Major Human Health Impacts of the Increase in Tanker Traffic Due to the Trans Mountain Pipeline Expansion

An Update to the 2015 Report Prepared for Burnaby Residents Opposing Kinder Morgan Expansion (BROKE) and North Shore NO Pipeline Expansion (NS NOPE)

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About this report

In 2015, the lead author of this report was contracted to conduct a review of the Kinder Morgan Trans Mountain Expansion Project (TMEP) and to prepare a report on the major impacts to human health in Greater Vancouver of the TMEP (Takaro *et al*., 2015). The primary purpose of that review was to:

1. determine the current standing of the Kinder Morgan Trans Mountain Expansion Project,
2. undertake an in-depth review of the major chemicals of concern and their health impacts
3. describe alternate and plausible case scenarios of oil spills and related health outcomes, and
4. provide recommendations to address any identified areas of concern.

The report was filed in 2015 with the National Energy Board of Canada (NEB) by the North Shore NO Pipeline Expansion (NS NOPE) and Burnaby Residents Opposing Kinder Morgan Expansion (BROKE) as part of the public comment process on the expansion application[1].

In May 2016, the NEB released a report that described the environmental assessment it had completed on the TMEP in accordance with its authority under the *National Energy Board Act* and the *Canadian Environmental Assessment Act, 2012 (CEAA, 2012)*. Based on its review, the NEB recommended that the Governor in Council approve the project (National Energy Board, May 2016). On August 30, 2018, the Federal Court of Appeal overturned the Canadian government's approval of the TMEP and ordered that a new review of the project be conducted that takes into consideration the potential impacts of increased tanker traffic as required under the *CEAA, 2012* (Federal Court of Appeal Decisions, 2018). On September 20, 2018, the Government of Canada referred aspects of the NEB's 2016 recommendation report back to the NEB for reconsideration. The NEB released a public hearing order on October 12, 2018 that sets out the steps and deadlines in the hearing for the reconsideration (National Energy Board, 2018).

The NEB did not respond to evidence we presented in our May 2015 report. However, the evidence of health risks presented are of significant interest to populations potentially impacted by the proposed increases in tanker traffic in Burrard Inlet. In this report, we have reiterated the evidence related to this increase in tanker traffic and added new evidence that has emerged since our 2015 filing.

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[1] The title of the report was "Major Human Health Impacts of the Kinder Morgan Trans Mountain Pipeline Expansion" (May 2015). Filing reference number: A4L9Q9, A4L9R0, A4L9R1.

Executive summary

This report, which was prepared in response to the Federal Court of Appeal decision to revoke the construction approval given by the Cabinet to the Trans Mountain pipeline expansion project, builds on our 2015 report, *Major Human Health Impacts of the Kinder Morgan Trans Mountain Pipeline Expansion*. That report was filed with the National Energy Board (NEB) as part of the public comment process on the expansion project (Filing reference number: A4L9Q9, A4L9R0, A4L9R1). As the NEB did not respond to evidence we presented in our May 2015 report, we have prepared an updated report that reiterates the evidence we presented and adds new evidence that has emerged since our 2015 filing. This project was supported by Burnaby Residents Opposing Kinder Morgan Expansion (BROKE) and North Shore NO Pipeline Expansion (NS NOPE).

In undertaking this review, we employed several key frameworks and theories (a population health framework, risk assessment and future climate projections) to assess the potential impact of the increase in tanker traffic, spill risk and subsequent impacts on human health. As the analysis contained in this report demonstrates, there are significant shortcomings in the evidence base on health impacts that the NEB used and there is a need for an independent comprehensive, cumulative human health impacts assessment. In this report, we focus on the acute and chronic health effects of exposure to two of the most potent chemical toxicants found in crude oil and diluted bitumen (benzene and benzo[a]pyrene) and on the community-level mental health impacts of a major disaster in Burrard Inlet – outcomes that were inadequately accounted for by the TMEP human health risk assessment. We also describe the potential impact of two plausible worst-case scenarios of the TMEP – during extreme weather conditions and following a Second Narrows marine spill. Both scenarios would have detrimental effects on the residential population within the potentially affected areas.

There were five key weaknesses of the human health risks assessment (HHRA) performed by the proponent's contractor and used by the NEB in its May 2016 Recommendation Report:

1. The impact of **increased tanker traffic** and subsequent increased risk to the environment and to the population that lives in Burrard Inlet was not assessed.
2. The HHRA did not adequately consider the **high risk to specific vulnerable populations**[2] from benzene and benzo[a]pyrene.
3. The conditions considered by the NEB that related to health pertain only to monitoring, an after-the-fact **"count-the-bodies" approach** that is unacceptable today.
4. Certain **outcomes** (i.e., risk of childhood leukaemia and lung cancer in clean-up workers) were **inadequately accounted for** by the TMEP human health risk assessment.
5. **Mental health impacts** were not assessed for the populations likely to be affected by a large spill in Burrard Inlet.

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[2] Includes those with genetic susceptibility to these carcinogens.

A comprehensive, cumulative health impacts assessment (HIA) of the TMEP must include the **combined effects of all toxicants** released from the complex petroleum mixture that is dilbit and their cumulative and possibly synergistic effects. As this report points out, benzene and benzo[a]pyrene are carcinogens with no safe exposure levels. Highly sensitive populations would likely be exposed in the event of a spill in Burrard Inlet, reinforcing the need for a comprehensive, cumulative health impacts assessment.

The **increase in tanker traffic** appears to be significantly greater than the seven-fold increase described by the proponent. Based upon the average number per year during the period 2015 to 2017, the increase is closer to twenty-fold. Burrard Inlet (through which these tankers must pass) contains three bridges and two dangerous narrows adjacent to downtown with over a million people, as well as an informal but easily accessed shellfish and crab fishery and Indigenous communities who harvest from the Inlet and whose close connection to the land makes them particularly vulnerable to environmental contamination.

In our opinion, the **marine spill scenario** in the original NEB review was very optimistic. It was set far away from any population center despite the clear hazards of the increase in tankers through Vancouver’s busy harbor. Based upon similar accidents around the world, a major tanker spill (i.e., an Aframax tanker with an average capacity of 750,000 barrels) in Burrard Inlet would likely result in widespread exposure and cause **significant acute and chronic health effects**. An independent, comprehensive, cumulative health impacts assessment should be bounded by a **worst-case spill scenario** that occurs on a hot day with stagnant conditions similar to week long periods in Burrard Inlet in the summers of 2017 and 2018. It should include the temperature increase projected for the Inlet which have been modeled for Burrard Inlet.

Under the *Canadian Environmental Assessment Act, 2012*, the Government of Canada has a mandate to protect the environment and human health and to apply the precautionary principle. To fulfill this mandate, any risk assessment of a fossil energy project must consider the **upstream and downstream contribution to mortality and morbidity** due to climate change of wildfires, heat events, air pollution, sea-level rise, flooding, water contamination, drought, food shortages, shifting infectious diseases, illness and injury from extreme weather events, mental health impacts, forced migration and related conflict, as well as the risks that climate change poses to healthcare structures and health-related supply chains. Therefore, we request that a robust, cumulative health impact assessment be conducted that takes into consideration the populations of the Inlet, as well as potential exposures and impacts resulting from the higher temperatures and extreme weather conditions predicted for the Inlet by mid-century due to climate change.

Introduction

This document, which was prepared in response to the Federal Court of Appeal decision to revoke the construction approval given by the Cabinet to the Trans Mountain pipeline expansion project, was supported by Burnaby Residents Opposing Kinder Morgan Expansion (BROKE) and North Shore NO Pipeline Expansion (NS NOPE). Both the City of Burnaby and communities along the North Shore will be directly affected by the increase in tanker traffic, spill risk and subsequent impacts.

The purpose of this report is twofold: (1) to demonstrate that the National Energy Board (NEB) recommendation report of May 19, 2016 does not adequately consider nor address the health impacts due to the 7-fold increase in tanker traffic through the First and Second Narrows and past the cities of Burnaby, Vancouver and North Vancouver; and, (2) to request that a robust, cumulative health impact assessment (HIA) be conducted as part of the consideration of the risk from increased tanker traffic. Under the *Canadian Environmental Assessment Act, 2012* (*CEAA, 2012*), the Government of Canada and those responsible for administering the *Act* must "exercise their powers in a manner that protects the environment and human health and applies the precautionary principle." To fulfill this mandate, an independent, comprehensive and cumulative health impacts assessment of a large or credible worst-case spill in this high-risk area must be part of any consideration of the proposed expansion.

The NEB's rationale for dismissing a spill scenario in Burrard Inlet runs counter to the requirement under the *CEAA, 2012* that the precautionary principle be exercised. Diluted bitumen (dilbit), the material of most concern in a transportation accident, is dangerous and considerably more toxic than crude oil. It behaves unpredictably in aquatic environments, sometimes floating, sometimes sinking, depending upon conditions. The marine spill scenario in the original NEB review was very optimistic. It was set far away from any population centre despite the clear hazards of the 7-fold increase in tankers through Vancouver's busy harbor. The Burrard Inlet through which these tankers must pass contains three bridges and two dangerous narrows adjacent to downtown with over a million people, as well as an informal but easily accessed shellfish and crab fishery and population which includes Indigenous communities who harvest from the Inlet and whose close connection to the land makes them particularly vulnerable to environmental contamination.

While efforts to reduce boat collisions in Vancouver Harbour are ongoing, collisions do occur (including those involving the critical bridges that cross the Inlet). The Pacific Pilotage Authority reports 10 incidents involving their members since the NEB 2014 report (A95234-1, 2018-10-29). This number does not include any incidents in 2018 or non-piloted incidents, such as the Nathan E Stewart sinking (October 2016) or the English Bay spill (April 2015). As we describe in this report, a major spill in the Inlet would be catastrophic for the region. The spill risk estimated by the Tsleil Waututh Nation in their submission to the NEB in 2015 describes the likelihood of a large spill (>1,000 barrels) at 37% in Burrard Inlet (TWN, 2016 p. 66). A large spill, releasing dilbit from an Afromax tanker, would present a high risk of fire, toxic contamination, cultural disruption and a prolonged clean-up with significant physical and mental health implications for workers and the many communities living on the Inlet. Even best-case scenario clean-up of crude oil results in only 5-15% oil recovery, with spilled bitumen likely to have even lower levels of recovery due its tendency to sink after floating under certain conditions. Those responsible for protecting the public health need to factor in the health impacts of a large or credible worst-case spill in the most populated area affected by the project. This scenario should be of a large volume tanker spill, close to shore and under poor air quality and under high temperature conditions similar to those of the past several summers in British Columbia.

The following are five key weaknesses of the NEB's human health risk assessment (HHRA):

1. The impact of increased tanker traffic and subsequent increased risk to the environment and to the population that lives in Burrard Inlet was not assessed.
2. The HHRA did not adequately consider the high risk to specific vulnerable populations[3] from benzene and benzo[a]pyrene.
3. The conditions considered by the NEB that related to health pertain only to monitoring, an after-the-fact "count-the-bodies" approach that is unacceptable today.
4. Certain outcomes (i.e., risk of childhood leukaemia and lung cancer in clean-up workers) were inadequately accounted for by the TMEP human health risk assessment.
5. Mental health impacts were not assessed for the populations likely to be affected by a large spill in Burrard Inlet.

Although these points were raised by Intervenors in the NEB process, none were addressed by the response or by the conditions imposed – and, there were no subsequent revisions to the project's health risk assessment. The NEB did not respond to evidence we presented in our May 2015 report. However, the evidence of health risks presented are of significant interest to populations potentially impacted by the proposed increases in tanker traffic in Burrard Inlet. We have reiterated the evidence related to this increase in tanker traffic and added new evidence that has emerged since our 2015 filing. Our analysis demonstrates the significant shortcomings of the evidence base on health impacts that the NEB used and points out the need for an independent comprehensive, cumulative human health impacts assessment.

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[3] Includes those with genetic susceptibility to these carcinogens.

Methods & organization of this report

The principal author and contributors first conducted a comprehensive search for relevant literature available in the public domain. They then employed several key frameworks and theories (a population health framework, risk assessment and future climate projections) to assess the potential impact of the increase in tanker traffic, spill risk and subsequent impacts on human health. As noted in *Major Human Health Impacts of the Kinder Morgan Trans Mountain Pipeline Expansion (May 2015)*, a population health framework is foundational to health promotion and protection. It is used to examine the complex interactions and linkages between the social, physical, economic and political factors that affect health, as well as the biological factors that contribute to health and illness. Risk assessment is a quantitative framework for identifying and evaluating levels of risk that are associated with adverse events or hazards (Frumkin, 2010). In undertaking this review, the author sought to answer three questions: What can happen with increased tanker traffic? How likely is it to happen? What are the consequences if it does happen?

To manage the scope of the review, we have chosen to focus on the acute and chronic health effects of exposure to two of the most potent chemical toxicants found in crude oil and diluted bitumen (benzene and benzo[a]pyrene) and on the community-level mental health impacts of a major disaster in Burrard Inlet. Both chemicals have long been known as harmful to human health and are recognized by the International Agency for Research on Cancer as known human carcinogens. Further, as described elsewhere in this report, there is clear evidence connecting adverse health outcomes with exposure to these chemicals, particularly in vulnerable populations. Of particular concern is the risk of childhood leukaemia and lung cancer in clean-up workers. These outcomes are all inadequately accounted for by the TMEP human health risk assessment.

The report also addresses other health impacts that would have large attributable risk to the populations who live in the regions around the tanker route and describes the potential impact of two plausible worst-case scenarios of the TMEP: during extreme weather conditions and following a Second Narrows marine spill. Both scenarios would have detrimental effects on the residential population within the potentially affected areas including impacts on health, quality of life, real estate values, fire hazard, economic impacts, environmental impacts and more.

Background & context

What is a comprehensive, cumulative health impacts assessment (HIA)?

A human health impact assessment (HIA) qualitatively and quantitatively assesses the health consequences which may result from specific policy actions or development projects. These include the health consequences to a human population of any public or private actions that alter “the extent to which an individual or group is able, on the one hand, to realize aspirations and to satisfy needs, and on the other, to change or cope with the environment (World Health Organization, 1984). Health impacts include any changes to the determinants of health (Rattle & Kwiatkowski, 1999). Comprehensive HIAs not only include an assessment of the impact of a project on the social determinants of health (such as housing, income, etc.) but also the ecological determinants of health (i.e., greenhouse gas emissions). Such an assessment allows health authorities to recognize and consider potential positive and negative health impacts of projects on their communities, to plan and fund healthcare provision services to address those impacts, and, to suggest modifications to plans in order to mitigate negative health impacts.

A comprehensive, cumulative HIA requires the following minimal components:

1. positions democracy, ethical use of evidence, a holistic approach to health, sustainable development and equity as key pillars;
2. incorporates a determinants of health approach as central features of an environmental assessment (EA) within an ecosystem health framework and includes consideration of greenhouse gas emissions;
3. integrates a highly empowering participatory process;
4. supports and advances existing best practices, includes the assessment of cumulative and multi-generational impacts, and provides a consistent yet flexible process and set of guidelines;
5. recognizes the value and importance of a diversity and different forms of information and knowledge;
6. maintains transparency, accountability and effective and accountable follow-up (including timelines, detailed plans, responsible actors and enforcement mechanisms);
7. is adequately developed with the engagement of key players, experts, and other stakeholders including Indigenous communities and provides for an adaptable set of guidelines.

What populations need to be considered in a comprehensive, cumulative HIA?

When examining the potential health impacts of the TMEP and a possible marine spill of crude or diluted bitumen, it is important to consider populations that are more vulnerable to the risk of exposure. Vulnerable populations[4] can include those who are homeless, those with chronic health conditions (including severe mental illness), economically disadvantaged, racial and ethnic minorities, low-income families, the elderly, those who live in remote communities or who have difficulty accessing certain services and those with genetic susceptibility as described later in this report (AMJC, 2006). Although it is important to note that individuals in all age groups could be affected by the pipeline expansion project, there are a few groups in particular that are at greater risk – namely, children, women of childbearing age, and older adults. The

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[4] The Government of Canada is currently undertaking a consultation on a proposed definition on vulnerable populations within the context of chemicals management. Information on the proposed definition is provided in Appendix 1: The Government of Canada’s proposed definition of vulnerable populations.

needs of these populations are specific and exposure to environmental contaminants can be more debilitating or detrimental to the health of these groups.

Children

Children have a particular physiological vulnerability to air pollution due to their immature organs, narrower airways, developing lungs and respiratory system, behaviour and lack of knowledge (Natural Resources Defense Council (NRCD), 1997; Health Canada, 2011). Children are often more active than adults and have greater respiratory rates due to their smaller size. They are more likely to engage in hand-to-mouth activity and as a result, irritation caused by pollutants or environmental contaminants that may only produce minor responses in adults can result in potentially more significant exposure in children. Children are also at higher risk than adults for acute myeloid leukaemia (AML), a health outcome ignored in the NEB's 2015 review.

Women of childbearing age

Environmental contaminants can have significant health consequences for women of childbearing age, and, in particular, expectant mothers. The foetus can be exposed to a number of chemical contaminants that enter through the placenta, causing developmental abnormalities, including to the central nervous system whose development is particularly sensitive (Health Canada, 2011). Depending on which stage of the pregnancy exposure occurs at, there can be detrimental health and developmental impacts for both the mother and neonate (Health Canada, 2011). This is addressed in further detail in the section on benzo[a]pyrene (page 12 of this report).

Older adults

Older adults are more likely to suffer from comorbidities (i.e., having one or more chronic conditions) making them more susceptible to environmental hazards. Even those in good overall health are more vulnerable than the average population (Health Canada, 2011). According to Health Canada, their bodies also contain a "lifetime worth of environmental contaminants, many of which can remain in their systems for decades". This higher "body burden" of environmental contaminants, potential cumulative effects, and general susceptibility to disease puts older adults at increased risk to hazards in the environment.

What are the main contaminants that a comprehensive, cumulative HIA should consider?

This section of the report expands on the 2015 report to: provide additional information on the properties of dilbit that should be factored into a comprehensive risk assessment; provide updated evidence on the health effects of benzene exposure; and, introduce new information on benzo[a]pyrene, another volatile organic compound that is present in crude oil and that is known to be a potent carcinogen and mutagen.

Benzene and 1,3-butadiene

Section 3.3 of our report *Major Human Health Impacts of the Kinder Morgan Trans Mountain Pipeline Expansion (May 2015)* (pages 15 to 20) describes the chemical composition, sources of exposure, and human exposure pathways of benzene and 1,3-butadiene, two volatile organic compounds found in crude oil and dilbit. Section 4 (pages 20 to 25) and Section 10.1 (pages 59 to 68) of the 2015 report outline the health effects associated with exposure to benzene and 1,3-butadiene. This section briefly reiterates the health effects associated with benzene exposure, with emphasis on evidence published since 2015.

Benzene

Benzene can enter the human body by three pathways: inhalation, ingestion and absorption through the skin. Approximately 50% of the human exposure route for benzene is passed through the lungs and a very small amount is absorbed through the skin (Agency for Toxic Substances and Disease Registry, 1989). Exposure to benzene can lead to number of health effects depending upon the route of exposure, the amount and the duration of exposure time, as well as the age of the individual exposed and whether or not there are pre-existing medical conditions. Acute exposure to benzene can cause dizziness, drowsiness, rapid/irregular heartbeat, loss of consciousness, tremors, convulsions, and death. Benzene is also highly flammable. The following table reprinted from Health Canada's 2018 document, *Guidance for the Environmental Public Health Management of Crude Oil Incidents: A guide Intended for Public Health and Emergency Management Practitioners* (Health Canada, 2018) is instructive on the importance of the hazard.

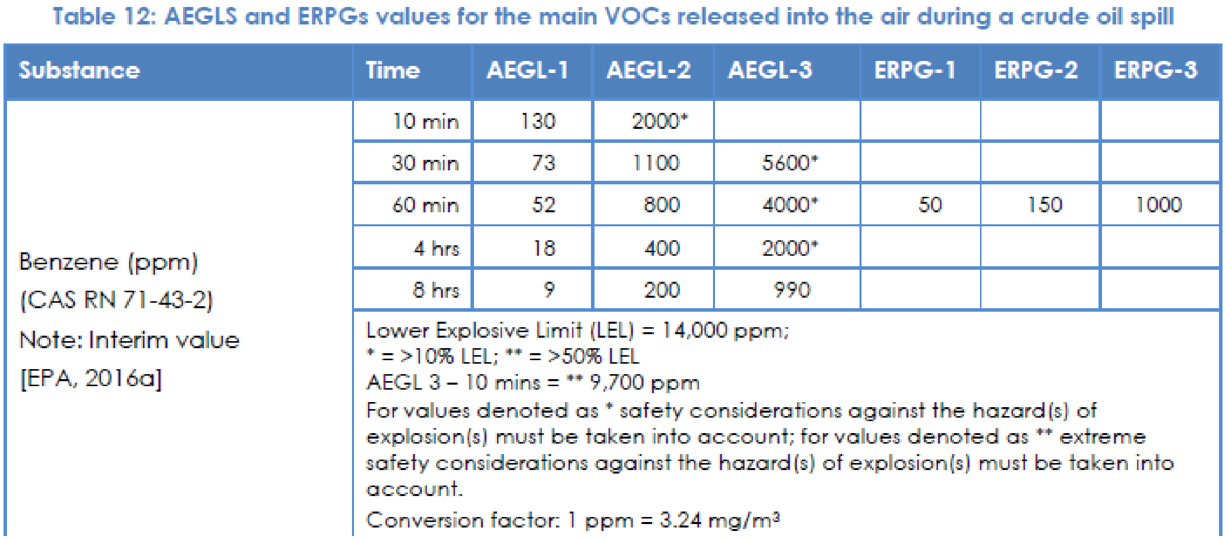

Table 12: AEGLS and ERPGs values for the main VOCs released into the air during a crude oil spill

Substance	Time	AEGL-1	AEGL-2	AEGL-3	ERPG-1	ERPG-2	ERPG-3
Benzene (ppm) (CAS RN 71-43-2) Note: Interim value [EPA, 2016a]	10 min	130	2000*				
	30 min	73	1100	5600*			
	60 min	52	800	4000*	50	150	1000
	4 hrs	18	400	2000*			
	8 hrs	9	200	990			
	Lower Explosive Limit (LEL) = 14,000 ppm; * = >10% LEL; ** = >50% LEL AEGL 3 – 10 mins = ** 9,700 ppm For values denoted as * safety considerations against the hazard(s) of explosion(s) must be taken into account; for values denoted as ** extreme safety considerations against the hazard(s) of explosion(s) must be taken into account. Conversion factor: 1 ppm = 3.24 mg/m³						

An AEGL-2 is the concentration above which the general population (not only susceptible individuals) could experience irreversible or other serious, long lasting adverse health effects. A population of Vancouver exposed for eight hrs above 200 ppm is a plausible scenario that demands examination in a comprehensive health impacts assessment.

Chronic exposure to low levels of benzene can cause destruction of the red blood cells (aka haematotoxicity), toxicity to the immune system (aka immunotoxicity), and the formation of tumours (aka neoplasia). Benzene and the BTEX[5] family of chemicals have also been linked to developmental and reproductive issues (Webb et al., 2014). These include: low sperm counts and sperm abnormalities; and, neurological, psychological, and behavioural abnormalities and neural tube defects in infants as a result of maternal exposure.

The chronic condition of most concern in relation to the TMEP is acute myeloid leukaemia (AML). AML is a type of cancer, which affects the blood stem cells in bone marrow. AML is the most common childhood cancer and is the leading cause of death from cancer in children. However, its incidence rate also increases with age and, as a result, more adults die of this disease than children (Jemal *et al*, 2002). An example of benzene's ability to cause leukaemia comes from a study of people living in close proximity to a gas station (a prime source of benzene) showing association with childhood leukaemia (Brosselin *et al*, 2009). Positive associations with exposure to benzene were also observed for chronic myeloid leukaemia and for lung cancer in several studies (Loomis, 2017).

Epidemiological studies have shown that there is an association between prenatal exposure to benzene and the development of childhood hematopoietic[6] cancers such as leukaemia. Benzene has been observed in foetal cord blood with levels similar to or higher than levels found in the maternal blood. The implication of this is that benzene can cross the placental barrier during pregnancy and can be transported from mother's blood to foetal blood (Dowty *et al*, 1976). This placental transfer has also been shown in studies of mice exposed to various levels of radiolabeled benzene (0, 5, 10, 20 ppm benzene from day 6 to day 15 during gestation). All concentrations of benzene caused changes in red blood forming cells. The study observed a number of changes in both the red- and white-blood forming cells following exposure in utero and again in adulthood. The authors concluded that, at the current occupational exposure limit, in utero exposure to benzene causes changes in the hematopoietic system of mice. These changes could persist into adulthood leading to an increased risk of leukaemia (Keller & Snyder, 1986).

Maternal exposure to solvents such as benzene has been associated with neurological, psychological, and behavioural abnormalities and neural tube defects in infants. In human epidemiological studies of women living in Texas between 1999 and 2004, mothers from census

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[5] BTEX is the acronym for benzene, toluene, ethylbenzene and xylene.

[6] The hematopoietic system is the system responsible for the formation of blood cells.

tracts where the ambient levels of benzene exposure ranged from low–medium (0.45–0.98 μg/m^3) to medium–high (1.52–2.86 μg/m^3) had positive associations with spina bifida. The highest levels of benzene exposure were associated with more than double the incidence of spina bifida (Lupu, 2011). A few epidemiological studies have found an association between maternal exposure to air pollution and autism spectrum disorders. One particular study by Von Ehrenstein *et al* (2014) sought to identify which environmental toxicants were more responsible than others by examining cases of autism at 3.5 and 5km from air quality monitoring stations in California. Elevated levels of maternal exposure to benzene was very high in their list of associations.

Dilbit

As noted in Section 3.2 (page 15) of our report, *Major Human Health Impacts of the Kinder Morgan Trans Mountain Pipeline Expansion (May 2015)*, diluted bitumen (or, "dilbit") is the main product expected to be transported in the expanded pipeline. From an environmental perspective, Dilbit possesses the unfavourable characteristics of both bitumen and condensate (or diluent). Its bitumen component gives it the characteristics of heavy weight crude oil (i.e., long-term persistence in the environment), while its diluent component contributes characteristics associated with a light weight petroleum product (i.e., high evaporation rates, high flammability and acute toxicity).

The unique properties and higher toxicity of dilbit are noted by the US National Academies of Sciences, Engineering and Medicine in its 2016 report (National Academies Press, 2016). For 11 of the 16 polyaromatic hydrocarbons (PAHs) designated as priority pollutants by the Environmental Protection Agency, higher concentrations (ranging from slightly higher to over 3 times higher) were found in Cold Lake diluted bitumen compared to other crude oils. For example, the concentration of benzo[a]pyrene in Cold Lake diluted bitumen was 3.01 μg/g compared to 0.25, 0.49 and 0.74 μg/g in medium, heavy and light crudes, respectively (National Academies Press, 2016). The concentrations of metals (dominated by nickel and vanadium) in dilbit were also found to be 7 times and 2.5 times higher light and medium crude, respectively (National Academies Press, 2016).

Dilbit is considered a flammable liquid by both the Workplace Hazardous Materials Information System (WHMIS) and the US Occupational Safety and Health Administration (OSHA). The material safety data sheet for dilbit notes: "Released vapours may form flammable/explosive mixtures. Vapours may travel considerable distances to ignition sources and cause a flash fire. Cool containing vessels with water jet in order to prevent pressure build-up, auto-ignition or explosion" (Vitol, 2015).

Dilbit has a lower flash point[7] than conventional oils and bitumen and it can be a fire hazard for about two days after a spill (Fingas, 2015). The use of butanes to supplement diluent streams in Western Canada (to offset a shortage of condensate for dilution of bitumen) contributes to decreased dilbit stability and increased flammability, thereby making it more of a hazard, though for a shorter period of time (Fingas, 2015).

Benzo[a]pyrene

First linked to scrotal cancer in chimney sweeps in the 18th century, benzo[a]pyrene (BaP) was one of the earliest recognized carcinogens. It is a potent carcinogen and mutagen, with no known safe level of exposure; and its primary effect is on DNA structure where it causes coding mutations that lead to cancers, the most common of which is lung cancer.

The Jan 2017 toxicological review by the US EPA notes that BaP is released into the atmosphere as a component of smoke from forest fires, industrial processes, vehicle exhaust, cigarettes, and through the burning of fuel (such as wood, coal, and petroleum products). BaP in the air is predominantly adsorbed to particulates but may also exist as a vapor at high temperatures. BaP exposure can occur through respiration, ingestion or through the skin. The minimum acceptable concentration (MAC) in drinking water is less than 0.0004 mg/L or *three orders of magnitude lower than the MAC for benzene*.

BaP is best known for its carcinogenic effects (Boyle, 2008; Shi, 2017). These effects occur through its binding at the cellular level to the aryl hydrolase receptor and its subsequent transfer to the cell nucleus where it activates xenobiotic response elements. These elements combine with epoxide hydrolase to form benzo[a]pyrene-7,8-diol-9,10-epoxide (BPDE), a compound that binds covalently to DNA to form adducts that lead to cancer-inducing mutations (Kucab, 2015; Denissenko, 1996). The formation of BPDE – and hence its carcinogenic potential – is enhanced by genetic differences in enzyme production along the aforementioned pathway and by inflammation which can be induced by other exposures (Shi, 2017). Such susceptibilities and multiplicative effects were not considered in the HHRA used by the proponent but are critical to assess population level risk.

In addition to its carcinogenic effects, BaP affects the developing foetus by interfering with reproductive, neurological and immunological development. The overall refence dose for these effects is estimated to be 0.0003 mg/kg-d, a very low dose effect (US EPA, 2017). This estimate was not available at the time of the NEB review nor were developmental effects considered for the HHRA submitted by the proponent and is another reason why a comprehensive health

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[7] Flash point is defined as "the temperature at which the liquid produces vapors sufficient for ignition by an open flame. A liquid is considered to be flammable if its flash point is less than 60C." (National Academies Press, 2016)

impacts assessment is needed to account for the increased risk from the 7-fold increase in tanker traffic.

What is known about the populations along the Burrard Inlet?

This section of the report summarizes current demographic information about the municipalities along Burrard Inlet, the population most at risk in the event of a marine crude oil spill. Figures and tables illustrating these data are provided in Appendix 3: Impacted Populations in Burrard Inlet.

City of Vancouver

The largest city in British Columbia and the eighth largest city in Canada, Vancouver occupies 114.97 square kilometres on the western half of the Burrard Peninsula (City of Vancouver, 2018; Statistics Canada, 2017(e)). Vancouver is bounded by: English Bay and Burrard Inlet on the north, the Fraser River on the south, the City of Burnaby on the east and the Strait of Georgia on the west. According to the 2016 Census, the population of Vancouver was 631,486 individuals, an increase of 27,984 (or 4.6%) over 2011 (Statistics Canada, 2017(e)). Its population density in 2016 was 5,492.6 individuals per square kilometre, up from 5249.1 individuals per square kilometre in 2011. In contrast, the population density of the Metro Vancouver (of which Vancouver is a member municipality) was 854.6 individuals per square kilometre, while that of the province as a whole was 5 individuals per square kilometre8 (Statistics Canada, 2017(b)).

According to the 2016 Census, the majority of the population (73.4%) in Vancouver is between the ages of 15 and 64, with an approximately 15.5% of the population distributed above and approximately 11% below that age range (see Figure 3 in Appendix 3). The median age of the total population in Vancouver was 39.9 years in 2016, slightly higher than the 39.7 years recorded in 2011. The median age for women in 2016 was marginally higher than for men (40.7 *vs*. 39.0, respectively).

Figure 4 (Appendix 3) depicts the distribution of the population of Vancouver, by 5-year age group and sex. Approximately half of the Vancouver population meet the definition of being "vulnerable". This includes: children and youth under the age of 19 (n=98,800), women of childbearing age[9] (n=110,650), and adults over 65 years of age (n=97,570). The number of individuals in vulnerable populations may, in fact, be much higher as it currently does not

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[8] Metro Vancouver (referred to as The Greater Vancouver Regional District in the 2016 Census) occupies 2882.68 square kilometres and its population in 2016 was 2,463,431. The province of British Columbia occupies 922,503.01 square kilometres and its population in 2016 was 4,648,055. Between 2011 and 2016, the populations of the Regional District and the province increased by 6.5% and 5.6%, respectively.

[9] Between the ages of 20 and 39.

factor in those individuals who would also be considered “vulnerable” under a proposed new definition by Health Canada[10] (Government of Canada, 2018a).

City of Burnaby

The third largest city in British Columbia (after Vancouver and Surrey), the City of Burnaby occupies 90.61 square kilometres and is located at the geographic centre of Metro Vancouver (Statistics Canada, 2017(a); The City of Burnaby, 2018). According to the 2016 Census, the population of Burnaby was 232,755 individuals, an increase of 9,537 (or 4.3%) over 2011 (Statistics Canada, 2017(a)). Its population density in 2016 was 2,568.7 individuals per square kilometre, up from 2,463.5 individuals in 2011 (Statistics Canada, 2017(a)). In contrast, the population density of the Metro Vancouver (of which Burnaby is a member municipality) was 854.6 individuals per square kilometre, while that of the province as a whole was 5 individuals per square kilometre (Statistics Canada, 2017(b)).

According to the 2016 Census, the majority of the population (71%) in Burnaby is between the ages of 15 and 64, with an approximately equal proportion of the population distributed above and below that age range (see Figure 5 in Appendix 3). The median age of the total population in Burnaby was 40.3 years in 2016, up from 39.8 years in 2011. The median age for women in 2016 was slightly higher than for men (41.8 vs.38.6, respectively).

Figure 6 (Appendix 3) depicts the distribution of the population of Burnaby, by 5-year age group and sex. Approximately half of the Burnaby population meet the definition of being “vulnerable”. This includes: children and youth under the age of 19 (n=43,665), women of childbearing age[11] (n=35,570), and adults over 65 years of age (n=36,860). The number of individuals in vulnerable populations may, in fact, be much higher as it currently does not factor in those individuals who would also be considered “vulnerable” under the proposed new definition by Health Canada (Government of Canada, 2018a).

North Shore

Residents of the North Shore were originally citizens of the same municipality but have been separated into the District of North Vancouver and the City of North Vancouver since the early part of the twentieth century. In 2016, the District Council began an initiative to explore reuniting the two municipalities under one administration (District of North Vancouver Corporate Services, January 2016). This section of the report presents information on the population demographics of both municipalities.

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[10] Individuals who would be captured under the proposed new definition include those who may be more susceptible due to pre-existing health conditions (e.g., genetic disorders) or those with higher exposures (for example, those with occupational or other environmental exposure)

[11] Between the ages of 20 and 39.

District of North Vancouver

The District of North Vancouver, which is adjacent to and surrounds the City of North Vancouver on three sides, occupies 160.76 square kilometres on the North Shore of Burrard Inlet (Corporation of the District of North Vancouver, 2018; Statistics Canada, 2017(c); Wikipedia contributors, 2018). According to the 2016 Census, its population was 85,935 individuals, an increase of 1,523 (or 1.8%) over 2011, and its population density was 534.6 individuals per square kilometre (Statistics Canada, 2017(c)).

The majority of the population (65%) in the District of North Vancouver is also between the ages of 15 and 64, with an approximately equal proportion of the population distributed above and below that age range (see Figure 7, Appendix 3). The median age of the total population in 2016 was 44.3 years, up from 43.3 years in 2011. Like the City of Burnaby, the median age for women is higher than for men (45.1 years *vs*. 43.4 years, respectively).

It is worth noting that the population in the District of North Vancouver tends to be older, with a higher median age than in Burnaby and in the Greater Vancouver Regional District. As the figure illustrates, approximately 18% of the population is aged 65 or older. This is up from 15.5% in 2011.

Figure 8 (Appendix 3) depicts the distribution of the population of the District of North Vancouver, by 5-year age group and sex. Approximately 52% of the District of North Vancouver population meet the definition of being "vulnerable". This includes: children and youth under the age of 19 (n=20,605), women of childbearing age[12] (n=8,800), and adults over 65 years of age (n=15,055).

City of North Vancouver

The City of North Vancouver, which is located directly across from the City of Vancouver, occupies 11.85 square kilometres on the North Shore of Burrard Inlet (Statistics Canada, 2017(d); Vancouver, 2018). According to the 2016 Census, the City of North Vancouver's population was 52,898 individuals, an increase of 4,702 (or 9.8%) over 2011. Its population density, which is the highest of the three municipalities discussed in this report, was 4,465.1 individuals per square kilometre (Statistics Canada, 2017(c)).

The distribution of the population by broad age group follows the same pattern as both Burnaby and the District of North Vancouver. That is, the majority of the population (71%) falls between the ages of 15 and 64, with an approximately equal proportion of the population distributed above and below that age range (see Figure 9, Appendix 3). The

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[12] Between the ages of 20 and 39.

median age of the total population in 2016 was 42.2 years, slightly higher than the City of Burnaby but lower than the District of North Vancouver. Like both of the other municipalities, the median age for women is higher than for men (43.6 years *vs*. 40.7 years, respectively).

Like the District of North Vancouver, the median age in the City of North Vancouver is higher than in Burnaby and in the Greater Vancouver Regional District. As the figure illustrates, approximately 16% of the population is aged 65 or older.

Figure 10 (Appendix 3) depicts the distribution of the population of the City of North Vancouver, by 5-year age group and sex. Approximately 52% of the District of North Vancouver population meet the definition of being "vulnerable". This includes: children and youth under the age of 19 (n=20,605), women of childbearing age[13] (n=8,800), and adults over 65 years of age (n=15,055).

Vulnerable populations in the municipalities along the Burrard Inlet

Table 1 synthesizes demographic data from the 2016 Census of Population on populations that meet the Government of Canada's proposed definition of "vulnerable". Data are presented for the Cities of Vancouver and Burnaby, the District of North Vancouver, and the City of North Vancouver. For comparison, the data for the Metro Vancouver are also presented.

Table 1: Population and age characteristics of vulnerable populations in the affection region

Demographic	City of Vancouver	City of Burnaby	North Vancouver		Total	
			District	City	Vancouver, Burnaby, North Shore	Metro Vancouver*
Total Population						
	631,485	232,755	85,935	52,900	1,003,075	2,463,430
Vulnerable Populations						
Children & youth under the age of 19	98,800	43,665	20,605	9,550	172,620	504,390
Children under the age of 10	47,520	21,270	9,195	4,875	82,860	239,000
Women of childbearing age	110,650	35,570	8,800	7,800	162,820	352,090
Adults over 65 years of age	97,570	36,855	15,055	8,525	158,005	387,315
Adults over 85 years of age	14,225	5,135	2,135	1,140	22635	51,280

*Statistics Canada refers to this geographical unit as the Greater Vancouver Regional District

Children and youth aged 0 to 19

As illustrated in Table 1, children and youth under the age of 19 account for nearly 20% of the total population in Vancouver, Burnaby and the North Shore municipalities, as well as in the

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[13] Between the ages of 20 and 39.

regional district as a whole. Nearly 60% of the children and youth under 19 who live in Vancouver, Burnaby and the North Shore live in Vancouver. Most of the remaining 40% live in the Burnaby, followed by District of North Vancouver. Of the 172,620 children and youth in Burnaby and the North Shore municipalities, 48% are under the age of 10. Children in this demographic represent approximately the same percentage of the population in Metro Vancouver.

Females aged 20 to 39

Women of childbearing age represent approximately 16% (n=162,820) of the total population in Vancouver, Burnaby and the North Shore municipalities. Vancouver accounts for the highest proportion of this total (67.9% of women aged 20 to 39; n=110,650). Women in this demographic represent approximately the same percentage of the population in the Metro Vancouver.

Adults aged 65 years or more

Approximately 15.7% of the total population in Vancouver, Burnaby and the North Shore consist of adults over the age of 65 years. Adults in this demographic also represent 15.7% of the population in the regional district as a whole. Just under 2.3% of the population in Vancouver, Burnaby and the North Shore consist of adults over the age of 85 years. This is slightly higher than what was reported for the regional district (2.1% of the population was 85 years or older).

What is known about the potential human health impacts of a major spill?

This section of the report sets out the potential human health impacts of a large, marine crude oil spill. Information is organized under the following categories of effects: toxicological (includes chronic diseases (like cancer), respiratory diseases (like asthma), neurological, etc.); mental health impacts (includes psychological, cognitive, behavioural); and community impacts (includes economic losses, impacts on Indigenous peoples, threats to traditional food sources, etc.). This categorization mirrors the framework that Health Canada used in its August 2018 report, *Guidance for the Environmental Public Health Management of Crude Oil Incidents*, to document the potential acute and chronic human health effects resulting from major crude oil incidents (Health Canada, 2018).

Toxicological effects

As noted in the Background and Context section of this report, benzene and benzo[a]pyrene are chemical toxicants found in crude oil and dilbit. Both are recognized as Class 1 (i.e., the most potent) human carcinogens with no known safe threshold of exposure. Though the carcinogenic potential of dilbit constituents are clear, long term studies of duration great enough to show latent carcinogenesis (i.e., 30+ years for most common solid tumours) are very challenging to do and are therefore rare.

Research conducted after major tanker spills around the world show that such incidents result in widespread exposure and cause significant health acute and chronic health effects. For example, the National Center for Disaster Preparedness (NCDP) at Columbia University, in partnership with the Children's Health Fund assessed community level exposure in more sparsely populated areas of Alabama, Florida, Louisiana and Mississippi after the Deepwater Horizon oil spill that occurred 40 miles off the coast in 2012. Over half of the parents interviewed in four highly-impacted communities reported oil spill-related exposure in their children (Abramson DM, 2013). One in every five parents described direct contact with the oil by their children. Just over 40% of parents in these high-impact communities reported some type of health effect experienced by their children since the oil spill, with 18.1% of the parents saying their children had experienced breathing problems since, 14.8% noting skin problems, 16.0% reporting visual problems and 21.6% mentioning emotional or behavioral problems following the spill. None of these health impacts were assessed for the children of Burrard Inlet.

In an examination of health effects of the Hebei-Spirit oil spill site two years after the incident, Jeong and colleagues (2011) conducted a survey of 457 elementary school students and 9242 adults in the contaminated area from February to August 2009. Among the children, the researchers found much higher prevalence of asthma in the study population than in similar populations of children in non-contaminated areas. As assessed by questionnaire, the presence of symptoms in the exposed group was 27.2% as opposed to 16.0% in the unexposed group. By methacholine provocation test, the rate was 16.8% as opposed to 6.4% in those unexposed. Among the adults, they found a dose-response relationship between length of time engaged in clean-up work and 8-hydroxydeoxyguanosine and malondialdehyde. Furthermore, allergic disease and multiple chemical sensitivities were associated with length of time spent working on cleanup as well as proximity to contamination from the spill. A study by Kim et al. (2013) found asthma to be the most prominent disease burden (followed by PTSD and allergic rhinitis;). This burden was found to be 6138 DALYs (Disability-Adjusted Life Year) in the study area (9233 DALYs/100 000 individuals), which is 6.5 times higher than the total burden of asthma for South Korea (1418 DALYs/100 000 individuals).

Studies of community and clean-up workers exposed to crude oil have common themes. A study on people who joined in the cleanup work after the Nakhodka oil spill (in the Sea of Japan, 1997) identified symptoms differentiated by being female (higher), the number of working days on cleanup activities (dose-response), direct exposure to oil products, history of hypertension, and history of low back pain (Morita *et al*, 1999). Other studies on cleanup workers after the Erika oil spill (off the Coast of France in 1999) also found duration of work as a risk factor for similar health problems including lumbar pain, migraine, dermatitis, ocular irritation, respiratory problems, and nausea (Schvoerer *et al*, 2000). Later studies on this population found increased risk for developing skin irritations and dermatitis for people who had been in bare-handed contact with oil, but no significant increase in risk to developing cancers (Baars, 2002; Dor *et al*, 2003).

Research on cleanup workers after the Prestige, a 'small' Aframax ship, broke apart in a storm off the coast of Spain in 2002 showed a higher prevalence of lower respiratory tract symptoms and significantly higher DNA damage with higher exposure time to volatile organic compounds from oil (Zock *et al*, 2007; Laffon *et al*, 2006; Perez-Cadahia *et al*, 2006 and 2007). Those who used proper health protective devices during work had lowered frequency of health problems (Suarez *et al*, 2005). For the Tasman Spirit that ran aground off of Karachi, Pakistan in 2003, studies showed that a person's perception of health impact decreased with the distance of the person's residency from the spill site (Janjua *et al*, 2006) suggesting a dose-response to the adverse effects.

Mental health effects

Research has identified that oil spills have significant impacts on the mental health of individuals and communities where they happen. The most frequently documented effects are anxiety, depression and post-traumatic stress disorder (PTSD) (Eykelbosh, 2014). Other short- and long-term effects include: somatic complaints; relationship problems; increases in use of mental health services; intrusive stress; increased substance use; increased domestic violence; increased calls to police departments; chronic feelings of helplessness, betrayal, and/or anger; headaches, insomnia, and/or anorexia (Aguilera, Méndez, Pásaro, & Laffon, 2010; Goldstein, Osofsky, & Lichtveld, 2011; Green & Lindy, 1994; Norris, Friedman, & Watson, 2002; Arata, Picou, Johnson, & McNally, 2000; Gill, 2007; Gill & Picou, 1998; Impact Assessment, 1990; Lima et al., 1993; Murphy, 1984; Palinkas, Downs, Petterson, & Russell, 1993; Palinkas, Petterson, Russell, & Downs, 1993; Palinkas, Russell, Downs, & Petterson, 1992; Picou et al., 1992; Picou & Martin, 2007; Rodin, Petterson, & Russell, 1992). Even those individuals who are not directly affected by the event can suffer secondary effects as a result of negative impacts on their wider community (i.e., job and income loss, damage to tourism and fishing industries, worries about the environment) (Arata et al., 2000; Fan, Prescott, Zhao, Gotway, & Galea, 2015).

Impacts of human-caused *vs.* natural disasters

Evidence suggests that the impact of technological disasters is greater than that of natural disasters (Gill and Picou, 1998). In a study comparing victims of a crude oil spill (human-caused) with those of a typhoon (natural), Chung & Kim (2010) found that effects were worse among the spill victims. Baum and Fleming (1983) suggest that while natural disasters produce a situation where there is a lack of control over processes perceived to be uncontrollable, technological disasters produce the opposite – a loss of control over processes perceived to be controllable, which creates a sense of uncertainty (Kroll-Smith & Couch, 1993). Furthermore, since technological disasters are human-caused, a litigation process often follows the event, which can have its own separate negative mental health impacts, including extending the time it takes for victims of disaster to recover (Picou & Rosebrook, 1993).

Prevalence of mental health effects

Palinkas and colleagues (1992, 1993) correlated prevalence of psychiatric disorders with level of spill exposure (none, low, or high) in communities affected by the Exxon Valdez oil spill. Those in the high-exposure group, when compared to the non-exposed group, were found to be much more likely to show strong clinical indicators of anxiety disorders (3.7-fold), PTSD (2.6-fold), and depression (2.13-fold). Similarly, in the wake of the Deepwater Horizon spill, Osofsky and colleagues (2011) found a prevalence of PTSD symptoms of 12% in communities impacted by that event, as compared to the national baseline of 3%. For symptoms related to mental illness more generally, the impacted communities showed a prevalence of 15%, with 6% being the national baseline. Furthermore, proximity to the oil spill predicted increased psychiatric symptoms (i.e., post-traumatic stress, anxiety, depression).

Chronicity

Evidence suggests that the impacts of technological disasters on mental health persist over the long-term. For instance, six years after the Exxon Valdez oil spill, high rates of distress (anxiety, depression, PTSD) were still observed in commercial fishers (Arata, et al., 2000). This is in line with findings from other technological disasters such as the Three Mile Island nuclear accident, which also had measurable mental health impacts six years post-incident (Baum & Fleming, 1993). In this case, the researchers also discovered biochemical changes associated with the chronic stress observed in victims (i.e., elevated blood pressure and impaired immune function). Some individuals continue to show symptoms 14 years (Green et al., 1990) and even 17 years (Picou & Martin, 2007) after a human-caused disaster.

Community impacts

Effects related to resource loss

Evidence suggests that the mental health impacts of a tanker disaster differ between segments of the population and that those who experience resource loss as a result of a disaster are particularly vulnerable. Resource loss can be economic (including loss of possessions) but can also function through disruption of social systems (i.e., relationships with others), personal characteristics, and an individual's ability to garner and retain resources (Freudenburg & Jones, 1991; Arata et al., 2000). The loss of one's own physical health (a type of human resource) can also have adverse effects on mental health. Arata and colleagues (2000) found that deterioration in physical health was found to predict higher levels of all psychological symptoms in victims of the Exxon Valdez oil spill.

Long-term adverse mental health effects were especially seen among fishermen. Eykelbosh (2014) reported that previous oil spill events have also been shown to: impact fisherman's immune function long-term, particularly PAHs increasing levels of cortisol and decreasing levels of natural killer cell; limit Indigenous peoples' access to traditional foods and fishing activities; shift trust in government bodies and politicians; and, lead to significant decreases in traditional harvesting activities, decreased consumption in traditional foods, and continued distrust in the safety of traditional foods post-spill (Eykelbosh, 2014).

In a study of the Deepwater Horizon oil spill, researchers found that participants who had suffered income loss as a result of the spill were less resilient than their counterparts with stable incomes, and displayed more anxiety, depression, fatigue, confusion, and mood disturbance (Grattan et al., 2011). Furthermore, it seems that for individuals and households where there was significant resource loss and/or low-income status, their mental and physical health status actually *worsens* in the year after a disaster (Cope, Slack, Blanchard, & Lee, 2013; Morris, Grattan, Mayer, & Blackburn, 2013). Decreases in community cohesion, an indicator of community health, were frequently reported. Community members who were impacted financially experienced anger, fatigue, depression, tension/anxiety, and confusion compared to income-stable residents (Grattan, 2011; Buttke, 2012).

Effects related to clean-up efforts

A special population to consider in the wake of a technological disaster is those involved in clean-up and relief efforts. Studying the impacts of the Exxon Valdez oil spill, Palinkas and colleagues (1993) reported that in the community in general, there was decreased participation in pro-social activities such as community celebrations, religious activities, volunteer work, and social visiting; these impacts were more pronounced in those who had engaged in clean-up work than in the rest of the community. Furthermore, Kwok and colleagues (2017) demonstrated that clean-up workers for the Deepwater Horizon oil spill experienced higher prevalence of PTSD and depression than non-workers. Rodin and colleagues (1992) delineate a number of measurable negative impacts to the community from the Exxon Valdez oil spill, stating that "in addition to the measurable impacts to local government and to individuals through visits to mental health facilities, the cleanup caused conflict and divisiveness between residents in most of the study communities." There is also evidence that the psychological impacts on clean-up workers extend even further, resulting in negative sequelae for their families. Rung and colleagues' (2015) findings (Deepwater Horizon oil spill) suggest that female partners of oil spill clean-up workers experienced an increase in depression, domestic partner fights, memory loss, and an inability to concentrate. These mental health impacts are not assessed for the populations likely to be affected by a large spill in Burrard Inlet.

Effects on Indigenous Peoples

Indigenous peoples may be particularly vulnerable to increased exposure to physiological risks and can be considered a vulnerable population in this regard. Indigenous peoples may well also be particularly vulnerable to the mental health effects of technological disasters due to resource loss. In the wake of the Exxon Valdez oil spill, indigenous Alaskans (who suffered great resource loss) fared worse in terms of their mental health than their non-indigenous counterparts (Palinkas, Petterson, Russell, & Downs, 1993). Symptoms of depression were linked with damage to larger social support systems which were eroded in the time following the disaster. Another likely source of distress was the lack of ability to engage in traditional subsistence activities, such as harvesting traditional food sources (Miraglia, 2002).

Individuals from the Tsleil Waututh Nation continue to harvest shellfish and crabs from the mudflats even though this fishery has been closed since 1972. Contamination from poly aromatic hydrocarbons (PAHs), such as BaP and other constituents of dilbit, is a hazard from marine traffic and the refinery in Burrard Inlet. These compounds are accumulated in benthic organisms (e.g., crabs and other shellfish) where they pose a human health hazard. Boehm et al. (2004) looked at levels of PAHs in the years 1998-2002, after the Exxon Valdez oil spill. Shellfish samples were collected from 72 oiled sites from previous sampling and 72 non-oiled sites randomly selected, with 218 samples collected from oiled areas and only 70 samples from non-oiled areas. Their work found that mussels in both oil-affected and non-oil effected areas had similar levels of PAHs (Boehm, 2004). Elevated levels of some mussels found in spill-affected sites were still elevated enough to cause harm in other wildlife (Boehm, 2004). Although PAH levels were still detectable, the authors concluded that there was no additional risk by 2002. It is important to note that the work performed by Boehm et al. was funded by Exxon Mobil, that this study focussed on short term levels PAHs in mussels over the study period and that it had no focus on viability or health impacts of PAHs.

Work performed by Peterson et al. (2003) identified that there remained long-term presence of oil-causing toxicity to the ecosystem. The authors noted previous risk assessments have assumed oil that settles on soils and marshlands that would quickly disperse and degrade (Peterson et al, 2003). The authors report that oil can degrade at varying rates and can remain undisturbed in sub-surface sediments and that oil trapped under mussel beds could be readily taken up and enter food chains (Peterson et al., 2003). Peterson et al. also stated that past studies focused on short-term, acute toxicity and failed to acknowledge the impacts of long-term, subacute concentrations of oil. Continued biological exposures to oil at sub-acute levels have led to decreased health and increased mortality in organisms not accounted for in previous studies (Peterson et al., 2003). Cumulative impacts of impaired health on food chains have also led to a lack of improvement in oil recovery. Previous studies failed to acknowledge inter-species effects and impacts on food chain systems (Peterson et al., 2003).

Gilroy (2002) examined the protocol for reopening shellfish harvesting in Coos Bay, Oregon after an oil spill. Samples were collected and analyzed using gas chromatography/mass spectroscopy (GC/MS) and PAH concentrations were calculated as total benzo[a]pyrene equivalents (BaPe). A level of 10 µg/kg BaPe was determined to be safe for the average consumer, while a concentration >45 µg/kg BaPe was determined to be unsafe to the average consumer. The authors identify that there were no standard procedures addressing the risk in shellfish after an oil spill. These levels were identified as not acknowledging safe levels for sensitive populations, and the lack of standard procedures for declaring "safe levels".

Vinaz et al. (2009) examined PAH levels in three commercial shellfish in an area impacted by the Prestige oil spill. Their research found median PAH values of 58 µ/kg for razor shells, 26 µ/kg for barnacles, and 25 µ/kg for sea urchins one year after the spill (Vinaz et al., 2009). Authors noted that there were changes in cellular response and immune function in mussels affected by the spill (Vinaz et al., 2009). A lack of baseline data on the health of mussels meant that no solid conclusions could be found from the data (Vinaz et al., 2009).

Marigomez et al. (2005) previously reported that there were biological changes in appearance and development of mussels after the Prestige oil spill. There was also a lack of previous monitoring data to accurately determine the baseline levels of PAHs and other contaminants in marine species (Mariogomez et al., 2005), Previous data on shellfish health indicators made multiple assumptions and lacked information on seasonal and geographical variability, making previous conclusions on shellfish health preliminary (Mariogomez et al., 2005).

Xia et al. (2012) examined PAH levels in seafood (including oysters, crabs, and finfish) in areas affected by the Deepwater Horizon oil spill. A total of 278 seafood samples were collected weekly for the first six months then monthly for 10 months (Xia et al., 2012). PAH levels in oysters were reported to be similar to levels found in 10-year, national baseline data (Xia et al., 2012). Authors identified statistically higher levels of PAHs in all species sampled in earlier phases of the study compared to later samplings and concluded the levels found were similar to processed foods and below the Food and Drug Administration's (FDA) Level of Concern (Xia et al., 2012). No full reporting of other species or baseline data was found in this study.

Criticisms of the FDA's Level of Concern (LOC) guidelines were evaluated and reported as underestimating the cancer risk, particularly for vulnerable populations (Ellman, Wong & Solomon, 2012). The FDA guidelines were found to underestimate the seafood consumption rates of people living on the Gulf Coast, and the combined effects of eating multiple types of seafood (Ellman et al., 2012). The FDA failed to acknowledge the carcinogenic effects of naphthalene, one of the PAHs likely found, and assumed oil would be present for 5 years as opposed to previous data which indicate that PAHs can be present up to 13 years after contamination (Ellman et al., 2012). The FDA also ignored vulnerable populations, which included pregnant women. Revised LOC showed a maximum risk for pregnant women of 8 cases per 100,000.

PAH levels in traditional foods

Irvine et al. (2014a) examined cancer risk from PAH levels in soil levels in northern Alberta and examined if the additional risk in First Nations who engaged in traditional wilderness activities (Irvine et al., 2014a). The researchers collected soil samples and conducted air monitoring to examine environmental PAH concentrations. The authors concluded that individuals participating in traditional wilderness activities had an additional risk of 0.02 new cases of cancer per 100,000 persons, and PAH air concentrations led to an additional 0.01 new cases of cancer per 100,000 persons (Irvine et al.,2014a). The authors concluded that the level of risk identified in this study did not significantly increase the estimated lifetime risk of cancer. It is worth noting that their conclusions came from a short-term sampling campaign with a limited number of samples. The authors also used a relatively small population size of 14,000 and did not acknowledge any risks for vulnerable populations. This study only considered direct hand-to mouth and inhalation of PAHs, it did not acknowledge additional exposures through contaminated food sources. The authors conducted a separate study that examined PAH exposure via traditional foods. This article used similar methods and concluded a negligible risk but did not look at the impacts of total PAH exposure (Irvine et al., 2014b) The authors also assumed exposure for one-third of the year due to reduced access of soil to in winter months, further minimizing the frequency of exposure. Estimates of soil ingestion came from a previous study of the authors (Irvine et al., 2014).

Kelly et al. (2009) studied levels of polycyclic aromatic compounds (PAC) in the Athabasca river and its tributaries. Samples were taken and samples from the Athabasca were found to be dissolved PAC concentrations were mostly <0.025μg/L in winter and 0.030 μg/L in the summer. Levels in tributaries ranged to a maximum of 4.8 μg/L, levels which were concluded to be “likely toxic to fish embryos” (Kelly et al., 2009). Melted snow also showed high concentrations of PAC, indicating that spring snowmelt and heavy rain washouts were likely unknown sources of variability. The authors were not able to distinguish seasonal variability with this research.

Elevated levels of PAHs from oil sands pollutants have been found in foods, including moose, duck, and muskrat (CMAJ, 2014). Concerns about pollution have were also reported to lead people to buy more store-bought food rather than consume Traditional foods (CMAJ, 2014). In a study examining PAH levels in the tissues of fish in waterways near Oilsands Operations in northern Alberta, a total of 425 samples were collected across four species of fish (Ohiozebaue et al., 2017). Concentrations ranged from 11 to 129 ng/g near the oil production sites and from 4.3 to 33 ng/g among samples furthest away from production. Cumulative PAH levels found to be slightly higher in collected samples compared to previous findings from areas without oil production. The authors concluded the lifetime risk of cancer associated with these PAH levels "acceptable". Limitations to this work include: the lack of data on daily intake of fish species from these waterways; national-level data on Indigenous fish consumption was used to estimate daily intake; body mass levels were estimated using national data; data were segregated into 4 age groups but did not estimate risk for vulnerable populations; estimated risks did not factor in the interaction of consuming several types of fish; the researchers assumed PAH had a short half-life in fish species and did not bioaccumulate; and, the researchers also focused on one exposure pathway and did not look at the cumulative effects of multiple sources of PAH exposures (Ohiozebau et al., 2017).

A study on PAH levels in traditional foods harvested near Mississauga First Nation examined eight food sources (including 3 fish species). Results showed the highest levels of PAHs in geese, ducks, and bottom-feeding fish (Setton, Palmer, and Moher, n.d). Calculations of estimated lifetime risk of cancer ranged from range from 14 cases per million from average consumption level and average PAH levels, to a worst-case scenario of 4,050 cases per million. Thompson et al (2017) looked at PAH levels in butter clams, blue mussels, and Nuttall's cockle, traditional foods of Gitga'at First Nation. PAHs were elevated in the three species after diesel spills but were back to baseline concentrations within 5 months. Gitga'at harvesters were also reported to avoid bivalves from diesel-spilled environments for longer periods due to decreased quality and flavour.

What factors must be considered in modelling a major spill?

In its Nov. 2016 report, the proponent applied the major spill scenario in areas where few people live, only modelling scenarios at sea and removed from populated areas. A more relevant approach for public health would be to consider exposures from a spill scenario in a populated area, such as the Mayflower Arkansas spill of 2013. In this spill, 3,190 barrels of Wabasca heavy crude oil (80% bitumen, 20% diluent) were released into a neighborhood from a pipeline rupture. A response team was on the scene within 30 minutes. Despite this rapid response, total volatile organic compounds (VOCs) were up to 29 ppm on the day of the spill, falling to 3ppm within 3 days. In this event, there were no reports of oil sinking in the quiet waters of Lake Conway. However, the dense vegetation had to be removed to access the oil, and intensive mechanical methods were used to remove trees, rootballs, shrubs, and other debris over a large forested wetland mixing oil into soils and the following year a massive solid removal and replacement was required by Exxon Mobile (National Academies Press, 2016).

Anticipated increase in tanker traffic

An analysis by Dr. David Huntley (NEB, 2018) shows that the capacity for increased tanker traffic based upon the observed loading time of about three days for a large tanker, including maintenance time. This rate could produce about 120 tankers per year or a six-fold increase over 2017 with no expansion project. With the new pipeline capacity (24-inch pipe to 30 inch) and the increase in the number Aframax tanker berths to three, the terminal can load 1 to 1.5 tankers per day which brings the number of tankers per year to slightly more than Kinder Morgan's projected loading rate of 400 tankers per year (Trans Mountain, December 21, 2016). Compared to the average 20 tankers per year between 2015 and 2017, this is actually at least a 20-fold increase in tanker traffic over the past three years, not the 7-fold increase described by the proponent.

Marine traffic through the Second Narrows, near the mid-point of Burrard Inlet, faces strong tidal currents, a highway bridge and a railway bridge, with restrictions on transits due to slack tide, visibility, and daylight hours. The addition of one large tanker transit each way each day would be a substantial increase, approximately doubling the tanker and freighter transits through Second Narrows. This presents a substantial increased risk of a tanker accident and spill. The catastrophic nature of such a spill in this densely populated area demands scrutiny in a comprehensive, cumulative health impacts assessment.

Chemical characteristics of dilbit

The chemical characteristics of dilbit will enable it to float for a period of time in most aqueous media off-gassing hazardous materials through evaporation and then, after weathering, it can sink depending upon conditions (Health Canada, 2018; National Academies Press, 2016) making clean-up extremely difficult and expensive. In a recent report, the Royal Society of Canada used a standard mix of 70% bitumen and 30% diluent to describe behavior in aquatic environments (Royal Society of Canada, 2015). Neither these data nor the 2016 US National Academies of Science, Engineering and Medicine report was available to the proponent at the time of the HHRA.

In its report, the Royal Society expert panel concluded that the impact of a spill depends mainly upon the environment and weather conditions present at the time. In other words, largely luck. They identified five key areas where "high-priority research" is needed (Royal Society of Canada, 2015):

1. environmental impact of spilled crude oil in high-risk and poorly understood areas such as shores or inland rivers and wetlands;
2. effects of oil spills on aquatic life and wildlife at the population, community and ecosystem levels;

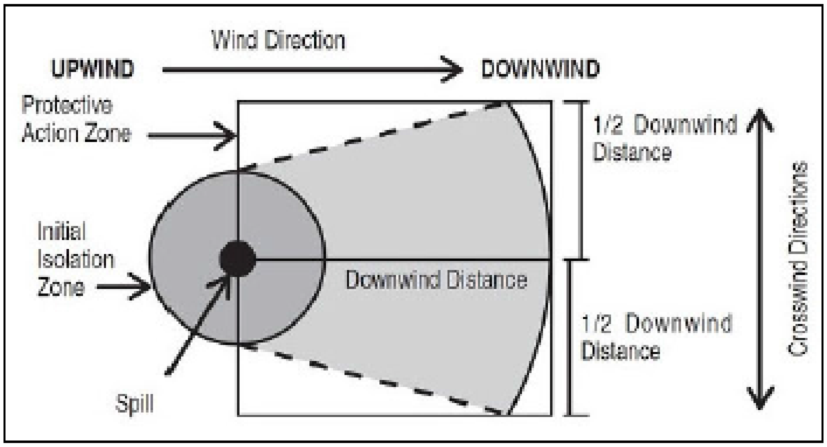
3. controlled field research is needed to better understand spill behaviour and effects across a spectrum of crude oil types in different ecosystems and conditions;
4. the efficacy of spill responses and to take full advantage of ‘spills of opportunity’;
5. update and refine risk assessment protocols for oil spills in Canada.

The Royal Society’s expert report acknowledges that we do not have sufficient information to perform adequate risk assessments for dilbit spills and calls for updated protocols: “Answers to these research questions are considered by the Panel to be essential for equipping policy makers, oil industry decision-makers, oil spill responders and other Canadians with critical tools to better anticipate spills and their consequences and to better protect Canada’s marine and inland waters from the adverse effects of spilled oil.” The Expert Panel goes on to note that the risk assessment methods should “include such things as credible spill scenarios, analyses of seasonal differences in fate, transport and effects of oil (particularly for spills in winter) and the prediction of chronic toxicity” – exactly what is needed for the comprehensive and cumulative health impacts assessment that we are requesting.

Transport Canada’s emergency response guidelines for a marine spill of crude oil

The Emergency Response Guidebook used by Transport Canada describes “initial isolation distances” from which all public should be evacuated and within which respiratory protection is required, and “protective action zones” from which people either need to be evacuated or shelter in place in the event of a marine spill of crude oil (ERG, 2016). These zones are illustrated in Figure 1.

Figure 1: Initial isolation zone and protective action distance



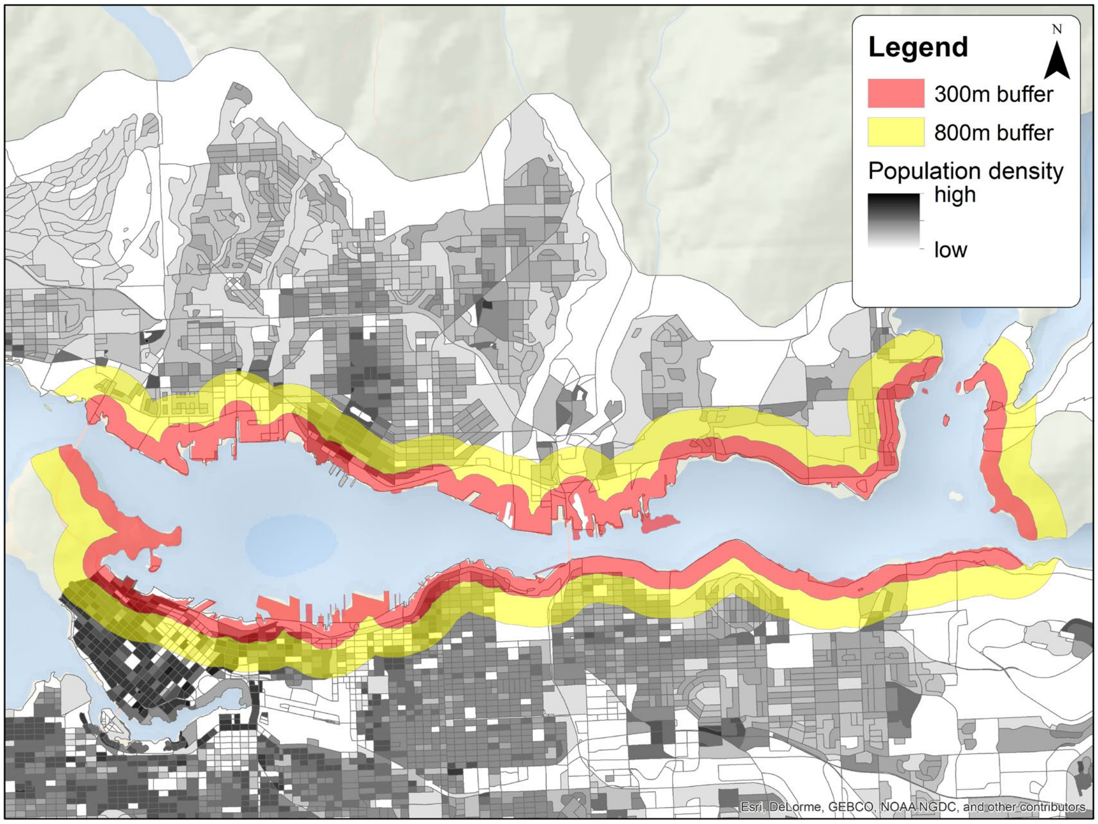
(Source: Health Canada 2018 and ERG 2016)

Population at risk

Population at risk: present day

For emergency planning and evacuation estimates, the Canadian National Oil Spill Preparedness and Response Regime characterizes a large spill as greater than one barrel of sweet crude[14] (Health Canada, 2018). Applying the emergency response guidelines described in Figure 1 above, Figure 2 shows the population that would be impacted by a large spill of approximately 500,000 barrels or 67% of an Aframax tanker filled to capacity within the Inlet[15].

Figure 2: Population likely impacted by a large tanker spill in Burrard Inlet



(Data source: Statistics Canada)

If only one half of one percent reached shore, this would equal 2500 barrels distributed along

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[14] Note that this guidance is for sweet crude which is less volatile than dilbit – which means that a greater evacuation zone is likely to be required for dilbit immediately following a similar spill and for several days following depending upon weather conditions.

[15] Data used to create Figure 2 are from the 2016 census population data at the dissemination block level from Statistics Canada downloaded from the Government of Canada's open data portal (https://open.canada.ca/en/open-data) along with the 2016 Dissemination block shapefile. The inside buffers were created using the Buffer Wizard tool in ArcGIS by specifying distances (300 and 800m) from the shoreline. The 2016 population census data at the dissemination block level was converted to population density (population/km^2) using a method described in detail in Appendix 2.

the populated shoreline of Burnaby, Vancouver and North Vancouver. Over 24,587 people live within 300 meters of the shoreline (i.e., the red region) and would therefore be required to immediately evacuated according to Health Canada Guidance for the Environmental Public Health Management of Crude Oil Incidents (Health Canada, 2018). In the event of a fire, approximately 105,515 people living within 800 meters of the shoreline (i.e., the yellow and red bands combined) would be affected.

Population at risk: 2041 (projected)

The MetroVancouver 2014 report on density and urban growth estimates that by 2040 (which includes that lifespan of TMEP), the urban boundary of Metro Vancouver will increase by approximately 42% with an estimated additional immediately effected population of 10,300 for spill alone and 44,300 if spill with fire at stage in the project's life. This projected growth in population at risk needs to be included in a comprehensive and cumulative HIA.

Projected population figures for Burnaby, the District of North Vancouver, the City of North Vancouver and the region as a whole for the years 2021, 2031 and 2041 are presented in Table 2, below. These numbers are drawn from Metro Vancouver's regional growth strategy[16] (Metro Vancouver, 2011 (Updated 2017)). In preparing this strategy, Metro Vancouver, in association with its member municipalities, used data from the 2011 Census of Population to project population figures for the overall region and for member municipalities.

Table 2: Projected population figures for Burnaby, the North Shore and Metro Vancouver

	Total Population			
Region/Municipality	**2011**	**2021**	**2031**	**2041**
Metro Vancouver Total	**2,356,000**	**2,788,000**	**3,152,000**	**3,443,000**
Burnaby	227,700	270,000	314,000	345,000
North Shore	185,100	206,425	224,650	243,700
City of North Vancouver	49,800	56,000	62,000	68,000
District of North Vancouver	87,700	98,000	105,000	114,000

Source: Table A.1, Appendix A, *Metro Vancouver 2040*.

As shown in the table, Metro Vancouver is projecting a significant increase in the populations of these municipalities and in the region as a whole by 2041. The largest projected percent increase in population is in Burnaby (48%), followed by the District of North Vancouver (33%) and the City of North Vancouver (28.5%). The population of the region as a whole is projected to increase by 39.8%.

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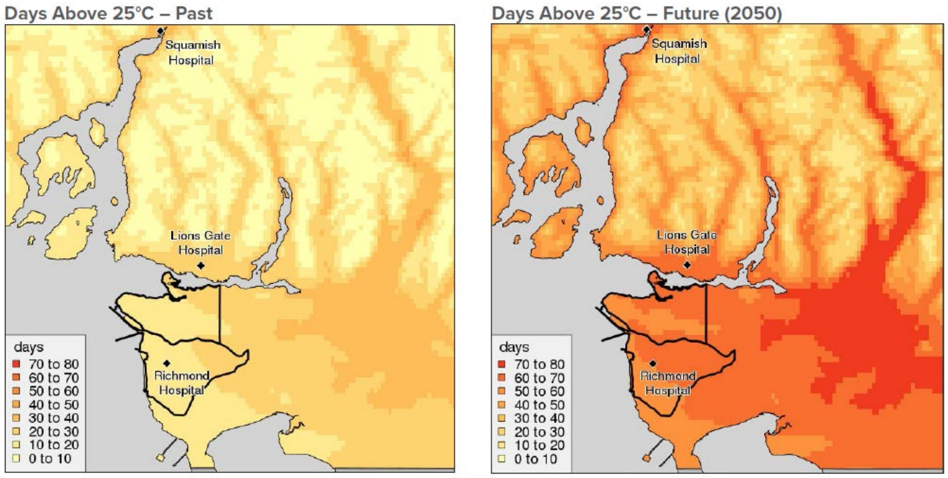
[16] The regional growth strategy is published in a report entitled *Metro Vancouver 2040: Shaping Our Future* and is available online at: http://www.metrovancouver.org/services/regional-planning/metro-vancouver-2040/about-metro-2040/Pages/default.aspx.

Worst-case spill scenarios

Present day scenario

A comprehensive, cumulative health impacts assessment for health risk of increased tanker traffic in Burrard Inlet should be bounded by a worst-case spill scenario that occurs on a hot day with stagnant conditions similar to week long periods in Burrard Inlet in the summers of 2017 and 2018. It should include the temperature increase projected for the Inlet which have been modeled for Burrard Inlet (Figure 4, VCH 2018).

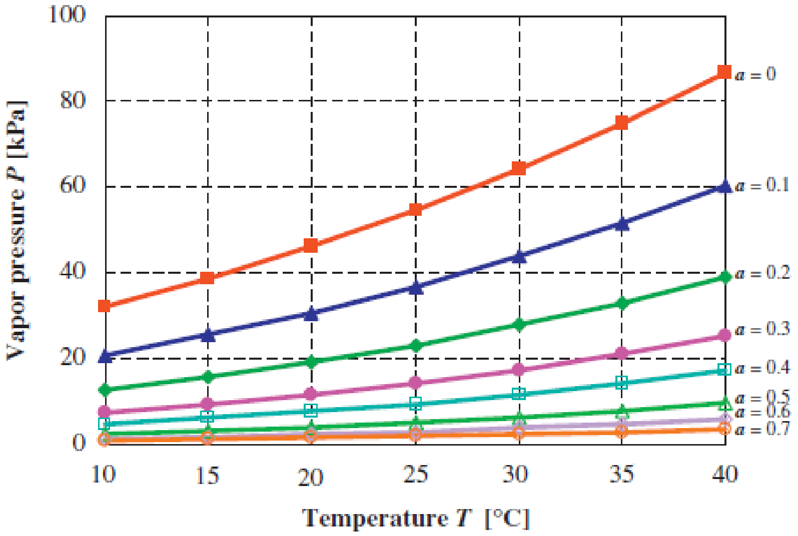
Figure 4. Days above 25^{0} C – baseline average and 2050 (VCH 2018)



Future scenario

Conditions for 2050 near the end of projected lifespan of TMEP are described below. The average number of days above 25^{0} C between 1970 and 2000 (reference period) was 10-20 days per year. This is predicted to triple by 2050 to 60-70 days per year. This temperature increase can have a dramatic impact on the evaporation rates and hence exposure to the constituents of dilbit. The diluent in dilbit is similar to gasoline in its evaporative properties. The vapor pressure is a measure of this evaporative potential and increases by approximately 40% with a temperature increase from 15^{0} C to 25 ^{0}C (see Figure 5, below). The increased evaporation will increase exposure and, therefore, the impact of future temperatures on a major spill scenario needs to be addressed in the HIA.

Figure 5. Changes in vapor pressure for degraded samples of gasoline with temperature



(Source: Okamoto, 2009)

Discussion

Exposure model issues and transparency

For our 2015 report on the health impacts of TMEP (Takaro, 2015), several requests were made to local health authorities to generate a new risk assessment based upon less ideal conditions than those outlined by Trans Mountain. The Fraser Health Authority, Vancouver Coastal Health, Metro Vancouver, BC Centres for Disease Control and the BC Cancer Agency were all asked to contribute. Due to the resources required, the organizations did not feel equipped to carry out a new risk assessment; and, as a consequence, this has not been done. In the two rounds of Information Requests, Trans Mountain would not provide the necessary information regarding model inputs to adequately assess the human health risk assessment undertaken as part of the original proposal. Citing proprietary aspects of the modelling, the proponent effectively circumvented important scrutiny of the model inputs. The NEB's conclusions therefore lack validation, providing yet another reason a transparent comprehensive health impacts assessment is required for the project.

Components of a comprehensive, cumulative health impacts assessment

As described elsewhere in this report, comprehensive human health impact assessments include an assessment of the impact of a project on the social determinants of health (e.g., housing, income) as well as ecological determinants of health (including greenhouse gas emissions). Such an assessment allows health authorities to recognize and consider potential positive and negative health impacts of projects on their communities, to plan and fund healthcare provision services to address those impacts, and, to suggest modifications to plans in order to mitigate negative health impacts.

An HIA requires the establishment of baseline health and community well-being data prior to any development proposal being made. This moves the needle beyond consultation and engagement to that which the next generation environmental assessment processes will need to achieve: empowerment for individuals and communities. Done well, this can be a key enabler of democracy. Effective HIA builds such practices into its process. Where there are considerable and reasonable scientific uncertainties with potential for serious present or future harm, the UNESCO 2005 definition of the precautionary principle must be used to inform the discussion. Reconsideration of the TMEP project requires such a health impacts assessment for the increase in tanker traffic through Burrard Inlet.

List of deficiencies identified in the HIA performed by the proponent

As previously noted in this report, the human health risk assessment performed previous by the proponent's contractor was inadequate for the following five reasons:

1. The impact of increased tanker traffic and subsequent increased risk to the environment and to the population that lives in Burrard Inlet, was not assessed.
2. Human health risk assessment did not adequately consider the high risk to specific vulnerable populations from benzene and benzo[a]pyrene including those with genetic susceptibility to these carcinogens.
3. The conditions considered by the NEB that related to health pertain only to monitoring, an after-the-fact "count-the-bodies" approach that is unacceptable today.
4. Certain outcomes (i.e., risk of childhood leukaemia and lung cancer in clean-up workers) inadequately accounted for by the TMEP human health risk assessment.
5. Mental health impacts are not assessed for the populations likely to be affected by a large spill in Burrard Inlet.

Table 3 synthesizes these deficiencies, providing a complete list of what we believe are crucial – and as yet unfulfilled – components of a comprehensive cumulative health impacts assessment related to increased tanker traffic in Burrard Inlet and the associated risk of shoreline contamination by greater than one barrel of dilbit.

Table 3: Summary of identified deficiencies in the evidence base for the project to date

Crucial component	Reason why this component in the NEB HIA is insufficient	Relevant section(s) of the report
Human health risk assessment	The human health risk assessment performed previous by the proponent's contractor was woefully inadequate and did not address the increase in tanker traffic. New information from 21 references published since 2015 should also be included.	What are the main contaminants that a comprehensive, cumulative HIA should consider? What is known about the potential human health impacts of a major spill?
Combined toxicant effects	A comprehensive health impacts assessment would include the combined effects of all toxicants released from the complex petroleum mixture that is dilbit and their cumulative and possibly synergistic health effects.	What are the main contaminants that a comprehensive, cumulative HIA should consider? What is known about the potential human health impacts of a major spill?
Increase in tanker traffic	Consider 20-fold increase in tanker traffic not seven-fold increase described by the proponent.	Anticipated increase in tanker traffic
A major spill within Burrard Inlet is credible	The marine spill scenario in the original NEB review was very optimistic, set far away from any population center despite the clear hazards of the 7-to-20-fold increase in tankers through Vancouver's busy harbor.	What factors must be considered in modelling a major spill?
Approximate worst-case scenario today	A comprehensive, cumulative health impacts assessment for health risk of increased tanker traffic in Burrard Inlet should be bounded by a worst-case spill scenario that occurs on a hot day with stagnant conditions similar to week long periods in Burrard Inlet in the summers of 2017 and 2018	Present day scenario
Approximate worst-case scenario for 2050	Government mandate requires a precautionary approach to populations at risk. A robust, cumulative health impact assessment (HIA) must conducted as part of the consideration of the risk from increased tanker traffic to include the populations of the Inlet using exposures and added impacts from higher temperatures and extreme weather conditions predicted for the Inlet by mid-century due to climate change.	Future scenario
Climate change impacts are a crucial component of health risk from a large fossil-fuel energy project	Any risk assessment of a fossil energy project must consider the contribution to mortality and morbidity due to climate change of wildfires, heat events, air pollution, sea-level rise, flooding, water contamination, drought, food shortages, shifting infectious diseases, illness and injury from extreme weather events, mental health impacts,	What is known about the potential human health impacts of a major spill? What factors must be considered in modelling a major spill?

	forced migration and related conflict, as well as the risks that climate change poses to healthcare structures and health-related supply	
Consider exposure from both floating dilbit and weathered sunken dilbit in the marine environment and answer research questions raised by Royal Society of Canada expert panel	The chemical characteristics of dilbit will enable it to float for a period of time in most aqueous media off-gassing hazardous materials through evaporation and then, after weathering, sink depending upon conditions, greatly hampering cleanup and producing long term contamination of the environment through release of poly-aromatic-hydrocarbons over years.	Dilbit Exposure model issues and transparency
Protect the people and cultural heritage of the original inhabitants of Burrard Inlet	Any oil spill in Burrard Inlet puts key components of the Tsleil-Waututh subsistence economy—salmon, herring, clams, and birds—at risk and poses the threat of harm or damage that may persist for years.	Community impacts Effects on Indigenous Peoples PAH levels in traditional foods

Limitations of this report

This report has significant limitations. It was researched and written within the restricted schedule imposed by the NEB, less than six weeks since funding was secured. We sought additional contractors who could not work for us on such short notice. Even the impacted health authorities do not have the resources to perform the required human health risk assessment and certainly BROKE and NSNOPE are not resourced to do one. The purpose of our research was to demonstrate the significant shortcomings of the evidence base on health impact that the NEB is using for its decision on increased marine traffic, and to point out the need for an independent assessment (not the proponent or its hired contractor) due to the conflict of interest now held by the Government of Canada as an owner of the project. We could not perform the research that is required to answer questions raised by citizens, scientist and government officials about the health risk of diluted bitumen in aquatic environments, hence the demand for an independent comprehensive, cumulative human health risk assessment.

Recommendations

The Government of Canada under *CEAA, 2012* has a mandate to protect the environment and human health and to apply the precautionary principle. To fulfill this mandate, an independent, comprehensive and cumulative health impacts assessment of a large or credible worst-case spill in this high-risk area must be part of any consideration of this proposed project.

Any risk assessment of a fossil energy project must consider the **upstream and downstream contribution to mortality and morbidity** due to climate change of wildfires, heat events, air pollution, sea-level rise, flooding, water contamination, drought, food shortages, shifting infectious diseases, illness and injury from extreme weather events, mental health impacts, forced migration and related conflict, as well as the risks that climate change poses to healthcare structures and health-related supply chains. Benzene and benzo[a]pyrene are carcinogenic exposures from dilbit with no safe exposure levels. Highly sensitive populations would likely be exposed in the event of a spill in Burrard Inlet, reinforcing the need for a comprehensive, cumulative health impacts assessment.

A robust, independent, cumulative health impact assessment (HIA) must be conducted as part of the consideration of the risk from increased tanker traffic. This HIA must: include the **combined effects of all toxicants** released from the complex petroleum mixture that is dilbit and their cumulative and possibly synergistic effects; consider the populations of the Inlet; and be based upon exposures and impacts due to higher temperatures and extreme weather conditions predicted for the Inlet by mid-century due to climate change. Inclusion of these elements would be consistent with the recommendations of a recent Royal Society of Canada report in which the expert panel notes that risk assessment methods should “include such things as credible spill scenarios, analyses of seasonal differences in fate, transport and effects of oil (particularly for spills in winter) and the prediction of chronic toxicity.”

The **increase in tanker traffic** appears to be significantly greater than the seven-fold increase described by the proponent. Based upon the average number per year during the period 2015 to 2017, the increase is closer to twenty-fold. Additionally, marine traffic through Second Narrows, near the mid-point of Burrard Inlet faces strong tidal currents, a highway bridge and a railway bridge, with restrictions on transits due to slack tide, visibility, and daylight hours. The tanker and freighter transits through Second Narrows would approximately double. Due to the catastrophic nature of such a credible spill in this densely populated area, the substantial increased risk of a tanker accident and spill demands better scrutiny.

The **marine spill scenario** in the original NEB review was very optimistic. It was set far away from any population center despite the clear hazards of the increase in tankers through Vancouver’s busy harbor. The Burrard Inlet through which these tankers must pass contains three bridges and two dangerous narrows adjacent to downtown with over a million people, an informal but easily accessed shellfish and crab fishery and population which includes Indigenous communities who harvest from the Inlet and whose close connection to the land makes them particularly vulnerable to environmental contamination. As noted elsewhere in this report, even best-case scenario clean-up of crude oil results in only 5-15% oil recovery, with spilled bitumen likely to have even lower levels of recovery due to the chemical characteristics that enable it to float for a period of time in most aqueous media, off-gassing hazardous materials through evaporation and then weathering and sinking depending upon conditions (Health Canada, 2018, National Academies Press, 2016). These characteristics make clean-up extremely difficult and expensive.

Furthermore, an independent, comprehensive, cumulative health impacts assessment for health risk of increased tanker traffic in Burrard Inlet should be bounded by a **worst-case spill scenario** that occurs on a hot day with stagnant conditions similar to week long periods in Burrard Inlet in the summers of 2017 and 2018. It should include the temperature increase projected for the Inlet which have been modeled for Burrard Inlet. It should include the additional evidence, much of it produced by the Government of Canada that is available since 2015. In short, the evidence presented in this report.

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Appendices

Appendix 1: The Government of Canada's proposed definition of vulnerable populations

The Government of Canada is currently undertaking a consultation on a proposed definition on vulnerable populations within the context of chemicals management[17]. The definition is the first step in the creation of an over-arching policy framework that would enhance the protection of vulnerable populations through a range of activities across the chemical management continuum. These include targeted monitoring and surveillance activities to examine the exposure potential for specific populations at risk (e.g., Indigenous peoples, people living near contaminated sites or in rural communities, etc.), as well as risk assessment, risk management, risk communication activities.

The definition of vulnerable populations that Health Canada has proposed to adopt for the assessment and management of chemicals is set out below, along with additional language the Government has included to clarify the interpretation of the definition.

> Definition:
>
> *a group of individuals within the general Canadian population who, due to either greater susceptibility and/or greater exposure, may be at greater risk than the general population of experiencing adverse health effects from exposure to chemicals*
>
> Interpretation:
>
> For the purposes of the proposed definition of vulnerable populations, individuals with greater biological susceptibility include those who may be more vulnerable due to biological or health status including:
>
> 1. life-stages where there is a change in normal development or function of biological systems, including the developing fetus during pregnancy, infants, children, youth and the elderly. Certain life stages are more susceptible to impacts on development, including from exposures to chemicals with endocrine related modes of action
> 2. sex-related susceptibilities such as impacts on reproduction including from exposures to chemicals with endocrine related modes of action

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[17] The consultation is part of a strategy to strengthen the Government's overall approach to how it takes vulnerable populations into consideration in its chemical management and risk assessment activities. The 60-day consultation period is November 22, 2018 to January 21, 2019. More information on the proposed definition can be found here: https://www.canada.ca/en/health-canada/services/chemical-substances/consulting-future-chemicals-management-canada/defining-vulnerable-populations.html.

3. individuals who may be more susceptible to the impacts of chemicals due to pre-existing health conditions, such as illnesses or genetic disorders or due to heightened sensitivity to chemicals

For the purposes of the proposed definition of vulnerable populations, individuals with greater exposures may include:

- infants and children who may have greater exposures to certain chemicals due to behavioural reasons such as soil and dust ingestion
- people living near industrial or commercial facilities or any other area with elevated levels of pollutants, including mixtures
- Indigenous Peoples and communities who may be significantly impacted, due to their close ties to the land and their consumption of country and traditional foods
- individuals with dietary habits different from the general population, including individuals with special dietary requirements, newborns and infants, new immigrants, or individuals in hunting and fishing communities consuming country foods that may have elevated levels of certain chemicals
- individuals who may have increased exposure to chemicals due to their usage patterns
- individuals, who for occupational reasons, may be exposed to higher levels of chemicals
- individuals, who for socio-economic considerations may be exposed to higher levels of chemicals, for instance through compromised housing conditions

Source: (Government of Canada, 2018b)

In its consultation document, the Government acknowledges that the proposed definition “focusses primarily on physiological and exposure considerations” and notes that “individuals’ unique backgrounds (such as culture, language, geography, disability) can impact how they are exposed to chemicals, as well as influence their understanding and how they manage risks related to chemicals.”

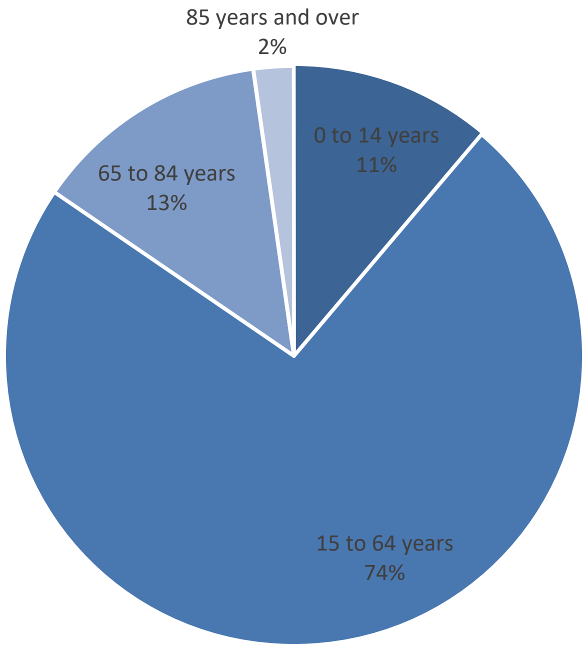
Appendix 2: Methods for dissemination block conversion for population density

Census data at the dissemination block and the census subdivision levels were obtained from Statistics Canada for 2016 and downloaded from the Government of Canada's open data portal (https://open.canada.ca/en/open-data), along with the 2016 Dissemination block shapefile. To calculate populations of the various zones, the dissemination block population data was clipped using the population ecumene layer with a 500-meter buffer. Using the field calculator, the next step was to calculate a population density for each clipped dissemination block by dividing the population by the area of the polygon. The shapefile was then converted into a raster with 25-meter pixel resolution using the population density value. Finally, in order to calculate the population for any given overlaying variable, the ‘zonal statistics as table’ tool was used to sum the pixel values within each polygon. Finally, using the field calculator, this sum was divided by 1600 to convert the density back into a population count. The value of 1600 was used because that is the number of 25m by 25m squares in a single square kilometer.

Appendix 3: Impacted Populations in Burrard Inlet

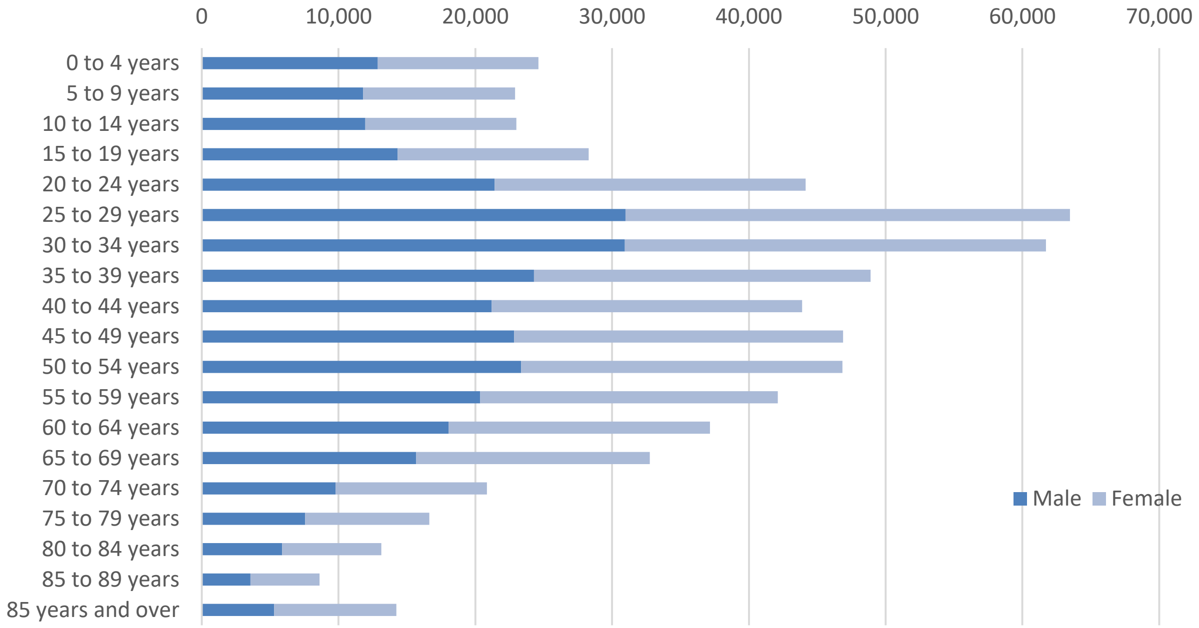
City of Vancouver

Figure 3: Distribution of population in Vancouver, CY by broad age group



Data Source: Statistics Canada, 2016 Census of Population

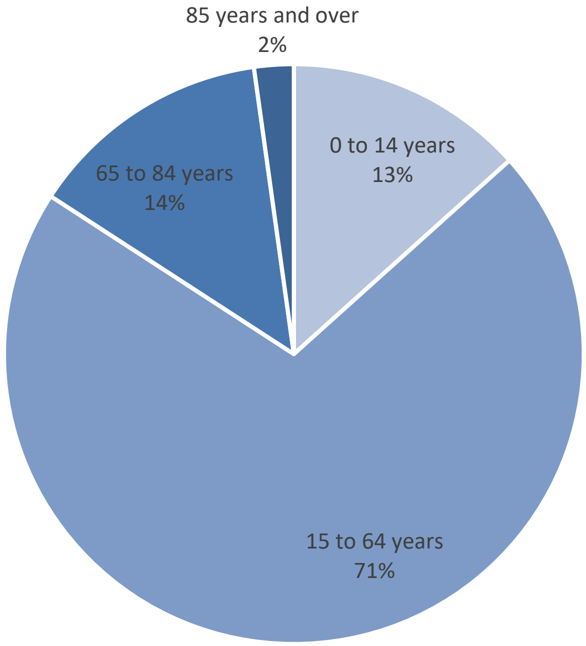
Figure 4: Population of Vancouver, CY by 5-year age group and sex



Data Source: Statistics Canada, 2016 Census of Population

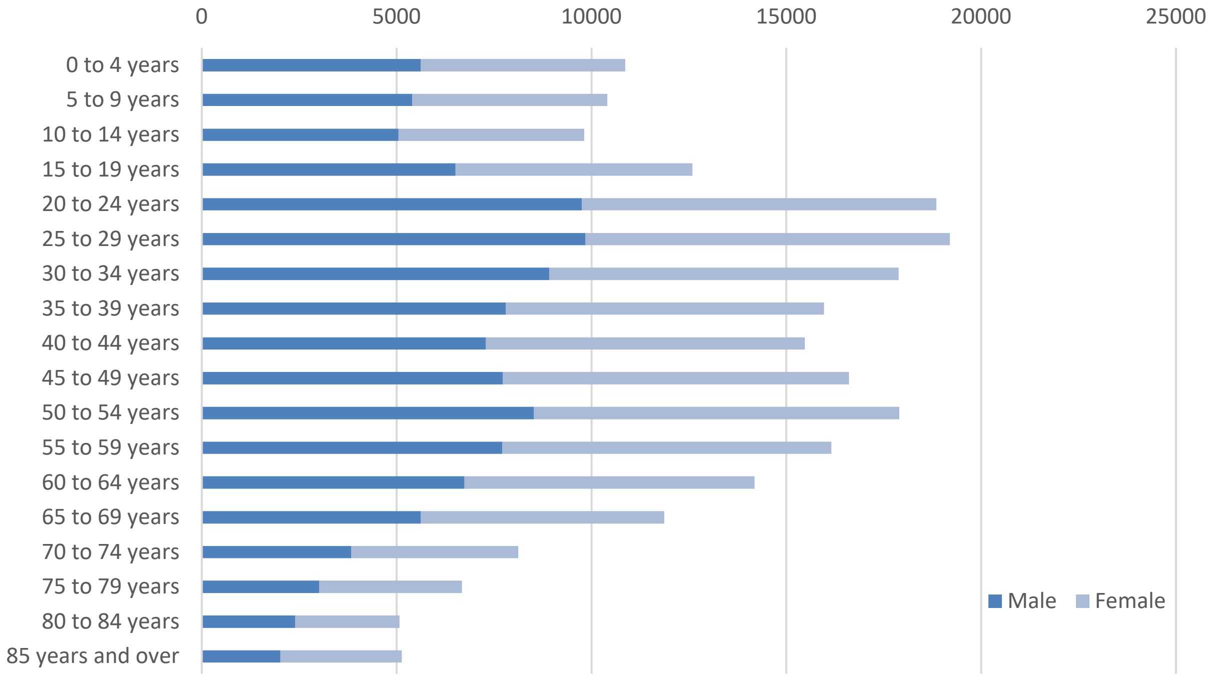
City of Burnaby

Figure 5: Distribution of population in Burnaby, CY by broad age group



(Data Source: Statistics Canada, 2016 Census of Population)

Figure 6: Population of Burnaby, CY by 5-year age group and sex

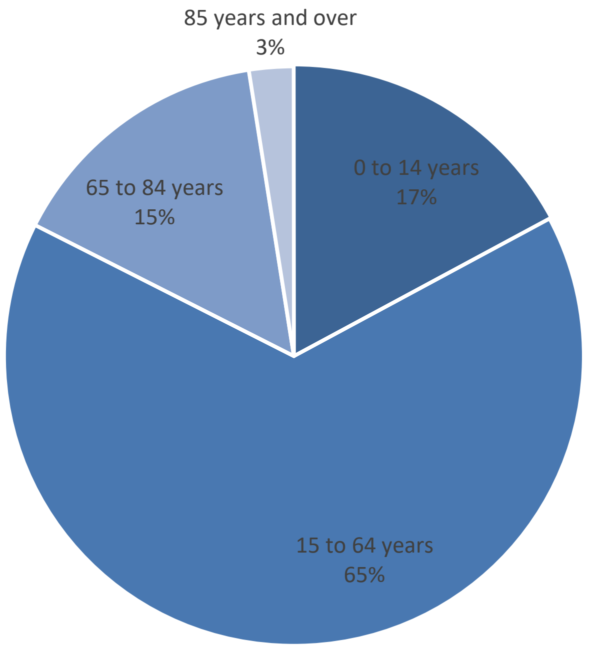


(Data Source: Statistics Canada, 2016 Census of Population)

<u>North Shore</u>

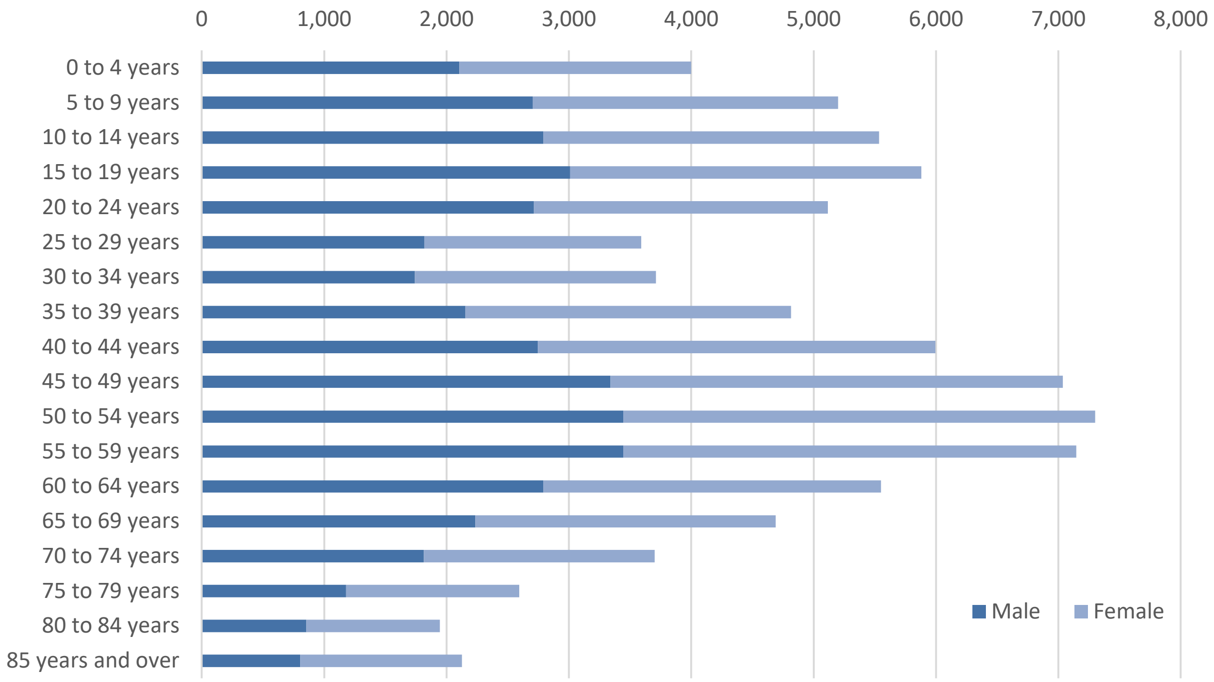
District of North Vancouver

Figure 7: Distribution of population in the District of North Vancouver, by broad age group



Data source: Statistics Canada, 2016 Census of Population

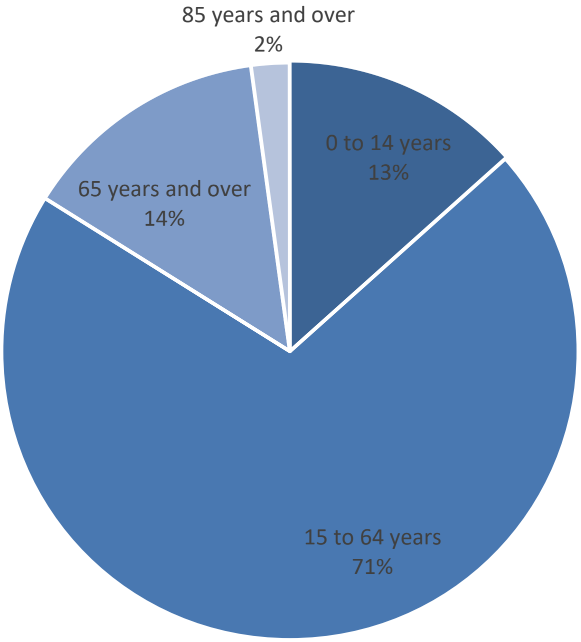
Figure 8: Population of the District of North Vancouver, by 5-year age group and sex



(Data source: Statistics Canada, 2016 Census of Population)

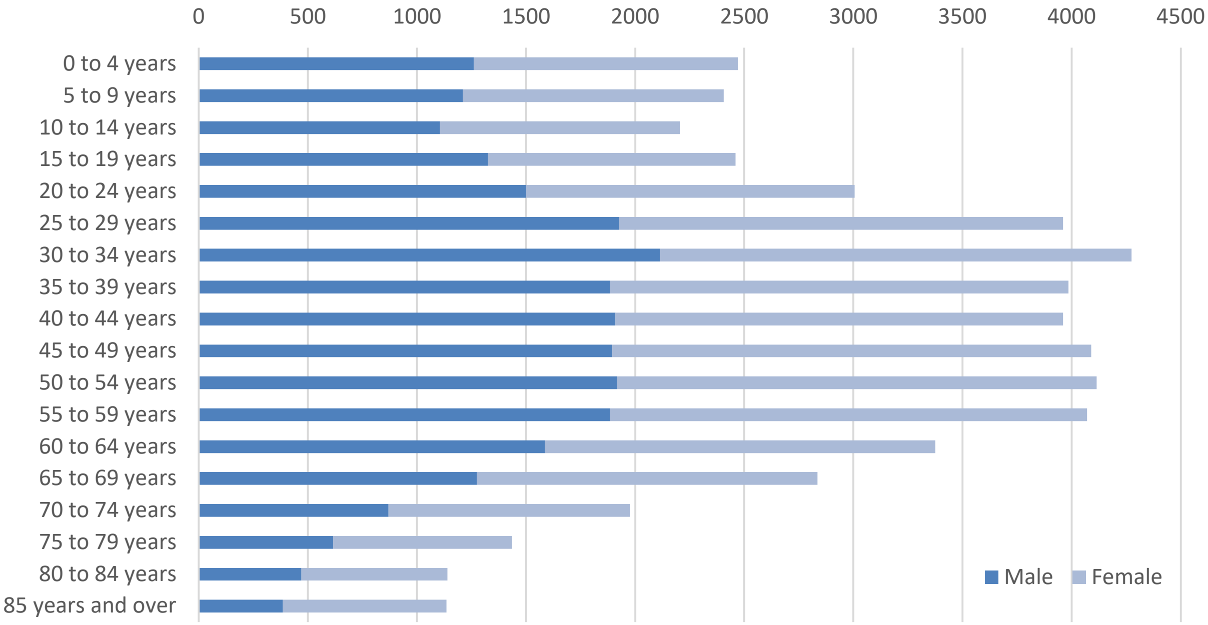
City of North Vancouver

Figure 9: Distribution of population in the City of North Vancouver, by broad age group



(Data source: Statistics Canada, 2016 Census of Population)

Figure 10: Population of the City of North Vancouver, by 5-year age group and sex



(Data Source: Statistics Canada, 2016 Census of Population)