CLIMATE CHANGE AND HEALTH VULNERABILITY AND CAPACITY ASSESSMENT

VANCOUVER COASTAL HEALTH AND FRASER HEALTH

FEBRUARY 2022

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Vancouver Coastal Health

Acknowledgements

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The offices where this work was carried out are located on the unceded territories of the xʷməθkʷəy̓əm (Musqueam), Sḵwx̱wú7mesh (Squamish), and Sel̓íl̓witulh (Tsleil-Waututh) Nations, and the work of our organizations takes place in numerous territories and Métis chartered communities in the regions. We approach our work with Indigenous leaders and knowledge keepers with a commitment to respect and reconciliation, and acknowledge the leadership role that all of the First Nations within the Vancouver Coastal Health and Fraser Health regions play in creating healthy, equitable, resilient communities.

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Executive summary

Vancouver Coastal Health (VCH), Fraser Health (FH), Health Emergency Management BC (HEMBC), and VCH/FH Facilities Management (FM) partnered on a three-year Health Canada-funded grant to undertake a climate change and health vulnerability and adaptation assessment. In the first of two phases of the HealthADAPT project, a vulnerability and capacity assessment has been produced that assesses the degree to which population health, health care facilities, and certain health services are susceptible to, and prepared for, the effects of several climate-sensitive hazards.

Key findings include:

- The connection between climate change and negative impacts to human health and the health system is strong, especially so during recent extreme heat, smoke, and flooding events.
- **Extreme heat** events like the one that occurred in June 2021 will become much more common as the global climate warms, intensifying impacts to population health and the health system.
- **Wildfire** risk is expected to increase in BC as the climate changes. In addition to direct impacts from fire, the smoke from wildfire events contributes to poor air quality, in addition to other climate related air quality impacts of increased ground-level ozone, and longer pollen seasons.
- **Flooding** from extreme precipitation and coastal storm surge will intensify as climate change alters hydrological regimes and sea levels rise. Windstorms are expected to remain a feature of the regional climate, although there is low confidence in future projections. These events will continue to create risk for electricity distribution systems, and health impacts will be heightened when they occur alongside flooding, extreme heat, or poor air quality.
- Changes to our climate will contribute to conditions favourable to the spread of **infectious disease**, including water- and food-borne diseases (e.g., *Vibrio*), Legionellosis from contaminated water, Lyme Disease, and other less prevalent diseases including those acquired outside of Canada. Not enough is known about the changing epidemiology and ecology of many of these diseases and precautions should be taken to avoid dismissing risks.
- **Changes to our ecosystems** from increasing annual temperatures, ocean warming and acidification, and longer periods of drought are likely to exacerbate the conditions that lead to increased exposure to environmental toxins including blue-green algae and toxins that lead to marine shellfish poisoning. These general changes will likely create widespread mental health challenges. Indigenous communities may be uniquely impacted when cultural practices centred around traditional foods and medicines are affected.
- Many of the impacts described above disproportionately affect populations that already experience **health inequities**, including those experiencing socioeconomic deprivation including poverty and under-housing, those experiencing social isolation, older people, and people with disabilities.
- **Indigenous people** and First Nations communities in the VCH and FH health regions are impacted in unique ways by a changing climate. Many Indigenous-led adaptation efforts are underway, as are efforts by the health sector to centre and respectfully support this work.
- An assessment of existing levels of preparedness and capacity indicates a moderate amount of existing health authority activities and collaboration relating to the management of many climate-related health risks. There is a need for more consistency across the health regions, deeper collaborations and public health leadership, and stronger advocacy for climate resilience.

The full assessment is presented below and a fully designed **summary report** is available as a PDF. A *Climate Change and Health Adaptation Framework* for VCH and FH will follow after additional internal and external engagement. This framework will help define the health authorities' role in climate change and health adaptation by presenting priorities and actions corresponding to the risks and gaps identified in the vulnerability and capacity assessment, and based on guidance from our many collaborators and advisors.

1. Introduction

Vancouver Coastal Health (VCH), Fraser Health (FH), VCH/FH Facilities Management (FM), and Health Emergency Management BC (HEMBC) partnered on a three-year project with support from Health Canada to undertake an integrated climate change and health vulnerability and adaptation assessment. This project (“HealthADAPT”) has the following objectives:

1. Conduct a climate change and health vulnerability and capacity assessment;
2. Identify adaptation needs and options through iterative stakeholder engagements and stress testing;
3. Understand the knowledge translation needs of stakeholders and disseminate knowledge relating to impacts, vulnerabilities, and adaptation options;
4. Pilot the inclusion of the climate change adaptation lens into existing policies and programs as opportunities arise;
5. Create a coordinated, integrated, and multi-agency approach and action plan for adapting to climate change and building health system resiliency.

This report summarizes all of the activities and findings involved in accomplishing the first objective, and provides the fundamental information required to achieve the remaining ones.

1.1 Context

The global climate is changing and there is currently a “40% chance of the annual average global temperature temporarily reaching 1.5°C above the pre-industrial level in at least one of the next five years” (World Meterological Association, 2020). Climate models predict significant changes to regional climate characteristics when global mean temperatures consistently exceed 1.5° (IPCC, 2018). These changes will exacerbate all of the climate hazards described in this report. Temperatures are expected to rise to at least 2°C this century, with temperature rise in excess of 3°C being the most likely outcome given our current trajectory (United Nations Environment Programme, 2020). It is likely that the global average temperature will reach a 2°C increase between 2041 and 2052 (Milman, Witherspoon, Liu, & Chang, 2021). Leading scientists also note the risk that self-reinforcing feedbacks will push the global climate across a planetary threshold that could prevent stabilization of the climate, even as human emissions are reduced (Lenton et al., 2019; Steffen et al., 2018).

The annual Lancet countdown on health and climate change emphasizes that climate change is the greatest global health threat facing the world in the 21st century, but it is also the greatest opportunity to redefine the social and environmental determinants of health (Watts et al., 2019). The human health and health system impacts of climate change are receiving increasing focus in Canada, and calls for climate change and health adaptation are common, including in the forthcoming *National Adaptation Strategy* (Government of Canada, 2021a) Climate change is recognized as a top health priority in several federal initiatives (Council of Canadian Academies, 2019; Government of Canada, 2018; Public Health Agency of Canada, 2019). Health Canada is also leading a forthcoming (Q3 2021) national knowledge assessment—Health of Canadians in a Changing Climate—that will provide an in-depth assessment of the risks of climate change to human health and to health systems, and is relied upon throughout this assessment.

During the development of the forthcoming provincial climate preparedness and adaptation plans, the BC Government surveyed people across BC in late 2019. Nearly 3,000 respondents shared their thoughts and concerns around climate change impacts and provided their ideas on supports and actions to help prepare. Mental and physical health impacts had the highest rankings, and the results highlighted unique impacts to Indigenous communities including cultural impacts resulting from a loss of hunting, fishing or wild harvesting opportunities. Forty percent of respondents said they would rely on public sector organizations to prepare (BC Ministry of Environment and Climate Change Strategy, 2020).

This public sentiment is mirrored by decision-makers at the highest levels within BC. In a press release for the community vulnerability index project described below, BC Minster of Health, Adrian Dix, said "we know that climate change is affecting the health of British Columbians, and will continue to pose challenges in the future" and that the health authorities can "help communities and governments better understand and respond to the climate change-related health risks at a local level." This support was further reflected in a recent UBCM panel discussion featuring the Minister of Health, Provincial Medical Health Officer, lead researcher from BCCDC, and others.

This political will is complemented by research and communication efforts across a range of institutions including BC Centre for Disease Control (BCCDC), National Collaborating Centre for Environmental Health (NCCEH), Metro Vancouver, Government of BC's Climate Action Secretariat, and many others. Impacts to health have been considered in some climate risk assessments conducted by local governments and others, and the Government of BC's preliminary strategic climate risk assessment considered direct and indirect (e.g., impacts to social determinants of health) impacts to physical and mental health and identified significant consequences across a range of hazards (BC Ministry of Environment and Climate Change Strategy, 2019). In November 2021 a Nelson, BC-based doctor curiously, and perhaps presciently, captured the world's attention by likely being the first physician to diagnose a patient with "climate change" (Sajan, 2021).

All of this amounts to a window of opportunity for the four project partners to strengthen their leadership in this context. This opportunity is recognized by Health Canada's HealthADAPT funding itself, and by the award of funding to the four project partners.

1.2 Climate change and health overview

1.2.1 Population health

British Columbia is already experiencing the effects of global climate change: average temperatures are increasing, variable and extreme weather is becoming more frequent, and sea levels are rising (BC Ministry of Environment and Climate Change Strategy, 2019). These broad changes will increase the frequency and intensity of a variety of climate-sensitive hazards. Generally speaking, the warmer it gets, the greater the risks.

Literature review and expert engagement suggests that the climate-sensitive hazards below are already leading to—or will soon lead to—negative impacts to population health and health systems in VCH and FH. Figure 1details the primary hazards and lists some of the common impacts to population health and the health system.[1] More details on the health impacts from these climate-sensitive hazards can be found in the sections below.[2]

Changing environmental conditions are themselves a determinant of health that impact food systems, water security, people's ability to use active modes of travel, to recreate outside, livelihoods, etc. The field of public health has taught us that these determinants affect individual health, community health and resilience, and overall population health. Successful adaptation to a changing climate will not only keep people healthy, but also has the likely benefit of reducing health system demand.

[1] For a detailed overview of the pathophysiology associated with many common climate-sensitive hazards, see the Pan American Health Organization (2020).

[2] Figure 1 does not reflect the compounding effect that occurs when two or more hazards occur at the same time, which is a nascent and rapidly evolving research area (Ebi, Vanos, et al., 2021; Simpson et al., 2021). The same is true for cascading impacts, where impacts in one part of the health system (e.g., overheating in a person's home due to a power outage) creates impacts elsewhere in the health system.

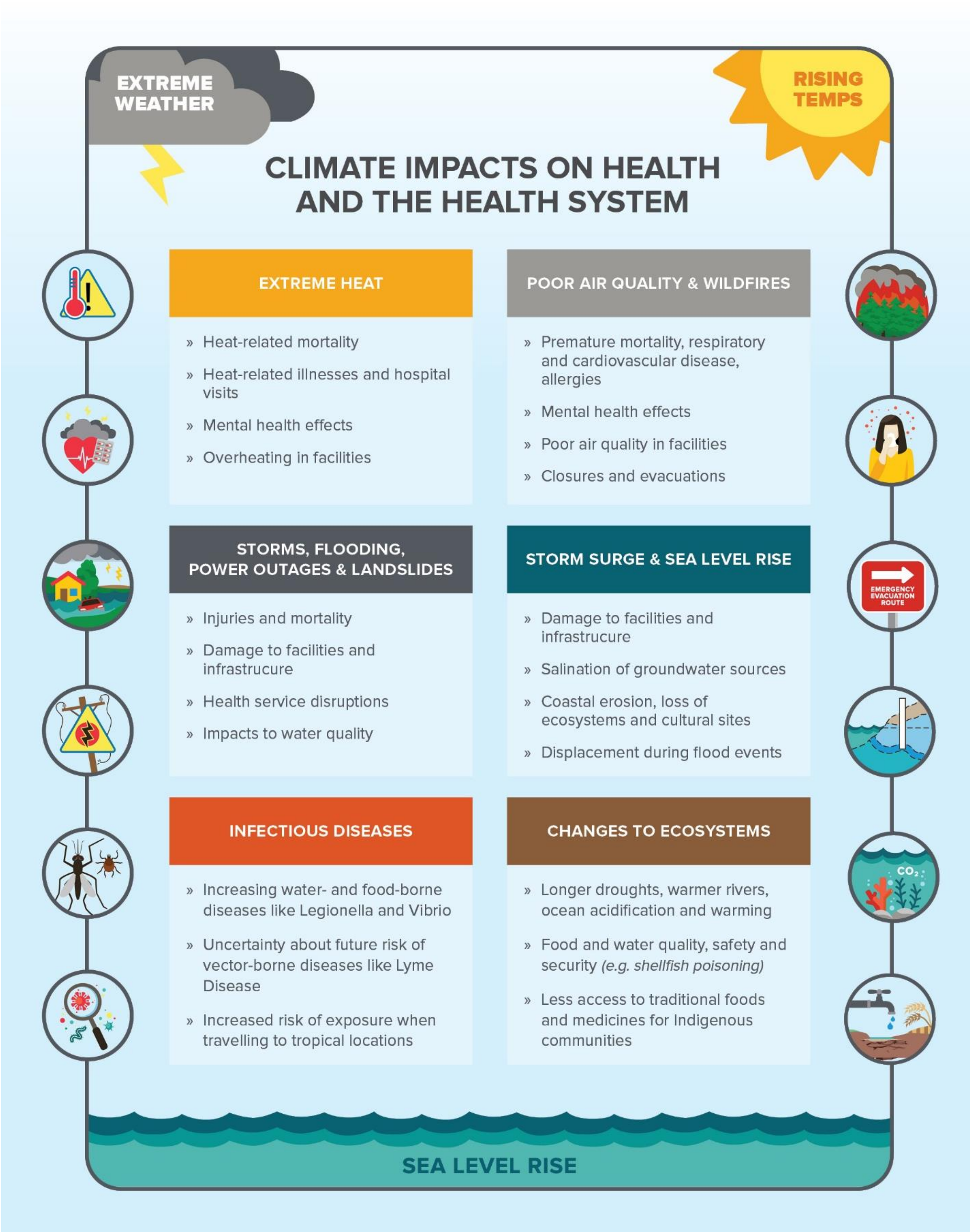

Figure 1: Climate hazards and impacts for VCH and FH health regions.

1.2.2 Mental health and wellness

The Public Health Agency of Canada defines mental health as "the capacity of each and all of us to feel, think and act in ways that enhance our ability to enjoy life and deal with the challenges we face." Mental health is located in the larger domain of psychosocial wellbeing, which links psychological and social wellness. Psychosocial wellbeing is affected by social, spiritual, ecological, historical, and economic circumstances and/or determinants (Hayes & Poland, 2018). This conceptualization is very similar to Indigenous conceptualizations of health and well-being that are discussed elsewhere (First Nations Health Authority, 2020b).

Mental health impacts result from a number of direct (e.g., anxiety during extreme weather), and indirect (e.g., stress from economic loss due to displacement, impacts on cognition from wildfire smoke) climate-related pathways. These pathways can lead to post-traumatic stress disorder (PTSD), depression, anxiety, complicated grief, survivor guilt, vicarious trauma, recovery fatigue, substance abuse, suicidal ideation, financial and relationship stress, and increased risk of violence and aggression (Clayton, Manning, Speiser, & Hill, 2021; Hayes, Blashki, Wiseman, Burke, & Reifels, 2018). The burden of illness, including mortality, is significantly increased for those experiencing mental illness (Galea & Ettman, 2021).

In developing the provincial climate preparedness strategy, the Climate Action Secretariat conducted engagement with residents of BC between November 7, 2019 and January 10, 2020. Mental health impacts were the second highest rated impact—behind physical health impacts—from respondents when asked about impacts to them or their communities (BC Ministry of Environment and Climate Change Strategy, 2020).

The mental health impacts caused by climate-sensitive hazards are often overlooked, and only beginning to be included in climate and health vulnerability assessments (Hayes & Poland, 2018). This report uses existing data to assess the mental health impacts associated with each of hazards of interest for people with and without existing mental illness. It also has started the process of assessing impacts to mental health services delivered by VCH and FH, but results are limited.

Climate grief

Climate grief—also sometimes referred to as ecological grief or solastalgia—reflects the loss that people feel as their ecosystems, landscapes, and sense of place is complicated by climate change (Cunsolo & Ellis, 2018). This is common, for example, following wildfire events (D. P. Eisenman, Kyaw, & Eclarino, 2021). For example, experts say the destruction of Lytton will have mental health ramifications across BC (Ghoussoub, 2021).

1.2.3 Health system

Health systems are complex, comprised of people, organizations and institutions, facilities, and resources that interact to support individual and population-level health (Ebi et al., 2019). Beyond iconic elements like ambulances, hospitals and doctors, health systems include diverse services like home visits by nurses, community cooling centres, supply chains, emergency management coalitions, and much more (*see* Section 9 for more detail). Health systems vary from place to place. In Ontario, for example, public health agencies are either autonomous or integrated into municipal structures whereas health authorities in BC encompass a more monolithic approach to health service delivery with public health and health care services falling under one organization.

The health system is networked and collaborative, requiring multiple entities to work together towards shared objectives. For example, Figure 2 shows how the First Nations Health Authority (FNHA) describes their work with community (on-reserve), health service organizations and health system partners in BC to support First Nations access to culturally safe, quality care and services with the goal of improved health and wellness outcomes (First Nations Health Authority, 2020a).[3]

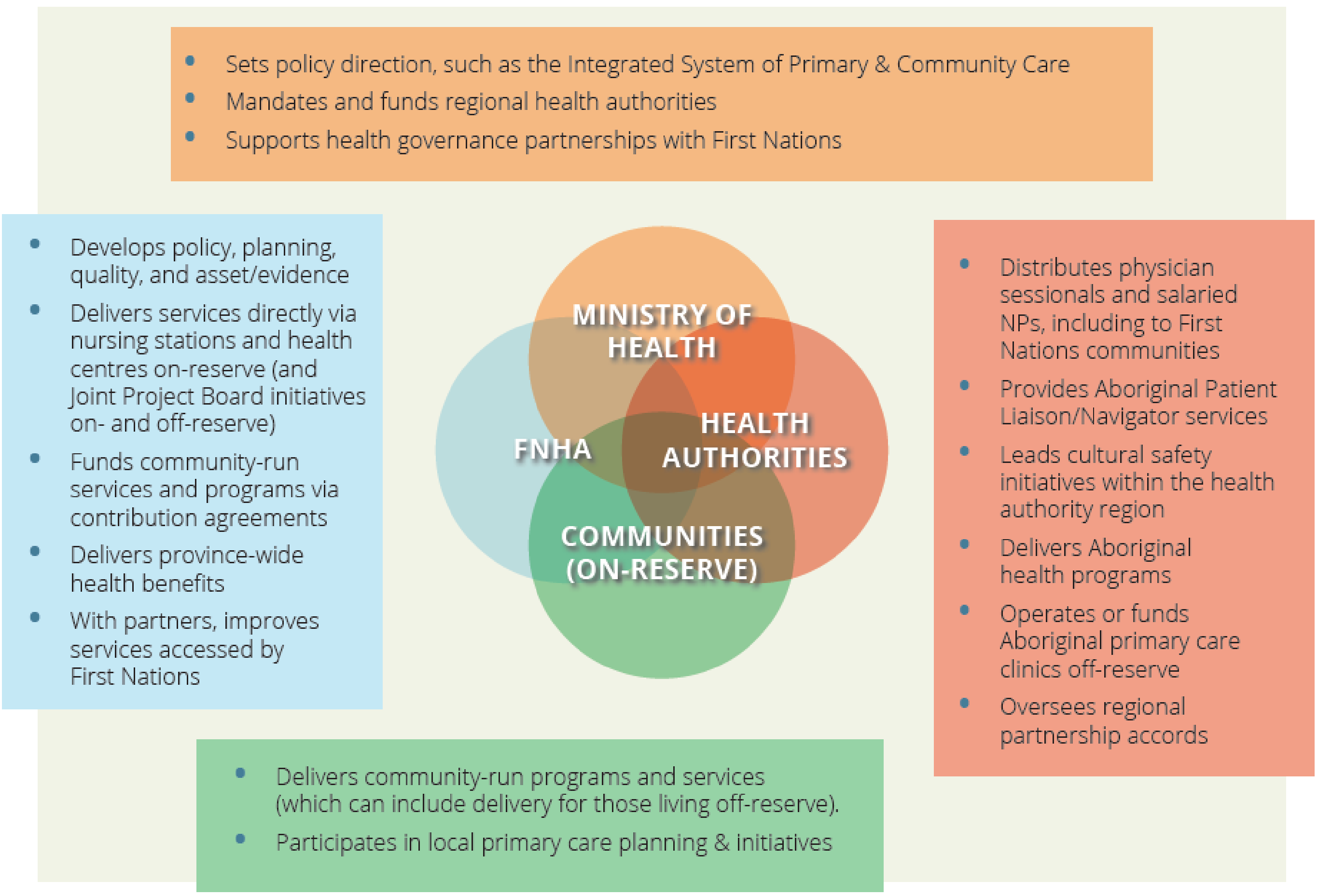

Figure 2: FNHA conceptualization of the health system (First Nations Health Authority, 2020a)

In addition to conceptualizing health system elements, it is important to understand how climate change affects health systems, as well as the components of a resilient health system. The most preeminent conceptualization of health system resilience health system resilience comes from the

[3] For a more detailed description of the Indigenous health landscape see *Fraser Health Indigenous Adaptation Landscape* report, available upon request.

World Health Organization (WHO) presentation of 10 key components that health organizations need to address in order to be better able to anticipate, prevent, prepare for and manage climate-related health risks. These components are:

- Leadership and governance
- Health workforce
- Vulnerability, capacity and adaptation assessment
- Integrated risk monitoring and early warning
- Health and climate research
- Climate-resilient and sustainable technologies and infrastructure
- Management of environmental determinants of health
- Climate-informed health programmes
- Emergency preparedness and management
- Climate and health financing

1.2.3.1 Health care facilities

The impacts of climate change are particularly disruptive for individuals and communities when they affect health care facilities. A number of direct and indirect hazards can negatively impact all types of facilities (World Health Organization, 2020). VCH and FH operate and oversee hospitals, primary care clinics, community health centres, long-term care facilities, hospices, licensed child care facilities, etc., all of which will be impacted as the climate changes (*see* Figure 3).

Climate risks and impacts create challenges for the capital planning phase of health care facilities, as well as during operations over the course of the facility's service life. Cascading impacts on health staff and patients, communities and critical infrastructure create additional challenges. Hazard specific impacts are discussed in the respective hazard sections, and cascading impacts are discussed in the health system resilience chapter.

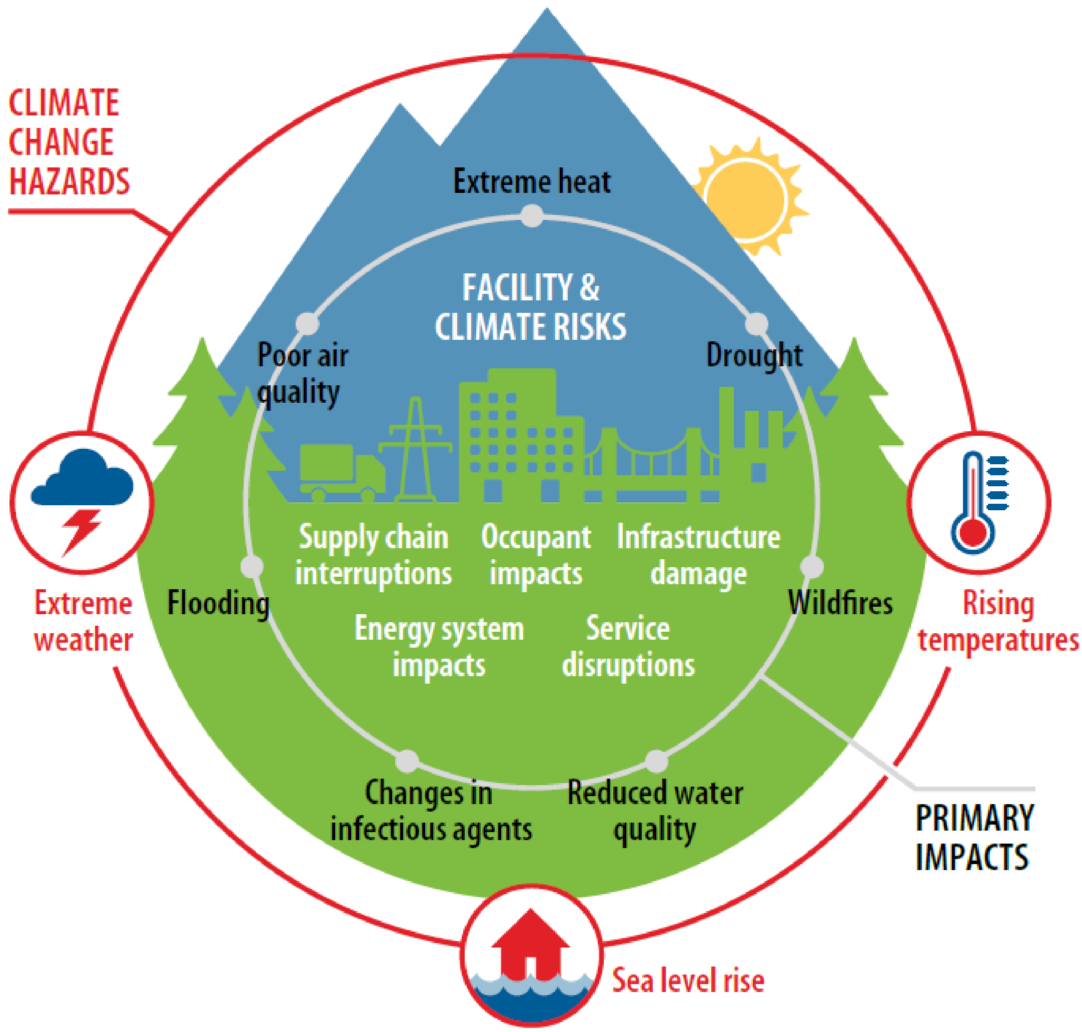

Figure 3: Image from Public Sector Organization Climate Risk Reporting – Draft Policy Proposal for Comment (BC Ministry of Environment and Climate Change Strategy)

1.3 Project partners

This vulnerability and capacity assessment represents a partnership between Vancouver Coastal Health, Fraser Health, VCH/FH Facilities Management, and HEMBC. This partnership was created to integrate the currently fragmented approach to climate change and health vulnerability assessment within—and between—the four organizations. This approach supports the creation of adaptation options that are co-produced by organizations who play a complementary role in ensuring healthy communities and resilient health systems. This integration will be reflected in the forthcoming adaptation framework, which will be a coordinated, integrated, and multi-agency action plan for adapting to climate change and building health system resilience.

Vancouver Coastal Health

VCH is responsible for the delivery of $4.1 billion in community, hospital and long-term care services to more than one million people in communities including Richmond, Vancouver, the North Shore, Sunshine Coast, Sea to Sky corridor, Powell River, Bella Bella and Bella Coola. While many of VCH's services are offered in the 13 hospitals, other services include:

- Primary care
- Community-based residential and home health care
- Mental health and substance use services
- Public health
- Hospital care
- Research

VCH supports the health and well-being of Indigenous people in First Nations communities and urban and away- from-home populations (*see* Figure 2). Indigenous Health is an organizational priority for VCH—along with Diversity, Equity and Inclusion, and Planetary Health. More detail on these populations, and on their contribution to this assessment is described below.

VCH and FH deliver a wide variety of services including those delivered in hospitals, primary care clinics, community health centres, hospices, and long term care facilities, those delivered in the community or in people's homes, and those carried out by the various public health programs.

Fraser Health

Fraser Health is responsible for the delivery of hospital and community-based health services to over 1.8 million people in 20 diverse communities from Burnaby to Fraser Canyon on the traditional territories of the Coast Salish and Nlaka'pamux Nations. Their communities include a diverse multicultural population and approximately 62,000 Indigenous Peoples, associated with 32 First Nation communities and 5 Métis chartered communities. Services include:

- 12 acute care hospitals from Burnaby to White Rock to Hope
- An outpatient care and surgery centre
- 7,760 long term care beds
- Mental health care
- Public health
- Home health services
- Community care

VCH/FH Facilities Management

VCH/FH Facilities Management (FM) supports Fraser Health Authority (FH), Providence Health Care (PHC), Provincial Health Services Authority (PHSA), and Vancouver Coastal Health (VCH) in the planning, design and operation of their health care facilities. For five years, Vancouver Coastal Health and Fraser Health have been supported by a regional shared service, Climate Risk & Resilience program, which strives to ensure that health facilities enable and safeguard high quality, reliable and continuous health service delivery in the face of current and projected climate-related risks. A primary focus of this team's efforts is on capital projects (e.g., new hospitals), but the team also focuses on existing facilities, critical infrastructure interdependencies, supply chain issues, and service provision.

Health Emergency Management BC

HEMBC helps to ensure that the health system can effectively respond to, and recover from, emergency events while continuing to deliver safe, quality care. They work to minimize impacts of climate-sensitive hazards on the health system, for example when there are evacuations, or loss of power or other utilities, or when transportation disruptions make it difficult for patients, health care workers, and supplies to reach their destinations. HEMBC was created in 2013 to consolidate the emergency management programs from across BC's health system into one program that provides the following:

- Monitor BC's disaster risk;
- Helps prepare the health system for emergencies;
- Supports the response to emergency events.

During the vulnerability and capacity assessment, HEMBC provided information about observed and predicted impacts, and will help compile a list of ongoing and proposed actions. Their inclusion in the project aligns with calls in the academic literature to build the links between disaster risk reduction and climate change adaptation in health (Banwell, Rutherford, Mackey, & Chu, 2018) and to adopt a health equity lens in emergency management (Spence, Kara, Plamondon, Astle, & Joe-Ikechebelu, 2020).[4]

[4] HEMBC overview video: www.youtube.com/watch?v=t4_s0kx2rp4&feature=emb_title

2. Methodology

Climate change and health vulnerability assessments assess the degree to which individuals, communities, facilities, and the services delivered by the health system, are susceptible to, and prepared for, the effects of climate change (Buse, 2018). Vulnerability is commonly conceptualized as a composite of exposure, sensitivity, and adaptive capacity, all of which function slightly differently when applied to individuals and communities, facilities, and the broader health system.

In all cases, adaptive capacity is meant to reflect the ability to adjust to climate change and to reduce associated risks. This ability, or capacity, is informed in part by existing assets and initiatives. For example, people living in Vancouver will be increasingly exposed to extreme heat events, but the baseline of adaptive capacity (e.g., cooling centres operated by the City in public buildings) reduces overall vulnerability. As such, an important component of this vulnerability and capacity assessment is an inventory that reflects internal and external initiatives that directly or indirectly increase adaptive capacity (*see* "Adaptation inventory" section for each hazard).[5] The concept of resilience is most closely related to adaptive capacity and is often a response to exposure and sensitivity. This is explained in more detail in Section 9.

A vulnerability and capacity assessment facilitates evidence-based decision making about which climate-sensitive hazards and attendant impacts to prioritize, typically in the next five years. A small number of completed assessments exist (e.g., Berry, Paterson, & Buse, 2014; Oregon Health Authority, 2014; San Francisco Department of Public Health, 2017; Schnitter et al., 2019; Simcoe Muskoka District Health Unit, 2017). Health Canada has developed a preliminary climate change and health vulnerability and adaptation assessment methodology based on work by the WHO and the Government of. This pilot methodology has informed VCH and FH's vulnerability and capacity assessment, and will also inform the forthcoming adaptation framework. In order to contribute to practice in this area, footnotes will be added to let the reader know which steps of the workbook correspond to sections of this assessment.

As is common practice, adaptation planning will be revisited approximately every five years, ideally aligned with similar reevaluations by the BC Climate Action Secretariat and Ministry of Health.

Data collection

This vulnerability and capacity assessment focuses on various components of the health system, including population and public health, health care facilities, health services, and health emergency management. Table *1* summarizes the methodology for the HealthADAPT project, with more detail provided below.

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[5] Note: due to capacity, the efficacy of existing programs will not be evaluated per guidance from Health Canada (Step 2e of the workbook). This will be, however, added to the forthcoming adaptation strategy.

Table 1: Summary of compiled data and information for HealthADAPT vulnerability and capacity assessment.

	Data sources
Population health	• Historical health outcome data from internal and external studies, discussions with experts, and community engagement • Future burden of illness projections from external studies • A community climate vulnerability index that spatially represents variations in community vulnerability to four climate hazards in the VCH and FH health regions • Adaptation inventories for each hazard containing initiatives that aim to improve health outcomes or health system resilience, including those delivered by allied organizations • Stress testing exercise designed to surface impacts to priority populations, and insights into health system functionality and resilience (delayed due to COVID-19)
Health care facilities	• Observed and anticipated impacts for a variety of facilities, using internal and external studies, and results from completed site-level vulnerability and risk assessments and emergency management planning initiatives • Results from a critical infrastructure interdependencies project overseen by FM • An inventory of existing initiatives that aim to increase resilience of facilities, health services, and communities
Health system	• Health system resilience indicators (delayed due to COVID-19) • A list of observed and anticipated impacts for heat and air quality generated via internal engagement with health authority staff and community engagement • Stress testing exercise • An inventory of ongoing and proposed initiatives for select health services • Outcomes from an internal stress testing exercise with FH staff

* Projections of future risks will be presented for the period from 2040-2059—the same timeframe used in the BC provincial risk assessment. Where appropriate, risks beyond 2050 will be assessed.

Where possible, findings will be disaggregated geographically, for example for urban and rural settings, or for distinct regions within VCH. For example, community engagement is taking place with First Nations in the Central Coast, where the context is much different than other regions in VCH. This will result in the identification of impacts and adaptation initiatives that are specific to the region. While it would be desirable to disaggregate results for many subregions, this was not be possible given the resources available for this work.

2.1 Population health

The following data sources will be used to assess the physical and mental health impacts of climate change for VCH and FH:

1. Health outcome studies and projections;
2. Community climate change vulnerability index;

3. Evidence collected during community engagement.

2.1.1 Health outcome studies and projections

When available, internal studies have been used to demonstrate the historical disease burden (e.g., emergency department visits during wildfire smoke events) associated with heat, air quality, and extreme weather events. Relevant regional literature augments these findings (e.g., studies published by BCCDC) to address data gaps. A selection of international work has also been included.

Figure 4 is commonly used by public health professionals to communicate how health impacts from various exposures manifest in populations. It shows ways that health impacts can be characterized, and also serves as a reminder that health statistics often only reflect a small proportion of the number of people impacted by a specific exposure. Consequently, results can be skewed towards what is collectable, and can create an inaccurate picture. The various categories were used to guide data collection for each of the climate-sensitive hazards.

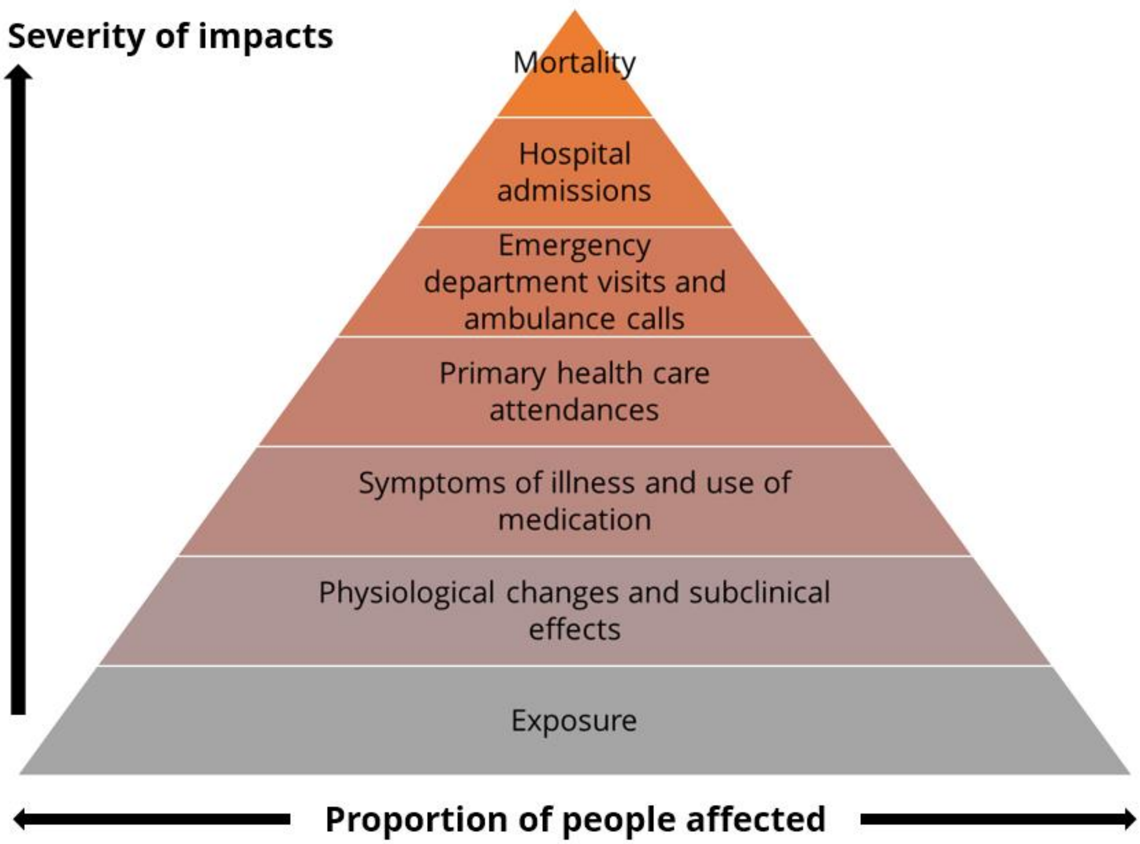

Figure 4: Adapted the air pollution pyramid that is commonly used to describe the spectrum of health impacts from exposure to air pollution (original source). Addressing exposure helps to promote and protect health as well as reduce negative impact and demand for health care outlined in the other levels of the triangle.

Where data exists, future disease burdens have been included in order to demonstrate how certain health impacts will change over time. A comprehensive burden of illness assessment was planned at the outset of the HealthADAPT project but could not be completed due to resource challenges. Results have been retrieved from relevant studies, including recent work by the Canadian Institute for Climate Choices (Canadian Institute for Climate Choices, 2021).

2.1.2 Climate vulnerability index and mapping

Working in partnership with researchers from UBC, VCH and FH have released a series of maps that spatially represent community vulnerability to four climate hazards (heat, smoke, ozone, and flooding). The maps were originally inspired by similar work in San Francisco department of public health, and are meant to advance the collective understanding of what makes individuals and communities vulnerable to climate change, and to contribute to conversations about community climate resilience.

The maps display a climate vulnerability index that contains variables that were identified via an extensive systematic literature review of hundreds of journal articles. The maps demonstrate the disproportionate impacts of climate change, and the need to consider the social determinants of health. Maps like these are foundational to creating equitable outcomes (PlanH, 2020) and VCH and FH have been sharing these with partners in local government and elsewhere since their release in August, 2020. Updates were performed in 2021 and all images that appear herein represent updated modelling and images.

2.1.3 Community engagement

Collaboration with communities, and with allied organizations is an essential part of climate change and health adaptation (Fox, Zuidema, Bauman, Burke, & Sheehan, 2019). Community engagement leads to a comprehensive understanding of vulnerability, as well as to adaptation strategies that are informed and supported by community health priorities.

Public Health at VCH—where the HealthADAPT project is managed—regularly collaborates with local municipalities including city/district planners, engineers, and air quality regulators on a number of topics including built environment, housing, transportation, drinking water quality, and air quality. The same is true for FH.

Since its design, this project has aimed to document potential actions that will enhance the ability of health agencies to meaningfully contribute to local and regional climate change planning and further facilitate the integration of community-identified health impacts and population vulnerability into planning considerations. To better understand and develop these actions, engagement has been conducted with municipal and regional governments, First Nations, Indigenous knowledge keepers, public sector organizations, non-profits/NGOs, researchers, and private sector organizations. This engagement does not assess the extent to which an external health-related service provider is vulnerable to climate change. Instead, these organizations are engaged to improve our understanding of impacts, vulnerability, and existing initiatives, and to contribute to the creation of the forthcoming adaptation framework.

Capacity constraints and COVID-related delays meant that not all communities, partners, and stakeholders in VCH and FH could be engaged during this phase of the project. In line with the project's aspirations, and with strategic priorities for VCH, communities in the Central Coast region were prioritized for engagement. This process includes Heiltsuk Nation, Kitasoo/Xai'xais Nation, Nuxalk Nation, Wuikinuxv Nation, and the Central Coast Regional District. These coastal communities face particular challenges related to climate-sensitive hazards, access to resources, limited transportation options in and out of the community, and negative impacts to traditional food and medicine sources and cultural practices.

In FH, an opportunity to engage communities with the health community partnership tables was pursued. Additionally, engagement with rural, remote, and/or Indigenous communities in the Fraser East region was prioritized. Sessions completed to date focused on current and future impacts to community health, focusing on populations placed at risk and how Fraser Health can support local government and community organizations as they undertake climate change adaptation initiatives. Sessions have been completed in the following communities:

- Boothroyd First Nation
- Spuzzum First Nation
- Coquitlam, Port Coquitlam, Port Moody, Anmore, and Belcarra (i.e., Tri-Cities Healthy Community Partnership)
- Chilliwack
- Hope
- Abbotsford (limited session focused on the climate vulnerability index)

Results from these engagement efforts are included below in the respective sections, and are available upon request. In addition to the completed engagement sessions above, a joint external engagement session was held on November 3, 2021, and included over 80 participants from a range of organizations. A full summary is available.

2.2 Health system resilience

Findings relating to health system resilience were difficult to produce given the already large scope of the HealthADAPT project. A pilot methodology for assessing health system resilience was developed (see Section 9) however it was not utilized due to capacity constraints and leadership on health system resilience by BC's Ministry of Health. Still, useful information has been presented in Section 9 that represents leading work by the four project partners and others. Also, various insights were collected about the impacts of climate change of health service delivery within VCH and FH, and these have been shared throughout the report.

2.2.1 Vancouver Coastal Health services

VCH Public Health provides a number of services that were included in this assessment. These include:

- Environmental health and the healthy environment program
- Public health surveillance unit (PHSU)
- Population health and healthy public policy programs
- Care facility licensing (e.g., childcare, long term care)
- Aboriginal health
- Communicable diseases

Engagement with these programs focused primarily on collecting data relating to human health impacts, and identifying initiatives to include in the adaptation inventory. Continued engagement with Public Health staff will be essential in the development of the adaptation framework.

Community services

As a result of conversations with HealthADAPT steering committee members, senior leaders, and other advisors, as well as a preliminary engagement questionnaire delivered in winter 2020, the HealthADAPT project conducted pilot engagement with staff from the following home and community care service:

- **Home support** provides visits to help with daily activities (e.g., bathing), medication administration, relief for primary caregiver and are usually delivered by a personal care worker.[6]

- **Hospice palliative care** (summarized in this VCH video) provides comfort and quality of life care for people living with life-limiting illness and their families. Palliative care can be delivered in hospital, hospice, long-term care, or in people's homes. Palliative care is also delivered to people experiencing homelessness, those in shelters, and other populations that have been placed at risk.

These services are an essential part of the health system. Leaders from within these areas participated in pilot sessions aimed at improving their understanding their susceptibility and preparedness to heat and air quality (*see* Appendix for agenda and summary reports). This engagement was opportunistic, and should be augmented by more formal engagement when resources permit.

2.2.1.1 Stress test exercise

A stress test explores potential health system risks far outside the range of recent experience, and uses hypothetical scenarios that describe a situation in which it would be difficult for the health system to maintain its essential functions (Ebi et al., 2018). Stress testing helps identify health system vulnerabilities and priorities, and supports collaboration and relationship building. As described above, the stress test is also an opportunity to explore compounding hazards and impacts.

The goal of a stress testing exercise is to assess the extent to which the assembled participants could manage expected outcomes based on the scenarios, and to identify what additional initiatives (e.g., collaborations, policies, resources) would be needed to effectively handle these situations. The insights gathered, including specific actions for the four project partners, will be included in the forthcoming adaptation framework.

As Ebi et al. (2018) point out, the first step for the HealthADAPT project is to "decide which aspects of health systems and services to include, such as focusing on the preparedness of facilities and infrastructure, acute care and emergency department capacity, pharmacies, first responders, public health services, and non-governmental organizations."

Due to COVID related delays, and capacity constraints, a stress testing exercise for VCH was not conducted during the HealthADAPT project.

2.2.2 Fraser Health services

From December 2019 to January 2020, an electronic questionnaire was delivered by Dr. Martin Lavoie, Chief Medical Health Officer for Fraser Health, to all Vice Presidents, asking them to appoint a director or manager to complete the questionnaire. The questionnaire had the following objectives:

[6] A pilot assessment of a Community health centre has been cancelled due to COVID-19 related setbacks, as has engagement with staff from Pacific Spirit, Three Bridges, Robert & Lily Lee and Pender Community Health Centres, all of whom expressed interest in participating. An opportunity to engage with staff leading a redesign of the rehab/stroke program was also postposed. These activities will all be flagged in the forthcoming strategy. Similarly, leaders from Menta Health and Substance Use and Home Health expressed interest but were not able to participate due to COVID related capacity challenges.

1. Assess the impact of weather-related events on health outcomes and service delivery;
2. Inventory existing and proposed work that reduces climate risk;
3. Identify perceived staff needs with respect to climate change adaptation;
4. Identify key stakeholders and champions that can be engaged as needed.

A total of 17 responses were received from the following services (raw data available upon request):

- Abbotsford Regional Hospital
- Absence and Disability Management, Health & Safety
- Addiction Medicine
- Facilities Management
- Home Support Transition Project
- Informatics, Technology and Facilities
- Medicine, Renal Program
- Mental Health and Substance Use
- New West & Tri-Cities Health Services
- Obstetrics and Genecology
- Patient Experience
- Pediatrics
- Professional Practice
- Quality and Safety

This effort was complemented (and dwarfed) by and initiative led by Fraser Health's Culture Transformation Team, who conducted an internal environmental scan relating to climate change and workforce resilience, both of which were identified as priority topics by senior leaders. Through a review of the published peer-reviewed literature, grey literature and news articles as well as interviews with subject matter experts, the future impacts of climate change and workforce resilience were examined. Key questions raised during this exercise included:

- How do we plan for the impact of flooding on our workforce, infrastructure, facilities and access to care?
- How will Fraser Health manage the impacts of extreme heat and wildfire exposure for our staff, medical staff and patients?

In April, 2021 an opportunity was identified to engage a Regional Emergency Operations Committee that is chaired by FH's VP Pandemic Preparedness and attended by executive directors and directors from across the health system. In May 2021, members of the REOC participated in a climate change stress testing exercise that was designed to:

- Explore Fraser Health's preparedness for managing climate-related risks;
- Discover opportunities for embedding resilience in strategic planning and operations.

At the 90-minute session, participants considered two scenarios and associated discussion questions. Results for this session have been included throughout this assessment, and a full summary is available upon request.

Finally, an internal engagement session with population and public health staff was conducted on October 5, 2021. This session identified impacts to services and communities, and contributed to the adaptation inventories. A full summary is available upon request.

2.3 Climate data

Access to historical and future projections for a variety of climate-sensitive indicators is increasing (Environment and Climate Change Canada, 2020) and evolving (Bourdeau-Goulet & Hassanzadeh, 2019). Canada's Changing Climate Report is the first in-depth, stand-alone assessment of how and why Canada's climate has changed, and what changes are projected for the future (Bush & Lemmen, 2019). This was followed by the creation of Canadian Centre for Climate Services (overseen by Environment and Climate Change Canada) that works directly with decision-makers and practitioners to build capacity, for example by providing downscaled climate projection data via www.climatedata.ca.

In addition to these sources, a number of valuable local sources also exist. For example, the Pacific Climate Impact Consortium's Plan2Adapt tool can be sorted by health authority boundary to produce temperature and precipitation projections for 2020's, 2050's, and 2080's. Other resources include the 2016 Climate Projections for Metro Vancouver report—also produced by Pacific Climate Impacts Consortium, Fraser Basin Council's regional flood maps, and the localized data that appears in the 2018 report *Moving Towards Climate Resilient Health Facilities For Vancouver Coastal Health* produced by VCH/FH Facilities Management (a similar report is forthcoming for the Fraser Health Authority in 2021) have all been essential in the present project. The data needed to create climate-resilient buildings have also improved, in part as a result of the Climate-Resilient Buildings and Core Public Infrastructure Initiative (report here).

In addition to these static resources, ECCC delivers Integrated Seasonal Climate Bulletins to the health authorities to help with seasonal preparedness planning. For example, on June 17 2021 ECCC led a webinar on relevant meteorological predictions for summer in BC and Yukon. There are also a number of resources that describe the specifics risks that could result from these changes. Internationally, there is the 2018 Special Report on Global Warming of 1.5°C authored by the IPCC (IPCC, 2018). These results are contextualized to a limited degree by the Preliminary Strategic Climate Risk Assessment for British Columbia.

The hazard assumptions in this report are based on RCP 8.5, which is explained here by the Pacific Climate Impacts Consortium: "Various future trajectories of greenhouse gas (GHG) emissions are possible, and depend directly on global political initiatives and socioeconomic changes that will occur over the coming years. This report presents the internationally recognized "business as usual" greenhouse gas emissions scenario, known as Representative Concentration Pathway 8.5 (RCP8.5)… It is prudent to plan for an RCP8.5 future until global mitigation actions begin to catch up with commitments" (Metro Vancouver, 2016, p. 2).

3. Climate change and health equity

3.1 Overview

Climate change does not impact individuals and population groups uniformly. Instead, the impacts tend to correspond to existing health inequities. These differences in health status or in the distribution of health resources between different population groups arise due to individuals' and groups' relative physiological, social, political, and economic disadvantages (Public Health Agency of Canada, 2018). In the context of climate change, this means that some people and communities are more exposed to hazards, more physiologically sensitive to the hazards, and/or less able to adapt than others (American Public Health Association, 2018; H. Brown, Spickett, & Katscherian, 2014; Clean Air Partnership, 2009; Hoogeveen, Klein, Brubacher, & Gislason, 2021).

Table 2 provides an overview of the ways that different populations can experience heightened susceptibility to climate change and presents some demographics for the VCH and FH health regions. More detailed breakdowns for each health authority are available upon request, and more detailed information on health impacts is presented in the hazard-specific sections below. Additionally, the *Climate Change and Community Health* maps provide a snapshot of community vulnerability using a subset of the variables in Table 2.

Table 2 and the maps do not reflect the extent to which individuals may fit into multiple categories, thereby potentially increasing their vulnerability. The concept of **intersectionality** accounts for this, and reflects how "issues of sex, gender, race, ethnicity, age, and ablism interact" to increase systemic marginalization, oppression and discrimination (Hoogeveen et al., 2021). This is important because many people in our community face a combination of financial, social and systemic barriers to preparing for and addressing the burdens associated with climate change, which has the potential to exacerbate existing health and wellbeing gaps (Jubas-Malz & Perri, 2020).

Recently, those working on climate change and health (including those working on the social determinants of health) have begun to try and incorporate an intersectional lens in their work (Jubas-Malz & Perri, 2020). Initiatives like Metro Vancouver's *Social Equity & Regional Growth Study* (Metro Vancouver, 2021b) and recent work on Climate change, intersectionality, and GBA+ in British Columbia (Hoogeveen et al., 2021) enables a more complete understanding that will lead to more equitable outcomes. The HealthADAPT project is committed to understanding the disproportionate and intersectional nature of climate impacts, and ensuring that adaptation options acknowledge and reduce existing inequities. The project also acknowledges that those who have been most affected by climate change are a needed voice and driving partner in adaptation efforts (Jubas-Malz & Perri, 2020; Muzumdar, 2020).

In addition to physiological sensitivities, an individual and community's vulnerability is influenced by its ability to adapt during extreme heat events (Kafeety et al., 2020). When adaptive capacity is high, overall vulnerability is reduced. The June 2021 heat event demonstrated just how important air conditioning is as an adaptive capacity. Just like other temperate cities like San Francisco, coastal BC's temperate history means that much of its buildings are not equipped with air conditioning to help people cope during extreme heat events (Metro Vancouver, 2016). In 2011, only 575,537 households, or 31% of the total, had air-conditioning, compared with four out of every five households in Ontario

(Stewart et al., 2017). Community engagement in Fraser Health identified concern that purchasing and using A/C would create financial challenges for lower income populations. Hence, there is an interest in exploring alternative cooling strategies such as canopy cover and shading in public spaces for their equity benefits, as well as their low carbon intensity.

Of course, the issue of housing affordability affects adaptive capacity as well as exacerbating inequities. This is seen very clearly in housing affordability trends. In 2015 in Metro Vancouver, approximately 28% of homeowners paid more than 30% of their income to housing costs; while the proportion of renters who pay more than 30% of their income to housing alone was approximately 45% (Metro Vancouver, 2015). These trends have likely gotten worse in the years since this study was conducted. Supporting approaches to healthy public policy that address the wicked problem of housing affordability, thermal comfort, and low carbon resilience will be a priority in the forthcoming adaptation framework.

Table 2: Climate and health equity demographics

PRIORITY POPULATIONS	VULNERABILITY TO CLIMATE CHANGE	VANCOUVER COASTAL HEALTH	FRASER HEALTH
 **CHILDREN** Source: Stats Canada. Data reported at the Health Service Delivery Area level.	Higher sensitivity to environmental exposures, behaviors that increase exposure risk and great dependence on caregivers. During heat events, children's greater surface area to body mass ratio than adults, production of more metabolic heat per kilogram of body weight, blunted thirst response, and lower cardiac output increases their sensitivity (NCCEH, 2010b). During poor air quality, their still-developing lungs are more sensitive (BC Centre for Disease Control, 2020).	11-15%* of the population was 0-14 years old	15-18% of the population was 0-14 years old
 **OLDER ADULTS** Source: My Health My Community 2014. Data reported at the MHMC neighborhood level. The number of people 65 and over is estimated to grow 63% between 2020 and 2041 (source).	Higher sensitivity to environmental exposures, more likely to have existing chronic disease (e.g. cardiovascular disease) and increased risk of falls and non-fatal injuries. During heat events, older people's increased burden of chronic disease and decreased thermoregulation increase their sensitivity (Kafeety et al., 2020). Older people who experience greater social isolation and poorer mental health are at even greater risk during extreme heat events. Older adults are at increased risk of health effects from short-term exposures to poor air quality because of their higher prevalence of pre-existing lung and heart diseases, and because important physiological processes decline with age (Stone, 2019).	6-40% of the population was 65 years and older	15-18% of the population was 65 years and older
 **PEOPLE EXPERIENCING SOCIOECONOMIC DISADVANTAGE** Source: My Health My Community 2014. Data reported at the MHMC neighborhood level.	Higher likelihood of suffering from chronic medical conditions. People may reside in areas with older infrastructure and increased exposure (e.g. urban heat islands) and to experience social isolation (Vancouver Foundation, 2017). Some people experiencing poverty lack the means and opportunity to take protective health measures such as affording extra medications, accessing quality housing and/or air filtration (NCCEH, 2010b). Certain populations are also more likely to experience income inequality (e.g. single parents, new immigrants, seniors, etc.). In the FH health region, some cities are seeing increases in low and very low income earners and a shrinking middle income demographic (Gold, 2017).	14-76% of households had incomes under $40,000	30-32% of households had incomes under $40,000
 **INDIVIDUALS WITH EXISTING CHRONIC ILLNESSES** Source: My Health My Community 2014. Data reported at the MHMC neighborhood level.	Increased susceptibility to environmental exposure such as temperature, poor air quality, vector-borne disease and food- and water-borne diseases. During heat events, individuals with one or more of these conditions experience amplified health risks (Health Canada, 2011). People taking certain medications (e.g., antihypertensives, antidepressants) are more sensitive, as are those who are confined to bed or dependent on assistance for daily living. During poor air quality, people with respiratory conditions such as asthma or chronic obstructive pulmonary disease (COPD) are at highest risk, as are those with heart disease, diabetes, cancer, or mental illness (BC Centre for Disease Control, 2020).	15-43% reported that a doctor had diagnosed them with one or more chronic condition±	16-48% reported that a doctor had diagnosed them with one or more chronic condition±

**Ranges represent differences between neighbourhoods or regions*

± Includes diabetes, heart disease, stroke, high blood pressure, or a chronic breathing condition

PRIORITY POPULATIONS	VULNERABILITY TO CLIMATE CHANGE	VANCOUVER COASTAL HEALTH	FRASER HEALTH
MENTAL HEALTH AND ADDICTION Source: My Health My Community 2014. Data reported at the MHMC neighborhood level.	Mental health challenges make it more difficult to cope during extreme events, and can occur for those with pre-existing conditions, as well as people not typically affected. During heat events, anxiety, depression, and suicidal ideation increase, as do the risks associated with social isolation. There is an association between certain psychiatric medications and adverse health outcomes during heat events, and people experiencing addiction and/or substance use disorders are also at higher risk. Those with depression or anxiety are at increased risk of further mental health impacts from heat, air quality, and flooding. In addition, those with severe mental illness are more likely to be dependent upon service, infrastructure, and medication supply chains that are often disrupted after disasters (American Psychiatric Association, 2019).	7-26% of residents report being diagnosed with mood or anxiety disorder	8-30% of residents report being diagnosed with mood or anxiety disorder
SOCIALLY ISOLATED INDIVIDUALS Source: My Health My Community 2014. In Metro Vancouver, 23% of people spend more time alone than they would like; 14% of people report feeling lonely almost always or often (source).	Lack of social support and strong social networks, reducing adaptability and increasing susceptibility to climate change impacts. Social isolation has been found to be a predictor of mortality in heat waves in Paris, Chicago, and Montreal, and individuals with stronger social supports have more resources to draw on during poor air quality events (Kafeety et al., 2020). During flood events, people experiencing social isolation, especially those with mobility limitations, may not have the social resources to get the evacuation support they need.	37-61% of residents reported having four or more people to confide in	27-57% of residents reported having four or more people to confide in
INDIGENOUS STATUS AND RACE First Nations, Metis, Inuk, other Aboriginal Identity. Source: Stats Canada. Data reported at the Health Service Delivery Area level.	Indigenous status is commonly included in the social determinants of health (e.g., Canadian Public Health Association) because of the ways that the legacy of colonial policies, and current structural, political, cultural, and economic power imbalances can negatively impact adaptive capacity. This does not reflect an inherent physiological sensitivity on the part of Indigenous people. Instead, it suggests that efforts related to reconciliation, self-governance, and anti-racism will help to increase climate resilience. Additional information about community-level adaptive capacities is provided below in the adaptation strengths section. Race is commonly included in the social determinants of health (e.g., Canadian Public Health Association) because systemic racism influences the living and working conditions that people experience every day.	1-5% of the population identify as Indigenous	3-7% of the population identify as Indigenous
RECENT IMMIGRANTS Source: Stats Canada. Data reported at the Health Service Delivery Area level.	May speak limited English and are more likely to live in areas with urban heat islands, have difficulty finding suitable employment, and experience material deprivation and food insecurity (Macdonald, Perri, Jubas-Malz, & Mulligan, 2019). May also experience lower socioeconomic status. The number of immigrants in the Metro Vancouver region is projected to increase between 2020 and 2049.	5-7% of the population immigrated in the previous 5 years	14-32% of the population immigrated in the previous 5 years

PRIORITY POPULATIONS		VULNERABILITY TO CLIMATE CHANGE	VANCOUVER COASTAL HEALTH	FRASER HEALTH
	**PREGNANT WOMEN**	During pregnancy, physiological changes, such as higher respiratory rates and increases in blood and plasma volumes, increases a woman's vulnerability to poor air quality and extreme heat. Additionally, during critical windows of human development, a mother's exposure to poor air quality may harm the developing fetus. Maternal and fetal health outcomes may be adversely impacted during extreme heat events (i.e. pre-term births, lower birth weights) (Konkel, 2019; Kuehn & McCormick, 2017).	*Data forthcoming*	
	**PEOPLE WITH DISABILITIES**	People with disabilities are at increased risk of the adverse impacts of climate change and extreme weather events due to limited mobility, increased reliance on caregivers, social isolation, other compounding health related challenges, interruption to supply chains for medicines, and also due to discrimination, marginalization, and certain social and economic factors.	*Data forthcoming*	
	**OUTDOOR WORKERS AND ACTIVITY**	People in occupations where it is difficult to limit exposure high temperatures, poor air quality, and extreme weather are at higher risk of health impacts (Flouris et al., 2018). These include outdoor workers and wildland firefighters (Navarro, 2020), farmers and temporary foreign workers. Smoke, for example, can lead to or worsen respiratory and cardiovascular conditions, and affect mental health, for example via increased irritability, loss of concentration and a decreased ability to do mental tasks or heavy work (Canadian Centre for Occupational Health and Safety, 2021).	*Data forthcoming*	
	**HOUSING QUALITY AND ACCESS**	Climate change affects the physical and mental health of those experiencing homelessness or underhoused, who can be completely exposed during extreme weather events (Bezgrebelna et al., 2021; Kidd, Greco, & McKenzie, 2020). Those living in homes without air conditioning, with fewer natural ventilation opportunities, or in high-rises can lack the ability to reduce their exposure to high temperatures and poor air quality. Those living in floodplains and without the means of protecting themselves experience higher flood risk, and renters generally experience less agency and higher risk.	Seniors aged 55 and over represented 24% of people experiencing homelessness during a 2020 count inn Metro Vancouver. This proportion has been growing since 2002 and is projected to continue to grow without appropriate intervention (BC Non-Profit Housing Association, 2020).	

3.2 Indigenous people and communities

"By excluding Indigenous peoples, our realities and needs within climate policies, Canada simply reproduces the inequality we end up paying for with our lives" (Deranger, 2021).

Indigenous Peoples in BC and across the world are among those that have contributed the least to climate change, yet remain among those being most impacted as the climate changes. Climate change enhances the risks created by "environmental degradation from economic activities and leads to the loss and disturbance of animals, plants and watersheds, and affects First Nations' ability to live according to reciprocal relationships with the natural world, upon which our unique worldviews, legal orders, and cultures are founded" (BC Assembly of First Nations, 2020).

Indigenous individuals and communities are not inherently vulnerable, and often possess unique strengths. First Nations perspectives on health and wellness often emphasize that health and wellness are influenced by environmental, social, cultural and spiritual determinants. This holistic and integrated approach is instrumental in achieving improved health and wellness outcomes for First Nations peoples, and in creating climate resilience in Indigenous communities and beyond.

While acknowledging these strengths, it is also important to acknowledge that the legacy of colonialism and land dispossession creates significant challenges for maintaining and creating "healthy, self-determining and vibrant BC First Nations children, families and communities" (First Nations Health Authority, 2020b). Inequities can be seen in across many aspects of society, including Indigenous overrepresentation among those experiencing homelessness in Metro Vancouver (BC Non-Profit Housing Association, 2020), in boil water advisories resulting from subpar infrastructure, and in the legacy of environmental racism in Canada, where First Nations, Inuit, and Métis people (as well as other marginalized communities) experience higher exposure to environmental contaminants and hazards like flooding, especially in communities for which dykes were not created along the Fraser River. It can even be seen in the command and control approach taken in emergency management, which has links to settler military roots (Dicken & Yumagulova, 2017).

Inequities exist in the health care system as well. For example, the 2020 *In Plain Sight* report listened to thousands of voices and found widespread systemic racism against Indigenous peoples in the BC health care system. This racism results in a range of negative impacts, harm, and even death (Turpel-Lafond, 2020). A changing climate is seen as a risk multiplier for the structural inequities that Indigenous Peoples continue to face.

In addition to the multitude of Indigenous-led efforts described below, the Government of BC recently introduced legislation to ensure that its laws are brought in line with the UN Declaration on the Rights of Indigenous Peoples (Government of BC, 2020a). Similarly, non-Indigenous researchers and practitioners are building their capacity to understand Indigenous knowledge systems and the need to 'center' Indigenous knowledge keepers, leaders, and experts. This can be motivated by a commitment to equity and reconciliation, or by paradigms like planetary health, which are reflective of Indigenous understandings of health and wellness.

3.2.1 Impacts

It is common to hear that Indigenous communities are uniquely impacted by climate change. Some of these impacts are described below using a combination of desktop research and direct engagement.[7] Other impacts appear in the each of the hazard sections, and others appear in the Central Coast and Fraser East engagement summary reports.

In 2019, the First Nations Leadership Council (FNLC) delivered a climate emergency survey to gather insights regarding the perspectives of First Nations on the climate emergency and related impacts, concerns, barriers and priorities. The survey was hosted online from August to September 2019, and the target audience was all First Nation communities and Tribal Councils in British Columbia, including the Chiefs, Elders, Youth, Women, staff and community members (First Nations Leadership Council, 2020). Some of the impacts identified include:

- Climate change has caused impacts to sacred and cultural sites due to either disappearance, damage or loss of access because of extreme heat, rain and wind; fires, floods, erosion, landslides; overland flooding; and droughts that caused sacred creeks disappeared or low flow of the rivers and creeks affecting fish populations (First Nations Leadership Council, 2020; Indigenuity Consulting Group Inc., 2020).
- Stress and anxiety linked to the loss of traditional foods and extreme weather events;
- Respiratory disease from wildfires and extreme heat events, especially when the poor conditions of on-reserve housing are taken into account;
- Changes to traditional foods (described in more detail in Ecosystem Changes section).

In the spring of 2019, the Province of BC hosted a series of regional workshops attended by over 110 Indigenous participants from every region of the province to discuss issues related to climate change and the suite of government policies, programs, and legislative actions that fall under the umbrella of CleanBC (Indigenuity Consulting Group Inc., 2020). Key themes that emerged include:

- **Human health**: risks from heat waves, risks from water shortages, risks from decrease in food security, and risks from increase in airborne illnesses. Impact on elders' health was specifically mentioned by many participants, as well psychological impacts.
- **Social impacts**: Some participants said that climate events have led to a displacement from homes and created social problems within families because of stresses and forced separations.
- **Ancestral remains**: Impacts from climate events on burial grounds and sacred sites was raised as an important climate effect by many participants.
- **Cultural impacts**: Many participants shared that climate events directly and indirectly affect Indigenous culture and traditions. Direct impacts include not being able to access spiritual sites or not being able to use medicinal plants; indirect impacts include lack of salmon leading to inability to practice culture. Multi-generational impacts were cited by many participants. Effects of climate change on hunting was also listed as a significant impact.
- **Food insecurity**: Impacts on fish, game and related habitat, as well as on berries, roots and other wild foods and medicinal plants is contributing to health problems, and loss of family and community gathering as well as increasing poverty as people are forced to turn to buying more processed foods in grocery stores.

[7] More detail is available in *Fraser Health Indigenous Adaptation Landscape* and *Fraser Health Indigenous Engagement Summary Report*, both available upon request.

- **Traditional foods**: Traditional foods/seafood is impacted by climate change (e.g. salmon, clams, crabs, oysters). Medicinal plants were also cited as being at risk from climate events. Salal and cedar were particular species mentioned.
- **Fisheries**: Impacts to fisheries such as sockeye, coho, and steelhead from climate events was a common area of discussion at virtually every session. This included recognition that impacts to fish also leads to impacts around culture, particularly social and ceremonial issues. Some participants shared that an increase in algae has led to decreased access to shellfish. Increased water temperatures and low water flows were cited as some of the reasons for decrease in fisheries resource.
- **Economic effects**: Some participants shared that impacts from climate change have limited economic development opportunities in their areas; for example, fire is restricting potential for forestry and mushroom harvesting, rising water temperatures are impacting Indigenous commercial fisheries. Plants like salal can't be harvested and ingredients for traditional medicines are more difficult to access (Indigenuity Consulting Group Inc., 2020).

A similar process highlighted that transportation is critical to health and safety, and for many First Nations it can create significant barriers to safely evacuating communities in times of emergencies. Further, once an individual is evacuated, individuals living in poverty are forced to rely on the "system" and outside supports for basic necessities, such as food, clothing and shelter. This creates a dependency for basic survival once the individual leaves their home and their community (Hoogeveen et al., 2021). Evacuations also create conditions under which culturally unsafe or inappropriate support is offered. "Evacuation orders from fires and floods force First Nations to move away from their territories, and often without culturally appropriate assistance and support, and especially impact Elders, women and those with special needs" (BC Assembly of First Nations, 2020).

Climate change also threatens traditional knowledge, practices and skills. Traditional teachings about how to responsibly steward lands and waters are threatened when the health of territories is threatened. The multigenerational impacts of loss of way of life is also a strong theme (BC Assembly of First Nations, 2020).

During engagement efforts led by the HealthADAPT project, we heard quite clearly that impacts are very contextual and that generalizations should not be made. For example, Stó:lo Tribal Council is very concerned with flooding and wildfire whereas Nlaka'pamux Nation Tribal Council was more concerned with wildfire, impacts to salmon, and less concerned about flooding. We also heard about very specific impacts, like how wildfires around the Wuikinuxv Nation led to more wolf attacks on families' dogs that protected them from bears, which decreased their ability to leave their property due to the risk of a bear attack.

Much more work is needed to understand the impacts that a changing climate has on the Indigenous communities that VCH and FH have the pleasure to serve. Gathering this information needs to be done respectfully, and with an approach that also acknowledges the strengths that Indigenous communities possess. It is also important to focus efforts on understanding and engaging with urban and away-from-home populations. This is echoed by the forthcoming Health Canada national assessment.

Note that other impacts are described in the hazard-specific sections below.

Health and social impacts of long-term evacuation

The National Collaborating Centres for Public Health (NCCPH) led a project to explore knowledge gaps and inform priorities for public health responses to long-term evacuations due to natural disasters including flooding and wildfire. This included identifying issues related to the impact of natural disasters on First Nations communities (National Collaborating Centres for Public Health, 2021). They found that:

- Long-term evacuation, particularly for individuals dislocated from rural, remote and Indigenous communities and evacuated to cities, heightens risks of developing addictions.
- Long-term evacuation appears to be associated with increased chronic physical health conditions such as asthma and diabetes, and chronic infectious diseases such as tuberculosis and sexually-transmitted and blood-borne infections.
- Long-term evacuation seems to have an adverse effect on family dynamics, with notable increases in relationship break-down and intimate-partner violence.
- More extensive consequences of evacuation tend to fall on Indigenous peoples and communities due to colonization and structural inequities, and the cultural dislocation associated with geographic displacement

Guidance for public health practitioners included “utilize and incorporate the knowledges, lived experiences, and worldviews of respective First Nations peoples and communities in all response and recovery plans.” This resource will inform the planning that follows from this vulnerability and capacity assessment.

3.2.2 Adaptation and Preparedness

Researchers and practitioners are encouraged to focus on strengths and assets instead of vulnerabilities, as the emphasis on hazards, risks, impacts, and vulnerability can have the effect of disempowering individuals and community groups. It is also essential to center Indigenous leadership. **Error! Not a valid bookmark self-reference.** contains a non-exhaustive summary of Indigenous-led initiatives that give a sense of the breadth of work being undertaken across the VCH and FH health regions.

Table 3: Indigenous-led climate change adaptation initiatives

Emergency preparedness and response	- FNHA’s Health Emergency Management facilitates coordinated FNHA activities in response to emergencies that may impact the health of BC First Nations community members. They work to ensure that communities are effectively linked within the provincial emergency response system and receive emergency management support at a level equivalent to non-First Nations, and that an effective FNHA response during the response and recovery stages of an emergency. - The First Nations Emergency Services Society (FNESS) works closely with First Nation communities, Emergency Management BC (EMBC), Indigenous Services Canada (ISC) and

	various other stakeholders to support the successful implementation of emergency management for First Nation communities in BC. The FNESS Emergency Management (EM) department provides community-based emergency management guidance, support and assistance to BC First Nation communities. Their activities are informed by the British Columbia Emergency Management System (BCEMS), which is recognized as a standard system for emergency response, and currently mandated for use within the Government of BC and recommended to local authorities. - The Cultural Burning & Prescribed Fire program operated by Fire Smart relies on Indigenous knowledge of prescribed burning practices in the BC landscape to reduce wildfire risk
Assessment and epidemiology	- Fraser Salish First Nations are served by a range of health service including community services providers (e.g., Stó:lō Service Agency), FNHA, and Fraser Health. - FNHA has surveillance and research programs for a variety of climate-sensitive impacts. - Health information on Métis Citizens in British Columbia will become available as a result of a historic information-sharing agreement signed between Métis Nation BC and the provincial government. The Métis Public Health Surveillance Program will enable the ministry to identify consenting Métis Citizens from among existing databases and report on specific health outcomes and chronic diseases (Government of BC, 2011).
Population and public health	- FNHA is responsible for a number of areas under Environmental Public Health including drinking water safety, food safety, health and housing, wastewater, facilities inspection, communicable disease prevention and control, emergency preparedness and response, and environmental contaminants (this includes air contaminants). This work is supported by community services providers (e.g., Stó:lō Service Agency). In the Central Coast, for example, the Heiltsuk Health Centre provides home and community care, patient transportation, and several other services.
Key resources and Indigenous-led initiatives	- First Nations Health Authority and BC Office of the Provincial Health Officer recently released the *First Nations Population Health And Wellness Agenda* that presents a strategy for improving the environmental and social determinants of health for Indigenous communities. - The FNHA is now offering funding through its Indigenous Climate Health Action Program (ICHAP). ICHAP funds community-driven projects that strengthen the resilience of First Nations people to the impacts of climate change on physical, mental, emotional and spiritual health. - First Nations Health Directors Association acts as a technical advisory body to the First Nations Health Council and the FNHA on research, policy, program planning and design, and the implementation of the Health Plans. - First Nations Health Council provides political leadership and oversight for the First Nations health governance process in BC - Several successful initiatives exist in Central Coast communities, including the N-EAT project between SFU and Kitasoo Xai'Xais First Nation, an emerging Food Resilience Plan for the Nuxalk Nation, and a Food Systems Resiliency Program run by the Qqs Projects Society in Heiltsuk territory. Similarly, community-supported research has been conducted in the area (e.g., Whitney et al., 2020). - The First Nations Leadership Council, made up of the BC Assembly of First Nations, the First Nations Summit and the Union of BC Indian Chiefs, as mandated by the Chiefs in BC, is drafting a BC First Nations Climate Change Strategy and Action Plan informed by First Nation priorities and knowledge. The objective of the plan is to identify strategies and actions to strengthen Indigenous climate leadership in BC. This includes helping mitigate carbon pollution, reducing vulnerability to impacts, and building capacity, understanding, and resilience in First Nation communities. The Strategy will also communicate to governments and partners of First Nations' priority areas and remind them that successful climate action is

only possible when co-created with First Nations in ways that protect and strengthen Title, Rights, and jurisdiction, and when Indigenous Knowledge and unique connections to territories are respectfully acknowledged and thoroughly incorporated in all aspects of climate planning and action. A final version of the draft Strategy will be completed and presented to Chiefs in their respective FNLC Assemblies for approval between September and October 2021. Once endorsement is complete, the Strategy will be publicly distributed and presented to partners. Simultaneously, the FNLC will be collaborating with governments and partners to identify actions for implementation.

- The *Coastal First Nations Climate Adaptation Workshop Series* took place virtually over three Thursday mornings in February, 2021. It was co-hosted by the Coastal First Nations-Great Bear Initiative (CFN-GBI) and Fraser Basin Council. The goal of the series was to "present changes taking place and future climate scenarios, as well as actionable steps for climate preparedness, in a First Nations-centered and fun way to a coastal audience while promoting connections." Similarly, the Métis Nation BC, in partnership with Fraser Basin Council, hosted a series of virtual Climate Preparedness Workshops. These two-hour, free virtual workshops focused on Climate Preparedness topics relevant to Métis Nation members and were designed because the multi-generational knowledge, skills and experiences of Métis People are needed to make good decisions on how to shift and build resilience in this changing world (Métis Nation BC, 2021)
- The BC Climate Action Secretariat is working to develop an Indigenous perspectives report that brings together all of the engagement that the Province has done related to Adaptation the past three years as well as the work led by others such as FNLC and Métis Nation of BC. Also, through its CleanBC commitment, the government of BC has collated some of the resources available for Indigenous communities to adapt to climate change (Government of BC, 2021). This does not have a specific health focus, but is part of the suite of efforts required for successful adaptation.
- The Indigenous Climate Hub is an Indigenous-led project and national online platform for First Nations, Inuit and Métis peoples, communities, and organizations to learn, share and connect. The purpose of the Indigenous Climate Hub is to provide helpful resources and information on climate change, and to provide a space to share resources, information, and impactful climate change stories from Indigenous perspectives.
- First Nations Health Council have produced very valuable resources, including this video on the social determinants on health.
- PlanH, a partnership of BC Healthy Communities Society and the Ministry of Health, has awarded Community Connectedness and Healthy Community Engagement grants to several First Nations within the VCH and FH health regions.
- The Rural Health Services Research Network of BC (RHSRNbc) 2020 BC Rural Health Research Exchange (BCRHRx)
- The Indigenous Centre for Cumulative Effects (ICCE) is an independent organization that supports Indigenous communities to understand cumulative effects, which are changes in the environment caused by multiple interactions among human activities and natural processes that accumulate across time and space. The primary objective of ICCE is to help build and enhance the technical and scientific capacity of Indigenous communities to address cumulative effects, based on the values of First Nations, Métis and Inuit communities across Canada
- Métis National Council's new national Climate Change and Health Vulnerability Assessment (Métis National Council, 2020)
- Tsleil-Waututh Nation have undertaken Community Climate Change Resilience Planning. Phase 1 report is available (Tsleil-Waututh Nation, 2019).
- Government of BC provides information on impacts and adaptation from Indigenous

	perspectives (Government of British Columbia, 2021). This includes the Indigenous Climate Adaptation Technical Working Group and the BC First Nations Leadership Council Technical Working Group on Climate Change.

In addition to the Indigenous-led initiatives in Researchers and practitioners are encouraged to focus on strengths and assets instead of vulnerabilities, as the emphasis on hazards, risks, impacts, and vulnerability can have the effect of disempowering individuals and community groups. It is also essential to center Indigenous leadership. **Error! Not a valid bookmark self-reference.** contains a non-exhaustive summary of Indigenous-led initiatives that give a sense of the breadth of work being undertaken across the VCH and FH health regions.

Table 3, other strengths and assets have been identified during engagement and research activities. For example:

- HealthADAPT interviewees in the Central Coast did not separate climate change and health from other elements such as governance, self-determination, systemic racism, and connections to the land. These are all complementary elements of resilience that need to be considered simultaneously.
- Regional engagement carried out by the Government of BC identified the following community strengths:
  - Knowledge of community: including knowledge of fisheries and the land, and knowledge from elders;
  - Ability to adapt based on knowledge and experience in the territory;
  - Skilled members with knowledge in a variety of areas;
  - Data and knowledge of their territories and important areas;
  - Long-term visioning: this was cited as being a strength because it will likely result in Nations restricting harvesting to protect at-risk species;
  - Agreements that communities have with governments and industry in areas related to clean energy, sustainability, and waste;
  - Leadership in environmental issues and community buy-in of the importance of addressing environmental issues;
  - Experience living through various climate events (Indigenuity Consulting Group Inc., 2020).
- A government-funded research project that used the gender-based analysis+ (GBA+) approach found that Indigenous communities are important leaders of climate action in BC and there are valuable lessons for non-Indigenous communities and organizations. When looking at gender impacts of climate change, policy formation must not focus on Indigenous women as ‘victims’ of climate hazards, but also the strength and assets Indigenous women bring, providing leadership to address climate change as traditional knowledge keepers (Hoogeveen et al., 2021).
- Whitney et al. (2020) conducted a major study with members of the Heiltsuk, Kitasoo/Xai'xais, Nuxalk, and Wuikinuxv Nations during which four key strategies emerged as critical for climate change adaptation:
  - Strengthening Indigenous governance autonomy and authority;
  - Promoting knowledge sharing for adaptation practices within and among communities;

- Promoting adaptive co-management among governance scales, and;
- Developing learning platforms for climate impacts and adaptive strategies.

These findings, as well as those presented in the hazard-specific sections below, provide very important direction for climate change and health-related work in the region. Non-Indigenous people involved in this work encouraged to embody approaches and values including two-eyed seeing, respect for diverse and distinct Nations, intergenerational decision-making, respect, humility, and inclusion (adapted from the Indigenous Centre for Cumulative Effects), as well as centering lived experiences (Charles-Norris, 2020), empathy, teamwork, collaboration, adaptability, and innovation (Métis Nation BC, 2021).

4. Extreme heat

4.1 Key messages

- Extreme heat events like the one that occurred in June 2021 will become much more common across the VCH and FH health regions as the global climate warms.
- Extreme heat already causes measurable health impacts (i.e., morbidity and mortality) in our region and will become more of an issue as the climate warms. Older adults, people with chronic conditions, people on certain medications, infants and young children, those with disabilities, and outdoor workers are especially sensitive to the health effects of heat.
- High indoor temperatures are a major driver of negative health outcomes during extreme heat events, especially in buildings without air conditioning, and on higher floors. This can lead to high demands for necessary action from social housing providers and landlords, as well as health care workers who provide services in people's homes. Although market-based, site-level adaptation measures in people's homes can be adaptive in some circumstances, cooling and air filtration can be expensive and difficult to provide consistently. The same is often true at the building level, where cooling and air filtration retrofits are very costly.
- Cooling centres play an essential role in keeping some people safe during extreme heat events, but it is often difficult for municipal governments to keep up with demand and not all region residents are able to benefit from cooling centres. Municipalities are primarily responsible for leading the response to emergency events, and meanwhile work closely with health partners, and community-based organizations to deliver these health-related services.
- The importance of social connection (and risks of social isolation) are increasingly well known in relation to the health impacts of extreme heat events. It is important to take intersectoral action in support of social connection, which can be mobilized during extreme heat events (e.g. through check-in practices among communities and networks).
- Negative effects of heat on mental health and wellness are established in the scientific literature, and local evidence on impacts during heat events is emerging.
- Heat events impact health care facilities and community health services by affecting patients, staff, indoor environmental conditions, and by increasing demand on public health, community, and acute services. Seasonal readiness planning and design guidelines for climate-resilient health facilities represent important capacities in this area, but more work is needed to assess and improve resilience of the health system to extreme heat events.
- Existing initiatives and collaborations are evidence of significant adaptative capacity in the VCH and FH health regions, although there is a need to better understand where gaps in capacity exist and to intensify and accelerate action as the climate warms. It is also essential to better understand and support the heat response planning and capacities of municipal and regional governments, First Nations, and social service providers.

4.2 Current heat exposure and expected changes[8]

The extreme heat event in June 2021 provided a new understanding of how intense and impactful extreme heat can be in the VCH and FH health regions. By June 23, there was strong meteorological

[8] Health Canada workbook Step 2C

evidence for an imminent and unprecedented extreme heat event in BC (*see* Figure 5). The subsequent heat event affected much of British Columbia from June 25 to July 1, 2021, peaking on June 27-28.

On June 28, single-day heat records were set in Squamish, British Columbia at 43.0°C, Abbotsford at 42.9°C. On the morning of June 28, a meteorological station at Simon Fraser University in Burnaby registered an overnight low of 29.0°C, the highest ever recorded in the province (Government of Canada, 2021b). That this event occurred early in the season, when preparedness tends to be lower, is also likely a factor in the severe impacts discussed below (Section 4.3).

While we have come to anticipate more extreme heat events as our climate warms, the magnitude of this recent heat event in 2021 was beyond all projections for this point in time. A rapid attribution study determined that this event would not have occurred without climate change, that events of this magnitude could occur every 5 – 10 years by 2040 (Philip et al., 2021), and that it is possible that scientists are "overconfident" in their knowledge of heat wave causes and severity (Flanagan, 2021).

In addition to extreme heat warnings and alerts, a number of other warnings were triggered as a result of the severe temperatures. These include air quality advisories that started on June 26 and covered eastern Metro Vancouver and central Fraser Valley Regional District due to high concentrations of ground-level ozone (higher than had been observed since the 1908's). On June 30, *Smoky Skies Bulletins* were being issued as a result of wildfires elsewhere in BC. There were also dozens of flood watches, warnings, and high streamflow advisories issued across the entire VCH and FH health regions as a result of rapid snowpack and glacier melt. Impacts to food crops were also reported by the media (e.g., Gomez, 2021) in addition to increases in *Vibro* cases likely due to warming waters (CBC News, 2021a).

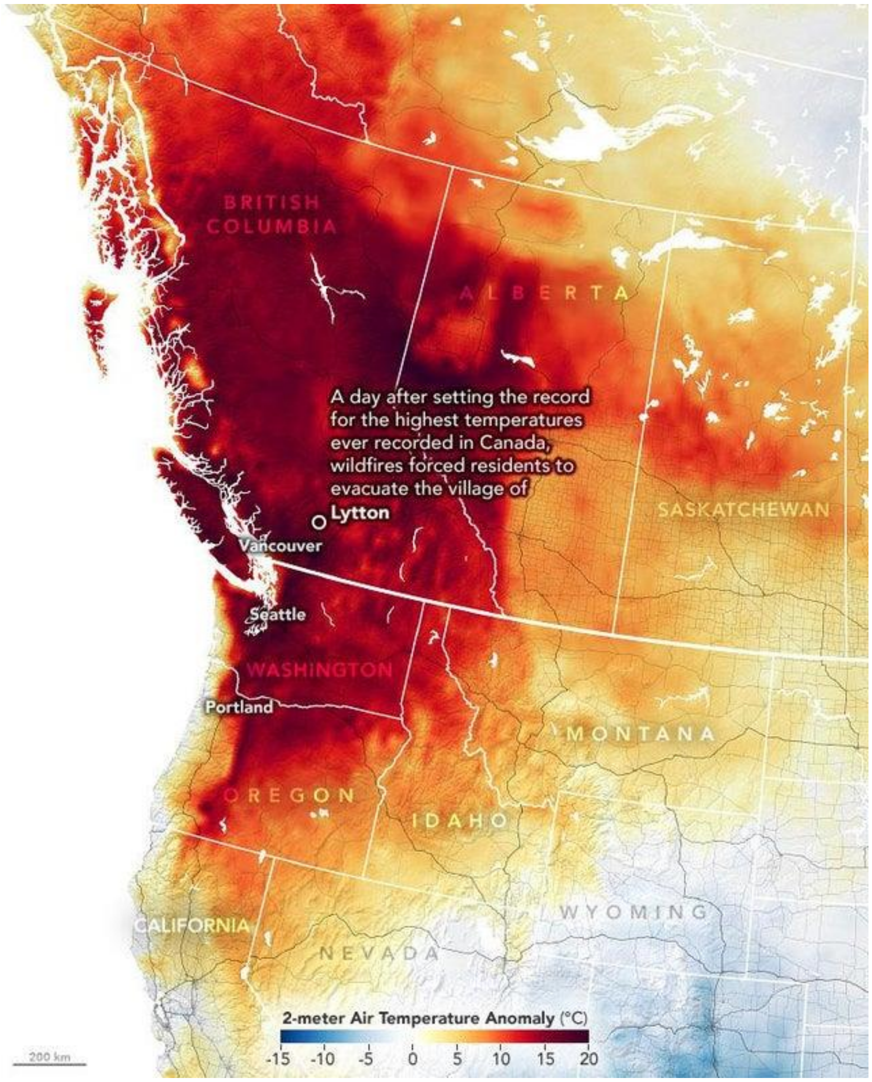

Figure 5: The map depicts air temperatures at 2 meters above the ground. Red areas are where air temperatures climbed more than 15°C higher than the 2014-2020 average for the same day (NASA Earth Observatory, 2021).

Extreme heat events have historically occurred across VCH and FH, with the greatest effects being felt in the eastern region of FH, and in the metropolitan areas of the lower mainland, particularly in urban heat islands. Heat events across VCH and FH are expected to rise in frequency, duration, geographical range, and intensity as the climate changes (BC Ministry of Environment and Climate Change Strategy, 2019). The tables and figures below—as well as projection maps that VCH created for the Central Coast—show a clear trend. [9] When this is combined with the experience of the June 2021 event clearly signalling that the timeline for adaptation must be accelerated to protect the health of residents within

[9] Information about the number of historical and projected heat warnings has been collected but has not been presented here. It is available upon request.

the VCH and FH health regions.

It should be noted that the displays of temperature below do not include wet bulb temperature, which accounts for both heat and humidity. Similarly, nighttime temperatures are a significant determinant of the severity of extreme heat exposure, and are available but not reported below.

Table 4: Historical and future days above 25°C for cities in the VCH and FH regions

	Average days above 25°C (1975-2005)*	Projected annual days above 25°C in 2050 (RCP 8.5)**	Projected annual days above 25°C in 2080 (RCP 8.5)**
Bella Coola	9 days	15 - 50 days	28 – 82 days
Powell River	20 days	35 – 77 days	57 – 110 days
Sechelt	14 days	30 - 69 days	49 – 98 days
Squamish	29 days	41 – 84 days	62 – 112 days
Whistler	25 days	32 – 72 days	49 – 96 days
Pemberton	31 days	32 – 78 days	58 – 106 days
Vancouver	17 days	38 – 84 days	64 – 117 days
Abbotsford	33 days	53 – 96 days	75 – 128 days
Burnaby	22 days	44 – 89 days	68 – 121 days
Chilliwack	43 days	61 – 104 days	82 – 132 days
Delta	17 days	39 – 86 days	66 – 119 days
Port Moody	30 days	41 – 85 days	64 – 115 days
Hope	46 days	50 – 92 days	71 – 117 days
Langley	30 days	46 – 91 days	70 – 122 days
Surrey	25 days	46 – 92 days	71 – 125 days
Maple Ridge	36 days	52 – 96 days	74 – 127 days

* Data retrieved from climatedata.ca using modelled historical data because models and meteorological observations do not generally represent information at the same spatial scales. It is important to use modelled historical data when making direct comparisons with modelled future data. Data for Richmond was not available.

** 2041-2070 and 2071-2100. 10th and 90th percentile

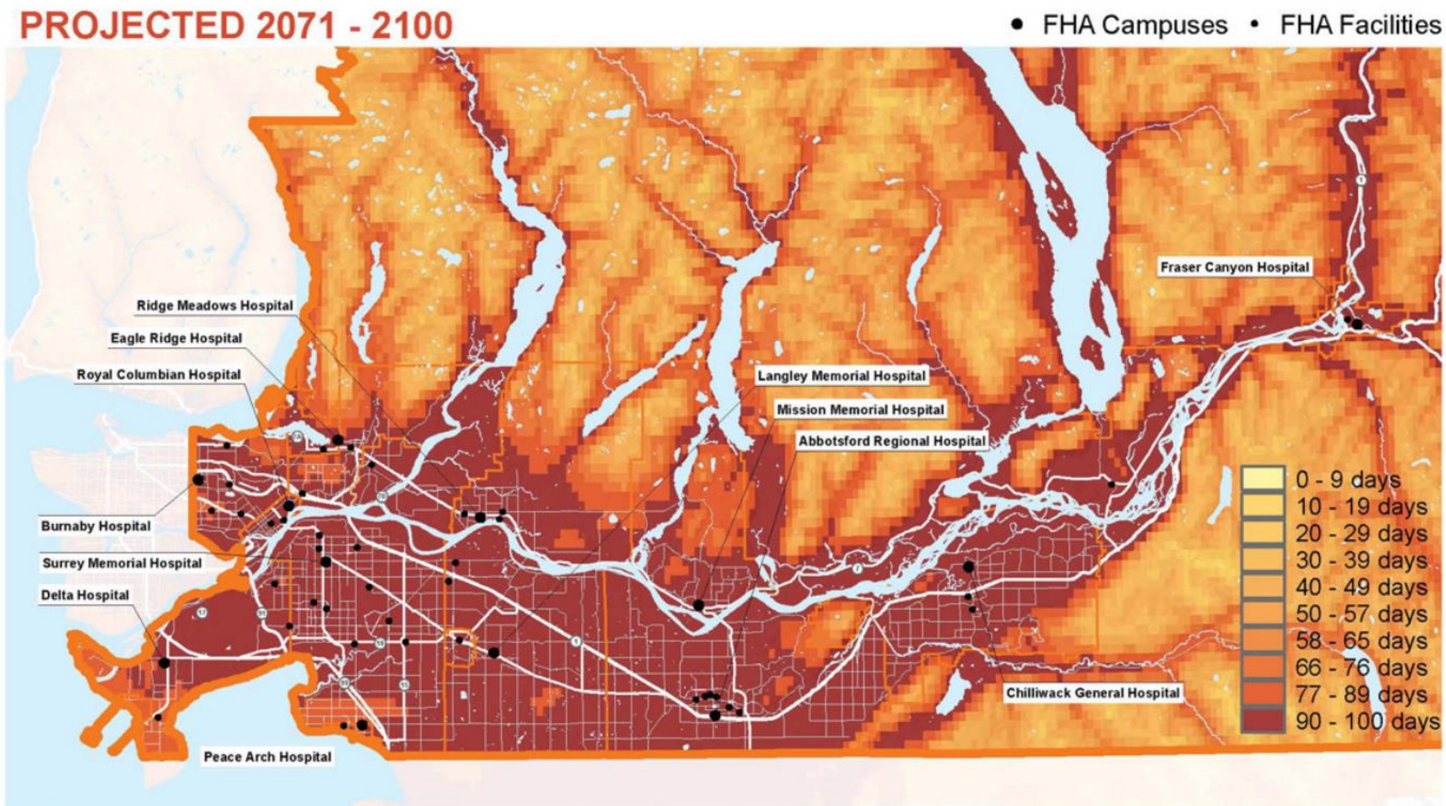

Figure 6: Projected days above 25°C for the Fraser Health region (Facilities Management, 2019)

Table 5 displays historical and projected days above 30°C for cities in the VCH and FH regions.

Table 5: Average annual days above 30°C *for cities in the VCH and FH regions*

	Average days above 30°C (1971–2000)*	Projected annual days above 30°C in 2050 (RCP 8.5)**	Projected annual days above 30°C in 2080 (RCP 8.5)**
Bella Coola	1 day	2 - 11 days	4 - 24 days
Powell River	1 day	4 - 16 days	11 - 48 days
Sechelt	1 day	3 - 14 days	9 - 45 days
Squamish	6 days	9 - 27 days	18 - 56 days
Downtown East Side	2 days	5 - 21 days	14 - 60 days
Richmond	1 day	4 - 16 days	10 - 54 days
Abbotsford	6 days	11 - 27 days	22 - 61 days
Burnaby	2 days	5 - 21 days	14 - 57 days
Chilliwack	9 days	15 - 35 days	25 - 67 days
Delta	1 day	4 - 17 days	10 - 54 days
Port Moody	5 days	9 - 25 days	19 - 57 days
Hope	13 days	16 - 36 days	26 - 63 days
Langley	5 days	9 - 26 days	20 - 59 days
Surrey	3 days	7 - 23 days	17 - 57 days
Maple Ridge	7 days	12 - 29 days	22 - 62 days

* Data in this table comes from Facilities Management (2018) and was produced by PCIC.
** 2041-2070 and 2071-2100. 10th and 90th percentiles.

Heat warning criteria

To provide the public and partner organizations with a warning of the health risk from heat events, temperature thresholds have been established by the BC Center for Disease Control in collaboration with Environment and Climate Change Canada, Health Canada, and BC health authorities.

Environment and Climate Change Canada issues a *Heat Warning* when:

- **Southwest**: (Includes the North Shore, Vancouver, Richmond, Howe Sound, Whistler, Pemberton and the Sunshine Coast as well as Eastern Metro Vancouver including Coquitlam, Surrey, and the Fraser Valley):
    - **Coastal station** (Vancouver Airport): Two or more consecutive days of daytime maximum temperatures are expected to reach 29°C or warmer and nighttime minimum temperatures are expected to be at 16°C or warmer.
    - **Inland station** (Abbotsford Airport): Two or more consecutive days of daytime maximum temperatures are expected to reach 33°C or warmer and nighttime minimum temperatures are expected to be at 17°C or warmer.
    - Warnings are issued for both Coastal and Inland sections if either criteria are met.
- **Northwest** (Central and Northern Coast (inland and coastal regions), Northern Vancouver Island, and northwestern BC): Two or more consecutive days of daytime maximum

temperatures are expected to reach 28°C or warmer and nighttime minimum temperatures are expected to be at 13°C or warmer.

According to historical BCCDC data, the *Heat Warning* criteria indicate temperatures at which an increase in deaths in the community is expected. Note that different temperature thresholds are set for different parts of the province, as the relationship between heat and mortality differs. More information on heat alert criteria for other regions, including a map, can be found here.

For the **Southwest** region only (defined above), VCH and Fraser Health Authority will on occasion issue a joint *Extreme Heat Alert* when the expected risk to the public is extremely high. This is based on current and forecasted temperature criteria[10] recommended by the BCCDC in addition to a health authority assessment of anticipated risk to health. The *Extreme Heat Alert* criteria indicate temperatures at which a larger increase in deaths in the community is expected. During the 2009 extreme hot weather event there was a 40% increase in regional mortality over a 1-week period.

The *Extreme Heat Alert* triggers additional responses from the health authority, local government and partner organizations as well as public messaging to strongly encourage individuals and communities to be aware of the risk and take action to stay cool.

4.3 Population health impacts[11]

Extreme heat already causes measurable health impacts in our region and will become more of an issue as the climate warms. These events can trigger a number of heat-related illnesses (such as heat exhaustion, heat stroke) and in extreme situations, can lead to permanent disability or death. Older adults, people with chronic conditions, people on certain medications, infants and young children are especially sensitive to the health effects of heat.[12]

A variety of data could be used to quantify the health impacts of extreme heat, including: HealthLink BC calls, emergency department data, ambulance data, Vital Statistics (i.e. death), physician visits and primary care (billing), transfers from LTC, staff absenteeism and wellness needs, prescription dispensations, and overdose deaths. Anecdotal evidence is a useful complement, but can be difficult to collect, vet and assess. What follows is a presentation of the data available for VCH and FH health regions, followed be a more general literature assessment.

4.3.1 Local data

The June 2021 heat event provided a unique and alarming opportunity to understand the impacts of extreme heat in the VCH and FH health regions. Early analysis of excess mortality from the BCCDC has estimated 740 excess deaths from the period of June 25- July 2 with a larger majority of these deaths occurring in the community (i.e. outside of residential care and acute care settings) and in people age 50 and older. Neighborhoods experiencing material and social deprivation were more highly impacted

[10] Calculated when the two-day average of high temperatures is predicted to reach 36°C or higher at the Abbotsford Airport and/or is predicted to reach 31°C or higher at the Vancouver airport, based on the temperatures measured at 2pm.

[11] Health Canada workbook Step 2B

[12] For more detail, see this piece in Scientific American.

and tree canopy coverage was independently shown to decrease the risk of death. Preliminary analysis suggests that people experiencing mental illness and substance use disorders were at an increased risk of death (Henderson, 2021). Separate investigative analysis by the BC Coroners Service for the period of June 25 - Jul 1 have confirmed a reported 526 heat-related deaths. The overwhelming majority of these deaths (96%) occurred in residence, i.e. including either decedent's own or another's residence, hotels/motels, rooming houses, SRO (single room occupancy), shelters, social/supportive housing, seniors' homes, long term care facilities, and nursing homes (BC Coroners Service, 2021). Forthcoming research by BC Coroners Service will examine the context surrounding each death.

In VCH, the heat event resulted in increased emergency department (ED) and Urgent Primary Care Center (UPCC) visits. Heat-related ED visits are defined as people presenting with heat exhaustion/stroke, heat edema, heat cramps, heat syncope, effect of heat and light, heat related illness presentation, and sunburn. A significant surge of heat-related ED visits was observed during the heat wave from June 25-July 1, 2021. An internal study found:

- A total of 213 heat-related ED visits presented at the nine VCH facilities on June 26-29, 2021.
- A large majority of visits (90%) were VCH residents and lived within an urban area;
- 32% presented with acuity level as emergent (54 visits) and resuscitative (15 visits), both of which indicate a person in dire need of urgent care. About 40% of visits with severe acuity presentations (including resuscitative and emergent) were admitted to hospital;
- 61% of visits were aged 60 years and older, and these patients presented with high acuity level compared to other age groups;
- Majority of visits (76%) were discharged to home after treatment.
- No significant differences between male and female visits were observed by age, local health regions, acuity, and disposition distribution;
- Heat exhaustion/stroke was the most common diagnosis;
- Compared to previous weeks, there was no significant increase in cardiac, respiratory, mental health and overdose related ED visits during the heat wave. There was an increase in visits for acute renal failure, other disorders of the external ear as well as somnolence, stupor and coma.
- The heat wave had a minor impact on UPCC visits.
- Analysis of the emergency department data for this heat event is ongoing.

Results in FH were similar to those observed in VCH:

- An increase in ED visits, including for high acuity patients, and by those aged 65 or older. There was a sharp increase for visits relating to heat/sun stroke, and a marked increase in ED visits for renal conditions. The increase in ED visits was observed across all health service delivery areas.
- Some visits were by those already receiving care from Fraser Health, including home health clients, residents of long-term care and assisted living, and Mental Health and Substance Use (MHSU) clients.
- Hospital admissions related to heat/sun stroke increased during the June 2021 heat event, with no significant changes observed during subsequent heat events later in the summer.
- Preliminary internal analysis suggests that areas with higher rates of social and economic vulnerability are at higher risk of health impacts from extreme heat events.

In addition to findings from the June 2021 heat event, previous work has found heat impacts on emergency department visits. For example, a study conducted in 2018 by Fraser Health's Population Health Observatory found that "extreme heat significantly or marginally significantly increased ED visits due to: heat/sun stroke and angina across FH regions; renal failure and suicide ideation/attempt in Fraser North; COPD in Fraser South; renal failure, suicide ideation/attempt, social problem and cardiac arrhythmia in Fraser East." (Li, 2018). Although studies for the VCH region are needed to contextualize these results and to build the evidence base, hospitalizations trends are likely to be similar.[13]

It is important to note that this data is only for emergency department and urgent primary care center visits and is therefore only one piece of the health impact picture. As the heat wave also had impacts on other health services, VCH will continue working with our partners to examine the potential impact on ambulance services, mortality and physician visits (some of which are described below). We also recognize that there were likely many community and wellbeing impacts that were not captured by the health system data, and that measuring mortality and morbidity to large-scale events can be very challenging (Stoto, Rothwell, Lichtveld, & Wynia, 2021).

The lack of air condition in many buildings in the VCH and FH health regions is a significant factor in the extent of the impacts experienced. Examples were common of multi-unit residential buildings overheating and affecting the health of their occupants (e.g., CBC News, 2021d). Only eight of Vancouver Parks Board's 20 facilities had air conditioning at the time of the June 2021 heat event.

The use of air conditioning in buildings that have it led to record electricity consumption during the three hottest days of the event, along with localized outages (e.g., BC Hydro, 2021)—which are known to elevate risk during extreme heat events (Stone et al., 2021). Encouraging safe indoor environments in homes, schools, and other public buildings that are low carbon and resilient is an area of public policy that VCH and FH will continue to contribute to in the coming years.

Conditions in LTC facilities across VCH and FH vary greatly and conclusions cannot be drawn at this time about how they performed during the heat event. It is likely that LTC facilities play a protective role during heat events for their often very elderly patients, many of whom have comorbidities. Being in long term care greatly reduces the impact of material deprivation, housing quality, social isolation, and increases the proximity of people to health services, all of which reduce vulnerability during a heat event.

The BCCDC has led much of the effort to quantify the health impacts of extreme heat in BC, relying on daily data from the BC Vital Statistics Agency for the purposes of routine surveillance and evaluation of public health threats (Ho, Knudby, Walker, & Henderson, 2017). Prior to the June 2021 heat event, our understanding of the relationship between heat and mortality and morbidity was shaped by research into an event in 2009 that included three consecutive days above 30°C, leading to 120-160 excess deaths (Kosatsky, Henderson, & Pollock, 2012), and a total estimated cost of $120 million—a sum reflecting the value of lives lost, electricity costs, and reduction in Vancouver's daily GDP (Stewart et al.,

[13] Public health surveillance of heat related illness can be difficult to conduct for a number of reasons. Heat-related symptoms can often be under diagnosed as the symptoms are quite variable in presentation, and only extreme cases might be correctly reported and coded, so medical records will not reflect the entire range of people impacted (Stewart et al., 2017).

2017).

Kosatsky et al. (2012) found that “persons aged 65–74 years were at 47% greater risk of mortality than those aged ≥85 years”, though no comparative demographic or case-specific measures were found that could explain this. It is plausible that those ≥85 years old were in long term care or similar spaces where social isolation and lack of acute support were less of a concern.

A more recent study assessed the geographic distribution of heat-related mortality in the region to investigate relevant risk factors. Results showed that areas at higher risk of heat-related mortality experienced maximum apparent temperatures—i.e., combined measures of temperature and humidity—of ≥ 34.4°C and had ≥ 60% of the population who were neither employed nor looking for work (Ho et al., 2017). The labour nonparticipation rate was the most significant of 11 variables relating to social vulnerability, but this finding may not hold in other cities with different geographic and demographic contexts. Figure 7 shows the spatial distribution of these results across the lower mainland.

The heat-mortality relationship varies by geographic region, and mortality in costal regions can often occur at lower temperatures relative to hotter regions of BC and Canada. Henderson et al. (2013) found that mortality starts to increase at temperatures that are below the established heat warning criteria. For example, a small increase in mortality was observed for the Coastal region below 25°C. BCCDC plans to update their exposure-response curve to reflect the exponential relationship at high temperatures, as well as the relationship at lower temperatures.

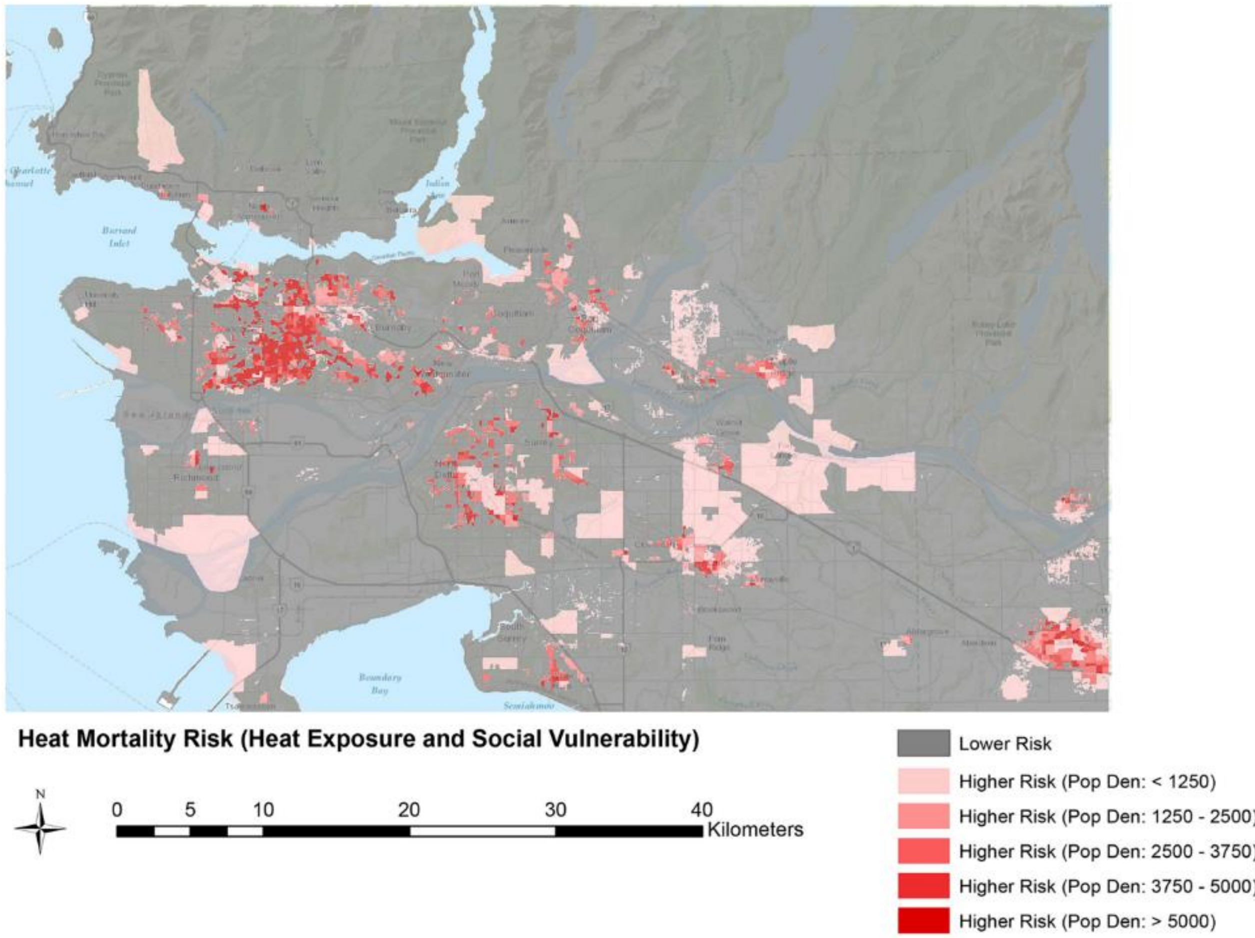

Figure 7: Distribution of heat-related mortality in the region (Ho et al., 2017).

As discussed in Section 3.1, certain groups are more susceptible to the impacts associated with extreme heat. For example, those in lower paying and/or status jobs are less able to avoid unsafe working conditions during heat waves, and certain groups may not feel fully accommodated at cooling centres (e.g., underhoused and Indigenous individuals). Other inequitable elements of the impacts include potential increases in housing unaffordability, for example rents could increase if landlords are mandated to invest in building upgrades to make homes thermally safe. Increased cost of living/financial burden/income inequities may increase as people are forced to spend $$ on adaptation technology and strategies.

4.3.1.1 Mental health and wellness

No significant increase in ED and UPCC visits for mental illness or mental health issues was found in the VCH internal study of the June 2021 heat event. However, the collection and analysis of relevant data is still evolving, and the absence of evidence is not necessarily evidence of absence. For example, during the Metro Vancouver heat wave in 2009, 18 deaths were attributed to self-harm or accidental overdoses, which is significantly higher than normal rates (Stewart et al., 2017). Early data from the BCCDC for the June 2021 heat event suggests that people experiencing mental health and substance use disorders were at an increased risk of death. Further insights into these impacts will continue to develop following the June 2021 heat event.

Reports fromlived evidence also point to the impacts of extreme heat on mental health and wellbeing. For example, HealthADAPT consultation sessions in Hope and Chilliwack identified impacts on those with substance use challenges. There is a concern about the compounding effect of the climate crisis—and particularly extreme heat—on the opioid crisis. Extreme heat can have physiological impacts on high-risk substance users (e.g. dehydration) and create greater risk for overdose. BCCDC is preparing a report on heat and deaths related to illicit drug use, and other work of this nature is needed.

More studies that explore the relationship between extreme heat events (and milder heat events) on anxiety and mood disorder, absenteeism, overdose events/deaths, etc. in the VCH and FH health regions are needed to build the evidence base. For example, BCCDC has an innovative research project under development that uses crowd sourced data from a popular smart phone app to correlate cognitive performance with environmental conditions. We also heard during community engagement that extreme heat can exacerbate social isolation—and its attendant mental health impacts—for people sheltering in place. We also heard that cancellation of outdoor community events (sporting, stewardship related) can have a similar effect.

4.3.2 National and international data

Extreme heat events negatively impact human health, health facilities, and levels of service for health service delivery organizations (Direction Régionale de Santé Publique, 2018; Henderson et al., 2013; Prairie Climate Centre, 2019; World Health Organization, 2020).

Studies in the United States (US) have found a relationship between extreme heat events and mortality and illness (Sarofim et al., 2016), adverse birth outcomes (Bekkar, Pacheco, Basu, & DeNicola, 2020), increased suicide rates (Burke et al., 2018), as well as emergency department visits for conditions including renal failure, appendicitis, dehydration, ischemic stroke, non-infectious enteritis, and primary diabetes (Sherbakov, Malig, Guirguis, Gershunov, & Basu, 2018; Winquist, Grundstein, Chang, Hess, & Sarnat, 2016). It is popularly claimed in the Canada and the US that extreme heat causes more deaths annually than all other weather events combined. Although it is very difficult to know with certainty, research suggests that the US is likely underreporting the number of deaths attributable to heat (Popovich & Choi-Schagrin, 2021; Weinberger, Harris, Spangler, Zanobetti, & Wellenius, 2020). It is very likely that the June 2021 heat event is one of the most deadly natural disasters in Canadian history.

Studies from Canada have found the following relationships with elevated ambient temperatures:

- Risk of death from cocaine overdose in Quebec (Auger, Bilodeau-Bertrand, Labesse, & Kosatsky, 2017);
- Increased coronary heart disease and stroke hospitalisations in Ontario (Bai et al., 2018);
- Increased risk of emergency department visits for renal colic in Ontario (Ordon et al., 2016);

- Risk of placental abruption for pregnant women in Quebec (He, Kosatsky, Smargiassi, Bilodeau-Bertrand, & Auger, 2018);
- Earlier delivery among term births in Montreal (Auger, Naimi, Smargiassi, Lo, & Kosatsky, 2014);
- Increased ambulance response calls for heat-related illness in Ontario (Bassil et al., 2011);
- Increase in emergency room visits in rural communities in Ontario (Bishop-Williams, Berke, Pearl, & Kelton, 2015);
- A relationship was also found for mild heat and increased diabetes-related hospitalizations in Ontario, indicating that not only extreme heat events drive negative health outcomes (Bai et al., 2016);
- The physiological factors characterizing heat-vulnerable older adults (Meade et al., 2020).
- There is evidence from outside BC that heat increases accidental mortality, including occupational injuries (Martínez-Solanas et al., 2018) and drowning (Fralick, Denny, & Redelmeier, 2013).

These studies indicate that heat events lead to adverse health outcomes and that the effects are somewhat established in the Canadian literature.

Mental health impacts

A forthcoming assessment from Health Canada has a chapter devoted to mental health impacts of climate change, including heat. Although not yet published, this assessment has found that “extreme heat affects mental health directly (e.g., mood, behavioural disorders) and indirectly (e.g., aggression, violence, and suicide), especially for those with pre-existing mental health conditions. More research on the different ways extreme heat impacts mental health is required to guide public health actions focused on reducing the mental health risks associated with extreme heat in Canada” (Health Canada, forthcoming). Results from this chapter will be synthesized here once the content is finalized by Health Canada.

Research in Canada has empirically found a relationship between heat and mental health, both as a predictor of adverse outcome, and as an outcome of exposure. Research in Toronto found an association between temperatures above 28°C and emergency department visits for mental and behavioral disease (Xiang Wang, Lavigne, Ouellette-Kuntz, & Chen, 2014). Similar results were found in Quebec in even lower temperatures of 22°C and 25°C (Vida, Durocher, Ouarda, & Gosselin, 2012).

International research echoes the link between heat and mental health. Research in a temperate Australian city observed a 7.3% increase in hospital admissions for mental and behavioral disorders when ambient temperatures were above 26.7°C (Hansen et al., 2008). Using self-reported sleep data from the US Centers for Disease Control and Prevention Behavioral Risk Factor Surveillance Survey (BRFSS), researchers found increases in nighttime temperatures amplify self-reported nights of insufficient sleep, particularly for lower income and elderly adults (Obradovich, Migliorini, Mednick, & Fowler, 2017). A study in Boston found that “cognitive function deficits resulting from indoor thermal conditions during heat waves extend beyond vulnerable populations” (Cedeño Laurent et al., 2018). Using national data, Schmeltz et al. (2017) found that nondependent alcohol/drug abuse, dementia, and schizophrenia were among the disorders that were associated with increased frequency of HRI hospitalizations.

Impacts of extreme heat can be exacerbated when relative humidity levels are high (Kravchenko, Abernethy, Fawzy, & Lyerly, 2013; Lubik, Mckee, Chen, & Kosatsky, 2017; Raymond, Matthews, & Horton, 2020), and when multiple (i.e., compounding) heat events occur with minimal time between (Baldwin, Dessy, Vecchi, & Oppenheimer, 2019). In addition, ground level ozone concentrations are often higher on days with high temperatures, another climate risk that will be discussed in the air quality section below. And lastly, people on specific medications, such as antidepressants and antipsychotics can be predisposed to heat related illness, as these medications can interfere with thermoregulation (Martin-latry, Goumy, Latry, Gabinski, & Andre, 2007; NCCEH, 2010).

4.3.2.1 Urban form and heat

As shown below in the Community Climate Change and Health maps, the urban form influences people's and communities' vulnerability during heat events. Forthcoming research from the BCCDC will examine the spatial distribution of those who died during the June 2021 heat event, as well as the influence of social vulnerability, built form, and other factors. Preliminary research by Post Media used surface temperature data from NASA's Landsat 8 satellite and found that wealthier neighbourhoods in Vancouver were significantly cooler than lower-income neighbourhoods during the June 2021 heat event. Average ground temperature varied by as much as 23°C between Metro's coolest and hottest census tracts, in large part due to the presence of mature urban trees in wealthier neighbourhoods (Griffiths, 2021). This is an area of study that is highly complex and still evolving (Krstic et al., 2017), but these results provide strong evidence for the established need to maximize the protective function of certain urban forms

According to Health Canada, the Urban Heat Island effect is a phenomenon where the ambient temperature in an urban area is hotter than that of surrounding rural areas. UHIs occur where there is minimal vegetation cover and a high percentage of dark surfaces such as tar roofs, asphalt roads or parking lots. Figure 8 shows surface temperatures across Metro Vancouver, with darker areas indicating higher temperatures and the possible presence on a heat island (Metro Vancouver, 2021b).[14]

[14] Note that this measure of temperature (i.e., surface) differs from the apparent temperature used in Ho et al. (2107) described above.

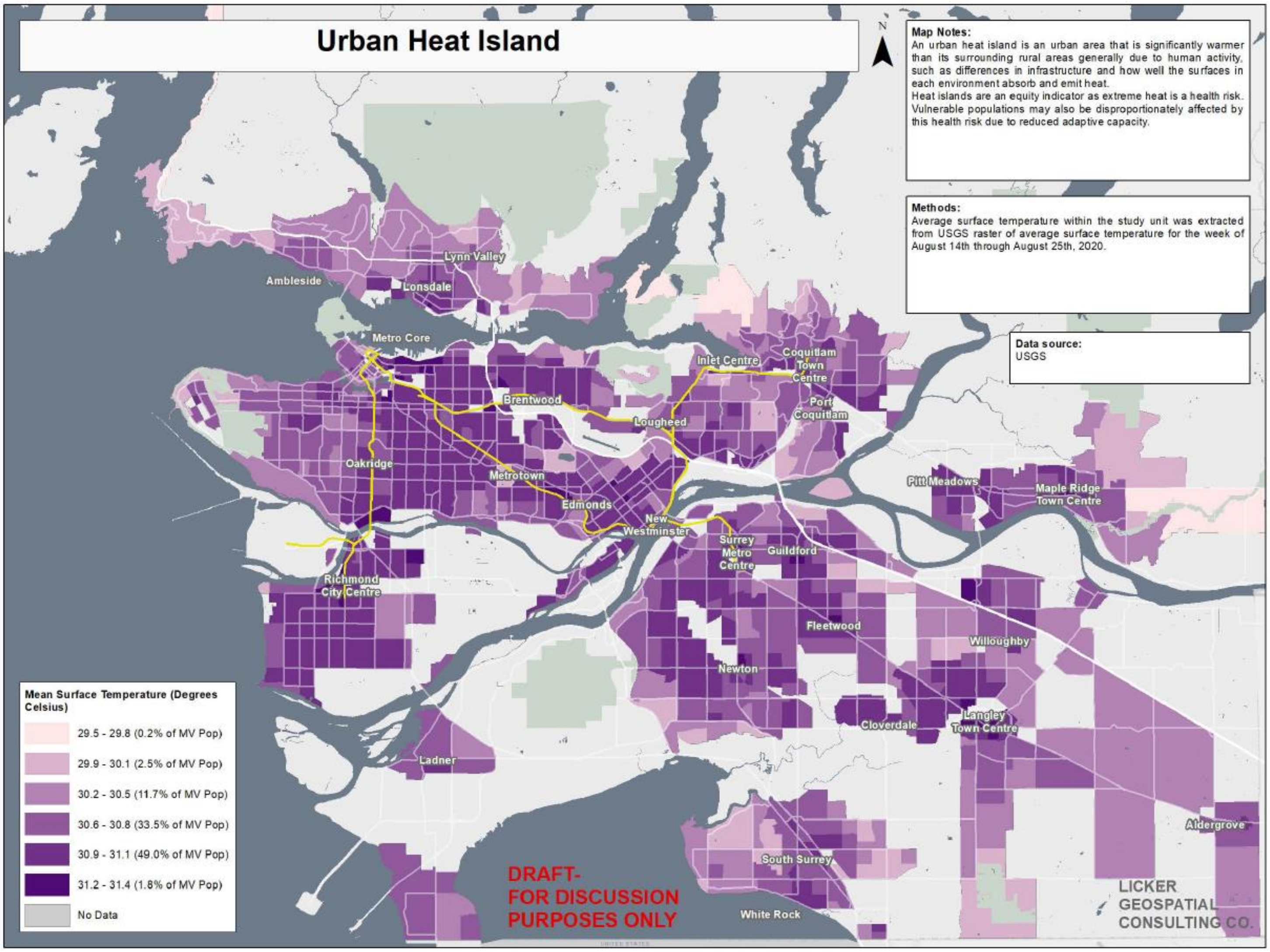

Figure 8: Surface temperatures across Metro Vancouver (Metro Vancouver, 2021).

In Metro Vancouver, impervious surfaces are expected to increase as parts of the region urbanize (Metro Vancouver, 2019c). This is problematic because urban trees and greenspaces can reduce the Urban Heat Island effect and have many co-benefits that are well understood in addition to increasing access to nature for people living in these urban environments. These include “shading and cooling, carbon storage, stormwater management, and wildlife habitat” (Metro Vancouver, 2019c). Nature experiences have also been associated with increased psychological well-being, and cognitive restorative effects (WHO Regional Office for Europe, 2016; World Health Organization, 2021). Higher levels of greenness around a person’s home have been associated with a reduction in cardiovascular disease mortality, all-cause mortality, low birthweight, per-term birth and type 2 diabetes (van den Bosch & Ode Sang, 2017). These health benefits likely occur through a number of pathways include the impact of greenspace on the promotion of physical activity, stress reduction and social connection. Evidence suggests that socioeconomically disadvantaged groups and other vulnerable groups see stronger health benefits from access to greenspace (Toronto Public Health, 2015; WHO Regional Office for Europe, 2016). Although the regional tree canopy is in decline in Metro Vancouver, efforts are underway to reverse this trend, including for health care facilities (e.g., Barron et al., 2019).

Figure 9 shows urban canopy trends for several Metro Vancouver municipalities, as well as the extent of the urban canopy.

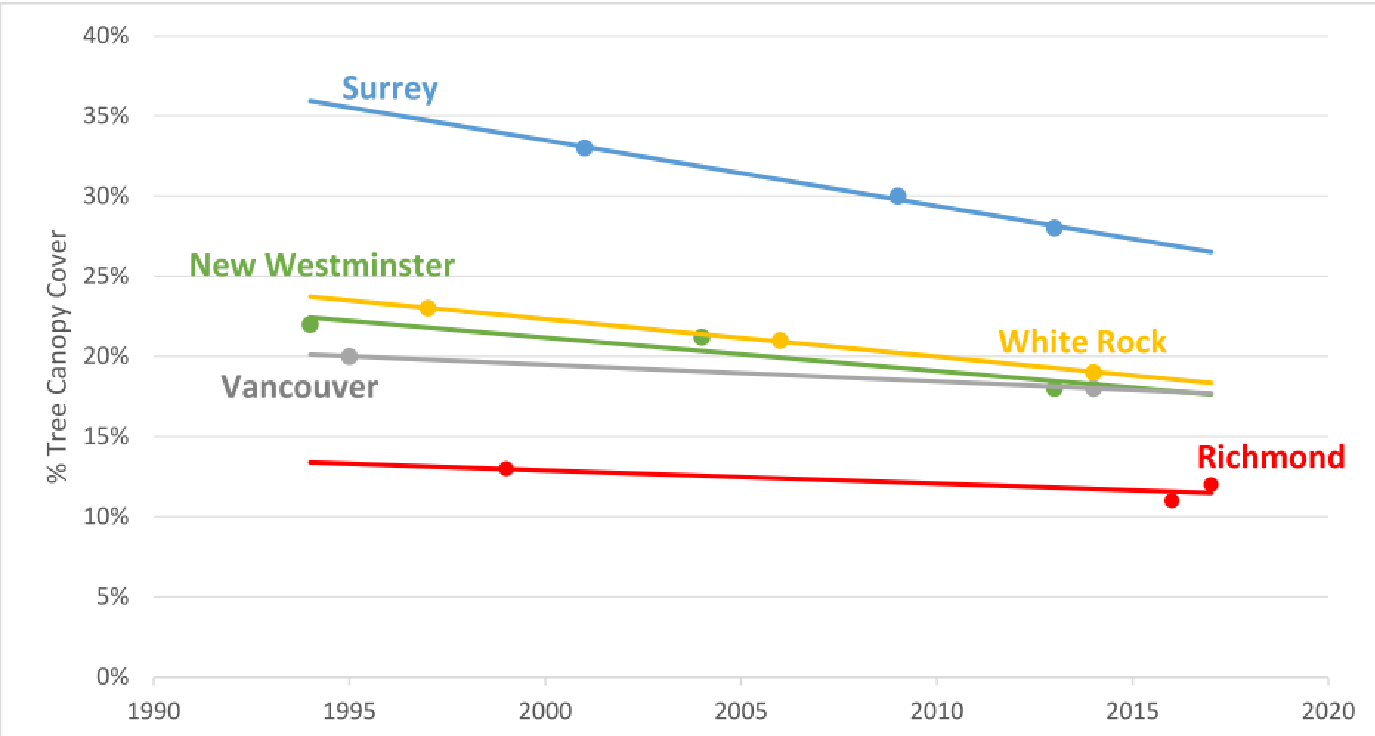

Figure 9: Reported change in % tree canopy cover for several cities in Metro Vancouver (Metro Vancouver, 2019c)

Work by the City of Vancouver has shown an inequitable distribution of tree canopy coverage across the city, with higher income areas having more greenspace and tree coverage (City of Vancouver, 2018). This is reflected in the broader literature as well (Anguelovski et al., 2019; Donovan, Prestemon, Butry, Kaminski, & Monleon, 2021). This presents a key equity issue that may also be playing out in other VCH and FH regions. An urgent focus on greenspace and tree canopy coverage in communities that currently have low coverage is a key adaption strategy and equity must be considered throughout the process (Hunter & Harford, 2021).

4.3.3 Community vulnerability mapping[15]

VCH, FH, and UBC produced a set of maps that displays vulnerability to heat across the following regions:

- City of Vancouver
- Richmond
- Coastal, Rural—Squamish, Whistler, Pemberton, Gibsons, Powell River, Bella Coola

[15] Health Canada workbook Step 2D

- Coastal, Urban—District of North Vancouver, West Vancouver, Bowen Island,
- Delta, Surrey, Langley
- Abbotsford, Chilliwack, Hope
- Burnaby, Coquitlam, Maple Ridge

These maps display historical heat exposure using datasets from ClimateBC, which use downscaled PRISM climate normal data from 1981 to 2010. The variable used for extreme heat are degree days over 18°C. This data has been downloaded at a 500 m grid and an interpolated surface created from the heat variable. The mean interpolated heat value was used for each dissemination area.

When adaptive capacity is high, overall vulnerability is reduced. Sensitivity and adaptivity capacity were modelled using variables including age, pre-existing conditions, socioeconomic status and built environment conditions (full list of variables and methodology available upon request).

Figure 10a shows the results for City of Vancouver. Those interested are encouraged to access the web versions of these maps to learn more and to generate screenshots. Future work could assess the extent to which the vulnerability predictions in the maps correspond to mortality during the heat event. Initial visual comparisons of the City of Vancouver map (Figure 10b) in comparison to the location of residence for people who visited the ED for heat related illness during the June 2021 heat event suggests that the maps do a fairly good job at predicating areas of impact.

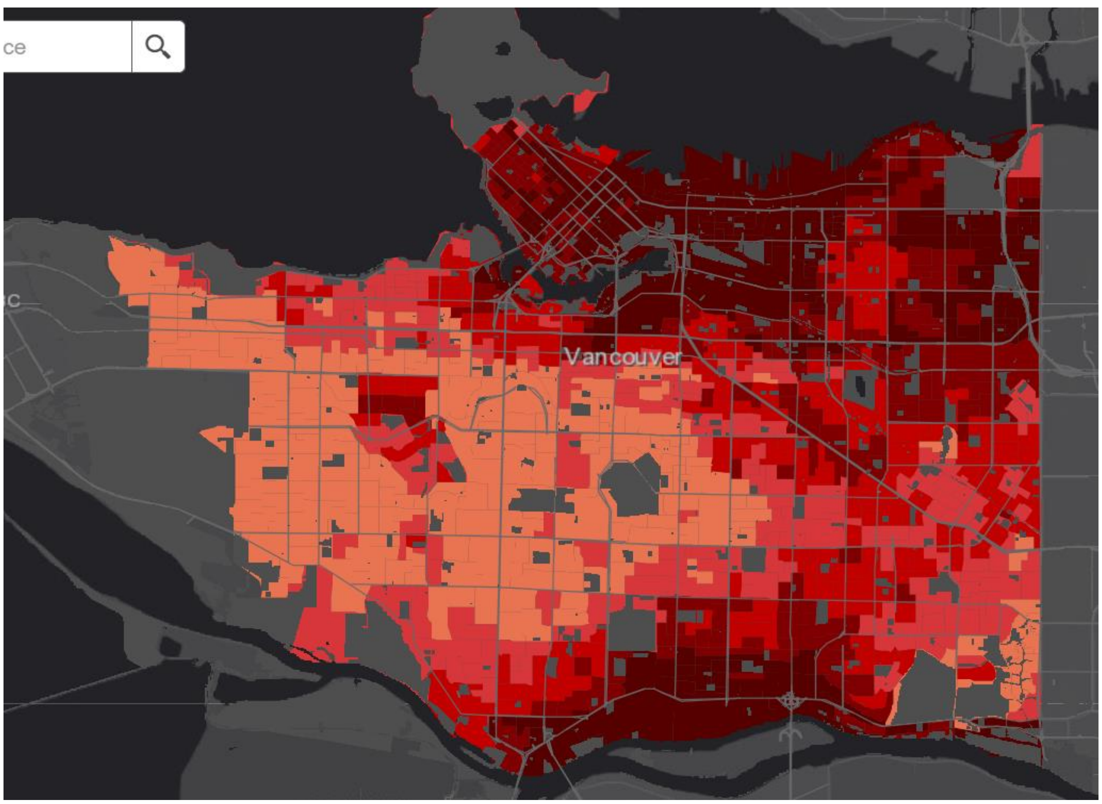

Figure 10a: Heat vulnerability results for City of Vancouver.

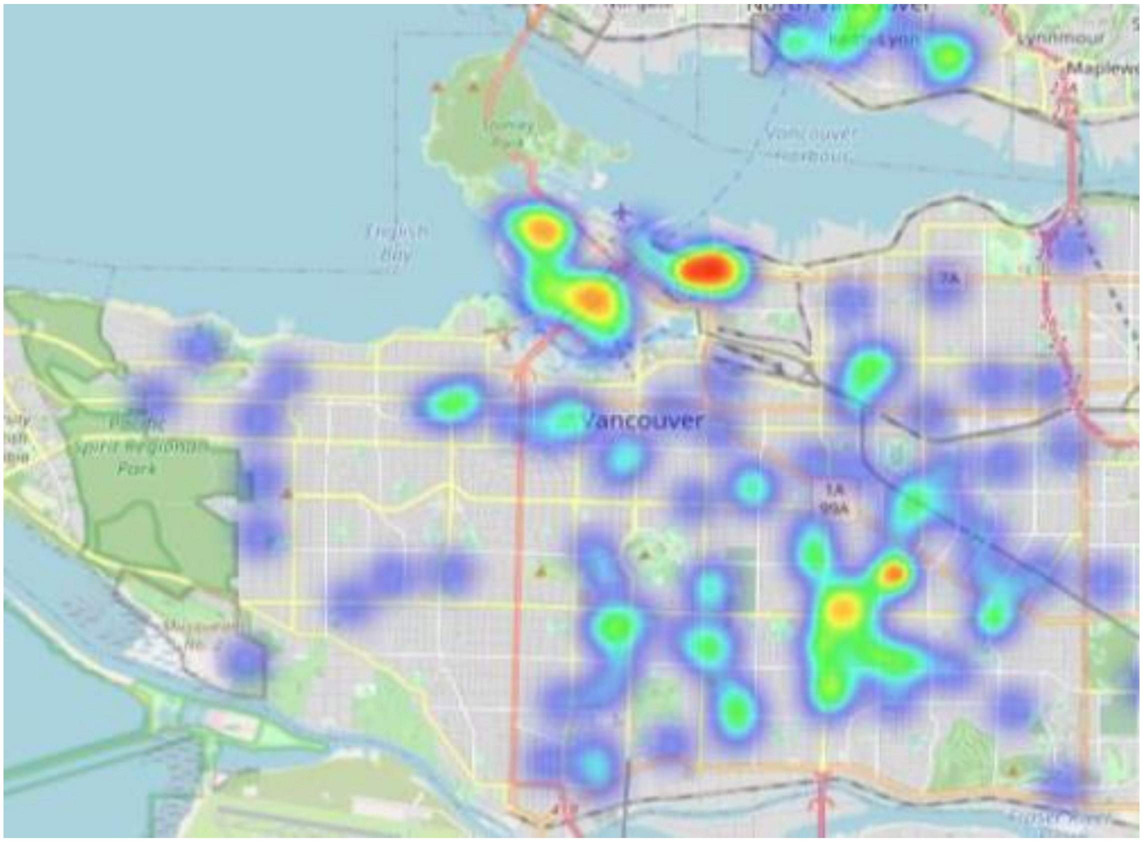

Figure 11b: Emergency departments visits from the heat event in June 2021.

4.4 Future population health impacts[16]

Projecting likely future impacts from extreme heat events could provide a useful tool for planners and decision-makers. Although if projections appear insignificant, or have high uncertainty, they could be maladaptive and lead decision-makers to neglect this important issue.

A national study from 2012 found that the annual heat-related mortality rate in Vancouver is 0.53/100,000 (baseline period 1981–2000) and that this rate it is expected to increase to 2.25 in 2031–2050 (325%), 3.51 in 2051–2070 (562%), and 6.71 in 2071–2090 (1166%) (Martin, Cakmak, Hebbern, Avramescu, & Tremblay, 2012, p. 615).[17] This study also found an expected decrease in cold related mortality for Vancouver over the same years. The main limitation of these findings is that they do not account for any changes in adaptive capacity (e.g., increased air conditioning) that would mediate these increases. Notwithstanding, the results do provide an indication of the trends that can be expected in Vancouver for heat mortality.

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[16] Health Canada workbook Step 3B

[17] The climate modelling was done by Ouranos using the A2 scenario, which is similar to the RCP 8.5 scenario used elsewhere in this assessment.

Guo et al. (2018a, p. 5) modelled excess deaths related to heatwaves under RCP 8.5 using population projection variants developed by the UN, and considering “no adaptation” and “full adaptation” scenarios. In other words, the results account for warming trends and population growth, but not changes to demographic distribution, mortality rate, socioeconomic factors, etc. For Canada, they found a 455% change under RCP 8.5 in 2031–2080 comparing to 1971–2020, with assumption of no adaptation and using the high variant population (Guo et al., 2018b). This number appears to correspond to the percent change for Vancouver based off of the figure on page 5 of the full article, which indicates an increase of 400-525% for Vancouver. Under the full adaptation scenario, they found a 92% change under RCP 8.5 in 2031–2080 comparing to 1971–2020, using the high population variant. These results, although very high-level, lend some validity to the findings from Martin et al. (2012).

In a forthcoming study, the Canadian Temperature-related Excess Mortality and Morbidity Projections project (CanTEMP) has projected excess non-accidental mortality as a result of heat and cold, under various future climate scenarios, and relative to 2000 – 2015. For RCP 8.5, the study predicts a 3% increase for the 2050’s and a 9% increase for the 2090’s for the Vancouver health service area. It should be noted that the same study projects a 6% decrease in cold weather mortalities for the 2090’s, leading to an estimated 3% net change in excess mortality for the Vancouver health service delivery area for the period from 2090-2099. The data for each HSDA can be found in Figure 12.

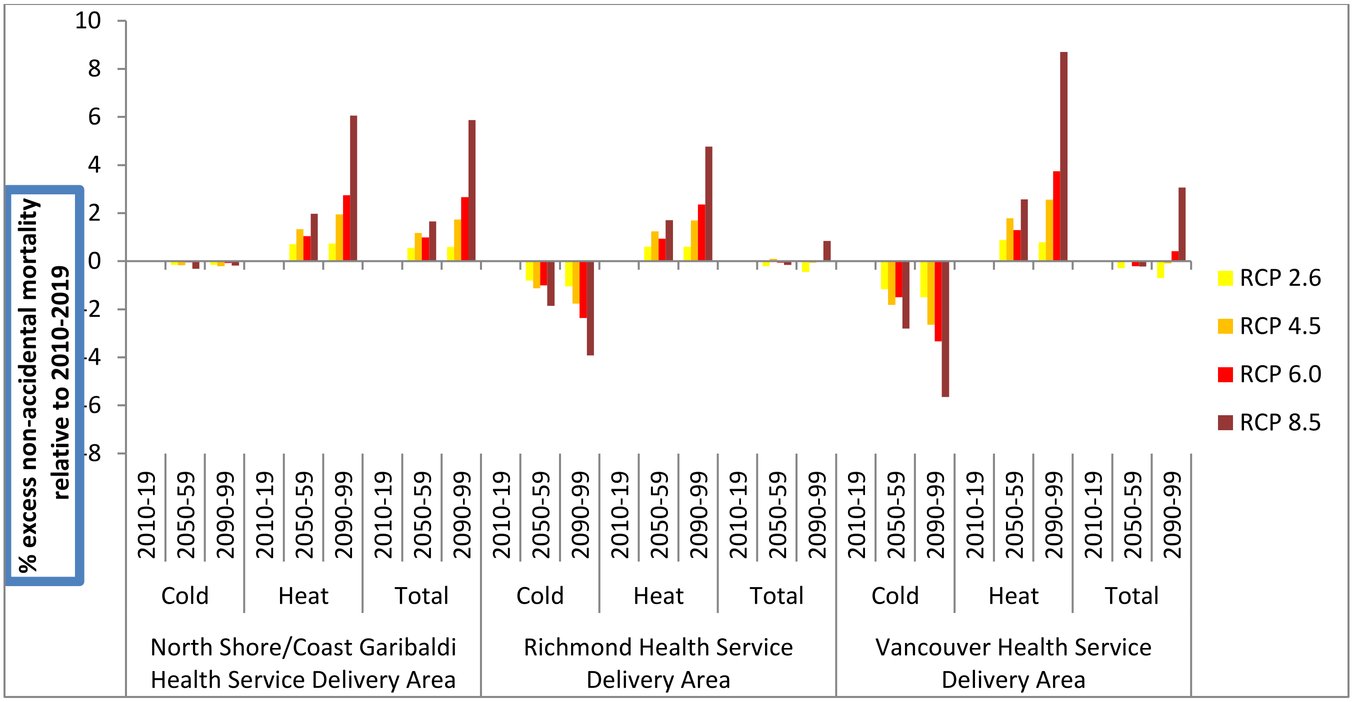

Figure 12: Gross and net changes in mortality for Vancouver Coastal Health

For Fraser Health, the study found the following: 2% increase for the 2050's and a 7% increase for the 2090's for Fraser East, and a net of 5% by 2090. For Fraser North, the study found a 1% increase for the 2050's, a 4% increase for the 2090's for Fraser North, and a net increase of 0.6% for 2090. For Fraser South, the study found a 2% increase for the 2050's, a 6% increase for the 2090's, and a net increase of 4% for 2090 (*see* Figure 13).

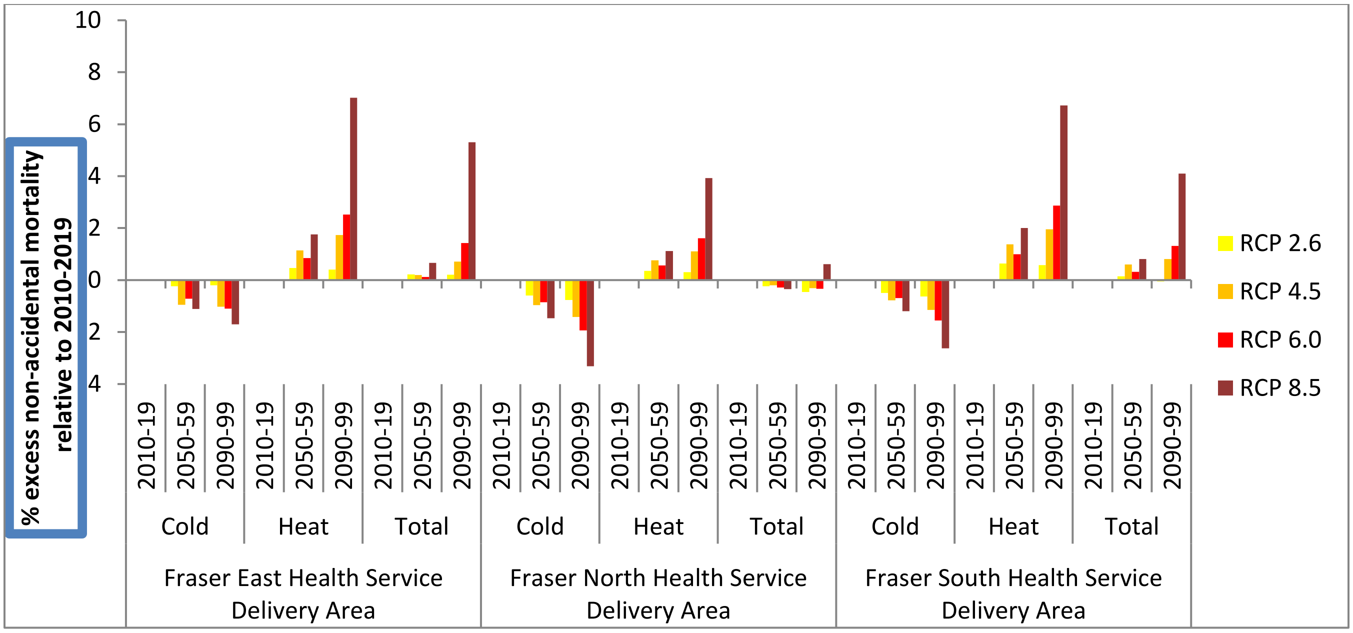

Figure 13: Gross and net changes in mortality for Fraser Health

This study was conducted under the assumption of no adaptation or population changes (i.e., it did not use socioeconomic modelling), and is currently being updated and resubmitted for peer review.

Together, the three studies above take different methodological approaches and do not converge on similar estimates--although they do illustrate the likely direction of change. As more research comes out that uses the Multi-Country Multi-City (MCC) Collaborative Research Network methodology, it should become easier to compare findings. The MCC is an international research program that studies the associations between environmental stressors like heat and air quality and health.

In 2021, the Canadian Institute for Climate Choices estimated the change in hospitalizations from four diseases: coronary heart disease, stroke, hypertensive disease, and diabetes, all of which have a strong relationship with ambient temperature (Canadian Institute for Climate Choices, 2021). They found dramatic increases in hospitalizations under RCP 8.5, as well as economic impacts associated with healthcare costs, and lost productivity. Nationally, they find that heat-related mortality will nearly double by 2100.

Overall, there is a lack of data relating to the future health impacts of extreme heat in BC, and in VCH and FH in particular. Future work should consider multiple `economic factors (e.g., population growth, affordability) to produce multiple scenarios (Boyd et al., 2020; Ebi, Hess, & Isaksen, 2016). This work could be aided by advances in climate and health projections methodologies (e.g., Guo et al., 2018a; Hess et al., 2016), including shared socioeconomic pathways being developed by CCCS, and by others (Ebi, Boyer, et al., 2021).

Despite the uncertainty and variability in these estimates, it is clear that heat health impacts will increase as the climate warms and the July 2021 heat event suggests that these impacts may large and far reaching in our regions, without significant urgent adaptation.

4.4.1 Projections from other regions

International research indicates increases in excess mortality as climate warming trends continue (Lee et al., 2020). A systematic assessment of 63 studies examining future projections of heat and mortality found that all papers indicated that mortality from high temperatures would increase under a warming climate. Only a small number of studies included possible changes in population and demographics in their estimates of future mortality, meaning many estimates of mortality could be biased low (Sanderson, Arbuthnott, Kovats, Hajat, & Falloon, 2017).

City-specific studies are available that build the case as well. For example, "under three different climate change scenarios for 2081–2100 and in the absence of adaptation, the city of Chicago could experience between 166 and 2,217 excess deaths per year attributable to heat waves, based on estimates from seven global climate models" (Peng et al., 2011). However, Chicago is a very hot, and very dense city, and therefore not a good proxy for our context. Additional studies from the US could be useful if additional evidence is needed (e.g., Mills et al., 2015; Schwartz et al., 2015). Benmarhnia et al. (2015) found an increase between the observed and projected years of life lost as a result of heat events in Montreal, especially for those in more vulnerable neighbourhoods.

4.4.2 Mental health projections

Regarding mental health impacts, a study of the United States and Mexico found that 9,000 to 40,000 additional suicides could occur by 2050 (RCP 8.5) as a result of increase in monthly average temperatures (Burke et al., 2018). This represents a 1.4% increase in the suicide rate in the US, and a 2.3% increase in Mexico. Similar results do not yet exist for Canada. A related study relied on self-reported sleep data from the US Centers for Disease Control and Prevention Behavioral Risk Factor Surveillance Survey (BRFSS), and projected increases in sleepless nights for both 2050 ad 2080, using RCP 8.5 (Obradovich, Migliorini, Paulus, & Rahwan, 2018).

4.5 Health system impacts

4.5.1 Health care facilities

Hospitals, long term care centres, hospices, and clinics are essential to the health system. Exposure of facilities in VCH and FH is expected to be significant. In VCH, Squamish Hospital experienced 6 days above 30°C in the past, and by 2080, is expected to experience 41 days above 30°C on average. Richmond Hospital experienced only 1 day with temperatures above 30°C in the past on average, but by 2080 this is projected to increase to 28 days with these extreme temperatures (Facilities Management, 2018).

In Fraser Health, sites at the eastern end of the Fraser Valley are expected to experience greater warming than those closer to the moderating influence of the ocean. For example, Fraser Canyon Hospital will experience the highest number of days above 30°C, 38 days by 2050, and 57 days by 2080 (Facilities Management, 2019a, p. 8). Royal Columbia Hospital, in New Westminster is expected to see an over 350% increase in cooling degree days by 2050, and an over 600% increase by 2080 (Facilities Management, 2019a).

A number of observed and expected impacts of extreme heat are presented in Table 6 from Yip and Woo (2016) and Facilities Management (2020). In addition, preliminary findings from the June 2021 heat event suggest an increase in HVAC-related work requests in VCH facilities and a number of LTC that had significant cooling challenges.

Table 6: Extreme heat impacts to facilities and operations

Infrastructure	- Increased wear on equipment - Increased electricity costs - Electricity disruptions - Strained cooling systems impacting medical research samples - Power outage (planned and unplanned) due to overloaded grid and generators (e.g. staff used portable air conditioners) - Information technology system failure - Refrigeration failure in mortuary and laboratory - HVAC system failure—Chiller plant capacity overload during high humidity events can lead to excessive condensation indoors - Higher rate of usage in high temperatures (e.g. bed linens changed more frequently) - Decreased efficacy of some medication in storage - Overheating causes operation mechanisms of sliding glass doors to seize; other building components see decreases service life - Failure of IT systems due to operating at temperatures above design thresholds - Lab results lost or deemed inaccurate due to higher temperature in Lab Equipment Room - Overheating causes operational issues for sliding doors
Staff and services	- Patient surges at hospitals - Missed work days, increased overtime, and staff retention difficulties - Increased work load and number of work hours due to increases in emergency

	admissions; addressing discomfort and/or exacerbated health outcomes of in-patients; and, admission of patients transferred from other affected facilities - Increased physical demand from working high indoor temperatures - Impaired cognitive ability—Increases risk of experiencing an accident
Patients	- Overheating beyond typical comfort conditions - Decreased indoor air quality - Exacerbation of existing health conditions (e.g., chronic pulmonary diseases, mental illnesses, respiratory illnesses) - Additional health impacts (e.g., dehydration, heat stroke, bladder infections, heart failure, chest infections) - Medical devices affected or inactivated by utility outages (e.g. water, electricity) - High temperatures result in postponed physiotherapy procedures and other outdoor activities - Increased risk of perioperative complications (e.g., for elderly surgical patients and trauma patients)

There are a variety of staff and patient responses that can minimize some of the impacts described above. For example, staff have pre-cooled areas that tend to overheat and have also used fans to provide additional cooling. Although opening windows is also a common response, various issues (e.g. limited extent to which the windows can be opened for safety purposes, or insects entering through the windows) can prevent it from being a viable measure (Yip & Woo, 2016). During the June 2021 heat event, HEMBC provided portable air conditioner to a number of LTC in order to reduce high indoor temperatures.

Climate vulnerability and risk assessments have been conducted at several sites, including:

- **Fraser Canyon Hospital**—Operations and administration staff report elevated temperatures in the building during extreme heat events. Operations staff reported that the HVAC system was operating at full capacity most daytime hours during the summer.
- **St. Paul's Hospital** redevelopment**—**results from a stress testing exercise indicate that prolonged heat could lead to power outages in the city of Vancouver for prolonged periods, and that loss of power may affect internal data management and digital infrastructure affecting patient information management, care, and internal/external communications. They also identified that hotter temperatures may increase climate stress resulting in depletion of staff, missed work days and increased overtime (Facilities Management, 2019b).
- **Redevelopment of Royal Columbian Hospital—**identified high risks resulting from cooling capacity being exceeded and impacting facility operations, and extreme heat leading to extended power outages in the community that lead to increased demand on the hospital (Ellis Don, 2020).

Additional impacts have also been identified for hospices, as described below.

4.5.2 Health services

The heat event in June 2021 highlighted the many ways that the health system can be impacted during an extreme heat event. Anecdotal examples include:

- Overheated indoor spaces and increased workload led to psychosocial impacts;
- Staff challenges were exacerbated by school and daycare closures, likely leading to increase absenteeism;
- Some COVID vaccination clinics were closed or had modified operating hours;
- WorkSafeBC asked employers to close workplaces that could not protect workers from heat-related illness (CBC), and workers at food processing plants and restaurants experienced overheating;
- Morgues experienced demand surges and experienced challenges with refrigeration.

Table 7 presents additional impacts that were identified during engagement that occurred before the June 2021 heat event, and which includes impacts to facilities not listed above. The adaptive capacities identified during engagement with these health service providers have not been included in the main assessment summary, but will be reflected in the forthcoming adaptation framework.[18]

Table 7: Impacts to health services from heat

Extreme Heat Events
Home and community care
- Higher temperatures can lead to increases in mood disorders, anxiety disorders, dementia, and psychological distress, which can lead to increased need for additional prescriptions (e.g., Ativan, anti-depressants)—especially for those who are socially isolated, First Nations, remote/rural communities - Being unable to go outside (e.g., doing errands) during extreme heat events can increase social isolation, prevent exercise, and can make it impossible to access cooling centres and other air conditioned spaces - Patients experience dehydration, which could be complicated by alcohol and substance use, and certain prescription medications - Staff experience respiratory impacts (e.g., asthma) or heat stress as a result of exposure while having to travel throughout the city to provide care, particularly those relying on transit or walking/biking. - Increased stress managing poorer patient health and demands on time - Difficulty keeping patients hydrated - Less efficiency due to fatigue and inability to travel to multiple clients in schedule - Excess demands and heat stress could lead to decrease in staff morale, stress, and aggression - Staff working at home experiencing overheating and heat stress - Extra time required on visits (e.g. to share information about how to cope with heat) - Increased scheduling demands from increased visits required (e.g., more bathing tasks) - Extra breaks required by staff - Staffing challenges due to family obligations and sickness resulting from heat - Costs associated with surge contracts - Heat event prompting school or child care closure, leading to staff missing shifts - Difficulty recruiting and retaining for jobs that require travel/being outside if environmental conditions are poor - Inability to meet demand (specifically because of difficulty hiring – finding enough CHWs is already an issue, especially in rural areas) - Communication with all clients and staff with available resources in office is difficult in times of heightened demand - Attendance issues for those who have pre-existing conditions that get exacerbated by high heat and humidity levels

[18] COVID-19 has led to significant delays for this part of the project, and meant that engagement sessions were limited to one hour in length, and could only be held every 4-6 months.

- Staff needing to care for family members affected by extreme heat (elderly parents, children)
Palliative care
- Increase in respiratory issues, especially for patients with pre-existing COPD - Clients unable to travel due to clinics (e.g., wound clinics, cancer, cardiac) due to extreme heat or poor air quality, leading to missed appointments - Poor air quality and extreme heat could prevent visits by neighbours and friends, and this could lead to increased isolation - Increased risk of dehydration for some patients, especially elderly and those without access to freshwater (e.g., people experiencing homelessness that do not have easy access to fountains) - Overheating in private homes occurs because of hot temperatures combined with poor building quality, lack of air conditioning and few operable windows. This overheating can be significant and can exacerbate health conditions. Situations can occur when a patient needs to be transferred to acute/hospice because the home was too hot for workers to do physical work. - Some patients can have difficulty accessing cool spaces (e.g., cooling centres) or clean air centres. - Overheating in certain parts of facilities can require patients to be moved to cooler areas. This can impact dignity and safety. Hospices have less ability to control their temperature as it is likely that very few have air conditioning - Heat stress or air quality impacts for health care workers, especially those that rely on bicycle or transit to travel to patients. Similarly, nurses sometimes encounter high-rises where elevators are out of services, leading the difficult stair climbs in hot buildings - There can be cases where it is difficult for nurses to refill their water while at patient's homes
Public health/OCMHO
- Increased burden on health systems and interruptions in regular services like clinics and appointments, and disruption to essential services such as child care - Disruption to services e.g. immunization clinics that were shut down to protect worker health - Staff possibly being unprepared at home to handle heat at home, impacting quality of life, thus work productivity. Staffing absences, including when staff stay home to take care of family members, pets, etc. - EHOs in district limiting their fluid intakes to prevent using restrooms (difficult to find sometimes) - increasing risk of heat-related illness (also being in hot kitchens) - Rapid changes to work--dropping projects to address crisis, stress - Impact to businesses (e.g., restaurants refrigeration units not working). - In Fraser Health, people that were evacuated from overheated sites in Interior Health needed to be accommodated in facilities within Fraser Health - Business closures and loss of income - Overheating in child care and long-term care facilities (based on anecdotal evidence from licensing officers) - Increased demand on PHSU for climate-related monitoring and surveillance - Increased demand for MHO/health protection to provide specific advice and recommendations during heat and smoke events (sporting events, outdoor concerts, schools, childcare, Long-term care, BC housing, cooling and clean air spaces) - Increased need for MHO and health protection presence at emergency operation centers - Overheating and air quality concerns in shelters inspected by EHOs - Potential impacts of heat on food-borne illness and inspection practices for events etc. - Increased use of generators etc. to enable events to provide adequate cooling with resultant impacts on GHG emissions and local particulate matter - Impact of heat on recreational water quality and the need to close beaches more often

4.6 Adaptation inventory—Heat[19]

Understanding VCH and FH's vulnerability to extreme heat involves assessing existing initiatives that increase preparedness for our communities, facilities, and services. Table 8 presents a high-level inventory that is not exhaustive, but rather is meant to highlight key initiatives that give a general indication of the general adaptative capacity within the VCH and FH health regions. The inventory portrays a public health system in VCH and FH that has at least some mechanisms in place for mitigation, preparedness, response, and recovery for extreme heat events. Although some of these processes are novel, having been created during the 2021 heat dome event, others are mature, having been in place for a decade or more. Given the level of collaboration required to protect health outcomes in communities, there is evidence of strong leadership in some of the communities in the VCH and FH region, and evidence of heat response planning in most communities. However, much more work and capacity are required to determine how best the health authorities can provide the right level of support, leadership and advocacy in each community.

Table 8: Adaptation inventory for heat

<table>
<tr><th colspan="2">ADAPTIVE CAPACITY INVENTORY - EXTREME HEAT</th></tr>
<tr><td>HEALTH AUTHORITY EMERGENCY PREPAREDNESS AND RESPONSE</td><td>Seasonal readiness planning and climate risk management occurs in many areas within the health authorities: In hospitals, clinics, and long-term care (LTC) facilities, and also for services delivered in patients' homes or directly in the community for underhoused populations. A new Seasonal Readiness Committee at VCH, for example, has participants from across the entire health system who share existing resources, assess risks, and collaboratively plan for future events
Before heat (and smoke) events, Public Health staff work with interested municipal partners on updating their emergency response plans and the development of designated cooling and cleaner air spaces. Public Health and HEMBC send out letters to VCH municipalities encouraging heat response planning and how to access further information. Both VCH and FH maintain websites that provide information and links to additional resources, including how to find information about cooling centre locations and resources to explain the health risk and tips for keeping cool.
VCH and FH Public Health staff produce and share resources for LTC, schools and childcare facilities, Facilities Management develops guidelines for design and operation of health facilities, and HEMBC facilitates planning across departments and authorities
BCCDC's British Columbia Health Impacts Prediction System (BCHIPS) framework uses a model of historic daily temperatures and historic daily counts of relevant ambulance dispatches to predict the impacts of the temperature forecasts for the upcoming days. This system also identifies when the criteria for extreme heat are met and in the case of an extreme heat alert, Public Health and</td></tr>
</table>

[19] Health Canada workbook step 2E

	communications staff will issue a media release to media outlets ◦ Health authorities develop and maintain relationships with all levels of government, First Nations, social service providers, researchers, etc. and advocate for projects that equitably reduce exposure to heat, improve the built environment, and improve the social determinants of health. E.g., Public Health staff review municipal climate change adaptation and mitigation plans on request to strengthen a health equity lens and identify opportunities to collaborate ◦ Site level risk assessments carried out by VCH/FH Facilities Management have explored the impacts of extreme heat on different types of health facilities, and including redevelopment and new builds. • **During** heat events, Public Health and HEMBC staff work with municipal emergency response partners – often joining regular municipal meetings, provide messaging to the media through interviews and social media, and providing advice to other local partners such as schools, childcare, and service providers like BC Housing ◦ Public Health staff conduct rapid surveillance of key indicators (e.g., hospitals visits) to understand impacts and enable decision-making. Similar work occurs at the BC Observatory for Population & Public Health overseen by BCCDC • **After** the June 2021 heat event, Public Health and HEMBC staff collected data (e.g. questionnaire to municipal emergency managers), organize debriefs and after-action reports, and work on special projects--for example, in July 2021 VCH supported the City of Vancouver to create a citizen science reporting system of indoor temperatures during subsequent heat events
KEY INITIATIVES AND RESOURCES Examples of leadership and collaboration	• **Local government: E.g. City of Vancouver** ◦ Operates cooling centres and misting stations, providing updates on locations/hours on their website and social media. Include VCH and other collaborators in daily operational meetings during heat events ◦ Provide direct support to populations that experience higher risk. Vancouver Parks Board has proposed a registration system for vulnerable seniors to ensure they're actively being checked on during a climate emergency (i.e. call list) ◦ Passed a motion as a result of a Vancouver City Planning Commission memo (July 2021) detailing short-, medium- and long-term actions to equitably mitigate the effects of extreme heat and poor air quality on the residents of—and visitors to—Vancouver ◦ Leads and collaborates on post-event studies and initiatives. For example, CoV and VCH partnered on a survey to better understand indoor temperatures during a less severe heat event at the end of July 2021 ◦ Studying and monitoring canopy coverage and urban heat island, ground truthing private property green infrastructure typologies, and actively growing urban canopy • **Local government: E.g. City of Surrey** ◦ City of Surrey's Urban Heat Ready is a two-year project funded by the Real Estate Foundation of BC that brings together residents, community partners, development professionals and City staff to collaborate and co-create solutions to minimize urban heat impacts in Surrey City Centre.

- **Public sector organizations: E.g. BC Housing**
    - Has an explicit focus on serving populations that have been placed at risk including individuals who are homeless, individuals with disabilities, Indigenous individuals and families, women and children at risk of violence, and low-income seniors and families
    - Has developed resources on extreme heat and wildfire smoke for operators and tenants; and engages in guidance for social housing providers
    - Lead the Mobilizing Building Adaptation and Resilience project and developed an Overheating and Air Quality Design Guide
    - Proposed work to understand extreme heat resilience for shelters and transition homes to help this sector come up with an extreme heat and wildfire response plan
- **Health Canada**
    - Chairs the Canadian Heat Health Community of Practice (HCoP). In July 2021, chaired a national call to discuss opportunities for better communication before, during, and after extreme heat events
    - Have produced recommendations for health care workers working in the community and in patient/client homes, for health care workers in acute care settings, and for effective health facility management to protect staff and patients
    - Heat Division has produced brochures, infographics, videos, as well as their Health Living clearinghouse
    - Leading a train-the-trainer program with pharmacists about heat and drug interactions
- **Communities of Practice and other leaders**
    - Hey Neighbour Collective brings together housing providers, non-profits, researchers, local and regional governments, housing associations and health authorities to experiment with and learn about ways of building community, social connectedness and resilience in BC’s fast-growing multi-unit housing communities
    - BCCDC has provided several useful resources for the public, and are working in partnership with the Ministry of Health to produce a heat vulnerability index to better predict the impacts of future events
    - BC Non-Profit Housing Association (BCNPHA) has been the provincial umbrella organization for the non-profit housing sector for nearly 30 years. BCNPHA contributes to the extreme heat response by providing webinars, guidance on conducting door-to-door wellness checks for housing providers, and instructions for housing providers to access funds for transporting clients to cooling centres, supplies like fans, and additional staff hours
    - Aboriginal Housing Management Association (AMHA) provides operations support, asset management, capital and portfolio planning for all non-profit Indigenous housing providers. AMHA tries to add common area cooling during MURB retrofits, though this is harder in townhome complexes and single family homes.
    - National Collaborating Centre for Environmental Health has produced extreme heat resources, as well as for COVID-19 management during public health emergencies

	○ Interior Health released a Heat Response Toolkit that contains valuable information and guidance ○ BC Hydro provides guidance on staying cool, and is also leading residential fuel switching efforts that will certainly increase the prevalence of air conditioning in homes across BC via air source heat pump technology ○ WorkSafe BC provides information on the dangers to workers and how to protect them

Box: BC Housing

BC Housing develops, manages and administers a range of subsidized housing options and programs across British Columbia. BC Housing works in partnership with the private and non-profit sectors, provincial health authorities and ministries, other levels of government and community groups to develop a range of housing options. Similar to the health authorities, BC Housing has an explicit focus on serving populations that have been placed at risk including individuals who are homeless, individuals with disabilities, Indigenous individuals and families, women and children at risk of violence, and low-income seniors and families.

This diagram below (Figure 14) illustrates the housing continuum in the province and BC Housing's contribution in the fiscal year 2019/20:

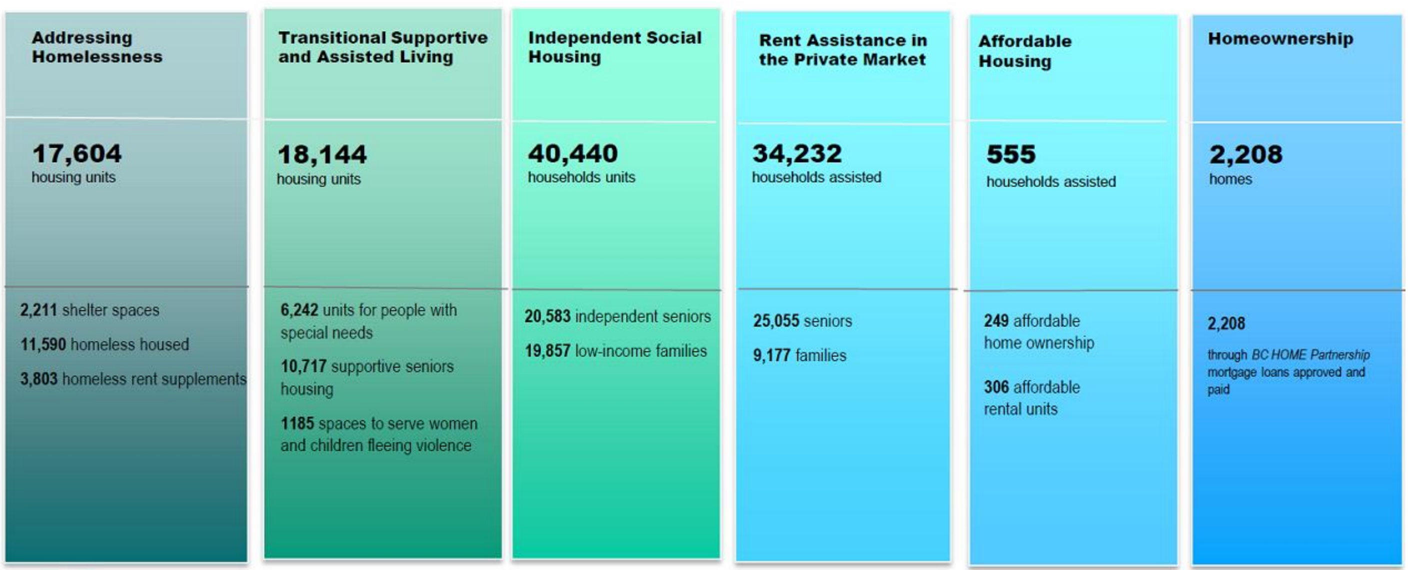

Figure 14: BC Housing's portfolio

Similar to the health authorities' oversight of long-term care facilities, BC Housing provides about 10% of the spaces directly, while the other are delivered by non-profits. Many of the buildings in BC Housing's portfolio, which includes shelters, lack air conditioning, and air filtration. However, as will be described below, adaptive measures have been introduced to mitigate these risks.

For years, BC Housing has been leading climate change adaptation for their sector. Significant initiatives include:

- Resources on extreme heat and wildfire smoke for operators and tenants;
- Guidance for social housing providers, as well as their own internal actions (BC Housing, 2020);
- Completed and proposed work that generates understanding and resources for people experiencing homelessness
- Mobilizing Building Adaptation and Resilience (MBAR): a multi-year, multi-stakeholder knowledge and capacity building project led by BC Housing, with participation and contribution from over 30 organizations, including national, provincial, and local agencies; and industry partners. To date,

guidelines have been produced to help manage impacts from a range of climate-sensitive hazards, including all of those covered in this assessment.

- Overheating and Air Quality Design Guide;
- They are working with Indigenous partners and tenants to determine culturally appropriate housing.
- Climate change projections are considered during building condition assessments.
- They have proposed work to understand extreme heat resilience for shelters and transition homes to help this sector come up with an extreme heat and wildfire response plan.
- VCH and FH will support BC Housing as they develop a provincial extreme heat and wildfire smoke response plan for populations disproportionately impacted by climate change (e.g., those experiencing homelessness).

5. Air quality

5.1 Key Messages

- Significant wildfire smoke impacts in five of the last seven summers demonstrate that we need to continue to adapt to a changing climate that is expected to increase the frequency and severity of both wildfires and heatwaves.
- Acute wildfire smoke events have already led to measurable health impacts in the VCH and FH health regions, and new exposure-response relationships are still emerging (e.g., smoke and cognition). Exposure to wildfire smoke can make it more difficult to fight respiratory infections such as COVID-19.
- Ground-level ozone creates acute and chronic physical and mental health impacts and is expected to increase as a result of climate change. The symptoms associated with aeroallergen exposure are expected to increase, though much more monitoring will be required to understand the burden of illness. Data on the future impacts and costs of smoke, ozone, and aeroallergens is still relatively nascent.
- Older adults, people with existing respiratory conditions, infants and young children, pregnant women and outdoor workers are especially susceptible to the health effects of poor air quality. The built environment can play a protective role, with access to cleaner air spaces, and to cool spaces when it is hot *and* smoky, being most important. Most public and private buildings in both health regions lack the required filtration to keep occupants safe during smoke events.
- Wildfire smoke can increase demand on health services, impact indoor environmental conditions in facilities and in patients' homes, and can affect staff wellbeing and productivity. Wildland urban interface fires can directly affect health facilities and private property, although these risks have not been formally assessed. Wildfires also lead to property loss and displacement, creating challenges for health authorities and local governments who receive displaced people. The same is true during major flooding events. Internal seasonal readiness planning for heat produces many useful operational and data-related capacities that apply to air quality events.
- Collaborations between health authorities and provincial and regional organizations is quite strong for air quality, but gaps will need to be strategically address by multiple sectors. There is a leadership opportunity to better understand and support response planning of municipal and regional governments, First Nations, and social service providers.

5.2 Population health impacts

Air quality in the VCH and FH regions is affected by the presence of wildfire smoke and ground-level ozone, and to a lesser degree pollen. This chapter describes the human health and health system impacts associated with poor air quality, focusing on smoke and ozone.

To provide context to this section it is important to highlight a recent Health Canada report on long-term exposure to ambient air pollution and the expected impacts on morbidity and mortality. Health Canada estimates that exposure to ambient concentrations of $PM_{2.5}$, ground-level ozone, and nitrogen dioxide leads to 1,900 premature death per year in BC and a total cost of almost $14B per year for all of the health impacts attributable to air pollution (Health Canada, 2021). It is estimated that these air pollutants lead to 166,000 asthma symptom days in the Greater Vancouver census division alone (Air

Health Effects Assessment Division, Health Canada. Personal communications, April 2021).

The number of annual premature deaths in Canada that can be attributed to air pollution from human sources in North America is estimated to be 15,300 (Health Canada, 2021). This report states that "chronic exposure to PM2.5 air pollution contributed to 8.0% of all-cause nonaccidental mortality among Canadians over 25 years of age, equivalent to 10,000 deaths per year or 27 deaths per 100,000 population" (Health Canada 2021, p. 17). Annual morbidity outcomes are significant as well, and include 2.7 million asthma symptom days, 35 million acute respiratory symptom days, 42 thousand child acute bronchitis episodes. It is estimated that the total cost for all health impacts attributable to air pollution is $120B per year (2016 CAD), $114B for premature mortality and $5.6B for non-fatal morbidity (Health Canada, 2021).

Figure 15: Vancouver's False Creek during an area of normal visibility and during a wildfire smoke event (Instagram photo / @false_creek_smitty).

5.2.1 Wildfire smoke

5.2.1.1 Wildfire smoke exposure

Wildfires and the smoke they create are a regular part of summer in British Columbia. As the climate has warmed, the number, size, and duration of wildfires has increased and has dramatically impacted air quality in British Columbia. This is due to a confluence of factors: hotter-drier summers, pine beetle, past fire suppression efforts, and forest management practices (Statistics Canada, 2019).

Wildfire smoke causes episodes of the worst air quality that most people will ever experience in BC. The 2017 and 2018 wildfire seasons were particularly intense (Abbott & Chapman, 2018). In August 2018, British Columbia declared a provincial state of emergency as a result of over 560 wildfires burning in the province, resulting in 22 days of air quality advisories for Metro Vancouver (*see* Figure 16). The smoke from the fires travelled thousands of kilometers, causing air quality warnings to be issued across BC, Alberta, and as far away as southern Manitoba (Climate Atlas of Canada, 2019) (*see* Figure 17). Similarly, smoke from far away fires can affect air quality in the VCH and FH regions. This was the case in fires in September 2020 when fires in California and Washington State caused $PM_{2.5}$ levels as high as 170 µg/m^3 in Squamish—normally between 7-10 µg/m^3 (ECCC and UNBC, 2021). Figure 18 shows the number of Smoky Skies bulletins issued for areas outside of Metro Vancouver over the past several years.

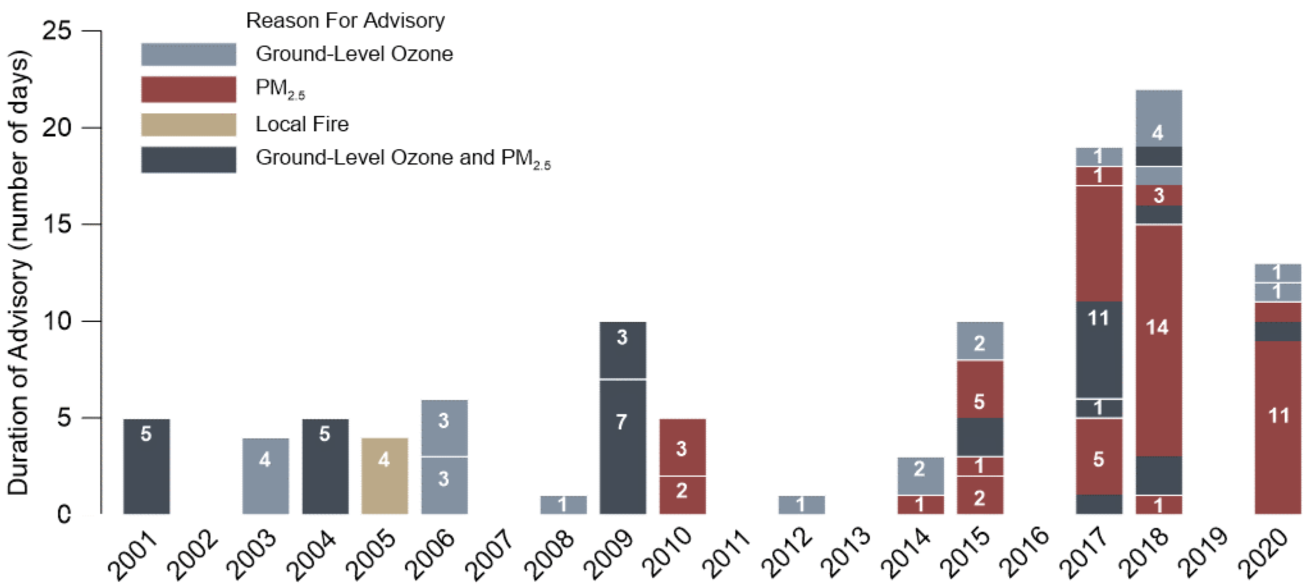

Figure 16: Metro Vancouver AQ advisories. The stacked graph shows the duration of the events, and the reason for the advisory. E.g., 2010 has a 2-day event, and a 3-day event, both of which were the result of PM 2.5.

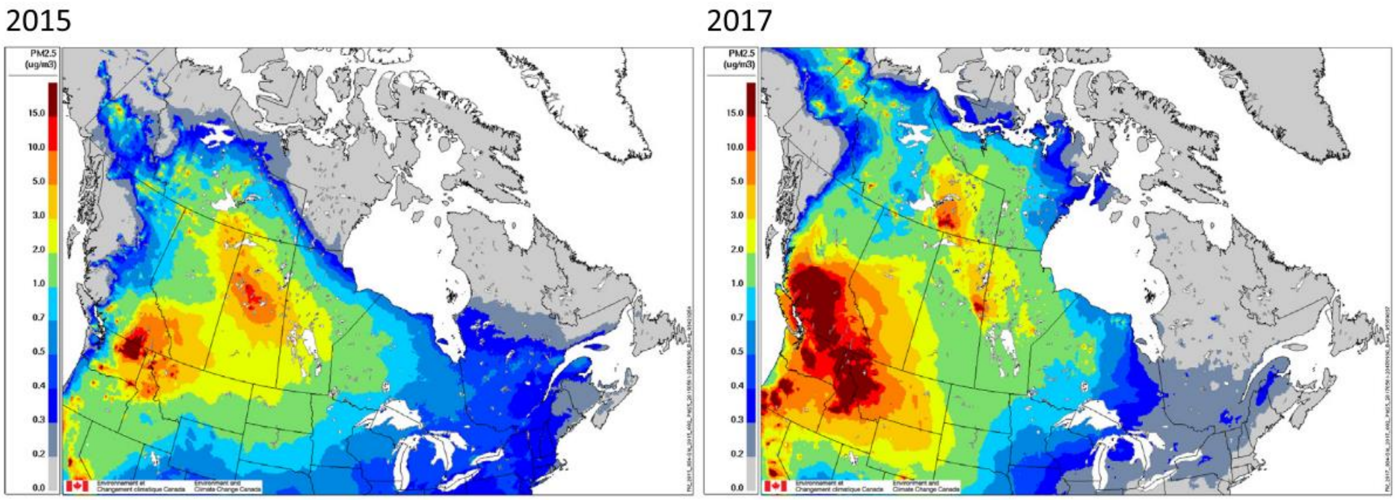

Figure 17: Matz et al. PM2.5 concentrations (May to September) attributable to wildfires for 2013–2015 and 2017–2018 based on FireWork and GEM-MACH. A

Events like the 2017 and 2018 wildfire season can be attributed to anthropogenic climate change (Kirchmeier-Young, Gillett, Zwiers, Cannon, & Anslow, 2019), and risks from an extreme wildfire season is the highest ranked in the provincial risk assessment, which focuses on future risks (BC Ministry of Environment and Climate Change Strategy, 2019). There is also a compounding effect due to the increase risk of flooding and soil erosion in fire impacted areas the following year, though this is not formally assessed.

Future projections for wildfire smoke (and for wildfire itself) can be difficult since neither are primary outputs of climate models. Notwithstanding this challenge, research points to wildfire becoming more common as the climate changes as a result of hotter and drier conditions leading to longer and more intense wildfire seasons (Coogan, Robinne, Jain, & Flannigan, 2019; Kirchmeier-Young et al., 2019). Although specific predictions are not common, Wang et al. (2017) predict a 50% increase in wildfire in Western Canada by 2100 based on patterns of daily fire-conducive weather. Yue et al. (2015) also projected increases in area burned, but exact values are difficult to extract from their extensive study. An internal planning exercise led by facilities management, saw a predicted 75% increase in wildfire activity by 2100 according to the BCCDC (Ellis Don, 2020). It should also be noted that exposure to smoke is driven by wildfires as far as away as California, and that conditions there are expected to follow similar trends as Western Canada.

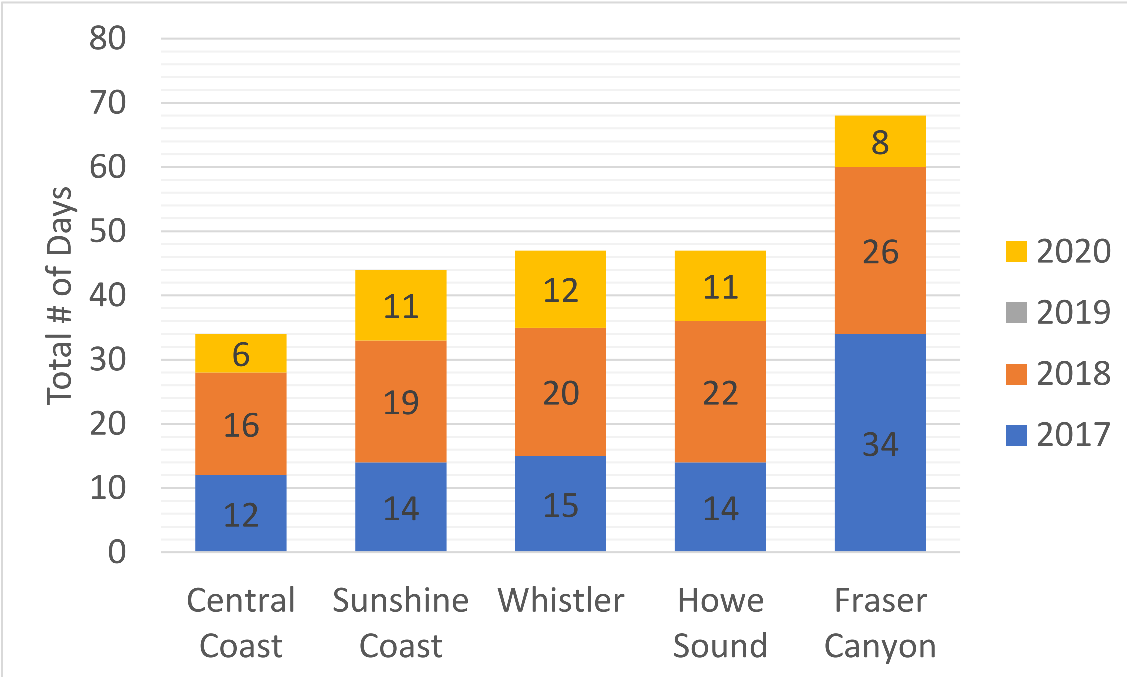

Figure 18: Smoky Skies Bulletins for areas outside of Metro Vancouver

Interface fire risk

Wildland urban interface (WUI) fire risk is not included as a hazard in the community vulnerability index, but its potential to negatively impact communities is clear (as was seen in Lytton in July 2021). Wildfires can result in burns and injuries during fires and during clean up, displacement, and can even lead to an increase in sexual assaults during displacement, as well as interpersonal violence (Canadian Institute for Climate Choices, 2021). Fire fighters are identified as at at-risk group, including for mental health impacts including PTSD (D. P. Eisenman et al., 2021). Fires can also lead to environmental exposures to contaminants released into the soil and waterways during combustion and fire suppression, although these impacts are only beginning to be understood.

Some of the facilities and communities that are a part of VCH and FH are exposed to wildland urban interface fires (e.g., Pemberton, District of North Vanouver), however an assessment of WUI risk to facilities has not been conducted at this time and more information is needed about the human health and health system impacts of these events. Like flood preparedness, WUI preparedness is common in communities throughout VCH and FH through programs like FireSmart and with funding from sources like UBCM. National Research Council of Canada just released a seminal guide: National guide for wildland-urban-interface fires that will influence collaborative community planning for WUI fires.

5.2.1.2 Current health impacts

Wildfire smoke is a complex mixture of fine particulate matter ($PM_{2.5}$) and gases, such as carbon monoxide, nitrogen oxides, and volatile organic compounds (*see* Figure 19). Of all the pollutants in wildfire smoke, $PM_{2.5}$ poses the greatest risk to human health (BC Centre for Disease Control, 2020). These very small particles are inhaled and travel deep into the alveolar membrane/gas exchange surface. As a result, the body mounts an immunological response in the same way it would with a virus, leading to a state of inflammation in the lung and, if severe enough, the entire body.

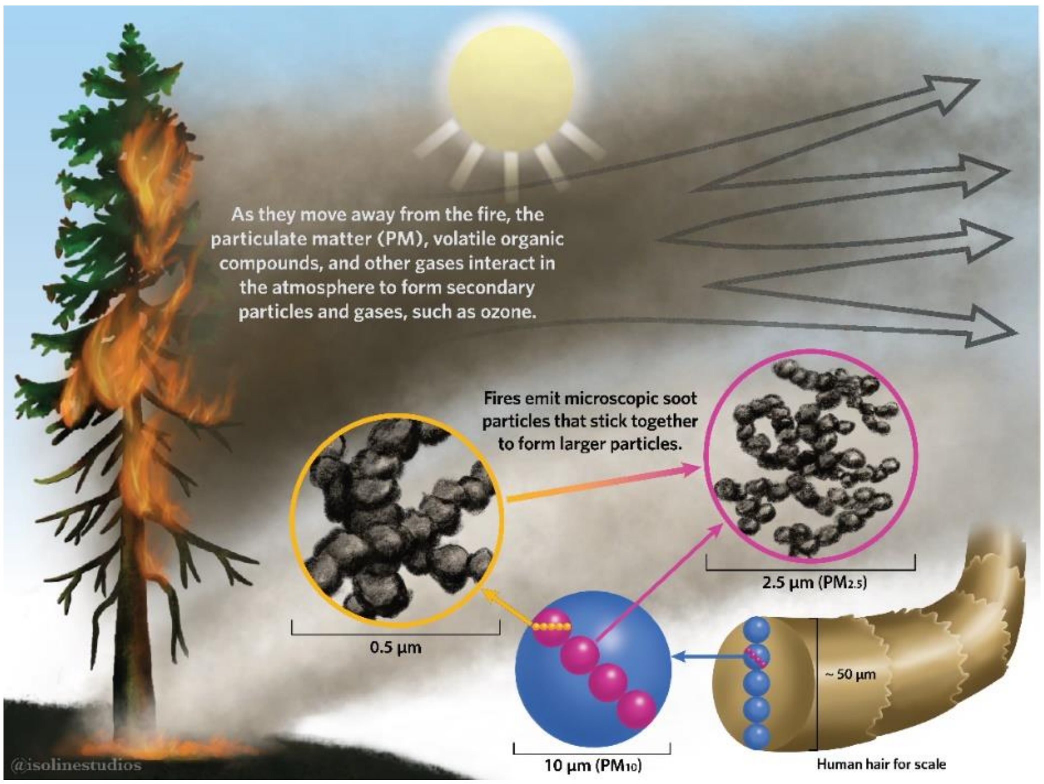

Figure 19: Size and composition of wildfire smoke (BCCDC, 2019)

Exposure to $PM_{2.5}$ can exacerbate asthma and other respiratory disease, worsen heart disease, lead to adverse birth outcomes and childhood respiratory disease, and a host of mental health impacts (Bekkar et al., 2020; Elliott, 2014; Rudolph, Gould, & Berko, 2015; Yao et al., 2020); all of which drives demand on the health system (Moore et al., 2006).

Mortality can occur as a result of long term exposure from $PM_{2.5}$, [even at low concentrations](#) (Christidis et al., 2019; Erickson et al., 2019), and research in Ontario establishes a link between exposure to $PM_{2.5}$ and lung cancer (Public Health Ontario, 2016).

Individuals with co-morbidities of diabetes and cardiovascular disease (CVD) in Canada were found to experience a higher risk of mortality associated with PM2.5 exposure relative to those with only CVD (Pinault et al., 2018). Many of these impacts are exacerbated when smoke is mixed with urban air pollution like ozone, and when daytime temperatures are high (Elliott, 2014). Studies using nonhuman primates suggest that exposure to wildfire smoke early in life can lead to negative health impacts in adolescence (Black et al., 2017). Much more information can be found in BC Lung Association (2018, p. 4).

Writing specifically about wildfire smoke, the BCCDC describes the following impacts to health:

- Smoky air makes it harder for your lungs to get oxygen into your blood.
- Wildfire smoke can irritate your respiratory system and cause an immune response, which may lead to inflammation that affects other parts of your body;
- Common symptoms include eye irritation, runny nose, sore throat, mild cough, phlegm production, wheezy breathing, or headaches. Such symptoms can usually be managed without medical attention;
- Some people may have more severe symptoms, such as shortness of breath, severe cough, dizziness, chest pain, or heart palpitations. You should seek prompt medical attention if you experience any of these symptoms;
- Smoky air may increase risk of some infections, such as pneumonia in older people and ear infections in children (BC Centre for Disease Control, 2020).

Matz et al. (2020) assessed the health impacts from wildfire seasons across Canada using data from 2013–2015 and 2017–2018 seasons. They estimated that Metro Vancouver experienced 100 acute premature mortalities attributable to wildfire PM2.5 exposure during these two wildfire seasons, although results are somewhat limited given that the exposure response relationship for long-term ambient exposure was used as a proxy for acute exposure from smoke. This study also estimated an economic valuation from changes in risk to health outcomes including medical costs, reduced workplace productivity, pain and suffering, and the impacts of increased mortality risk, which was estimated to be of $765M for Metro Vancouver.

An internal VCH study found the following increases in emergency department (ED) visits in VCH during the 2017 wildfire smoke season (June 1st and September 11th, 2017):

- **Respiratory symptoms**: +29% (Vancouver), +42% (Richmond);
- **COPD**: +42% (Vancouver), +19% (Richmond) (Zandy, 2017a).

An internal Fraser Health study found the following increases in emergency department (ED) visits in Fraser East during the 2017 wildfire smoke season: 35% increase for respiratory symptoms, 42% increase for COPD, 49% increase for asthma (Zandy, 2017b).

Using local ambulance data, Yao et al. (2020) found that increased $PM_{2.5}$ during wildfire seasons in BC was associated with increases in some respiratory (e.g., asthma) and cardiovascular (e.g., ischemic heart disease) outcomes within one hour following exposure. The authors also found an association with diabetic outcomes that increased over time following exposure. Surveillance conducted by the BCCDC has shown an increase in salbutamol sulphate (Ventolin) dispensations, physician visits for asthma, lower respiratory infections and otitis media (Yao, Eyamie, & Henderson, 2016). The researchers also tested a promising approach for modelling the smoke exposure that underpins these effects. It should be noted though, that ambulance is not the most sensitive or precise indicator and that dispensation rates has a better signal/noise ratio.

Research in the Northwest Territories found an increase in emergency room visits for asthma as well as primary care visits for cough, asthma, and pneumonia and dispensations for prescription inhalers (salbutamol) during their 2014 wildfire event (Dodd, Howard, et al., 2018).

There are significant gaps in our understanding of acute high exposure PM events from wildfire and the impact on health, child development, pregnancy, as well as a need for better monitoring of hospitalizations during smoke events. For example, recent research suggests that of about 7,000 preterm births in California, nearly 4% were associated with exposure to wildfire smoke (Heft-Neal, Driscoll, Yang, Shaw, & Burke, 2022). A US systematic review found that the subpopulations at highest risk of preterm birth, low birthweight, and stillbirth from air pollution and heat exposure were persons with asthma and minority groups, especially black mothers (Bekkar et al., 2020).

COVID-19 and Air Quality

Henderson (2020) highlights a potentially dangerous interaction between smoke and COVID-19, as does the BCCDC in their rapidly-disseminated guidance for managing exposure to wildfire smoke during the COVID-19 pandemic. VCH and other organizations supported the development of this work with BCCDC's strong lead, and it serves as a good example of amplified risk (i.e., COVID + smoke) and the need for adaptation in light of known impacts of air quality on severity of various communicable diseases. Issues identified include impacts to those who are immunosuppressed and those with existing acute conditions (e.g., COPD). There is also potential that exposure to smoke can drive future susceptibility to COVID-19, and that exposure to COVID-19 reduces emergency preparedness by impacting first responders, restricted access to clean air spaces, reduce access to PPE, etc. (video source).

Mental health and wellness

Community engagement sessions held in Fraser Health found that recent wildfire events have increased stress levels and impacted mental health as people isolate inside. Air quality advisories also affect personal health behaviours, like going outside for recreational activity and active transportation such cycling, running and walking—all of which are pathways to physical and mental wellbeing. During recent smoke events, some families were so impacted by the air quality that they temporarily left the community to stay with friends/family elsewhere. We also heard that wildfire smoke prompts the cancellation of programs that get Indigenous youth onto the land to participate in traditional activities.

Engagement carried out by Indigenous leaders found that "evacuation orders from fires and floods force First Nations to move away from their territories, and often without culturally appropriate assistance and support, and especially impact Elders, women and those with special needs" (BC Assembly of First Nations, 2020). They also found that "in some First Nation communities, the loss of homes to wildfires is exacerbated by the lack of normal house insurance policies 'on reserve' because of outdated, patriarchal federal Indigenous policy, and the general poverty of our communities. The federal bureaucracy is also ill equipped to enable rebuilding efforts to occur, so when homes are lost, there are a myriad of challenges to begin restoration and rebuilding efforts." Although the connection to mental health is not explicit in all of these examples, a strong connection can be implied.[20]

Existing research in Canada (e.g., forthcoming assessment chapter on mental health from Health Canada) tends to focus on direct experience of wildfire (e.g., displacement, evacuation), which does impact some communities within VCH and FH. For example, research in the Northwest Territories found feelings of fear, stress, and uncertainty that arose from evacuation and isolation contributed to acute and long-term negative effects on their mental and emotional wellbeing (Dodd, Howard, et al., 2018). However, some work exists for wildfire smoke exposures as well. For example, Szyszkowicz et al. (2009) results support the hypothesis that ED visits for depressive disorder correlate with ambient air pollution, and Szyszkowicz et al. (2010) indicate a potential association between air pollution and emergency department visits for suicide attempts.

The international $PM_{2.5}$ literature suggests association between long-term exposure and mental health impacts (Roberts et al., 2019; Vert et al., 2017; Xue et al., 2021). Over the past decade, researchers have found that high levels of air pollution may damage children's cognitive abilities, increase adults' risk of cognitive decline and possibly even contribute to depression (Weir, 2012). A study in Edmonton found that "even at low levels, increases in ambient CO, NO_2, and $PM_{2.5}$ are associated with increased hospital admissions for substance abuse, possibly as a result of impacts of air quality on mental health or depression" (Mieczystaw Szyszkowicz, Thomson, Colman, & Rowe, 2018).

The effect of $PM_{2.5}$ on processing, cognition, and behavior in adults—including anxiety, suicide completion and attempts and ED visits for exacerbation of psychiatric disorders—has been observed in studies, however evidence is still scarce (Brokamp, Strawn, Beck, & Ryan, 2019). This gap is particularly pronounced for children and youth, who are thought to be particularly susceptible to neurotoxic effects of air pollution. Evidence is emerging (e.g., Ali & Khoja, 2019; Brokamp et al., 2019) which suggests future work is needed in British Columbia.

For wildfire smoke, research in the Northwest Territories found that prolonged smoke events were linked to extended time indoors and respiratory problems (Dodd, Scott, et al., 2018). These events were found to have "livelihood and land-based activities were disrupted for some Indigenous interviewees, which had negative consequences for mental, emotional, and physical wellbeing" (Dodd, Howard, et al., 2018). Impacts also emerge when communities are exposed to fire in addition to smoke. For example, PTSD was observed after the Fort McMurray wildfires 2016 (Belleville, Ouellet, & Morin, 2019).

The best evidence for the effects of wildfire (i.e., not smoke) on mental health are likely to come from Fort MacMurray, Alberta, which experienced devastating interface fires in 2016. For example, Brown et al. (2019) studied grade 7–12 students and found that "mental health symptoms were statistically significantly elevated in the Fort McMurray population when compared to the control population in Red Deer. This occurred for scores consistent with a diagnosis of depression (31% vs. 17%), moderately severe depression (17% vs. 9%), suicidal thinking (16% vs. 4%), and tobacco use (13% vs. 10%)." Studying adults, Agyapong et al. (2018) found that generalized anxiety persisted six months after the fire.

[20] See box in Section 3.4.2 for more information on impacts and adaptation relating to evacuations.

Box: Air filtration

The text below is taken from the resource Portable Air Cleaners for Wildfire Smoke produced by BCCDC (BC Centre for Disease Control, 2016):

> "Most people spend up to 90% of their time indoors, where portable air cleaners can be used to reduce the impacts of wildfire smoke. Studies have tested indoor portable air cleaners on pollution from many different sources, including wildfire smoke. In most of these studies, portable air cleaners have reduced small particle concentrations by 40-80%. Use of portable air cleaners has been associated with better lung function, lower blood pressure, and reduced inflammation in children and adults (Barn et al., 2016). Barn et al. (2016) make a strong case that portable air cleaners should be at the forefront of the public health response to landscape fire smoke."

BC Housing (2019a) and VCH/FH Facilities Management (2020b) have produced guidance for filtration at the building level, including for very large buildings (*see* Figure 20).

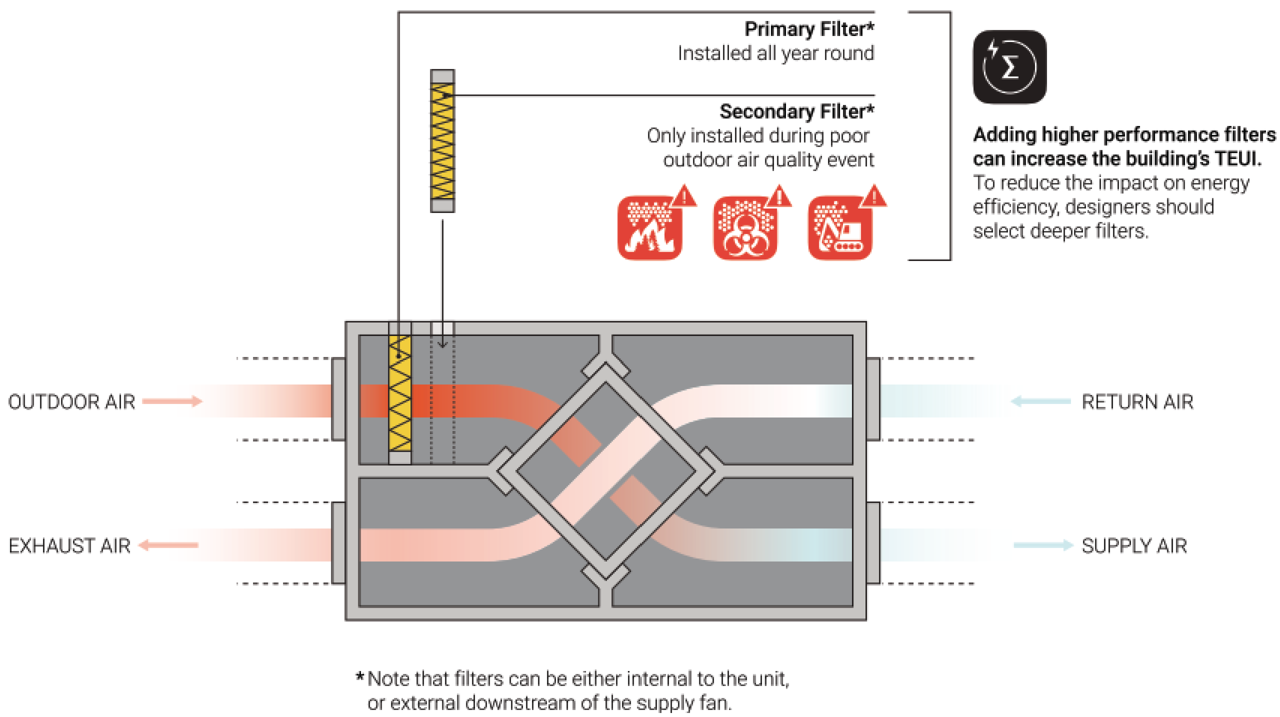

Figure 20: Filtration guidance for energy recovery ventilators (BC Housing, 2019).

5.2.2 Ozone

5.2.2.1 Ozone exposure

Ozone is a pungent gas and respiratory irritant that can form in the atmosphere ("good ozone") or at ground-level ("bad ozone") (Metro Vancouver, 2019d). "Ground-level ozone" is formed when nitrogen oxides (NOx, e.g. NO and NO_2) and volatile organic compounds react in the air during hot and sunny days (Figure 21).

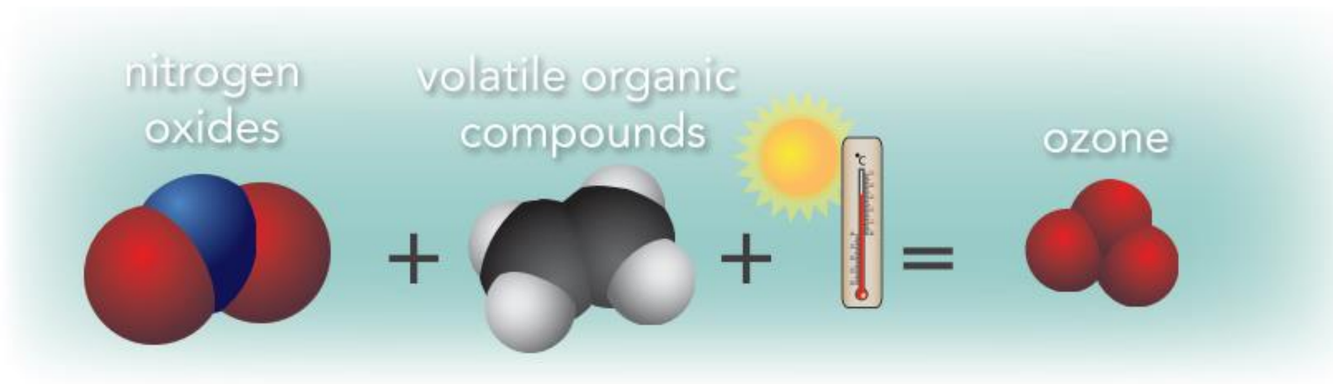

Figure 21: Composition of ozone (Metro Vancouver, 2019)

In Metro Vancouver, the highest ozone concentrations typically occur in the eastern regions and in the Fraser Valley Regional District. The lowest annual average ozone concentrations occur in highly urbanized areas due to O_3 scavenging in locations where higher levels of NOx are found such as near busy roadways. In these areas, emissions containing NOx react quickly with O_3 to form NO_2 (nitrogen dioxide) and O_2 (oxygen) thus decreasing O_3 concentrations (Doerksen, Howe, Thai, & Reid, 2020, p. 34). Also, ozone is produced photochemically so it takes some time to be produced in the atmosphere - in that time emissions from urban areas can disperse downwind (e.g., into the Fraser Valley) as the ozone production is occurring. By the time ozone is produced the emissions tend to have been transported downwind into rural areas.

Ground-level ozone appears to be intensified by the presence of wildfire smoke (Metro Vancouver, 2019a, p. 15), and also during extreme heat events—as was reported during the June 2021 heat event.

As is the case with smoke, it can be difficult to project ozone exposure in the future. The formation of ground-level ozone is contingent on nitrogen oxides, which largely come from the burning of fossil fuels making it difficult to predict, and to control. Since ozone formation occurs during hot weather, temperature is associated with ozone levels, especially when temperatures stay below 37°C (W. Chen & Lindner, 2019). Based on this, ozone can be expected to increase as BC's climate gets warmer, and hot summer days become more common.

Reuten et al. (2012) studied projected ozone exceedances for the eastern Fraser Valley. They found that increases in temperatures at Abbotsford (YXX) from 1991–2000 to 2046–65 are associated with an increase in the probability of ozone exceedances days from 3.34 days per year in 1991–2000 to about 7.1 per year in 2046–65. These results do not take into account other factors “such as anthropogenic and biogenic emissions, and changing background levels resulting from the trans-Pacific transport of pollutants” (Reuten et al., 2012, p. 52). Metro Vancouver points out that without additional action, “emissions of nitrogen oxides and volatile organic compounds (which lead to the formation of ground-level ozone) are projected to start increasing after 2030” (Metro Vancouver, 2019b, p. 5).

The literature on the relationship between wildfires and ozone indicates that wildfires will be an important driver of ozone as the climate changes (Yue et al., 2015). In fact, it could drive more ozone formation than temperature increases (W. Chen & Lindner, 2019).

5.2.2.2 Current health impacts

In addition to $PM_{2.5}$ from smoke, British Columbians are exposed to ground-level ozone, usually during hot summer days.[21] This exposure can cause eye, throat and nose irritation and coughing, worsen existing lung and heart diseases, and reduce life expectancy (Government of Canada, 2021c; Metro Vancouver, 2019d). There is growing evidence that long-term exposures can cause the development of respiratory effects, especially in the young and elderly (BC Lung Association, 2018; Y. Chen, Branch, Canada, & Mcgrail, 2003). For example, long-term exposure to ground-level ozone may elevate an individual’s risk of respiratory and cardiovascular illnesses later in life (Atkinson et al., 2016). We are not aware of any local analysis in VCH or FHA that has studied the health effects of ozone exposure.

In their 2020 *Integrated Science Assessment For Ozone And Related Photochemical Oxidants*, the US EPA found “recent evidence continues to support ozone-induced effects on the respiratory system. In addition, recent evidence indicates that short-term exposure to ozone is likely to induce metabolic effects… There is also some evidence that ozone exposure can affect the cardiovascular and nervous systems, reproduction and development, and mortality, although there are more uncertainties associated with interpretation of the evidence for these effects” (pg. ES-5).

Some limited evidence exists that links ozone exposure to psychological distress (Pinault et al., 2020) and that points to poor mental health as a modifier of the association between long-term exposure to ambient pollutants and mortality (Thomson et al., 2020). More high quality study is needed given the difficulty of modelling ozone exposure in epidemiolocal studies (US EPA, 2020) and the strong biological plausibility of a causal relationship (Zhao, Markevych, Romanos, Nowak, & Heinrich, 2018).

5.2.3 Aeroallergens

5.2.3.1 Aeroallergens exposure and health impacts

Pollen allergies are widely recognized as a health concern (*see* Figure 22 below for a list of common allergens in BC). Aeroallergens of various sizes can lead to conjunctivitis, allergic rhinitis, and also to asthma exacerbation (Sierra-Heredia et al., 2018). Approximately two-thirds of people with asthma are allergic to aeroallergens, with allergens acting as triggers for asthma exacerbations (Sierra-Heredia et al., 2018).

[21] See Yu et al. (2020, p. 87) for a bibliography of background literature on ozone exposure and vulnerable populations.

Climate change can impact the timing and length of the growing season, lead to increased production and allergenicity of pollen, and shift the range of species resulting in exposure to pollen that BC's populations has not historically been exposed to (Romero-Lankao et al., 2014; Sierra-Heredia et al., 2018). Although urban trees are very valuable in helping mange heat-related impacts in cities and possibly some aspects of air quality(*see* Figure 23), there is no scientific consensus that urban trees reduce asthma by improving air quality (T. S. Eisenman et al., 2019) and they can also serve as local sources of pollen, potentially leading to adverse respiratory/allergic outcomes locally (Weinberger et al., 2018).

More research is needed to understand current and future impacts of allergens in VCH and FH. These impacts include increased medical management of aeroallergens, some of which have significant side effects (e.g., antihistamines in elderly). These findings can be used to ensure a commensurate public health response. One of the challenges of conducting research in this area generally is a lack of exposure data. There is a private company that has been doing aeroallergen sampling in Canada for many years, but their monitors are mostly located in large cities, typically with only one monitor per city (personal communication, confidential).

Floristic Zone	Trees		Grasses and Weeds	
	Common Name	**Genus**	**Common Name**	**Genus**
Northwest Coastal: Southwestern British Columbia (BC)	Cedar Fir Pine Alder Birch Hazel Oak Cypress	*Juniperus* *Abies* *Pinus* *Alnus* *Betula* *Corylus* *Quercus* *Cupressaceae*	Rye & Orchard grass Fescue grass Brome/chess grass Timothy & velvet grass Sweet grass Plantain & Amaranths Short ragweed Chenopods & Orach Dock & Sorrel	*Lolium & Dactylis* *Festuca* *Bromus* *Phleum & Holcus* *Anthoxanthum* *Plantago & Amaranthus* *Ambrosia* *Kochia & Atriplex* *Rumex*

Figure 22: Major allergenic plants that grow in Southwestern BC (Sierra-Heredia et al., 2018; Table S1 in the supplementary materials)

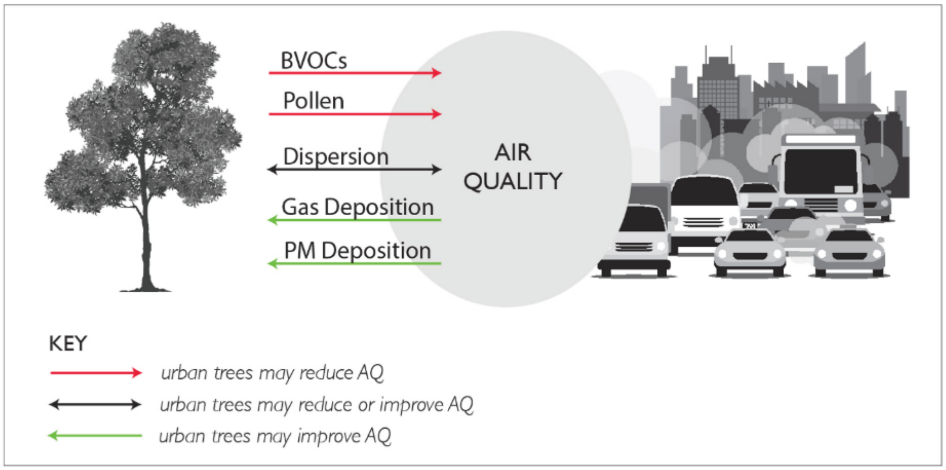

Figure 23: Links between urban trees and air quality (Eisenman et al., 2019)

5.3 Community vulnerability mapping

VCH, FH, and UBC produced a set of maps that displays vulnerability to wildfire smoke and ozone across the following regions:

- City of Vancouver
- Richmond
- Coastal, Rural—Squamish, Whistler, Pemberton, Gibsons, Powell River, Bella Coola
- Coastal, Urban—District of North Vancouver, West Vancouver, Bowen Island,
- Delta, Surrey, Langley
- Abbotsford, Chilliwack, Hope
- Burnaby, Coquitlam, Maple Ridge

Exposure data for wildfire smoke (i.e., $PM_{2.5}$) have been modelled from BCCDC data, where the number of days over 25 ug/m^3 have been calculated for the fire seasons over the years 2009, 2010, 2014, 2015, 2017, 2018, 2019, and 2020. For Metro Vancouver and the Fraser Valley Regional District air quality measurements collected by Metro Vancouver's air quality monitoring network has been used to calculate the number of days with 24-hour rolling average $PM_{2.5}$ > 25 ug/m^3. Data was used from the three most severe fire seasons between 2009 and 2018 (i.e., 2015, 2017 and 2018) and were interpolated with an elevation barrier of 400 m. The interpolated surface was then summarized at the dissemination area. For ozone, CANUE 2015 annual mean ozone concentration modelling was used for ground-level ozone estimates at the census dissemination area. For Metro Vancouver and Fraser Valley Regional District, air quality monitoring data was used to calculate the number of days with 8-hour rolling average O_3 concentrations above 62 ppb over the three most severe summer seasons between 2009 and 2018, which was the same as the wildfire smoke years. Sensitivity and adaptivity capacity were modelled using variables including age, pre-existing conditions, socioeconomic status and built environment conditions (full list of variables and methodology available upon request).

Figure 24 shows community vulnerability to ozone, and Figure 25 shows community vulnerability to smoke. Those interested are encouraged to access the web versions of these maps to learn more and to generate screenshots.

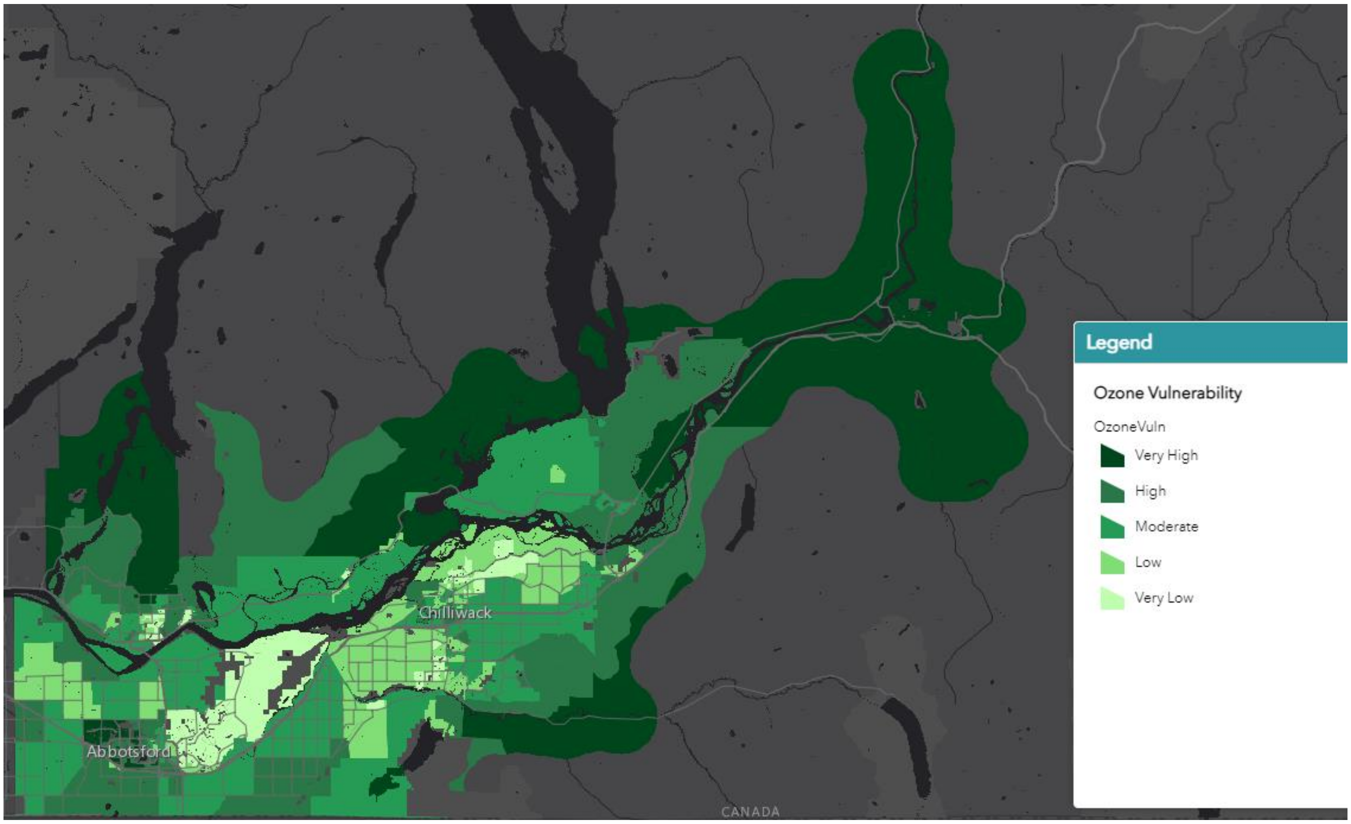

Figure 24: Ozone vulnerability for the Fraser Valley

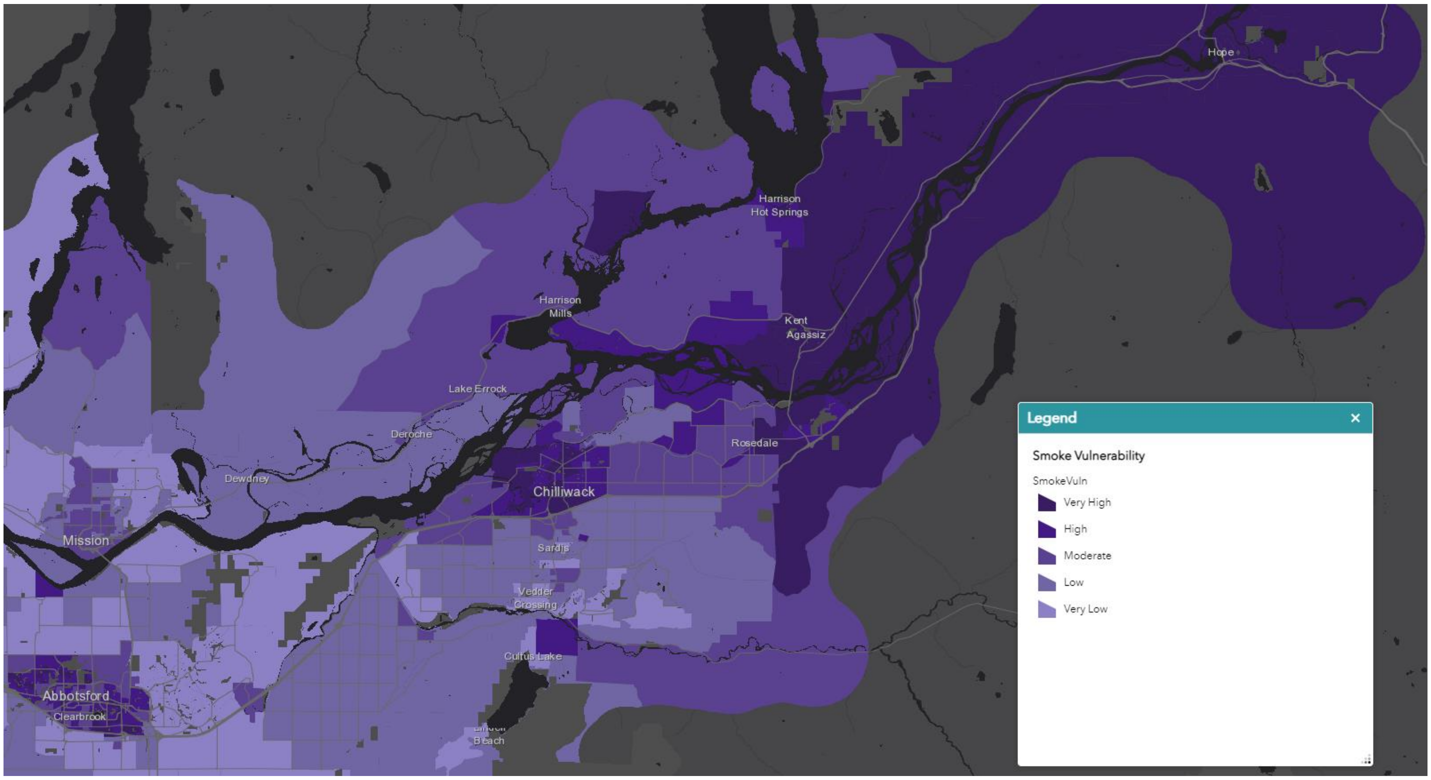

Figure 25: Wildfire smoke vulnerability for the Fraser Valley

5.4 Future health impacts

As described above, wildfire seasons in BC will continue to be a major public health risk (Matz et al., 2020). This will be driven by the occurrence of extreme seasons similar to what occurred in 2017 and 2018 (M. Flannigan, 2017; M. D. Flannigan, Krawchuk, De Groot, Wotton, & Gowman, 2009; Xianli Wang et al., 2017).[22] Similarly, ozone is expected to increase as a result of hotter temperatures, and increased prevalence of wildfires.

The Canadian Institute for Climate Choices modelled three key health morbidity outcomes associated with ground-level ozone: asthma symptom days, acute respiratory symptom days, and respiratory emergency room visits (Canadian Institute for Climate Choices, 2021). The combined annual healthcare costs of these three respiratory illnesses is expected to be approximately $1.1B by 2100. Acute respiratory symptom days are projected to be the most expensive, making up about 77 per cent of the costs. The costs of premature deaths from ground-level ozone could exceed $300B by 2080 under RCP 8.5. These national results provide an indication of the direction that health impacts are likely heading

[22] Xu et al. (2020, p. 2179) display global projections maps and could serve as useful context.

in BC, though additional contextualization of these results would be beneficial.

Given how difficult it is to predict future wildfire smoke, modelling of the future health impacts from wildfire smoke has not been performed to our knowledge. Having said that, the impacts are expected to be significicate given the expected increase in fires and the continually growing body of evidence on the health impacts from smoke.

5.5 Health system impacts

5.5.1 Health care facilities

Poor air quality affects facilities directly by impacting indoor air quality, and indirectly by creating increased demand for services, and increased operational costs (e.g., expensive filters). Increases in air contaminants from wildfire activity, pollen and other sources can infiltrate through building envelopes, impacting the ability of HVAC systems to maintain adequate indoor environmental quality (Facilities Management, 2020a). These trends will likely be exacerbated as poor air quality events become more common and widespread. Table 9 summarizes some observed and expected impacts of poor air quality (Facilities Management, 2020a).

Table 9: Impacts to facilities from poor air quality

Infrastructure	- Increase in air contaminants that infiltrate into the building impacting the HVAC systems ability to maintain adequate IAQ - Wildfires may disrupt infrastructure systems such as transportation, electricity supply, telecommunications, water treatment, and sewage systems (BC Ministry of Environment and Climate Change Strategy, 2019) - Redundancy and sufficient resources only allow systems to handle catastrophes for short duration (<72 hours) - Ventilation systems requiring more energy and resources to ensure operational levels are maintained (LMFM, 2018)
Staff and services	- Power impacts due to forest fires near power lines, loss of power and impact to virtual communication - Higher number of staff absences - Increased operational costs (filters, overtime)
Patients	- Decreased ability to discharge patients due to oxygen needs - Poor air quality in homes; Home Health/Home Support clients may need to visit hospital if homes have poor ventilation and filtration - Decreased indoor air quality

A stress testing exercise carried out for the St. Paul's Hospital redevelopment did not directly explore the impact of poor air quality events on facilities, nor did a study of the Fraser Canyon Hospital. A climate and vulnerability risks assessment for the Redevelopment of Royal Columbian Hospital explored wildfire smoke events and air quality concerns, with impacts summarized in Figure 26 (Ellis Don, 2020).

WILDFIRE SMOKE EVENTS & AIR QUALITY CONCERNS			
Impact Statement	**Vulnerability**	**Risk**	**Advanced**
Wildfire smoke events can lead to increased air contaminants, requiring hospitals to change air filters more frequently and store a ready supply of stock	V4	Medium	✓
Wildfire smoke events may lead to regional and local transportation limitations for general supplies, filters, and helicopter transportation for patients	V4	Low	
Wildfire smoke events may lead to an increase in patients with respiratory issues	V3	Medium	✓
Wildfire smoke may lead to community surge, especially for older individuals	V3	Medium	✓
Wildfire smoke could cause hospital closures and redirection between regions in BC	V3	Medium	
Increased length of seasonal dissemination of pollen can exacerbate allergies	V3	Low	

Figure 26: Summary of impacts from poor air quality on operations at Royal Columbian Hospital, where V3 and V4 represent a vulnerability rating on a five-point scale, where V5 is the highest (Ellis Don, 2020).

Additional impacts have also been identified for hospices, as described below.

5.5.2 Health services

HEMBC (2018, p. 6) identified the following select impacts to the health system during wildfire events:

- Damage or closure of health facilities, or facilities are under evacuation alert or evacuation order;
- BC Emergency Health Services (BCEHS) stations have been evacuated resulting in no, or limited, 9-1-1 emergency response in community;
- Actual or imminent impacts to population health and health programs due to wildfires or smoke;
- Wildfire has or is likely to cause impacts to transportation infrastructure that may impact supply chain, staff movement, or patient transportation, including emergency health services;
- BCEHS capacity to transport non-critical patients has been compromised due to wildfire smoke disrupting air travel, or road corridors rendered inaccessible due to the wildfire hazard;
- Wildfire has or is likely to cause impacts to communications infrastructure.

Poor air quality has many observed and expected impacts on the services offered by VCH and FH's Home Health and Palliative programs. Table 10 presents a summary of the impacts, which includes impacts to facilities not listed above. The adaptive capacities identified during engagement have not been included in the main assessment summary, but have been included in the Appendix and will be reflected in the forthcoming adaptation framework.[23]

Table 10: Poor air quality impacts to VCH health services

Poor Air Quality
Home and community care
- Poor air quality in patient's homes exacerbates existing conditions (e.g., COPD) and increases risk of complications (e.g., pneumonia). This leads to increased medical needs (e.g., prescriptions for Ventolin) and increased admissions and transfers to the acute care setting - Poor air quality can lead to increases in mood disorders, anxiety disorders, dementia, and psychological distress, which can lead to increased need for additional prescriptions (e.g., Ativan, anti-depressants) - Being unable to go outside due to respiratory challenges can increase social isolation and can make it impossible to access clean air shelters - Staff experience respiratory impacts as a result of having to travel throughout the city to provide care - Excess demands and health impacts could lead to decrease in staff morale - Inter-staff connections/relations may suffer because staff may not be working in the office - Staff with pre-existing conditions may not be able to work - Increased admissions and transfers to the acute care setting, requiring increased capacity - Need for safety policies and/or procedures for staff, including office staff. This could include regular health/respiratory assessments for staff - Specialized masks may be needed - Staff needing to stay at home to care for children when schools are closed
Palliative care
- Increase in respiratory issues, especially for patients with pre-existing COPD - Clients unable to travel due to clinics (e.g., wound clinics, cancer, cardiac) due to extreme heat or poor air quality, leading to missed appointments - Poor air quality and extreme heat could prevent visits by neighbours and friends, and this could lead to increased isolation - Some patients can have difficulty accessing cool spaces (e.g., cooling centres) or clean air centres. - Heat stress or air quality impacts for health care workers, especially those that rely on bicycle or transit to travel to patients. Similarly, nurses sometimes encounter high-rises where elevators are out of services, leading the difficult stair climbs in hot buildings
Public health/OCMHO
- Poor air quality in child care and long-term care facilities due to a lack of filtration - Increased demand on PHSU for climate-related monitoring and surveillance - Increased demand for MHO/health protection to provide specific advice and recommendations during heat and smoke events (sporting events, outdoor concerts, schools, childcare, long-term care, BC housing, cooling and clean air spaces) - Increased need for MHO capacity at emergency operation centers - Overheating and air quality concerns in shelters inspected by EHOs – currently not a major component of inspection - Increase demand for advice, collaboration, advocacy vis a vis supportive environments (e.g., schools, child cares, healthy housing, etc.) and protection of determinants of health

[23] COVID-19 has led to significant delays for this part of the project, and meant that engagement sessions were limited to one hour in length, and could only be held every 4-6 months.

5.6 Adaptation inventory—Air quality

The public health response to wildfire smoke events is complex, involving inter-sectoral collaboration, community engagement and the use of many sources of information in decision-making (Maguet, 2018). A 2019 survey found consensus among public health practitioners that wildfires pose a significant threat to public health and safety and are expected to continue or worsen under climate change. Despite high levels of awareness and concern, planning for interventions that would reduce population level exposure to wildfire smoke is still in the very early stages of development in most jurisdictions and not well funded, if at all. Planning in these regions has included:

- Assessments of community infrastructure that might be suitable for clean air spaces;
- Modifications to health care facilities' heating, ventilation and air conditioning (HVAC) systems;
- Acquisition, distribution and deployment of residential and commercial air scrubbers;
- The development of innovative communication strategies; and
- Early exploration of strategies to support community resilience (Maguet, 2019).

Understanding VCH and FH's vulnerability to poor air quality involves assessing existing initiatives that increase preparedness for our communities, facilities, and services. As described above, this response requires a multitude of actors working collaboratively towards shared objectives. Table 11 presents a high-level inventory that is not exhaustive, but rather is meant to highlight key initiatives that give a general indication of the general adaptative capacity within the VCH and FH health regions. The inventory portrays a public health system in VCH and FH that has a fairly good level of activity from many of the actors that are needed to protect health during periods of poor air quality. This inventory will support the strategic planning process that will help the health authorities to better define their role in preparing and responding to poor air quality events, including ground-level ozone and increasing allergens, which are not as well represented in the inventory.

Table 11: Adaptation inventory for air quality

ADAPTIVE CAPACITY INVENTORY – AIR QUALITY	
HEALTH AUTHORITY EMERGENCY PREPAREDNESS AND RESPONSE	• **Advance forecasting** for wildfire risk comes from several sources, including the Canadian Drought Outlook maps and monthly and seasonal prediction maps for fire weather severity released by Natural Resources Canada. Short-term wildfire smoke forecasting is available through Canada's Wildfire Smoke Prediction System (FireWork) and BlueSky**. Real-time PM2.5 air quality data** is available at Metro Vancouver's Air Map website and the BC Ministry of Environment air quality website. Low-cost PM2.5 sensor data is available on a UNBC and Environment and Climate Change Canada map. ○ Metro Vancouver issues an air quality advisory when air quality over a large portion of Metro

	Vancouver and the Fraser Valley Regional District temporarily deteriorates, or is expected to deteriorate.
	    ○ Outside of Metro Vancouver, a smoky skies bulletin is issued by BC Ministry of Environment and Climate Change Strategy when areas of the province are being impacted or have reasonable potential to be impacted by wildfire smoke within 24 to 48 hours.
	    ○ The Air Quality Health Index (AQHI) is a Canadian tool designed to help people understand how air quality can affect their health, and how they can protect themselves when air quality is poor. It uses a scale of 1-10+ to indicate potential health risk and to recommend actions to reduce risk.
	    ○ BCCDC's British Columbia Asthma Prediction System (BCAPS) is a surveillance system to forecast the public health impacts of wildfire smoke
	• Seasonal readiness planning and climate risk management occurs in many areas within the health authorities: In hospitals, clinics, and long-term care (LTC) facilities, and also for services delivered in patients' homes or directly in the community for underhoused population
	    ○ Public Health produces and shares resources for LTC and childcare facilities, Facilities Management develops guidelines for design and operation of health facilities, and HEMBC facilitates planning across departments and authorities
	    ○ BC Health System Wildfire Response Plan developed by HEMBC outlines the emergency response structure of the provincial health system as well as the coordination processes and information required to support wildfire response across the health system
	• **Before** smoke seasons, Public Health and HEMBC send out letters to VCH municipalities encouraging wildfire smoke response actions and how to access further information. Public Health staff work with interested municipal partners on updating their emergency response plans and the development of designated cleaner air spaces. Both VCH and FH have websites to educate the public about poor air quality events
	    ○ Site level risk assessments carried out by VCH/FH Facilities Management have explored the impacts of poor air quality on different types of health facilities, including redevelopment and new builds.
	• **During** wildfire smoke events, Public Health works with municipal emergency response partners, provides messaging to the media, and provides advice to other local partners such as schools and BC housing. This includes guidance on cleaner air space design and the need for upgraded filtration in all types of buildings, and guidance to schools and daycares on when to keep children indoors during wildfire events
	    ○ Public Health staff conduct rapid surveillance of key indicators (e.g., hospitals visits) to understand impacts and enable decision-making. Similar work occurs at the BC Observatory for Population & Public Health overseen by BCCDC

KEY INITIATIVES AND RESOURCES
 	
Examples of leadership
	• **Local government: E.g. Chilliwack**
	    ○ Maintains a webpage on Air Quality and Climate Change that describes exposure risks in the airshed, provides links to monitoring data, and provides information on the Community and Corporate Air Quality, Energy and Greenhouse Gas Action Plans.
	    ○ Emergency management resources to help families plan for the direct impacts of wildfire, including

and collaboration	evacuation
	• **Regional government: E.g. Metro Vancouver**
	  ○ Monitors air quality, sends regular updates to Health Authority and municipal staff, issues Air Quality Advisories and communicates with the media about air quality impacts
	  ○ Develops and implements the Clean Air Plan—which is a regional plan for managing air quality and greenhouse gases over the next 10 years
	  ○ Organizes a pre-season media event on the science of wildfire smoke and the health impacts
	  ○ Metro Vancouver, in partnership with VCH assessed the performance of low cost air quality sensors in the lower mainland context
	  ○ Various other plans and tools that seek to increase climate resilience, including Regional Tree Canopy Cover and Impervious Surfaces study (2019), Tree Regulations Toolkit (2021), Social Equity and Regional Growth Study (2021), Metro 2050 Regional Resilience Framework (2021), and Climate 2050 (ongoing)
	• **Provincial initiatives**
	  ○ BC's Climate Preparedness and Adaptation Strategy identifies wildfire as a major risk, though the focus is primarily on the direct impacts of wildfire (e.g., damaged infrastructure, evacuation) and not on the impacts of wildfire smoke
	  ○ EMBC's Emergency Info BC provides info on response, including links to help manage mental health impacts for adults and children. GeoBC and EMBC's Common Operation Picture is the province's one-stop-shop for emergency GIS information and the primary mechanism to display real-time emergency response data for stakeholders at agencies like EMBC. It has been used during wildfire and flood events
	  ○ FNHA Community Evacuation and Wildfire Response Supports (2021)
	  ○ The Office of the Provincial Health Officer together with the BC Observatory for Population & Public Health co-chair an Environmental Health Working Group that can help to better understand regional health impacts of air quality
	• **BC Centre for Disease Control**
	  ○ BCCDC has produced a number of public facing evidence-based fact sheets on the health impacts of wildfire smoke and measures that can be taken to reduce risk. They are a leader in wildfire smoke and health messaging, including webinars, research, articles and media interviews
	  ○ BC Health and Smoke Exposure Coordination Committee (HASE) is chaired by BCCDC and meets bi-weekly during the smoke season to coordinate planning and response efforts related to public health impacts for significant wildfire smoke events in BC. A similar group is being created for the 2022 heat season. The group is composed of health system actors including the regional health authorities and FNHA, provincial ministries including health, environment, EMBC, BCCDC, BC Emergency Health Services, and Public Health Agency of Canada
	• **Communities of practice and other leaders**
	  ○ Health Canada's guidance for cleaner air spaces during wildfire smoke events

	○ BC Lung Association's work on wildfire smoke, including annual Air Quality and Health Workshop ○ ECCC and UNBC's map that presents AQ monitoring data from federal monitors and less expensive purple air monitors. Data is available almost real time at this link ○ VCH is supporting UBC research into air quality in childcare facilities ○ Government of Canada's Air Quality Benefits Assessment Tool is a computer application developed by Health Canada which is designed to estimate the human health impacts of changes in Canada's ambient air quality ○ The Legacy for Airway Health conducted a survey on public messaging on wildfire smoke, and which could inform the improvement of communication during wildfire smoke events ○ Compendiums of best practices (e.g., "Cities adapt to extreme wildfires: Celebrating local leadership" produced by Institute for Catastrophic Loss Reduction) ○ The Cultural Burning & Prescribed Fire program operated by Fire Smart relies on Indigenous knowledge of prescribed burning practices in the BC landscape to reduce wildfire risk

5.6.1 BOX: Metro Vancouver

Metro Vancouver is a leader in air quality and climate change work and a close collaborator of VCH and FHA. Through their regulatory authority Metro Vancouver develop and implements plans, policies, regulations and projects that improve air quality and reduce greenhouse gas emissions. These plans and policies are supported by comprehensive monitoring of outdoor air quality, and tracking of emissions in the Lower Fraser Valley airshed. The video in Figure 27 gives a great overview of Metro Vancouver's services:

Figure 27: Air quality and climate change video (https://vimeo.com/295488069)

Metro Vancouver has a number of initiatives that reduce emissions and increase adaptive capacity throughout the region, and are important points of collaboration with VCH and FH. As part of their Climate 2050 Buildings and Transportation road maps, they have proposed actions that address a range of climate change adaptation and resiliency issues for buildings and transportation such as:

- Resiliency of our buildings to the impacts of heat waves and wildfire smoke
- Water conservation and management in our buildings
- Protecting our existing transportation networks from climate change impacts such as flooding
- Developing a more resilient transportation network to extreme events

Similarly, the Metro 2050 Regional Resilience Framework, which investigated how to integrate resilience into Metro 2050 and Transport 2050. The framework includes a definition of resilience as it pertains to regional growth management and transportation, an evaluation framework to test the resilience of Metro 2050 and Transport 2050, an assessment of Metro 2040's policies, and recommendations to increase the resilience of proposed policies for Metro 2050. For example, they seek to “Add actions that specifically speak to increasing resilience in the region. This should speak to Metro Vancouver’s role and leadership in providing robust and redundant infrastructure. It should speak to expectations from member jurisdictions. It should highlight partnerships, expectations, roles, and coordination capabilities for preparing and responding to both shocks and stresses” (Metro Vancouver, 2021a).

These commitments are complemented by several other initiatives, including:

- Climate 2050
- Clean Air Plan
- Metro 2050
- Social Equity & Regional Growth Study (2021).

6. Storms and flooding

6.1 Key Messages

- Population health and the health system impacts from flooded rivers, coastal storm surges, landslides and extreme precipitation in urban areas will intensify as climate change alters hydrological regimes and sea levels rise. Windstorms are expected to remain a feature of the regional climate, although there is low confidence in future projections. These events will continue to create risk for electricity distribution systems, and health impacts will be heightened when they occur alongside flooding, extreme heat, or poor air quality.
- Research into the regional population health and health system impacts of extreme precipitation and windstorms is relatively limited. Evidence from community engagement and published literature indicates a number of challenging outcomes, and the extreme precipitation event in November, 2021 provides an opportunity to better understand impacts to mental health and wellness, critical infrastructure, water and food security, and others.
- Storms and floods exacerbate existing health inequities and increase vulnerability for populations that have been placed at risk. This includes those experiencing social isolation, mental illness, homelessness, as well as those that experience oppression as a result of systemic racism. Some people experiencing poverty lack the means and opportunity to take protective health measures, such as affording extra medications, property level flood protection, and evacuation planning. Exposure is less widespread than hazards like smoke, however the cascading impacts of a major flood event create disproportionate impacts for populations that have been placed at risk, including those who are outside of the flooded areas.
- Impacts to the health care facilities and health services have occurred historically, and represent significant risk in the future. Flooding in particular can cause significant disruptions to health service delivery and emergency management by disrupting and damaging community and health infrastructure.
- Since local flood risks are primarily managed by municipal and regional governments, and First Nations, collaborations are essential to ensure that health impacts are considered in local planning and response, and that the project partners have the most up to date information. Existing initiatives indicate a scattered approach to flood risk management, although a variety of regional initiatives could hold potential. As with heat and smoke, there is a need to better understand where gaps in capacity exist and to intensify and accelerate action as the climate warms.

6.2 Population health impacts

This section will present available data that shows direct and indirect impacts to human health and the health system in the VCH and FH regions. Flooding and windstorms are the primary climate-sensitive hazards in this section and impacts to food and water security are explored to limited extents here, with additional information appearing in the section on Ecosystem Changes.

6.2.1 Flooding

6.2.1.1 Flooding exposure

Many of the communities that VCH and FH serve experience flooding as a result of rainfall events, coastal storm surges in the winter, and spring snowmelt (freshet) flooding in rivers. Flood risk differs significantly across this vast service area, and is shaped by the local hazards that an area is exposed to. For example, flooding in Whistler is dependent on a variety of conditions including precipitation amounts, snowpack composition and depth, soil moisture, stream flow conditions, and temperature. Detailing the biophysical drivers of flood risk at a local level is beyond the scope of this assessment. Notwithstanding this limitation, a brief summary is provided here:

- **Precipitation**: The technical appendix of Facilities Management (2018) contains historical and projected data for seasonal precipitation and extreme rainfall for Bella Bella, Bella Coola[24], Powell River, Sechelt, Squamish, Downtown East Side, Richmond. All locations will see drier summers, wetter winters, and more extreme rainfall events. The same is true for all locations in FH (Facilities Management, 2019a). The intensity of atmospheric river events will increase as the climate warms due in part to the fact that warmer air is capable of holding and transporting more moisture.
- **Riverine flooding**: Changes in air temperature and precipitation can modify the extent of snowpack, and the timing and intensity of springtime snowmelt. The June 2021 heat event also demonstrated the connection between heat events and hastened melting during summer (CBC News, 2021b). In the Fraser River Basin, for example, the fraction of precipitation falling as snow is projected to decrease by nearly 50% in the 2050s compared to the baseline, and onset of springtime melt will be 25 days earlier (ul Islam, Déry, & Werner, 2017). This will likely lead to increases in winter and spring flooding (e.g., when melting is combined with heavy precipitation events), and water quality issues in summer during low flows. Also, most dikes in the lower mainland were built in the 1970's and 80's, do not meet current minimum provincial standards, and will not be able to withstand flood levels now projected (Mu, 2018). Riverine flooding beyond the Fraser River is caused by freshet (e.g., Bella Coola), or intense rainfall events (e.g., Squamish). These risks are usually well understood by the local and regional governments that serve these communities, and will be better understood by VCH and FH as our climate change work develops. Some communities have advanced modelling of their flood risks, for example the Village of Pemberton has an impressive video that shows the extent of a 1-in-200 year flood event.
- **Landslides**: Increases in the magnitude of extreme rainfall events and flooding will increase the possibility of landslides in our region's mountain areas, which could introduce additional turbidity into drinking water reservoirs, damage critical infrastructure like highways, sewers and water mains, as well as health care fatalities (Metro Vancouver, 2016; Sobie, 2020). Landslide susceptibility maps exist (e.g., Bobrowsky & Dominguez, 2010) and some internal work has been carried out. Understanding exposure to landslides, and the attendant population and health system impacts remains a gap. The unprecedent flood events of November 2021 will provide an opportunity to better understand these impacts and to prepare for future events.
- **Urban flooding** occurs as a result of precipitation overwhelming municipal drainage systems, leading to pooling on roads, sidewalks, and lawns, and also to sewer backups in buildings. It is very difficult to acquire data on localized flooding of this nature, given that this information is not often

[24] VCH created precipitation projection maps for the Central Coast

publicly shared. Hazard and exposure data could be found in community Hazard Risk Vulnerability Analyses (HRVAs), climate risk assessments, official community plans, master plans (e.g., stormwater), and climate adaptation plans. However, it was beyond the scope of the present project to gather and present this data. Hamilton et al. (2021) modelled impervious surfaces in Metro Vancouver and found increased run off depths and inundated areas using future precipitation projections. As above, VCH will identify ways to continue supporting support this work in the future.

- **Sea level rise and storm surge**: Based on 1m of sea-level rise by 2100, Fraser Basin Council's coastal flood maps present coastal flood hazard information for coastal areas from Squamish to White Rock (Northwest Hydraulic Consultants Ltd., 2016). Fraser Basin Council have also produced a set of Fraser River freshet flood maps for multiple scenarios that show significant risk for Squamish, Richmond, Vancouver, Delta, Surrey, and others. Local government documents (e.g. the City of Surrey's Coastal Flood Strategic adaptation plans, Coastal Climate Change in Gibsons) can provide more granular information on areas susceptible to sea level rise and/or storm surge, but have not been systematically assessed here. It should be noted that projections continue to evolve based on new science, including rapid advances in glacier failure in Greenland and Antarctica (Voosen, 2021).

Extreme precipitation: November 2021

From the afternoon of November 14 to the afternoon of November 2021 an atmospheric river event brought just over 100mm of rain to Vancouver, and over 150mm to Abbotsford. As CNN has reported, Abbotsford recorded it hottest and its wettest days ever within a 140 day period (Ramirez, 2021). Hope, BC, received 252 millimetres of rainfall measured in 48 hours. For context, 344 millimetres is the average rainfall for the entire month of November in Hope (Schmunk, 2021).

This extreme precipitation led to severe flooding across southwestern BC, and triggered landslides that critically damaged several primary highways. As many as 15,000 people were forced to evacuate their homes and the damage is estimated to be at least $450M (Charlebois, 2021). At the time of writing, the precise impacts to supply chains, medical and otherwise, and to the health system generally are only beginning to be articulated. Although the extent and nature of the health impacts caused by flooding in private residents is not known at the time of writing, a number of facilities across VCH and FH (e.g. hospitals, hospice, clinics, and vaccination sites) were directly impacted by the storm. BC Hydro reported power outages across both VCH and FH, which prompted the closure of vaccination clinics and testing sites in Richmond and Vancouver (and likely elsewhere as well). Acute and chronic impacts to mental health and wellness, and disproportionate impacts to populations that experience higher risk are both important areas of future study.

Just as the heat dome did in the summer of 2021, this storm showed the devastating impact that extreme weather can have on our infrastructure, communities, and health systems. The floods also highlighted the historical difficulty of flood risk management and governance in the province (Corcoran, 2021), leading experts like Tamsin Lyle to conclude that flood risk governance in BC is broken.

6.2.1.2 Current health impacts

A relationship between flood events and mortality has not been established for the VCH and FH health regions. Studies that assess morbidity tend to focus on the impact of flood events on food and water safety and security. For example, Liang and Kosatsky (2020) discuss the impact of coastal flooding on food security for coastal populations[25], as well as the impact of saltwater infiltration of groundwater, although no empirical evidence is presented.

There is a relationship between precipitation and enteric diseases, particularly in the summer when heavy rainfall after a drought can flush contaminated material into water supplies. This can be exacerbated by precipitation-related turbidity, which may reduce the effectiveness of water treatment (McVea, Copes, & Galanis, 2018). High turbidity could trigger boil water advisories as a precaution to avoid gastrointestinal illness. A 2006 boil water advisory affected approximately 1 million residents in the Lower Mainland and required that hospitals, long term care, child care and school either boil water for a minute or drink bottled water (CBC News, 2006).

In a study of Metro Vancouver's drinking water system, Chhetri et al. (2017) found significant increase in turbidity, cryptosporidiosis and giardiasis 4–6 weeks after extreme precipitation, with the effect being greater after a dry period. The study relied on reported cases of cryptosporidiosis and giardiasis in the population served by the drinking water system, made available by the BCCDC. After the study, Metro Vancouver installed filtration for two of its three surface water sources to increase the protection from both direct and indirect turbidity-causing events.

The smaller systems outside of the Metro Vancouver region are often more vulnerable to these impacts as a result of relying on surface-fed wells for their source, and being operated with more limited resources tan larger systems (Chhetri et al., 2019). It is estimated that 70% of small water systems in VCH rely on wells for their water supplies. In systems like these, flooding can cause contamination of drinking water supplies with untreated sewage or chemicals (Ministry of Health, forthcoming).

Extreme precipitation events can also overwhelm municipal drainage systems, including combined sewer overflows leading to contamination (Lapp, 2010). Another concern with flooding is that the majority of the province is on septic systems which are impacted hugely during flooding and in turn contaminate wells and other water sources/courses which could lead to increased infectious outbreaks from water.

Monitoring and surveillance data does not currently exist to assess hospitalization and morbidity in the study area. Abbott and Chapman (2018) performed an independent review examining the 2017 flood and wildfire seasons. Although the report emphasizes the mental health impacts that arise during flood events, specific data for the VCH and FH regions was not provided.

National and international data

Generally speaking, the human health impacts of storms, floods and landslides range widely from

[25] This is the topic of a HealthADAPT project being carried out by the First Nations Health Authority, described more in the adaptation strengths section below.

acute, direct impacts, to those that are indirect, and/or occur over a longer time period. Table 12 provides an overview of primarily direct health impacts from flooding in Canada, based on a review of epidemiological evidence (Burton, Rabito, Danielson, & Takaro, 2016; Du, Fitzgerald, Clark, & Hou, 2010) and information from Government of Canada.

Table 12: Select population health impacts from flooding

Health hazard	Examples of health impact
Mortality	Drowning, other asphyxiation
Injury	Fractures, contusion, lacerations
Contamination of drinking water	Acute gastrointestinal illness
Flooded sewers and wastewater treatment plants	Acute gastrointestinal illness and other water-borne illnesses
Mental illness	Post-traumatic stress disorder
Zoonotic disease	Leptopirosis, hook worm
Respiratory tract irritation	Asthma exacerbation, exposure to mold
Vector borne disease	West Nile virus infection
Prenatal stress	Low-birth weight, childhood obesity

During floods, immediate health impacts include injury from debris, drowning, hypothermia, electrical injuries, chemical exposures, as well as major disruptions in a person's quality of life from displacement or evacuation (Mu, 2018; Oregon Health Authority, 2020). Post-flood, residents in flooded areas experience increased risk of water-borne and vector-borne disease, respiratory illness from mold exposure, and mental illness (Mu, 2018).

The greatest source of information on the mental health impacts of flooding is the forthcoming national climate and health assessment. These impacts occur during and after a flood, exacerbating pre-existing mental health conditions, but also potentially provoking distress and contributing to new or additional mental health conditions (citation forthcoming). In Canada, Sahni et al. (2016) explored the psychosocial consequences of the 2013 Southern Alberta flooding and found a 1.64-fold increase in new prescriptions for anti-anxiety medications for females and 2.34-fold increase in new prescription of sleep aids. A similar study found that women with underlying mental health conditions may be more vulnerable to the psychological impacts of a natural disaster regardless of their level of exposure (Hetherington, McDonald, Wu, & Tough, 2018). This study also found that women who experienced damage to property, or who provided help to others, were more likely to perceive an increased sense of community cohesion.

Some post-flood morbidity relates to the psychosocial stress from experiencing a flood event and subsequent loss, disruption and reduced sense of security. Studies have found an increase in post-traumatic stress disorder (PTSD), anxiety and depression following flooding events (Burton et al., 2016). Research in England found a connection between evacuation and displacement on mental health impacts like depression, anxiety, and PTSD (Munro et al., 2017).

6.2.2 Severe weather (windstorms)

6.2.2.1 Wind exposure

Emergency Management BC defines severe weather as thunderstorms, hail, blizzards, ice storms, high winds or heavy rain. Heavy rain is described above, leaving exposure relating to thunderstorms, hail, blizzards, ice storms, and high winds to be discussed here. Through literature reviews and consultation with experts, it was decided that the impacts from hail will not be considered in this assessment, nor will thunderstorms, given how rarely they occur (Read, 2015).

Blizzards and ice storms are rare but disruptive for most of the areas served by VCH. The decision not to consider these hazards in this assessment is informed in part by the following:

- Winter precipitation will increase, with more of it falling as rain (Metro Vancouver, 2016, p. 36);
- Frost days (number days when daily minimum temperature is less than 0°C) will decrease over 30% by 2050;
- Icy days (number of days on which the air temperature does not rise above freezing) are expected to decrease 10-20% by 2050;
- Snow and ice management plans are already likely in place, and therefore not a valuable use of planning resources that flow from this assessment.

Extreme cold is also a significant driver of mortality, although as above these events are more rare in BC than they are elsewhere in Canada. Based on conversations with experts, the likelihood an extreme cold event like that experienced by Texas in 2020 is unlikely, but difficult to determine precisely. On the one hand, as time goes on there is less cold air in the Arctic, which is warming at twice the average global rate. On the other hand, there is competing evidence whether cold air events are getting worse with climate change. There is no scientific consensus regarding frequency, and papers that talk about cold air outbreaks and stalling weather events exist, although a consensus is still emerging.

The most salient hazard in the severe weather universe is wind. British Columbia is in the fortunate position of not being exposed to the hurricanes that dominate so much of the literature relating to severe or extreme weather, climate change, and health (e.g., hurricane Sandy) (Landsea, 1999). However, as seen in Figure 28, high-wind generating extratropical cyclones routinely strike southwest British Columbia (Mass & Dotson, 2010; Read, 2015). For example, a windstorm on December 18, 2018 saw windspeeds at the Vancouver airport of 87 km/h, and in Abbotsford of 101 km/h (BC Hydro, 2019). Windstorms usually happen in VCH between October and February.

Metro Vancouver's Urban Forest Climate Adaptation Framework highlights that "extratropical cyclones are a recurring feature of Metro Vancouver's climate and can match Category 3 hurricanes in terms of sustained wind speeds" (Diamond Head Consulting Inc., 2017).

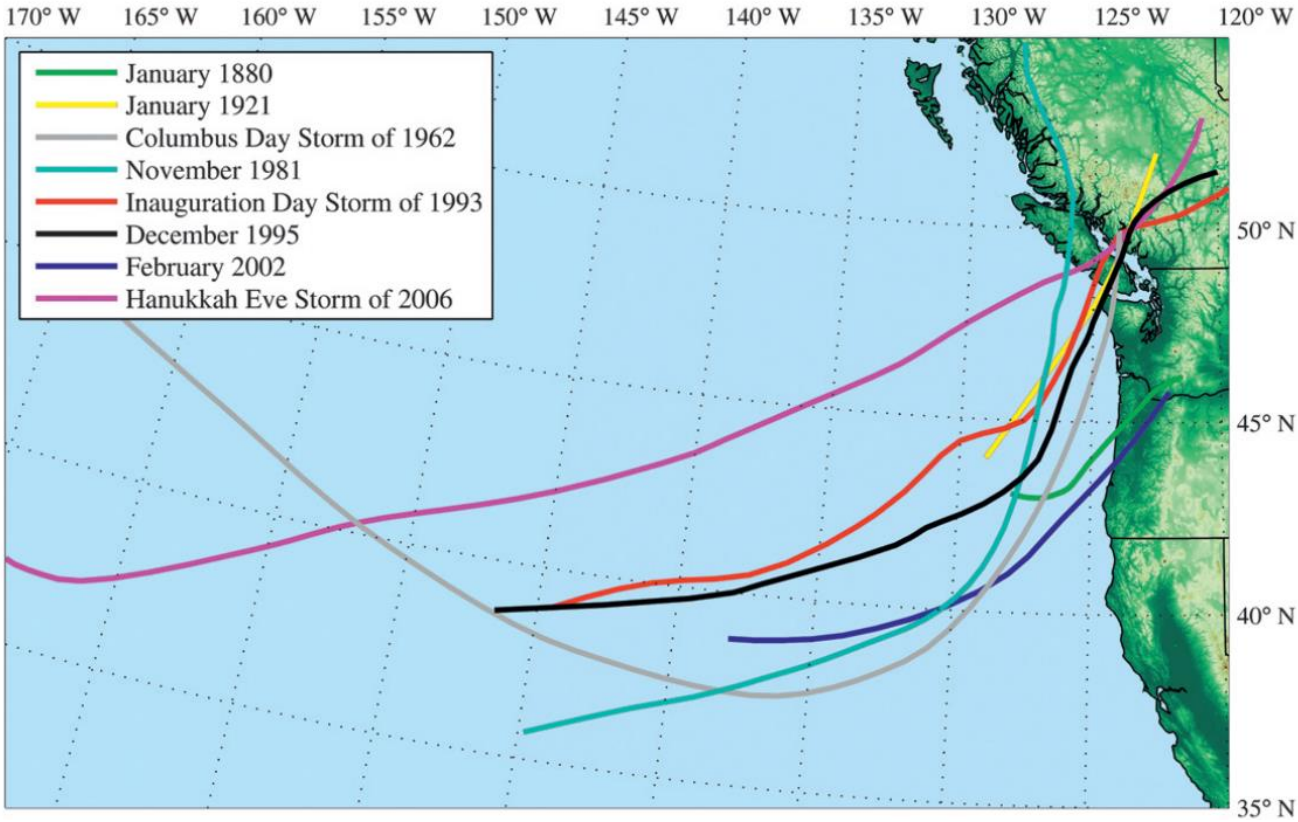

Figure 28: Tracks of some major cyclones striking the Pacific Northwest (Mass and Dotson, 2010)

Although wind is one of the salient hazards relating to severe weather in VCH (and likely to a lesser extent in FH), the literature on future exposure is somewhat sparse. For example, wind is not included in the Metro Vancouver climate projections report produced by PCIC (Metro Vancouver, 2016), nor in the provincial risk assessment, or as part of Canada's Changing Climate Report (Bush and Lemmen, 2019). Also, the relationships between trends in mean wind speeds and those in extreme winds are still not well understood (Cannon, Jeong, Zhang, & Zwiers, 2020).

Information that does exist paints an uncertain picture about windstorms in the future. On the one hand, Cheng et al. (2014) projected increased frequency of future daily wind gust events over 70km/h for Vancouver for scenario A2 (RCP 8.5) during the period 2081–2100. On the other hand, Read (2015, p. 283) suggests "a small reduction frequency of extratropical cyclones, with perhaps a slight weakening of the most intense storms, as the 21st century progresses. This would likely translate into slightly fewer high-wind storms, with perhaps the most extreme storms becoming more rare. Given strong variability associated with projected extratropical cyclone tracks and intensities, windstorms, including rare catastrophic events, are expected remain as a feature of the regional climate." However, in studies like these, there is very low confidence in the findings given significant challenges with prediction (Cannon et al., 2020).

But the most compelling source on wind comes from the *Resilient Buildings and Core Public*

Infrastructure: An Assessment of the Impact of Climate Change on Climatic Design Data in Canada (Cannon et al., 2020). However, even in this very robust analysis, future wind is characterized as a Tier 3 variable, signifying very low confidence in the future projections for a given level of global warming (Cannon et al., 2020, p. 57). This report modelled wind pressure, which is a function of wind speed, and "considers external pressures or suctions caused by strong winds on the main structural systems and all secondary components of buildings or structures."

The data table at this link (which comes from Appendix 1.2 in the report) contains projections for various locations in BC for the 3C warming, which corresponds to the 2080 timeframe in RCP 8.5, and for 2C which corresponds to RCP8.5 in the 2050's. Table 13 displays this data and conveys the changes to wind pressure that could be expected during a 1-in-50 year wind event.

Table 13: Projected (median) changes to 50-year return period hourly wind pressure with respect to the 1986-2016 baseline period. Values represent the median value (Cannon et al., 2020).

	2°C warming	3°C warming
BC	4%	7.5%
Abbotsford	9%	12%
Bella Coola	14%	20%
Powell River	8%	15%
North Vancouver	10%	13%
Surrey (88 Ave & 156 St.)	4%	7%
Vancouver (city hall)	4%	7%

It is difficult to determine the extent of power outages that result from windstorms in the VCH and FH health regions, and data does not currently exist that communicates the number of outages experienced by health care facilities. What is known is that outages typically occur as a result of winter storms and that therefore loss of heating is the primary impact—as opposed to summer brownouts where loss of cooling and overheating are the primary risks.

In addition to the wind hazards described above, a tornado formed in Vancouver on November 6, 2021. A similar event has not happened in over five decades and is thought to be very rare (CBC News, 2021e). However, it did lead to local impacts, and it is likely to assume that it contributes to a growing sense of perceived instability and vulnerability in regards to BC's climate.

6.2.2.2 Current health impacts

Windstorms and power outages

As described below, windstorms are common and intense, especially in coastal regions. Although direct injury is possible, power outages are the primary driver of health impacts. For example, the December 2018 storm described in the exposure section impacted more than 400,000 BC Hydro customers in the Lower Mainland and Fraser Valley (BC Hydro, 2019). The impacts on health care facilities and communities have not been collected for this event, however it is likely that there were impacts to the health system and to human health as a result of the storm and resulting power outage.

In August 2003, a major power outage occurred in the Midwest and northeast United States, and in Ontario, affecting an estimated 50 million people. Kile et al. (2005) studied the impacts that this event had on human health and the health system and found that only "minimal morbidity and mortality reported that could be attributed to the event." However, the power outage impacted multiple municipal infrastructures, and affected medical services, emergency response, and public health efforts. Specific issues related to communications failures, alternate power source problems, human resources and training issues, and psychosocial concerns. Another study on the 2003 event and other in New York revealed that cold weather outages are more impactful that those occurring in warm weather (Dominianni, Lane, Johnson, Ito, & Matte, 2018).

A systematic review of 20 articles, including five from Canada, on the health impacts of power outages revealed difficulties of accessing healthcare, maintaining frontline services and the challenges of community healthcare (Klinger, Landeg, & Murray, 2014). Impacts were discovered across the health system, including: acute care services, IT infrastructure, demand on services, facilities, community services (e.g., home transfers), mental health impacts. Impacts to public health infrastructure related to water, sewage treatment, food safety, and people's ability to regulate temperature in their homes (Klinger et al., 2014). Electricity disruptions can lead to improper use of generators resulting in carbon monoxide poisoning, and also have "serious implications for people who rely on electricity for medical needs such as oxygen, dialysis and refrigerated insulin" (Oregon Health Authority, 2020).

Power outages that occur during hot summer (i.e., outside of the typical storm season) are less well understood and likely to be very impactful since the ability to provide cool spaces in private and public buildings will be compromised. Figure 29 presents the many ways in which power outages can affect human health and the health system.

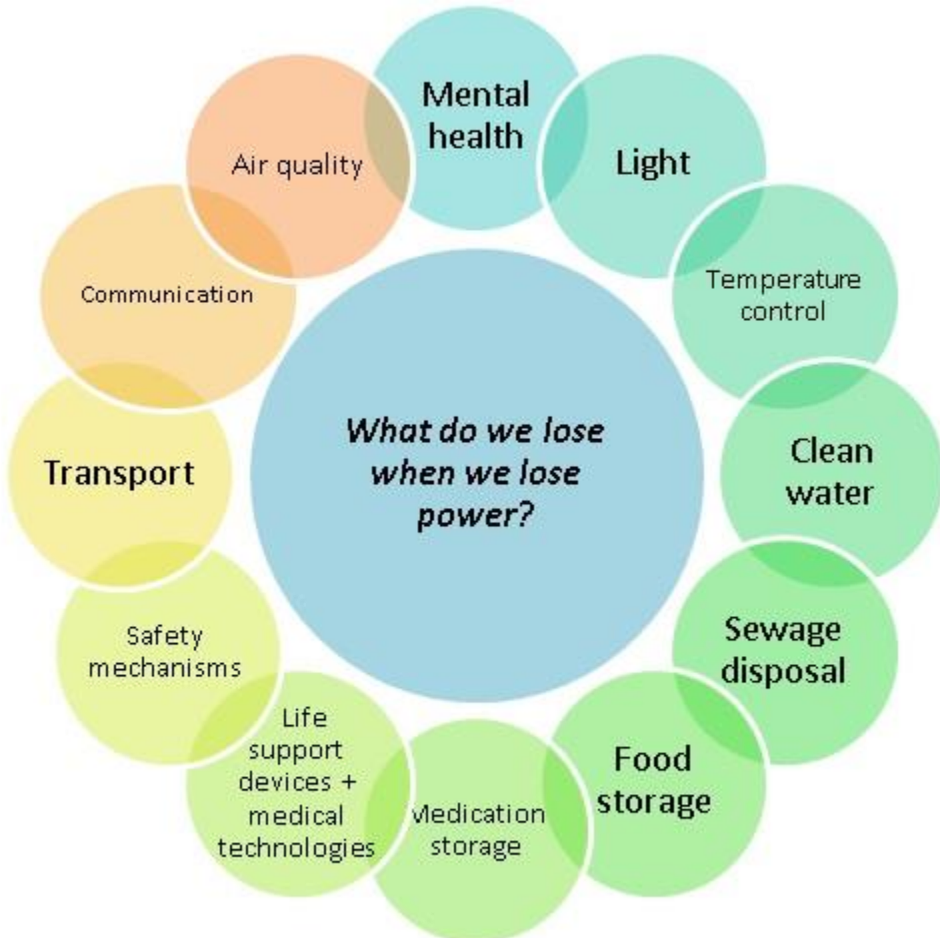

Figure 29: Population and health system impacts of power outages (Klinger et al., 2015)

Literature that explicitly explores the mental health impacts of electricity disruptions was not found. It should also be noted that windstorms can cause secondary impacts (e.g., oil spills) that can undermine climate resilience for coastal communities. These impacts have not been assessed in the HealthADAPT project.

6.3 Community vulnerability mapping

A set of maps has been created that displays vulnerability to flooding across the following regions:

- City of Vancouver
- Richmond
- Coastal, Rural—Squamish, Whistler, Pemberton, Gibsons, Powell River, Bella Coola
- Coastal, Urban—District of North Vancouver, West Vancouver, Bowen Island,
- Delta, Surrey, Langley
- Abbotsford, Chilliwack, Hope
- Burnaby, Coquitlam, Maple Ridge

Exposure data was created using floodplain datasets collected from various municipal and provincial sources across the study area; 200-year interval floods were chosen if available. Sites that identified flood-related hazardous areas were also included. All flood layers were merged into a single feature, which was then intersected with dissemination areas and expressed as % of dissemination area within flood area. Sensitivity and adaptive capacity were modelled using variables including age, pre-existing conditions, socioeconomic status and built environment conditions (full list of variables and methodology available upon request).

Figure 30 shows flood vulnerability for the Fraser Health region. Those interested are encouraged to access the web versions of these maps to learn more and to generate screenshots.

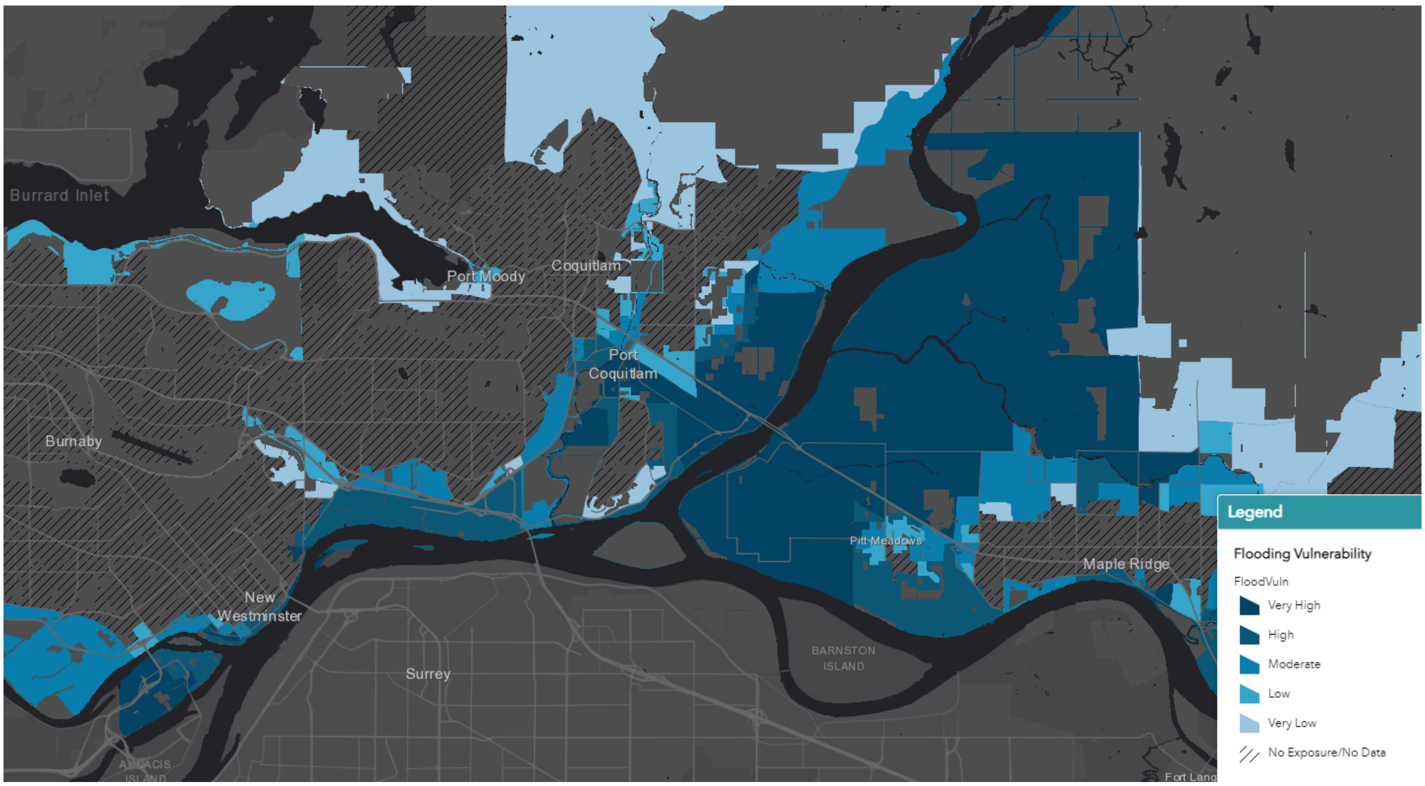

Figure 30: Flood vulnerability for the Fraser North health region

6.4 Future health impacts

Flooding

The conditions that lead to riverine, coastal, and urban flooding are all expected to increase in the future. The provincial risk assessment ranked the health consequences for two flood events: a 500-year Fraser River flood event, and a moderate flood in a single BC community. The consequences were higher for the Fraser River flood scenario, but both risk events were expected to have substantial health impacts due to direct (e.g., drowning) and indirect (e.g., health system disruptions) pathways (BC

Ministry of Environment and Climate Change Strategy, 2019).

Climate change is expected to increase the global burden of water-borne acute gastrointestinal infections (AGI) (Chhetri et al., 2019). Locally, Chhetri et al. (2019) investigated the change in cryptosporidiosis and giardiasis risk due to increased extreme precipitation for the Metro Vancouver drinking water system, had the filtration not been updated. They found that the “combined incidence of cryptosporidiosis and giardiasis relative to 1970–2000 mean baseline increased by an average of 8% in the 2040s, 12% in the 2060s and 16% in the 2080s. Compared to the historical average of 558 cases per year, this corresponds to an expected 649 cases per year in the 2080s” (Chhetri et al., 2019).

Combined with the moderate certainty that flooding will increase in frequency and intensity, these results point to elevated health risks resulting from flooding in the future. Additional work is required to determine the extent of these impacts and the appropriate level of adaptation.

Land use conditions and planning are important factors when considering future flood risk. Flood exposure, and the ways that cities choose to adapt to this exposure, will create challenges around equitable access to climate resilient housing. As flood risk increases, those lacking access to affordable housing could face conditions where the only housing that can be afforded is in areas that are prone to flooding. This could further undermine efforts to ensure that all residents of a city have access to essential amenities like food, proximity to work, etc. A similar phenomenon is evident in the location of First Nations reserves in BC (Yumagulova, 2020).

The extent to which this could lead to a sort of ghettoization, or climate gentrification, is not known for the VCH and FH health regions, but efforts should be made to consider it in any future scenario modelling as it likely represents a significant risk multiplier for populations that have already been placed at higher risk. Public health efforts should also continue to advocate for equitable land use planning and an emphasis of access and affordability of housing.

Windstorms

The evidence presented above is inconclusive in regards to future projections of the frequency and intensity of windstorms for the health regions served by VCH and FH.

6.5 Health system impacts[26]

Flooding and extreme weather events create immediate care needs (e.g., injuries), but also impacts to infrastructure that affect the health system—the latter of which is less common during a heat or smoke event. These include impacts to facilities, but also the infrastructure upon which they depend. Road closures, for example, disrupt access for emergency vehicles, prevent patients from getting treatment as well as food and supplies (Oregon Health Authority, 2020; Read, 2015). Further, the aftermath of extreme weather, such as contamination of public water sources or disruption on medication supply chains, may have a greater impact on older individuals (Lowe, Ebi, & Forsberg, 2013). The impact of extreme weather on supply chains for VCH and FHA is not well known. For example, during the recent 2021 rain event, landslides blocked all roadways in and out of the lower-mainland to the rest of Canada, with some committees in the region being completely isolated (e.g. hope).

This is likely to be especially problematic for communities that rely on access of a single major highway. A national transportation assessment found that: "British Columbia highways have exhibited clear vulnerability to extreme rain events that have caused road washouts, mudslide blockages and bridge closures… In some instances, these events can isolate communities from their principle lines of supply." (Nyland & Nodelman, 2016). For example, Highway 20 between Tatla Lake and Bella Coola is vulnerable to flooding, which can impact the flow of goods, workers, and services.

Power outages have the potential to create significant challenges for delivery of virtual care, and other services delivered remotely. During engagement sessions in 2021, both Spuzzum Nation and Boothroyd Indian Band described going without power for extended periods (e.g. as long five days) due to a landslide. They also communicated that if a landslide has blocked the highway, communities are often isolated from medical services and need to get flown out by helicopter. Much more information is needed about the health system impacts from flooding and landslides, and communities are likely a valuable source of this information.

The *North Shore Sea Level Rise Risk Assessment & Adaptive Management Strategy* found that access to emergency routes was at a high risk of negative impacts during coastal flooding events. Relevant medium risks included impacts to vulnerable populations, healthcare facilities, social services, emergency services and operations (Kerr Wood Leidal, 2020).

Public health services

Engagement with public health staff from VCH and FHA revealed a number of observed and probable impacts to clients, staff, community, and services. Some of these include:

- Most overdose prevention services and food programs are run out of the ground floor of SROs putting those services at high risk in flood scenarios
- Areas where there is farming (e.g. Pemberton, Richmond) will experience higher risk. Higher risk for renters living in basements (e.g., sewer backups).

[26] The internal engagement sessions with VCH home support and palliative care did not collect information about flood risks due to time limitations during the sessions, and the complexity of the geography.

- Disruptions to staffing of outreach teams --> increased acute mental health outcomes for complex clients requiring outreach
- Staff shortages when staff cannot make it to work
- Logistics for deployment to maintain PPH Services e.g., immunizations
- An increase in public requests for direction on environmental issues: sewage/water quality
- Mold and other structural damage to homes
- Impacts to businesses that public health inspects or regulates
- Communities with limited road access (especially those served by a forestry road are at higher risk)
- A risk of reappearance of non-cholera vibrio in smaller systems
- Challenges with accommodating and/or relocating unstably housed populations during flood-related displacements
- Lack of awareness and preparedness among communities who have English as second language. Emergency messaging during disaster in a single language can be inadequate and alarming. Misinformation can be rampant
- Disproportionate impact to residents in LTC/care settings
- Loss of power impacts recreation/food available for care sites
- Residents in care homes may have decreased capacity to emotionally manage significant events
- Requirement to coordinate with local governments
- Challenges maintaining communicable disease programming and management in the event of an outbreak
- Recurrent power outages and impact on cold chain and other processes depending on a functioning electrical grid
- As people are displaced (from all over the province and even between provinces/countries), can contribute to overall sense of instability and decrease community connection

Health care facilities

Floodplain mapping exists for many of the facilities in Fraser Health. Figure 31 shows the approximate location of hospitals and campuses in relation to projected flood extents (Facilities Management, 2019a). “Much of the existing health infrastructure in BC will require relocation as a consequence of sea level rise, disrupting health services not only for people living near the ocean but those across the province who rely on these coastal facilities. Richmond and Delta hospitals in Metro Vancouver, which together serve a population of 300 000 people, are vulnerable to a 1-in-500-year storm surge even at today’s sea level” (Liang & Kosatsky, 2020). The Canadian Institute for Climate Choices found that 8% of BC’s 619 health facilities were at risk of flooding during a 1-in-50 year flood event (Canadian Institute for Climate Choices, 2021, p. 47).

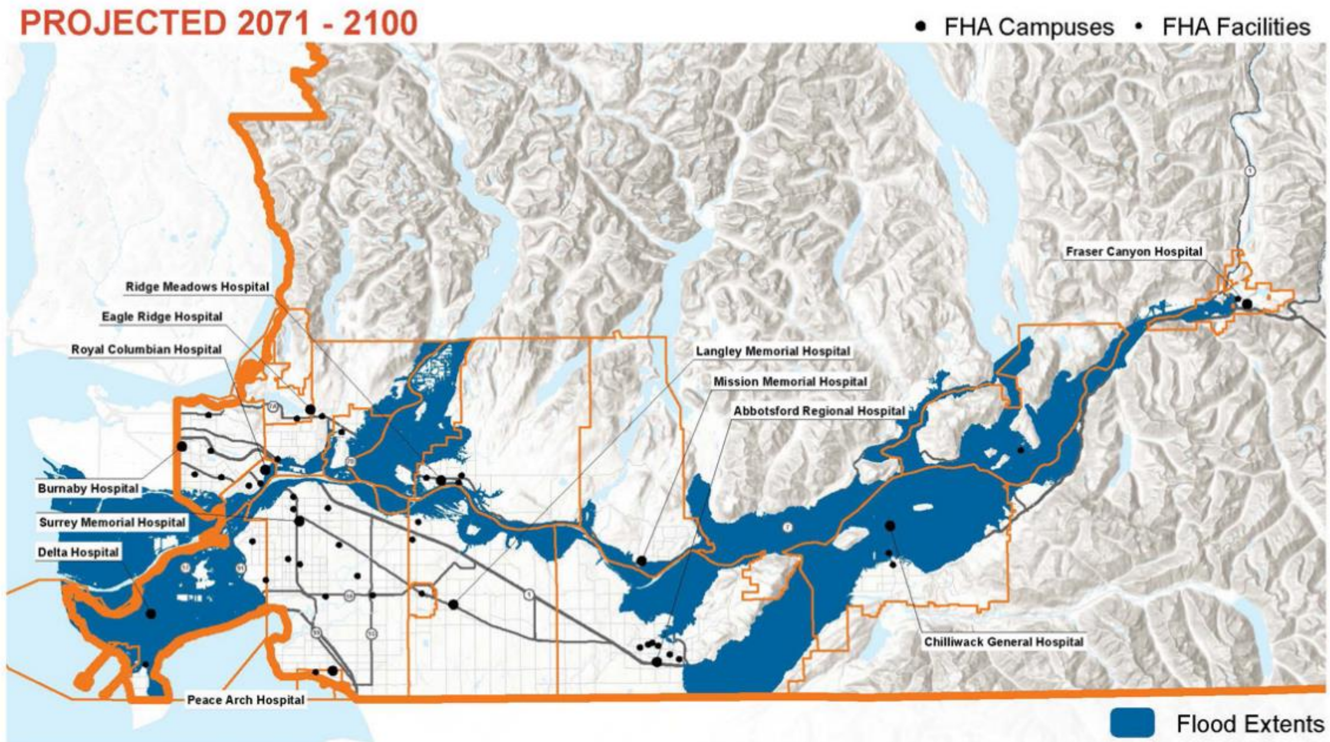

Figure 31: Floodplain projections and facility locations for FHA (Facilities Management, 2019)

Physical damage to facilities from storms and flooding can threaten building integrity and compromise sanitary conditions (Facilities Management, 2020a). Facilities can be impacted by flood via structural damage, loss of power beyond auxiliary power, loss of road access, loss of essential personnel, loss of supplies, including food and medicine, contamination of facilities from flood waters (Fraser Basin Council, 2016), disruption of sewage systems, salinization of soils, and surge capacity (BC Housing, 2019b). Road closures can affect workers ability to get to sites, and patients (e.g., those seeking dialysis) can experience difficult accessing services.

Some of the completed climate vulnerability and risk assessments have considered flooding and wind events. A stress testing exercise carried out for the St. Paul's Hospital redevelopment identified the following impacts:

- Ground floor flooding will increase mold risk at the facility;
- Community flooding will reduce community health, and increase demand for health services;
- Flooding and storm surges may result in global transportation limitations, impacting access to building supplies for capital projects;
- Loss of power due to wind, flood or high loads may affect internal data management and digital infrastructure affecting patient information management, care and internal/external communications;
- Strong winds will decrease transportation and access impacting community connection for patients;

- Strong winds may result in increased demand on health facilities (Facilities Management, 2019b).

A climate and vulnerability risks assessment for the Redevelopment of Royal Columbian Hospital explored flooding and wind events, with impacts summarized in Figure 32 (Ellis Don, 2020).

HEAVY RAIN, WIND & SEVERE STORMS			
Impact Statement	**Vulnerability**	**Risk**	**Advanced**
Strong winds may lead to power outages that cause an increased demand on health facilities	V4	Medium	✓
Heavy rain and community flooding may decrease ability of patients and staff to access the site	V4	Low	✓
Heavy rain and flooding at all levels of the hospital may increase infection and mold risk at facility	V3	Low	✓
Heavy rain may overwhelm municipal sewer infrastructure and lead to bacterial outbreaks and unsanitary conditions	V3	Low	✓
Strong winds may result in transportation system failures impacting travel patterns of staff and patients	V3	Low	

Figure 32: Expected impacts to RCH from extreme weather (Ellis Don, 2020)

Building power systems are subject to a number of climate-related threats: high demand for cooling during heat waves may overwhelm the grid, and flooding may down power lines or flood critical infrastructure – and these challenges will only increase in the future. As health facilities must have reliable power supplies to maintain appropriate interior temperatures and ventilation rates, any interruption to these systems can have dramatic consequences on patient care (Facilities Management, 2020a).

- Power outages lead to the following additional impacts:
    - Power outages impact ability to deliver care for complex patients (patients)
    - Stress to facility staff due to power and system outages
    - Power outages cause facilities to run on generator power, burning excessive fuel
    - Higher loads on building envelope, leading to premature degradation; hazards from flying objects and debris
    - Disruption to transportation and community health care, resulting in increasing hospital visits
    - Home health inaccessible due to loss of phone and internet access.

6.6 Adaptation inventory—Storms and flooding

Understanding VCH and FH's vulnerability to storms and flooding involves assessing existing initiatives that increase preparedness for our communities, facilities, and services. As described above, this response requires a multitude of actors working collaboratively towards shared objectives. Table 14 presents a high-level inventory that is not exhaustive, but rather is meant to highlight key initiatives that give a general indication of the general adaptive capacity within the VCH and FH health regions. Communities have been managing floods since their inception, and the management of flood risk is very multi-jurisdictional and complex (see Figure 32). Public health efforts tend to focus on water quality impacts, especially in smaller systems, and in general leadership and support for flooding is less developed than for heat and air quality. That said, existing emergency management processes like those led by HEMBC represent significant adaptive capacity for both floods and power outages.

Table 14: Adaptation inventory for extreme weather events

ADAPTIVE CAPACITY INVENTORY – STORMS AND FLOODING	

HEALTH AUTHORITY EMERGENCY PREPAREDNESS AND RESPONSE	• **Advance forecasting** and riverine flood watches and warnings are issued by the River Forecast Centre
	• Seasonal readiness planning and climate risk management occurs in many areas within the health authorities: In hospitals, clinics, and long-term care (LTC) facilities, and also for services delivered in patients' homes or directly in the community for underhoused populations.
	    ○ VCH/FH Facilities Management's Climate resilience guidelines for BC health facility planning and design provides guidance for designers and operators to ensure that new and retrofitted health care facilities manage climate risks. Site-level risk assessments have explored the impacts of storms, flooding, and power outages on different types of health facilities, and including redevelopment and new builds.
	    ○ The BC Residential Care Regulation requires residential care facilities to have an emergency plan that addresses each of the four pillars of emergency management (mitigation, preparedness, response, recovery). VCH provides a template for facility managers to use to create this plan
	    ○ Hospital colour codes are used in hospitals to denote to staff various kinds of emergency situations. Events like a power outage, for example, would trigger a code grey, triggering a standard escalation procedure. This 'all hazards' approach means that there are no plans in place for each specific hazard, but that general emergency management capacity can be relied upon during climate shocks and stresses
	    ○ First Nations Health Authority's (FNHA) Health Emergency Management facilitates coordinated activities in response to emergencies that may impact the health of BC First Nations community members. They work to ensure that communities are effectively linked within the provincial emergency response system and receive emergency management support at a level equivalent to non-First Nations, and that an effective FNHA response during the response and recovery stages of

	an emergency. ▪ FNHA environmental health officers conduct home inspections ahead of flood season. This directly benefits populations in VCH and FH, and also could serve as a peer-to-peer learning opportunity for VCH and FH staff • **During** storms and floods: ○ PHSA's Disaster Psychosocial Program aims to help diminish long-term psychosocial effects of extreme weather events, and improve an individual or community's adaptive coping mechanisms ○ Virtual care services enable health care providers to reach remote populations that are cut off from physical services. This was the case in in 2017, when a Fraser Health virtual clinic ensured isolated patients could still receive health care when the highway between Hope and Boston Bar was closed by a rock slide, preventing the regular nurse practitioner from reaching the Anderson Creek Health Clinic at the Boston Bar First Nation ○ Public Health monitors water quality issues (e.g., turbidity during flooding) and provide information to system operators and home owners, as well as guiding testing to confirm water is bacteriologically safe. VCH has mapped the locations of all small water systems across the health authority
KEY INITIATIVES AND RESOURCES *Examples of leadership and collaboration*	• **Local government** ○ A tremendous amount of work has already been undertaken by local and regional governments and others to manage flood risks at the community level. This includes mapping, emergency management planning (e.g., HRVAs), investments in flood mitigation strategies, etc. • **Provincial initiatives** ○ BC's Climate Preparedness and Adaptation Strategy seeks to enhance predictive services and early warning capacity, including the B.C. River Forecast Centre, to bring the future climate into forecasting floods, water scarcity, and wildfires. This strategy will also enable leadership by BC's Ministry of Health ○ Investments of more than $103 million in 248 flood risk reduction projects across the province through Emergency Management B.C. including the Community Emergency Preparedness Fund, which helps local governments and First Nations build resilience in response to emergencies, as well as joint investments with the federal government for the Adaptation, Resilience and Disaster Mitigation program, and the National Disaster Mitigation Program ○ The province will conduct initial work on a BC Flood Strategy in collaboration with other levels of government ○ EMBC's Emergency Info BC provides info on response, including links to help manage mental health impacts for adults and children. GeoBC and EMBC's Common Operation Picture is the province's one-stop-shop for emergency GIS information and the primary mechanism to display real-time emergency response data for stakeholders at agencies like EMBC. It has been used during wildfire and flood events ○ BC Hydro's ongoing work to adapt their system to the impacts from extreme storms. BC Hydro also

	maintains a list of facilities that are prioritized during electricity disruptions
	• **Not-for-profits: E.g. Fraser Basin Council (FBC)**
	  ○ FBC's Lower Mainland Management Strategy (LMFMS) is a collaborative initiative that aims to anticipate, mitigate and plan for major Fraser River and coastal flooding in the Lower Mainland. This initiative led to the creation of widely used flood scenario maps for the Fraser River, and the insight that a large magnitude flood in the region could result in direct and indirect costs of $20-30 billion. Phase 2 of the initiative is now underway, and will deliver recommendations for flood mitigation actions and funding options, though it is not known how this will interact with the forthcoming BC Flood Strategy
	• **Communities of practice and other leaders**
	  ○ The First Nations Emergency Services Society works closely with First Nation communities, Emergency Management BC, Indigenous Services Canada and various other stakeholders to support the successful implementation of emergency management for First Nation communities in BC. The FNESS Emergency Management department provides community-based emergency management guidance, support and assistance to BC First Nation communities. Their activities are informed by the British Columbia Emergency Management System, which is recognized as a standard system for emergency response, and currently mandated for use within the Government of BC and recommended to local authorities
	  ○ The First Nations Leadership Council, made up of the BC Assembly of First Nations, the First Nations Summit and the Union of BC Indian Chiefs, as mandated by the Chiefs in BC, is drafting a BC First Nations Climate Change Strategy and Action Plan informed by First Nation priorities and knowledge. The objective of the plan is to identify strategies and actions to strengthen Indigenous climate leadership in BC. This includes helping mitigate carbon pollution, reducing vulnerability to impacts, and building capacity, understanding, and resilience in First Nation communities.
	  ○ Environmental organizations can play an important role in reducing flood risk. E.g. the Rivershed Society works with First Nations, land owners, and municipalities to restore Fraser River tributaries, thereby mitigating local flooding
	  ○ The ImpactR tool was co-developed by BCCDC and Simon Fraser University and assesses the impact of climate change on waterborne illness (e.g., the relationship between extreme precipitation, drinking water and acute gastro-intestinal illness)
	  ○ Canadian Mental Health Association's provides guidance for coping through a natural disaster, as does HealthLink BC resources, Ministry of Health, and NCCEH
	  ○ The National Collaborating Centres for Public Health led a project to explore knowledge gaps and inform priorities for public health responses to long-term evacuations due to natural disaster

Figure 33 gives a sense of the flood risk governance landscape and suggests how the regional health authorities can support flood risk management. For example, VCH/FH Facilities Management is in a position to consider direct reductions to flood risk, whereas public health and HEMBC play a role in awareness raising, preparedness, and response. It has been included to encourage conversation and not to accurately portray BC's flood risk management landscape.

Figure 33: A typical flood risk governance context (source)

7. Ecosystem changes

Degradation of our natural environments and ecosystem services threatens human health directly and indirectly (World Health Organization, 2021). Changing environmental conditions are often a primary determinant of health that impact food systems, water security, people's ability to use active modes of travel, to recreate outside, livelihoods, etc. The field of public health has taught us that these determinants affect individual health, community health and resilience, and overall population health. The connection between natural environments and health is perhaps most prominent in the planetary health paradigm, which seeks to understand how changes to natural systems affect human health and wellbeing at multiple scales (Pongsiri et al., 2019).

In addition to the sudden onset events described above (e.g., heat, air quality, flooding), the VCH and FH regions will be affected by longer term—sometimes called slower onset—hazards that include increasing annual temperatures, ocean warming and acidification, and shifting precipitation patterns. Projected changes include:

- Annual average **temperatures** in BC could increase by as much as 5.2°C by 2100 (Bush & Lemmen, 2019);
- Annual **precipitation** is expected to increase by 5.7% by 2050, and by 13.8% by 2100 under RCP 8.5 (Zhang et al., 2019, p. 167). These increases will generally occur in fall, winter, and spring, with less snow and more rain.
- Changes in seasonal precipitation along with warming will lead to more frequent and intense **droughts** and soil moisture deficits, especially in the interior, as well as regions that depend on snowmelt and/or glacial meltwater for their main dry-season water supply (Bonsal, Peters, Seglenieks, Rivera, & Berg, 2019; Yang, Gan, & Tan, 2021). Some of the smaller rivers in southern BC are likely to dry up during the summer and early fall, and most small glaciers in southern BC will disappear (BC Ministry of Environment, 2016).
- **Coastal Pacific waters** will become warmer, more acidic, and less oxygenated, in addition to stronger storm surges and rising sea levels (Greenan et al., 2018; Vadeboncoeur, 2016).

These changes will create impacts to ecosystems across VCH and FH, including changes to forest conditions, animal and plant species (Government of BC, 2020b), and impacts to food and water safety, quality, and security. Impacts to cultural practices will also arise whereby communities are prevented from engaging in cultural practices that are land-based. As described below, many of these impacts are particularly pronounced for Indigenous communities.

Densely populated areas also rely on ecosystems within and beyond their boundaries to provide essential ecosystem services. However, development places pressure on already strained ecosystems and sprawl threatens ecosystems surrounding cities and towns. Public Health continues to advocate for policies that equitably preserve ecosystems.

This section provides a high-level overview of the relationship between climate-sensitive hazards, ecosystem changes, and impacts on human health, focusing on changes to ecosystems within and outside of cities, and the impact this has on food and water safety and security, as well as cultural impacts.

The June 2021 extreme heat event produced a number of impacts to ecosystem across the VCH ad FH health region. A preliminary list includes:

- Harmful implications for the province's approximately 17,000 glaciers (Watson, 2021).
- 10 confirmed cases of *Vibrio* (*see* Section 8.1) illness in people that had harvested their own shellfish (CBC News, 2021a).
- Shellfish farmers reported major losses in their stocks of Pacific oysters and clams. The combination of extreme heat and extremely low tides meant the crops were left exposed on the beach for hours at a time, leading to hundreds of thousands of dollars of losses (Edmiston, 2021).
- Damaged fruit crops in the Okanagan and Fraser valleys, with up to 75% of some fruits too damaged to sell fresh (Gomez, 2021).
- Mass death event of more than 1 billion marine animals along Canada's Pacific coast, mostly mussels, starfish, and clams, *see* Figure 34 (Cecco, 2021).
- Anecdotal evidence that Sockeye salmon retreated from a coastal First Nations fishery at the exact time that they were in season, requiring additional boats to be hired to catch them at sea.
- Destroyed crops at Christmas tree farms where the heat scorched brown patches on the sides of some trees, leaving them not satisfactory for market or likely only available for sale at reduced rates, and killed many seedlings (Meissner, 2021).

The health impacts of environmental degradation not only come with changes to our local environments, but also from changes in other parts of the world with the resulting increase in climate refugees, economic impacts, etc. Canada will come under growing internal and external pressure to accept larger numbers of migrants from climate-disrupted regions (Eyzaguirre, Morton, Wabnitz, Copage, & McLeman, 2021). Understanding of the extent and nature of this impact on BC are still nascent.

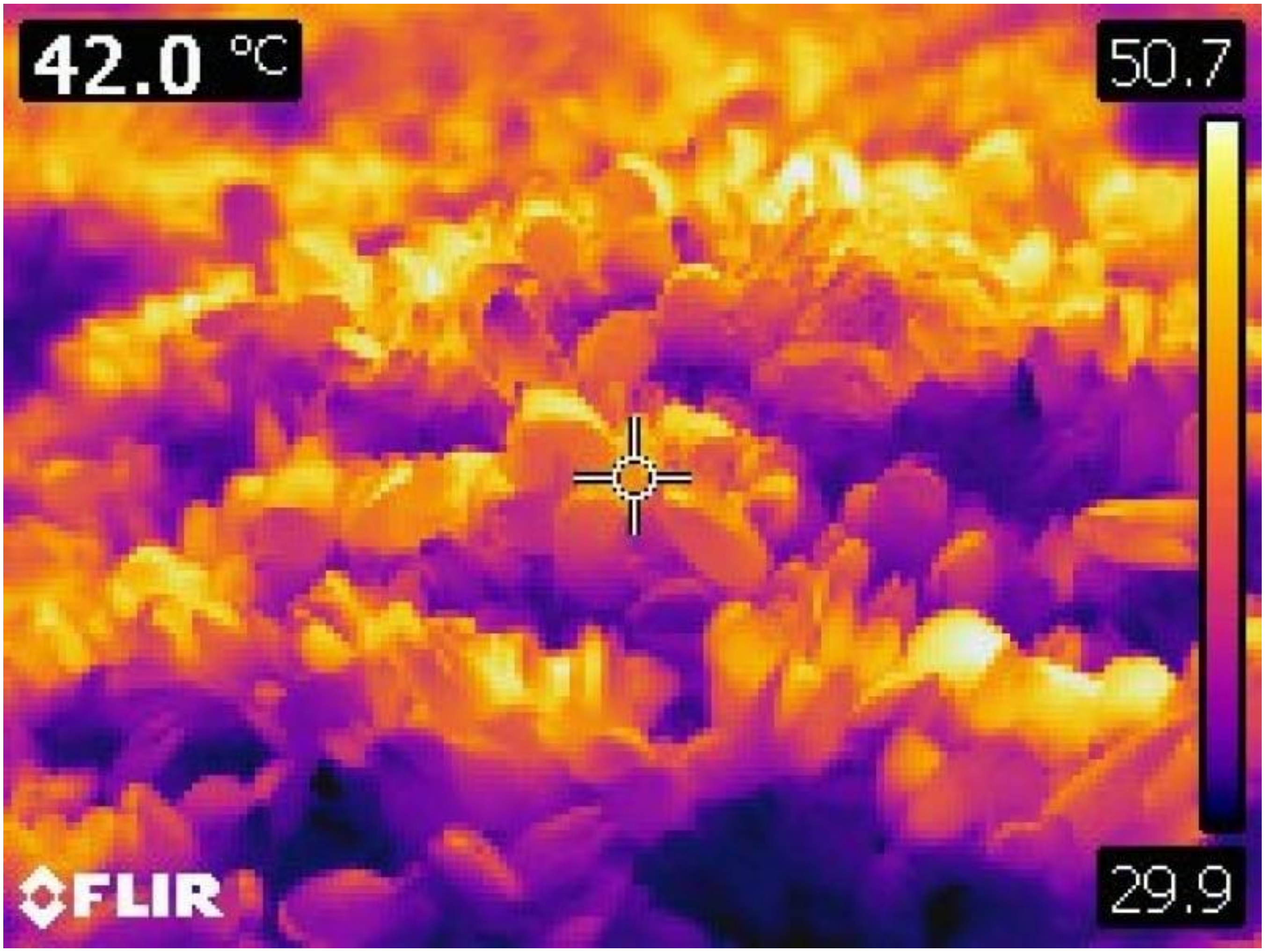

Figure 34: A thermal image of recently killed mussels in Lighthouse Park in West Vancouver, B.C., captured on June 28. The scale bar on the right shows the hottest and coolest temperatures recorded in the image. (Chris Harley/University of British Columbia, retrieved from CBC News).

7.1 Water security

Warmer annual temperatures, longer dry spells in the summer, reductions in snowpack, and increased agricultural demand affect the supply, treatment, storage, distribution and operation of drinking water supply systems (Mu, 2018; Metro Vancouver, 2016). Water stress could impact people in their home by limiting the amount of available water, and could also affect health care facilities, which receive water from regional water sources, and could experience shortages for sterilization, sanitation, and human consumption" (Facilities Management, 2018), and could also influence shifts in food cultivation practices. Higher temperatures may cause loss of residual chlorine in water distribution systems, leading to legionella growth or regrowth. Also, increase in temperature encourages algal growth in lake water sources.

These impacts are felt across the health regions. For example, the Sunshine Coast imposed Stage 4 water restrictions several summers in a row due to low water capacity. In addition, an extensive study undertaken by Metro Vancouver confirmed future supply storage vulnerabilities due to changes in snowpack and seasonal inflow. However, their *Water Supply Outlook 2120* outlines a plan to complete a second water intake at the Coquitlam Reservoir by mid-2030s, and highlights that no water shortages are projected under the low stress planning scenario and that under the moderate- and high-stress scenarios, an additional source supply is projected to be needed by approximately 2070 to avoid a shortage (Metro Vancouver, 2019e).

At the time of writing, no similar studies could be found for other water systems in the VCH and FH region, although some research exists for the prevalence of water stress and restrictions across BC (Gower & Barroso, 2019). Similarly, no data could be found on the extent to which warmer air temperatures will make it more difficult to safely store water for long periods in reservoirs, an impact identified by BC Ministry of Health (forthcoming).

These data gaps are important, especially for smaller systems which are likely to be more sensitive and lack the adaptive capacity of the Metro Vancouver system. Guidance exists for local governments (Auditor General for Local Government, 2018; BC Ministry of Health, 2017; UBCM, n.d.), but more work is needed to understand the observed and projected health impacts, and the role of the health authority in supporting adaptation.

7.2 Environmental toxins

Climate change will exacerbate the conditions that create favorable conditions for several environmental toxins, described below.

- **Marine shellfish poisoning** refers to illnesses in humans caused by consumption of marine bivalve shellfish (e.g., clams, mussels, oysters, scallops, cockles) and other seafoods, such as invertebrates (e.g., crabs) and planktiverous fishes (e.g., eulachon, herring). The 3 toxins of concern in BC currently are: paralytic shellfish poisoning, diarrhetic shellfish poisoning and amnesic shellfish poisoning. Poisoning occurs when human eat shellfish that contain biotoxins (e.g., domoic acid, okadaic acid, saxitoxin) (NCCEH, 2019b) that are accumulated via phytoplankton. Phytoplankton species often occur in blooms, known as harmful algal blooms (HABs, referred to colloquially as *red tides*) when they contain toxin-producing species. HABs are expected to become more frequent, of longer duration, and with a greater distribution as the climate changes (NCCEH, 2019b). Marine toxins in seafoods do not affect the colour, taste, or odour of seafood and are not destroyed by cooking or boiling. Marine shellfish poisoning is likely to have a disproportionate effect on Indigenous communities, as described below. Recent research indicates that there is reason to believe that a continuum of memory difficulties may be associated with domoic acid exposure (Grattan, Kaddis, Tracy, & Morris, 2021).
- **Cyanobacteria**, also known as blue-green algae, can be found in shallow, slow moving or still water, including ponds, wetlands and shorelines of fresh water lakes, streams and rivers (HealthLinkBC, 2019). Under certain environmental conditions, cyanobacteria multiply quickly and create blooms (i.e., algae blooms). These blooms can produce several types of cyanotoxins that can pose a serious public health risk as exposure through skin contact, or ingestion of contaminated drinking water or food can cause symptoms ranging from minor irritation to more serious illness and, in worst case scenarios, can be fatal (NCCEH, 2019a). Climate change

is expected to increase the frequency and duration of blooms (D. P. Hamilton, Salmaso, & Paerl, 2016), which in addition to affecting humans, also often affect pet dogs.

Ecosystem changes have, and will continue to include, altered patterns of infectious disease caused by microbial organisms. These impacts are described in Section 8.

7.3 Food security

Food systems—and the food security that they enable—in Canada and BC are complex, with a variety of determinants (*see* Figure 35), and complex governance, logistics, and economics. Climate change is an important environmental determinant that affects the food system from production through to consumption (NRCan forthcoming). The primary climate-related drivers in BC are drier conditions and drought, pests and pollinators, seasonal variability, wetter conditions and flood, and wildfire (British Columbia Agriculture & Food Climate Action Initiative, 2021).

BC-focused research tends to focus on production, as can be seen in the large amount of resources made available through the Climate & Agriculture Initiative BC. Climate change is often cited as one of the top threats to BC's agricultural sector (MNP LLP, 2020, p. 6). Impacts to local food suppliers include higher costs, lower productivity, and changing pest regimes (BC Ministry of Agriculture and Lands, 2006; British Columbia Agriculture & Food Climate Action Initiative, 2015). Production and supply can be very difficult to understand and assess, given that foreign producers like California currently supply so much of our imported fruits and vegetables (Provincial Health Services Authority, n.d.) and that a changing climate may present opportunities for BC producers to gain market share in competing agricultural jurisdictions (e.g. California) (MNP LLP, 2020).

Understanding this dimension of the food system is beyond the scope of the current assessment, but much more detail can be found in Brown and Gifford (forthcoming) and findings from the B.C. Food Security Task Force (2020).

Less is known about the impacts of climate change on the processing, distribution, preparation, and consumption of our food. Climate change may affect the health of Canadians through effects on the amount of nutrients they obtain from their food (NRCan forthcoming). Longer, hotter summers will likely lead to increased exposure to food safety risks (e.g. backyard BBQ and food sitting in heat, storing food, transportation of high risk food). More frequent heat waves could cause increased foodborne illness outbreaks resulting from bacteria, parasites, and viruses.

The impacts of flooding, droughts and heat waves on crops and the spread of pathogens through the food chain (e.g. farmers markets) is not well studied. PHAC collects and tests irrigation water in BC and AB, but do not test food or correlate the results to food outbreaks to better understand the impact of pathogen replication in water/irrigation and people eating fresh food.

Similarly, extreme weather events affect food system infrastructure. For example, a freshet flood would have severe consequences for agricultural operations in the Fraser Valley, which is home to intensive production and much of the province's food storage and food processing. A freshet flood in this region would affect the entire province's food supply and infrastructure (British Columbia Agriculture & Food Climate Action Initiative, 2015).

More work is needed to understand how climate change will impact these dimensions in the VCH and FH health regions. The primary role of the health authority at this point is not to solve all of these research gaps, but to contribute health impact data, advocate, review literature, and collaborate towards better understanding the impacts and adaptation options for BC's food system.

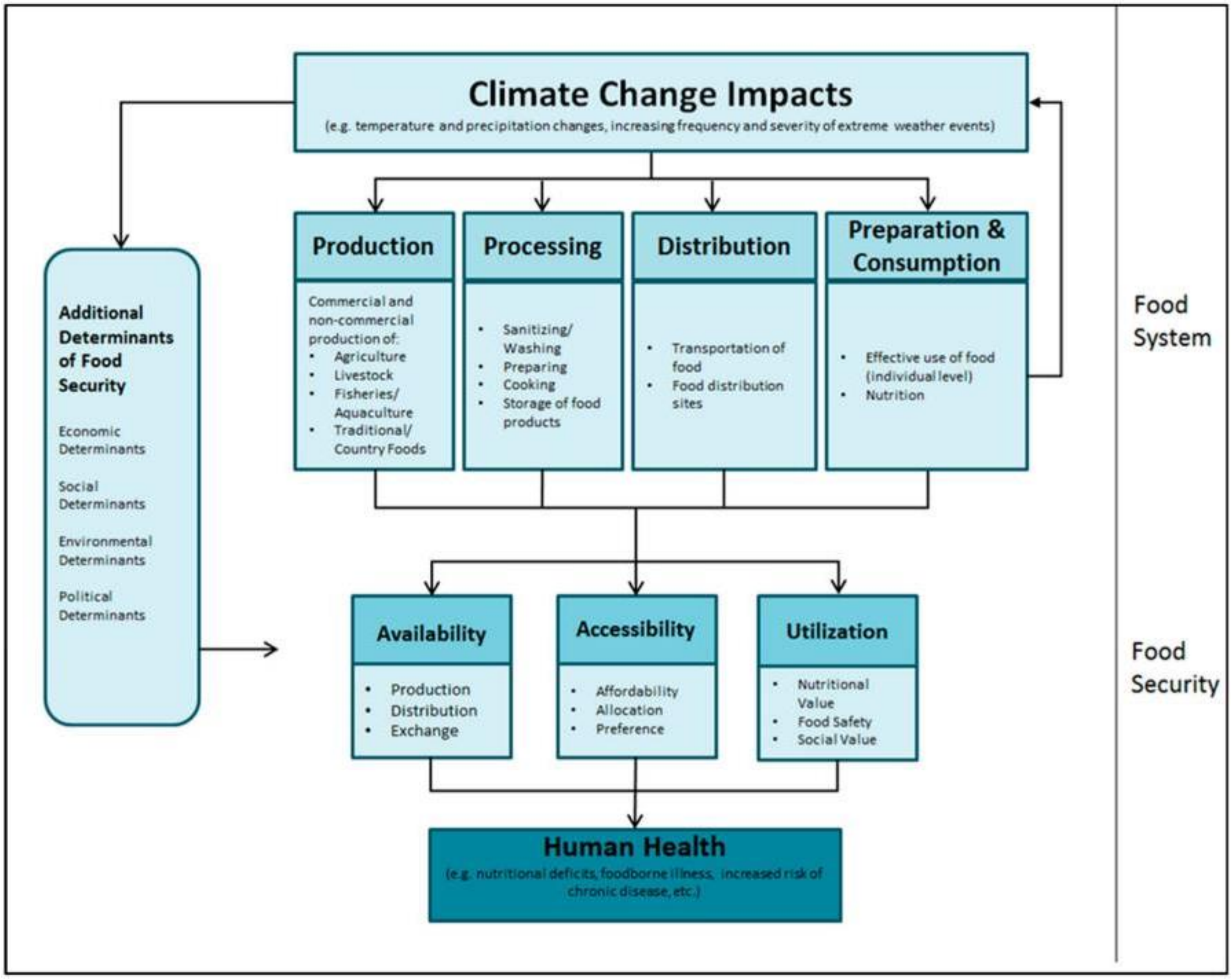

Figure 35: Food security and climate change (Schnitter & Berry, 2019)

7.3.1 Traditional foods and medicines

Indigenous food systems and traditionally-harvested food are central to the health and wellness in Indigenous communities (Health Canada, forthcoming) (Marushka et al., 2019; Steiner & Neathway, 2019). Indigenous Knowledge Keepers often pass information on through medicines and foods. For example, the eulachon (also known as salvation fish, or candlefish) is a small, oily fish that has been central integral part of Nuxalk tradition as a food source and as an important land-based activity. A number of environmental pressures led to the decline of this species, and the loss of an important cultural practice and food source for Nuxalk people, but efforts are underway to rehabilitate fisheries in the Central Coast region (First Nations Health Authority, 2021).

Substantial research has been conducted about the impacts of climate change on Indigenous peoples' access to traditional foods, medicines and materials (Liang & Kosatsky, 2020; Marushka et al., 2019; Mu, 2018; Steiner & Neathway, 2019). This is augmented by the HealthADAPT project's focus on Indigenous communities during its engagement.

A number of climate-sensitive hazards affect access to food and traditional food, including unpredictable weather patterns, extreme heat and cold events, less predictable drought conditions; increasingly intense wildfires; irregular water conditions (such as flooding); impacts of invasive species on plants and animals; and decreased access to traditional sources of food (Lower Fraser Fisheries Alliance, 2020; Steiner & Neathway, 2019). Indigenous communities' access to food has been—and is currently—affected by colonial policies in Canada, and efforts like the Indigenous Food Sovereignty movement seek to expose this, and to improve the determinants of poor health outcomes via access to better food.[27]

Impacts to traditional foods, medicines and materials have been identified in a number of large scale engagement efforts (First Nations Leadership Council, 2020; Indigenuity Consulting Group Inc., 2020). These include impacts on fish, game and related habitat, as well as on berries, roots and other wild foods and medicinal plants. Impacts to these food sources contributes to health problems, and loss of family and community gathering as well as increasing poverty as people are forced to turn to buying more processed foods in grocery stores.

During HealthADAPT engagement, Boothroyd and Spuzzum shared observations around changes to the conditions and cycles for harvesting traditional foods (e.g. mushrooms) and plants picked for salves and medicine.

- Spuzzum Nation is a mushroom harvesting nation and foraging is an important cultural practice. They have noticed mushroom harvests impacted by drier conditions.
- Spuzzum has also observed an increase in dust on the leaves they use for medicinal salves and teas leading to challenges in using these plants for traditional purposes.
- Boothroyd has noticed the blooming cycles for some key medicinal plants (e.g. arnica) is changing, making it less predictable to harvest.
- Boothroyd has been building their own mapping system for traditional foods and plants in their territory based on observations and interviews with hunters, fishers, elders and knowledge keepers in the community. They have offered to present this to Fraser Health.

Marine foods

To better understand the impacts to traditional marine foods, Weatherdon et al. (2016) projected scenarios of climate-related changes in the relative abundance, distribution and richness of 98 exploited marine fishes and invertebrates of commercial and cultural importance to First Nations in

[27] See Health Canada (forthcoming, chapter 8, box 1) for a much more detailed description of this issue.

coastal British Columbia. They found that “while a cumulative decline in catch potential is projected coastwide (-4.5 to -10.7%), estimates suggest a strong positive correlation between the change in relative catch potential and latitude, with First Nations’ territories along the northern and central coasts of British Columbia likely to experience less severe declines than those to the south” (Weatherdon, Ota, Jones, Close, & Cheung, 2016).

A similar study found that in the Nuxalk Nation, the consumption of spring salmon decreased from 38 Kg/family/year to 13 Kg/family/year, and sockeye decreased from 27 Kg/family/year to 5 Kg/family/year between 1981 and 2009 (Marushka et al., 2019). This decrease was due to a confluence of social, environmental, and economic factors, many of which will be exacerbated by a changing climate. The same study projected an estimated reduction in essential nutrients accessed from traditional seafood consumption of 31% by 2050 under RCP 8.5, relative to 2000 (Marushka et al., 2019). These quantitative findings are echoed by the findings from the community engagement sessions described below.

Salmon are a very important food source for many Indigenous communities, and fishing for salmon is often an important cultural practice. Conditions in rivers and in the Pacific Ocean are likely to threaten many of the species that are central to Indigenous communities. For example, climate change is expected to have profound negative impacts on Fraser River salmon stocks, with less certainty for more northerly rivers (e.g., Rivers Inlet area) (BC Ministry of Environment, 2016). Figure 36 shows some of the pathways by which salmon populations are affected by climate change.

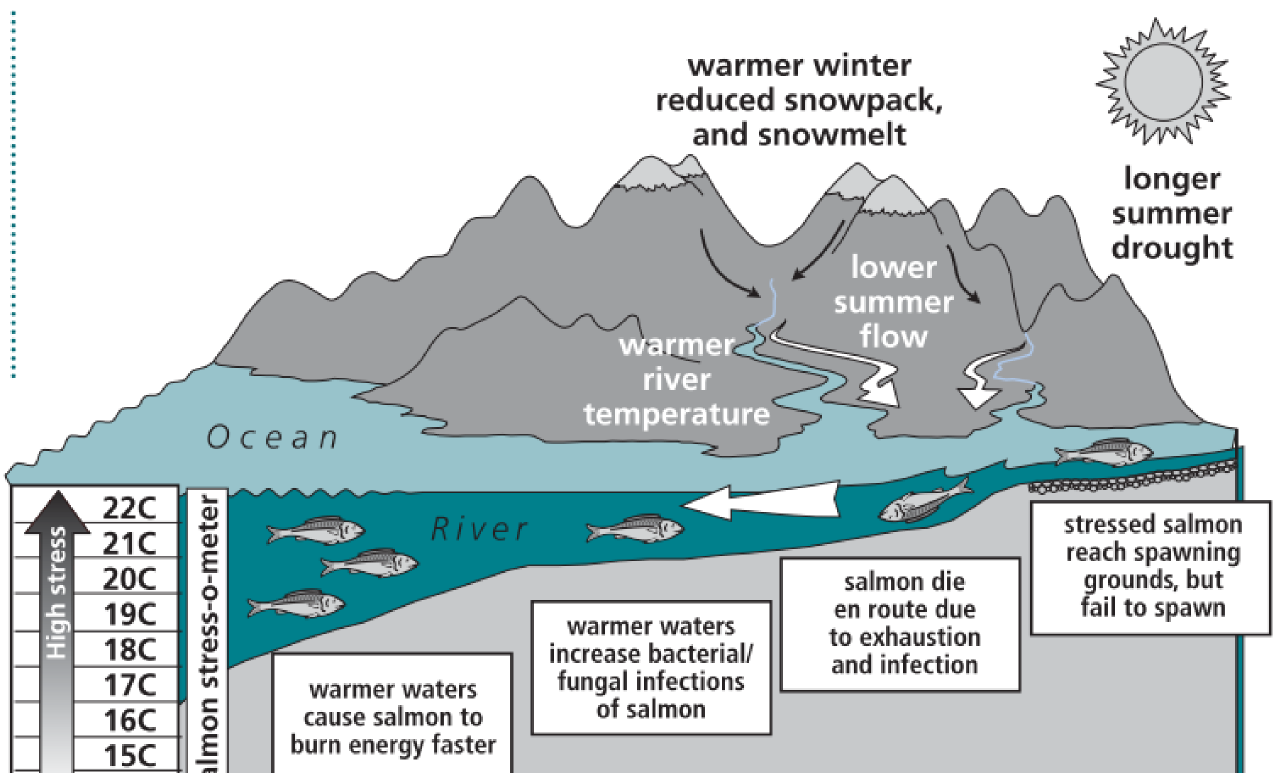

Figure 36: Impacts to salmon from warmer river temperatures (BC Ministry of Environment, 2016)

Indigenous communities in the Fraser Canyon rely on salmon as an important traditional food of great cultural significance. During HealthADAPT engagement, communities reported stressed and declining salmon populations due to warmer water temperatures that affected salmon spawning channels across their traditional territories. Specifically, communities named:

- Higher rates of pre-spawn salmon mortality;
- Observing salmon with heat spots;
- Bans for community members on salmon fishing due to depleted stocks; and
- Challenges associated with sharing traditional knowledge/skills and educating youth about salmon harvesting.

7.3.2 Cultural impacts

The *First Nations Perspective on Health and Wellness* makes an explicit connection between the ability to engage in cultural practices and health and wellness (First Nations Health Authority, 2016). The cultural impacts of climate change have historically been very poorly understand, despite a strong connection between Indigenous cultural identities and the resilience needed to adapt to the impacts of climate change (BC Assembly of First Nations, 2020).

In BC, resources that are critical to First Nations' participation in cultural life have been severely affected by climate change such as:

- The declining stocks of salmon, loss of wildlife, berries, roots and other wild foods is contributing to health problems, and loss of family and community gathering as well as increasing poverty as people are forced to turn to buying more processed foods in grocery stores (First Nations Leadership Council, 2020).
- Medicinal and ceremonial plants and trees have been affected by fires, heat waves, droughts and floods, as well as by invasive non-native plant species, which negatively affect the ability of First Nations' use of these plants for cultural purposes (BC Assembly of First Nations, 2020).
- Climate change-affected species decline (moose, caribou, elk, and salmon) destroy the ability to exercise constitutional rights to fish, hunt and gather for food for social and ceremonial purposes (BC Assembly of First Nations, 2020).

The Government of BC survey described above found that mental and physical health impacts were the area of highest concern among respondents. The results highlighted unique impacts to Indigenous communities including cultural impacts resulting from a loss of hunting, fishing or wild harvesting opportunities (BC Ministry of Environment and Climate Change Strategy, 2020).

In Spuzzum and Boothroyd, many cultural ceremonies and rites of passage take place on the land. Extreme heat, wildfire smoke, and impacts on traditional food systems have created challenges for communities to be in ceremony together on their territory. Moreover, the decline in salmon populations is a major emergency and has serious implications on the cultural way of life for many Indigenous communities. For example, a traditional fish ceremony is now held later in the summer due to changes in salmon stocks. Fire is an important part of this ceremony, however there are often fire bans in late summer due to extreme heat and dryness.

7.4 Mental health impacts

It is increasingly understood that ecosystem changes affect the mental health of Indigenous and non-Indigenous communities. These impacts can arise as a result of limited access to nature, anxiety about the global climate crisis or the threat of environmental disaster (also called 'climate anxiety' or 'eco-anxiety'), and climate grief, which is the "grief felt in relation to experienced or anticipated ecological losses, including the loss of species, ecosystems and meaningful landscapes due to acute or chronic environmental change" (Cunsolo & Ellis, 2018). Impacts to Indigenous mental health resulting from ecosystem changes have been identified in a number of large scale engagement efforts (BC Assembly of First Nations, 2020; First Nations Leadership Council, 2020; Indigenuity Consulting Group Inc., 2020). They have also been identified anecdotally through VCH engagement (e.g., disruption to community and schools food systems projects and resulting impacts on mental health).

While the impacts are likely more pronounced for Indigenous communities—whose health and wellness is often intimately connected to the land (First Nations Health Authority, 2020b)—the impacts to mental health likely affect people across the VCH and FH regions and is an area where further work is required.

7.5 Adaptation inventory

Below is a list of ongoing and completed initiatives that either directly or indirectly address one or more of the impacts associated with ecosystem changes.

- VCH and FH conduct surveillance on a wide range of food- and water-borne diseases as does the BCCDC's Reportable Diseases Data Dashboard that provides summary statistics on a variety of reportable diseases and conditions in BC
- Health authority's Environmental Public Health staff (including FNHA) work in a number of areas related to these ecosystem changes including drinking water safety, food safety, health and housing, wastewater, care facility inspection, communicable disease prevention and control, emergency preparedness and response, and environmental contaminants (this includes working with partner agencies on air contaminants). This work is supported by Indigenous community services providers (e.g., Stó:lō Service Agency)
- As a result of the 2015 Vibrio outbreak, a multi-jurisdictional work group implemented a host of control measures, including public communications, targeted messaging for restaurants serving raw BC oysters, warnings for the public at restaurants serving raw BC oysters, and the ability to issue an order to stop the sale of raw BC oysters if necessary
- BCCDC's Shellfish Harvesting Status Map helps users determine if a location is open or closed to shellfish harvesting due to contamination or for sanitary reasons. This map includes information for all of the Central Coast communities served by VCH
- FNHA's 'We all take care of the harvest' (WATCH) project will result in the development of local- and Indigenous-relevant adaptation strategies to reduce the impacts of climate change on Indigenous marine foods and enhance the resiliency of First Nations communities in British Columbia
- The BC Drought Response Plan focuses primarily on response; i.e., the actions taken preceding, during and immediately following a hydrological drought to reduce its impacts, and will assist with ensuring water needs for people and aquatic ecosystems are met in times of drought and

water scarcity

  - The Government of BC is implementing its Water Sustainability Act, with initiatives that include protecting stream health and aquatic environments, considering water in land use decisions, regulating during scarcity, etc.
  - VCH has been working with City of Vancouver on water usage as they implement water saving requirements in Food premises, to ensure that there are not impacts on food safety
- VCH's emerging work to understand and accelerate Planetary Health-related work, and its partnership with UBC's Planetary Healthcare Lab
- Public Health staff at VCH and FH work on issues relating to food security in communities
- Several successful initiatives exist in Central Coast communities, including the N-EAT project between SFU and Kitasoo Xai'Xais First Nation, an emerging Food Resilience Plan for the Nuxalk Nation, and a Food Systems Resiliency Program run by the Qqs Projects Society in Heiltsuk territory. Similarly, community-supported research has been conducted in the area
  - Heiltsuk College owns the copyright for The Traditional Heiltsuk Food Book, which was produced by Hilistis Pauline Waterfall as a pathway to understanding, reclaiming and renewing food sovereignty
- The BC Salmon Restoration and Innovation Fund is jointly funded by the Government of Canada and the Province of British Columbia and supports wild fish stocks for fisheries in the province. As one of 14 projects announced in September of 2019, PCIC researchers are working on a project to inform and support evidence-based fisheries management. PCIC's efforts will assist managers as they focus on the restoration, protection and maintenance of healthy and diverse salmon populations and their habitats in the province. Work like this is supported by leadership by non-profit organizations like Watershed Watch Salmon Society and the Lower Fraser Fisheries Alliance
- Work led by UBC and Fraser Basin Council is underway to better understand climate grief resulting from changing ecosystems, and various adaptive responses to it

8. Infectious diseases

This section will provide a high-level overview of the relationship between climate-sensitive hazards, infectious diseases, and impacts to population health. Across Canada, climate-sensitive diseases include:

- **Vector-borne diseases**, including i) Mosquito-borne diseases which are not currently endemic in Canada for which humans are the main reservoirs (e.g., Malaria, Chikungunya virus); ii) Canada-endemic mosquito-borne diseases (e.g. West Nile virus); iii) Tick-borne diseases (e.g., Lyme disease, Rocky Mountain Spotted Fever);
- **Infectious diseases (direct) directly transmitted human-to-human (e.g., respiratory viruses);**
- **Infectious diseases (indirect)** acquired by ingestion or inhalation from environmental sources (e.g. Legionella, Cryptococcus);
- **Directly-transmitted zoonoses** (e.g. rabies, Hantavirus) (Health Canada, forthcoming).

The extent to which these climate-sensitive diseases affect—and will affect—the VCH and FH health regions is discussed below, noting that existing data makes it difficult to describe how these risks will change in the future. Note that food- and water-born illnesses are discussed in Section 7.3.

8.1 Water-borne and food-borne illness

Climate change will exacerbate the conditions that lead to water- and food-borne diseases, which are caused by a range of pathogens. This will likely result in an increased burden in Canada, and to the emergence of risks not currently seen in our food chain (Smith & Fazil, 2019).[28] In BC, warmer water temperatures will lead to the proliferation and range extension of vibrio species, and other pathogens like Enterovirus. This will very likely contribute to incidence of contaminated drinking water, recreational water, fish, and shellfish (Peterson & Lu, 2017).

The following is a list of some of the climate-related water-borne or food-borne illnesses of interest:

- ***Vibrio*** is a naturally occurring bacterium that inhabits coastal waters in BC. Most incidences of shellfish poisoning from *Vibrio* occur from consuming raw oysters, but exposures from recreational water contaminated with *Vibrio* can also result in gastroenteritis and wound infections (BCCDC, 2021c). Spikes in vibrio illness typically occur later in July, August and September when sea surface temperature are highest (Konrad, Paduraru, Romero-Barrios, Henderson, & Galanis, 2017). *Vibrio* is the most temperature-sensitive food and waterborne disease and a very good indicator of CC impact. During the summer of 2015, 73 persons became ill with culture-confirmed vibrio after eating raw BC oysters (BCCDC, 2021c; Galanis, Otterstatter, & Taylor, 2020; Taylor et al., 2018). This is the largest outbreak of vibrio in Canadian history and was 2.5 times the number of cases expected. Since vibrio is related to sea surface temperature, increased Vibrio incidence was observed in most El Niño years (Galanis et al., 2020), and conditions will change as the climate changes (McVea et al., 2018). From 2009 – 2019, Fraser Health had 130 infections, while VCH had 237 (BCCDC Reportable Diseases Data Dashboard).

[28] A link to a visual abstract for this study is available here.

- **Norovirus** is a highly contagious virus that causes vomiting and diarrhea. While it is most commonly spread person- to-person, illness may also occur from consuming contaminated food or water (Miller, Cumming, & Mcintyre, 2018). The main reasons norovirus and other pathogens found in human sewage could lead to food or water contamination is through increased storms (sewage overflow) or drought (concentration of pathogens in water). Heavy rainfall, low sunlight conditions, and colder than normal temperatures allow norovirus to persist in marine waters for extended periods (Miller et al., 2018). In November 2016, a norovirus outbreak linked to BC harvested oysters began. The outbreak affected more than 400 Canadians over six months; it was declared over on May 11, 2017. During this prolonged outbreak, 12 BC shellfish farms were closed. It is likely that climate change will affect incidence of human exposure, but this is not currently established in the literature. Norovirus incidence data is not available in the BCCDC Reportable Diseases Data Dashboard.
- Brubacher et al (2020, p. 8) project increases of **Campylobacter, Shigatoxigenic Escherichia coli (STEC), and Salmonella** for many of the regions served by VCH and FH. In Canada, outbreaks of E. coli, campylobacter, and cryptosporidium have been linked to summer weather (e.g., swimming, boating, and communal outdoor eating), and outbreaks may become more frequent in the future, especially in the summer when precipitation events caused runoff into surface water (McVea et al., 2018). According to the BCCDC Reportable Diseases Data Dashboard, incidence of campylobacteriosis range from 29 – 24/100,000 for FH, and from 29 – 63 for VCH. Incidence of salmonellosis range from 14 – 40 for FH, and from 17 – 35 for VCH. Incidence for STEC in VCH was 28 cases total in 2019.

8.2 Legionella

Legionella bacteria occur naturally in freshwater and soil and multiply in environmental protozoa. They become a human health risk when they multiply in water between 25°C and 45°C, become aerosolized and are inhaled into the lungs (Health Canada, forthcoming). Infection with Legionella bacteria causes legionellosis, which presents as Legionnaires' disease (LD), Pontiac fever or as an asymptomatic infection. The infection is not passed from human to human, but can result in pneumonia and mortality.

In a study of US data, cooling towers, air conditions, and evaporative condensers were implicated in a large portion (60%) of outbreak-associated deaths due to Legionnaires' disease or Pontiac fever between 2006 and 2017 (K. A. Hamilton, Prussin, Ahmed, & Haas, 2018). Other exposure pathways include hot tubs, spa pools, decorative water features, and rainwater harvesting systems (which can be an important adaptive strategy for buildings).

Symptoms of Legionnaires Disease (LD) are indistinguishable from those of other causes of community-acquired pneumonia (CAP). Specific tests are required to detect the presence of Legionella. The prevalence of Legionellosis is assumed to be greatly underreported as CAP cases are seldom tested for Legionella. Figure 37 shows incidence rates in the US, with a clear upward trend. A less intense upward trend is observed on BCCDC's Reportable Diseases Data Dashboard and internal VCH surveillance.

Various international studies report prevalence of LD as a % of CAP in the 1-8% range. One of the highest prevalence rates reported to date came from a small study done in Toronto in the summer of

2018 where 28% of CAP cases were LD positive (Spiegelman, Pedutem, & Francisco, 2020). The CAP prevalence in BC is estimated by experts to be roughly 16,000 cases per year, but non-anecdotal sources could not be found at the time of writing. Many more cases of Legionellosis will likely be discovered in BC if CAP cases were more routinely screened for Legionella.

Legionella can create impacts—and the need for responses—across the health system. This includes increased management requirements in facilities, more surveillance by public health, and greater need for community members and private sector building operators to correctly manage water systems.

Currently, there is limited research into the effect of a changing climate on incidence of legionellosis (Walker, 2018). According to NCCEH, it is difficult to say how climate change may impact the occurrence of legionellosis in the future. Increased use of air conditioning systems or rising ambient temperatures in a building's cold-water systems may increase opportunities for Legionella to survive and grow in those systems (Fitzhenry et al., 2017).

Recent research in the US has suggested that warming temperature and precipitation surplus have likely elevated the density of Legionella bacteria in the environment, and together with road exposure (e.g., traffic-generated aerosols) explain the rapidly rising incidence of legionellosis in the United States (Han, 2021). Recent outbreaks in Surrey and New Westminster are likely linked to warmer temperatures, and a warming climate may increase the incidence of Legionella-related diseases (McVea et al., 2018). WIn 2005, VCH had an outbreak which occurred as temperatures spiked and non-travel related case of LD in VCH have tended to occur in summer months.

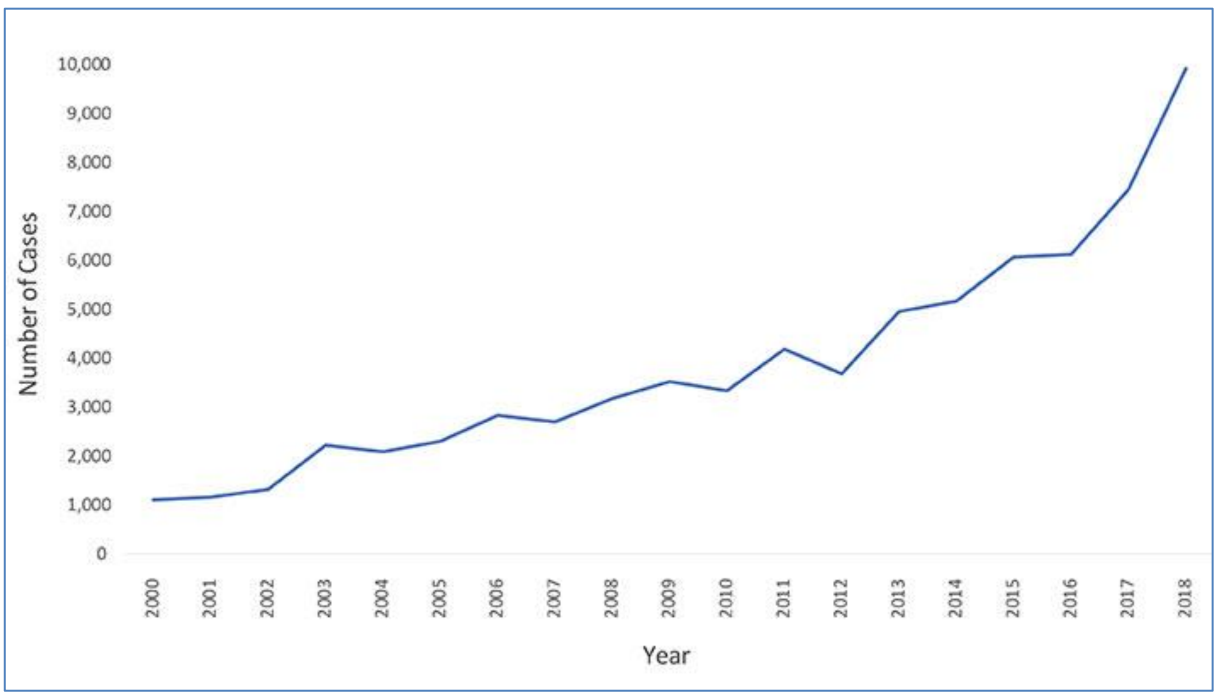

Figure 37: Legionnaires disease in the US from 2000-2018 (source)

8.2.1 Box: Supporting City of Vancouver

VCH is actively working with the COV to support its ambitious water and wastewater management strategies to:

1. Reduce the volume of wastewater discharge to surface water from CSOs;
2. Reduce water use and expand use of Alternate sources (e.g. Rainwater Harvesting);
3. Protect the public from building water systems (BWS) related Legionella risks;
4. Protect potable water quality from threats posed by BWS management.

Keys to the development of the COV programs has been networking with industry and government groups in North America to increase awareness, harmonize and clarify requirements, strengthen infrastructure (e.g. increase private laboratory resources), and improve education/training levels (e.g. creating a BWS Operator certification course).

Legionella-control initiatives include amendments to the COV Building By-law (VBBL) requiring:

1. Registration and operating permits for cooling towers, decorative water features, and alternate water source systems
2. Cleaning and disinfection regimens
3. Operator training
4. Maintenance logs
5. Equipment design/ quality standards (e.g. drift eliminators for cooling towers)
6. System monitoring
7. Regular Legionella testing by competent laboratories, and reporting of results.
8. Standards for response actions if test results exceed acceptable levels

The COV is incorporating Operating Permit and test results into a public-access GIS map system and the same database will be available to VCH for outbreak response and research purposes. Both VCH and the COV are working with WorkSafeBC to orient their staff to BWS management and Legionella control/risk assessment issues.

Improvements in Legionella control are expected to result in reductions in other BWS-related opportunist pathogens (e.g. Non-tuberculous mycobacteria, Stenotrophomonas, Pseudomonas, Acinetobacteria, and others) as well. In 2020 VCH conducted a study for COV on the impacts of BWS water stagnation due to COVID-related reductions of building occupancy. The study results demonstrated the importance of the BWS flushing strategy to maintaining adequate free chlorine levels and reduce accumulation of Lead (Pb).

The COV has been recognized as a North America leader in Legionella control by the US CDC, the NSF, and other groups.

8.3 Vector-borne Diseases

Climate change affects the animals and insects that act as vectors for many diseases that affect humans (*see* One Health) (Rupasinghe, Chomel, & Martínez-López, 2022)

8.3.1 Lyme Disease

In BC *Ixodes pacificus* and *Ixodes angustus,* also known as western black-legged ticks, are the main carriers of the bacterium agent of Lyme disease (*Borrelia burgdorferi*). These ticks are already present in both VCH and FH health regions (BCCDC, 2021b). Morshed et al. (2021) recently just published a paper showing an increase in the submission of ticks to the lab in recent years. It is unclear if this is due to increased awareness or increased prevalence. Infection rates are consistently low, especially when compared to increasing rates observed in Eastern Canada where I. scapularis ticks are present. Since 2002, annual cases have not exceeded 11 in FH, and 15 in VCH (BCCDC Reportable Diseases Data Dashboard), although under-reporting is likely occurring (Ogden et al., 2019).

The preliminary strategic climate risk assessment for British Columbia ranked increased incidence of vector-borne disease (Lyme disease) as the lowest of the 15 risks that they examined (BC Ministry of Environment and Climate Change Strategy, 2019). However, a fulsome assessment of how climate change may impact Lyme disease risk posed by Ix*odes pacificus* has not been done, and potential future risk should not be dismissed based on the extent of research that still needs to be conducted.

The TCC-3W (Tick-borne and Climate Change - 3 West) project is a One Health initiative that is funded by the Public Health Agency of Canada. The project aims to improve the evidence base and response capacity to address the impacts of climate change on tick-borne diseases in Alberta, British Columbia, and Saskatchewan, and to model tick distribution under future potential climate scenarios (BCCDC, 2021d). This one health project will explore other sources of tick and tick-borne disease data (e.g. animal tick-borne disease data, citizen science tick surveillance, ticks in wildlife, genomics of tick-borne pathogen), identify surveillance gaps and opportunities, and assess and apply different modelling approaches to understand the role of climate change in the distribution and abundance of tick-borne pathogens in BC.

Responses to a 2011 survey indicate that physicians in BC generally are aware of the low but real risk of Lyme disease, know to treat patients with clinical symptoms, and understand that Lyme disease is preventable and treatable (Henry & Morshed, 2011). It is likely that these adaptive capacities still exist, and should be augmented as the exposure likelihood changes over time.

The risk associated with Lyme Disease should be assessed periodically given the uncertainty about the role of climate change, and the outcomes of projects like TCC-3W.

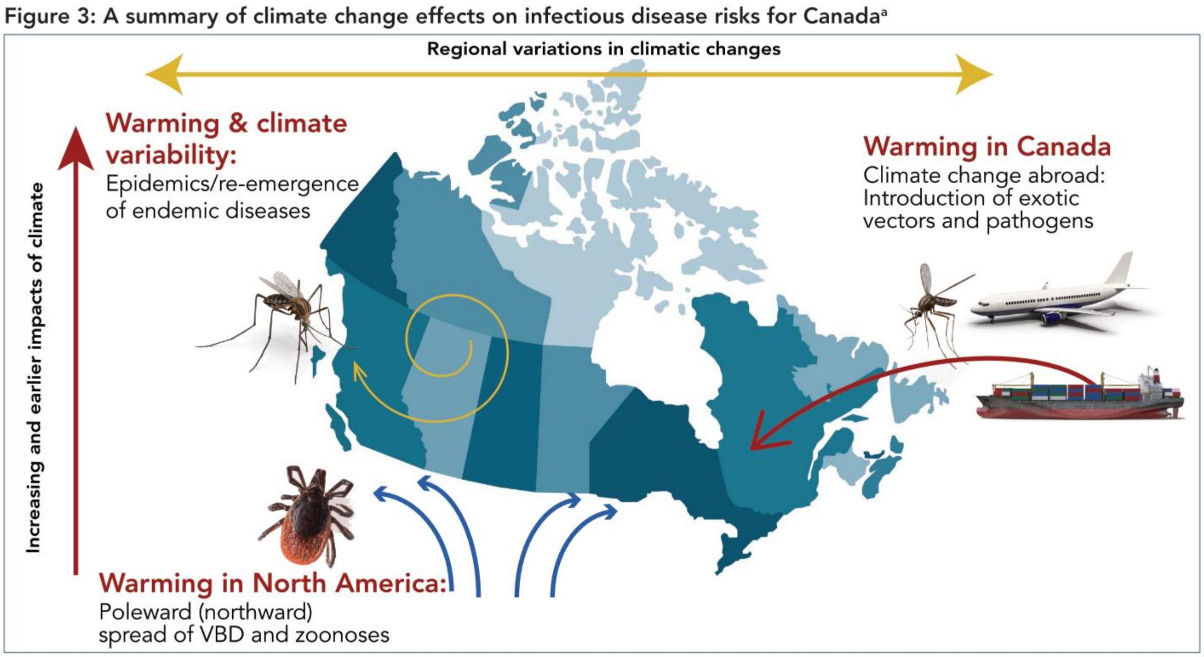

Figure 38: A summary of climate change effects on infectious disease risks for Canada (Ogden & Gachon, 2019)

8.3.2 Exotic Mosquito-borne Diseases

Exposure to *Aedes* mosquitoes when visiting other countries can lead to a variety of diseases, including chikungunya, dengue and Zika. A changing climate means that these diseases can become endemic to BC. Khan et al. (2020, *see* Figure 6) found that the suitable ecological niche for *Aedes aegypti* (which also can transmit West Nile Virus) will expand under RCP 8.5 into southern BC by the end of the century. For chikungunya virus—Ng et at. (2017) projected increased risk of short-term autochthonous CHIKV transmission under RCP 8.5. There is a risk that these mosquitoes become endemic in BC, and permit autochthonous transmission and outbreaks during the summer months, as have been seen in Europe. The same may hold true for malaria as the malaria vector *Anopheles freeborni* is endemic to southern BC.

Dengue and Zika virus could also become more common as the climate changes. Though these diseases may not expand their range to BC, they will increase their range into areas that Canadian travelers visit, including the Caribbean, Latin America, and Asia (McVea et al., 2018). Also, assessments of risk from chikungunya may correlate with risks from dengue and Zika since all are transmitted by the same *Aedes* species mosquitoes.

Chikungunya virus is not currently reportable in BC. As with Lyme disease, it is likely that not enough is known about its epidemiology/ecology to accurately predict future risks.

8.3.3 West Nile Virus

West Nile Virus (WNV) is most commonly transmitted to humans by mosquitoes. Mosquitoes pick up the virus by biting an infected bird, and humans can become infected through the bite of an infected mosquito. WNV is extremely rare in BC. From 2009 – 2019 there were only two cases for the entire VCH and FH health regions (BCCDC Reportable Diseases Data Dashboard).

Recent research suggests that this could change as the climate warms. Although the risks are more severe for eastern Canada, BC will be exposed to increasing risk as the century progresses. *Culex tarsalis*, the main vector of WNV in western Canada, has been found as far north as Yellowknife, Northwest territories in 2010 (Kulkarni et al., 2015). Similar findings are presented in Ng et al. (2019) and Ludwig et al. (2019), although regional impacts are difficult to summarize given the national focus of the research. Though incidence rates are currently extremely low, this will likely change later in the century.

8.4 Respiratory infections: The example of Enterovirus

Enterovirus (i.e., EV-D68) is a virus that causes mild to severe respiratory illness. Most people with enterovirus infections have only mild, cold-like symptoms or no symptoms at all. More severe cases can include neurological complications such as muscle weakness or paralysis. People with asthma and other lung conditions are more susceptible to more serious complications (BCCDC, 2016).

Transmission occurs through respiratory secretions and close contact with infected people, or by fecal-oral transmission. From August to October 2014, there were about 220 confirmed cases in B.C., with about 140 hospitalizations reported. There were three deaths. Several other provinces and US states also experienced outbreaks (BCCDC, 2016). The relationship between temperature and humidity and virus viability, transmission, etc. is evident in the literature (Audi et al., 2020). The relationship is complex, and studies that explore the relationship between future climate conditions in BC and the behaviour of EV-D68 do not et exist. These studies would be useful to understand the directional nature of the risk, and the effect of extreme heat events on virus and patient behaviour.

Enterovirus is not currently reportable in BC.

8.5 Cryptococcus

Cryptococcus gatti is a fungus that is has become established in soil and trees in the Lower Mainland in the last 15 years (BCCDC, 2021a). Infection occurs after exposure to the spores, and though negative health impacts are rare, they can include pneumonia or meningitis. Older age is one of the most important risk factors in C. gattii infection (BCCDC Reportable Diseases Data Dashboard). Although climatic conditions affect the survival of *C. gattii*, the role of climate change in the emergence and expansion of *C. gattii* is unclear. From 2009 – 2019, Fraser Health had 55 infections, while VCH had 19 (BCCDC Reportable Diseases Data Dashboard). As with West Nile Virus, this risk is expected to be very low in the coming decades, but should now be dismissed given the lack of knowledge.

8.6 Adaptation inventory

The following are some of the initiatives that have been identified to date. This list is meant to evolve as the project continues.

- VCH and FH conduct surveillance on a wide range of diseases, including Legionellosis, Vibrio, Campylobacteriosis, Cryptococcus, Giardiasis, Lyme Disease, and West Nile Virus, and alerts occur if prescribed prevalence thresholds are met.
- BCCDC operates the Reportable Diseases Data Dashboard that provides summary statistics on a variety of reportable diseases and conditions in BC
- Doctors of BC—a voluntary association of 14,000 physicians, residents and medical students—has an Environmental Health Committee, a subcommittee of Doctors of BC's Council on Health Promotion that has published on infectious diseases
- VCH and FHA participate in the BC Vibrio Intersectoral Working Group to monitor the risk of Vibrio during summer months
- BCCDC's Lyme Disease risk area maps and Tick Talk resources and E-tick. BCCDC PH Lab conducts testing of certain vectors (ticks for Lyme disease)
- Work on **Legionella** includes:
    - VCH Public Health staff work with WorkSafe BC on Legionella and other building water system issues and have helped to develop content for the forthcoming Building Water System Operator course, with certification managed by the Environmental Operators Certificate Program. This has been nominated for a water/wastewater industry award
    - Staff work to increase awareness of, and guidance for prevention of health hazards posed by stagnant water systems and are actively involved in City of Vancouver responses to reports of high Legionella counts in cooling towers, decorative water features, and alternate water source systems
    - VCH and FHA participated in the update to the BC Legionella prevention and control guidelines (2021)
    - BOMA Canada is an ally for Legionella tracking and prevention, as conducts work that explores wastewater reduction alongside energy efficiency in cooling tower operations (e.g. Austin Texas)
- Alerts are created when West Nile Virus occurs in horses, and the wildlife branch (Ministry of FLNRORD) also maintains a dead bird surveillance program and reports any West Nile Virus cases to BCCDC. If animal cases occur in VCH or FH, BCCDC's public health veterinarian would notify the respective communicable disease teams

9. Health system resilience

A climate-resilient health system has the ability to anticipate, prepare for and respond to hazardous events, trends or disturbances related to climate. Improving climate resilience involves assessing how climate change will create new, or alter current climate-related risks, and taking steps to better cope with these risks. The hazard-specific sections above inventoried some impacts to the health system as well as components that contribute to resilience for each respective hazard (e.g., public health planning efforts in advance of heat and smoke seasons). However, this approach is limited because it does not consider the health system as a whole, how the various climate-sensitive hazards interact and compound to amplify risk, the cascading nature of impacts across the health system, or adaptive capacities like emergency management that apply across the health system. This section seeks to advance the understanding of health system vulnerability and resilience, though in a cursory and exploratory way given limited resources.

9.1 Impacts and vulnerabilities

The complexity and scale of the health system makes it difficult to identify and assess impacts. The health system can be impacted by climate change in myriad ways and can result from singular or compounding (i.e., multiple) hazards. Climate impacts also often occur at multiple sites or nodes of the health system, and impacts in one part of the system can create impacts elsewhere (often called cascading impacts to indicate their movement from one part of the health system to another).

For example, overheating in a home support patient's home could lead to a transfer to the acute setting, exacerbating patient surges for heat-related illness. Similarly, Figure 39 presents cascading impacts that were identified in a 2016 internal study, and shows how direct impacts can produce secondary, tertiary, or even quaternary impacts.

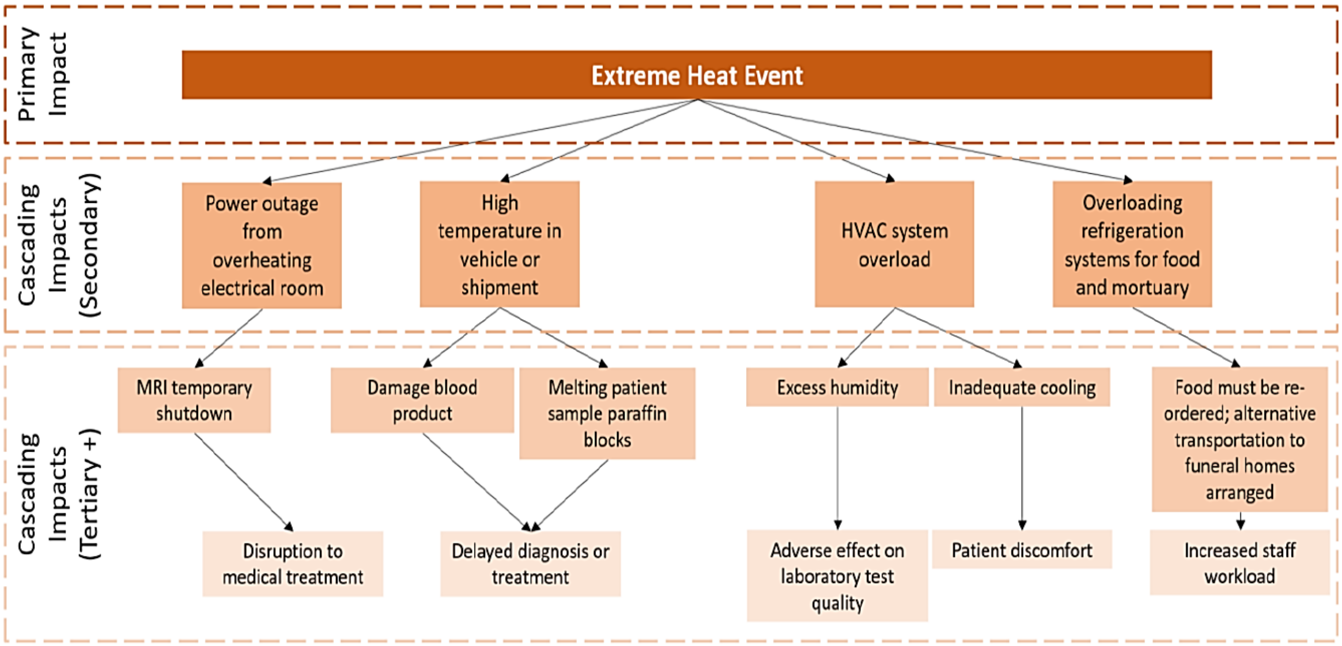

Figure 39: Examples of potential cascading impacts during extreme heat events (adapted from Yip and Woo, 2016)

What follows is an overview of some of the health system impacts that have been identified over the course of the HealthADAPT project, and an acknowledgement that much more work of this nature is required.

- Heat events and poor air quality impact **health care facilities** and **community health services** by affecting patients, staff, indoor environmental conditions, and by increasing demand on public health, community, and acute services (*see* Section 4.5.2). The ways that impacts are amplified when these events occur concurrently is not well known.
- There are a variety of ways that the **health system workforce** (human resources) can be impacted by climate-sensitive hazards. This could include absenteeism as a result of staff being unable to leave children or elderly parents home alone, or from concerns about the perceived medical risks associated with coming to work. This could even include the movement of health care staff away from certain health services areas, as is being seen in Australia (Pendrey, Quilty, Gruen, Weeramanthri, & Lucas, 2021), however this type of 'climate gentrification' is not well understood in the VCH and FH health regions.
- Impacts to **supply chain** were briefly discussed at the FH REOC stress testing exercise in May 2021. These included impacts to local production and transportation of goods, but also the dependence on global resources and supply chains. These impacts are very challenging to assess. Examples from the academic literature provide some guidance, for example, Errett et al. (2019) studied the impacts of maritime transportation disruptions on the health care supplies and workers necessary to deliver hospital-based acute health care in Powell River (and in Victoria). Results identified limited local supply storage and workforce capacity, a lack of

information about the existing supply chain, and a lack of formal plans and agreements. They identified that multisector engagement is required to address complex interdependencies and competing priorities in emergency response and that additional research and public-private collaboration is necessary to quantify potential impacts of maritime transportation disruption on the acute health care system (Errett et al., 2019).

Critical infrastructure interdependencies

The extent that critical infrastructure is planned, designed and operated with climate risk in mind has a bearing on all health services, whether provided at the site, in homes and in the community, or by the broader health system for all British Columbians (e.g. quaternary care). Hospitals and other health care facilities rely on the greater community to function effectively, and the changing climate threatens the continuity of many of these functions. Strain on municipal sewer infrastructure from increasing precipitation, for example, can lead to bacterial outbreaks that in turn place additional pressure on hospitals. Damage to utilities and roads as a result of extreme weather events can impede supply chains and the ability of people to reach the facility. In the future, shortages in regional power and water restrictions will further challenge facility operations (Facilities Management, 2020a).

In order to better understand the critical infrastructure interdependencies for hospitals and long-term care facilities in VCH and FH regions, a pilot project was undertaken with consulting firm XDI (based in Australia). This project aimed to understand how climate hazard risks and critical infrastructure interdependencies—in this case electricity, gas, and telecommunications—affect the resilience of facilities and their broader communities of care. The project analyzed data for 30 hospitals and 14 residential care facilities in VCH and FH and disseminated results to staff from VCH, FH, and PHSA, many of whom were seeking insight into how better to incorporate future climate risk into capital projects in planning, design and operations. Preliminary results include:

- Total risk costs for 17 VCH hospitals increase almost 7-fold throughout the century, reaching almost $13M by 2100
- While flooding and coastal inundation are the highest risk hazards In 2030 and 2050, forest fire also becomes significant by 2100
- By 2100 all assets show very high Heat Failure Probability figures, suggesting they may experience heat-related failure at least once every two years

Aside from direct impacts to the health system, endemic characteristics of the health system contribute to overall vulnerability and resilience. For example, the way that the health system in BC is—or is not—structured and organized to deal with risks influences the resilience of facilities. The first five facility-level climate resilience assessments led by VCH/FH Facilities Management produced recommendations that were not actionable due to lack of operational resources, mandate, and buy-in. A consequent shift to focusing on increasing climate resilience in major capital projects (e.g., new construction and major redevelopment) has created new opportunities for managing climate risks over a facility's lifespan (i.e., 60-120 years). This has been further amplified by the new Health Capital Policy Manual Chapter 12 "Carbon Neutral and Climate Resilient Health Facilities Policy" (effective Feb 22, 2021) which requires facilities to identify and address climate risks in business plan development using a key stakeholder workshop and health system stress tests as a key delivery mechanism (i.e. Step 2: Climate Risk Assessment in the *Climate Resilience Guidelines*, December, 2020).

This type of insight is important to flag since future work should strive to do a systems-level resilience assessment that considers these types of issues. Similarly, the stress testing approach piloted with Providence Health Care's St Paul's Hospital Redevelopment Project in July 2019 – and later replicated in simplified format for Fraser Health's Regional Emergency Operations Centre - was helpful, as was the XDI-led study, but more substantial collaborative risk assessment and resilience planning is needed.

9.2 Adaptive capacities

The most common conceptualization of health system resilience comes from the WHO presentation of 10 key components that health organizations need to address in order to be better able to anticipate, prevent, prepare for and manage climate-related health risks (World Health Organization, 2015). These components are:

- Leadership and governance
- Health workforce
- Vulnerability, capacity and adaptation assessment
- Integrated risk monitoring and early warning
- Health and climate research
- Climate-resilient and sustainable technologies and infrastructure
- Management of environmental determinants of health
- Climate-informed health programmes
- Emergency preparedness and management
- Climate and health financing

This framework does a good job of indicating the capacities that are needed within the health sector, but does not explicitly emphasize the extent to which collaborations with actors outside of the health sector contribute to these capacities. For example, emergency management is a deeply collaborative exercise. Yip (2016) speaks to how this is the case in the local context: "given the close linkages between emergency planning, different units within a hospital, hospital infrastructure and the community it serves; successful resilience-strengthening solutions would require system-level approach in addition to site-focused interventions."

Figure 40 shows some of the collaborations and partnerships that are likely needed for a climate-resilient health system in the VCH and FH regions. Note that nodes and relationships are not accurate, and that the network presented is only meant to be illustrative.

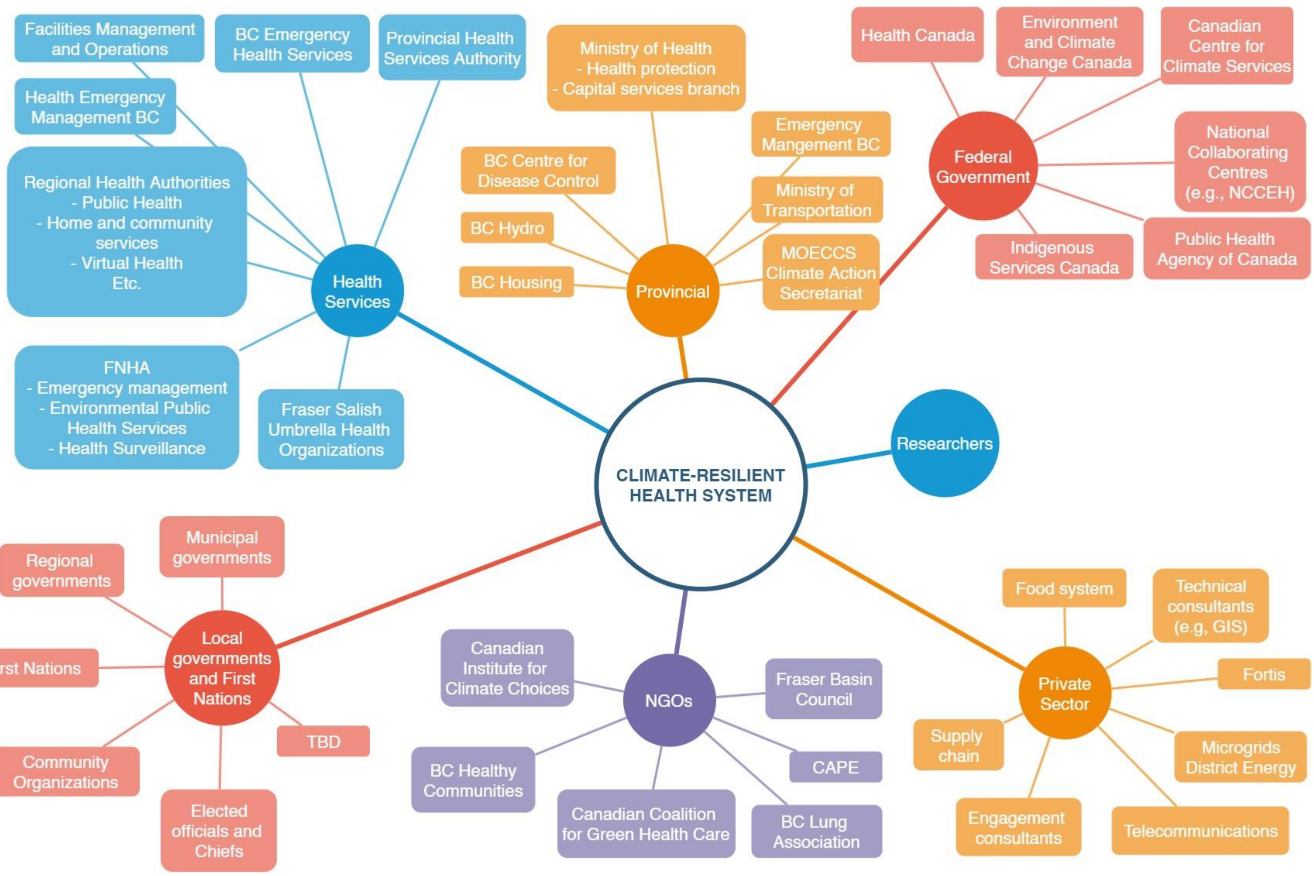

Figure 40: Collaborators for a climate-resilient health system

A full assessment of the resilience capacities of each of these sectors/organizations would increase our understanding of health system resilience. However, given the immense resources and planning that would be required, and the fact that the Ministry of Health started leading this initiative in June 2021, this is not possible or appropriate in the current project. Instead, a narrative summary of the systems-level resilience/adaptive capacities of select actors is included below.

9.2.1 Regional health authorities

The regional health authorities play a very important role in creating health system resilience through the direct delivery of services, health promotion and protection, and emergency management. Internal leadership following the June 2021 heat dome event (e.g., the organization-side seasonal readiness planning supported by HEMBC) has likely greatly increased adaptive capacity at VCH and FH. The stress test conducted with FH REOC—and an environmental scan performed by FH's Culture and Transformation Team uncovered many adaptive capacities across the organization. The REOC itself is seen as a significant resource since it is comprised of senior leaders who have the opportunity to advance climate change and health leadership (a summary report of this session is available upon request).

The health authorities also play an important advocacy role whereby they can encourage non-health system actors to take actions that contribute to health system resilience. The health authorities, and especially public health leaders, possess a moral authority that has the power to create the political will that actors in local government—for example—can leverage to advance their own work relating to climate change, environment health, social determinants of health, and the like. Through the course of this project, we have heard from several local governments that health authorities need to deepen their leadership to create political will. The COVID-19 pandemic has put public health in the spotlight, and the post-COVID-19 era needs to be characterized by deepened leadership and collaboration with regards to climate change on the part of the health authorities.

9.2.2 HEMBC

HEMBC provides expertise, education, tools, and support for VCH and FH, including standardized emergency management plans, all hazards emergency plans, code procedures, business continuity plans, and response structures. They stand up emergency operation centres (EOC) during heat events, facilitate seasonal readiness planning, and in July 2021 collaboratively designed a survey that was delivered to local governments across the VCH and FH health regions to understand their management during the heat event.

VCH and FH possess significant emergency management capacities that would help to manage a variety of climate impacts, for example during an extreme flood event, which is very likely to be the most impactful to the health system. As described above, this type of event would have direct impacts on facilities and the workforce. Staffing challenges are common in the health authority and are dealt with on a case-by-case basis using existing operational processes (e.g., regional calls). Staffing shortages that create a system-level issue by threatening service delivery thresholds would trigger a more formal emergency response (e.g., an EOC) during which HEMBC would provide support and advice.

Similarly, hospital colour codes are used in hospitals to denote to staff various kinds of emergency situations. The use of codes is intended to convey essential information quickly and with a minimum of misunderstanding to appropriate staff, while minimizing stress and preventing panic among patients and visitors to the hospital. Health authorities and the Ministry of Health Services, worked together in 2009 to standardize the use of hospital colour codes in British Columbia. Events like a power outage, for example, would trigger a code grey, indicating system failure. This triggers a standard escalation procedure in hospitals (e.g., ID of impacts, notification to those that need to know, etc.). This all hazards approach means that there are not plans in place for each specific hazard, but that general emergency management capacity can be relied upon during climate shocks and stresses.

To date, the focus of HEMBC in the Lower Mainland has been building capacity for acute, long-term care, and community facilities and programs. This includes health services that are increasingly expanding to allow and encourage people with medically complex needs to receive care while remaining in their homes. For example, before COVID-19, HEMBC was developing a project that would identify all health care programs that support clients in their homes, develop a response plan that outlines their expected roles and responsibilities, and find pathways to promote personal preparedness with those receiving care at home.

9.2.3 Facilities Management

VCH/FH Facilities Management's climate risk and resilience program has developed planning and design guidelines to help ensure that major capital projects including new construction, major redevelopment, and renovations understand and manage climate risks throughout the lifecycle of a facility (Facilities Management, 2020a). These guidelines enable BC Health Authorities to (i) align the project delivery lifecycle with Provincial policy and legislation; (ii) meet directives to "align operations with targets and strategies for minimizing greenhouse gas emissions and managing climate change risk"; and, (iii) demonstrate public sector leadership in a dynamic context with inherent uncertainty, whether increasing climate shocks and stresses, or evolving policy and regulations.

A key first step (Step 1) as outlined in the *Climate Resilience Guidelines* is an exposure screen as a key input into the High Level Master Plans and concept plan phase of business plan development. High Level Master Plans (HLMP) characterize the broader community of care with a review of key characteristics, indicators and trends, such as demographics and population growth. Presenting projected community vulnerabilities alongside projected demographic and socioeconomic trends can provide a valuable perspective to decision-making on health services and programs since a community's resilience to climate shocks and stresses has a bearing on the demand for health services at the site, service delivery area, and health system levels.

The goal is to have the HLMP act as a primary information source for other master plans - including clinical, site and infrastructure – and planning documents such as concept and business plans to inform siting and design options, respectively. The HLMP guidance document includes guidance on:

- How to characterize and map the exposure, sensitivity, and adaptive capacity of service delivery areas, which will, in part, involve findings from the climate vulnerability index;
- Quantifying the costs and benefits of action;
- Achieving co-benefits for health and climate resilience.

This work advances facility and community resilience by accelerating and amplifying ongoing efforts to better understand how to effectively integrate climate resilience into key planning and design phases of hospitals, long term care facilities, and community centers among other facility types that serve a dynamic, growing and diversifying population.

These guidelines also inform how to improve existing buildings. Moreover, the default to design facilities to existing building codes and standards that need updating is a challenge over which the health authorities have little control aside from advocacy and leadership work. These efforts need to be accompanied by systems level changes including data collection, prioritization of services, and the like.

Adaptive capacities

Table 15 lists many of the ongoing and proposed initiatives that VCH/FH Facilities Management is leading or involved in that will increase climate-resilience in the health system.

Table 15: Adaptive capacities relating to health care facilities

Facilities
- Facilities Management's *Moving Toward Climate Resilience Health Facilities* (2018) report positions health authorities to meet legislated requirements for addressing climate risk and reducing emissions, and enables major infrastructure projects to assess climate resilience. A similar report is underway for Fraser Health. - Projects at Squamish General Hilltop North Expansion, Lion's Gate, Richmond Acute Care Tower, and VGH to reduce GHG emissions and climate risk support a coordinated and synergistic approach to climate action at the site level. - To date, four Fraser facilities have been assessed for climate risks during redevelopment and new builds (LTC Delta, New Surrey Hospital & Cancer Centre, Burnaby Hospital and Royal Columbian). - The new St. Paul hospital (1.5 million-square-feet) will be a post-disaster hospital, meaning the facility must be functional even after a flood. Its design takes into account future flood conditions including factoring the site in the roads and all the infrastructure around the hospital (CBC News, 2021c). - In addition to the risk assessments described above, a project was undertaken in 2016 by then-UBC sustainability scholar Jackie Yip to systematically and simultaneously assess both physical and social climate resilience of hospitals and subsequently develop site adaptation actions plans.[29] The first phase of the project sought to assess each of five hospital site's level of resilience to extreme events with focus on their structural, non- structural, operational elements. This project identified a number of gaps that still persist; for example, lack of site-level hazard exposure and past hazard information and no contingency planning for personnel transportation during emergency. It also proposed many resilience-building actions that will be used to inform the HealthADAPT strategic planning process. - Preliminary design strategies have been collaboratively produced for 12 new construction and major redevelopment projects (i.e. acute and long term care facilities) in the lower mainland (as of Spring 2021). - Climate impact questions were piloted as vendor evaluation criteria in 6 PHSA Supply Chain RFPs for equipment, supplies and services contract - Fraser Health's voluntary 2019 Environmental Performance and Accountability Report maintains the theme of climate risk and resilience throughout. - As of 2021, Fraser Health will publish the mandatory Climate Change Accountability Report detailing our progress in reducing emissions and managing risks. - EES supported the capital project team to complete an application for a Climate Action Design Charrette. The project was awarded to receive consultant support for the Long term Care project. A combined approach to the ZeBX and MBAR Design Charrette Workshop resulted in a project briefing that outlines a range of emission reduction and climate resilience strategies, and a costing report to help quantify proposed strategies. Also resulted in renewed leadership commitment, and conveyed a new approach for VCH. - VCH/FH Facilities Management participated in a CAS pilot project resulting in climate risk analysis for all owned facilities in the cities of Richmond and Surrey, training on developing and costing adaptation pathways, and understanding of how the level of risk for health care facilities is affected by the infrastructure that they are dependent on (e.g., electricity distribution). - VCH is part of a study that measures indoor and outdoor air quality during wildfire smoke events at a number of facilities. Collaborators include Emily Peterson, Kori Jones, Angie Woo, Ghazal Ebrahimi (Pembina), Sarah Henderson, Metro Vancouver. **Key resources and initiatives** - Establishing Design Conditions for BC Health Facility Planning & Design (2020)

[29] This is a confidential internal report and not all details can be shared.

- Greening blocks: A conceptual typology of practical design interventions to integrate health and climate resilience co-benefit
- Health Canada guidance for retirement and care facilities
- World Green Building Council. (2020) Health and wellbeing framework
- World Health Organization. (2020). Who guidance for climate resilient and environmentally sustainable health care facilities.
- Climate-Resilient Buildings and Core Public Infrastructure Initiative
- The Canadian Coalition for Green Health Care Health Care Climate Change Resiliency toolkit
- Engineers and Geoscientists British Columbia's Climate change action plan (Engineers and Geoscientists British Columbia, 2021).
- https://www.vancouvereconomic.com/blog/news/pace-financing-how-an-innovative-tool-could-help-fund-resilience-in-vancouver/

9.2.4 Other health system actors[30]

Many relevant dimensions of adaptive capacity for VCH and FH as organizations have been described in the respective hazard sections. There are, of course, many other capacities that could be described, for example relating to governance and leadership, but these are best explored in a systematic resilience assessment conducted at the provincial scale.

The actors and organizations shown in Figure 40 all have a role to play in creating health system resilience. What follows is a list of some of their relevant capacities and initiatives. The list is not meant to be exhaustive, but shows the types of capacities that need to be assessed and coordinated as the practice and outcome of health system resilience deepens in BC. These include:

- **BC Centre for Disease Control** produces leading research and programming for most of the climate hazards facing BC, especially extreme heat, wildfire smoke, ecosystem changes, traditional foods, and infectious diseases. They often provide essential data and analyses that quantify health impacts of climate-related events and facilitate evidence-based decision making across the health authorities.
- The **BC Ministry of Health**, Health Protection Brach is currently leading the health sector contribution to BC's Climate Preparedness and Adaptation Strategy, which includes a baseline assessment of health system resilience.
- The **First Nations Health Authority** supports climate change and health adaptation in their HealthADAPT project, funding programs, and in many of the health services that they offer. There is an appetite to strengthen collaboration in order to manage climate risks effectively, in a culturally safe manner, and in a way that respects First Nations' right to self-determination, connectedness to land, and cultural wellness. For example, a table top scenario planning exercise has been proposed to better understand objectives and responsibilities during extreme weather events.
- The **Climate Action Secretariat** is leading a BC's Climate Preparedness and Adaptation Strategy which aims to improve climate resilience for B.C.'s public sector. Proposed actions include working with public sector organizations to develop and implement climate risk reporting requirements. Proposed reporting requirements aim to improve public sector capacity to accurately track

[30] Noting the leadership by BCCDC, BC Housing, Metro Vancouver, and Indigenous-led initiatives and others is described elsewhere in the report.

progress and better prepare for a changing climate.

9.3 Health system climate resilience indicators[31]

In their pilot methodology, Health Canada encourages those assessing climate and health vulnerability to consider health system-wide risks, and to assess the climate-resilience of the health system. They provided a list of indicators for climate-resilient regional health systems that incorporated indicators from WHO (2015) as well as indicators tailored to the Canadian context, such as information that may help public health authorities better serve Indigenous Peoples. They provided these as a list, and did not use the 10 categories from the WHO framework. The indicators provided below are organized into seven categories that were inspired by Oregon Health Authority's *Climate and health resilience plan*, which is currently being used as a way to organize the actions in the forthcoming framework for VCH and FH.

The Health Canada indicators in Table 16 have been augmented using the following sources:

- A list that will appear in the forthcoming Health Canada national health assessment;
- Public Health Ontario's *Public health emergency preparedness framework and indicators a workbook to support public health practice* (2020) and Khan et al. (2019)[32];
- A draft *Framework for measuring climate resilience of health systems* presented by Kris Ebi to HealthADAPT funding recipients;
- *Proposed climate change impact and resiliency indicators for Canadian health care facilities* developed by Linda Varangu, Ed Rubinstein and Angie Woo in 2018.

Health Canada has provided some advice on how to measure the various indicators. As seen elsewhere in the climate resilience field (*see* Figure 29), they have proposed a blend of quantitative and qualitative metrics (e.g., expert opinions gathered via Likert scale questions during focus groups). Public Health Ontario (2020) echoes the use of qualitative metrics: "health agencies may decide to capture self-assessment details as text or in a scale, depending on what works for their context."

This summary would give a baseline indication—or gestalt, based on the idea from Moser and Boykoff (2013)—of the vulnerability and resilience of the VCH and FH health systems. This would help inform the forthcoming framework, and also serve as a potential way to assess efficiency of resilience efforts in the future. Due to resource constraints, pandemic response and to the emergence of a similar process at the provincial scale being led by the Ministry of Health, the indicators were never populated.

It should be noted that there is an opportunity to consider indicators like these to complement the indicators that many communities monitor for their planning purposes (e.g., Squamish, Vancouver, Surrey) in addition to the data from My Health, My Community. These activities will be considered in the strategic planning process and elsewhere.

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[31] Health Canada workbook: Step 4A

[32] These sources represent a robust and valuable source of indicators on public health preparedness.

Table 16: Climate-resilient health system indicators

	Scales: Excellent > very good > good > fair > poor Very high > high > medium > low > very low	**Self-assessment**	**Narrative evidence**
	Health equity and cultural responsiveness		
	- Extent to which relevant health authority staff have received training in Indigenous cultural safety		-
	- Extent to which risk assessments and adaptation planning rely on Indigenous Knowledge Systems and GBA+ methods		-
	-		-
	Community preparedness and partnerships		
	- Perceived quality of coordination with municipal and regional governments and community organizations		-
	- Perceived quality of coordination with Indigenous communities		-
	-		-
	Risk assessment and epidemiology		
	- Extent to which priority/climate sensitive populations been identified		-
	- Extent to which the vulnerability of local communities to climate change-driven cultural loss is understood		-
	- Extent to which the health authority understands water and food security and food sovereignty amongst priority populations		-
	- Prevalence of facilities-level resilience assessments. Consider Indigenous and remote communities		-
	- Extent to which the health authority understands the resilience of its supply chains, particularly those located in remote areas		-
	- Prevalence of established integrated monitoring systems for analysis of environmental hazards and health risks from climate change		-
	- Extent to which the health authority has the capacity to		-

	diagnose and treat physical and mental conditions that are climate-sensitive		
	-		-
	Policy and planning		
	- Extent to which risk assessment and resilience planning methods and results are shared with communities (e.g., First Nations health service providers)		-
	- Extent to which the health authority is able to meet its climate-related research needs internally or with external partners		-
	-		-
	Preparedness and response		
	- Extent to which the health authority is a member of a coordinated local/regional structure for health-sector emergency management		-
	- Extent to which emergency management and continuity plans consider climate impacts		-
	- Extent to which staff health and safety plans consider climate impacts		-
	- Extent to which existing emergency management processes (e.g., colour codes) are likely to be sufficient for deployment health personnel in extreme events		-
	- Prevalence of health professionals (e.g., clinicians, mental health, facilities managers, public health officials) who have received climate change capacity training?		-
	- Extent to which health facilities have implemented physical or social resilience measures		-
	- Extent to which key community stakeholders are considering climate and health adaptation in their planning		-
	- Perceived effectiveness of early warning systems for extreme whether events and disease outbreaks. Consider Indigenous communities as well		-
	- Prevalence of public cool spaces throughout the health region		-
	- Prevalence of public clean air spaces throughout the health region		-
	-		-

	Communications and engagement		
	- Extent to which relevant health authority staff have received training in climate change communication		-
	- Extent to which climate change and health information is shared on health authority websites (e.g. suggestions for behavioural changes that may reduce negative health outcomes)		-
	- Extent to which local media covers climate change and health issues		-
	- Extent to which knowledge translation materials are shared with communities		-
	-		-
	Leadership and resources		
	- Extent to which senior leaders within health authorities support climate-resilience planning and implementation		-
	- Perceived quality of coordination with provincial government, other health authorities, and public sector organizations?		-
	- Perceived adequacy of funding obtained from government and non-government sources which is allocated to climate change		-
	-		-

10. Conclusion

This climate change and health vulnerability and capacity assessment sought to integrate evidence and activities relating to human health and health systems from across the four project partners. It represents a foundational repository of information and resources, provides the basis for the forthcoming climate change and health adaptation framework, and will also support future vulnerability and capacity assessments for other communities and health sector organizations.

The findings indicate vulnerability to population health and the health system from a variety of climate-sensitive hazards. Though the impacts relating to heat and poor air quality are immediately evident, those relating to less frequent—but catastrophic—flood events, as well as those that arise from slower-onset events, must also be managed. Understanding these risks is an essential step in ensuring that resilience-building efforts are sufficient in the coming years. This will require more formal risk assessment processes that flow from some of the activities described above (e.g., the stress testing exercise with FH Regional EOC). The adaptation inventories demonstrate that a significant amount of activity is already underway across all of the hazards.

Though recruitment and retention of participants was extremely difficult due to the COVID-19 pandemic, the HealthADAPT process tapped into an appetite to work on climate change across a variety of highly capable and empowered decision-makers within and beyond the health authorities. The vulnerability and capacity assessment is much richer as a result and we thank the many participants for their time, energy and wisdom.

This vulnerability and capacity assessment represents an important step forward in integrating impacts and adaptation perspectives and initiatives from the four project partners. Achieving this level of integration in a vulnerability and capacity assessment was not straightforward, and the approach taken above will certainly be built upon in future iterations. The project to date has strengthened the four project partners' leadership in climate change and health adaptation, and has created fertile ground for continued collaboration during the strategic planning phase, and in implementation period that will follow.

The forthcoming adaptation framework will prioritize those activities that could not be completed during this phase of work, including engaging with Community Health Centres in VCH, incorporating the services offered by Mental Health and Substance Use and Home Health, conducting other internal engagement at FH and VCH, and engaging with away-from-home Indigenous populations across VCH and FH. The *Climate Change and Health Adaptation Framework* will also define the health authorities' role in climate change and health adaptation by presenting priorities and recommendations corresponding to the risks and gaps identified in the vulnerability and capacity assessment, and advice from our many collaborators and advisors.

It is the project team's hope that our findings and analyses will be valuable to other health organizations who are embarking to better understand the resilience of their health systems. Lessons learned across multiple HealthADAPT-funded projects across Canada are currently being co-produced with Health Canada and can be shared upon request.

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Appendix: Engagement summary reports

The following reports are available upon request:

Vancouver Coastal Health

- Central coast engagement summary, including a list of engagement contacts and research partnerships
- Regional palliative quality and service improvement committee – focus group summary
- Home support focus group summary
- Summary notes from May 2021 meeting with District of Squamish
- Internal engagement from October 5, 2021
- External engagement from November 3, 2021

Fraser Health

- Regional emergency operations centre climate change stress testing exercise summary
- Indigenous adaptation landscape
- Indigenous engagement summary report
- Community engagement summary report
- Summary reports for individual community engagement sessions in hope and area, Chilliwack, and tri-cities (Coquitlam, Port Coquitlam, and Port Moody)
- Presentation to the Fraser Canyon Hospital multidisciplinary healthcare coordinating committee
- Internal engagement from October 5, 2021
- External engagement from November 3, 2021