8 and aromatic C_9-C_{16} groups, benzene, toluene, and xylenes. The exceedances indicate the possibility that people exposed to each of these COPC during the early stages of the spill incident could potentially experience adverse health effects. The nature, extent and relevance of the exceedances are examined in the following subsections. The predicted concentrations for the remaining COPC were consistently lower than the corresponding Exposure Limits, indicating that no obvious prospect for people's health to be affected by exposures to these chemicals exists. As a result, these COPC were removed from further consideration.

TABLE 5.7

MARINE TRANSPORTATION SMALLER SIMULATED SPILL SCENARIO 1-HOUR AVERAGE COPC VAPOUR CONCENTRATIONS AND CORRESPONDING EXPOSURE LIMITS

COPC[1]	Maximum Predicted 1-Hour Average Vapour Concentration (µg/m³)	Acute Inhalation Exposure Limit (µg/m³)
Aliphatic C_1-C_4 group	69,298	78,000
Aliphatic C_5-C_8 group	807,000	200,000
Aromatic C_9-C_{16} group	24,772	2,000
Benzene	5,454	580
Ethanethiol group	28	2,500
Ethylbenzene	3,405	21,700
Toluene	28,250	15,000
Trimethylbenzenes	2,346	690,000
Xylenes	25,360	7,400

Note: 1 COPC for which the maximum predicted one-hour average vapour concentrations exceeded the Exposure Limits are shown in bold font.

5.2.2.1.2 Areal Extent of Exceedances

Contour maps showing the predicted one-hour average concentrations of the COPC within the LSA for which exceedances of the Exposure Limits were identified are provided as Figures 5.39 to 5.43 of Appendix A. The figures also show the location at which the maximum predicted one-hour average concentration of each COPC was predicted to occur. Examination of the figures revealed the following:

- In all cases, the predicted maximum one-hour average concentrations of the COPC were predominantly seen to exceed the corresponding Exposure Limits over water. The only exceptions were the aromatic C_9-C_{16} group and benzene for which exceedances also were predicted to occur over land.

- There were substantial differences in the areal extent and coverage of the exceedances of the individual COPC within the LSA. Similar to the CWC scenario, the areal extent and coverage of exceedances was greatest for the aromatic C_9-C_{16} group and benzene, with exceedances continuing to extend up to approximately 20 km from the spill source but with noticeably less coverage over both water and land. In the case of the aliphatic C_5-C_8 group, toluene, and xylenes, the areal extent of the exceedances did not reach beyond 10 km from the spill and were confined predominantly to areas over water, with no island communities likely to be affected.

5.2.2.1.3 Duration of Exceedances

Vapour concentration-time plots showing the hour-by-hour maximum predicted one-hour average concentrations of the COPC as a function of time during the early stages of a spill event are provided as Figures 5.44 to 5.48 of Appendix A. Again, these plots illustrate the predicted change in these maximum airborne concentrations over time, independent of the location within the LSA at which they occurred. Examination of the figures revealed the following:

- In all cases, the maximum predicted one-hour average concentrations of the COPC continued to follow a biphasic pattern similar to the CWC spill scenario.
- Regardless of the COPC, the data revealed that exceedances of acute inhalation Exposure Limits could occur for up to 30 hours following the start of the CWC spill event.
- Similar to the CWC spill scenario, the overall pattern of temporal exceedances aligned with the spatial extent of exceedances discussed above. The largest number of exceedances were revealed for the aromatic C_9-C_{16} group and benzene, and fewer exceedances seen for aliphatic C_5-C_8 group, toluene, and xylenes. The number and pattern of exceedances for the different COPC are obvious from examination of Figures 5.44 to 5.48 of Appendix A.

5.2.2.1.4 Comparison Against Other Health-Based Benchmarks

The predicted maximum one-hour average airborne concentrations of the COPC predicted to occur within the LSA together with the corresponding AEGL and ERPG guidelines are provided in Table 5.8. Again, examination reveals that the predicted concentrations were consistently lower than these guidelines, including the Tier-1 values, again, continuing to indicate that people in the area would not be expected to experience health effects other than mild, transient sensory and/or non-sensory effects. As discussed previously, examples of these effects are: discomfort, irritability, mild irritation of the eyes, nose and/or throat, mild cough, and symptoms consistent with nominal CNS involvement such as mild headache, light headedness, minor vertigo, dizziness, and/or nausea. These effects would likely resolve quickly upon cessation of exposure without lingering after-effects. Odours could be apparent to some individuals, especially those with a keen sense of smell. The odours would be dominated by a hydrocarbon-like smell, with some potential for other distinct odours due to the presence of sulphur containing chemicals in the vapour mix. The odours could contribute to added discomfort and irritability among these people.

TABLE 5.8

MARINE TRANSPORTATION SMALLER SIMULATED SPILL SCENARIO - MAXIMUM PREDICTED 1-HOUR AVERAGE COPC VAPOUR CONCENTRATIONS AND CORRESPONDING AEGLS AND ERPGS

COPC	Predicted Maximum 1-Hour Average Vapour Concentration (μg/m³)	1-Hour AEGL (μg/m³)			1-Hour ERPG (μg/m³)		
		1	2	3	1	2	3
Aliphatic C_5-C_8 group	807,000	—	—	—	—	—	—
Aromatic C_9-C_{16} group	24,772	—	—	—	—	—	—
Benzene	5,454	166,131	2,555,858	12,779,288	159,741	479,223	3,194,822
Toluene	28,250	753,703	4,522,218	16,958,319	188,426	1,130,555	3,768,515
Xylenes	25,360	569,847	4,032,761	10,958,589	—	—	—

As previously stated, AEGLs and ERPGs have not been developed the aliphatic C_5-C_8 and aromatic C_9-C_{16} groups. In the case of the aliphatic C_5-C_8 group, evidence indicates that substantial adverse health effects from exposure to this COPC would not be expected to occur for the same reasons outlined above for the CWC spill scenarios. In the case of the aromatic C_9-C_{16} group, based on a review of available scientific literature, there is no evidence to indicate that people would experience health effects from exposure to this group at the concentrations predicted to occur during the early stages of a spill event. However, information on the health effects that can follow acute inhalation exposure to the aromatic C_9-C_{16} group is quite limited.

5.2.2.2 Chemical Mixtures

As with the CWC spill scenario, the chemical mixtures that were examined as part of the smaller spill scenario were the eye irritant, respiratory irritant, and neurotoxicant mixtures. Maps showing the predicted maximum areal extent from the spill source where people's health could potentially be affected from the combined vapour concentrations of the COPC comprising each of these mixtures are provided as Figures 5.49, 5.50, and 5.51 of Appendix A for the eye irritants, respiratory irritants, and neurotoxicant mixtures, respectively. Examination of the figures reveals the following:

- The areal extent and coverage was greatest for the eye irritants mixture, less for the neurotoxicant mixture, and least for the respiratory irritant mixture.
- Areal coverage was almost exclusively over water for the respiratory irritant mixture, predominantly over water for the neurotoxicants mixture, and over both land and water for the eye irritants mixture. The areal extent of the mixtures did not differ materially from the maximum extent of the individual COPC comprising the mixtures.
- As described above for the CWC spill scenario, people in the area exposed to the mixtures would not be expected to experience health effects other than the mild, transient sensory and non-sensory effects.

6.0 DISCUSSION

The present assessment was completed in order to permit understanding of the nature and extent of health effects that people in the area of an oil spill could experience from exposure to the hydrocarbon and other chemical vapours released from the surface of the oil slick during the early stages of the incident under each of the various simulated and unmitigated oil spill scenarios examined. The assessment represented an extension of the preliminary qualitative assessments that were conducted earlier and submitted as parts of Volumes 7 and 8B of the Application. It provides a more complete picture of the types of health effects that might be experienced as well as their spatial and temporal pattern.

The assessment remained focused on the two principal types of oil spills that were examined earlier: i) a set of simulated spill scenarios involving different sized spills resulting from an incident while loading a tanker at berth at the Westridge Marine Terminal; and, ii) a second set of simulated spill scenarios of different sized spills resulting from the grounding of a laden tanker on Arachne Reef. In both cases, the spill sizes corresponded to the volumes of oil that could be released under a CWC spill scenario and a smaller sized spill scenario. The assessment also remained at a screening-level and qualitative in nature, without proceeding to the calculation of numerical risk estimates that feature prominently in most conventional HHRAs. This approach was taken partly because of the rare, unpredictable nature of oil spills that render detailed quantitative estimates of the probability of occurrence of health effects from these incidents questionable *vis-à-vis* the precision that such risk estimates infer, especially if applied broadly. It was conservatively assumed that the oil spill(s) had taken place despite a low probability of occurrence, and without regard for the spill prevention programs described in Volumes 7 and 8A that will be in effect to minimize the prospect for spills to occur along the entire length of the pipeline, at the Westridge Marine Terminal, and along the marine shipping route. This allowed the assessment to remain focused on identifying and understanding the types of health effects that could occur in the event of an oil spill, with the results used to inform Trans Mountain, the Project team and other emergency and spill response authorities in their preparedness and planning around such incidents to help protect public health.

Similar to the earlier preliminary assessments, the present assessment focused on the nature and extent of health effects that people might experience from inhalation of the COPC vapours released from the surface of the oil slick during the early stages of the spill event before the arrival of first responders and the implementation of emergency and spill response measures aimed at quickly isolating, containing and recovering the spilled oil. Other exposure scenarios involving exposure pathways apart from inhalation (*e.g.*, physical contact with the spilled oil, consumption of foodstuffs containing residues of the spilled oil) were considered unlikely, largely because of: i) the spill surveillance, containment, recovery and monitoring programs described in Volumes 7 and 8A that will be implemented by Trans Mountain, the WCMRC and other spill response agencies; and, ii) the authority granted to different regulatory agencies under federal, provincial, regional and/or local acts, regulations and ordinances to implement added measures for the protection of public health and safety. These latter measures include options such as closure of recreational and commercial fisheries, beach closures, issuance of food consumption advisories, and evacuation of people from affected areas if public health and safety is threatened. The exact measures taken will be dictated, in part, by the circumstances and real-time events surrounding the spill, including the size, behavior and immediate hazards presented by the oil slick; however, attention invariably will be given to the need to protect public health, with a principal objective being to limit any opportunity for people to be exposed to the spilled oil on both a short-term and longer-term basis whether through direct physical contact, inhalation of vapours or other exposure pathways.

The assessment followed a paradigm adapted from that used for conventional HHRAs to accommodate the specific focus of the present work, but still proceeding step-wise through the various steps as outlined in Section 4.0 Specific Methods. The principal outcomes of the Problem Formulation step were summarized in Table 4.4. The Exposure Assessment step focused on understanding the exposures to the COPC vapours released from the surface of the oil slick that people in the area could receive during the initial stages of the oil spill. Reliance was placed on hour-by-hour predictions of the one-hour average concentrations of the vapours at varying distances from the source based on spill simulation modelling performed by EBA, with emphasis placed on the maximum predicted values. The predictions served as proxies of the acute inhalation exposures that the people might experience. Vapour concentration contour maps and concentration-time plots were constructed to more fully understand the exposures that might be received based on the extent of spatial coverage and elapsed time from the start of the spill event. The Toxicity Assessment step focused on understanding the types of health effects that can follow exposure to the COPC vapours, with a specific interest in identifying health-based acute inhalation Exposure Limits for the COPC as indicators of the levels of exposure below which adverse health effects would not be expected to occur. Exposure Limits developed by a number of leading scientific authorities and regulatory agencies for the protection of public health were selected for use, with the Exposure Limits affording a high degree of protection, extending to even sub-populations who might be especially responsive to chemical exposures, such as young children, the elderly and people with compromised health. The Exposure Limits were used as initial screening-level comparison benchmarks to determine the prospect for people's health to be affected by acute inhalation exposure to the COPC vapours at the concentrations predicted to occur during the early stages of the spill event. Additional benchmarks, notably the one-hour AEGLs and ERPGs, were identified and used for comparison purposes to provide added perspective opposite the likelihood of occurrence of health effects. The latter benchmarks were particularly well suited for assessing the potential health implications of the exposures since they are intended for use in situations involving rare, accidental exposure to chemicals, such as spills, that can involve the general public. The characterization of the health effects followed a multi-tiered approach, beginning with comparison of the predicted maximum one-hour average COPC vapour concentrations against the corresponding acute inhalation Exposure Limits, with the relevance and meaning of any exceedances explored through examination of the vapour concentration contour maps and concentration-time plots as well as further comparison of the predicted vapour concentrations against the corresponding AEGLs and ERPGs. The principal findings that emerged from the assessment are presented below, beginning with some general observations, followed by comments specific to the different types of simulated oil spill scenarios examined.

6.1 General Observations

The following general observations were common across each of the spill scenarios examined:

- Comparison of the predicted maximum one-hour average airborne concentrations of the COPC against the corresponding acute inhalation Exposure Limits revealed occasional instances in which the Exposure Limits were exceeded for certain of the chemicals, indicating some prospect for people's health to be affected. The interpretation of the relevance and meaning of these exceedances formed part of the characterization of the potential health effects (*i.e.*, Step 4 of the paradigm), and was reserved until the assessment was complete.

- The pattern of exceedances varied by spill type, but within each spill type, a consistent pattern emerged. For the Westridge Marine Terminal spill scenarios, the exceedances were confined to the first few hours of the spill incident, as might be expected since the volatile and semi-volatile hydrocarbons and other chemicals comprising the CLWB diluted bitumen would be most concentrated on the surface of the oil slick at this time. With elapsed time, the mass of these COPC on the slick surface would be expected to decline, consistent with the overall downward trend in the number and/or magnitude of exceedances that was observed. For the marine transportation spill scenarios, a biphasic pattern emerged, with exceedances or near exceedances often noted during the first several hours following the start of the incident (*i.e.*, consistent with observations for the Westridge Marine Terminal spill scenarios), followed by a second phase of exceedances that peaked approximately 15 to 20 hours later. The latter exceedances may have been attributable, in part, to certain meteorological conditions affecting the dispersion of the COPC vapours that formed part of the spill modelling simulations. The patterns are evident from the concentration-time plots provided in Appendix A.

- Most exceedances occurred either exclusively or predominately over water. This observation was most apparent for the Westridge Marine Terminal spill scenarios, partly because of the smaller spill volumes involved, but also because of the complete or nearly complete containment of the spills by the pre-deployed spill containment boom. In fact, the assessment revealed no exceedances over land for the Westridge Marine Terminal spill scenarios. For the marine transportation spill scenarios, the exceedances were predicted to occur predominately over water, but for certain COPC, the exceedances extended over land, in some cases involving island communities where people live or might stay. The spatial pattern of the exceedances is evident from the concentration contour maps found in Appendix A.

- As might be expected, the coverage and spatial extent of the exceedances was influenced by spill size, with the overall size of the area within which exceedances occurred and the outward distances from the spill source to which the exceedances extended being greater for the CWC spill scenarios than for the corresponding smaller-size spill scenarios. The differences were most apparent for the Westridge Marine Terminal spill scenarios, largely because of the fact that the spilled oil was fully contained by the pre-deployed boom in the smaller spill scenario; whereas, some of the spilled oil was assumed to escape the boomed area in the CWC scenario. For the marine transportation spill scenarios, the differences were obvious for most COPC, but less apparent, albeit still evident, for the remaining chemicals. Again the coverage is evident from the concentration contour maps found in Appendix A. It is expected that the coverage and spatial extent of the exceedances would be diminished had the assessment allowed for the various spill and emergency response measures that will be taken by Trans Mountain, the WCMRC and other authorities to quickly isolate, contain and recover the spilled oil as described in Volumes 7 and 8A. As already mentioned, as part of the conservatism incorporated into the work, the assessment was performed without regard for these response measures in order to avoid overlooking or understating the potential health effects that people might experience.

- Comparison of the predicted maximum one-hour average airborne concentrations of the COPC against the corresponding one-hour AEGLs and ERPGs consistently revealed the levels of the COPC that people in the area might encounter during the early stages of the spill to be well below these guidelines, including the “Tier-1” values, indicating no obvious prospect for people’s health to be adversely affected. The absence of exceedances of the AEGL and ERPG guidelines applied across the entire series of simulated spill scenarios examined, including the CWC scenarios. The lack of available AEGLs and/or ERPGs, coupled with an absence of relevant health effects information for certain of the COPC introduces some uncertainty; however, this uncertainty needs to be weighed against the entire set of observations that consistently showed no exceedances of the guidelines across the majority of chemicals, coupled with the finding that the predicted vapour concentrations remained well below even the Tier-1 values.

- Although the assessment revealed exceedances of the Exposure Limits on occasion for some COPC, the interpretation of the relevance and meaning of these exceedances required consideration of the conservatism incorporated into the assessment, including the Exposure Limits themselves. In this regard, by virtue of the level of protection demanded of the Exposure Limits, these guidelines correspond to exposure levels well below those known to cause adverse health outcomes. For this reason, an exceedance of an Exposure Limit does not necessarily indicate an imminent health risk, but rather only infers some prospect for health effects to occur, the interpretation of which requires further analysis. As part of this further analysis, reliance was placed on the AEGLs and ERPGs since these guidelines are deliberately intended for use in assessing the potential health effects that might occur among the general public from exposure to relatively high concentrations of chemicals for short duration under rare, accidental circumstances, such as chemical spills. As indicated above, comparison of the predicted maximum COPC vapours concentrations against the AEGLs and ERPGs showed no exceedances of even the Tier-1 guideline values.

- The weight-of-evidence gathered from the characterization of the potential health effects as outlined above showed no obvious prospect for people’s health to be substantially adversely affected by exposure to the COPC vapours during the early stages of the spill events. Using the tiered AEGL and ERPG health effects criteria for guidance, the evidence revealed that people in the area would not be expected to experience health effects other than mild, transient sensory and/or non-sensory effects, related largely to the irritant properties and/or CNS depressant effects of the COPC. These effects would likely resolve quickly upon cessation of exposure. Odours could be apparent to some individuals, especially those with a keen sense of smell. The odours would be dominated by a hydrocarbon-like smell, with some potential for other distinct odours due to the presence of sulphur containing chemicals in the vapour mix. The odours could contribute to added discomfort and irritability among these people.

6.2 Observations by Spill Type

6.2.1 Westridge Marine Terminal Spill Scenarios

Notable observations gathered from the assessment of the Westridge Marine Terminal simulated spill scenarios were:

- For the majority of instances in which the predicted maximum one-hour vapour concentrations of the COPC exceeded the corresponding acute inhalation Exposure Limits, the exceedances were confined to the first 1-to-2 hours following the start of the spill incident, indicating that the opportunity for exposures that could possibly cause health effects would be confined to a narrow window of time. The exceptions included the aliphatic C_5-C_8 and aromatic C_9-C_{16} groups and benzene, for which exceedances were predicted to occur for up to 12 hours under the CWC spill scenario only. From a practical standpoint, these latter exceedances likely represent hypothetical constructs only insofar as the assessment did not allow for the emergency and spill response measures described in Volume 7 of the Application that will be implemented by Trans Mountain, WCMRC and other spill response authorities in the event of a spill at the Terminal. These measures include not only isolating, containing and recovering the spilled oil but also notifying the public, restricting public access to the affected area and possibly evacuating people from the area, all of which will serve to limit the opportunity for people to be exposed to the COPC through direct physical contact with the spilled oil and/or through inhaling vapours released from the surface of the oil slick. Moreover, these emergency and spill response measures will be implemented quickly (*i.e.*, within as little as one hour) because of pre-planning to ensure that the equipment and resources that are needed will be nearby. Thus, the prospect for the latter exceedances to occur is remote.

- For the majority of cases, the spatial extent of the exceedances was confined to an area within the immediate vicinity of the tanker vessel berths, where public access would be restricted or limited. For the remaining cases, the exceedances extended for no more than 300 m from the berths, well within an area where people could quickly and easily be alerted of the spill, and advised to leave the area. In all cases, the predicted exceedances occurred over water only. They did not extend to the shoreline, or to any of the communities lining Burrard Inlet or located further inland. Although the exceedances indicate some prospect that people on the water in pleasure craft or other vessels near the berths could experience health effects from exposure to the COPC vapours during the early stages of a spill, the possibility is considered to be remote given that: i) public access to much of the area will be restricted; ii) the area will be manned and supervised by Trans Mountain personnel trained in emergency and spill response who can quickly alert and/or direct people away from the area in the event of a spill; and, iii) the area itself is an industrial parcel and complex that would not be expected to be inviting to recreationalists or water sport enthusiasts. In other words, few people would be expected to frequent the area, and resources would be available to quickly notify and instruct any people who might be nearby on the water to vacate the area in the event that an oil spill was to occur.

- In no case did the predicted maximum one-hour average concentrations of the COPC vapours exceed the corresponding AEGL and/or ERPG guidelines, including the Tier-1 values. As indicated already, these guidelines are particularly relevant to the oil spill scenarios since they are intended for use in situations involving exposure of the general public to chemicals as a result of rare accidental events. Again, the lack of any exceedances of the Tier-1 AEGL and ERPG guidelines indicates that people in the area would not be expected to experience health effects other than mild, transient sensory and/or non-sensory effects, possibly accompanied by odours that may contribute to discomfort and/or irritability.

6.2.2 Marine Transportation Spill Scenarios

Notable observations gathered from the assessment of the marine transportation simulated spill scenarios were:

- As would be expected, differences were evident in the overall prospect for people's health to be affected from exposures to the COPC vapours under the marine transportation spill scenarios compared to the Westridge Marine Terminal spill scenarios owing largely to the differences in the spill circumstances involved *vis-à-vis* spill volumes (*i.e.*, the marine transportation scenarios assumed much larger amounts of oil being spilled compared to the amounts assumed for the Westridge Marine Terminal), spill containment (*i.e.*, the Westridge Marine Terminal scenarios allowed for pre-deployed booms to be in place to contain most if not all of the spilled oil), and physical parameters affecting the movement, fate and behavior of the oil slick (*i.e.*, the open water in the northern portion of the Haro Strait represents a different environment than the relatively protected waters in Burrard Inlet at the Westridge Marine Terminal site). In this regard, the spatial coverage, areal extent and temporal extent of the exceedances of the acute inhalation Exposure Limits observed for the marine transportation spill scenarios were greater than those predicted for the Westridge Marine Terminal scenarios. Yet despite these overall differences, the weight-of-evidence still revealed that people would not be expected to experience health effects other than the mild, transient sensory and/or non-sensory effects from exposure to the COPC vapours under the marine transportation spill scenarios. In this respect, the differences between the two types of oil spill scenarios relate not to the overall nature of the health effects that might be experienced, but rather to the intensity of these effects and the likelihood that they might be manifest. In the case of the marine transportation scenarios, the degree or intensity of the irritant and CNS effects resulting from exposure to the COPC vapours, although still remaining mild or minor in nature, would likely be heightened. Similarly, the nuisance, discomfort and irritability caused by the hydrocarbon- and chemical-based odours could be more noticeable. The prospect for these mild, transient effects to occur would be heightened largely because a greater number of people could potentially be exposed to the COPC vapours at sufficiently high concentrations, as evidenced by the greater spatial coverage and areal and temporal extent of the exceedances, including coverage not only over water but also over land, including island communities where people live or might stay (see below).

- Although the exceedances noted for the marine transportation spill scenarios were predicted to occur predominantly over water, in some cases, the coverage extended to land, including islands and peninsulas on which people live or which people might frequent for recreational or other purposes. Therefore, the prospect for people's health to be affected from exposure to the COPC vapours applied not only to people who might be on the water in commercial vessels or pleasure craft, but also to people living or staying on or visiting these lands. As might be expected, the spatial coverage and areal extent of exceedances predicted for the CWC spill scenario were greater than those predicted for the smaller size spill; however, the overall pattern was similar for both spill sizes, with exceedances also extending over land for the smaller spill in some instances.

- As mentioned earlier, the pattern of exceedances noted for the marine transportation spill scenarios was biphasic, with exceedances or near exceedances often noted during the first few hours following the start of the incident, followed by a second phase of exceedances that peaked approximately 15 to 20 hours later. These latter exceedances were more striking than those occurring in the first phase, with the highest hourly maximum predicted one-hour average concentrations of the COPC peaking during this time period. It is reasonable to assume that some prospect for these concentrations to be encountered exists since appreciable numbers of people potentially could be found where these concentrations were predicted to occur. In addition, it is conceivable that first responders may not yet have arrived on scene and implemented measures to safeguard public health and safety albeit with improvements in emergency and spill response planning standards and expected response times, the prospect for the occurrence of such exceedances would likely be diminished.

- Again, in all cases, the predicted maximum one-hour average concentrations of the COPC vapours remained below the corresponding AEGL and/or ERPG guidelines, including the Tier-1 values, indicating that people in the area would not be expected to experience health effects other than mild, transient sensory and/or non-sensory effects, possibly accompanied by odours that could contribute to discomfort and/or irritability. The absence of exceedances of the guidelines still applied despite the higher volumes of oil spilled, the greater spatial coverage of the oil slick, and the higher concentrations of the COPC that people in the area might encounter compared to the Westridge Marine Terminal spill scenarios.

6.3 Other Considerations

Other considerations bearing on the interpretation of the relevance and meaning of the results of the assessment are:

- As outlined earlier, an appreciable degree of conservatism was incorporated into the assessment (see Section 4.5 Uncertainty Analysis), consisting, in part, of a number of conservative assumptions that could contribute to heightened exposure of people to the hydrocarbon and other chemical vapours released from the surface of the oil slick in the event of an oil spill compared to actual exposures that might be experienced. The reliance on these conservative assumptions was consistent with the screening-level approach used for the assessment, with the aim being to avoid underestimating or overlooking any potential health effects that people could experience. By the same token, the conservatism incorporated into the assessment may have contributed to overstatement of the manner and extent to which people's health might be affected. Examples of the conservatism employed in the assessment are:

  - It was conservatively assumed that the spill(s) had occurred despite a low probability of occurrence and without regard to the spill prevention programs described in Volumes 7 and 8A of the Application that will be in place.

  - In estimating the exposures to the COPC vapours that people in the area might experience during the early stages of the spill(s), allowance was not made for the emergency and spill response measures that will quickly be taken by Trans Mountain, the WCMRC, the Coast Guard and other spill response agencies to isolate, contain and recover the spilled oil, thereby reducing the prospect for exposures to occur and/or the concentrations of the vapours that might be encountered. This conservative element is especially relevant to the Westridge Marine Terminal spill scenarios since the response measures will be implemented within as little as one hour of notice of the spill being received.

  - In determining the manner and extent to which people's health might be affected by exposure to the COPC vapours, reliance was placed on the predicted maximum one-hour average concentrations that people in the area might encounter.

  - The assessment relied, in part, on Exposure Limits as comparison benchmarks to gauge the prospect for people's health to be adversely affected by exposure to the COPC vapours. The Limits are deliberately set to afford a high degree of protection with respect to the health of the general public, extending to sub-populations who may be especially sensitive to chemical exposures. By virtue of the manner in which the Limits are developed, including reliance on the most sensitive endpoint affected by the chemical in the most sensitive species as its basis, coupled with the application of uncertainty factors to confer added protection, the Limits correspond to exposure levels well below those at which adverse health effects have actually been observed.

- Exposure of people might reasonably be expected to be self-limiting owing to the irritant properties of a number of the COPC as well as the odours that might be noticed. Both of these properties would provide warning of the presence of the chemicals such that people could take action to remove or distance themselves from the source, thereby reducing the amount and duration of any exposure received. This situation would apply especially in the case of the Westridge Marine Terminal spill scenarios in which the areal extent of the oil slick is relatively confined, and people could quickly and easily vacate the area, reducing and even removing any threat of exposure. The situation is perhaps less applicable, but still relevant, for the marine transportation spill scenarios owing to the larger areal extent of the oil slick, which could delay people removing themselves from the area entirely. However, the prospect would still exist for these people to either shelter-in-place or distance themselves from the source in order to reduce the concentrations of the COPC that they might encounter. With respect to these actions that people could take to limit exposures, it is noteworthy that the predicted maximum one-hour average concentrations of the COPC were considerably below the Tier-2 AEGL and ERPG guidelines, indicating that any health effects that they might experience would not impair their ability to remove themselves from the area.

- The simulated oil spill scenarios that were examined reflected specific circumstances *vis-à-vis* spill location and size, as well as water movement, water temperature, wave action, meteorological conditions and other physical parameters affecting the fate and behavior of the spilled oil and/or the dispersion of the chemical vapours released from the surface of the oil slick. The results of the assessment necessarily apply to the specific scenarios that were chosen. In defense of the choice of spill scenarios, it is important to acknowledge that: i) the scenarios included CWC conditions in terms of the spills themselves; and, ii) the deterministic model simulations that the assessment relied upon were chosen on the basis of selection criteria capturing a number of important parameters from a human health perspective. The combination of these items with the conservatism incorporated into the assessment provides some measure of assurance that the results of the assessment provide a reasonable representation of the nature and extent of any health effects that people might experience under each simulated spill scenario, with no obvious reason to suspect that effects were overlooked or understated. However, uncertainty remains as to how well the results reflect the potential exposures to the COPC vapours and associated health effects that could be experienced by people under different spills scenarios because of differences in circumstances. In this regard, there is need for recognition of the multitude of factors that can act as determinants of the exact nature and severity of any health effects that could potentially result from an oil spill, as well as the variability that can surround these factors. Examples of these factors and the manner by which they were addressed in the present assessment are discussed below. Consistent with the approach used for the assessment, the discussion of these factors is based on the premise that the spills had taken place despite their low probability of occurrence, and without regard for the numerous spill prevention measures that will be implemented as part of the Project as outlined for the Westridge Marine Terminal in Section 2.0 of Volume 7 of the Application, and for marine transportation in Section 5.3 of Volume 8A of the Application.

- The circumstances surrounding the spill, including the time of year and the meteorological conditions in effect at the time. These circumstances will affect the extent to which chemical vapours are released from the surface of the oil slick and the manner in which these vapours disperse. For the purposes of the assessment, the potential exposures to the COPC vapours that people in the area could experience were based on estimates derived using the deterministic spill simulation modelling that captured seasonal and weather conditions favouring the volatilization of the hydrocarbons from the oil slick.

- The person's whereabouts in relation to the spill, including their distance from the oil slick and their orientation to the slick with respect to wind direction. The prospect for people's health to be affected by acute inhalation exposure to the hydrocarbon and other chemical vapours released from the spilled oil will be greatest at locations close to and downwind of the oil slick, where the highest concentrations of the vapours will be encountered. The assessment relied on the predicted maximum one-hour average COPC vapour concentrations as proxies for the exposures that people might experience.

- The timeliness of emergency response measures. Measures taken to either remove the hazard from the general public (*e.g.,* spill isolation, containment) or to remove the general public from the hazard (*e.g.,* securing the spill area, restricting access, notifying the public to avoid the area and/or evacuation of people from the area) will reduce the prospect for exposure and any associated health effects. The sooner these measures can be implemented, the lower the likelihood of any effects. Prompt measures taken by Trans Mountain, the Coast Guard authorities, the WCMRC, Port Metro-Vancouver, local authorities (such as police and fire departments) and other emergency and spill response agencies will serve to protect public health and safety. The improvements to response times proposed by Trans Mountain and WCMRC in Table 5.5.3, Section 5.5, Volume 8A of the Application (December 2013) would further limit the exposure and potential health effects on the general public. The assessment was completed without regard for these emergency and spill response measures for added conservatism to avoid any potential health effects being overlooked or understated.

- A person's sensitivity to chemical exposures. The manner and extent to which people in the area at the time of an oil spill may respond to the chemical vapours released from the surface of the oil slick will depend, in part, on their age, health status and other characteristics, with the young, the elderly and people with compromised health possibly showing heightened sensitivity. The assessment allowed for the possibility that these sensitive sub-populations might be exposed to the COPC vapours by using the Exposure Limits and AEGLs as comparison benchmarks. Both types of guidelines afford protection to these sub-populations.

7.0 SUMMARY AND CONCLUSIONS

An assessment of the potential health effects that might be experienced by people from exposure to hydrocarbon and other chemical vapours released from the surface of the oil slick during the early stages of the oil spills defined under the Westridge Marine Terminal spill scenarios and the marine transportation spills scenarios was completed. The assessment represented an extension of the preliminary qualitative assessments that were conducted earlier and submitted as parts of Volumes 7 and 8B of the Application. It provides a more complete analysis of the types of health effects that might be experienced as well as the prospect for people's health to be adversely affected.

The assessment relied on predictions of the one-hour average airborne concentrations of a number of COPC derived on the basis of oil spill simulation modelling as proxies for the acute inhalation exposures that people might experience in the area. The predictions were made at different locations and at different times from the start of the spill incident in order to permit understanding of the spatial and temporal patterns of the exposures that could be received. The predicted concentrations were compared to the corresponding health-based acute inhalation Exposure Limits developed by a number of scientific and regulatory authorities, with the Limits corresponding to levels of the COPC that would not be anticipated to cause adverse health effects among the general public, including people who might be especially sensitive to chemical exposures. The results of the comparison were used to assess the nature and extent of any potential health effects that the people could experience. For added perspective, the predicted concentrations of the COPC vapours also were compared to the corresponding one-hour AEGL and ERPG guidelines. These latter guidelines were considered to be especially relevant benchmarks since they are intended for use in situations involving rare, unpredictable exposure circumstances of the general public to chemicals, with an example of such situations being accidental spills.

An appreciable amount of conservatism was incorporated into the assessment to avoid any health effects being overlooked or understated. The high degree of conservatism involved is reflected, in part, by the use of the predicted maximum one-hour average airborne concentrations of the COPC as proxies for the acute inhalation exposures that might be received by people. Conservatism also was introduced by the use of the Exposure Limits as comparison benchmarks, with the understanding that the Exposure Limits correspond to levels of the COPC well below those at which adverse health effects are known to occur.

The major findings and conclusions that emerged from the assessment are summarized below.

7.1 Westridge Marine Terminal Spill Scenarios

- The initial screening-level comparison of the predicted maximum one-hour average concentrations of the COPC to the corresponding acute inhalation Exposure Limits revealed some exceedances for certain chemicals at certain times for both the CWC spill scenario (160 m^3 of oil) and smaller size spill scenario (10 m^3 of oil). These initial findings suggested that human health could possibly be affected by exposure to the vapours released from the surface of the oil slick during the early stages of the spill incident. The findings signalled the need for further analysis to define the nature and extent of any effects, including comparison against the relevant AEGLs and ERPGs as well as consideration of the conservatism incorporated into the assessment.

- The exceedances of the Exposure Limits revealed by the initial screening-level analysis were predicted to occur over water only, with the spatial extent of the exceedances either confined to an area within the containment boom (*i.e.*, small size spill) or an area in the near vicinity of the tanker berths (*i.e.*, CWC spill). Public access to most of the affected area would be restricted or limited. Due to the relatively small area involved, it is expected that people who might be on the water in the area at the time of a spill could be quickly and easily alerted and directed to leave the area, thereby reducing or removing any prospect for exposure to the COPC vapours.

- The temporal extent of the exceedances of the Exposure Limits comprised a relatively narrow window of time, with exceedances predicted to occur only over the first one-to-two hours following the start of the spill under the small size spill scenario. For certain of the COPC, the exceedances were predicted to occur for up to 12 hours after the start of the spill under the CWC spill scenario. However, the prospect for people who might be on the water in the area at the time of the spill to sustain the exposures associated with the exceedances would be expected to be low since emergency and spill response measures, including notifying the public, restricting access to the area and/or evacuating people from the area, will be quickly implemented. Because of pre-planning, these measures could be initiated within as little as one hour.

- Comparison of the predicted maximum one-hour average airborne concentrations of the COPC against the corresponding one-hour AEGL and ERPG guidelines revealed no exceedances of the Tier-1 values, indicating that people who might be in the area at the time of the spill would not be expected to experience health effects other than mild, transient sensory and/or non-sensory effects, examples of which could include: discomfort, irritability, mild irritation of the eyes, nose and/or throat, mild cough, and symptoms consistent with nominal CNS involvement such as mild headache, light headedness, minor vertigo, dizziness, and/or nausea. Odours could be apparent to some individuals, especially those with a keen sense of smell. The odours would be dominated by a hydrocarbon-like smell, with some potential for other distinct odours due to the presence of sulphur-containing chemicals in the vapour mix. The odours could contribute to added discomfort and irritability among these people.

- The absence of substantial adverse health effects applied whether the COPC were assessed on an individual chemical basis or as part of mixtures, with the mixtures defined on the basis of commonality of effects and the individual chemical constituents interacting in an additive manner.

7.2 Marine Transportation Spill Scenarios

- The initial screening-level comparison of the predicted maximum one-hour average concentrations of the COPC to corresponding acute inhalation Exposure Limits revealed some exceedances for certain chemicals at certain times for both the CWC spill scenario (16,500 m^3 of oil) and smaller size spill scenario (8,250 m^3 of oil), again suggesting that human health could possibly be by exposure to the vapours released from the surface of the oil slick during the early stages of the spill incident. The findings signaled the need for further analysis to define the nature and extent of any effects, including comparison against the relevant AEGLs and ERPGs as well as consideration of the conservatism incorporated into the assessment.

- The exceedances of the Exposure Limits revealed by the initial screening-level analysis were predicted to occur predominantly over water, but in some instances, extended over land, including island communities along the marine shipping route. The areal extent of the exceedances was similar for the two sized spills; albeit, overall the spatial coverage of the exceedances predicted for the CWC spill was greater than that predicted for the smaller spill. The spatial coverage was such that moderate numbers of people could be found within the affected area under either size spill scenario.

- The temporal extent of the exceedances of the Exposure Limits followed a biphasic pattern, with the second phase extending out to approximately 20 to 30 hours after the start of the spill event, regardless of the spill size. It is conceivable that these exceedances could occur before the arrival of first responders and the implementation of emergency and spill response measures, albeit with improvements in emergency and spill response planning standards and expected response times, the prospect for the occurrence of such exceedances would likely be diminished.

- Comparison of the predicted maximum one-hour average airborne concentrations of the COPC against the corresponding one-hour AEGL and ERPG guidelines revealed no exceedances of the Tier-1 values, indicating that people who might be in the area at the time of the spill would not be expected to experience health effects other than mild, transient sensory and/or non-sensory effects. Odours might be noticeable and could contribute to added discomfort and irritability among these people. The specific types of effects that might be experienced would be similar to those described above for the Westridge Marine Terminal spill scenarios; however, the intensity of the effects would be expected to be greater because of the higher concentrations of the COPC vapours that people could encounter under the marine transportation spill scenarios.

- Again, the absence of substantial adverse health effects applied whether the COPC were assessed on an individual chemical basis or as part of mixtures, with the mixtures defined on the basis of commonality of effects and the individual chemical constituents interacting in an additive manner.

7.3 Conclusions

The principal conclusions of the assessment are listed below. In arriving at the conclusions, consideration was given to:

- the results of the comparisons of the potential exposures to the COPC vapours that people might experience against the various heath-based benchmarks *(i.e.*, Exposure Limits, AEGLs and ERPGs);
- the spatial and temporal extent of any exceedances that were noted, partly as an indicator of the number of people who potentially might be affected as well as an indicator of the duration of the exposures they might receive;
- the nature and timing of the emergency and spill response measures that will be implemented by Trans Mountain, the WCMRC, Coast Guard authorities, and other spill response agencies in the event a spill was to occur;
- the conservatism incorporated into the assessment; and
- the uncertainties that remained despite the appreciable degree of conservatism involved.

The conclusions are:

- Based on the weight-of-evidence, there is no obvious indication that people's health would be seriously adversely affected by acute inhalation exposure to the chemical vapours released during the early stages of a spill under any of the simulated oil spill scenarios examined.
- The evidence suggests that the health effects that could be experienced by people in the area would likely be confined to mild, transient sensory and/or non-sensory effects, attributable largely to the irritant and CNS depressant properties of the chemicals. Odours also might be noticed, which could contribute to added discomfort and irritability.
- The evidence indicates that these mild, transient health effects could be experienced under all of the simulated oil spill scenarios examined; however, the intensity of the effects would be greatest for the larger spill sizes because of the higher concentrations of the chemical vapours that could be encountered and the longer durations of exposure.
- Although mild and transient, the effects would still be annoying and discomforting, indicating the need for and importance of the spill prevention programs described in Volumes 7 and 8A of the Application. Planning and preparedness around emergency and spill response also are critical to ensure timely and adequate response to any spill events in order to limit opportunities for chemical exposures such that public health is not threatened or compromised, again highlighting the need for and importance of the emergency and spill response programs described in Volumes 7 and 8A.
- The absence of any serious adverse health effects from exposure to the chemical vapours released from the surface of the oil slick during the early stages of the spill scenarios applies to people in general, including the general public as well as first responders arriving on scene. However, because the first responders could remain on scene for some time while working to isolate, contain and recover the spilled oil, and could face the prospect of direct physical contact with the oil and/or more prolonged exposure to the vapours, it is important that they be trained in emergency and spill response procedures, be equipped with personal protective equipment, and be alert to potential exposure opportunities so as to minimize any exposures they might receive.

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APPENDIX A

FIGURES

LIST OF FIGURES

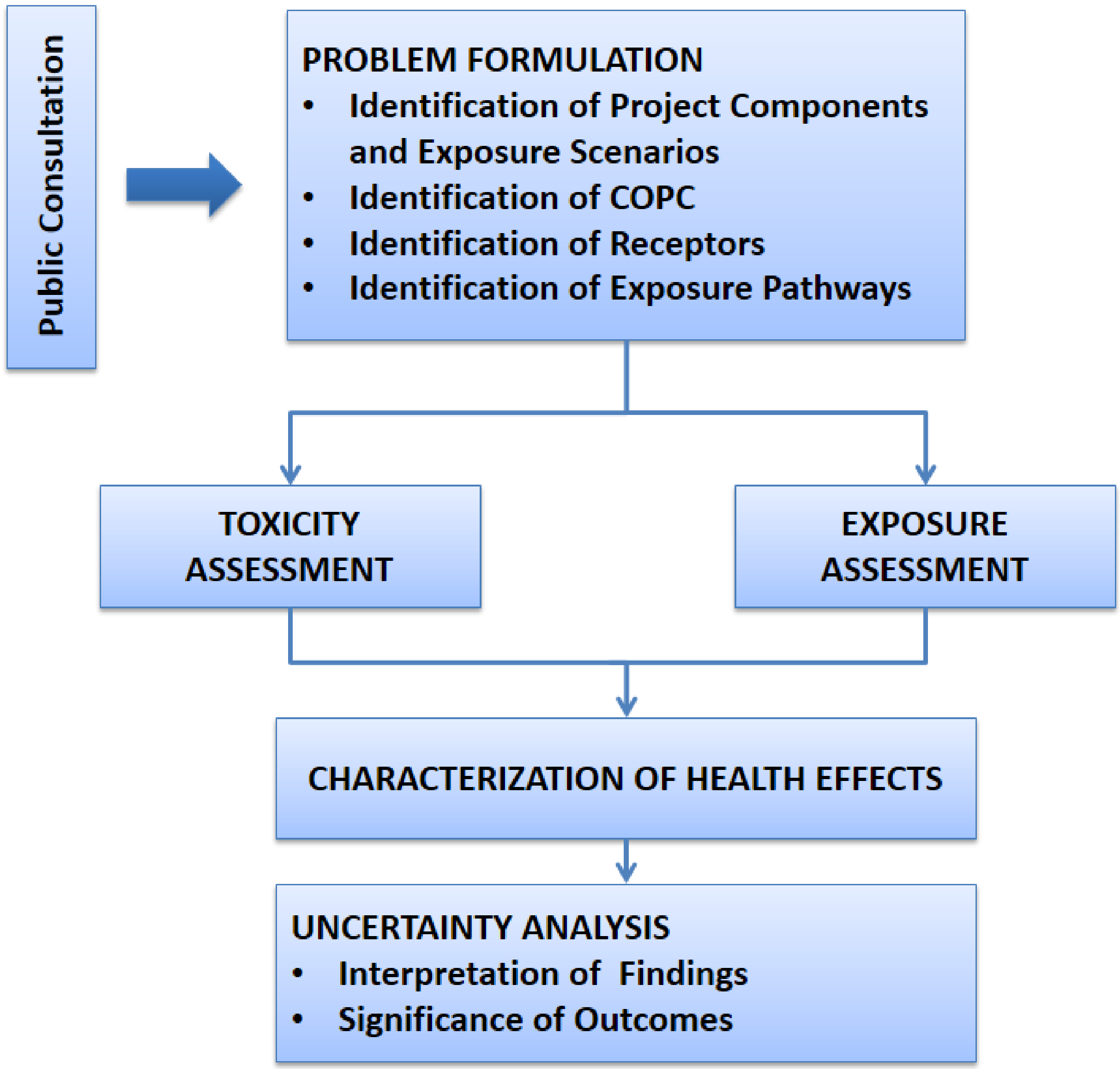
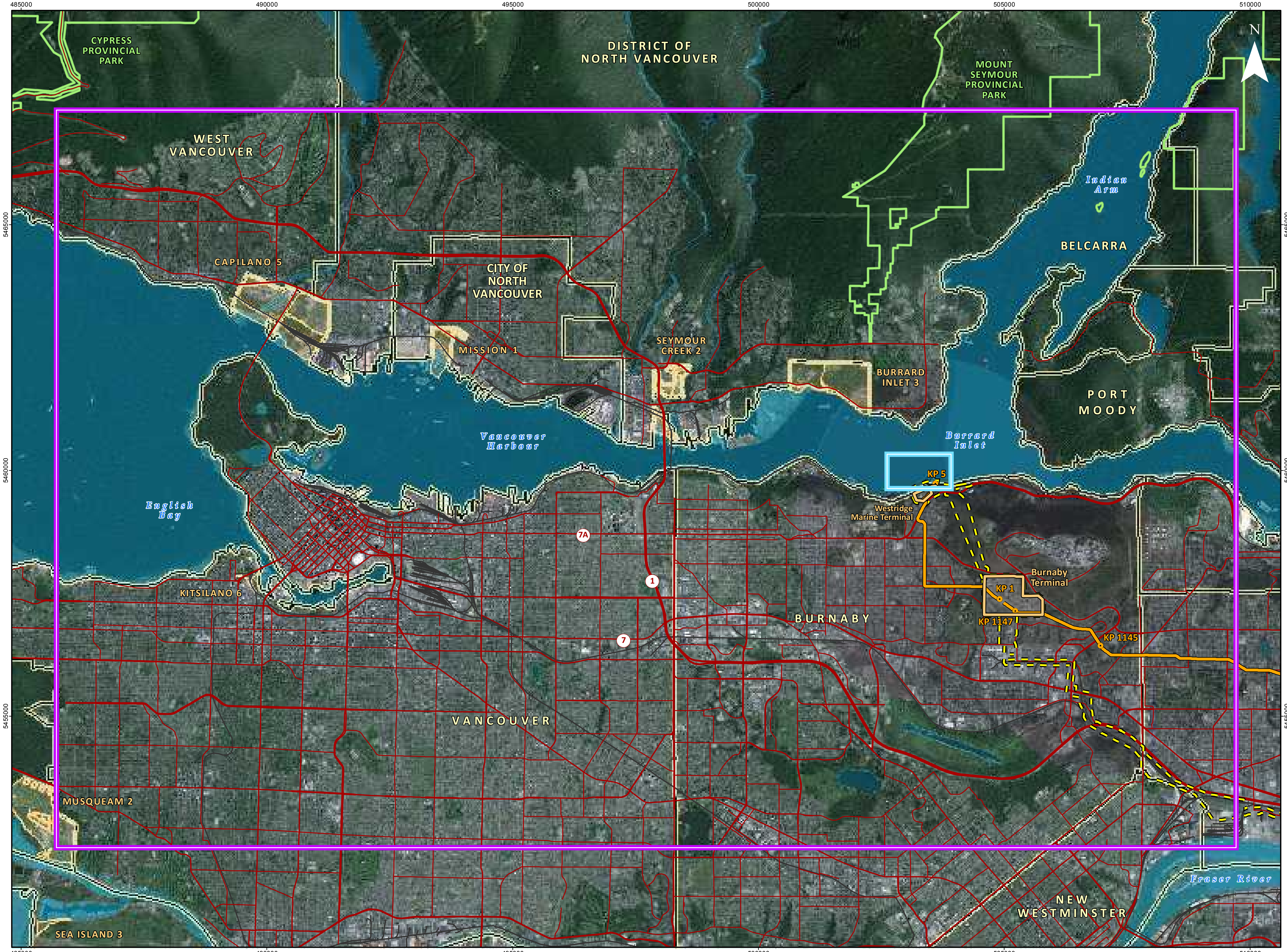


Figure 3.1 The Health Effects Assessment Paradigm



TRANS MOUNTAIN

FIGURE 4.1

HUMAN HEALTH
STUDY AREA BOUNDARIES

TRANS MOUNTAIN
EXPANSION PROJECT

- Kilometre Post (KP)
- Trans Mountain Pipeline (TMPL)
- Trans Mountain Expansion Project Proposed Pipeline Corridor
- Terminal Property Boundary
- Regional Study Area (RSA)
- Local Study Area (LSA)
- 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, 2012-2013; Proposed Pipeline Corridor V9: provided by UPI, Mar. 19, 2014; B/W & Colour Imagery: 2005-20112 provided by KMC, 2012-2013, 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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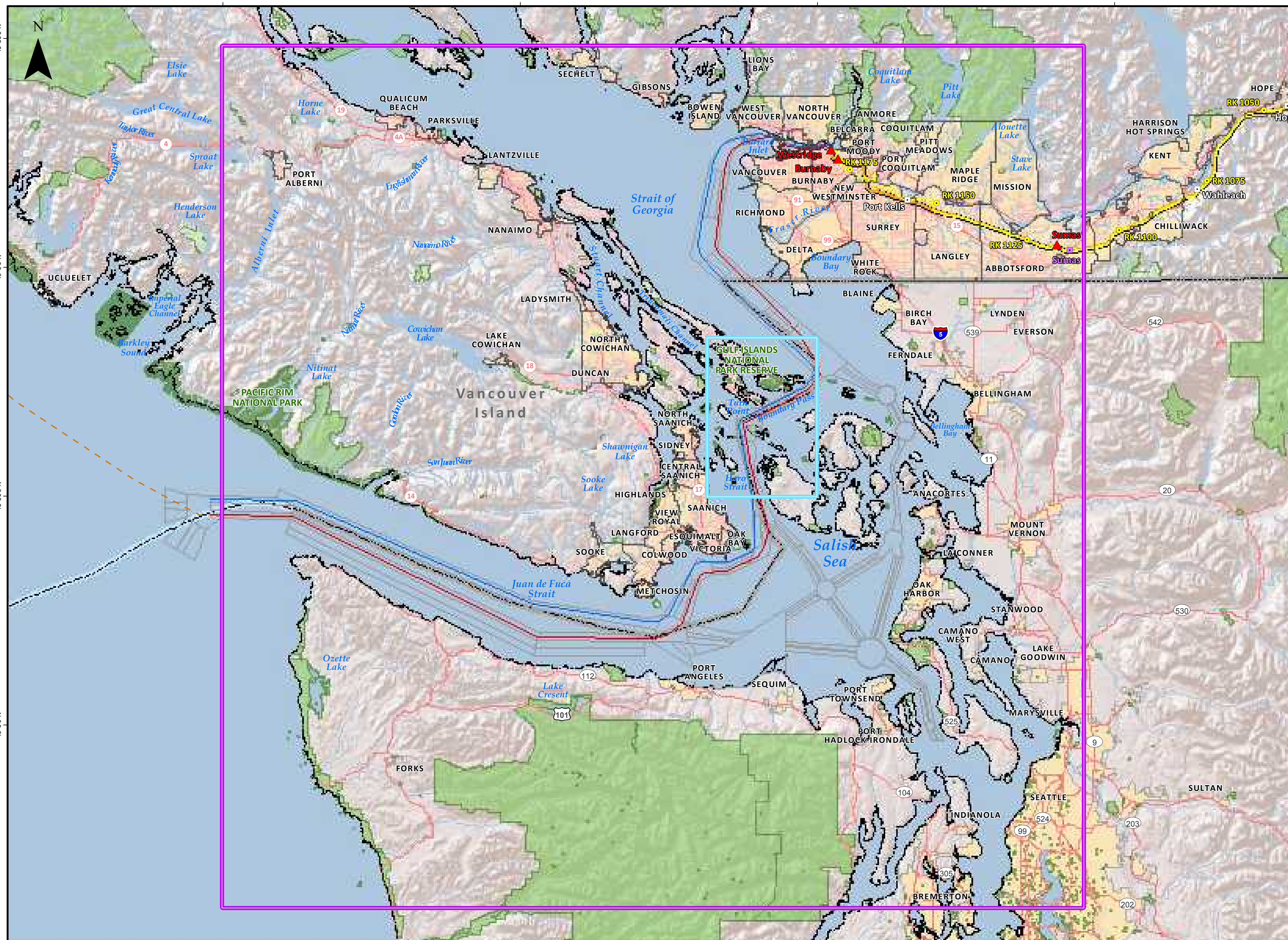

FIGURE 4.2

HUMAN HEALTH
STUDY AREA BOUNDARIES

TRANS MOUNTAIN
EXPANSION PROJECT

- Reference Kilometre Post (RK)
- Trans Mountain Pipeline (TMPL)
- Trans Mountain Expansion Project Proposed Pipeline Corridor
- Terminal
- Existing Pump Station
- Pump Station (Pump Additions, Station Modifications and/or Scraper Facilities)
- Highway
- Road
- 12 Nautical Mile Limit (Territorial Sea)
- Limit of Exclusive Economic Zone (EEZ)
- International Boundary
- Marine Vessel Outbound Shipping Lane
- Marine Vessel Inbound Shipping Lane
- Local Study Area (LSA)
- Regional Study Area (RSA)
- Traffic Separation Scheme
- City / Town / District Municipality
- Indian Reserve / Métis Settlement
- National Park
- Provincial / State Park
- Protected Area/Natural Area/ Provincial Recreation Area/Wilderness Provincial Park/Conservancy Area

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TRANS MOUNTAIN

FIGURE 5.1

WESTRIDGE MARINE TERMINAL - CREDIBLE WORST CASE SIMULATED SPILL SCENARIO - ALIPHATIC C_1-C_4 - VAPOUR CONCENTRATION CONTOURS (HEALTH EFFECTS ASSESSMENT)

TRANS MOUNTAIN EXPANSION PROJECT

- TMPL Kilometre Post (KP)
- Trans Mountain Pipeline (TMPL)
- Trans Mountain Expansion Project Proposed Pipeline Corridor
- Road
- Railway
- Terminal Property Boundary
- Local Study Area (LSA)
- City / Town / District Municipality
- Maximum Predicted Concentration

Predicted Air Concentration (µg/m³)

- 103 793.50 - 109 823.00
- 97 764.00 - 103 793.50
- 90 873.14 - 97 764.00
- 84 412.97 - 90 873.14
- 78 000.00 - 84 412.97

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ALL LOCATIONS APPROXIMATE

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TRANS MOUNTAIN

FIGURE 5.2

WESTRIDGE MARINE TERMINAL - CREDIBLE WORST CASE SIMULATED SPILL SCENARIO - ALIPHATIC C_5-C_8 - VAPOUR CONCENTRATION CONTOURS (HEALTH EFFECTS ASSESSMENT)

TRANS MOUNTAIN EXPANSION PROJECT

- TMPL Kilometre Post (KP)
- Trans Mountain Pipeline (TMPL)
- Trans Mountain Expansion Project Proposed Pipeline Corridor
- Road
- Railway
- Terminal Property Boundary
- Local Study Area (LSA)
- City / Town / District Municipality
- Maximum Predicted Concentration

Predicted Air Concentration (µg/m³)

- 1 202 896.75 - 1 452 300.00
- 953 493.51 - 1 202 896.75
- 704 090.26 - 953 493.51
- 454 687.02 - 704 090.26
- 200 000.00 - 454 687.02

Classified by using Natural Breaks (Jenks)

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ALL LOCATIONS APPROXIMATE

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TRANS MOUNTAIN

FIGURE 5.3

WESTRIDGE MARINE TERMINAL - CREDIBLE WORST CASE SIMULATED SPILL SCENARIO - AROMATIC C_9-C_{16} - VAPOUR CONCENTRATION CONTOURS (HEALTH EFFECTS ASSESSMENT)

TRANS MOUNTAIN EXPANSION PROJECT

- TMPL Kilometre Post (KP)
- Trans Mountain Pipeline (TMPL)
- Trans Mountain Expansion Project Proposed Pipeline Corridor
- Road
- Railway
- Terminal Property Boundary
- Local Study Area (LSA)
- City / Town / District Municipality
- Maximum Predicted Concentration

Predicted Air Concentration (µg/m³)

- 12 082.78 - 14 597.71
- 9 567.85 - 12 082.78
- 7 052.92 - 9 567.85
- 4 537.99 - 7 052.92
- 2 000.00 - 4 537.99

Classified by using Natural Breaks (Jenks)

Projection: NAD 1983 UTM Zone 10N. Routing: Baseline TMPL & Facilities: provided by KMC, 2012; Proposed Pipeline Corridor V9: provided by UPI, Mar. 12, 2014; Marine Air Modeling Data: Provided by RWDI Air Inc., Mar. 13, 2014; Colour Imagery: 2005-2012: provided by KMC, 2012-2013; Transportation: BC FLNRO, 2012, Natural Resources Canada, 2012; Geopolitical Boundaries: Natural Resources Canada 2003, IHS Inc., 2013; Hydrology: BC FLNRO, 2008.

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MAP NUMBER		PAGE
201402_MAP_TERA_HEA_00531_REV0_03		SHEET 1 OF 1
DATE: April 2014	TERA REF.: 7894	REVISION: 0
SCALE: 1:8,000	PAGE SIZE: 11x17	DISCIPLINE: HEA
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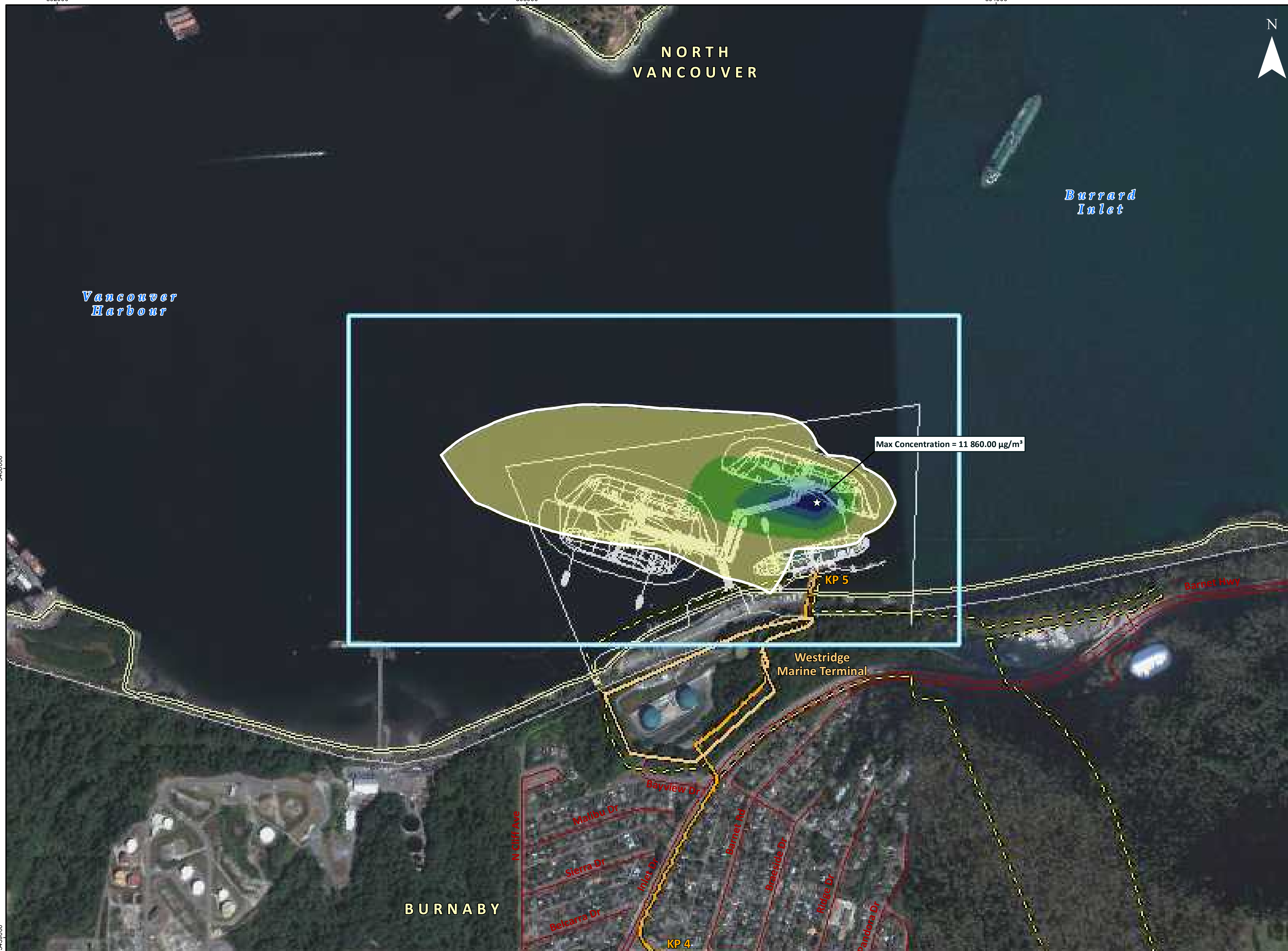

TRANS MOUNTAIN

FIGURE 5.4

WESTRIDGE MARINE TERMINAL - CREDIBLE WORST CASE SIMULATED SPILL SCENARIO - BENZENE - VAPOUR CONCENTRATION CONTOURS (HEALTH EFFECTS ASSESSMENT)

TRANS MOUNTAIN EXPANSION PROJECT

- TMPL Kilometre Post (KP)
- Trans Mountain Pipeline (TMPL)
- Trans Mountain Expansion Project Proposed Pipeline Corridor
- Road
- Railway
- Terminal Property Boundary
- Local Study Area (LSA)
- City / Town / District Municipality
- ☆ Maximum Predicted Concentration

Predicted Air Concentration (µg/m³)

- 9 610.64 - 11,860.00
- 7 361.28 - 9 610.64
- 5 111.92 - 7 361.28
- 2 862.56 - 5 111.92
- 580.00 - 2 862.56

Classified by using Natural Breaks (Jenks)

Projection: NAD 1983 UTM Zone 10N. Routing: Baseline TMPL & Facilities: provided by KMC, 2012; Proposed Pipeline Corridor V9: provided by UPI, Mar. 12, 2014; Marine Air Modeling Data: Provided by RWDI Air Inc., Mar. 13, 2014; Colour Imagery: 2005-2012: provided by KMC, 2012-2013; Transportation: BC FLNRO, 2012, Natural Resources Canada, 2012; Geopolitical Boundaries: Natural Resources Canada 2003, IHS Inc., 2013; Hydrology: 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.

MAP NUMBER		PAGE
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DATE: April 2014	TERA REF.: 7894	REVISION: 0
SCALE: 1:8,000	PAGE SIZE: 11x17	DISCIPLINE: HEA
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0 100 200 300 m

ALL LOCATIONS APPROXIMATE

201402_MAP_TERA_HEA_00531_Rev0_04.mxd

TRANS MOUNTAIN

FIGURE 5.5

WESTRIDGE MARINE TERMINAL - CREDIBLE WORST CASE SIMULATED SPILL SCENARIO - TOLUENE - VAPOUR CONCENTRATION CONTOURS (HEALTH EFFECTS ASSESSMENT)

TRANS MOUNTAIN EXPANSION PROJECT

- TMPL Kilometre Post (KP)
- Trans Mountain Pipeline (TMPL)
- Trans Mountain Expansion Project Proposed Pipeline Corridor
- Road
- Railway
- Terminal Property Boundary
- Local Study Area (LSA)
- City / Town / District Municipality
- Maximum Predicted Concentration

Predicted Air Concentration (µg/m³)

- 21 760.17 - 23 610.00
- 20 002.85 - 21 760.17
- 18 338.01 - 20 002.85
- 16 673.17 - 18 338.01
- 15 000.00 - 16 673.17

Classified by using Natural Breaks (Jenks)

Projection: NAD 1983 UTM Zone 10N. Routing: Baseline TMPL & Facilities: provided by KMC, 2012; Proposed Pipeline Corridor V9: provided by UPI, Mar. 12, 2014; Marine Air Modeling Data: Provided by RWDI Air Inc., Mar. 13, 2014; Colour Imagery: 2005-2012: provided by KMC, 2012-2013; Transportation: BC FLNRO, 2012, Natural Resources Canada, 2012; Geopolitical Boundaries: Natural Resources Canada 2003, IHS Inc., 2013; Hydrology: BC FLNRO, 2008.

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MAP NUMBER		PAGE
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DATE April 2014	TERA REF. 7894	REVISION 0
SCALE 1:8,000	PAGE SIZE 11x17	DISCIPLINE HEA
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ALL LOCATIONS APPROXIMATE

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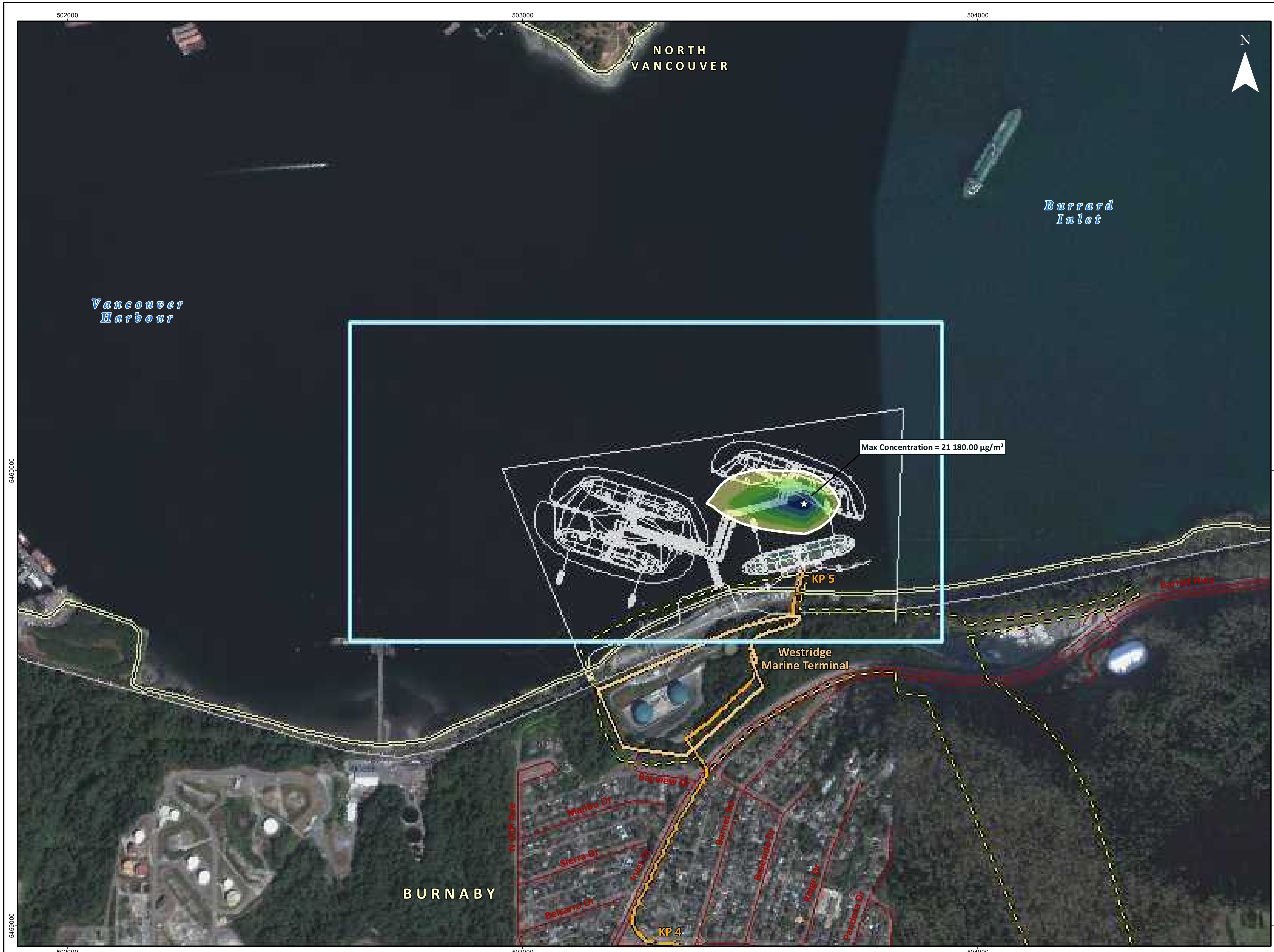

TRANS MOUNTAIN

FIGURE 5.6

WESTRIDGE MARINE TERMINAL - CREDIBLE WORST CASE SIMULATED SPILL SCENARIO - XYLENES - VAPOUR CONCENTRATION CONTOURS (HEALTH EFFECTS ASSESSMENT)

TRANS MOUNTAIN EXPANSION PROJECT

- TMPL Kilometre Post (KP)
- Trans Mountain Pipeline (TMPL)
- Trans Mountain Expansion Project Proposed Pipeline Corridor
- Road
- Railway
- Terminal Property Boundary
- Local Study Area (LSA)
- City / Town / District Municipality
- Maximum Predicted Concentration

Predicted Air Concentration (µg/m³)

- 18 607.88 - 21,180.00
- 15 952.79 - 18 607.88
- 12 965.81 - 15 952.79
- 9 978.83 - 12 965.81
- 7 400.00 - 9 978.83

Classified by using Natural Breaks (Jenks)

Projection: NAD 1983 UTM Zone 10N. Routing: Baseline TMPL & Facilities: provided by KMC, 2012; Proposed Pipeline Corridor V9: provided by UPI, Mar. 12, 2014; Marine Air Modeling Data: Provided by RWDI Air Inc., Mar. 13, 2014; Colour Imagery: 2005-2012: provided by KMC, 2012-2013; Transportation: BC FLNRO, 2012, Natural Resources Canada, 2012; Geopolitical Boundaries: Natural Resources Canada 2003, IHS Inc., 2013; Hydrology: BC FLNRO, 2008.

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MAP NUMBER		PAGE
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DATE: April 2014	TERA REF.: 7894	REVISION: 0
SCALE: 1:8,000	PAGE SIZE: 11x17	DISCIPLINE: HEA
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ALL LOCATIONS APPROXIMATE

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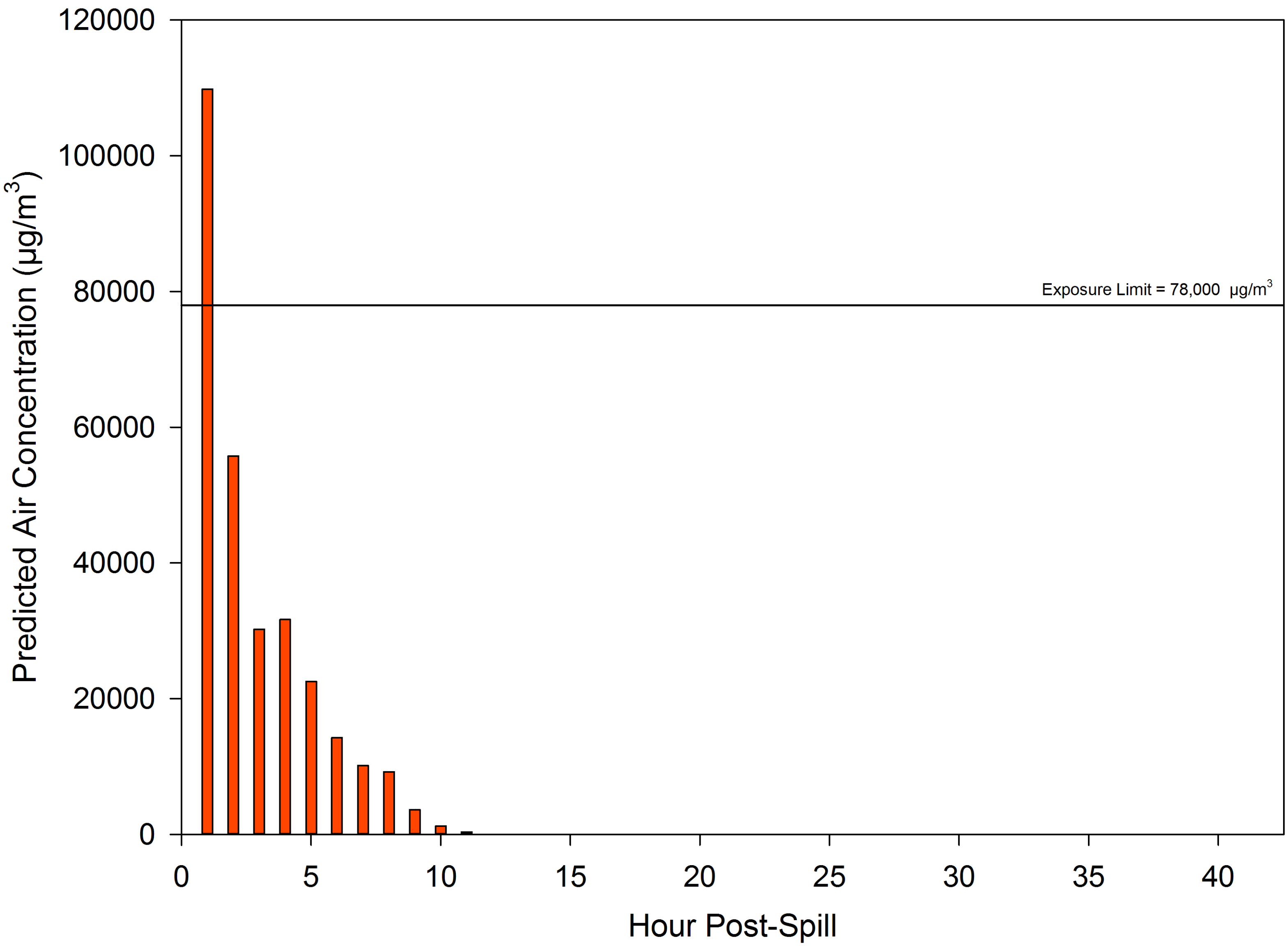

Figure 5.7 Westridge Marine Terminal - Credible Worst Case Simulated Spill Scenario - Aliphatic C_1-C_4 - Vapour Concentration-Time Plot

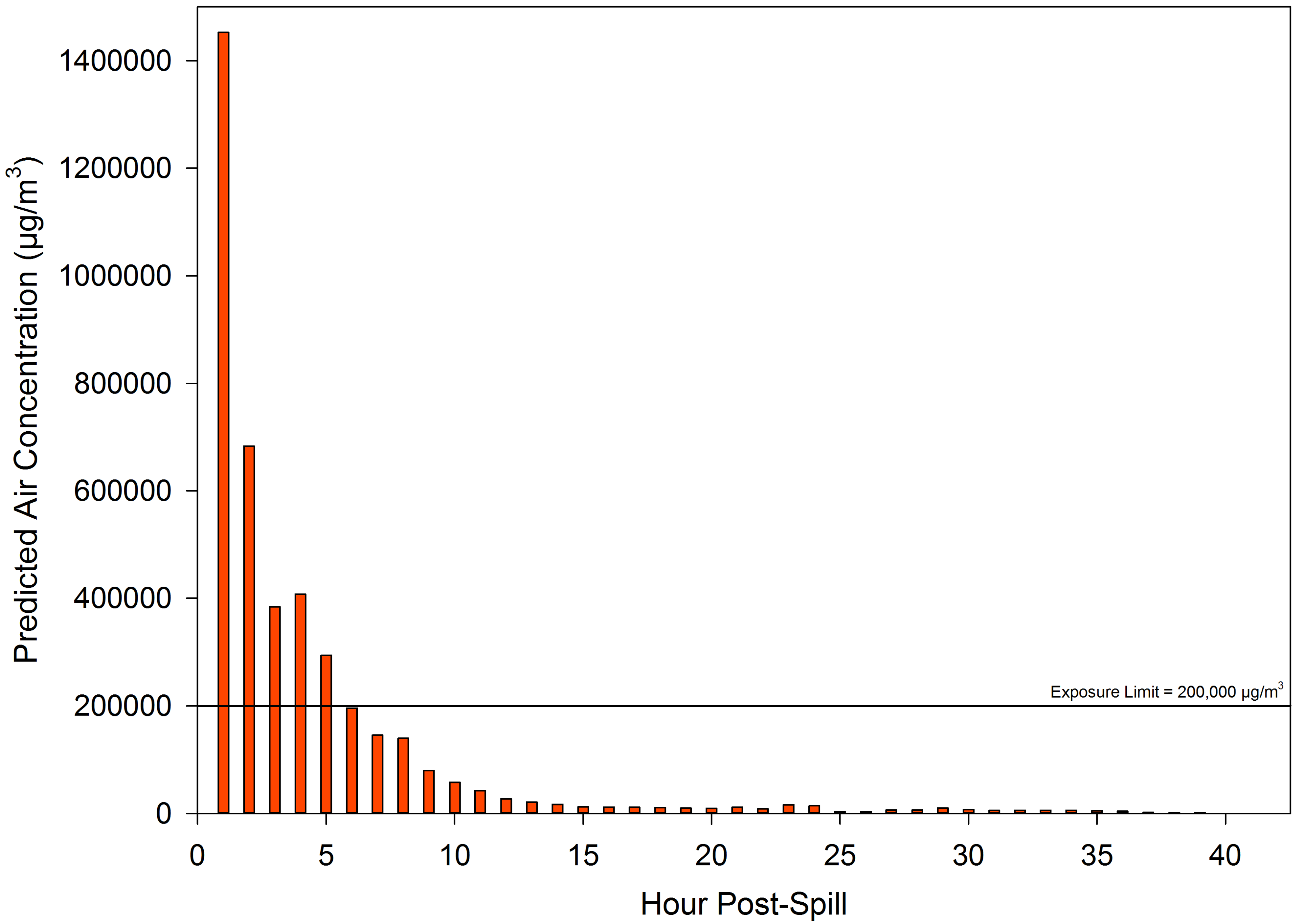

Figure 5.8 Westridge Marine Terminal - Credible Worst Case Simulated Spill Scenario - Aliphatic C_5-C_8 - Vapour Concentration-Time Plot

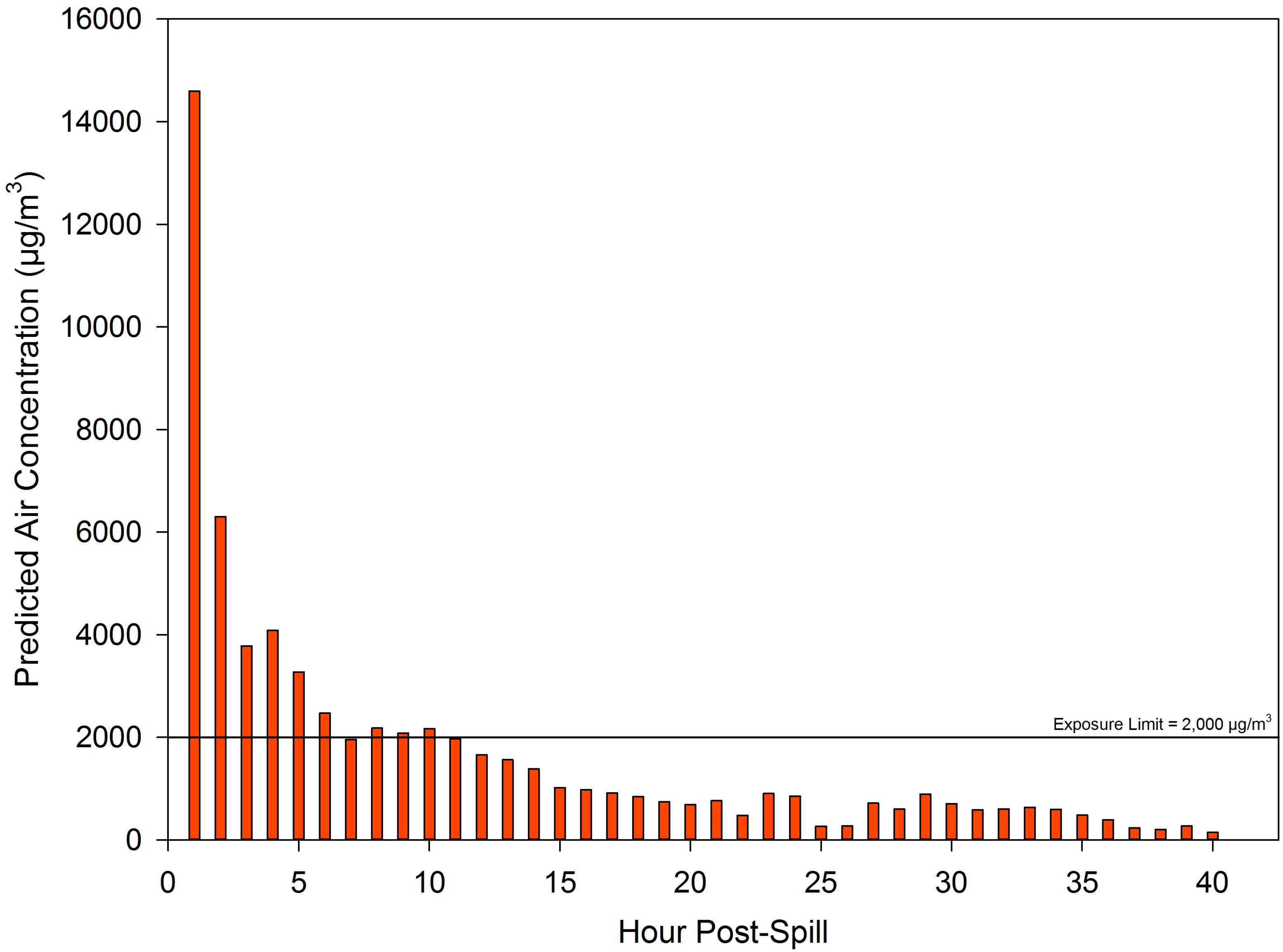

Figure 5.9 Westridge Marine Terminal - Credible Worst Case Simulated Spill Scenario - Aromatic C_9-C_{16} - Vapour Concentration-Time Plot

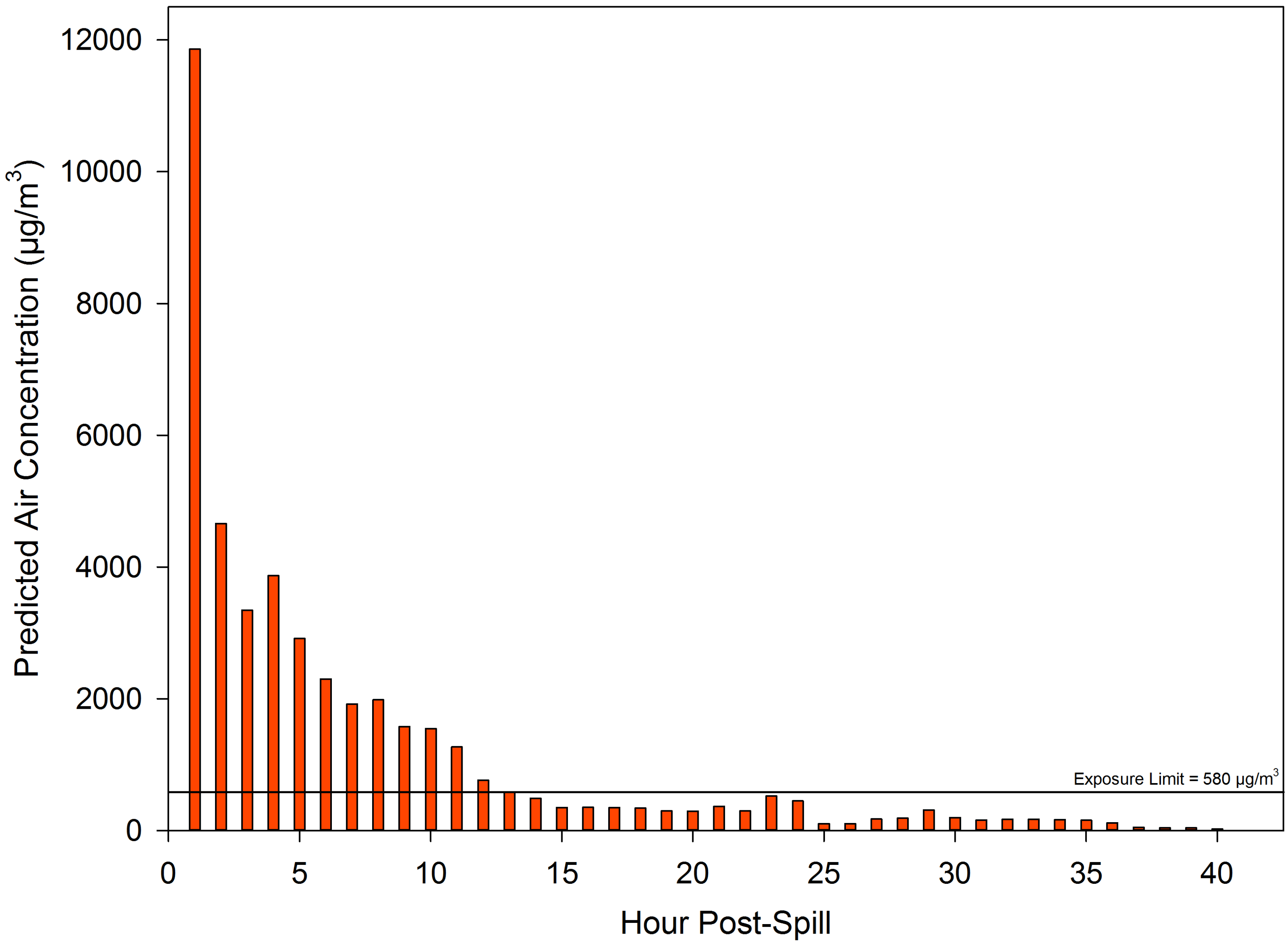

Figure 5.10 Westridge Marine Terminal - Credible Worst Case Simulated Spill Scenario - Benzene - Vapour Concentration-Time Plot

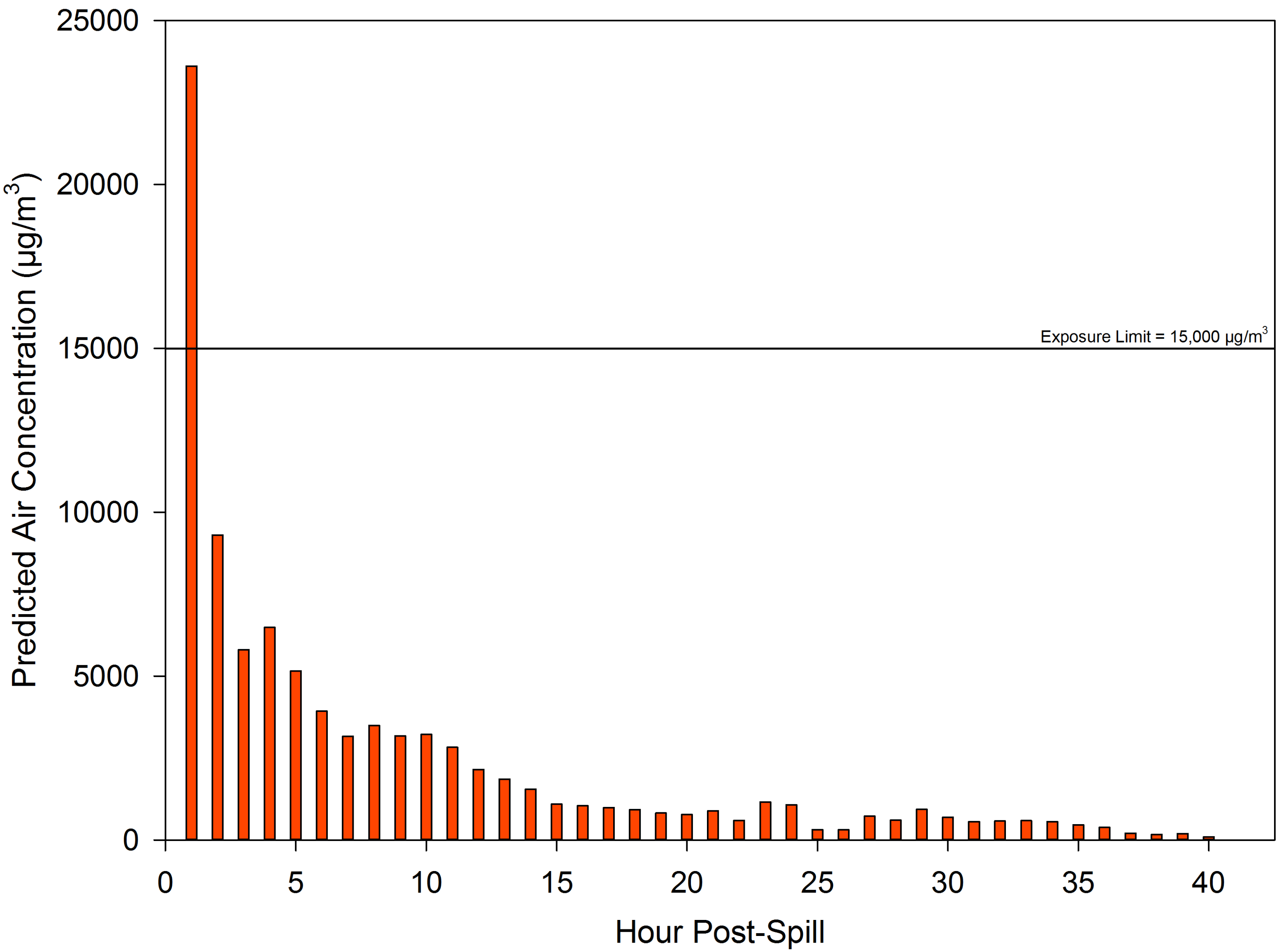

Figure 5.11 Westridge Marine Terminal - Credible Worst Case Simulated Spill Scenario - Toluene - Vapour Concentration-Time Plot

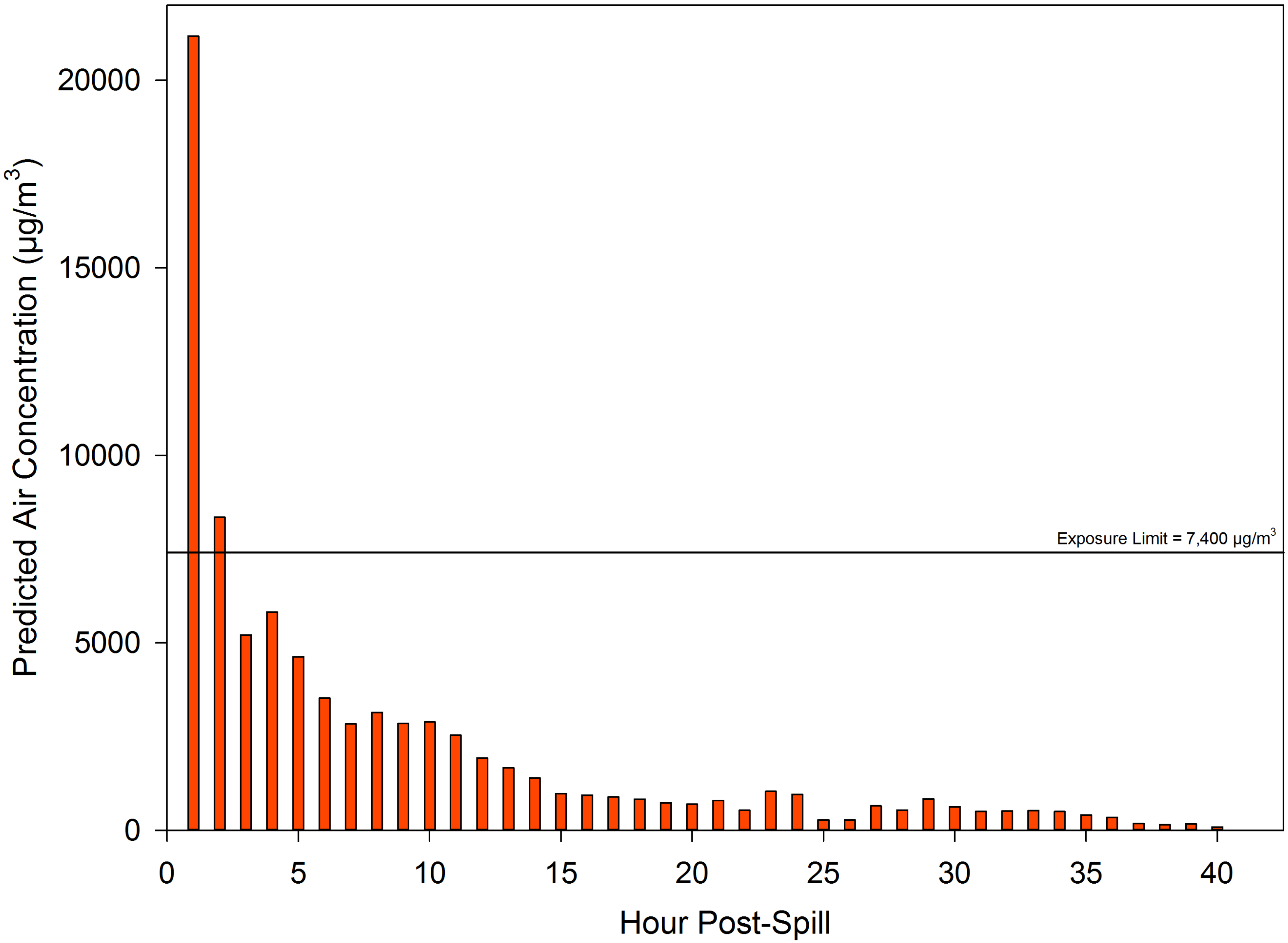

Figure 5.12 Westridge Marine Terminal - Credible Worst Case Simulated Spill Scenario - Xylenes - Vapour Concentration-Time Plot