Climate change adaptation in Metro Vancouver: examining the role of managed retreat

by
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A thesis
presented to the University of Waterloo
in fulfilment of the
thesis requirement for the degree
Master of Environmental Studies
in
Geography

Waterloo, Ontario, Canada, 2018

Author's Declaration

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners. I understand that my thesis may be made electronically available to the public.

Abstract

Climate changes are intensifying and introducing new flood risks to coastal regions. As a result, past flood risk reduction measures may not be suitable for future sea level rise and climate extremes. Ensuring the resilience of coastal cities will require tough decisions and long-term coastal adaptation strategies. Among the suite of options: avoid, protect, accommodate, and retreat, managed retreat often faces the greatest barriers and the most contention along urbanized shorelines. A region at the forefront of this challenge, Metro Vancouver, British Columbia, must adapt its coastline to sea level rise and coastal change while meeting population and development pressures in highly desirable coastal municipalities. Many municipalities in Metro Vancouver are protected from coastal hazards by hard structural adaptation methods, such as dikes and seawalls. Alternative approaches including soft structural methods such as ecosystem-based designs, and non-structural adaptation methods such as managed retreat, have to date received little consideration, yet are often regarded as flexible, sustainable, and effective adaptation measures in areas vulnerable to sea level rise risk. Through primary data collection involving key informant interviews (n = 27) with actors involved in flood management and coastal adaptation, and review of secondary data, this research explores sea level rise coastal adaptation plans and activities in three of Metro Vancouver's coastal municipalities: Vancouver, Surrey, and Delta. This thesis responds to recent calls for actor-centred analysis of barriers to climate change adaptation. It presents an in-depth account of the factors that influence structural and non-structural responses, and barriers to managed retreat and coastal adaptation. Findings reveal that structural protect responses will continue to dominate in coastal adaptation, while non-structural approaches are not emphasized. In addition, findings reveal several barriers to coastal adaptation, which constrain the adaptation path even before selecting a specific coastal adaptation option. Furthermore, managed retreat faces numerous barriers and is an unlikely coastal adaptation strategy for the case study municipalities. Managed retreat is likely only to be triggered post disaster. The implications of this study offer insight to coastal adaptation barriers and encourage municipalities to strive for long-term coastal adaptation responses.

Acknowledgements

Over the course of this degree and thesis, there are many people that ‘thank you’ cannot begin to express my appreciation and gratitude throughout this process. First, to my incredible supervisors, Dr. Brent Doberstein and Ms. Linda Mortsch, thank you both so much for your intellect, guidance, encouragement, and countless edits! I feel extremely lucky to have had both of you on my team. Brent, thank you for your enthusiasm, positivity, and wisdom even before I arrived in Waterloo. Linda, thank you for your kindness, expertise and confidence in me. Both gave me courage to attempt more than what I ever thought I could do. You both went beyond the advisory role and became true friends.

I am also very grateful to Deborah Harford, who connected me with several contacts in Metro Vancouver, and also provided valuable support, insight, and laughs during my time in Vancouver. Furthermore, I am entirely thankful to all the interviewees that dedicated their time and knowledge to this research.

Thank you to Gregory Richardson at the Climate Change Innovation Bureau at Health Canada for your patience and support as I worked through my thesis. Thank you to Dr. Fes deScally whose positive nature gave me the initial encouragement to pursue a graduate degree.

I was very fortunate to have received financial support from several organizations. I am grateful to the Social Sciences and Humanities Research Council (SSHRC) of Canada for the Joseph-Armand Bombardier Masters Graduate Scholarship. The University of Waterloo, providing the Ontario Graduate Scholarship (OGS) and Research Travel Assistanceship(s), also supported research and travel. And finally, I was also fortunate to have been supported by the Coastal Cities at Risk (CCaR) project funded by International Research Initiative on Adaptation to Climate Change (IRIACC), and a collaborative partnership of organizations (IDRC, CIHR, NSERC, SSHRC). I am grateful to have been able to undertake this research and given the opportunity to travel to conferences and meet many interesting people.

Thank you to my parents, Christine and Eamonn, and brother, Chris, whose unbroken support helped me though the ups and downs of this process. Eamonn, thank you for sacrificing your TV time (especially Saturday morning soccer games) so I could continue to work. Thank you my mom Christine, for your unwavering reassurance, strength, and kindness. You have been there for me to proof read countless drafts, go on countless walks, and bake me countless cookies. You are truly an inspiration to me. Thank you to my grandpa, aunts, uncles, and cousins, who always showed interest in my research. Finally, thank you to my pups, Grace and Bobby who were with me throughout the writing process, bringing me joy, humour, and relaxation.

To my dear friends, old and new, thank you for your continued friendship, understanding, and coffee dates, drinks, and laughs. To my coach Pat Gallagher, and soccer team, thank you for being a source of motivation and relief. You all are family to me.

Dedication

This thesis is dedicated to my godmother and aunt Lorraine Homes, whose lively, generous, and unyielding spirit continues to encourage me.

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List of Abbreviations

AEP: Annual Exceedence Probability
ALR: Agricultural Land Reserve
AR5: IPCC Fifth Assessment Report
BARC: Building Adaptive and Resilient Communities
BC: British Columbia
CCA: Climate change adaptation
CFAS: Coastal Flood Adaptation Strategy (City of Surrey)
CFRA: Coastal Flood Risk Assessment (City of Vancouver)
DAAP: Delta Agriculture Adaptation Project
DPA: Develop permit areas
DRR: Disaster risk reduction
EMBC: Ministry of Emergency Management
FBC: Fraser Basin Council
FCL: Flood Construction Level
FLNRO: Ministry of Forests, Lands, and Natural Resource Operations
ICLEI: Local Governments for Sustainability
IFHM: Integrated Flood Hazard Management (IFHM) Program
IPCC: Intergovernmental Panel on Climate Change
KI: Key Informant
LKI: Local Key Informant
NHC: Northwest Hydraulic Consultants Ltd
OCP: Official Community Plans
RCP: Representative Concentration Pathway
RKI: Regional Key Informant
SLR: Sea level rise
UBC CALP: University of BC Collaborative for Advanced Landscape Planning
UNISDR: United Nations International Strategy for Disaster Reduction

CHAPTER 1 THESIS INTRODUCTION

1.0 Research problem and research gap

1.0.1 Research problem

Coastal areas worldwide are highly vulnerable to the impacts of climate change (Wong et al., 2014). In its last assessment report, the Intergovernmental Panel on Climate Change (IPCC) accumulated scientific evidence that established climate change is undisputable, with warmer land and ocean temperatures, loss of ice and snow cover, and rising sea levels and alterations in hydrological patterns observed around the globe (IPCC, 2014). Coastal areas in Canada, with approximately 243,000 km of coastline (Lemmen et al., 2016), are likely to experience a variety of changes driven by climate change. With sea level rise (SLR), it is expected that the frequency and magnitude of storm surge flooding, inundation, and coastal erosion will increase in the future for Canadian coasts (Lemmen et al., 2016). In addition, the impacts of SLR and increased coastal hazards could displace millions of people, and cause high-priced damage to infrastructure in coastal areas.

Sea level rise is noted as one of the most important climate factors which contributes to increasing coastal flood risk (Kundzewicz, 2002). The West Coast of British Columbia (BC) is characterized by the continental connection to the Pacific Ocean. Rising sea levels threaten the urbanized and most densely populated region in the Lower Mainland BC. Coastal areas in Metro Vancouver are anticipated to experience increasing flood risk from rising seas and changes in storminess, higher tides, and combined effects from alterations in river flows (BC Ministry of Environment, 2016). Exacerbating these hazards is the societal pressures for development, growth, and urbanization in low-lying coastal zones. Altogether, climate change poses a number of new challenges for flood management and coastal adaptation in the region.

A future major flood in the Lower Mainland is expected to trigger the most costly natural disaster in Canadian history (Fraser Basin Council (FBC), 2016). As flood risks are likely to worsen due to SLR and other projected climate change related impacts, present-day coastal flood losses of an estimated $19.3 billion may rise to $24.7 billion of losses in 2100 from a 1-in-500 year storm surge flood and a 1m SLR (FBC, 2016). In addition to this, a present-day major coastal flood in the Lower Mainland would be expected to inundate 54,700 hectares, increasing to 61,100 hectares by 2100 (FBC, 2016). Impacts of a flood of these magnitudes would be far-reaching, resulting in damage to infrastructure, disruption of livelihoods, displacement of people, and the potential for injury and loss of life. These risks warrant proactive measures to respond to SLR and changing flood risks.

Responding to the impacts of SLR and coastal hazards requires adaptation. Adaptation is defined as the process of adjustment to actual or expected climate and its effects in order to avoid harm or exploit beneficial opportunities (IPCC, 2014). Municipalities in Metro Vancouver are in various stages of developing and implementing climate change adaptation (CCA) strategies, with specific adaptation measures pertaining to flood risk and coastal hazards. Options for adapting to SLR are broadly divided into four activities: protect, accommodate, avoid, and retreat (IPCC, 1990; Nicholls et al., 2007; Nicholls, 2011; Delcan, 2012; Wong et al., 2014). *Protect* is often considered a structural response, divided between soft and hard measures, while *avoid*, *accommodate*, and *retreat* are considered non-structural or regulatory responses. For the purposes of this study, *protect, accommodate*, and *retreat* will be the high-level focus of coastal adaptation strategies discussed in research since most *avoid* options are not possible in Metro Vancouver's intensely developed landscape.

Traditional flood risk management practices may either constrain or enable actors to undertake a long-term and diverse approach to adapt to SLR and climate change. In other words, some have recognised that traditional, structural approaches to flood risk management are insufficient in the face of SLR and climate change impacts, with present-day adaptation actions allowing the persistence of the structural approach (Lyle & Day, 2003; McEvoy et al., 2010; Nicholls, 2011, Moser, Williams, & Boesch, 2012). Alternatively, experts encourage a long-term perspective and an inclusive combination of options including structural, non-structural and low-regrets adaptation measures (IPCC, 2012).

Among the coastal adaptation options (i.e. protect, accommodate, retreat), retreat is often considered a contentious strategy (Abel et al., 2011; Alexander, Ryan, & Measham, 2012; Niven & Bardsley, 2013). Managed retreat is a strategy whereby a planned decision is made to relocate people and infrastructure in anticipation of rising seas and coastal hazards (Turbott & Stewart, 2006). Despite the potential benefits of reduced hazard exposure through managed retreat, relocation is often dismissed due to economic, social, and political controversy (Freudenberg et al, 2016). Therefore, managed retreat may not be a suitable adaptation option for many coastal communities. Despite a number of key policy documents offering managed retreat as a potential coastal adaptation strategy for communities in BC, it is unclear whether municipalities are seriously considering managed retreat beyond a policy option due to the potential barriers that exist in these local contexts.

1.0.2 Research gap and rationale

It has become increasingly clear through the evolving field of CCA that there are barriers to adaptation (Klein et al., 2014). Adaptation barriers (or constraints) are factors that make adaptation harder to plan and implement, or may restrict adaptation options (Klein et al., 2014). While there is a growing body of literature on barriers to adaptation, there are limited studies on barriers to coastal adaptation and even fewer on barriers specific to coastal adaptation options, particularly managed retreat. Moreover, Barnett (2013) explains that adaptation to SLR is constrained both by general adaptation barriers and barriers specific to local contexts. *This thesis addresses these knowledge needs by examining the coastal adaptation barriers in Metro Vancouver, and then focuses specifically on the barriers to managed retreat.*

Moreover, in light of climate change risks, increases in SLR, and the non-stationarity of hydrological systems, researchers have questioned the reliability of structural flood protection built under the assumption of hydrological stationarity (Milly et al., 2008). A logical response to reduce exposure to SLR and coastal hazard impacts would be to minimize the number of people and infrastructure that could be inundated from future SLR by relocation before they become at great risk (Gibbs, 2016). However, despite the effectiveness of managed retreat at reducing exposure from SLR, consideration of the costs and outcomes to people, stakeholders, and the surrounding community are required. Understanding these challenges for selecting coastal adaptation options, particularly managed retreat, has seldom been explored in the context of Metro Vancouver. Furthermore, as municipalities in Metro Vancouver are at critical stages of developing CCA plans, selecting and implementing coastal adaptation options, the time is optimal to explore actors' perspectives in working through the complex task of adapting to SLR and determining appropriate adaptation actions.

1.2 Research purpose and questions

1.2.1 Research purpose

This thesis aims to further the understanding of barriers to coastal adaptation to SLR and the understanding and experience of managed retreat as a CCA option. Using a qualitative approach, the research targets the perspectives of actors involved in flood management, coastal planning and adaptation, and climate adaptation fields. The purpose of this research is to uncover the factors that influence the choice between traditional, structural methods, versus a diversified portfolio of adaptation options, including non-structural coastal adaptation options such as managed retreat. To explore this topic, the overarching research questions follow below.

1.2.2 Overarching research questions

To understand the perceptions of managed retreat and the challenges of adapting to SLR and coastal hazards in Metro Vancouver, the main research questions for this thesis are the following:

- What factors influence the choice of traditional, structural flood management methods, versus non-structural methods to coastal adaptation?
- What are the barriers to coastal adaptation in Metro Vancouver?
- How is managed retreat viewed as a climate change adaptation strategy in Metro Vancouver and the three case study municipalities?

This thesis responds to calls for more research on barriers to adaptation (Moser et al., 2012; Biesbroek et al., 2013). Furthermore, managed retreat, despite its effectiveness at reducing exposure to SLR and coastal hazards, remains an under-explored and under-applied coastal adaptation strategy. Therefore, managed retreat deserves careful analysis.

1.3 Sea level rise and coastal adaptation responses in Metro Vancouver

The research explores adaptation planning and implementation for SLR and coastal hazards in Metro Vancouver, British Columbia. Through examining actors' experiences in flood management and coastal adaptation, the research highlights approaches to flood management, factors that impede coastal adaptation, and challenges to managed retreat and non-structural SLR responses. Three Metro Vancouver municipalities, the City of Vancouver, the City of Surrey, and the Corporation of Delta, were used as case studies to examine coastal adaptation planning and implementation for SLR.

The research is based on a qualitative analysis of local and regional coastal adaptation and flood management documents together with semi-structured interviews with actors involved in coastal adaptation planning, management, and decision making in Metro Vancouver. In total, 27 semi-structured interviews were conducted, comprised of 18 regional key informant interviews and 9 local key informant interviews, with 3 local key informants representing each case study municipality. Key informants (KI's) represented actors from local, regional, and provincial governments, and members from engineering and consulting firms, urban development, non-governmental and research organizations. Interview themes explored flood and coastal adaptation challenges, structural and non-structural flood management approaches, general barriers to coastal adaptation, and barriers specific to *protect*, *accommodate*, and *retreat*. These themes informed the research results and findings.

1.4 Thesis organization

The thesis is organized as follows; Chapter 1 begins with a brief overview of the research problem, research gap, and research questions. Chapter 2 provides an in-depth literature review detailing the scientific understanding of climate change drivers of SLR and coastal hazards, CCA and risk management concepts, a review of coastal adaptation options protect, accommodate, and retreat, and a review of coastal adaptation barriers and opportunities. Chapter 3 explains the qualitative methodology used for this research, describing the research design and interview process. Chapter 4 describes the context for this research, detailing projected climate change impacts for Metro Vancouver, the state of flood management and coastal adaptation in each municipality, and the current status of managed retreat in each case study municipality from review of local and regional flood management and coastal adaptation documents. Chapter 5 presents the results of the KI interviews, exploring preferred adaptation responses, the principal barriers to coastal adaptation generally, and the chief barriers specific to managed retreat. Chapter 6 discusses core themes extracted from the results, revealing insight into challenges to long-term coastal adaptation planning and implementation and why proactive coastal adaptation and managed retreat options face numerous barriers. And finally, Chapter 7 provides recommendations, limitations, avenues for further research, and concluding remarks.

CHAPTER 2 LITERATURE REVIEW

2.0 Climate change and sea level rise

Climate change is projected to have adverse impacts on coastal and low-lying areas due to SLR (associated with warming temperatures and melting of glaciers and ice sheet) and extreme weather events (Nicholls, 2011; Wong et al., 2014). SLR may increase coastal flood risk, coastal erosion, saltwater intrusion, and loss of wetlands and other coastal ecosystems (Nicholls & Cazenave, 2010; Nicholls, 2011). The Fifth Assessment Report (AR5) of the IPCC reported that projected global sea levels may rise between 0.28 to 0.98 m by 2100, depending on emission scenarios and regional variations (Wong et al., 2014). According to the IPCC chapter on Sea Level Change (Church et al., 2013), there is high confidence that over the 20th century, global averaged sea levels have risen by a mean rate of 3.2mm/y between 1993 and 2010. Moreover, it is very likely that the mean rate of global SLR will increase beyond the rate observed from 1971 to 2010 and continue through the 21st century (Church et al., 2013). Some researchers expect that global sea levels will rise by one metre by 2100 and will continue to rise further into the 21st century even if atmospheric greenhouse gas concentrations were to stabilize (Church et al., 2013; Nicholls et al., 2014; Wong et al., 2014).

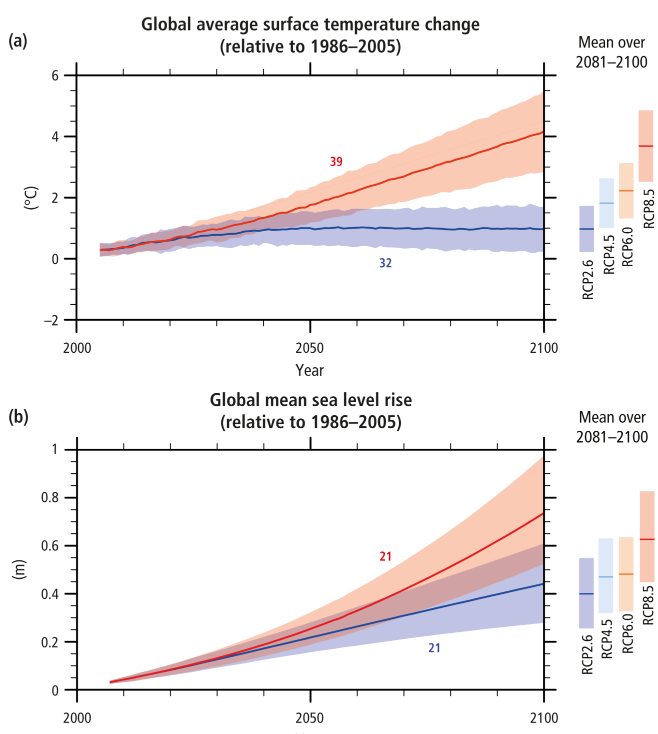

Figure 1 Global average surface temperature change (a) with global mean SLR (b) and RCP scenarios (IPCC, 2014).

Figure 1 represents the projected global mean SLR with the different Representative Concentration Pathway (RCP) scenarios for the period 2081 – 2100 relative to 1986 to 2005. For the "rigorous mitigation scenario" (RCP2.6) the rise is likely 0.26 to 0.55 m; for "intermediate scenarios" (both RCP4.5 and RCP6.0), the rise is expected to be marginally higher; and for the "business-as-usual, high greenhouse gas emissions scenario" (RCP8.5), SLR is expected to be 0.45 to 0.82 m and possibly reach 1m by 2100 (Church et al., 2013). Researchers note that the uncertainty associated with the accelerated decline of polar ice sheets raises the possibility of future SLR greater than 1 m by 2100 (Nicholls & Cazenave, 2010). For the year 2200, SLR estimates range from 0.35 to 0.72 m under the low emissions scenario, and 0.58 to 2.03 m under the high emissions scenario (Wong et al., 2014).

2.0.1 Causes of sea level change

Changes in sea levels are complex, varying locally and regionally. Sea levels may change as a result of both climatic and non-climatic processes (Nicholls et al., 2014). There are two key climatic mechanisms driving global rises in sea levels, including the thermal expansion of ocean water due to ocean warming, and the water mass input from glacier melt and land water reservoirs (Nicholls & Cazenave, 2010). Additionally, ocean volume may change through salinity shifts in water density (Bornhold, 2008), changes in ocean currents, and shifting wind systems, causing regional changes in sea level (Bornhold, 2008; Church et al., 2013). Temperature change causing thermal expansion and warming of ocean water contributes significantly to the global average ocean volume in recent years (Church et al., 2013).

Non-climatic processes influencing sea level change include glacial isostatic rebound or uplift, subsidence, and tectonic processes (Bornhold, 2008). Non-climatic processes, such as subsidence, intensify local SLR. It is important to recognize that human activities can contribute to localized sea level change. For example, dams, reservoirs, and groundwater depletion can influence runoff rates causing sea level change (Church et al., 2013). Additionally, dredging and construction of dikes and other large infrastructure projects have been found to add to subsidence rates in deltas (Bornhold, 2008).

2.0.2 Sea level rise and uncertainty

The large uncertainties associated with the possible contribution to SLR of the Greenland and Antarctica ice sheets has been heavily debated in the literature. The recent IPCC AR5 includes potential additional SLR owing to improved understandings, observations, and model results related to Greenland and Antarctica ice-sheet dynamics (Church et al., 2013).

Despite SLR ranges of 0.28 m to 0.98 m by 2100 reported in the AR5, higher projections and concerns over rapid and accelerated SLR have been reported by other researchers. Recent data suggest that the Greenland and Antarctic ice sheets are losing mass more rapidly than previous estimates (Hansen et al., 2013; Hansen et al., 2016). Moser et al. (2012) summarize a variety of studies with SLR estimates exceeding the 1 m by 2100 benchmark. For instance, Grinsted, Moore, and Jevrejeva (2008) estimate sea level of 0.9 to 1.3 m by 2100, exceeding IPCC AR4 confidence limits. Additionally, Pfeffer, Harper, and O'Neel (2008) found that a SLR of 2 m is possible by 2100 from extremely high rates of ice discharge from Greenland and Antarctica glaciers. More recently, new research (coupling ice sheet dynamics with climate dynamics) modeled future contribution of the Antarctica ice sheet under RCP scenarios (DeConto & Pollard, 2016). Using the RCP 8.5 scenario, they found sea levels could rise more than 1 m by 2100, and more than 15 m by 2500, with major ice sheet retreat occurring sooner (~2050), and faster than previous studies (DeConto & Pollard, 2016). Although such accelerated SLR scenarios are considered to have a low probability, implications of an accelerated rise in sea levels may test the limits of adaptation and flood management responses (Lonsdale et al., 2008).

Despite uncertainties, confidence limits, varying models, assumptions, and estimates, all studies referenced here highlight that sea levels are rising, and will continue to rise for centuries. Irrespective of global mitigation efforts to curb greenhouse gas concentrations, thermal expansion of the ocean will continue as it takes centuries to millennia for the entire ocean depth to adjust to surface warming (Nicholls, 2011). This consequence has been termed "commitment to sea level rise" (Nicholls, 2011), and accordingly, with this commitment to rising sea levels and coastal impacts, there must also be a commitment to adaptation (Nicholls, 2011). Although sea level change is uncertain, failing to account for change beyond planning benchmarks (i.e. 2100) may have very negative consequences.

2.0.3 Sea level rise impacts

SLR amplifies flooding, inundation, and erosion of low-lying coastal areas (IPCC, 2012). It is very likely that there will be an increase in the frequency of future sea level extremes and storm surge threats as a result of the combined effect of increased mean sea levels and climate extremes related to storms (Church et al., 2013).

The impacts associated with SLR manifest in a variety of physical and socioeconomic impacts. The physical impacts of SLR include flooding and inundation, ecosystem loss and change, long-term erosion, and salt-water intrusion (Nicholls et al., 2014). Impacts are likely to have synergistic effects and are likely magnified by the loss of natural coastal buffers such as dunes, marshes and wetlands (Linham & Nicholls, 2012). Rising sea levels may also trigger 'coastal squeeze' whereby natural habitat migration landward is prevented by human-engineered infrastructure located inland from the natural features. Rising seas reduce coastal habitat area between the water and the fixed barrier (Linham & Nicholls, 2012; Moser et al., 2012). The potential socioeconomic impacts from extreme coastal storms and SLR are numerous. Coastal areas are vulnerable to damage to coastal infrastructure, loss of property, saltwater intrusion into groundwater, loss of cultural and historic sites, reduced biodiversity and habitats, loss of economic activity, loss of recreation and tourism, damage to social networks and sense of place, as well as posing significant risk to human well-being (Moser et al., 2012).

Coastal zones globally are generally experiencing a continuous influx of people and economic activity, and regardless of climate change and SLR impacts, human activities are placing substantial pressure on coastal ecosystems (Moser et al., 2012). Coastal systems experience pressure from population growth, pollution and waste disposal, and high-intensity land-use for transportation, agriculture, aquaculture, urban development, resource extraction and industrial activities (Moser et al., 2012). Undoubtedly, there are many factors contributing to the increasing pressures on coastal regions. It is essential to review key concepts within natural hazards and climate change scholarship to understand the range of possible approaches to reduce vulnerability and increase resilience and adaptation.

2.0.4 The wicked problem of sea level rise?

SLR is regarded as a creeping environmental hazard (Moser, 2005; Tribbia & Moser, 2008; Gibbs, 2015). Decision-makers have great difficulty developing awareness of, and responding to, creeping problems (Moser & Dilling, 2004; Tribbia & Moser, 2008). In addition, the wider challenge of maintaining coastal sustainability has itself been termed a "wicked problem" (Moser et al., 2012). Wicked problems are characterized by evolving complexity and uncertainty, the presence of many stakeholders with diverse interests, often no simple, single solution, responses to issues will have consequences for many stakeholders, and usually there are only temporary, best answers (Rittel & Webber, 1973; Moser et al., 2012; Bender, Judith, &

Beilin, 2012). Actors undertaking flood and coastal adaptation in Metro Vancouver face these problems associated with rising seas. This gradual and long-term process requires decisions to be made in the face of uncertainty. Ultimately society must balance the viability and feasibility of 'holding the line' versus retreating and relocating away from rising seas.

2.1 Climate change adaptation and risk management concepts

This section reviews the remarkable scholarship on CCA and risk management which was highlighted in The IPCC Special Report on Managing the Risk of Extreme Events to Advance Climate Change Adaptation (IPCC, 2012). A major recommendation from the report (IPCC, 2012) and from other scholars is the integration of disaster risk reduction (DRR) and climate change adaptation (CCA) into policy and planning (Solecki, Leichenko & O'Brien, 2011; McBean, 2012; Smith, 2013; Begum et al., 2014; Rosenzweig, et al., 2015), as the desired outcome of both CCA and DRR is to reduce vulnerability and enhance resilience (Solecki et al., 2011; IPCC, 2012; Smith, 2013; Begum et al., 2014). Linking fields provide valuable insights on how to respond to complex hazards such as SLR and climate change.

General terminology and definitions derived from the IPCC and other CCA and risk management work are used to frame the research conducted in this study found in Table 1.

Table 1 CCA definitions	
Adaptation	The process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities (IPCC, 2014)
Adaptation barrier	Factors that make it harder to plan and implement adaptation actions or restrict options (IPCC, 2014)
Adaptation opportunity	Factors that make it easier to plan and implement adaptation actions, that expand adaptation options, or that provide ancillary co-benefits (IPCC, 2014)
Adaptation options	The array of strategies and measures that are available and appropriate for addressing adaptation needs (IPCC, 2014)
Adaptive capacity	The ability of systems, institutions, humans, or other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to consequences (IPCC, 2014)
Climate change	Climate change refers to a change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forcings such as modulations of the solar cycles, volcanic eruptions, and persistent anthropogenic changes in the composition of the atmosphere or in land use (IPCC, 2014)
Exposure	People, property, systems, or other elements present in hazard zones that are thereby subject to potential losses (UNISDR, 2009)
Hazard	The potential occurrence of a natural or human-induced physical event of trend or physical impact that may cause loss of life, injury, or other health impacts, as well as damage and loss to property infrastructure, livelihoods, service provision, ecosystems, and environmental resources (IPCC, 2014)

Path dependence	The generic situation where decisions, events, or outcomes at one point in time constrain adaptation, mitigation, or other actions or options at a later point in time (IPCC, 2014)
Relative sea level	Sea level measured by a tide gauge with respect to the land upon which it is situated (IPCC, 2014)
Risk	The combination of the probability of an event and its negative consequences (UNISDR, 2009)
Risk management	The systematic approach and practice of managing uncertainty to minimize potential harm and loss (UNISDR, 2009). Includes plans, actions, policies to reduce the likelihood and/or consequences of risks or to respond to consequences (IPCC, 2014)
Sea level change	Sea level can change, both globally and locally due to (1) changes in the shape of the ocean basins, (2) a change in ocean volume as a result of a change in the mass of the water in the ocean, and (3) changes in ocean volume as a result of changes in ocean water density. Global mean sea level change resulting from change in the mass of the ocean is called barystatic. The amount of barystatic sea level change due to the addition or removal of a mass of water is classed its sea level equivalent (SLE). Sea level changes, both globally and locally, resulting from changes in water density are called steric. Density changes induced by temperature changes only are called thermosteric, while density changes induced by salinity changes are called halosteric. Barystatic and steric sea level changes do not include the effect of changes in the shape of ocean basins induced by the changes in the ocean mass and its distribution (IPCC, 2014)
Sensitivity	The degree to which a system or species is affected, either adversely or beneficially, by climate variability or change (IPCC, 2014)
Thermal expansion	In connection with sea level, this refers to the increase in volume (and decrease in density) that results from warming water. A warming ocean leads to an expansion of the ocean volume and hence an increase in sea level (IPCC, 2014)
Uncertainty	A state of incomplete knowledge that can result from a lack of information or from disagreement about what is known or even knowable (IPCC, 2014)
Vulnerability	The characteristics and circumstances of a community, system or asset that make it susceptible to the damaging effects of a hazard (UNISDR, 2009). Vulnerability encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and lack or capacity to cope and adapt (IPCC, 2014)

2.1.1 Research concepts: Risk and adaptation

Adaptation is now a key issue facing governments, decision makers, and actors involved in coastal and flood management to minimize growing risks. This section reviews core terminology used throughout the research.

2.1.2 Risk and risk management in a changing climate

For this study, risk refers to the risk of potential consequences from climate change impacts. Risk can be presented through quantitative assessment and is defined as the combination of the probability of a hazardous event (e.g. flood) and its negative consequences (Smith, 2013). Risk is the product of interactions between vulnerability, exposure, and hazard

(IPCC, 2014). In the natural hazards community, risk is the actual exposure of the valued elements to hazard and is often expressed as the result of probability and loss often stated as:

RISK= hazard probability x elements at risk x vulnerability

Statistical analysis of risk is expressed comparably, where risk (R) is a result of probability (p) and loss (L) represented by the equation:

$$R = p \times L$$

Along similar lines, Brooks (2003) explains climate change risk as a combination of the probability of a climate change-related hazard occurring and the severity of its potential consequences. In addition, risk is interrelated with vulnerability, exposure, and hazard concepts (Smith, 2013; IPCC, 2014).

Risk is an important concept as perceptions of risk influence actions related to managing risks and reducing vulnerabilities (Smit et al., 2000), and climate change adds to the complexities of adapting to climate-influenced hazards. As Smit et al. (2000) note, for climate change related risks, there is difficulty separating climate change signals or extremes, from the normal variability of the Earth's systems. This assumption of 'normal' behaviour (i.e. that the past is a reliable guide for the future), known as *stationarity*, ignores the possibility of environmental change (Smith, 2013). The objective analysis of past extreme events by probability methods assumes *uniformity*, meaning that historical events are a suitable guide for future events (Smith, 2013). Stationarity-based designs for flood hazards are a foundational practice for planners and engineers. Unfortunately, climate change and human disturbances in river basins and deltas compromise the stationarity assumption, rendering it invalid (Milly et al., 2008). Approaches that consider non-stationarity and change of flood risk over time because of factors such as climate change and floodplain development can provide useful information to adapt to changing flood risk in coastal systems.

The aim of risk management is to lower risks through the introduction of hazard reducing strategies (Smith, 2013). It is a process by which communities, organizations, or individuals assess vulnerabilities; identify options, or prioritize implementation of both short-term and long-term actions for avoiding, reducing, or eliminating vulnerabilities (Mercer Clarke, Manuel, & Warren, 2016). Adaptation planning supports risk management by focusing on vulnerabilities and identifying approaches to advance sustainability and resilience (Burby et al., 1999; Mercer

Clarke et al., 2016). A key principle of risk management is to encourage a broad portfolio of actions, in this case adaptation actions, to reduce risk and respond to hazards, as opposed to a singular focus on one type of action or response (IPCC, 2012). A risk management perspective highlights the opportunity to consider a multi-hazard approach to reduce exposure and vulnerability to complex and future hazards (IPCC, 2012). Moreover, adaptation and risk management approaches can adjust to risks as they change over time (IPCC, 2012).

These risk management concepts are important when considering adaptation options for SLR- and flood-related risk in coastal areas. Often a diverse suite of structural and non-structural coastal adaptation options are encouraged (Klein et al., 2001; Kundzewicz, 2002; Lemmen et al., 2016). Furthermore, climate change may transform existing hazards and influence the emergence of new hazards, changing the risk profile of the area (Solecki et al., 2011). Inundation from SLR, in combination with extreme events, may amplify the impacts from storm surges, shoreline erosion, and winds and waves. This suggests the need for a multi-hazard approach, as well as flexibility in adapting to the changing risk (Solecki et al., 2011).

2.1.3 Adaptation

Adaptation adjustments are made in ecological, social, and economic systems in response to climate change (Smit et al., 2000). The IPCC (2014) defines adaptation in human systems as the process of adjustment to actual or expected climate and its effects in order to avoid harm or exploit beneficial opportunities. Similarly, Warren and Lemmen (2014) explain that adaptation is making "adjustments in our activities and decisions in order to reduce risks, moderate harm or take advantage of new opportunities" (p. 2). The concept of adaptation is integral in natural hazard literature. Burton, Kates and White (1993) understand adaptation as the process that aims to share the loss, bear the loss, modify the event, prevent effects, change use or change location.

CCA is a response in reaction to, or anticipation of, changes arising from changing weather and climate and the associated risks (Smit et al., 2000; Adger, Arnell, & Tompkins, 2005b; Adger et al., 2013). As such, the timing of adaptation can be considered reactive to a stimulus (e.g, past flood event), concurrent to an occurring stimulus, or in anticipation of a future stimulus (Smit et al., 2000; Adger et al., 2005b; Nicholls, 2011). In addition, the intent of adaptation can be autonomous (i.e. spontaneous) or planned, and local or widespread in scope to respond to climate change risks (Smit & Wandel, 2006). Planned adaptation, rather than reactive adaptation can serve to reduce vulnerability (Nicholls, 2011; Linham & Nicholls, 2012). Table 2 displays a typology of adaptation characterized by different intent, timing, scale, form, and degrees of change, summarized by Smit and Wandel (2006).

Table 2 Typology of Adaptation

Intent	Timing	Spatial scale	Form	Degree of change
- Planned - Autonomous	- Anticipatory - Concurrent - Reactive	- Local - Regional - National	- Behavioural - Financial - Technological - Institutional	- Incremental - Transformational

Smit and Wandel (2006) note that adaptation is "a process, action or outcome in a system"(p. 282). Taken together, adaptation is both a conceptual and operational notion. With this in mind, this study researches both the processes and application of coastal adaptation and flood management in Metro Vancouver.

2.1.4 Vulnerability

Vulnerability is also a central concept in the natural hazards and climate change literature. A recent IPCC definition of vulnerability is "the propensity of predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements including sensitivity and susceptibility to harm and lack of capacity to cope and adapt" (IPCC, 2014, p. 9). Human vulnerability to environmental hazards is influenced both by societal and environmental conditions (Hewitt, 1983), and affect vulnerability to the climate change risk. Fundamental to the conceptualization of vulnerability are the components of exposure, sensitivity, and the capacity to adapt (Cutter, 1996; Adger, 2006; Smit & Wandel, 2006). Figure 2 represents the interactions of these components influencing vulnerability.

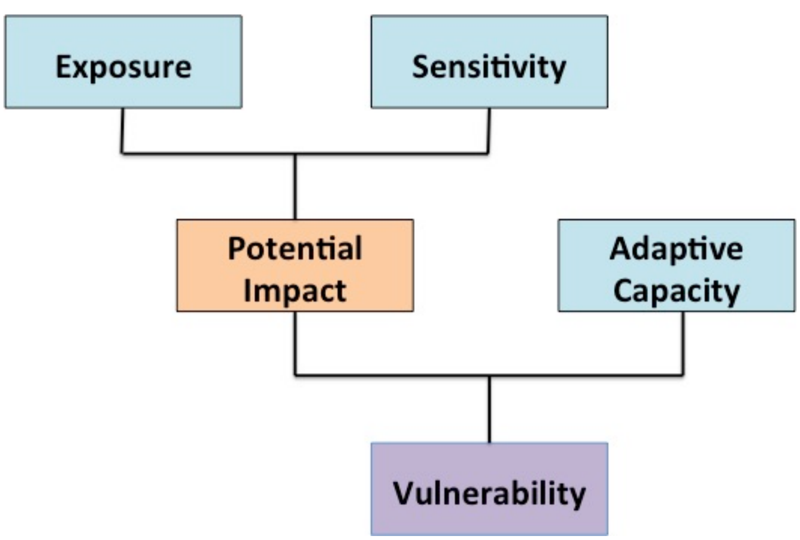

Figure 2 Components of vulnerability (Burch & Harris, 2014).

2.1.5 Exposure, sensitivity, & adaptive capacity

In the hazards literature, exposure commonly refers to the climate or biophysical characteristics of a hazard, or more simply, “the people, property, systems, or other elements present in hazard zones that are thereby subject to potential losses” (UNISDR, 2009). Sensitivity is the degree to which a system is affected by a given exposure (McCarthy et al., 2001). The combined interaction of exposure and sensitivity may influence or constrain adaptive capacity (Smit & Wandel, 2006).

Responses to climate change risks are related to a system’s adaptive capacity. Brooks (2003) recognizes adaptive capacity in human systems as the potential of the system to change in order to reduce its vulnerability and minimize the risk associated with a given hazard. This is achieved by the ability of the system to modify its characteristics so as to cope better with existing or anticipated external stresses (Brooks, 2003). At a working level, adaptive capacity is the ability to plan, prepare for, facilitate, and implement adaptation options (Klein, Nicholls, & Thomalla, 2003).

Adaptive capacity reflects broader societal conditions and contains determinants that influence the ability of the system to cope and adapt (Smit et al., 2000; Adger et al., 2005a; Smit & Wandel, 2006; Moser & Ekstrom, 2010), and may change with factors that can increase or decrease capacity. These factors may be hazard specific and may operate at different spatial and temporal scales (Brooks, 2003). At a community level, these factors could include economic wealth, social capital, institutional factors, and knowledge and technology (Smit et al., 2000; Klein et al., 2003). Smit and Wandel (2006) summarize these factors as including managerial ability; access to financial, technological and information resources; infrastructure; the institutional environment; political influence; and social and cultural networks, which can ultimately constrain or enable adaptation.

These components of vulnerability, exposure, sensitivity, and adaptive capacity, relate to the challenge of adapting and responding to climate change (Burch & Harris, 2014). Adaptations to climate change risk reflect adaptive capacity and support efforts to reduce vulnerability to hazardous conditions (Smit & Wandel, 2006). With these concepts in mind, a deeper understanding of vulnerability, risk, and adaptation in coastal zones can be addressed.

2.2 Climate change adaptation in urban coastal areas

Coastal cities continue to be attractive locations for economic development, investment, and migration. Given natural flood risk in coastal locations, the evolution of the coastal city recognized the need for risk reduction strategies concurrent with population growth, urbanization, and increasing economic activity. Climate change now increases hazard potential for coastal cities and low-lying areas (Klein et al., 2003; Moser et al., 2012; Wong et al., 2014). Coastal adaptation can be of benefit to traditional coastal flood management efforts, supporting prevention, protection, and preparedness, and introducing flexible and long-term options to adapt to current and future risks.

Coastal climate adaptation is a response to managing the increasing risk of inundation, coastal erosion, and storm surge flooding of coastal settlements and infrastructure (Gibbs, 2016). Coastal adaptation options are categorized in a number of different yet common ways. The most common coastal adaptation options recognized are: *protect*, *accommodate*, and *retreat* (IPCC, 1990; Fankhauser, 1995; Klein, Nicholls, & Mimura, 1999; Klein et al., 2001; Few, Brown, & Tomkins, 2007; Nicholls et al., 2007; Nicholls, 2011; Alexander et al., 2012; Wong et al., 2014; Harman et al., 2015). Along with protect, accommodate, and retreat, other recognized adaptation options include avoid (Delcan, 2012; Mercer Clarke et al., 2016), do nothing, and limited coastal intervention (Mycoo & Chadwick, 2012; Niven & Bardsley 2013), hold the line, move or advance the line (Linham & Nicholls, 2012). For the purposes of this study, *protect, accommodate*, and *retreat* is the high-level focus of coastal adaptation strategies discussed in research. In addition, an in-depth look into the concept of retreat is offered.

Consistent throughout flood risk reduction and adaptation strategies is the separation between structural and non-structural measures. This distinction is not always clear-cut, particularly with the introduction of "quasi-structural" measures such as green infrastructure. Traditional flood risk reduction strategies include structural measures such as engineered dams, dikes, and groynes, and non-structural measures such as flood forecasting and warning, regulations and zoning, flood hazard and risk assessment, stakeholder and public engagement, and awareness raising (Kundzewicz, 2002; Tingsanchali, 2012). For the purposes of this research, *protect* is considered a structural approach, while *accommodate* and *retreat* are considered non-structural. In some circumstances, quasi-structural measures such as green infrastructure and ecosystem-based adaptation are considered alternative, or soft structural approaches, given their non-traditional use.

2.2.1 Protect

Protect refers to structural flood protection, involving the construction of engineered defences that separate a watercourse from an area in need of protection, preventing impacts from being experienced (Few et al., 2007; APEGBC, 2012). Protect (Figure 3) creates a barrier between the hazard and the public and private assets behind the hazard (Delcan, 2012), defending economic activities and populations (Fankhauser, 1995). The protect approach is often seen as the most cost-effective solution in dense, economically intensive, urban areas (Gibbs, 2016). Gibbs (2015) notes that coastal *protect* options become the most cost-effective solution for coastlines with high economic value structures (e.g., high-rises or industrial facilities), but have relatively small footprints, because the cost of seawalls is directly proportional to the length of coastline being protected. Coastal *protect* options are less desirable for coastlines with low value buildings spread over long coastlines, where the cost of constructing seawalls will often outweigh the relocation value of the assets at risk (Gibbs, 2015). In addition, the *protect* option may not be cost-effective under projected long-term SLR. This is due to the likely need to continue to raise and widen the dikes to maintain protection against rising sea levels. Financing this option may not be feasible over the long-term.

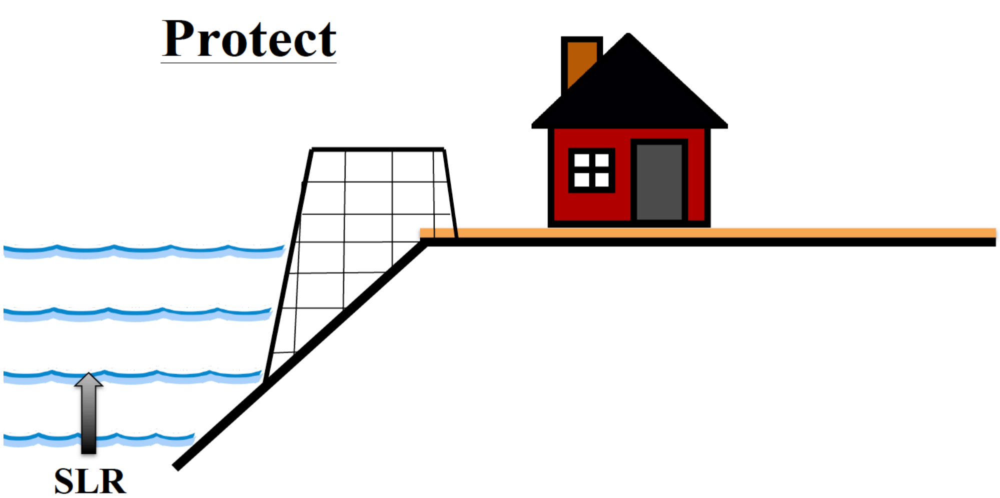

Figure 3 *Protect* as a coastal adaptation option to SLR (Courtesy of Eamonn Rutledge).

Furthermore, protect is divided into 'hard' or 'soft' structural protection (Few et al., 2007; Nicholls, 2011; Linham & Nicholls, 2012; Harman et al., 2015). 'Hard' protection includes dikes, seawalls, breakwaters, groynes, rip-rap walls, and levees (Niven & Bardsley, 2013; Harman et al., 2015), while 'soft' protection includes beach nourishment, dune construction, reestablishment of marshes and wetlands and other soft structures that mimic natural flood protective ecosystems or ecosystem-based approaches (Niven & Bardsley, 2013; Harman et al., 2015). The "living shorelines" approach, related to green infrastructure, is also considered a 'soft' protect method as the objective is meant to reinforce the shoreline and maintain coastal processes (Harman et al., 2015).

Although there is wide use of hard engineering methods for flood risk reduction, protection structures may reduce ecological and aesthetic values, contribute to coastal squeeze, and may cause downstream erosion impacts from deflected wave energy (Gibbs, 2013; Niven & Bardsley, 2013; Gibbs, 2016). In addition, it is widely noted that traditional hard protection structures may fail and overtop as a result of an event above the design standard, resulting in large costs and a difficult recovery. A well-known example is the flooding that resulted after levee failures during Hurricane Katrina in New Orleans (Kates et al., 2006). Despite the criticism of structural flood protection, they are often needed to protect existing urban development and infrastructure from the potential consequences of flooding.

2.2.2 Accommodate

Accommodate (Figure 4) is a non-structural coastal adaptation strategy, accepting occasional flooding, and allowing occupation in at-risk areas (Fankhauser, 1995; Harman et al., 2015). Accommodate includes methods that redesign, rebuild, or evaluate existing infrastructure (Niven & Bardsley, 2013), intended to cope with regular inundation (Few et al., 2007). Accommodate strategies include flood-proofing buildings, raising buildings, flood insurance, and improving preparedness (Nicholls, 2011; Linham & Nicholls, 2012). Other accommodate strategies include improving municipal drainage, changes to building codes and standards, and the redesign of urban districts (Harman et al., 2015). For example, the city of Rotterdam in the Netherlands plans to build floating urban districts to combat SLR and coastal inundation (Harman et al., 2015). Accommodate policies aim to reduce sensitivity to coastal risks (Few et al., 2007; Niven & Bardsley, 2013). In this study, accommodate options are not a major focus since accommodate strategies generally are the responsibility of homeowners to implement, such as elevating homes, buying flood insurance, and education. However, actors in Metro Vancouver offer insights on accommodate strategies that are in-process or implemented, and these insights are detailed in Chapter 5 Results.

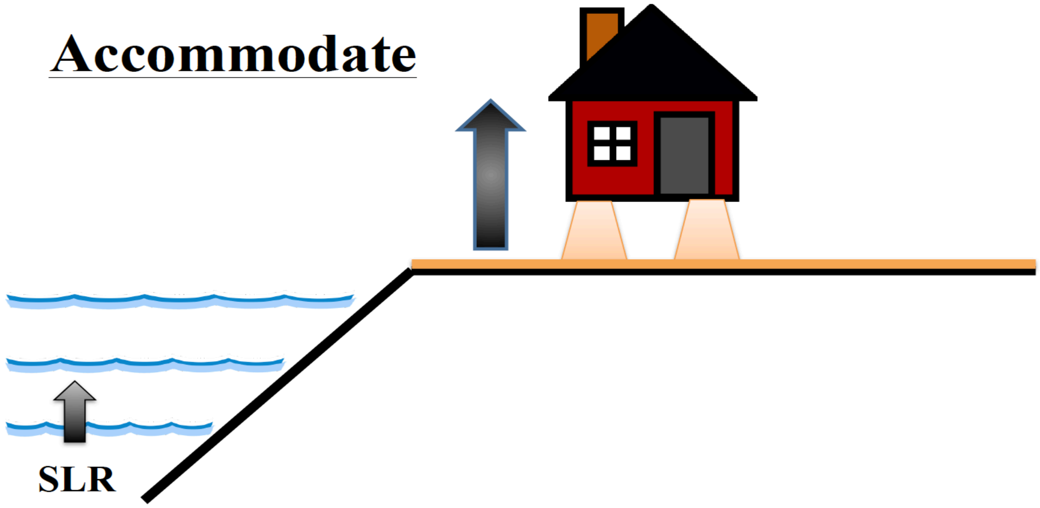

Figure 4 *Accommodate* as a coastal adaptation option to SLR (Courtesy of Eamonn Rutledge).

2.2.3 Retreat

Retreat (Figure 5) involves the abandonment or removal of buildings in high-risk areas and requires new buildings to be set back specific distances away from the shore (Fankhauser, 1995; Few et al., 2007; Nicholls, 2011). There are several terms similar to retreat including relocation, resettlement, managed realignment, and managed retreat. Migration away from the coast due to climate change can also be regarded as retreat, however this use of the term is beyond the scope and scale of this thesis so is not explored in any depth. For the purposes of this study, managed retreat and retreat are the main terms used.

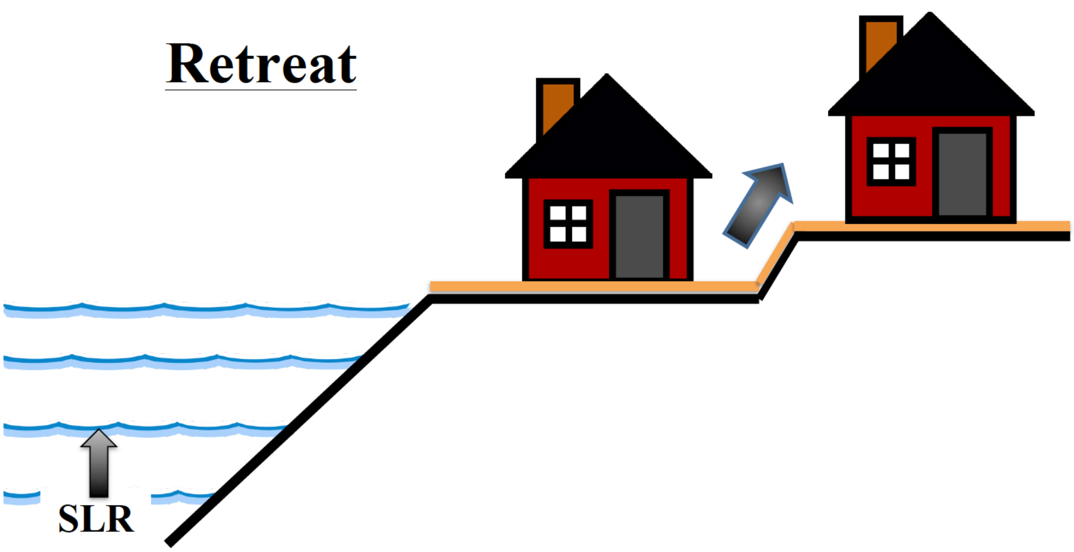

Figure 5 *Retreat* as a coastal adaptation option to SLR (Courtesy of Eamonn Rutledge).

Managed retreat is a non-structural adaptation strategy whereby a planned decision is made to relocate people or infrastructure in anticipation of a coastal hazard (Turbott & Stewart, 2006). Specific retreat methods include the abandonment of the coastline, relocation to other areas, setbacks from shorelines, buyouts and land acquisitions, re-zoning, and restricting further development on the foreshore (Niven & Bardsley, 2013; Sider, 2013). Gibbs (2016) establishes three different types of retreat:

- *Pre-emptive retreat:* or planned retreat, involves the systematic relocation of communities and buildings well before they are impacted by a major inundation event. This type of retreat requires relocating both private and public buildings and structures to locations further inland, to locations which are generally higher and less exposed to the hazard.
- *Just-in-time retreat:* involves implementing retreat as late as possible but prior to major damage occurring. This strategy may be implemented when the inundation risk becomes unacceptable to many land-owners or residents, or when the mean sea level reaches a threshold level specified in advance. This strategy may also be implemented when shorelines experience rapid erosion rates.
- *Reactionary retreat:* is often established immediately following a major inundation event and often involves governments reactively enacting laws that prevent impacted high-risk areas from being resettled, or implementing buy-back programs. The US buyout program following Hurricane Sandy is one such example (Freudenberg et al., 2016). This type of retreat can be seen as adaptation implemented during a ‘window of opportunity’.

In general, pre-emptive or planned retreat is often the type of retreat encouraged, as the strategy is proactive, rather than reactive occurring in the wake of a disaster. This type of retreat also refers to managed retreat, as the approach to retreat was planned or managed prior to disaster. To refer back to the typology of adaptation, Table 2 from Smit and Wandel (2006), managed retreat can then be explained with the following characteristics represented in Table 3. As the focus of this thesis research is on managed retreat, a greater description will be provided following a discussion of structural and non-structural adaptation, and adaptation barriers.

Table 3 Typology of Adaptation: Managed Retreat				
Intent	Timing	Spatial scale	Form	Degree of change
Planned ✓ Autonomous ✓	Anticipatory ✓ Concurrent ✓ Reactive ✓	Local ✓ Regional National	Behavioural ✓ Financial Technological Institutional	Incremental ✓ Transformational

2.3 Structural and non-structural coastal adaptation

Globally, reducing risk of loss from storm surge and inundation has relied heavily on hard, structural protection (McEvoy et al., 2010; Linham & Nicholls, 2012; Moser et al., 2012; Gibbs, 2013; Harman et al., 2015). Structural methods are widespread, while by comparison, implementation of non-structural methods continues to be weak. Structural methods are seen to have the greatest advantage in protecting dense, urbanized coastal cities, characterized by high levels of economic assets and high social and cultural significance (Alexander et al., 2012; Niven & Bardsley, 2013). By contrast, non-structural measures are often seen as non-scientific, and second best compared to an engineering, structural approach (Harries & Penning-Rowsell, 2011).

Gibbs (2015) argues the linear ‘fix and forget’ structural management method for CCA has reduced the uptake of a broad portfolio of coastal adaptation strategies. This linear approach, characterized by solutions that do not require an ongoing management obligation, is an obstacle to the increasing complexity of coastal systems (Moser & Ekstrom, 2010). Commenting about Australia, Gibbs (2015) suggested that amendments to land-use plans, revisions to engineering design standards, and consideration of coastal retreat were all promising non-structural methods, however, as of 2015, there is still a lack of uptake of these methods. Hard structural protections such as seawalls tend to be “lock-in options” which often hinder the uptake of other coastal adaptation options (Gibbs, 2013; Gibbs, 2015). Furthermore, Gibbs (2013) argues ‘asset anchoring’, the idea that major community infrastructure acts to anchor coastal communities in place, reducing the implementation of non-structural adaptation methods, particularly retreat. High value infrastructure often anchors coastal communities in place, leading to make structural protection strategies more desirable (Gibbs, 2013).

Despite the ability to defend shorelines, structural approaches require sustained financial commitment, and are often criticized for their environmental impacts (Linham & Nicholls, 2012) and social effects. Dikes must be periodically raised and widened. Moreover, building hard structures such as dikes or levees provide a false sense of security, thereby increasing encroachment onto floodplains and new investments in flood-prone areas (White et al., 2001;

Linham & Nicholls, 2012), a phenomenon which is now known as "the levee effect". Exposure and vulnerability to flood risk can increase with reliance on hard protection, and this is further exacerbated by climate change (Kundzewicz, 2002).

2.4 Adaptation barriers and constraints

A particular focus of this research is exploring the barriers to SLR-related coastal adaptation and managed retreat in Metro Vancouver. As a research topic, barriers to CCA continue to gain momentum (Smit & Wandel, 2006; Moser & Ekstrom, 2010; Biesbroek et al., 2013; Klein et al., 2014; Eisenack et al., 2014). Studies have examined the barriers to SLR adaptation (Barnett et al., 2013; Moser et al., 2012; Gibbs, 2013; Gibbs, 2015), and floods (Few et al., 2007; Burch et al., 2010; Harriers & Penning-Rowsell, 2011). However, few studies have examined the barriers to managed retreat. It should be noted that the terms 'barriers', 'constraints', and 'obstacles' are often used interchangeably in the literature. The IPCC defines adaptation constraints as factors that make it harder to plan and implement CCA strategies (Klein et al., 2014), ultimately constraining the effectiveness and variety of responses. Barriers make adaptation less efficient, less effective, inhibit adaptation implementation, or lead to missed opportunities and higher costs (Moser & Ekstrom, 2010; Eisenack et al., 2014).

As adaptation to climate change is context dependent, barriers and enablers of adaptation are often site-specific, reflecting the underlying community context (Adger et al., 2009). Barriers and constraints often act differently within different contexts, and may change over time (Moser & Ekstrom, 2010; Eisenack et al., 2014; Klein et al., 2014; Wong et al., 2014). For instance, changes in political leadership can impact the prioritization of adaptation. On a smaller scale, practitioners' access and openness to new technology and resources can influence adaptation. It is worth noting that barriers can be overcome with political will, social support, and sufficient resources and effort (Adger et al., 2009; Moser & Ekstrom, 2010). Enablers are the reverse of barriers. Enablers are defined as factors that enhance the development of norms, identities, or policies that support forward-looking and effective climate change action (Burch et al., 2010). Enablers arise from changed ways of thinking, political will, creative solutions, reprioritization of resources, land use and institutions (Eisenack et al., 2014).

Barriers commonly act in "bundles" (Moser et al., 2012), and it is worthwhile keeping this in mind when examining the coastal adaptation barriers and constraints in Metro Vancouver. Barriers can be categorized as physical, biological, knowledge and technological, economic, financial, human resource, social and cultural, governance and institutional, competing values, and cross-scale sensitive barriers. This wide-ranging categorization is taken from the IPCC AR5 *Chapter 16: Adaptation Opportunities, Constraints, and Limits* (Klein et al., 2014). These are described in the Table 4 below:

Table 4 Types of Barriers to Adaptation (modified from Klein et al., 2014)

Physical barriers	Physical constraints from the surrounding landscape including the built and natural environment and the climate itself. Physical constraints include the location and design of buildings as well as the geophysical characteristics of natural systems. For example, human engineered barriers hardening coastal shorelines prevent the inland migration of coastal wetlands from rising sea levels. Climate factors include constraints from the magnitude and rate of climate change possible. For example the uncertain magnitude of future SLR
Biological barriers	Biological factors that can constrain adaptation options for humans, species, and ecosystems. This can include biological capacity to cope to climate change and extremes, the capacity to migrate, and the resilience of ecosystems. For example, degradation of environmental quality in coastal wetlands can constrain natural adaptation buffers that protect against storm surge and flooding.
Knowledge barriers	Education and knowledge deficits, lack of expertise, capacity to access and manage technology and information. Decision making under uncertainty due to future climate change projections and the demand for more locally relevant information. For example guidance on adaptation planning and information on climate risks can empower actors to pursue adaptation.
Economic barriers	Trends in economic growth, economic investment, economic intensity, and development path. Economic resources available to actors influence may adaptive capacity. For example, financial resources available to governments through taxation arrangements to fund adaptation. Economic development can increase pressure natural environments. For example, development into hazardous landscapes increases human exposure to climate change and extreme weather events.
Financial barriers	Constraints due to lack of financial capital to dedicate to adaptation activities
Human resource barriers	Ability of humans to implement change. This includes fundamentals of knowledge, uptake, leadership, prioritization of adaptation policies and measures, and action and implementation. Expanding climate expertise in education and training in professional arenas present an opportunity.
Social and Cultural barriers	Societal values, worldviews, beliefs, cultural norms, behavioural norms, and place attachment can influence new decisions on selection of adaptation options, perceptions of risk, and the distribution of vulnerability among society. For example, the amenity value of an ocean view may outweigh flood risk perceptions resulting in settlement into hazardous locations.
Governance and Institutional barriers	Institutional arrangements, complexity of governance systems, and regulatory and legal issues affect the adaptation process. Institutions control the distribution of resources, decision-making, setting policy agendas, and setting the level of priority given to adaptation. Governance networks are composed of multiple actors, government agencies, and organizations. Actors may have different objectives, political choice, jurisdictional authority, power and resources influencing adaptation. The role of governments is key in adaptation. For example, lack of policy guidance from senior governments can constrain local adaptation.

Competing Values barriers	Differential values of societal actors and the trade-offs associated with selecting, prioritizing, and implementing adaptation options
Cross-scale sensitive dynamics	Constraints arise from interactions and dynamics within or among different scales (spatial, temporal), and are linked through processes and feedbacks that span multiple scales and levels. Path dependence or legacies (e.g., structural, policy) of decisions, a temporal-scale issue, can constrain future adaptation choices and responses.

Barriers are fluid and may not fit into one specific category, but may influence one another. Barriers work together to inhibit and exacerbate challenges linked to anticipatory and transformative adaptation (Few et al., 2007; Kates, Travis, & Wilbanks, 2012). Furthermore, uncertainty about the scale and rate of SLR and coastal change make adaptation decision-making difficult (Linham & Nicholls, 2012). It is worthwhile uncovering the barriers to coastal adaptation, and more specifically, managed retreat, by using the general rubric of barriers categorized by the IPCC (Klein et al., 2014) and described in the previous section. The next section reviews previous studies on managed retreat.

2.5 Managed retreat policy and review

Managed retreat is a policy and management action that involves moving existing infrastructure and people back from the danger of rising sea levels, coastal erosion, coastal flooding, and other climate-related coastal hazards (Turbott & Stewart, 2006; Niven & Bardsley, 2013). In order to reduce risks of flood hazards and coastal inundation, managed retreat strategies involve two important features. First, retreat involves the relocation, removal or abandonment of existing buildings and infrastructure in areas of risk (Alexander et al., 2012), and second, managed retreat involves a permanent change of land use in the area, often restricting residential and infrastructural uses of the area under threat (Alexander et al., 2012).

Managed retreat is usually implemented in phases. Policies may be introduced that prohibit new development or intensification in floodplains. Setbacks or rolling easements can be established to provide a buffer between the area of risk and the coastal development (Siders, 2013). However, setbacks will need to be reviewed periodically as SLR will generally decrease the buffer zone. During this time, temporary use and occupation of the land may be permitted depending on encroaching inundation and flood risk, yet in time, remaining development will be required to relocate (Harman et al., 2015). Kousky (2014) proposes a three part strategy for managed retreat by (1) reducing or restricting new development in high risk areas, (2) adopting policies that allow for the removal or modification of land use and development as inundation occurs, and (3) taking advantage of disasters to implement retreat strategies during post-disaster 'policy windows'.

In the medium to long-term, retreat can enable co-benefits for the creation of greenways and public space, promote habitat conservation, and enhance shoreline dynamics, while reducing vulnerability to coastal hazards (Barron et al., 2014; Harman et al., 2015). Managed retreat may help regenerate coastal habitats, such as salt marshes (French, 1999) and wetlands (Barron et al.,, 2012). Moreover, Abel and others (2011) expect that managed retreat options will be less expensive over the long-term, as compared to protect and accommodate options which generally involve maintenance and upgrade costs over their useful life. As well, managed retreat is regarded as flexible and able to deal with the uncertainty of SLR (Abel et al., 2011; Alexander et al., 2012; Niven & Bardsley, 2013). Even though managed retreat could reduce vulnerability from SLR and coastal climate change impacts, there are potentially significant up front costs to communities as managed retreat implies permanent abandonment.

Despite the many benefits, retreat is a contentious adaptation strategy facing multiple barriers and challenges. Managed retreat is not considered appropriate for dense and highly urbanized areas (Kousky, 2014; Harman et al., 2015), and is often objected to under social and economic concerns (Niven & Bardsley, 2013). Home buyout programs and land acquisitions, especially high-value waterfront properties, are financially costly and require large capital investment (Gibbs, 2015). Proponents of long-term retreat policies express confidence that retreat will be more cost-effective as the climate changes and sea levels rise. However, opponents argue that this ignores real-time economic conditions (Gibbs, 2015). In addition, displacement of people from their homes causes emotional and psychological harm, as well as losses linked to attachment to place (Agyeman, Devine-Wright, & Prange, 2009). Given potential social and economic costs, proposing a mandated managed retreat strategy is perceived to carry high political risk resulting in reluctance of elected officials to undertake such level of risk (Gibbs, 2016). Another drawback of the approach is the perception that this is a 'surrender of coastal lands to the sea', which often draws political and social controversy (Linham & Nicholls, 2012). This is further accompanied with unease if there is lack of available land needed to relocate the infrastructure in dense coastal areas (Harman et al., 2015).

Given the concerns above, managed retreat may not be a suitable adaptation option for all coastal communities or locations. Niven and Bardsley (2013) note that effective implementation of retreat methods may be constrained by concerns about current land uses, private development and assets, equity, and public and political acceptability. Alexander and others (2012) summarize the negatives associated with retreat policies as including increased market uncertainty and reduced land values; social inequity and compensation claims; and the loss of sense of place. Hence it is not surprising that managed retreat is often not a favoured adaptation strategy, or is considered a last resort option until significant threat materializes (Macintosh, 2013).

For managed retreat to be successful, the psychological, and emotional aspects of place-attachment must be considered (Agyeman et al., 2009). Thus, Agyeman et al. (2009) note that managed retreat is more likely to be accepted in the public realm if engagement is fair, transparent, and leads to positive outcomes. Adger et al. (2013) reinforce that adaptation decisions should involve the public in a transparent process. The process of implementing managed retreat itself is a potential enabler or barrier. Community participation throughout the coastal adaptation processes is necessary for managed retreat application (Agyeman et al., 2009). Overcoming barriers to retreat must address information gaps, and public and political reluctance.

2.6 Qualitative research approach

A qualitative study is appropriate to understand the ways in which actors involved in coastal city management and planning experience CCA, and their role in the decision-making process. In the context of responding to climate change, actors can be individuals, communities, organizations, corporations, governments, NGO's, policymakers, or those in positions that may respond to climate-related stresses or opportunities (Klein et al., 2014). Within the climate change literature, there is a strong call for actor-centered research (Moser et al., 2012; Dow et al., 2013; Eisenack et al., 2014), as actors can influence adaptive capacity and are at the forefront of undertaking adaptation measures. For this study, actors participating in the research are referred to as key informants (KI's).

Conducting interviews are valuable because they establish an open dialogue, allowing a window into the experience and feelings of the actors and KI's (Bouma, Ling, & Wilkinson, 2012; Creswell, 2014). Through semi-structured KI interviews, a qualitative approach aids in understanding the local context of Metro Vancouver and local conditions which constrain adaptation. Case studies of Metro Vancouver municipalities provide a rich and deep look into the capacity of municipalities to pursue adaptation initiatives. Thus, a qualitative case study approach is suitable to explore local perspectives, which might not be revealed through quantitative methods.

An actor-centred research approach is encouraged to understand the ways in which barriers to adaptation develop and persist (Dow et al., 2013; Eisenack et al., 2014). Interviews with Metro Vancouver actors assist in uncovering the barriers to coastal adaptation, as well as pinpointing specific opportunities for improvement helps address this research gap. Interviews can reveal consensus on some issues and allow diversity of experience on other issues, aiding in understanding the unique context of each coastal municipality. Moreover, the research examines the under-researched, sometimes controversial, and under-applied, yet increasingly pressing topic of managed retreat.

Qualitative research is a continuous reflection (Cope, 2010; Bouma et al., 2012). Along with notes and observations during the interview, entries are made on “how I felt”, and “what I thought” (Bouma et al., 2012). As the researcher, this self-observation increases awareness of inner subjectivity and perhaps wrong interpretations (Bouma et al., 2012).

CHAPTER 3 RESEARCH METHODS

3.0 Research Design

This study used a qualitative approach to examine coastal adaptation and flood management strategies in the context of climate change and SLR in Metro Vancouver municipalities.

Two phases of qualitative research were used:

1. Literature review of academic papers on coastal adaptation and SLR, barriers and enablers, and technical reports on the regional and municipal flood management context in Lower Mainland British Columbia, which established themes for interview script, and;
2. Qualitative semi-structured interviews (n=27) with local and regional actors involved in coastal adaptation and flood management in Metro Vancouver.

3.1 Literature Review

The study reviewed the academic and technical literature related to SLR, flood management, coastal adaptation, managed retreat policy and practice, and barriers to and opportunities for adaptation. Literature was accessed through online searches through university library databases, as well as governmental and non-governmental organization websites, relevant online news stories, and publically available technical reports, council and corporate reports, plans, policies, and guidelines. The literature review was used to gain a background understanding of the local context, identify key focus areas, and guide the interview schedule. The review framed the research problem, revealed gaps within existing knowledge, and identified connections with previous studies and situated the research within the context of existing literature.

The literature review assisted in identifying the following key themes to enhance inquiry for the interview schedule:

- Top coastal adaptation and flood management challenges in X municipality from adaptation plans and coastal assessments
- How is managed retreat considered as a CCA strategy in X municipality from policy and adaptation plans
- Structural methods (protect), versus non-structural methods (managed retreat)
- Barriers or constraints for adaptation to SLR from local and regional reports

- Barriers or constraints for managed retreat from local and regional reports

3.2 Qualitative data collection

3.2.1 Case study municipality

The City of Vancouver, the City of Surrey, and the Corporation of Delta were chosen as local case study municipalities within the Metro region, since they are primarily responsible for land-use planning in flood hazard areas, and CCA in urbanized regions of British Columbia (FBC & Arlington Group, 2008). Additionally, climate change impacts will affect each municipality's population, infrastructure, and services (Carlson, 2012).

The three Metro Vancouver case study municipalities were chosen for case study analysis based on the following criteria:

1. Proximity to the coast;
2. Vulnerability to SLR and other flood hazards (riverine, overland, storm surge);
3. Past involvement in SLR adaptation work; and
4. Willingness of informants to participate in interviews.

3.2.2 Semi structured interviews

Interviews gather data from a spoken exchange of information to gain a holistic account of an issue (Dunn, 2010). For this research project, interviews explore how KI's experience and pursue flood management and adaptation in the coastal urban environment of Metro Vancouver. Semi-structured interviews were conducted with actors involved with coastal management and planning for CCA. They were content-focused, with flexible questioning (Dunn, 2010).

3.2.2.1 Selection of Key Informants

The research is actor-centered because actors play a key role in adaptation-related decisions (Eisenack et al., 2014). KI's were selected purposefully for their prominent roles in flood management and coastal adaptation planning in Metro Vancouver. They were affiliated with provincial and municipal government, engineering and consulting firms, research and academic institutes, or non-governmental organizations (i.e. Green Shores or FBC), and had backgrounds in engineering, planning, environment, risk management, and sustainability. Although academics were not directly employed in planning for Metro Vancouver municipalities, they provided important background information through the research process.

As a way to organize sample selection and data analysis, KI's were characterized into local or regional actors. Local KI's were deemed to have site-specific knowledge and involvement with planning in the case study municipality. Regional KI's had broad knowledge of flood management activities in the Metro Vancouver or wider BC region, and were not exclusively involved with the chosen case study municipalities - Vancouver, Surrey, or Delta. The nomenclature of LKI(#) is used to identify local KI interviews and their quotes, and RKI(#) is used to identify regional KI interviews and their quotes.

Requests for interviews were initiated by sending an initial contact email asking if the prospective informant was interested in participating in the interview (see Appendix A and B). If the person expressed willingness, a consent letter for the interview was emailed and interview arrangements were made. The informant was made aware that the study had been given ethics clearance through the University of Waterloo's Research Ethics Committee. In total, fifty two people were contacted, and twenty seven semi-structured interviews were conducted.

3.2.2.2 Interview Design

Semi-structured interviews were conducted with twenty-seven KI's across Metro Vancouver from March to July 2016. The semi-structured format allowed flexibility throughout the interview as theoretically, such interviews are designed and adapted by the researcher to seek information in a way that is appropriate and relevant to each informant (Dunn, 2010). For this study, some questions were tailored specifically to ask about locally relevant climate change challenges in each case study location. As suggested by Dunn (2010), a mix of key themes and questions with prompts was available as a general guide or "interview schedule" from which questions were formulated during each interview (see Appendix C).

Findings from the literature review in the first phase of research were used to formulate the initial topics in the interview schedule, but as interviews were conducted, new information revealed by KI's was also used to formulate new interview questions and added to the interview schedule. The themes were current challenges to flood management and SLR, the barriers to coastal adaptation and climate-related flooding, the choice between structural and non-structural adaptation, thoughts on barriers to managed retreat, and ways in which barriers could be overcome or resources that could improve adaptation. The interview schedule was also used as a note-taking sheet to supplement audio recordings.

Audio recording and interviewer note taking were combined to record and track the information gathered in interviews. This combined technique is beneficial to capture the complete conversation, allow attentive listening, and note body language and subtle expressions of the informant (Dunn, 2010). Written notes also serve as a back up should the audio recordings fail (Dunn, 2010; Creswell, 2014). All KI's were requested to give written consent to allow audio recording during the interview, and at anytime the informant was allowed to stop the recording.

Interviews ranged from 30 to 130 minutes. The majority of the interviews were face-to-face, however, some KI's chose Skype and telephone interviews as a preferred option. The interview process began with easy-to-answer questions reflecting on the informant's role, day-to-day duties, responsibilities, and involvement in urban management and planning. Then, questions progressed to deeper, more challenging questions on implementing coastal adaptation. This pyramid structure allowed the informant to adjust and become comfortable with the interviewer, topic, and interview process before tackling more abstract and sensitive questions that required deeper contemplation (Dunn, 2010; Creswell, 2014).

3.2.2.3 Transcribing Interviews

Audio-recordings and notes from each interview were transcribed and the letters RKI or LKI along with a number replaced the name of the KI to maintain anonymity. The transcripts also had any identifying information removed to maintain informants' confidentiality. Each recorded interview was replayed and transcribed verbatim by typing the verbal conversations into text on MS Word. Next, written notes taking during each interview were matched with the corresponding transcript of the interview to reconstruct the experience, providing the best record of the interview. The nomenclature of LKI(#) and RKI(#) is used to protect the KI's identity.

3.2.2.4 Interview Data Analysis

A research journal was kept to record my thoughts, observations, and experiences throughout the research process. It was supplemented by field notes and photographs of coastal adaptation measures and land uses in each municipality. This aided in the descriptive and reflective components of the research (Creswell, 2014).

Interview data were analyzed by hand through a content analysis procedure searching for both manifest and latent content. Manifest content analysis involves counting the appearance of a word or phrase in the transcript (Cope, 2010; Dunn, 2010). Latent content analysis involves searching transcripts for the underlying meanings of what has been said in interviews and further coding into themes (Dunn, 2010).

Coding is used as an exploratory method and to organize and analyze data (Cope, 2010). The first step in the data analysis procedure was reading through each transcript and highlighting important concepts and phases. The transcripts were sorted and formalized into codes and categories by colour coordinating similarities (Crang, 2005). As suggested by Creswell (2014), a codebook is used to sort categories and track predetermined and emergent codes and themes. Descriptive and analytic codes were used for analysing the transcripts. Descriptive codes reflect explicit and blatant statements said by the informant (Cope, 2010). Analytic codes reflect a theme the researcher is interested in, or subject matter that has become significant in the research that may explain underlying concepts (Cope, 2010). Descriptive codes were used to inform analytic codes. For example, some descriptive codes were often discussed together, and among different interviewees. This represented a potential pattern in the data and an analytic code.

This analysis endeavoured to find connections and reoccurring themes among the interview transcripts. When informants' referred to specific subject matter, the word or phrase was given a code and colour. For example, barriers to adaptation (physical, knowledge, economic, financial, etc) were each given a different code and color. Cope (2010) notes that coding is a recursive process that may start with initial codes from the literature and research questions and then may further progress to codes that align with patterns, relationships, and differences. As suggested by Crang (2005), in this study the coded material was organized into separate coloured labeled piles depending on the theme. Themes are drawn from existing literature on CCA and coastal management, and emergent topics through the research process. The codebook was reviewed until the coding process was complete. Following coding, organizing transcripts, and synthesising themes, the themes informed the research results and findings in Chapters 5 and 6.

3.3 Reflexivity

As a researcher, reflecting on one's own assumptions, biases, and values throughout the research process is key to adding respectable contributions to research (Creswell, 1994). My perceptions on CCA are shaped through the climate change and risk reduction literature, as well as working closely with related scholars and researchers. For example, I am personally convinced that the severity of future climate change impacts merits anticipatory and proactive efforts to minimize impacts, rather than a reactionary approach. In addition, I also believe that there are limits to the effectiveness of structural flood risk reduction, and that additional investment in structural measures may actually increase the impacts and consequences of expected climate change in some places, or may end up costing more, or become harder to maintain than other approaches. Therefore, I acknowledge my limitations in understanding the day-to-day and on-the-ground workings of the KI's working in coastal management and planning. The conclusions drawn from other scholarly research in coastal adaptation may not be the experiences of those in Metro Vancouver. I believe that by working closely with those actively involved with coastal management and planning, my understanding of the local context has been strengthened and is distinct from issues in the literature. Efforts to erase assumptions and biases were made by keeping a research journal to reflect on interpretations, experiences, and assumptions, of the data collected.

3.4 Verification

Verification is achieved through triangulation (Creswell, 2014). Data collected through multiple sources, including interviews, observations, and relevant literature throughout the research process contributes to triangulation of the data. Triangulation finds points of convergence among different sources of information and researchers (Creswell, 1994; Creswell, 2014). This thesis uses data and information from CCA scholarship, local CCA work, and KI interviews who have experience in coastal adaptation and flood management activities.

CHAPTER 4 STUDY SITE AND METRO VANCOUVER CCA CONTEXT

4.0 Overview of Metro Vancouver

Metro Vancouver is located in the Lower Mainland of British Columbia and is an agglomeration of 21 municipalities, one Electoral Area, and one Treaty First Nation reserve (Figure 6). With a population over 2.5 million, the Lower Mainland continues to attract the most newcomers to BC (BC Stats, 2016). The coastal landscape provides significant lifestyle and economic benefits. However, this densely populated region will face new social and environmental challenges due to climate change and increasing flood hazards.

Metro Vancouver is exposed to natural hazards given its unique geography nestled between the Pacific Ocean, Fraser River delta, and the Coast Mountains. Some of the main natural hazards for the region include coastal hazards, and flood risk, earthquakes, heat events, drought, slope instability, and wildfire risk. Provincial and local governments have been engaged in risk reduction measures and preparedness programs to reduce potential disaster consequences. As arguably the primary risk reduction measure for flood hazards, the Lower Mainland has an extensive network of flood control structures. This includes over 500 km of dikes, seawalls, groynes, pump stations, and flood boxes to protect the region from flooding and inundation (FBC, 2016). Climate change is expected to heighten the risks and impacts from future flooding.

4.1 Metro Vancouver climate change flood risk and sea level rise context

Climate change will likely change the nature, timing, and severity of many of the region's hazards. Metro Vancouver is exposed to numerous flood hazards, including riverine flooding, coastal flooding, and urban flash flooding (Forseth, 2012; Oulahen, Shrubsole, & McBean, 2015), all of which are compounded by more uncertainty under climate change. There are separate climate change drivers changing the nature of exposure to these flood hazards in the Lower Mainland. These are:

- **Sea level rise**, resulting in changes in coastal flooding events. Coastal flooding often occurs in the winter when storm surges combine with high tides (FBC, 2016) and wind-driven waves.
- **Heavy precipitation**, resulting in overland and urban flooding from increased frequency and magnitude of extreme precipitation events.

- **Fraser River freshet changes** from accelerated snow and ice melt, and altered timing and magnitude of peak and low flows (Pike et al, 2008), resulting in changes to riverine flooding events.

Tsunami flooding from an earthquake is a fourth type of potential flooding, but is not considered in this analysis. For the purposes of this thesis, coastal flooding is the main type of flooding considered in the analysis.

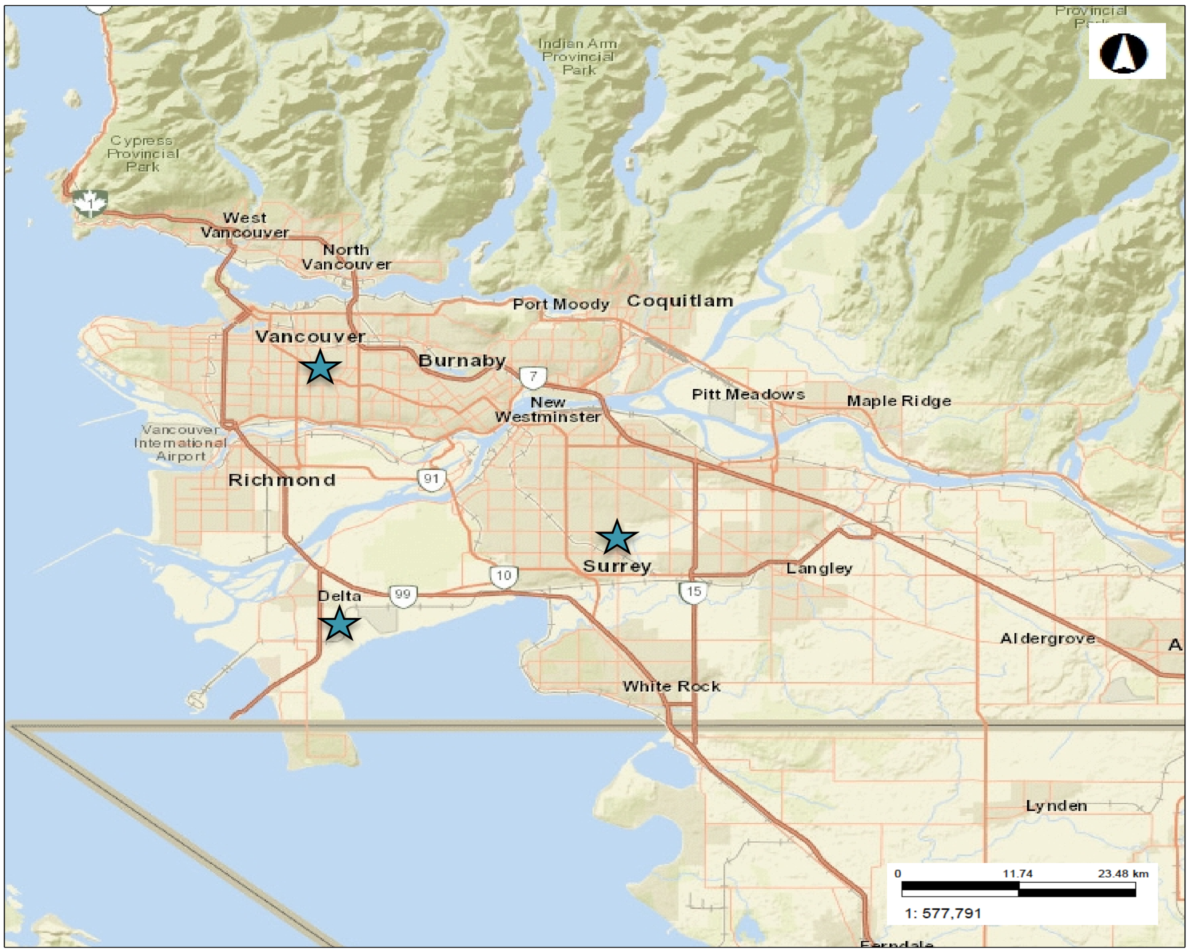

Figure 6 Map of Metro Vancouver (Source: https://www2.gov.bc.ca/gov/content/data/geographic-data-services/web-based-mapping/imapbc).

Hydrological and flood profile changes may result from warmer temperatures promoting earlier snowpack melt, break up of ice, and possible precipitation increases (BC Ministry of Environment, 2016). BC has four monitoring stations along the coast to measure changes in the average level of the sea (BC Ministry of Environment, 2016). Sea level change is a result of the collective impact of thermal expansion of the oceans, melting of ice sheets and glaciers, and localized geophysical processes, such as isostatic rebound or subsidence. Based on records from

1910 to 2014, noted change in sea level along coastal BC was a rise of 13.3 centimeters at Prince Rupert, 6.6 centimeters at Victoria, and 3.7 centimeters at Vancouver. With coastal BC experiencing higher mean sea level, the frequency of extreme high water levels and flood events are expected to increase as well (BC Ministry of Environment, 2016). Consequently, changes in the maximum height, frequency and return periods of high water events will have implications for structural flood control design criteria (Pike et al., 2008).

The Lower Mainland of BC, particularly the Fraser River delta, is highly sensitive to projected SLR (Shaw et al., 1998). By some estimates, sea level is estimated to rise approximately 1.2 metres in the Fraser Delta by 2100 (Bornhold, 2008). Sea level changes will be unequal along the coasts of BC because of geographically distinct rates of subsidence, uplift/rebound, and oceanographic factors (Okey et al., 2014). Sinking rates have been estimated at 1 to 2 millimetres per year on the Fraser Delta. Along with natural subsidence, the rate of subsidence can be increased by human activity in the Delta including dredging and by large infrastructure projects, which can include port facilities or dike construction (Bornhold, 2008).

Along with SLR, climate change is likely to change the flood risk for Metro Vancouver in concert with altered timing and magnitude of the spring freshet (spring melting of snowpack and ice into rivers), and extreme wind and heavy rainfall events. The combination of extreme weather, King tides[1], and SLR has the potential to be more destructive unless coastal defence methods and policies are updated. Globally, Vancouver is high on the list of port cities vulnerable to climate extremes, coming in at 15th of 136 cities (Nicholls et al., 2008). Vancouver is also ranked 11th for exposed assets, with $55 billion at risk, and 320,000 people exposed (Hallegate et al., 2013). A present-day major coastal flood in the Lower Mainland is expected to inundate 54,700 hectares of land, moving up to 61,100 hectares by 2100 (FBC, 2016). Additionally, a present-day Fraser River flood could be expected to inundate 99,300 hectares of land, with a possible 110,300 hectares by 2100 (FBC, 2016). Both present-day flooding and future flooding as a result of SLR and climate change would cause widespread loss and disruption in the Lower Mainland.

[1] King tides are predictable high-tide events along the shoreline without the exacerbation of an additional coastal storm (Lyle, Long, & Beaudrie, 2015). King tides occur once or twice a year on average and have caused significant flooding in coastal areas of Metro Vancouver in the past. While king tides are not influenced by climate change, storms that occur during a king tide event can cause increased risk of coastal flooding and erosion due to the rise in sea level in combination with the king tide.

The FBC (2016) estimated that a major Lower Mainland flood could result in the most costly natural disaster in Canada to date. Estimates range from $20 to $30 billion for a present-day flood scenario, with worsened conditions when considering the exacerbating influence of climate change on SLR and hydrologic changes. Present-day flood loss estimates for a coastal flood are $19.3 billion, and $22.9 billion for a Fraser River flood. Future flood loss estimate (constant dollars) in the year 2100 are $24.7 billion for a coastal flood, and $32.7 billion for a Fraser River flood (FBC, 2016). Although winter coastal storm surge design criteria for BC is a minimum requirement of 1:200 annual exceedance probability (AEP), others have recommended a 1:500 AEP given SLR and future climate change impacts (FBC, 2016). Therefore, Metro Vancouver is a highly relevant study site to examine the adaptation strategies of a Canadian city exposed to significant flood risk and multiple threats from future climate change and SLR.

4.2 Flood Management and Coastal Adaptation in Metro Vancouver

4.2.1 Flood Management Historic triggers

The Lower Mainland has experienced two major flood events in the last 150 years and have both influenced flood protection and management in the region. The largest magnitude flood (approximately 17,000 m^3/sec, measured at Hope) was in May 1894, triggered by rapid snowmelt, and used as the "design flood" for present-day structural flood protection (FBC, 2016). The 1948 flood caused greater damages than the 1894 Fraser flood because of population growth and increased development in the floodplain (FBC, n.d.). The goal of the Fraser River Flood Control Program initiated in the 1960s and 1970s was to raise and strengthen the dikes based on the high water profiles of the 1894 and 1948 Fraser floods (Lyle & Mclean, 2008). Although this design criteria for dikes is now considered too low to cope with anticipated climate change (Northwest Hydraulic Consultants Ltd (NHC), 2015a), to date, structural approaches to flood management have remained as the main flood control approach for both riverine and coastal floods.

4.2.2 Flood Management policy

In 2003, the responsibility of flood management shifted from the Province of British Columbia to municipal governments (FBC & Arlington Group, 2008; Stevens & Hanschka, 2014a; Stevens & Hanschka, 2014b). The *Local Government Act* delegated responsibility to manage land use in flood hazard areas from the Province to municipalities. One of the important implications of this Act is that municipalities were now allowed to permit development on floodplains (Stevens & Hanschka, 2014a; 2014b). Additionally, the *Dike Maintenance Act* and *Drainage Ditch & Dike Act* provide the regulatory framework for local governments to manage their flood risks.

The Province has also developed a set of guidelines to help municipalities with flood management planning. The 2004 *Flood Hazard Area Land Use Management Guidelines* help guide local government land-use decisions in areas subject to flood hazards (Stevens & Hanschka, 2014a). Under the *Local Government Act*, local governments are required to consider these guidelines when designating floodplains and approving development in floodplains.

The *Flood Hazard Area Land Use Management Guidelines* primarily focuses on river flood risks with a minor section on coastal flood exposure. The Province commissioned a series of reports in 2011 to incorporate new knowledge about climate change induced SLR and coastal hazard land management. Amendments to the *Flood Hazard Area Land Use Management Guidelines* reflected the need for local governments to plan for SLR (Government of British Columbia, 2013), and this was supported through a series of reports collectively titled *Climate Change Guidelines for Sea Dikes and Coastal Flood Hazard Land Use*. This series contained three reports from the BC Ministry of Environment:

- *Draft Policy Discussion Paper* (Ausenco Sandwell, 2011a),
- *Guidelines for Sea Dikes and Coastal Flood Hazard Land Use* (Ausenco Sandwell, 2011b), and
- *Sea Dike Guidelines* (Ausenco Sandwell, 2011c).

The series of reports offer guidance and recommendations for municipalities to plan for SLR. This includes land-use planning recommendations such as creating Sea Level Rise Planning Areas (area between the current natural boundary and the future estimated natural boundary to address rising sea levels), and methodological guidance for Flood Construction Levels (FCLs) and horizontal setbacks. As a general guideline, the Province includes benchmarks that identify thresholds for SLR of 0.5m by 2050, 1m by 2100, and 2m by 2200 (Figure 7) (Ausenco Sandwell, 2011a; 2011b; 2011c). Updated, FLCs should consider SLR, subsidence, storm surge, wave and wind effects, high tide level, and freeboard (Ausenco Sandwell, 2011c). The reports also recommend that local governments calculate their own FLC for the year 2100 and incorporate these into development planning processes.

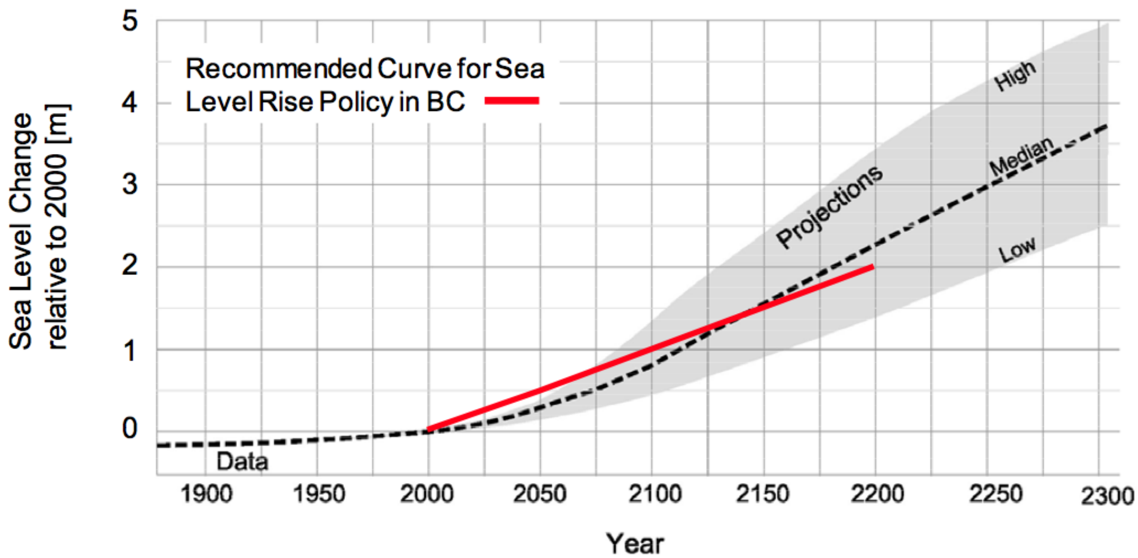

Figure 7 BC planning benchmarks for SLR (Source: Ausenco Sandwell, 2011a).

Over the 2012-2013 period, the Province released the *Cost of Adaptation – Sea Dikes and Alternative Strategies* (Delcan, 2012), and the *Sea Level Rise Adaptation Primer* (The Arlington Group, 2013), and the to expand understanding of the full range of methods BC municipalities could use to adapt to flood risks along their shorelines. Four broad categories of adaptation strategies – protect, accommodate, retreat, and avoid (Delcan, 2012) were divided into both structural and non-structural options. *Protect* was categorized as a structural option, while *accommodate*, *retreat*, and *avoid* were categorized as non-structural options (Delcan, 2012; The Arlington Group, 2013). Of a total of 33 Lower Mainland municipalities, the adaptation *protect*, through dike construction was identified for 29 municipalities (Delcan, 2012). Additionally, a *$9.5 billion* total was estimated as the cost for municipalities in Metro Vancouver to adapt to SLR (Delcan, 2012).

4.3 Metro Vancouver adaptation initiatives

For the purposes of this thesis, the research focuses on the coastal CCA in Metro Vancouver. This includes the adaptation plans, approaches, and initiatives of adapting to SLR and flood hazards influenced by SLR, such as tidally influenced rivers, and extreme events along the coast such as strong storms and wind events.

Under the provincial policy context just described, a number of municipalities have been actively pursuing adaptation initiatives to respond to SLR and changing flood risks. Broadly, many actions to date have focused on developing municipal adaptation plans, conducting hazard and vulnerability assessments, updating local flood construction levels, funding dike and pump station maintenance, and incorporating climate change policy into Official Community Plans (OCPs). Municipalities may also utilize land-use planning tools for CCA, through development permit areas (DPAs) and zoning in flood-prone areas to limit development in areas susceptible to flood hazards (FBC, 2016). At-present, most non-structural SLR adaptation that has been implemented is a minimal component of municipal adaptation actions such as conducting studies and producing plans (Lyle & Day, 2003; Lyle & McLean, 2008). Most adaptation actions implemented represent structural adaptation involving upgrades to dike infrastructure.

It has been well documented that most of Metro Vancouver current dike heights do not meet the new provincial guidelines in the region – only 4% of assessed dike segments in the Lower Mainland meet provincial standards for dike crest height (NHC, 2015a; FBC, 2016). Northwest Hydraulic Consultants Ltd reported that a reoccurrence of the 1894 or 1948 floods in the Lower Mainland would cause extensive dike overtopping and failure (Lyle & Mclean, 2008). As many communities in the Lower Mainland rely on structural flood protection from dikes and are in need of major upgrades (FBC, 2016), it is understandable that structural adaptation is a short-term priority for local governments.

There are many challenges facing Metro Vancouver municipalities hoping to adapt to SLR and flood risk. The combined effects of SLR, coastal erosion, and flood hazards, including storm surge and king tides, all pose major risk to the Lower Mainland's population and assets. These risks have the potential to overwhelm municipal resources, heavily reliant on a system of aging coastal and flood defence infrastructure that is unable to cope with rapid floodplain development, changing flood risks, and SLR. Despite the challenges, municipalities are taking action. The following paragraphs describe the coastal adaptation policy and practices of the City of Vancouver, the City of Surrey, and the Corporation of Delta. Municipalities are also referred to as Vancouver, Surrey, and Delta.

4.4 Case Study Municipalities

4.4.1 City of Vancouver

The City of Vancouver (see Fig. 6) is surrounded by water on all three sides, and is the most populous city in British Columbia, with over 650,000 people (BC Stats, 2016). Burrard Inlet and the North Shore mountains bound Vancouver to the north, the Fraser River to the south, and the Strait of Georgia to the west. A diverse and vibrant cosmopolitan city, Vancouver is internationally recognized as a burgeoning centre of coastal, economic, and tourist activity, with increasing growth and development interests.

The largest flooding threats for Vancouver are overland flooding from heavy precipitation, and coastal flooding from SLR and increased intensity of coastal storms and wind events (City of Vancouver, 2012). Vancouver is not protected by dike infrastructure and traditionally has had no designated floodplains. Projected SLR due to climate change is anticipated to expand and create new floodplains, thereby increasing the risk of flooding and inundation (NHC, 2014).

Vancouver adopted a Climate Adaptation Strategy in 2012 as part of its Greenest City Action Plan. The Climate Adaptation Strategy is based on ICLEI adaptation planning tools[2], and includes information on climate change impacts, vulnerability and risk assessments, and a detailed implementation and monitoring section (City of Vancouver, 2012).

The Climate Adaptation Strategy outlined SLR as a priority action to plan for anticipated local climate change impacts (City of Vancouver, 2012). The related Coastal Flood Risk Assessment (CFRA) intends to address anticipated SLR and design a plan for adaptation solutions. Through the CFRA, it was determined that with SLR of 1m, $7 billion of City assets are in the floodplain, representing almost 13km^2 of City lands (Lyle et al., 2015).

Phase 1 of the CFRA completed in 2014, included hydraulic modelling to determine determining changes to the extent and depth of floodplains over time with SLR; flood hazard maps which incorporate future SLR and storm scenarios; a vulnerability assessment identifying infrastructure, services and population at risk and associated potential consequences of flooding; and recommendations to reduce flood vulnerability and exposure to residents and property (NHC, 2014). With the increased risk of flood damage, Vancouver City council also adopted amendments to the building bylaw to incorporate SLR. Based on modelling and SLR projections, a new FLC of 4.6m was adopted where previously it was 3.5m since 1972 (City of Vancouver, 2014).

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[2] ICLEI – Local Governments for Sustainability, works with local governments to develop strategies to plan and implement solutions for mitigation and adaptation. For adaptation, municipalities are guided through the Five Milestone process of the Building Adaptive and Resilient Communities tool (BARC). This resource is designed to support strategic adaptation planning by developing a municipal adaptation plan, identifying climate change impacts and risks, assessing available adaptation options, and designing appropriate adaptation initiatives. Furthermore, ICLEI fosters capacity building and knowledge sharing for local governments across Canada.

Phase 2 of the CFRA was completed in 2015. Phase 2 outlines a number of specific adaptation options, alternatives, and trade-offs for eleven at-risk zones within the City (Lyle et al., 2015). The generic adaptation strategies established for the City include adapt, protect, and retreat (Lyle et al., 2015), represented in Figure 8. Additionally, CFRA Phase 2 provides a framework for addressing long-term risks given the inherent uncertainty associated with SLR, and promotes striving for flexible solutions that will work under many climate change scenarios. In this phase, Vancouver is engaging with the public and seeking input on the CFRA and SLR adaptation strategies.

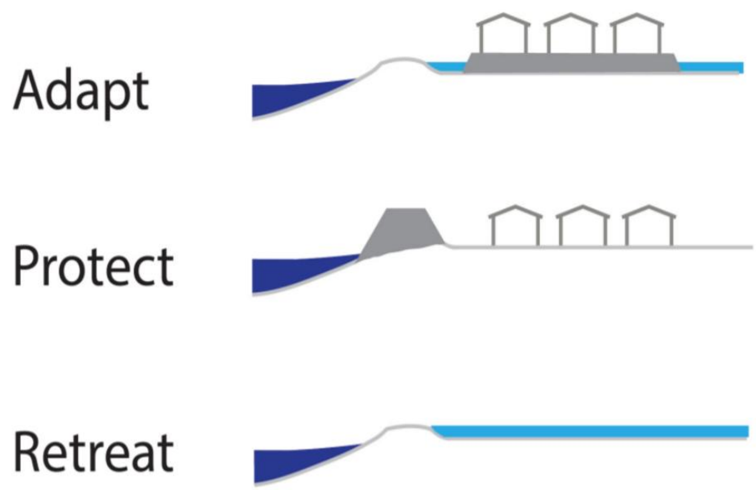

Figure 8 City of Vancouver generic coastal adaptation strategies (Lyle et al., 2015).

4.4.1.1 Status of Managed Retreat for the City of Vancouver

With the inclusion of managed retreat within the Climate Adaptation Strategy and the more recent CFRA, it can be determined that current policy for Vancouver supports managed retreat as a high-level potential adaptation strategy to SLR. Although, it is important to recognize that managed retreat still remains a theoretical approach for the City, with no plans underway to apply the retreat strategy.

Within Phase II of the CFRA, managed retreat is considered an exposure-reducing strategy, theoretically achieved by long-term and opportunistic buyouts of homes and businesses, removal of infrastructure, and followed by re-naturalization of the area (Lyle et al., 2015). In Phase II of the CFRA, managed retreat is theoretically considered for three out of the eleven at-risk zones due to the low population in the area: Southlands, Jericho-Spanish Banks, and Brighton Beach. However, it was recognized that managed retreat has significant implementation challenges, would imply the loss of valuable land, and is expensive. Therefore, the status of managed retreat for the city remains a high-level adaptation strategy, with no implementation plans.

4.4.2 City of Surrey

The City of Surrey (see Fig. 6) has a population of 540,000 (BC Stats, 2016) and is bounded by the Fraser River to the north and the Pacific Ocean on the southwest. Surrey has three tidally influenced rivers including the Nicomekl River, Serpentine River, and Campbell River. Surrey's land use is a mix of residential, industrial, agricultural, and parkland protected by over 100km of dikes, 30 pump stations, 170 flood boxes and spillways (City of Surrey, 2013).

Surrey is Metro Vancouver's second largest municipality with rapidly increasing urban and economic development. Surrey has over 8500 hectares of land currently within the four floodplains: the Fraser River, Nicomekl/Serpentine, Campbell River, and Boundary Bay floodplain (City of Surrey, 2013). It is estimated that within these floodplains there is over $1 billion in assessed property value, over 30km^2 of productive agricultural land, and significant natural areas (City of Surrey, n.d.).

By using an 'avoid' strategy, Surrey has managed to concentrate most of the high density residential and urban development out of the floodplains, while low density development, and land uses such as agriculture exist in the low-lying areas of Surrey. Around 1,500 residents live within the floodplains, in communities such as Crescent Beach, Cloverdale, Colebrook, Mudbay, and Panorama/Grey Creek. Council adopted the "Development within the Nicomekl and Serpentine River Floodplains" policy in 2008, which, despite its title, actually restricts development within the Serpentine/Nicomekl 200 year floodplain (City of Surrey, 2013). However, historic communities, such as the beachside community Crescent Beach, located at the southern tip of Surrey bordering Mud Bay and Boundary Bay, are subject to flooding and SLR.

Climate change is anticipated to increase the risk of flooding in Surrey in multiple ways (City of Surrey, 2013). SLR and more intense storm surges threaten to breach dike infrastructure, and SLR in combination with heavy precipitation may cause more frequent inundation in the floodplain (City of Surrey, 2013). Changes in snowmelt, temperatures, and precipitation may also alter Fraser River freshet enhancing the flood risk on the Fraser (City of Surrey, 2013). Additionally, local subsidence is expected to raise the SLR projections. As a result, when combining local sinking with SLR, Surrey is projected to see a SLR of 1.195m by 2100 (City of

Surrey, 2013). Surrey's coastal dikes do not provide adequate protection against current flood risk and with future SLR by 2070, would likely overtop multiple times a year (NHC, 2015b).

Surrey adopted its Climate Adaptation Strategy in 2013 as part of their Community Climate Action Strategy. The Climate Adaptation Strategy was developed using the ICLEI adaptation tool and this Strategy identifies anticipated climate change impacts and risks, sector impacts, actions and targets, indicators, and monitoring approaches. The Adaptation Strategy uses a risk management approach and has been integrated into the City's existing risk management frameworks and municipal departments (City of Surrey, 2013).

Surrey is working through their Coastal Flood Adaptation Strategy (CFAS) to identify priority areas for protection from SLR and coastal hazards, and to engage the community in identifying long-term adaptation strategies. The generic adaptation strategies of protect, accommodate, retreat and avoid are identified in their Climate Adaptation Strategy (City of Surrey, 2013) and modified slightly for their CFAS, including protect, accommodate, retreat, avoid, or a combination of approaches.

The impacts of SLR and climate change are already being felt in Crescent Beach. The interaction of higher sea levels, high tides and subsidence has raised the ground water table, resulting in drainage and flooding impacts (City of Surrey, 2013). Surrey has been actively involved in addressing climate change impacts in Crescent Beach, and is currently developing adaptation strategies through the Crescent Beach community charrette series, which involves the participation and perspectives of local residents. The charrette meetings generated a dialogue with residents to help them understand SLR and flood risk, and to discuss possible responses to the challenges ahead (Seiferling et al., 2016).

4.4.2.1 Status of Managed Retreat for the City of Surrey

Managed retreat is included as a potential SLR adaptation option for Surrey in their Climate Adaptation Strategy, as well as their CFAS. Although managed retreat is noted in a number of policy documents, it lacks refinement and detail and remains a high-level adaptation option along with similar flood protection options including realignment and re-naturalization.

As part of the Crescent Beach community charrette series meetings, managed retreat was not considered an adaptation option for the community, despite being regarded as an overarching adaptation approach. Instead the City focused on protect, and presented four conceptual protect scenarios for the community (Seiferling et al., 2016). Although the purpose of the charrette series is to educate, engage, and design possible responses to SLR and flooding for the Crescent Beach community, there remains questions as to why managed retreat was not presented, nor explored in-depth with the community. In this regard, managed retreat is only considered at a high-level adaptation option for the City, with no operational plans.

4.4.3 Corporation of Delta

Surrounded by water, the Corporation of Delta (see Fig. 6) is located at the mouth of the Fraser River and the Pacific Ocean and has a population of 102,000 (BC Stats, 2016). Land use is a mix of residential, industrial, agricultural, parkland, and an important component of this land use is an economic transportation and shipping gateway. With land historically reclaimed from the sea for farming, this low-lying municipality is between 0 - 2m above sea level and is protected by over 60km of dikes, as well as flood boxes and pump stations (Corporation of Delta, 2016b).

The municipality is exposed to riverine flooding, coastal flooding, and flooding from heavy precipitation. Delta has experienced many flooding events, with the primary threats due to spring freshet flooding, and coastal flooding from winter storms (Crawford, MacNair & Tatebe, 2013). In 2006, and more recently in 2016, Delta experienced major winter storms, with strong winds that combined with a morning high tide to produce damaging storm surges (Corporation of Delta, 2016a). In the 2006 event, waterfront homes in Beach Grove and Boundary Bay were inundated by the storm surge (Forseth, 2012).

Delta is currently undertaking a phased approach to dike upgrading, adding 0.6m by 2050 and 1.2m by 2100 (Corporation of Delta, 2016b). The dike system in Delta is currently between 3.4 - 4.2m above sea level with some private dikes at lower elevations, and currently in need of rehabilitation (Corporation of Delta, 2016b). The Delta Council is expected to review and update OCPs and DPAs reflecting flood protection, update dike height requirements and FLC for 2100 SLR (Corporation of Delta, 2016b).

Over 52% of the land area of Delta is the Agricultural Land Reserve (ALR), comprised of over 200 farms, most of which are actively farmed (Crawford et al., 2013). Climate change driving SLR threatens to inundate farms more frequently. Additionally, salt water intrusion from rising sea levels threatens to destroy valuable crops, as well as increase the salinity of water and soil reducing overall crop production and loss of land for farming (Crawford et al., 2013). The BC Agriculture and Food Climate Action Initiative, along with Delta and the Delta Farmers'

Institute, led the creation of the Delta Agriculture Adaptation Project (DAAP) to support adaptation strategies addressing climate impacts to the region's agriculture. The DAAP was completed in 2013 (Corporation of Delta, 2015). Delta is continuing to engage with the agriculture sector to protect valuable farmland and develop appropriate adaptation strategies.

CCA activities began over a decade ago with Delta Council approving the Delta Climate Change Initiative in 2007. Along with reducing greenhouse gas emissions, the initiative also set out to understand the region's climate change risks and prepare for climate change impacts. Delta has also worked extensively with the Collaborative for Advanced Landscape Planning at the University of British Columbia (UBC CALP) to better understand the processes and range of adaptation options to protect against SLR (Barron et al., 2012). CALP researchers produced a report visualizing future impacts of SLR and modeled adaptation options: hold the line, reinforce and reclaim, managed retreat, and build up (Barron et al., 2014). Delta also commissioned a *Flood Management Study* prepared by Kerr Wood Leidel Associates Ltd (2007), a Flood Risk and Consequence Study by Delcan-DHV (2010), and a *Sea Level Rise Breach Analysis – Technical Memorandum* prepared by Delcan-DHV (2011), to better understand the flood risk. These documents are not currently publically available.

4.4.3.1 Status of Managed Retreat for the Corporation of Delta

Managed retreat as an adaptation strategy for Delta's coastal land is not specifically supported in current policy or programs for adaptation and flood management. Although the UBC CALP (2009-2012) SLR study assessed managed retreat as a potential adaptation strategy, it seems the status of retreat remained unchanged for the municipality. In addition, the DAAP does not make any reference to retreat for agricultural land facing rising seas.

To address SLR, Delta plans to update flood policy to consider "new dike elevations for new developments taking into account future sea level rise", as well as "structural work that will raise and stabilize the dikes to ensure continued community protection in the coming decades" (Corporation of Delta, 2016b, p. 2). Delta's flood protection strategy support dike upgrades and improvements, sustainable and long-term funding for dike upgrading, research activities supporting impacts and solutions, and SLR monitoring. The policy direction for Delta does not endorse managed retreat.

4.5 Summary

Climate change is driving SLR and changing flood risk in Metro Vancouver. Historical flood protection using dikes, seawalls, and past flood policies is now recognized as insufficient in the face of rising seas and in need of updates to incorporate future risks. Although Metro Vancouver's coastal municipalities Vancouver, Surrey, and Delta face potential consequences from SLR and changing flood risk, each municipality is taking early steps to adapt. Each municipality is conducting studies and assessments to understand their risks and vulnerabilities, and identifying potential adaptation strategies. However, there are challenges determining appropriate adaptation strategies and implementing adaptation for each municipality. In addition, while managed retreat is specifically stated as a potential SLR adaptation option to consider in Vancouver and Surrey's adaptation strategies, managed retreat is not specifically identified for Delta. This research identifies barriers for coastal adaptation in Metro Vancouver and explores the consideration and experiences of the adaptation option of managed retreat, and barriers to applying the approach for each municipality. Moving beyond the high-level consideration of coastal adaptation and managed retreat, the results explore these concepts in greater detail through the actor-centred KI interviews.

CHAPTER 5 RESULTS

5.0 Overview of results

The results explore coastal adaptation approaches and barriers to adaptation to SLR in Metro Vancouver summarized from key informant (KI) interviews. Three topics are addressed; first, the factors that influence the choice of structural and non-structural methods for coastal adaptation; second, barriers to coastal adaptation for SLR are presented for Metro Vancouver; and finally, barriers specific to managed retreat are discussed for Metro Vancouver and the case study municipalities[3]. *Coastal adaptation* is used as an umbrella term to refer to flood management and coastal adaptation efforts to SLR in Metro Vancouver.

5.1 Factors that influence structural and non-structural adaptation responses

With few exceptions, coastal adaptation plans and actions in Metro Vancouver emphasize structural measures, which will continue to be a priority for implementation in the short-term. In contrast, non-traditional, soft structural, and non-structural approaches did not have a significant presence due to a lack of critical guidance and support needed to assist municipalities in moving forward with measures alternative to structural solutions. The structural approach is largely the primary coastal adaptation approach pursued for early adaptation actions to future SLR in Metro Vancouver municipalities and therefore is focus of the following account of factors that influence adaptation responses.

5.1.1 Structural coastal adaptation as a 'first resort' option

Hard, structural *protect* measures (i.e. dikes and seawalls) are the traditional approach to flood risk reduction in the Metro Vancouver. Both policy documents (i.e. adaptation plans) and opinions of the majority of local and regional KI's suggest this approach will continue to be used for coastal adaptation to SLR. Future coastal adaptation actions indicate constructing new dikes,

[3] Results were obtained from a review of KI responses. In order to aid the interpretation of the results, a rubric below (Table 5) was developed to associate the number of KI's that discussed, mentioned, or commented on specific subject matter.

Table 5 Key informant guide for in-text mentions	
None	0
Few	1-5
Several	6-13
Many	12 - 19
Most	20 - 26
All	27

and raising and widening existing dikes. There are no known plans to decommission or remove dike infrastructure in the region. The most common *protect* methods in Metro Vancouver include dikes, seawalls and floodwalls, rip rap shorelines, groynes, revetments, flood gates and flood pumps, and erosion control and sediment management. Vancouver, despite little coastal flooding historically, is exploring new *protect* adaptation options: *protect* adaptation options in Vancouver's CFRA Phase II include sea barriers, dike construction, raising a road to function as a dike, raising seawalls, and protection with armouring (Lyle et al., 2015). Surrey has identified numerous potential flood protection options including raising dikes, floodwalls, surge gates, and secondary dikes, along with non-structural solutions (City of Surrey, 2016). Delta is upgrading its dike network and raising it approximately 1.2 metres by 2100 to accommodate future SLR along with Provincial dike seismic stability considerations (Corporation of Delta, 2016b).

When asked about the preferred approach for coastal adaptation (given the protect, accommodate, retreat, and avoid options) for Metro Vancouver, many KI's suggested that *protect* was the favoured approach since it was the "least expensive", "easiest", and "least disruptive". KI's revealed several other reasons why *protect* adaptation measures are preferred. These reasons are further described in sections 5.1.1.1-5.1.1.7:

5.1.1.1 Legacy of the historical approach to flood management

The historic use of structural measures for flood protection in the Lower Mainland is one of the main factors that influences current and future use, and the preference of *protect* options for coastal adaptation. Reviewed in Chapter 3, the Lower Mainland has approximately 500km of dike infrastructure. Dike infrastructure has allowed settlement in flood-prone areas. As one KI explained, "...protect, you know, it's the most obvious [option], and it's what we've done already because we had to dike to live here. So that's the traditional approach" (RKI15). Following dike construction, agriculture, industrial and transportation infrastructure, and residential development occurred in what were previously unprotected floodplains and low-lying areas that historically flooded frequently. The damages from the 1948 Fraser River flood triggered a flood control program that mainly focussed on structural protection. Dikes were raised and strengthened during the 1960's and 1970's, and development in the now protected floodplains continued (Lyle & McLean, 2008). Several KI's noted that the existence of the dikes, and periodic expensive upgrades to these dikes, maintain the legacy of structural approaches for future SLR and coastal adaptation decisions. Wise et al. (2014) and Burch (2010) refer to this as “path dependency” or “lock-in” for CCA.

Research revealed that there is a mixed history of use of non-structural coastal adaptation options. Some non-structural flood management *accommodate* approaches have been used for many years to manage flood hazards (e.g. planning tools, zoning tools, building codes, covenants, public education) while *retreat*, and non-traditional adaptation options such as green infrastructure, have less of a history in the region. However, it is difficult to update past policy to incorporate new SLR risk information. It will take time and experience for other non-structural options to gain traction and normalize due to the legacy of the structural approach. However, a few KI’s suggested that if a community has had no prior need for structural protection measures, the municipality will more likely consider a wider range of approaches.

5.1.1.2 Familiar design and function to protect

Structural flood protection infrastructure are human-made structures that, either through original design or future upgrades, allow municipalities to factor in future SLR. These structures are methodically designed, constructed, operated and maintained to serve a particular function and to protect to a certain level or design criteria. Engineers and practitioners have experience in how to design, construct, and raise dikes to include SLR allowance, which is a factor in selecting structural protection.

Dikes protect people and assets behind the structure. Updated *Sea Dike Guidelines* (Ausenco Sandwell, 2011c) for BC recommend planning for SLR thresholds of 0.5m by 2050, 1m by 2100, and 2m by 2200. BC’s *Sea Dike Guidelines* (Ausenco Sandwell, 2011c) suggest that for year 2100 an additional 1.0m added to current dikes will protect against a overtopping and inundation caused by expected SLR in addition to calculating for new high tide levels, subsidence or uplift, storm surge, wind and wave effects, and freeboard; referred to as the ‘Designated Storm’. Several KI’s noted that the widespread use and understanding of statistically based dike criteria and methods make application of new dike requirements easy to design and apply in principle. In addition, by choosing structural flood protection, local governments can clearly meet the provincially recommend SLR safety targets of an additional 1m by 2100.

Generally, the BC Provincial Government recommends *accommodate* in combination with structural flood protection to incorporate updated FCL’s, and this approach was found in all three case study municipalities. Vancouver, Surrey, and Delta each have evaluated BC’s recommended SLR safety threshold of 1m by 2100 for their respective sensitive coastal areas. Several KI's communicated scepticism about the ability of non-structural responses, or soft structural approaches such as ecosystem-based approaches, to defend against a SLR of 1m by 2100, or the designated storm. There is a shortage of monitoring and evaluation of the performance of these projects in comparison to the long-term understanding of dike infrastructure and performance. This led some KI's to mention the lack of political confidence and professional familiarity with non-structural adaptation options. The familiarity with and confidence that dike infrastructure can protect to a specified threshold hampers implementation of other non-structural approaches.

5.1.1.3 Unintended government reinforcement

Many KI's identified 3 key government actions regarding flood management and coastal adaptation that inadvertently encourage hard, structural protect measures at the expense of a broad suite of new and flexible adaptation. First, one factor discussed was the funding pledged by senior levels of government to assist in municipal coastal adaptation. Funding to municipalities for flood projects is limited to dike upgrades and infrastructure, with few non-structural projects qualifying for funds (Box 1). Thus, it is no surprise that local governments often apply for grants specifically for structural flood protection projects such as dike infrastructure or pump station upgrades. Funding for non-structural projects is either inaccessible or limited to conducting coastal vulnerability and risk studies.

Second, the 2003/2004 legislative changes shifted flood management responsibility, and by extension, coastal adaptation, from provincial to local government through the *Local Government Act*. Local governments must therefore be actively engaged in coastal adaptation, although many KI's expressed that local governments are not equipped to be proactive with current resources. As one KI noted *"*…the BC government devolved responsibility for designating floodplains and managing dikes to municipal governments, but didn't give them the money to do this, so local governments - which don't have any money, now have this huge responsibility and expense" (RKI16). Moreover, the provincial government promotes a combination of structural and non-structural approaches for their Integrated Flood Hazard Management (IFHM) Program. However, local governments lack incentives to use non-structural responses that limit floodplain development and instead rely on dikes and other structural flood protection. As one KI explains the provincial IFHM program "…doesn't have any regulatory teeth. What actually has regulatory teeth in BC comes out of the *Dike Maintenance Act* and land use guidelines which says pretty much the opposite, that protect is the only response" (RKI3). BC's *Dike Maintenance Act* and *Drainage Ditch & Dike Act* provide the main policy framework for local governments to manage their flood risks, primarily using structural flood protection. Therefore, it is not surprising that structural *protect* is the preferred option for local governments: there are more opportunities for funding partnerships with senior levels of government, structural protection is clearly addressed and supported in B.C flood policy, and non-structural approaches are not promoted to the same extent.

Third, KI's frequently discussed the impact of Provincial Government guidance documents[4] on coastal adaptation. Local governments are required to consider (but not obligated to follow) these guidelines, which offer guidance to plan for SLR and coastal hazards. Despite the complexity of SLR and changing coastal hazard risks from climate change, provincial SLR planning benchmarks of 1m by 2100, and 2m by 2200, are understandable targets for local governments to commit to with diking infrastructure. Working toward these targets with a single adaptation approach (diking) mitigates some local government liability concerns related to the flood protection local governments should be doing to protect their communities from SLR impacts and coastal flooding.

Non-structural coastal adaptation, including both *accommodate* and *managed retreat* is included in BC flood policy. However, many KI's identified barriers such as the lack of clarity in *how* to implement, and unclear financial and legal implications of non-structural adaptation or alternative, ecosystem-based adaptation. For example, although some policy documents suggest that *managed retreat* is an option, KI's commented on the lack of implementation guidelines, procedures, or recommendations to follow.

Despite the lack of existing policy guidance for soft structural and ecosystem-based adaptation approaches, Metro Vancouver has a growing number of recent projects. For example, Jericho Beach in Vancouver represents a successful coastal shoreline restoration project using Green Shores. Green Shores is a voluntary ecosystem-based shoreline restoration method, which restores natural shoreline physical processes, habitat, and water quality. The restoration of Jericho Beach has created a new recreation space for the public, as well as supporting ecological

[4] Three reports from the BC Ministry of Environment: *Draft Policy Discussion Paper* (Ausenco Sandwell, 2011a), *Guidelines for Sea Dikes and Coastal Flood Hazard Land Use* (Ausenco Sandwell, 2011b), and *Sea Dike Guidelines* (Ausenco Sandwell, 2011c).

and shoreline features. The total cost of the project was $2,527,000 funded by the City of Vancouver. This project is recognized as significant for the City, setting a precedent for ecosystem-based designs for future plans (Stewardship Centre for BC, 2014). These additional benefits can be leveraged and publicized for influencing a broader discussion on alternative coastal adaptation responses.

Box 1 Province provides flood protection funding for City of Surrey dike infrastructure

In a News Release on Wednesday, July 6th, 2016 the Province announced $15.52 million in Provincial Ministry of Emergency Management (EMBC) funding toward two flood protection projects for Surrey. Surrey is contributing $10.06 million toward the projects. The first project will raise the Fraser River dike along approximately 2,000 meters of the Fraser River, protecting a high-density mix of industrial, commercial, and residential properties, as well as utilities, gas and water main lines, and railways and port lands. The second project will upgrade the Colebrook Dike and renovate the Colebrook pump station. The Province is also transferring dike operations and maintenance of the Colebrook Dike to the City (BC Gov News, 2016).

Provincial funding given to Surrey to assist in dike upgrades is welcomed given the extent of Surrey's dike infrastructure and the low elevations of the existing dikes. Speaking about the Colebrook Dike, one KI expressed that the move for the Province was a strategic withdrawal from a direct role in the operation of flood management: "that dike is currently owned by the Province and they wanted to hand over ownership over to the municipality so they wouldn't have to deal with it in the future, because they have no staff to manage these things anymore" (RKI17). The funding provided by the Province was for structural flood protection only, rather than for non-structural options or a blend of structural/non-structural options. One KI suggested the investment further ensures the path dependency of dikes in Surrey: "they have plunked 15 million dollars into building this dike so the fact that that dike is going to be constructed in the next year kind of you know, forces the hand of the people doing the strategy work. Because all of a sudden they've spent 15 million dollars on the dike and that's going to play in every decision that they make. If you retreat after you've spent 15 million dollars of public funds it's going to look stupid" (RKI17).

Additionally, funding was directed from the Ministry of Emergency Management, and the news release did not refer to SLR or CCA. Instead, dike upgrades are viewed as being part of hazard mitigation and public safety preparedness. The funding actions of the Provincial Government, focusing on structural flood management and adaptation, is further evidence of the Government's central focus on structural approaches for short-term hazard and disaster preparedness.

Figure 9 News Release photo of EMBC and City of Surrey funding announcement for flood protection. July, 2016. (Source: https://news.gov.bc.ca/releases/2016TRAN0181-001225).

5.1.1.4 Economic growth and development potential

There are many implicit advantages of proximity to the waterfront, ranging from aesthetic to economic advantages, making *managed retreat* more challenging in developed coastal areas. Although expensive, hard structural flood protection maintains the economic viability of a particular coastal location. *Protect* thus becomes favourable in sites with greater economic activity as one KI put it "it may be that in more densely populated, more intensely developed areas there is a rationale to invest more [and] to protect more" (RKI1).

Construction of structural flood protection typically maintains or may enhance the development potential and desirability on the landward side of the engineered infrastructure, a concept known as "the levee effect" (Smith, 2013). The decision to *protect* often encourages further development behind the protection infrastructure (Ausenco Sandwell, 2011a). One KI explained how dikes can incentivise economic growth:

> "I could picture irony here where there may be some areas that you would say wait a minute, that's in an area where the sea level rise is going to occur, but the municipality is thinking yeah but in this area were going to look at diking. And to make the diking worthwhile, [if] we are going to spend the money to dike the area, we might as well let more people in the area. So you're going to have some weird, contradictory policies potentially taking place" (RKI16).

Although hard structural protection infrastructure is costly, many KI's noted that there is a cost-effective rationale to *protect* high value infrastructure and residential properties along the shorelines of Metro Vancouver. Buyouts for *managed retreat* are seen as more expensive than structural protection given the current market value of Metro coastal land and property: "the value of the infrastructure, and the homes, and everything built behind the dikes and seawalls, there's a lot of people, [it] makes sense to protect what's there." (LKI6). Waterfront property is typically the most desirable and most expensive, it is difficult for local governments to limit the development potential. High value assets for the region provide a strong foundation for economic growth while at the same time posing huge costs for a *managed retreat* strategy. From an economic perspective, it makes sense to *protect* with hard, linear infrastructure.

5.1.1.5 Engineered paradigm response

The engineering profession, as well as the education, training, and past and current culture of flood prevention and control, serve as factors in encouraging the traditional structural approach. One KI commented:

> "…protect is the one that people lean towards. And I think there are a ton of reasons for that. Mostly it's historic. A lot of these projects come out of engineering departments. Engineering responses engineering solutions" (RKI3).

Among the group KI's who mentioned this as a factor, it was strongly noted that ecosystem-based coastal adaptation was not taught in formal education, and there was limited knowledge of what training was available. For a few KI's, the structural approach is familiar, engrained in tradition, and difficult to change. As one KI noted "A lot of old school guys – 50 to 60 years of age – engineers want to build hard structures because that's what they've done forever" (RKI6). In addition, one KI recognized that terms such as "flood control", "flood defence", and "flood protection" (e.g. terms in the title of Surrey's *Coastal Flood Protection Strategy*) lends itself to a certain approach, namely a structural approach. Moreover, stationarity-based dike designs for flood protection still dominate engineering and scientific circles (Milly et al., 2008).

In some cases, non-structural approaches demand less expertise related to engineering practices and instead rely on expertise related to collaboration with planners and policymakers. One KI summarized "no one is interested in the governance piece… like that just falls off the table… no one talks about it because no one sees any value in it" (RKI17). The dominant paradigm and confidence in engineering solutions to flooding prevents a broader discussion on non-structural adaptation.

5.1.1.6 Public and political backing of structural flood protection

In general, the research revealed that politicians and the public in Metro Vancouver trust structural flood protection. Certainly, on a day-to-day basis, the dikes in Metro Vancouver serve their function to prevent inundation. KI's noted a limited understanding the technical jargon of structural approaches and understanding of available alternatives for coastal adaptation. This constrains other adaptation choices and leads to a general acceptance of structural solutions, despite the inability of dikes to protect against flood and storm surge events that exceed their design criteria. Technical language used by professionals is not well understood by policymakers and the public. For example, AEP, Designated Flood, or Designated Storm are common flood management calculations to determine an acceptable elevation to design flood protection infrastructure in BC. However, the public often misunderstands these probability models; they do not know that dikes do not protect against larger events that exceed design thresholds. One KI noted "so obviously all these (provincial) funding announcements for dikes make people think that they're going to be protected when they might actually be making the situation worse" (RKI17). A few KI's noted that the public and political confidence in structural protection is so high that most Metro residents do not think that the dikes could fail in their lifetime.

When commenting about non-structural coastal adaptation, a few KI's noted that adaptation strategies or policies that suggest building restrictions, or relocation of infrastructure and property, and restriction of development in floodplains would be socially and politically "unpopular" and "unfair". Many *accommodate* strategies (e.g flood proofing, elevating property, and ecosystem-based or Green Shore soft structural approaches) are the financial responsibility of the homeowner to adapt their property, making this an undesirable choice. The transfer of responsibility to the homeowner means less incentive for the municipality to provide funding or support.

5.1.1.7 Dikes offer an immediate and tangible effect of protection

Another factor influencing the preference for structural flood protection and coastal adaptation is the desire for immediate and tangible results from projects. For municipalities in charge of coastal adaptation projects, dike construction leads to obvious visual 'proof' of action. When selecting adaptation options, politicians may look for an option that is an easy sell to the public and is quick to serve the community. As one KI explained "there seems to be a desire, … for more immediate returns, like where you see the more direct benefit to the community. The dikes are, you know people use them" (LKI7). One KI elaborated:

> "…all these press releases have these beautiful photos of dikes and people on dikes and they are just a really good photo-op strategy. So it's very political and public education is extremely low on this issue so people think dikes are the best response because it's, it's

> so much more clear, like its a clear response, like a tangible response to the problem" (RKI17).

Moreover, dike construction is perceived as a short-term project, which can be serving its function to protect the public from inundation and storm surge in under five years. This is in comparison to a *managed retreat* strategy, which is phased over decades, and where inundation may not perceived as an immediate threat. Additionally, other non-structural *accommodate* policies such as changing building codes are not visual or tangible for the public until redevelopment of existing buildings is needed, or new buildings are constructed. Structural *protect* coastal adaptation methods offer direct protection for the area, and a perceived return on investment in coastal adaptation.

5.1.2 Summary

Structural *protect* options are clearly the first resort or stand-alone coastal adaptation responses in Metro Vancouver. This is due to historical use and path dependency, familiar design and function, government support, maintenance of economic imperative, devotion to engineering solutions, the public and political acceptance, and a desire for fast and tangible results.

In general both *accommodate* and *retreat* options, and soft-structural measures, are used sparingly, and are not emphasized as flood or coastal adaptation approaches in Metro Vancouver. Despite this, many KI's expressed that non-structural and non-traditional coastal adaptation measures should be included in a municipality's suite of coastal adaptation strategies. Greater acceptance might require increased awareness from professionals, politicians, and the public, increased knowledge about ability to provide protection, and expanded opportunities for funding. At this time, non-structural and non-traditional coastal adaptation are generally viewed as secondary to structural approaches, while *retreat*, is generally seen as a 'last-resort' approach.

5.2 Barriers to coastal adaptation in Metro Vancouver

5.2.1 Top reported barriers for coastal adaptation in Metro Vancouver

While structural *protect* approaches for coastal adaptation to SLR are the primary approach in consideration for municipalities in Metro Vancouver, all options (i.e. *protect*, *accommodate* and *retreat*) face numerous barriers. This section addresses the main barriers to coastal adaptation in Metro Vancouver. It is important to note KI's mentioned examples of barriers from all types of adaptation barriers described in Table 4, however, the barriers presented here drew major acknowledgement from KI's. Table 6 summarizes the coastal adaptation barriers[5].

5.2.1.1 Institutional/Governance barriers

Institutional/Governance barriers were reported as a top constraint for coastal adaptation for most KI's. They discussed regulatory issues, lack of political willingness, complexity of governance systems, jurisdictional authority, and prioritization and resource distribution for coastal adaptation.

Coastal governance challenges, linked to the presence of many management jurisdictions and organizations within a coastal zone, each with diverse priorities, responsibilities, and authorities, was a barrier for most KI's. Flood hazard management and coastal adaptation in BC rests primarily with local governments, responsible for land use planning in floodplains, building structural flood protection, and implementing coastal adaptation projects (The Arlington Group, 2014). At the provincial level, flood management may cross several departments and ministries - Ministry of Forests, Lands, and Natural Resource Operations (FLNRO); Ministry of Emergency Management; Ministry of Community, Sport, and Cultural Development; and the Ministry of the Environment. The Province contributes funding, develops guidelines, and sets legislation for local implementation (The Arlington Group, 2014). The Federal government provides disaster assistance and flood recovery costs, as well as contributing to funding programs. In addition, various non-governmental and private organizations contribute to flood, watershed, and coastal management in BC. There is a mix of jurisdictional authority and responsibility, with little to no coordination and collaboration. Many KI's noted that this mix of stakeholders created confusion, silos of thinking, which complicates and slows adaptation responses. Most KI's articulated the current jurisdictional mismatch of responsibility and authority in coastal areas hinders adaptation.

[5] Some barriers are not included in the table because of few direct remarks from KI's (i.e. biological, competing values barriers, and cross-scale sensitive dynamics).

Table 6 Summary of coastal adaptation barriers in Metro Vancouver

Institutional/ Governance barriers	Social/ Cultural barriers	Financial barriers	Knowledge barriers	Human resource barriers	Economic barriers	Physical barriers
• Jurisdictional mismatch in responsibility and authority • Access to rights of way for municipal adaptation • Weak legislation to enable adaptation • Lack of leadership and support from higher levels of government • Lack of central or national agency to manage and coordinate coastal adaptation	• Attachment and investment in coastal locations • Inability to view SLR risks as an imminent issue • No sense of urgency because it is a future and long-term problem • Emotional response of denial, fear and apathy versus rational response • Upholding traditional anthropocentric versus ecocentric values	• Need for maintainable and sustainable funding • Inadequate financial revenue for magnitude of problem • Access to traditional sources of funding limited	• Lack of knowledge, expertise, and understanding of risks and consequences • Uncertainty of impacts, SLR projections, and mitigation efforts	• People involved in adaptation typically have multiple roles and cannot devote necessary time	• Protection of valuable assets to ensure economic growth • Short-term economic gain competes with long-term adaptation investment	• Physical features impede adaptation options (e.g. soil) • Other hazards (e.g. earthquake, freshet flooding) seen as a greater priority than SLR • Current infrastructure impose own challenges of how and when to retrofit and redevelop

In Metro Vancouver, important transportation and industry infrastructure operates in the coastal zone, including the Vancouver International Airport, Port of Vancouver, BC Ferries terminals, logging and shipping yards, mineral oil and coal refineries, and road and rail networks. In general, these are often owned and managed by non-municipal agencies and outside of local government control. KI's expressed concern over the lack of local government rights of way along oceanfront property to begin coastal adaptation activities. This has implications for coordinating, planning, and implementing coastal adaptation strategies. Municipalities may need to purchase rights of way, collaborate with the landowner on adaptation options, or accept that the area is beyond municipal jurisdiction.

Several KI's specifically linked adaptation barriers to the legislative changes in the *Local Government Act*, where the Province gave local governments the responsibility of flood management. The challenge for municipalities since 2003 has been how to mandate coastal adaptation or guide development away from floodplains without funding, technical support, or regulatory support from the Province. The challenge is further compounded by the poor state of upkeep of many older dikes - many dikes segments do not even meet past design criteria, let alone future SLR allowance[1]. As well, municipalities have limited avenues to generate income to provide services to communities and manage floodplain development. Municipalities rely on property taxes to support communities. A regional KI explained:

> "When you restrict development from floodplains, you reduce where people can go, you reduce your tax base, and you allow yourself to have again, even less money. So it's a really tricky situation that needs some leadership from higher up, the Province, but it's not forthcoming." (RKI6).

Furthermore, given the multiple responsibilities and services local governments must provide to their communities, adaptation must compete with other municipal interests.

The Province cannot compel municipal adaptation and the legislation for considering alternative adaptation beyond structural flood protection is weak. Many KI's identified that while the Province developed guidelines for coastal adaptation, the guidelines are ambiguous, and local governments are not obligated to follow these provincial guidelines. One KI commented "there's

[6] The design flood for the Lower Mainland is the 1894 flood of record (peak flow of 17,000 m^3/s) or winter coastal storm surge of 1:200 AEP. No dikes fully meet current provincial standard with SLR and some Fraser River dike segments may experience overtopping from a 1:20 year flood and few dikes are capable of withstanding a 1:200 year flood. Fraser River dikes in general can only withstand a 1:100 year flood (FBC, 2016).

no enabling legislation, they are giving us suggestions, but they are not giving us any sort of regulatory tools" (RKI12). The high-level guidance does not capture regional and local differences, creating uncertainties which slow adaptation. A few province-level KI's explained it is difficult to motivate local governments to adapt, as the Province lacks the authority to mandate adaptation. The Province can only recommend, support, and make sure there is access to traditional streams of funding. Some KI's suggest the lack of regulation has resulted in piecemeal flood management and coastal adaptation implementation in Metro Vancouver.

Coastal adaptation is also affected by institutional norms and lack of long-term planning. A few KI's stressed the presence of institutional norms favouring a reactive and short-term approach to adaptation which depends mainly on structural flood protection. These barriers bundle with temporal cross-scale sensitive barriers (i.e. those past decisions and legacies which can constrain future adaptation choices), as Metro's historically reactive and structural approach influences future adaptation responses. Several KI's noted that politicians primarily react to immediate flood threats or when the public demands a response. Structural protection options are implemented quickly, result in a visible response to the public, are politically acceptable, and are perceived as a historically trusted engineering solution. Lack of long-term planning was mentioned by some KI's: Decision-makers are hesitant to commit to coastal adaptation options that require long-term investment and extend beyond typical government planning horizons when resources and support are scarce.

Despite individual municipal-level coastal adaptation capacity and the support from the FBC, KI's identified a lack of coordination capacity. Many KI's agreed there is adaptation leadership in the municipalities. Vancouver and Delta were mentioned as having mayoral leadership on environmental protection and climate action, while Surrey had leadership interdepartmentally, contributing to their innovative approaches to CCA. These leaders have helped overcome resource capacity issues. Despite this, many KI's noted a need for a central agency to coordinate coastal adaptation. One KI commented:

> "Right now they [coastal adaptation projects] are done piecemeal. Some are way ahead of others; some are in the dark ages. There's no coherent methodology in Canada for managing the kind of things, to deal with coastal flooding there's no national program for it. There's no national context for how we manage that type of thing." (RKI18).

A few KI's linked this to the absence of a formal National-level institutional and regulatory structure for coastal management in Canada, which could assist to harmonise adaptation actions, among other activities in coastal zones across Canada[7]. Several KI's commented that leadership and support from higher levels of government is needed for local governments to proactively adapt and implement adaption options with a long-term vision.

5.2.1.2 Social/Cultural barriers

Most KI's identified Social/Cultural barriers, which ranged from the amenity value of oceanfront location, psychological constraints, perceptions of SLR risk, the inability for people to think long-term timeframes, and the belief that humans can overpower nature as adaptation constraints.

Metro residents' attachment to coastal locations is a key determinant for selecting coastal adaptation options. People are invested economically, socially, and culturally in the oceanfront, and many community members value coastal locations, creating strong feelings of connection to the land. Several KI's mentioned irreplaceable amenities such as the natural environment, recreational opportunities, aesthetic quality, neighbours and social networks, heritage buildings, family tradition and livelihoods as integral to living in these coastal locations, which may create barriers to certain adaptation options, particularly *protect* and *retreat*. For instance, raising a dike or seawall might disrupt recreational opportunities, block access to the waterfront, and obstruct views of the ocean. Many KI's suggested *retreat* would cause the displacement of people's livelihoods, culture and identity. Coastal locations are still seen as desirable, which will pose a future barrier as there is still demand to move to waterfront locations.

Psychological constraints were highlighted by several KI's as a barrier to coastal adaptation. They noted words like "fear", "denial", "fatigue", "scared", "disbelief", "resistance", and "apathy", as words describing barriers in public and political circles. Such strong feelings are difficult to change, which creates an obstacle for adaptation. A few KI's noted the link between public concerns about climate change and SLR and the translation of these concerns into political willingness to act. When there is high public concern about an issue, politicians are more likely to act. However, several KI's also suggested that public concern over climate change risks is not yet at a high level since the risks are not likely to affect people living today. This 'not in my lifetime attitude' was prevalent during interviews – both when KI's explained public attitude,

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[7] Following research, Natural Resources Canada has initiated a Coastal Management Adaptation Platform Working Group to bring together experts to collaborate and address common issues related to adaptation in Canada's coastal zones.

and when they expressed their personal beliefs. For example, “It’s [climate change] a good thing for children to understand and learn, because they’re going to be the ones to deal with it, probably, not me. Because it’s probably going to take a while for all this to happen” (LKI9). This psychological tendency to discount future risks and the lack of urgency poses significant barriers to implementing adaptation. Moreover, the inability of Metro residents and municipal politicians to think in long-term timeframes (i.e. 100 to 500 years out), which is what is required, makes SLR adaptation planning difficult.

The physical process of SLR and associated low risk perception was noted as a coastal adaptation barrier. Since SLR is a slow, gradual process, it is not a noticeable threat and therefore action is not perceived as needed. A few KI’s explained “because its a slower process people aren't really aware of it” (RKI2), and “the challenging thing with sea level rise is that its not a big event, but if you had like big storm surge event that was kind of exacerbated, then it might trigger something” (RKI9). The physical characteristics of SLR create a wicked problem of adapting to a slow, and invisible threat. For example one KI explained that adapting to SLR is “a staggering and overwhelming problem, at some uncertain, unknown date, that has massive implications, multiple levels of government, like its… everything about it just seems to overwhelm people” (LKI1). The social and psychological barriers that create emotions of denial, fear, or apathy of climate change risks creates barriers for adaptation as one may not feel able to engage with efforts to adapt to climate change.

Common anthropocentric attitudes that maintain human domination over nature, and resistance to adopting ecocentric attitudes – that humans must adapt with a changing climate – was identified as a coastal adaptation barrier. These constraints bundle with temporal cross-scale sensitive barriers, as Metro’s historically structural approach influences current and future adaptation responses. For example, past efforts to convert Metro’s natural flood buffers (e.g. wetlands and marshes) for agriculture, transportation, or urbanization, or diking low-lying areas across the Lower Mainland to make farming viable, reinforces human domination over nature. Continuing with engineering and traditional structural approaches to flood management upholds anthropocentric worldviews. To overcome many of the barriers to coastal adaptation, a shift, or worldview culture change will be needed.

5.2.1.3 Financial barriers

Financial constraints were a top barrier for coastal adaptation in Metro Vancouver. KI's frequently mentioned terms and phrases such as "expensive", "costly", "cannot afford", "how will we pay for this?" or "municipalities don't have the money", when referring to coastal adaptation options. Most identified the lack of financial capital and resources affect all stages of adaptation, including undertaking local climate change impact studies, risk and vulnerability assessments, planning potential options, consulting with communities and councils, creating an action plan, implementing projects, and monitoring and evaluating adaptation progress. KI's representing all three case study municipalities stressed the need for long-term and maintainable funding programs dedicated to adaptation. While each municipality has funded locally relevant coastal and SLR assessments, they will likely need financial help from senior levels of government to implement adaptation actions.

Financial barriers were paired with Institutional/Governance constraints. Metro municipalities have been given the responsibility for coastal adaptation, yet lack the necessary resources to dedicate to these activities when adaptation must compete with other municipal funded services. As municipalities only earn $0.08 of every dollar from municipal property tax, it is difficult to separate funds for adaptation. One KI summarized "municipalities get like 8% of the tax base, and deal with almost 90% of the problems. So I think they have a legitimate beef in terms of the magnitude of the problems they have to deal with and the little resources they've got to try and make it happen" (RKI18). More financial capital, funding mechanisms, and incentives were seen as essential to move forward with implementing coastal adaptation. Most KI's identified the lack of funding and support municipalities receive from senior levels of government and a lack of political will to dedicate resources for adaptation were common combinations of barriers.

5.2.1.4 Economic barriers

Economic considerations that influence coastal adaptation include valuable private property and economic assets, the focus on short-term growth, viability of low-lying economic sectors, and the perceived low return on investment in adaptation. For example, over 47% of oceanfront areas in Metro Vancouver are used for industry, businesses, and services (Culbert, 2016) and there are over 9,000 coastal properties from Lions Bay to South Surrey. Several KI's noted the exceedingly high value of these assets for the region. The Vancouver Convention

Centre is valued at $658 million alone (Pynn, 2016), and in Delta and Surrey, agricultural activities generate over $633 million annually (Robbins, Tatebe, & Crawford, 2014). Therefore many KI's mentioned the economic imperative to *protect* these assets against SLR and related coastal hazards.

Most local governments cannot afford to acquire exposed land for *managed retreat*, or acquire land needed to expand and raise a dike for SLR allowance (i.e. *protect*) given the high priced land. However, investing in dike infrastructure at least allows economic activities to continue, while *retreat* is seen to 'sterilize' potential economic growth. Given the high values of these assets, it is difficult for local governments to restrict economic development opportunities that may be exposed to future SLR and coastal hazards, and instead structural *protect* options become a cost-effective solution.

Economic barriers also hinder use of *accommodate* strategies. Some communities in Metro Vancouver have implemented policies that designate the ground level of houses (e.g. garage) as "sacrificial" first floors to prevent greater property damage in the event of a flood. However, Surrey has experienced illegal transformation of sacrificial floors of houses to rental spaces and living quarters. As one KI explained:

> "Part of it is because the housing is so expensive here, people have a mortgage, and that helps pay for the mortgage, to rent out a room. Also social issues, like low income housing is being torn down for more expensive housing types and then those people are actively looking for cheaper places to rent and all of a sudden that room that was supposed to be sacrificial, becomes a bedroom, someone whose renting it. It's challenging to accommodate" (LKI4).

Thus, economic pressures make restricting floodplain occupancy more difficult.

5.2.1.5 Knowledge barriers

Knowledge gaps, complexity, and uncertainty were considered barriers. For several KI's, these were described as lack of education and awareness of the public and politicians to understand SLR risks, projections, terminology, and consequences. They noted the lack of staff expertise or technical capacities for some municipalities in Metro Vancouver to make downscaled climate change projections and establish baseline coastline conditions. They also mentioned the lack of updated floodplain maps, inconsistent levels of data, and non-comparable data formats between municipalities.

Multiple KI's raised issues around uncertainty, which impede adaptation decision making and implementation. There is uncertainty around the local impacts of climate change and SLR being based on downscaled global climate models, or no local projections. Without information on future changes, it is difficult to plan for adaptation. Second, there is uncertainty around the magnitude and frequency of climate changes and SLR impacts. Third, there is uncertainty around the timing of SLR - when SLR will have a noticeable impact, or become a reality for people in Metro Vancouver. Four, there is uncertainty about when to begin planning and when to begin project implementation, or whether to just wait and see until SLR impacts become noticeable. Finally, there is uncertainty in global greenhouse gas mitigation efforts, and the impact that might have on the earth's climate and commitment to long-term climate changes. These uncertainties make adaptation an overwhelming problem for some practitioners and politicians, and slow decision making and adaptation implementation.

5.2.1.6 Human resource barriers

A key constraint is time to dedicate specifically to adaptation, which slows the process given that humans are primary actors in undertaking coastal adaptation activities and alleviating barriers to adaptation. One KI explained:

> "Its complicated for those people who work in those municipalities to get the information, to work with the people involved in their own staff and experts, and actually come up with something in a reasonable amount of time, with all the other things they have to do. It's very taxing, and even though pieces of information [are] available to them in their libraries, on the net, they don't even look at it. Because they are in a hurry." (RKI18).

People often work in silos in their own departments, and lack communication and integration between departments (i.e. engineering, planning, sustainability, financial departments) that can hinder adaptation. Moreover, staff require resources to assist in coordinating adaptation with other municipalities, the private sector, and within internal departments. Support and buy-in is needed from local councils to set priority and budgets for adaptation. The financial, technical, and human capacity to work through developing an appropriate adaptation path must be available. Local champions of SLR adaptation were celebrated as fostering council support, creating essential partnerships, and establishing new ways of thinking to overcome uncertainty and complexity challenges in climate change.

For several KI's, the task of adaptation was an overwhelming challenge, with many uncertainties and unknowns, thereby making it difficult to move forward. Needed were more local climate change impact studies to address salinity effects, and coastal squeeze for example. The academic backgrounds and experience of some people in high-level decision-making positions may be insufficient to address the complexity of climate change, SLR, and floods. Many KI's noted climate change education and training for decision makers and professionals as important tasks to integrate climate change into more policies, programs, and community activities.

5.2.2 Additional barriers

5.2.2.1 Physical barriers

Adapting to SLR can be constrained by physical features of a municipality, including geophysical features, hazard exposure, and built environment. A few KI's discussed local soil conditions as presenting challenges for building and upgrading dike infrastructure. One KI summarised:

> "[the dikes] are all sinking. It's called Delta for a reason right? And their soils are really soft, so any time they build the dike up it basically just sinks back down. It's a huge difference. Some of them were sinking 10-15cm per year… even if you're just managing that – you're chasing your tail - it becomes worse and worse. The higher you go the more weight on the soil. So at some point the technical solutions are not feasible" (RKI3).

Several KI's discussed issues with prioritizing different hazards, including earthquake and the different types of flood hazards. Earthquake risk is a concern for Delta and Surrey where the dikes are not up to seismic standards and may fail. Upgrading dikes to withstand the seismic risk, in addition to upgrades needed for SLR is a major financial cost for municipalities. For example, the estimated cost to upgrade Surrey's dikes with SLR and seismic upgrades is $1.57 billion (City of Surrey, 2014). As well, riverine flooding and overland flooding from heavy rainstorms present a barrier for municipalities to prioritize adaptation to SLR, because SLR is not seen as an immediate climate change risk, compared to freshet flooding or heavy precipitation.

The existing municipal streetscape and infrastructure also presents challenges to *accommodate*, and how and when to retrofit and redevelop existing infrastructure. KI's from Surrey and Vancouver suggested raising roads and streets would be aesthetically displeasing and difficult to integrate with private property, since it is the landowner's responsibility to raise to FLC's or to undertake adaptation actions only when redeveloping. This creates a mismatch in the potential timing and choice of adaptation, which may result in a patchwork of inconsistent adaptation. City planners and engineers would want to avoid this, which may ultimately result in no adaptation option being undertaken.

5.2.4 Summary

Across all scales, Institutional/Governance, Social/Cultural, Financial, Economic, Knowledge and Human resource barriers were reported as being a principal determining factor that can hinder coastal adaptation. Several local KI's also considered Physical barriers an additional obstacle in determining appropriate coastal adaptation actions in their respective municipality. Regardless of the coastal adaptation option (i.e. protect, accommodate, retreat), it seems that there are numerous barriers to coastal adaptation prior to actually selecting the specific coastal adaptation option, which pose as key barriers to begin the adaptation process. Moreover, there are also additional and unique barriers for each of the potential coastal adaptation options for Metro Vancouver that again may hinder the coastal adaptation process.

5.3 Barriers to managed retreat as a CCA strategy

Managed retreat faces numerous barriers in Metro Vancouver despite being included in multiple policy documents. This section explores local and regional perspectives on barriers to managed retreat highlighting some similarities and contextual differences between municipalities. Table 7 compiles the main barriers to managed retreat.

5.3.1 Barriers to managed retreat in Metro Vancouver

5.3.1.1 Institutional/Governance barriers

Institutional/Governance barriers were reported as a top factor constraining managed retreat by local and regional KI's. These factors were often related to political will, the municipal property taxation regime and scarce resources, jurisdictional responsibility, lack of provincial and federal support, and short-term investment interests.

Table 7 Summary of barriers to managed retreat in Metro Vancouver

Institutional/ Governance barriers	Social/ Cultural barriers	Economic barriers	Physical barriers	Financial barriers	Knowledge barriers
• At-risk areas not within municipal jurisdiction • Politically unappealing because of social and economic implications • Municipal income is based on taxes which will not be collected if land is not developed/ occupied	• Social and cultural sense and attachment to place • Amenity and environmental value of coastal living • Psychological inability to give up territory to the sea • Low risk perception of future SLR impacts • Social inequities may be exacerbated as the privileged with their expensive coastal properties are paid out by all taxpayers • Loss of sacred FN land and culture	• High land values make at-risk areas unaffordable to purchase for municipalities • Cost-benefit analysis favours protect • Coastal assets are economic generators • Do not want to forfeit economic growth opportunities as the land is valuable • Economic activity is valued higher than reducing hazard exposure	• New hazards may arise by retreating vertically up mountains (e.g. wildfires, landslides) • Land scarcity, and limited undeveloped space for people to retreat	• Municipalities are unable to afford purchasing properties	• Few examples of managed retreat strategies from which to learn • Still a new and abstract concept with little proactive application

Each municipality identified jurisdictional challenges along the foreshore as barriers to managed retreat. For Vancouver, industrial and commercial lands along the Fraser, Vancouver Harbour and False Creek are privately owned, as well as residential property in coastal neighbourhoods including Kitsilano, Southlands, Point Grey, Coal Harbour, and east parts of the Fraser River foreshore. Critical infrastructure, such as highways, bridges, ports, and an anticipated hospital, located in SLR at-risk areas, are provincial and federal responsibility. Surrey and Delta face similar challenges with critical industrial and transportation infrastructure along the Fraser River; most privately owned, or provincial or federally owned. The municipality can only recommend approaches and collaborate on adaptation implementation with stakeholders. Surrey KI's highlighted these challenges in their experience with potential realignment of a railway line that cuts through the municipality (Box 2). Some local KI's mentioned the difficulty of coordinating a managed retreat strategy, let alone any coastal adaptation strategy with multiple stakeholders and jurisdictions when several SLR at-risk areas are outside municipal jurisdiction.

A few KI's noted that various levels of municipal staff, management, decision makers, and stakeholders involved in SLR and coastal adaptation planning appear to have a clear preference to avoid managed retreat for areas that have current flood risk or future flood risk. One KI noted "the City of Vancouver, it's super progressive, council, mayor, and city management. And yet retreat fell of the table. It was purely a gut, we can't lose land thing. It was nothing to do with sound decision making" (RKI17). This highlights lack of political will or political biases influencing decision making, and also bundles with Social/Cultural barriers with the inability to give up territory. For Delta, a local KI remarked, "people were like 'no, I just can't imagine it.' And mayor and council were like 'no, we wouldn't like that.' So the answer in 2011 was no, we won't do managed retreat" (LKI3). For a Surrey KI, the key barrier was simply "politics". Managed retreat is politically unpopular because of the potential impact on re-election, which affects long term decision making for CCA.

Many local and regional KI's were frustrated that senior levels of government recommend costly adaptation strategies (i.e. financially and socially), yet do not provide sufficient support. One local KI commented:

> "Yeah and it's easy for the federal government to say retreat because they'll still collect income tax when that person moves. But for the local government, if they leave, then that land is no longer used…. and no one want to pay more tax. So the

> local government is really in the worst position to bring retreat up because it's our revenue stream that's at stake if we give up land to the ocean" (LKI4).

Municipalities have to be aware of the financial implications of retreat. With economic investment and increasing real estate prices, municipalities create a greater tax base. In contrast retreat will shrink that tax base, "municipalities have ability to zone land and to disallow development on flood prone lands, but there's an economic impact to doing that. So there's a lot of unwillingness on the part of government, to restrict development in hazardous areas." (RKI15). For example, a Delta KI commented, "no politician is going to say, yeah we've declared that a retreat zone, when the average price of a home is a million plus. There's a concern - an interest to keep real estate prices" (LKI3). For Surrey, a few local KI's remarked that it would be difficult to compensate the affected population without significant support from senior levels of government given insufficient resources. Moreover, some local KI's questioned whether it was a municipal responsibility to mandate a retreat strategy "I don't see it as a city responsibility to buy people out for managed retreat. The province or the feds have to come to the table" (LKI5). Senior levels of government have a greater resource capacity than local governments.

BOX 2 BNSF Railway relocation

The Burlington Northern Santa Fe Corporation (BNSF) railway operates along the shorelines of Surrey and White Rock BC. Freight operations run to the Vancouver Port facilities and cross the U.S – Canada boarder. Presently, freight train frequencies have increased ranging from 16 to 20 trips a day today, compared to a single daily freight train each way when it began operation in 1909. In the same time period, the railway now transports coal, oil, chlorine, and liquefied natural gas, compared to transport of mail and construction material when the railway began operation.

There are currently plans to increase train frequencies and commodity composition for the rail line. With increased settlement and development in both Surrey and White Rock, there are hazard and safety concerns for the local government and affected communities. In a corporate report to council, the City of Surrey (2015) contends that increasing freight train frequencies will create challenges including:

- Community access
- Noise disruption
- Public safety
- Bluff erosion
- Dangerous goods
- Incident management
- Environmental concerns

Local KI's explained the rail line passes over coastal floodplains in Surrey. Although SLR and increased coastal hazards from climate change is not included in the corporate report to council, local KI's indicated this is a concern moving forward for possible relocation. Local KI's indicated that the rail line was vulnerable to slope failure and there have been recurrent incidents of erosion in periods of intense coastal weather. In addition, the rail crosses over environmentally sensitive areas, prompting concerns of contamination should derailment or potential spilling should occur.

The City of Surrey is engaging with the City of White Rock and the provincial government to evaluate relocation of part of the BNSF railway along South Surrey. In addition, stakeholder consultation is required with federal agencies including transportation, environmental and trans-boarder U.S agencies. The project is expected to cost between $350 and $450 million. Given the large costs and multi-stakeholder project, the local government is looking for leadership from federal agencies and the BNSF Corporation, as well as sharing in the costs. However, cooperation has been slow and there has been minimal interest leadership. KI's indicated this is a highly contentious issue due to cost, complexity, and politics. Feasibility studies are underway, however, it is unclear if the railway will be relocated. Local KI's explained this example exemplifies jurisdictional and governance challenges for relocation.

5.3.1.2 Social/Culture barriers

Most KI's agreed that social implications of managed retreat were a major obstacle to its use for coastal adaptation. Social implications included displacement of people and communities, disruption of livelihoods and social cohesion, detachment from sense of place and amenities, the lack of public support and understanding, risk perception and long-term thinking, and loss of culture and territory.

Top of mind issues for KI's were the social and livelihood impacts of managed retreat. This is not surprising given the meaning and memories humans typically attach to place. One KI illustrated "most people see retreat as a last option. It's the toughest option. You're displacing people from [their] homes" (RKI11). This was a common theme. For a Surrey KI, the social cohesion in communities is important for public safety and emergency preparedness, and retreat would dissolve neighbourhood social capital. For Vancouver, the issue was in reference to people's livelihoods and socioeconomic status. For example "how do you tell the richest people in Vancouver they can't live in their houses anymore? So that's a big barrier" (RKI3). This suggests that political decisions regarding Metro Vancouver coastal adaptation will factor in those of higher tax base. In Delta, protecting agricultural land and farming livelihoods is a strong barrier to managed retreat. Despite the low-density characteristic of agricultural land, the historic, social, and economic significance of the land is too great to retreat.

Cultural amenity values and environmental benefits of coastal living hinder managed retreat. In Vancouver, Surrey, and Delta, the risks of living in hazard-prone coastal locations are mediated by government actions. In this regard environmental risks are externalized and the amenity values outweigh the risks. For Vancouver, managed retreat would not be appropriate even for low density parks and beaches, despite the absence of residences and valuable infrastructure. As one KI indicated, “we also did analysis of our beaches and parks and they are so viable and so heavily used…to let them go would not be supported” (LKI2). In addition, a few KI’s noted the cultural importance of diking to territoriality and historical settlement of Metro land. This is reflected in Vancouver and Delta, where KIs indicated there was unwillingness to give up coastal land to the sea for managed retreat. One KI commented Vancouver’s rejection of managed retreat signifies the importance of territoriality “Its like 13% of the City that would be underwater by 2100, so that’s a big chunk of the City, so the gut feeling that they couldn’t give up land” (RKI3). For Delta, the protection of dikes is symbolic and has allowed a local history and culture to develop. Farming livelihoods, as well as communities, homes, and infrastructure are invaluable, and managed retreat would take that history away. In relation to this, one KI applied this thinking to human dominance over nature:

> “I don't think humans really had in their mindsets giving anything up, because in our mindsets… we are conquering the natural world, we can survive in any environment, that’s a major psychological barrier for humans. To say nature is more powerful than us - we are going to give some of this up. We’ve had so much war over territory…. like our mindset is all about taking over territory - how much we control, how powerful we are” (RKI15).

This mindset is powerful, especially when managed retreat is associated with phases such as ‘give up’ or ‘take away’.

Another barrier to managed retreat relates to SLR’s “invisibility”, as it is not currently considered a major threat. The low risk perception hampers proactive coastal adaptation of all types, including retreat. Even after infrequent large magnitude King tide inundation and storm surge events, the risk does not trigger public concern that these coastal areas are unsafe. One KI explained “it becomes more of a reality for people in places where there are big flood events, then people can kind of see it and believe it with their own eyes. But much tougher if its kind of a future risk” (RKI11). For many KI’s, support for managed retreat was “too far out there” or people were “just not there yet”, considering the long-term planning and phased approach required for managed retreat.

A few regional KI’s noted the potential social inequities of a managed retreat strategy. Managed retreat may be implemented in areas vulnerable to SLR, yet have a low tax base, such as low-rent housing. Retreat is viewed less favourably for areas with residents of high socioeconomic status, given high value properties and potential political influence. Second, another KI lamented that social tensions may be created if collective public funds are used to buy out oceanfront properties:

> "You've got waterfront property, most expensive property, and then later on, when the municipality has to buy those properties, where's the money come from? It comes from ALL of the taxpayers. So the richest folks with the most privileged land are going to be bought out by everyone else. People are going to be mad, really mad" (RKI12).

With these social controversies conceivable, managed retreat may be avoided simply to avoid social injustices and public backlash.

5.3.1.3 Economic barriers

Economic conditions of high value real estate and assets, and pressures for continued growth and development presented major obstacles for managed retreat. These barriers were top of mind for local KI's, who often mentioned the hefty land prices first when considering barriers to managed retreat. Managed retreat was met with phrases such as "the land is just so valuable", and "with real estate the price it is retreat is not viable option". Each municipality emphasized their inability to afford properties for a managed retreat strategy given such high land values. Waterfront real estate in Vancouver is among the most expensive property in Canada, with individual lots often averaging well above $1 million. Real estate prices for Surrey and Delta also continue to rise, with most oceanfront property stretching above $1 million. One KI illustrated "a lot of municipalities can't afford to buy those properties, because typically, they are the priciest damn properties" (RKI4). Collectively, there is an interest to keep real estate prices high. Under these circumstances, managed retreat would hinder economic activity and growth potential would be constrained. For a municipality, this is detrimental to a local government's source of revenue. One KI summarized:

> "Economically they [local governments] feel trapped by the land costs. So when they have a piece of undeveloped land along the Fraser River, and it's several acres large, it's essentially worth hundreds of millions of dollars. And if they can develop that land for housing, that means the tax base they've created is huge… the biggest challenge they have now, if I isolate a piece of land because I think it's going to be flooded because of increase in sea level, I've essentially written off a large chunk of my municipality and I'm not ever going to get any taxes from that land. If I make it into a park, it's an expense. It's not an income anymore. But if I put a 50 story tower on that thing, my tax base is going to be huge, I'm going to be able to suck in a lot of money [and then] all I need is a dike" (RKI18).

The paradigm of continued economic growth is a barrier to managed retreat. One KI explained, "the concept of retreating or removing or not growing translates literally to weakness and loss and is not seen as an attractive approach" (RKI15). Attracting economic opportunity and growth is often presented as a key political promise and societal desire, despite its limits. Economic activity is prioritized over hazard reduction and climate adaptation activities as economic growth is seen as progress, wealth, power, and reaching higher levels of quality of life. Environmental considerations are often discounted or externalized to the detriment of natural ecosystems and development in hazardous places. Thus, economic growth interests may impede CCA strategies such as managed retreat.

5.3.2 Additional barriers

5.3.2.1 Physical barriers

Given the diverse topography and characteristics of the municipalities in Metro Vancouver, a few differences were revealed in the way physical barriers arise. Many KI's recognized the scarcity of land available for relocating people and infrastructure when most of Metro Vancouver is already built up and surrounded by mountains and the sea. For Vancouver, the high density infrastructure presents a barrier to managed retreat. As Vancouver is already lacking space for housing, KI's questioned *where* the affected population and assets could retreat to within municipality borders. Building higher, concentrating density, or relocating to inland municipalities were noted as possible solutions, yet none were favourable. For Delta, subsidence and the flat topography present a barrier to managed retreat as there is limited higher elevated land to retreat to within Delta. One KI commented that almost all of Delta is in the floodplain, so if retreat were to occur, the municipality would essentially forfeit the majority of its land base to rising sea levels.

5.3.2.2 Knowledge barriers

As a coastal adaptation strategy to SLR, managed retreat has few tangible examples for actors in Metro Vancouver to learn. A few KI's made the distinction between pre-emptive managed retreat and reactive managed retreat. Examples of managed retreat are often carried out reactively after a major flood or disaster, not proactively for climate change risks. Each case study municipality agreed the shortage of examples serve as a barrier to managed retreat because there is a gap in understanding whether retreat strategies are effective and successful. Furthermore, KI's noted there are no agreed upon standards or best practices to apply, monitor, or evaluate a managed retreat strategy. Each case study municipality referenced uncertainty with *when* to begin managed retreat and commented on the lack of understanding of specific circumstances in which retreat would be favourable, and many KI's noted the lack of clarity of how and why to implement. For Vancouver, it was questioned why managed retreat would be implemented with uncertain mitigation scenarios. For Surrey, this was problematic for both the public and politicians who do not have a firm understanding of the strategy. Managed retreat is still 'abstract' in academic literature.

Managed retreat remains a potential component of strategies to adapt to climate change and sea level rise. If a managed retreat strategy were to occur, most KI's expect a major disaster (e.g. flood or earthquake) to spark a retreat strategy. One KI explained there must be evidence of the risk, and presently, SLR is not a visible or immediate threat. Most KIs agreed that a managed retreat strategy would likely only be triggered post-disaster.

5.3.3 Summary

Managed retreat is currently seen as a possible but unlikely coastal adaptation strategy for the Metro Vancouver case study municipalities. The top barriers are Institutional/Governance, Social/Cultural, and Economic barriers, with Physical and Knowledge barriers also revealing additional constraints. For each case study municipality, jurisdictional authority serves as major Institutional/Governance barriers to managed retreat. In Vancouver and Surrey, the value of real estate and economic assets in the floodplain are perceived as strong economic barriers to managed retreat. Likewise, for Delta, the economic value and cultural significance of agricultural land in the floodplain is a Social/Cultural barrier to managed retreat. The research reveals a series of barriers that suggest that it is highly unlikely pre-emptive or proactive managed retreat will be implemented as a coastal adaptation strategy for parts of Metro Vancouver. Perhaps if there is significant coastal erosion, and the threat of SLR and coastal hazards becomes more visible and evident, a just-in-time retreat strategy may be considered before major damage is experienced. As noted by *most* KI's, retreat will likely be reactive after a disaster, and used as an opportunity to rezone the area to restrict development. This response will ultimately be more costly financially and socially, yet understandable given the various barriers presented here.

CHAPTER 6 CORE THEMES AND DISCUSSION

6.0 Introduction

Research results outlined in the previous chapter, reveal a number of core themes valuable for understanding why coastal adaptation to SLR generally, and managed retreat specifically, face numerous barriers[8], and these are indicative of the many challenges Vancouver faces as it attempts to implement a broad portfolio of structural and non-structural adaptation options. Each theme has implications for how barriers develop, and understanding this has relevance for present and future coastal adaptation activities in Metro Vancouver.

The literature on barriers to CCA reveal that barriers occur in bundles (Moser et al., 2012), can reinforce each other, and hidden barriers can trigger additional barriers to adaptation (Eisenack et al., 2014). Moreover, the adaptation barriers in Metro Vancouver are reinforced by components of historical legacies and lock-in/path dependency, which Wise and colleagues (2014) explain as future adaptation pathways being dependent to a certain degree on past historical choices and decisions that are difficult to change.

Research suggests that many of the main barriers to coastal adaptation and managed retreat in Metro Vancouver are underpinned by: 1) short-term priorities; 2) the complexity of SLR, and; 3) the historical legacy of structural protection. Researchers suggest that adaptation can be improved by careful dissection of the underlying causes of barriers (Moser & Ekstrom, 2010; Biesbroek et al., 2013; Eisenack et al., 2014). These themes are described below and illustrated in Figure 10.

Figure 10 represents how the core themes 'funnel' together to create barriers to coastal adaptation in Metro Vancouver. Although each core theme in Figure 10 is equal in size, some core themes may be stronger for different case study municipalities. This will be detailed in the paragraphs following.

[8] Other challenges and barriers were mentioned during KI interviews; however these are not considered in the following discussion as they were not frequently mentioned by KI's nor related closely with what are termed the 'core' themes of the research.

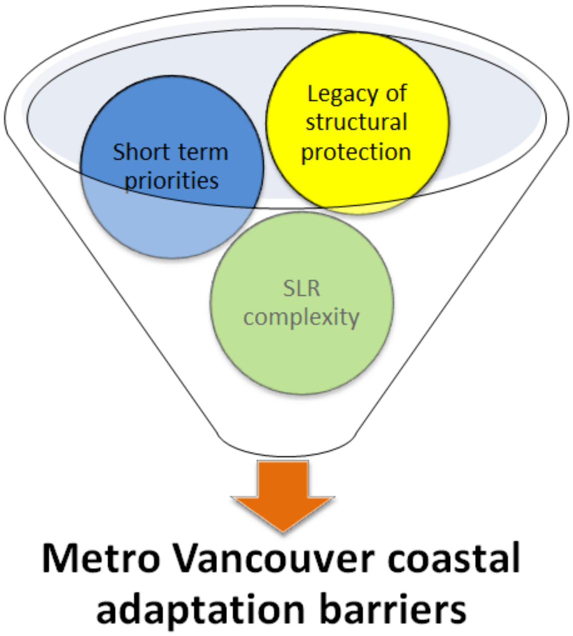

Figure 10 Diagram of main barriers to coastal adaptation in Metro Vancouver.

6.1 Response mismatch: Short-term responses for a long-term problem

The research revealed a significant tendency for adaptation decision makers to engage in *short-termism*, which Linham & Nicholls (2012) describe as short-term political and economic thinking that triumphs over longer term approaches. Adapting to SLR and coastal hazards requires overcoming factors that inhibit long-term thinking and decision making about future risks and gradual sea level changes. The research suggests that some of the strongest adaptation barriers bundle together, and are reinforced by temporal cross-scale sensitive barriers[9] and shorter-term issues which compete for attention. When humans favour short-term thinking and decision making, and by extension, allocation of resources, making decisions to address future impacts of climate change get put off or ignored altogether. Arros (2013) explains that the concept of *myopia* reflects the reluctance of stakeholders to invest in solutions for long-term or future problems. Similarly, research revealed tension between allocating resources for pressing short-term municipal needs, versus uncertain future SLR-related needs. This issue is apparent in Metro Vancouver where some politicians are unwilling to make long-term adaptation decisions for a far off future benefit, and where public support tends toward immediate solutions, such as structural protect infrastructure.

[9] Policies and decisions made today and in the past may create legacies that will affect and constrain adaptation options in the future (Klein et al., 2014; Wong et al., 2014)

Study findings indicate that coastal adaptation is not an immediate priority for either staff or council at various levels of government, and that lack of funding for immediate action reinforces the lack of urgency. KI's articulated that despite important staff champions at the local level, scarce resources to dedicate to coastal adaptation prevent needed investment and support for the long-term. Burch (2010) reported similar barriers in Metro Vancouver prior to 2010; lack of access to finances and resources is a persistent barrier hindering local adaptation implementation. Short-term election cycles and politicians representing short-term voter wishes are not beneficial to long-term adaptation planning, and generally low levels of public concern for SLR and climate change further reinforces the absence of resources for actors involved in flood management and adaptation. To overcome this, Vancouver, Surrey, and Delta officials are evaluating mechanisms to create long-term funding to sustain future adaptation. For example, Surrey funds parts of storm water and drainage adaptation through a monthly utility fee rather than exclusively relying on provincial grants or municipal property tax.

The research demonstrates that coastal governance arrangements pose significant barriers to adaptation, since these arrangements cross multiple government scales, resulting in inconsistent or delayed activity, which hinders long-term coastal adaptation planning. Lack of provincial guidance, regulatory clarity, and jurisdictional coordination were found to be strong barriers at the local level. The research revealed that there is no clear central authority that coordinates SLR adaptation activities in Canada or BC, although many KI's agreed that the FBC has provided invaluable direction, leadership, and best practices for local governments despite its lack of regulatory authority. CCA in Metro Vancouver is fragmented across different government departments, portfolios, and jurisdictions, resulting in inconsistent adaptation programs and an overall lack of coordinated long-term coastal adaptation planning.

It emerged that the strong desire to sustain short-term economic growth in Metro Vancouver essentially blocks the use of an adaptation option like *managed retreat*. Preventing new development and relocating existing development creates short-term economic, political, and social impacts that weigh more heavily than the long-term benefit of reduced exposure to SLR and coastal hazards. Using land for immediate economic growth, public amenities, and municipal revenue reflects a short-term benefit. Attracting and maintaining economic opportunity are strong factors in Vancouver and Delta, suggesting that short-term priorities is a strong core theme. Local Metro governments appear to face competing interests to maintain property values versus restricting floodplain development, or designating flood hazard zones which then impact on property values and municipal revenue. The priority of maintaining property values is echoed in the literature (Moser & Ekstrom, 2010; Niven & Bardsley, 2013; Klein et al., 2014) and a powerful influence in Vancouver, Surrey, and Delta. *Protecting* assets and property with a structural solution such as a dike reduces political, economic, and financial risks by maintaining current property values, while lessening social backlash as compared to a *managed retreat* strategy. The rising cost of protection over the long-term was not raised as a concern, which again reflects concentration on the short-term.

Case study findings show that local governments are willing to address the short-term impacts of SLR by changing building codes, increasing FCL's, updating emergency response capacity, and planning for future dike infrastructure upgrades. However, given inconsistent funding and short-term political cycles, adaptation strategies lack a long-term vision. In this regard, municipalities are willing to entertain dike construction and incremental upgrades that reach provincially recommended planning benchmarks. However, SLR is a long-term threat that will increase beyond planning benchmarks of 2100 and 2200. Few et al. (2007) also note short-termism as a CCA barrier and conclude that municipal decision-makers' time horizons for coastal planning and flood risk are generally too short to strategize a long-term plan for the future impacts of SLR. Similarly, the idea that SLR is a gradual and slow process may also invite local governments and stakeholders to postpone necessary adaptation action. This concept feeds into the second core theme of this research, the creeping and wicked problem of SLR.

6.2 The complex and wicked problem of SLR

The timing and magnitude of future SLR and coastal hazards is uncertain, which creates challenges for devising appropriate coastal adaptation plans and actions. Furthermore, the scale of the problem calls for the involvement of multiple stakeholders crossing numerous scales, jurisdictions, and time frames. The second theme addresses the underlying complexity and uncertainty in planning for a wicked problem such as SLR.

Local governments in BC are encouraged to adopt SLR planning benchmarks of 1m by 2100, and 2m by 2200; however, there are uncertainties about the rate and magnitude of SLR and related coastal impacts (Barnett, 2001; Nicholls & Cazenave, 2010) which adds to the complexity of the problem. Uncertainty in coastal management is a constraint for making future adaptation decisions, often delaying adaptation (Tribbia & Moser, 2008; Niven & Bardsley, 2013). Similarly, Metro Vancouver KI's often pointed to the challenges in making decisions for the long-term with imperfect information about the scale and rate of SLR and local coastal tectonic movement. For example, Surrey and Delta must adjust for local subsidence rates in addition to the general 1m by 2100 SLR benchmark. In the short-term, despite the complex nature of SLR and climate change, Provincial benchmarks give needed clarity and simplicity to address the problem. However, municipal CCA staff must always remember that SLR planning benchmarks may not be robust, and therefore may not capture the full range of possible SLR scenarios (Macintosh, 2013). Macintosh (2013) notes that Australian states have adopted similar planning benchmarks, and that given the physical uncertainties of SLR this may offer a false sense of SLR certainty.

The technical complexity and uncertainty of SLR is strongly recognized as a factor in Surrey. Local KI's indicated that the local geography, including four floodplains, tidally influenced rivers, winter coastal storms, and spring freshet, gives rise to multiple flood risks. The recognition and detailed work Surrey has conducted on these physical factors enhance their ability to plan for the risks as they change overtime.

Aligning and coordinating coastal adaptation actions with the suite of actors, decision makers, jurisdictions and communities is a consistent point of perplexity among KI's. These concerns are consistent with other literature (Moser & Ekstrom, 2010; Burch, 2010; Moser et al., 2012). For example, adaptation responses for Metro Vancouver's shoreline would ideally be also coordinated with the Musqueam, Tswwassen, Semiahmoo, Squamish, and Tsleil Waututh First Nations communities. However, given different funding bodies and governance systems, adaptation responses may end up to be dissimilar, incomplete or poorly coordinated, leading to, for example, a new dike cutting off First Nations land or leaving it exposed to rising seas.

Most KIs referenced negative public and political views as a significant reason to be reluctant to address SLR with non-structural adaptation measures. This sentiment is shared with UK flood risk managers who feel accountable to a public which favours engineered methods (Harries & Penning-Rowsell, 2011). Burch et al. (2010) also found that lack of public acceptance for some flood management options constrains adaptation implementation. This tension between rational long-term decision making and short-term public and political values represents a complex problem for actors in Metro Vancouver. The research indicates that there is significant discomfort in proposing or implementing a coastal adaptation strategy which may create negative social, cultural, or political consequences. For example, while managed retreat is recognized as a long-term CCA option, the short-term political risk and community impacts severely reduce consideration of a retreat strategy. In contrast, dikes can be constructed to provincially recommended SLR planning benchmarks, and are perceived to be less socially and politically disruptive and so are the favoured approach.

Surprisingly, only a few KI's noted the interdependencies between ongoing societal changes, such as population growth, and addressing the long-term impacts of SLR. Considering Metro Vancouver's projected population growth, and current housing vacancy and affordability challenges, SLR adaptation planning must factor in these considerations along with lack of future land availability. Concepts such as climate refugees and climate migration and displacement are relatively abstract concepts that have yet to filter through from academics to practitioners.

Despite the complex and obscure nature of SLR, dikes are seen by KIs and the public alike to provide an immediate, clear, and effective response to short-term coastal hazards, supressing the need for proactive change. Proactive adaptation is anticipatory, involving long-term and transformational planning (Kates et al., 2012; Linham & Nicholls, 2012), as well as the recognition that past solutions may be insufficient for future challenges, and may not be able to keep pace with new changes (Lyle & Day, 2003). Although dikes provide incremental adaptation benefits, such as reducing low- to moderate- magnitude losses, eventually, dikes will be overtopped and expensive to maintain (Lyle & Day, 2003; Kates et al., 2012). As the next core research theme describes, once built, *protect* coastal adaptation measures tend to be 'lock-in' options, constraining and even eliminating other future adaptation options.

6.3 Metro Vancouver's legacy and dependency on structural protection

Despite government policies offering considerations for a broad portfolio of structural and non-structural adaptation to manage SLR and flood risk in BC, traditional engineering approaches persist, while non-structural adaptation implementation is weak. This third 'structural path dependency' theme builds on the two previous themes of short-termism and the underlying complexity/wicked problem theme in SLR and adaptation planning.

Structural approaches to both flood protection and coastal adaptation were viewed both positively and negatively by KI's. Many KI's recognized that hard engineering infrastructure can lessen flood damage, while at the same time creating long-term adaptation limitations, financial cost commitments, and environmental harm. Despite this, the research demonstrates that structural *protect* approaches will continue to be used for SLR adaptation and flood protection. The research also suggests that coastal areas in Metro Vancouver that have existing structural protect infrastructure (i.e., Surrey, Delta, and Richmond) may already be 'locked in' to a structural adaptation approach, leaving little flexibility to attempt non-structural or even soft structural approaches. The legacy of structural protection as a core theme is not as strong for Vancouver given the absence of traditional hard protection such as dikes armouring the borders of the municipality. This suggests that Vancouver may have greater flexibility to try new approaches.

In Metro Vancouver, past flood control systems were built to a set of past hydrological and climatic conditions (i.e. stationarity) that are now not representative of the new long-term risks posed by SLR and coastal extremes. The non-stationarity of hydrological systems, compounded by rising sea levels, cause costs to increase as dikes in Metro Vancouver now need to be raised and upgraded in addition to regular maintenance costs. Burch et al. (2010) and Gibbs (2015) explain that historically evolved path-dependencies limit the range of options that actors in municipal institutions may now consider. Concepts such as path-dependence and lock-in express how future adaptation pathways are dependent on historical pathways, which are difficult to change (Wise et al., 2014). As Barnett and O'Neil (2010) note, maladaptation may result from historical commitment to large infrastructural developments, as investment in dikes reduces flexibility to respond to uncertain climate conditions (Barnett & O'Neil, 2010). The historical use of dikes, and continued preference for these structures displays pathway lock-in in some Metro Vancouver municipalities such as Surrey and Delta, reducing the likelihood that non-structural alternatives will be adopted.

The research revealed that there is a tilt towards structural protection due to the familiarity of design and function, and confidence in performance. Non-structural measures do not have the same familiarity among practitioners and are not as easily evaluated with traditional cost benefit analyses, leading to a bias towards structural measures. Lyle and Day (2003) explain that while cost benefit policies promote economic efficiency, they tend to overlook long-term factors, and discount non-monetized environmental and social aspects. Similarly, the legacy of cost benefit policy favouring structural flood protection is apparent in UK flood management studies (Harries & Penning-Rowsell, 2011). Until cost benefit analyses are adjusted to better account for long-term, environmental and social costs/benefits, non-structural methods will be unlikely to fare well in cost benefit analysis.

Study findings suggest that current available funding and past investment in structural protection simultaneously dictates continued structural choices, and ‘crowds out’ non-structural options. With few exceptions, KI’s voiced concerns over the lack of financial resources to dedicate to coastal adaptation, and with competing interests to deliver other municipal services. Additionally, when provincial funds become available, the money almost always funds structural flood management projects, despite the Provincial Government suggesting a broad portfolio of adaptation measures. For example, in 2008, the Province announced $100 million for flood projects, which largely funded hard protection (Lyle & Mclean, 2008). More recently, the 2016 Provincial budget dedicated 97% of all flood management funds to structural flood protection (Figure 11). The investment in and dedicated funding for structural methods reinforces lock-in sustaining the legacy of dike protection. This creates challenges for local governments faced with short-term priorities, while attempting to use sustainable and long-term adaptation measures encouraged by higher levels of government.

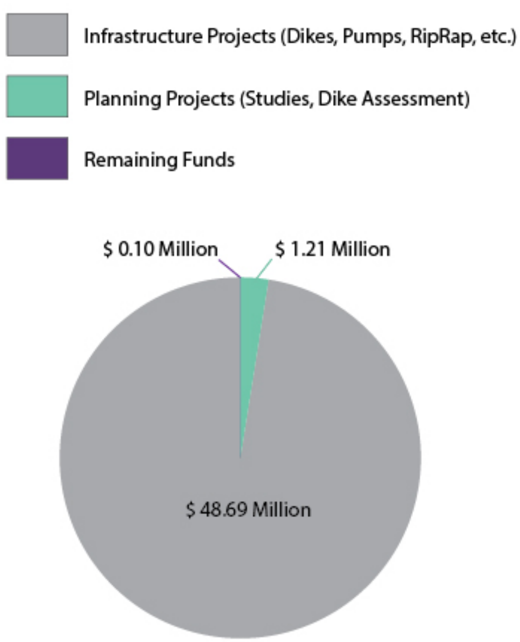

Figure 11 Provincial government flood protection funding allocations (Source: http://www.ebbwater.ca/wp/flood-funding-allocations-in-british-columbia/).

The legacy of structural protection further reinforces difficulty in implementing new planning responses. Existing structural flood protection measures have a long design life (i.e., 80-100 years), suggesting commitment to maintain these structures, which may also direct adaptation dollars away from potential non-structural adaptation. Additionally, built infrastructure can become a physical anchor in coastal communities, which then constrains retreat strategies (Gibbs, 2013) and other adaptation options. For example, the new hospital built in False Creek Vancouver will need a hard protection adaptation measure to protect against SLR. Adjacent infrastructure is now incentivised to use a similar hard protect measure. The need for the continual maintenance and investment in protection of the built environment, rather than investment in new adaptation options, can constrain future adaptation options (Klein et al., 2014). Plans in the near future in Surrey and Delta to upgrade dikes for SLR suggest path dependence, especially with no known plans to decommission these municipalities' dike infrastructure.

The structural legacy is also entrenched by persistent engineering traditions and staff who have been trained in disciplines that favour engineering solutions. One KI explained that their support for non-structural and non-engineering approaches to flood management drew criticism by colleagues, and the KI received the nickname "fluffy engineer". This is contrasted by engineering solutions that were referred to as more scientific, trustworthy, and even "epic". Surprisingly, Harriers and Penning-Rowsell (2011) found similar nicknames of "fluffy", "woolly" or "unscientific" assigned to engineers who promote non-structural methods in the UK, where the negative connotations of non-engineering flood management methods hinder their use. Harriers and Penning-Rowsell (2011) found that cultural biases and legacies that favour engineering approaches to flood risk reduction in the UK can make past adaptation decisions "sticky"- resistant to non-structural adaptation. Research results from Metro Vancouver show similar cultural legacies in force, favouring engineering approaches that may prevent the implementation of a broader spectrum of coastal adaptation projects. The degree to which this barrier may change is likely dependent on introducing new non-structural and non-traditional flood management approaches in formal engineering training and education. Furthermore, the degree to which this barrier may change is also dependent on the ability of those staff members to encourage a broad spectrum of approaches and aquire decision-making authority and power within a municipality.

To incorporate a broader spectrum of adaptation responses, and to move beyond the legacy of structural protection to consider longer term CCA approaches such as managed retreat, most KI's suggested that a future disaster may provide a "window of opportunity" for change in coastal adaptation approaches.

6.4 Disaster as a "window of opportunity" for managed retreat

The concept of disasters figuratively opening a "window of opportunity" for policy change in hazard risk reduction and CCA was raised by many KIs in this research. With few exceptions, most KI's indicated that implementation of managed retreat would require a catastrophic flood or earthquake disaster. Birkmann et al. (2010), describes that major disasters often drive change or shift the focus of organizational structures and societal decisions. Disaster events create *exogenous shocks* that can overcome barriers to policy change (Harries & Penning-Rowsell, 2011). For example, following a major flood disaster, there may be opportunities to introduce flood management approaches which are different from Metro Vancouver's status quo of structural flood protection. Some strategies, particularly managed retreat, may only become seriously considered after a disaster event which causes politicians and the public to be more open to transformative adaptation strategies (Rosenzweig & Solecki, 2014). This was exactly the case in coastal communities in New York, New Jersey, and Connecticut, where buyout programs were employed following Hurricane Sandy (Freudenberg et al., 2016). However, given the creeping and gradual nature of SLR, impacts are unlikely to be considered "a disaster" producing a window of opportunity for pre-emptive managed retreat. Even small events, such as annual king tide flooding, are unlikely to stimulate a shift in acceptance for managed retreat along Metro Vancouver coastlines. Given the perception that managed retreat is a 'last resort' and 'extreme' option, it is not surprising that managed retreat consideration would only be triggered by an extreme event such as a disastrous flood or earthquake event. Additionally, the degree to which the three core themes vary overtime may shift after a disaster event creates the opportunity to overcome barriers and reconcile the factors that hinder coastal adaptation.

Furthermore, a post-disaster policy window is usually short-lived, as communities want to return to normal soon after disasters (Solecki & Michaels, 1994). Without proper guidance and procedures in place for a managed retreat strategy, actors in Metro Vancouver are not yet equipped to take advantage of a potential window of opportunity. Therefore, the ability to take advantage of a 'window of opportunity' rests on the readiness of actors involved in coastal adaptation and flood management to prepare to overcome barriers in coastal governance, perceptions, and resources, and to ensure that enabling legislation, procedures, and plans are in place before a potential catastrophe. Managed retreat, if it is ever implemented, will likely be a reactive post-disaster response in Metro Vancouver.

6.5 Managed retreat case study comparison and connection to core themes

The research revealed clearly that *managed retreat* is not considered a favourable coastal adaptation strategy for Vancouver, Surrey, and Delta. This finding is consistent with other studies examining high-density and developed coastal areas (Kousky, 2014; Reisinger et al., 2015). At a basic level, barriers to managed retreat arise because of high value of land, properties, and assets at risk of SLR; the loss of sense of place and attachment from relocating affected residents; the political risk of proposing a highly contentious strategy to generally high socioeconomic status property owners in Metro Vancouver; the fear of backlash from the general public compensating a wealthy few who chose to live in high risk areas; and the general lack of guidelines, procedures, and implementation strategy for municipalities to follow. But through a deeper and richer analysis, the research revealed that barriers to managed retreat are also deeply entrenched within the historical development path, propensity for short-termism, and cultural attitudes reflecting human ownership of and domination over nature. In essence, these attitudes favour the status quo of structural flood protection and SLR adaptation.

While managed retreat is generally accepted as an optional adaptation strategy for SLR, it is unlikely it will receive any serious consideration in the near term. Managed retreat was recognized by many KIs as both progressive yet undesirable in areas with significant assets, land values, and people. Beyond this generalization, managed retreat is considered differently in each case study municipality. Potential managed retreat for at-risk agricultural areas in Delta and Surrey contrasted. Surrey KI's noted that parts of agricultural land may need to be retreated from in the future if SLR impacts grow (e.g. crop failure due to salt-water intrusion). In contrast, Delta KI's were strongly opposed to managed retreat for agricultural areas, explaining that *protect* is the favoured option for agricultural areas given their cultural significance, their role in local food security, and their economic value. Similarly, managed retreat is not likely considered for low-density beaches and parks in Vancouver given the public value. The perception that managed retreat implies the 'surrender of coastal lands to the sea', drawing political and social controversy (Linham & Nicholls, 2012), was strongly indicated for Vancouver and Delta. Research revealed low levels of support for managed retreat in both high value areas of metro Vancouver (e.g. City of Vancouver) and lower value areas (e.g. agricultural areas of Delta).

The experience of cultural barriers also differed in municipalities. The cultural concept of ‘place attachment’ was a strong factor when considering managed retreat in Delta and Surrey, while ‘sacrificing territory’ was a strong barrier in Vancouver. Historical, tight-knit and well-established coastal communities, such as Crescent Beach in Surrey, and Beach Grove and Boundary Bay in Delta, as well as the deep-rooted farming community in both municipalities are perhaps more significant cultural barriers.

Furthermore, while both Surrey and Vancouver clearly identify managed retreat as a coastal adaptation option in policy documents, Delta does not identify retreat, relocation, or any other ‘abandonment’ policy in its coastal adaptation options. Taken together, while each municipality is unlikely to apply managed retreat in the near term, Delta is the least likely to pursue this option, while Surrey and Vancouver were somewhat more receptive to managed retreat future extreme events require an equally ‘extreme’ response.

Study findings indicate a strong concern over the removal of private property owner rights that would come with managed retreat. Existing land tenure arrangements can be a barrier to implementing managed retreat (Turbott & Stewart, 2006). This is due to property owners’ expectation of permanent use and rights to the coastal property, despite potential non-permanence due to rising sea levels. The problem is exacerbated by the generally increasing value of coastal property (Turbott & Stewart, 2006). Asking homeowners to forego their private property rights for an invisible and uncertain threat of SLR is challenging. Furthermore, coastal adaptation actions that may be rational and appropriate in the minds of planners and engineers may be undesirable and unfair in the eyes of individuals, communities, and politicians (Adger et al., 2013). Moreover, given the invisible and slow nature of SLR, coastal homeowners may not perceive SLR as an immediate threat. With this in mind, feelings of place attachment dwarf any feelings of threat that might be felt from climate change, so coastal adaptation strategies like managed retreat that impact the psychological and emotional values attached to a vulnerable location will not be popular.

Results from case study municipalities in Metro Vancouver are similar to findings from overseas case studies in Australia, New Zealand, U.K, and U.S. Similar barriers include sense of place and fears about loss of attachment to place (Agyeman et al., 2009; Alexander et al., 2012), economic growth pressures (Kousky, 2014; Gibbs, 2015; Reisinger et al., 2015), concerns over current private land uses and rights, equity, public and political acceptability (Shih & Nicholls, 2007; Able et al., 2011; Niven & Bardsley, 2013; Gibbs, 2016). Likewise, each Metro Vancouver case study experiences a similar bundle of barriers to managed retreat.

Similar to the barriers found in this study, Burch (2010) reports financial constraints, the absence of strong leadership, governmental organizational culture, inconsistent regulatory climate change policy, jurisdictional coordination, and lack of long-term planning as barriers to climate action. These factors are a myriad of sources which maintain path dependency hindering climate change action. Burch (2010) also notes that the most critical barriers are less of a matter of *creating* more capacity (i.e financial, technical, human resources) than *facilitating* the effective use of existing resources for climate action, which depends on reworking the current development path. This conclusion is consistent with the path dependency and lock-in factors found in this study; however, KI's from this study maintain lack of capacity is still a barrier for CCA and more capacity needs to be created to enhance the uptake of non-structural coastal adaptation approaches. Prior to the study conducted by Burch (2010), translating capacity into action hindered effective climate change action. Given the time that has passed between studies, this research highlights that translating capacity into adaptation implementation remains a challenge.

As described in the fourth theme, due to deeply engrained tendencies toward short-term and structural risk management approaches, it is likely that only after a major disaster will managed retreat be considered as a flood adaptation strategy in Metro Vancouver. Still SLR may accumulate to such a point that the conditions will reach 'tipping points' of dangerous risk, the perception that SLR is a slow and gradual hazard looms large where there is little acknowledgement of the risks. Although actors in Metro Vancouver are keen to adapt to SLR, there is little sense of urgency driving the need for managed retreat and no major disasters upon which to reflect.

6.6 Summary

Core themes were identified through the research which underscore barriers to coastal adaptation and managed retreat in Metro Vancouver, including response mismatch due to short-termism, the complexity of SLR and adaptation planning, and the historical legacy of structural protection. Although not always obvious to KI's, it is suggested here that these themes create and exacerbate barriers to adaptation. Some Metro Vancouver KI's recognize that coastal management policies and decisions made today and in the past may create legacies that will affect and constrain adaptation options in the future, and this has been recognized in other studies (Moser & Tribbia 2006; Eisenack et al., 2014; Klein et al., 2014; Wong et al., 2014). Consistent with international understanding, it is expected that traditional structural *protect* methods will be pursued until a local or regional disaster event opens a window of opportunity which triggers a shift in the current ways of thinking about SLR and flood management. Managed retreat and other non-structural coastal adaptation strategies must compete with the status quo of structural flood protection that is supported by values that uphold economic growth and short-term priorities, human ownership and domination of nature, and political accountability to public preferences and stakeholder demands.

CHAPTER 7 CONCLUSION

7.1 Main conclusions

Rising sea levels along the coastline of Metro Vancouver will exacerbate coastal hazards and increase the likelihood of flooding. While the exact magnitude of SLR is uncertain, SLR will occur and the likely consequences of emerging hazards demand adaptation and rigorous reflection on contentious adaptation options such as managed retreat. This thesis offers an actor-centred, descriptive and exploratory account of SLR coastal adaptation experiences in Metro Vancouver with a particular focus on managed retreat. Through local and regional semi-structured interviews, the study highlights the factors that influence structural and non-structural coastal and flood management approaches, the barriers to coastal adaptation, and a more in-depth look at the barriers to managed retreat.

Studies indicate that structural flood protection has been and continues to be the main approach to controlling flood hazards in Metro Vancouver. Building on this research, this thesis' first objective explores factors that influence the use of structural flood management approaches. While KI's and policy documents acknowledge that the traditional 'hold the line' structural approach to flood and coastal adaptation is not sufficient, nor flexible enough, to adapt to long-term SLR and coastal change, current policies, plans, and interview responses gave strong indications that the structural approach continues. However, there are emerging alternative and natural shoreline adaptation initiatives, including shoreline restoration, and Green Shores methods. As indicated by local KI's, each municipality is actively examining adaptation responses that are "greener" than the traditional concrete dike. Certainly, this is a step forward beyond the traditional structural approach to flood management and coastal adaptation.

The second objective of this study was to explore the barriers to coastal adaptation in Metro Vancouver as experienced by local and regional KI's. Overall, Institutional/Governance, Social/Cultural, Financial, Economic, Knowledge and Human resource barriers emerged as key determining factors that can hinder coastal adaptation. Results also show that barriers hinder adaptation before selection of a coastal adaptation option even begins. With each option having its own set of unique barriers and challenges, the research highlights the multiple planning and implementation challenges to coastal adaptation. Finally, the third objective of this thesis was to explore the barriers to the coastal adaptation option of managed retreat. To a large extent, managed retreat is not seriously considered as an adaptation strategy to SLR, although many

KI's recognize the ecological benefits and more general benefits of long-term reduced exposure to SLR and coastal hazards. The main barriers to managed retreat are Institutional/Governance, Social/Cultural, and Economic barriers. These barriers are underscored by the need to maintain short-term priorities and decisions; the characteristically wicked, complex, and uncertain nature of SLR and SLR adaptation planning; and the legacy of structural flood protection in the region.

Prior studies indicate there are indeed barriers to CCA in Metro Vancouver that constrain local adaptation (Burch, 2010; Burch et al., 2010; Arros, 2013; Graham, 2016). However, the findings of this study highlight the significant barriers to managed retreat, and expose the underlying factors that constrain coastal adaptation to SLR in Metro Vancouver. Managed retreat is generally considered the 'extreme' and 'last resort' option for case study municipalities. It is unlikely that this perspective will change unless a disaster event triggers a shift in adaptation approaches and opens a window of opportunity for change. If municipalities are to move beyond the status quo of structural flood protection without a disaster event sparking this shift, municipalities must overcome barriers that justify and reinforce short-term priorities, human domination of nature, uncertainty and complexity of SLR, and historical lock-in for structural solutions. This thesis concludes with Table 8 summarizing the key research findings which then leads into recommendations (Table 9), limitations, and avenues for further research.

Table 8 Summary of thesis findings			
Research questions			
What factors influence the choice of traditional, structural flood management methods, versus non-structural methods to coastal adaptation?			
What are the barriers to coastal adaptation in Metro Vancouver?			
How is managed retreat viewed as a climate change adaptation strategy in Metro Vancouver and the three case study municipalities?			
Key findings and themes			
Coastal adaptation plans and actions in Metro Vancouver indicate that traditional structural *protect* measures are prioritized adaptation responses			
Factors that influence the selection of structural approaches for coastal adaptation include historical use, familiar design and function, government support, maintenance of economic imperative, devotion to engineering solutions, public and political backing, and immediate and tangible results			
In general both non-structural options, *accommodate* and *retreat*, and soft-structural measures are not emphasized as central coastal adaptation approaches to SLR in Metro Vancouver. They are viewed as secondary to structural approaches, while *retreat,* is generally seen as a 'last-resort' approach			
Many KI's articulated that non-structural and non-traditional coastal adaptation measures should be included in a municipality's suite of adaptation strategies			

Consistent with international studies, it is expected that traditional structural *protect* methods will be pursued until a disaster event opens a window of opportunity which triggers a shift in the current ways of thinking about SLR and flood management			
Across all scales, Institutional/Governance, Social/Cultural, Financial, Economic, Knowledge and Human resource barriers were reported as being a principal determining factor that can hinder coastal adaptation			
Regardless of the coastal adaptation option (i.e. protect, accommodate, retreat), there are numerous barriers to general coastal adaptation which act as key constraints prior to selecting the specific coastal adaptation option			
Managed retreat is seen as a possible but unlikely coastal adaptation strategy for the Metro Vancouver case study municipalities given the multiple barriers			
Top barriers to managed retreat are Institutional/Governance, Social/Cultural, and Economic barriers. Physical and Knowledge barriers are also additional constraints			
As noted by *most* KI's, retreat will likely be a reactive action after a disaster, and used as an opportunity to rezone the area to restrict development			
Research suggests that many of the main barriers to coastal adaptation and managed retreat in Metro Vancouver are underpinned by: 1) short-term priorities; 2) the complexity of SLR, and; 3) the historical legacy of structural protection			
Managed retreat and other non-structural coastal adaptation strategies must compete with the status quo of structural flood protection that is supported by values that uphold economic growth and short-term priorities, human ownership and domination over nature, and political accountability to public preferences and stakeholder demands			

7.2 Recommendations

There are a number of opportunities to improve coastal adaptation planning and implementation. Recommendations (Table 9) are offered to assist actors involved in coastal adaptation and improve adaptation within their work, their municipality, or the region.

Table 9 Recommendations to improve coastal adaptation

Opportunity	Needed actions to support actors in coastal adaptation
Funding	• Provincial and Federal governments can support ecosystem-based and non-structural adaptation initiatives through funding grants specific to these projects • Overhaul municipal taxation structure creating a process where municipal revenue is not solely linked to property tax to increase access to public sources of revenue for adaptation projects
Collaboration	• Coordinate efforts and knowledge between various levels of government, interdepartmentally within government, and First Nations groups and private sector • Establish an overarching authority and expert committee to achieve comprehensive coastal adaptation in BC. The FBC's past regional role of information sharing and coordination should be emulated and given greater support o FBC should maintain regional role in the Lower Mainland o Expert committee should oversee regional efforts in BC as well as collaborate to share best practices, and establish adaptation priorities coast to coast to coast
Support	• Provincial and Federal governments must play a leading role through financial, technical, and leadership guidance o Support local assessments of SLR risks and flood hazard map updates • Unequivocal support and empowerment of staff, which is critical for enhancing

	adaptive capacity and overcoming barriers to adaptation
Mandate	• Mandate coastal adaptation so that local governments comply with Provincial SLR adaptation recommendations • Establish policies that limit further intensification of coastal areas and consider ecosystem-based and non-structural approaches which attain environmental and public safety simultaneously
Mainstream	• Integrate CCA goals within existing DRR and sustainable development policies, plans, and strategies. • Build trust, engage, and educate the public to encourage a shift in attitude to long-term sustainable understanding whereby focus will no longer be reactive flood hazard management but proactive coastal adaptation responses
Policy	• Create managed retreat procedures, guidelines, and best practices for the region, which can be used as guidance for individual municipalities to establish baseline information and understanding of the potential strategy

7.3 Limitations

This study conducted 27 interviews with actors involved in flood management and coastal adaptation in Metro Vancouver. Although this study had a large amount of data from a variety of KI's, the diversity of government level perspective could be increased. For example, federal perspectives are not represented within the study.

Interviewees needed prompting to speak about managed retreat, likely due to the lack of experience and abstract nature of managed retreat as a SLR adaptation option for Metro Vancouver, and fear about its consequences. In contrast, KI's could discuss at length and in depth flood management challenges and experiences. This may reflect KI concerns that discussing retreat may negatively impact the local real estate market, repel development opportunities, discourage farmers to maintain food security, spoil political legacies and being subject to public scrutiny. Within many institutional and decision-making bodies, there is a certain degree of confidentiality to be maintained by staff, councils, and key stakeholders creating the possibility for actors to be unwilling to discuss extreme coastal adaptation policies like managed retreat (Niven & Bardsley, 2013). Therefore, information specific to managed retreat in some Metro Vancouver municipalities may not have been disclosed and may have remained confidential.

Additionally, other possible limitations from the study are the generalizability and repeatability of the results. Given that the research is conducted in a unique context, themes that emerged may not necessarily be repeated in another context (Creswell, 1994). For instance, as Metro Vancouver is part of a developed nation, the choice and capacity to implement specific adaptation strategies might be considerably different than the range of adaptation strategies available to developing nations.

7.4 Generalizability

While findings from interviews do not lend well to repeatability of results, there are opportunities to explore key empirical commonalities across CCA literature. There are a number of common themes that can be extracted from this study and may be experienced in other contexts. Studies in Australia, U.S., U.K., New Zealand and other developed countries have initiated the groundwork on coastal adaptation barriers to SLR in urban landscapes (Moser & Tribbia, 2006; Few et al., 2007; Harries & Penning-Rowsell, 2011; Macintosh, 2013; Niven & Bardsley 2013; Harman et al., 2015; Reisinger et al., 2015). Coastal adaptation barriers were found to interact in 'bundles' (Moser et al., 2012; Wong et al., 2014) to complicate adaptation. The issues of short time horizons, complexity of SLR, economic, social, and governance factors were found to be strong barriers or enablers for coastal adaptation, highlighted in other urban coastal contexts (e.g. see Few et al., 2007; Tribbia & Moser, 2008; Abel et al., 2011; Alexander et al., 2012; Linham & Nicholls, 2012; Niven & Bardsley, 2013; Barnett et al., 2013; Gibbs, 2015). Given the worldwide importance bestowed on economic growth, continued pressure for development into hazardous landscapes likely would triumph over coastal adaptation strategies that restrict or *retreat* growth. As well, coastal adaptation has an inherent multilevel governance structure, which affects prioritization, decision making, and implementation of adaptation.

Many KIs and several CCA authors recognized the power of path dependency and lock-in hindering CCA (Burch, 2010; Harries & Penning-Rowsell, 2011; Gibbs, 2015; Wise et al., 2014). Path dependency and lock-in underpin the preference for a structural flood management approach, while constraining a broader consideration of non-structural future coastal adaptation options in Metro Vancouver. This pattern of path-dependencies limiting the future range of adaptation options will likely be found in other cities and contexts.

In general, it would not be surprising if the findings related to managed retreat in Metro Vancouver are consistent with findings in future studies in different urbanized contexts. Similar to other studies (e.g. see Agyeman et al., 2009; Able et al., 2011; Niven & Bardsley, 2013; Kousky, 2014; Gibbs, 2016), despite the risk reduction effectiveness, managed retreat is unfavourable and contentious in urban coastal landscapes because of the potential social implications, lack of political will, and impacts on economic investment and growth. Given the debate, applications of this particular adaptation option are few and far between, and often limited to low value and low density landscapes in developed countries. It is expected that the prevailing view of managed retreat as 'extreme' will persist in other contexts and studies.

Finally, the use of a qualitative method of semi-structured interviews spanning different governance scales to discover the experiences and understandings of actors (Eisenack et al., 2014) involved in flood management and coastal adaptation planning can be useful and applied in different contexts. This qualitative research method proved useful for the purposes of this study to provide a rich and unique look into the capacity of municipalities to pursue adaptation initiatives not easily captured from a quantitative study.

7.4 Broader implications and avenues for further research

This thesis offers a number of contributions to research and practice for adapting to SLR and coastal hazards. First, the study highlights the complexity associated with adapting to SLR within the interface of climate change risks and the wider context of economic concerns, jurisdictional and legislative arrangements, and social processes which occur in the coastal zone. Second, this study provokes discussion on the limitations and lock-in of traditional structural flood protection as a coastal adaptation strategy, highlighting that there are many factors that have justified this approach. Third, the research adds unique insight to the growing understanding of barriers to coastal adaptation from an actor-centred approach in a Canadian context. The research not only provides a descriptive account of barriers, but also an account of how barriers endure and interconnect, in hopes that actions may be taken to overcome barriers. Findings can be used for comparative research studies in different contexts. Fourth, the analysis demonstrates the challenges of proactive and long-term planning for wicked challenges such as SLR. Fifth, the research adds to a small but growing understanding of the policy and practice of managed retreat as a coastal adaptation strategy. Certainly an underexplored adaptation option in Canada, a few KI's indicated that managed retreat had not yet been explored in depth for municipalities in Metro Vancouver. The research clarifies the abstract nature of managed retreat, enhancing the dialogue on proactive coastal adaptation to build an understanding of options to assist and strengthen planning for the long-term commitment to SLR. With difficult decisions ahead, the research can be used as a learning tool with the intent to provide a basis for ongoing conversations for consideration of adaptation paths that are proactive and long-term responses to SLR and coastal hazards for Canadian coastal cities.

There are opportunities for research that could add to the SLR coastal adaptation discussion in Metro Vancouver. It would be beneficial to examine and review existing policies that align with non-structural and ecosystem-based adaptations objectives, which then can be leveraged as an incentive to mainstream adaptation actions within existing frameworks and municipal goals. There is also a need to increase the understanding of public attitudes of SLR risk and selection of coastal adaptation options. A survey, distributed to coastal residents and inland residents, would provide perspectives on managed retreat. Moreover similar surveys could be distributed in Atlantic and Northern coastal communities in Canada to compare public perspectives of SLR risk and selection of adaptation options. It would also be beneficial to assess the total number of people, and value of infrastructure and services, in SLR at-risk zones. This is important information for balancing different adaptation options. Not all properties will be impacted at the same time or with the same risks. Yet it is important to have this baseline information. Last, there is great opportunity to track changes in policy and practice of managed retreat after a disaster event in Metro Vancouver. This specific study could add to existing literature on disasters opening 'windows of opportunity' in coastal adaptation practice.

7.5 Final thoughts

Actors involved in coastal adaptation planning and implementation are faced with the complex and wicked problem of SLR along with the increased potential for coastal hazards influenced by climate change. Although the challenge is daunting, and the actors are faced with numerous barriers, Metro Vancouver actors are dedicated and willing to address coastal adaptation challenges. Overall, there is a strong need for support and collaboration between policy makers, engineers, planners, and experts to begin developing a comprehensive framework that encourages long-term, effective, and equitable coastal adaptation across governments and sectors in Canada. Although managed retreat comes with many barriers and extremes, it is important to realize that there are few low cost solutions (Turbott & Stewart, 2006), but long-term sustainability can be guided effectively through thoughtful and integrated stages of coastal adaptation. While managed retreat may not be appropriate for all coastal locations, it is worth shifting traditional structural flood management approaches for broader considerations of proactive approaches that work under many climate change and development scenarios. Given the uncertainties with future climate and societal change it is difficult to advise for precise and robust solutions for long-term adaptation (Lyle et al., 2015). However, it is important to develop the mindset to start on an adaptation path in the direction of long-term sustainability. The direction can adjust acknowledging potential for learning, reviewing, and updating adaptation paths as the understandings and experience of SLR and changing flood risks grow (Lyle et al., 2015). Therefore, managed retreat deserves more fruitful and creative consideration to maintain a suite of options for coastal adaptation for future planning as values and risks change.

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Appendix A

Email Contact Script

University of Waterloo

Date:

Dear [Participant],

I am writing to you as a Master's student from the Department of Geography and Environmental Management at the University of Waterloo, Ontario to see if you might agree to a short meeting to discuss my research on climate change adaptation, and more specifically, potential coastal adaptations for sea level rise and other coastal hazards in Metro Vancouver.

My research explores coastal adaptation strategies, and current progress in sea level rise and climate change adaptation for Metro Vancouver's coast. The research aims to uncover the factors that influence the choice between the adaptation strategies of "protect, accommodate, retreat, or avoid", in the context of future sea level rise and climate change. I examine the perspective of those involved in coastal management and planning to identify barriers to the application of some adaptation options and opportunities to improve response to sea level rise and coastal flood risk.

I am contacting you because I would like to interview you or, if you are unavailable, I would like to speak with an associate concerning adaptation strategies and disaster risk reduction planning in Metro Vancouver. Specifically, I am interested in your thoughts on the local responsibility of municipalities to adapt to, and prepare for, climate change impacts in Metro Vancouver. I feel your experience would be a perspective of great value in my research.

Feel free to contact me, or either of my co-supervisors Dr. Brent Doberstein (bdoberst@uwaterloo.ca) or Ms. Linda Mortsch (ldmortsch@uwaterloo.ca), if you have any questions or would like further information. I look forward to hearing from you shortly. If you are unable to meet with me, or if you feel a different colleague would be better suited to speak with me, I would appreciate if you could forward this email on to other staff who may be available.

Kind regards,

Alexandra Rutledge
University of Waterloo
Email: a3rutledge@uwaterloo.ca
Phone: (403) 604-6551

Appendix B

Consent letter for interview

University of Waterloo

Date:

Dear [Participant],

This letter is an invitation to consider participating in a study I am conducting as part of my Master's degree in the Department of Geography and Environmental Management at the University of Waterloo under the supervision of Dr. Brent Doberstein and Ms. Linda Mortsch. I would like to provide you with more information about this project and what your involvement would entail if you decide to take part.

As a large coastal city, Metro Vancouver is considered vulnerable to climate change impacts such as sea level rise. The projected risks warrant the need to implement adaptation and disaster risk reduction measures. Municipalities in Metro Vancouver have been proactive in drafting climate change adaptation strategies to respond to sea level rise.

The purpose of this research is to uncover the influences that guide climate change adaptation choices. Therefore, the main goal of this study is to understand how municipalities are responding to environmental hazards in the context of future climate change. This study examines the constraints municipalities are facing in sea level rise and climate change adaptation, and the pathways for improvements.

I am conducting interviews to gain insight from actors that have significant knowledge in coastal management and planning activities in Metro Vancouver. Thus, I would like to include your perspectives, as a staff member of a [engineering firm, municipal planning department, non-profit organization, academia], in my study. I believe because you are actively involved in [planning, consulting, reporting], you are best suited to speak to the various issues, such as current adaptation priorities, funding, sources of sea level rise and climate change information, and the barriers to implementing non-structural adaptation, and what improvements could be made for the future of climate change adaptation and disaster risk reduction in Metro Vancouver.

Participation in this study is voluntary. It will involve an interview of approximately 30 to 45 minutes in length to take place in a mutually agreed upon location. You may decline to answer any of the interview questions if you so wish. Further, you may decide to withdraw from this study at any time without any negative consequences by advising the researcher. With your permission, the interview will be audio recorded to facilitate collection of information, and later transcribed for analysis. Shortly after the interview has been completed, I will send you a copy of the transcript to give you an opportunity to confirm the accuracy of our conversation and to add or clarify any points that you wish. All information you provide is completely confidential. Your name will not appear in any thesis or report resulting from this study, however, with your permission anonymous quotations may be used. Data collected during this study will be retained for a minimum of seven years. Only researchers with this project will have access. Participating in this research may involve minimal risk. While researchers will not use your name or other identifying information, given the relatively small pool of individuals who are qualified to comment on coastal management, planning, and adaptation in Vancouver, it may be possible for a motivated individual to attempt to discern your identity. Also, as research is interested in your thoughts, there may be risk to your career if personal thoughts on the topic being discussed differ from that of their employer and/or local government, in the event your identity becomes known. To mitigate this risk, all information provided by you in this study is kept confidential and you will not be identified in this study.

There is minimal risk anticipated to you as a participant in this study. However, one possible psychological risk to participants is the feelings of awkwardness when those involved in coastal management and planning are talking about, or admitting to, the lack of capacity or barriers they face in implementing changes or new scientific findings on coastal adaptation. If needed, to mitigate this risk, a local counselling service phone number will be made available to the participant. And all information is kept confidential.

If you have any questions regarding this study, or would like additional information to assist you in reaching a decision about participation, please contact me at 403-604-6551 or by email at a3rutledge@uwaterloo.ca. You can also contact either of my co-supervisors Dr. Brent Doberstein (bdoberst@uwaterloo.ca, 519-888-4567 ext. 33384) or Ms. Linda Mortsch (ldmortsch@uwaterloo.ca, 519-888-4567 x35495).

I would like to assure you that this study has been reviewed and received ethics clearance through a University of Waterloo Research Ethics Committee. However, the final decision about participation is yours. If you have any comments or concerns resulting from your participation in this study, please contact Dr. Maureen Nummelin in the Office of Research Ethics at 1-519-888-4567, Ext. 36005 or maureen.nummelin@uwaterloo.ca.

I hope that the results of my study will be of benefit to those organizations directly involved in the study, other voluntary recreation organizations not directly involved in the study, as well as to the broader research community.

I very much look forward to speaking with you and thank you in advance for your assistance in this project.

Yours Sincerely,

Alexandra Rutledge

CONSENT FORM

By signing this consent form, you are not waiving your legal rights or releasing the investigator(s) or involved institution(s) from their legal and professional responsibilities.

I have read the information presented in the information letter about a study being conducted by [**insert researcher names**] of the Department of [**insert department name**] at the University of Waterloo. I have had the opportunity to ask any questions related to this study, to receive satisfactory answers to my questions, and any additional details I wanted.

I am aware that I have the option of allowing my interview to be audio recorded to ensure an accurate recording of my responses.

I am also aware that excerpts from the interview may be included in the thesis and/or publications to come from this research, with the understanding that the quotations will be anonymous.

I was informed that I may withdraw my consent at any time without penalty by advising the researcher.

This project has been reviewed by, and received ethics clearance through a University of Waterloo Research Ethics Committee. I was informed that if I have any comments or concerns resulting from my participation in this study, I may contact the Director, Office of Research Ethics at 519-888-4567 ext. 36005.

With full knowledge of all foregoing, I agree, of my own free will, to participate in this study.

☐YES ☐NO

I agree to have my interview audio recorded.

☐YES ☐NO

I agree to the use of anonymous quotations in any thesis or publication that comes of this research.

☐YES ☐NO

Participant Name: ______________________________ (Please print)

Participant Signature: ____________________________

Witness Name: ________________________________ (Please print)

Witness Signature: ______________________________

Date: ____________________________

Appendix C

Interview Schedule for semi-structured interviews

Date:
Start time:
End time:
Municipality:

Interviewee #:

Key terms to keep in mind

Sea level rise, climate change induced coastal hazards, structural protection vs. non-structural, resources, funding, information

Key Themes

- Top coastal management and planning challenges in X municipality
- Current examples/progress in implementation of climate change adaptation for the coast in X municipality
- Possibility of managed retreat in X municipality
- Barriers or constraints to coastal adaptation (financial, institutional, physical, knowledge, social, etc)
- Barriers to managed retreat
- Needed improvements for climate change adaptation and coastal management
- Additional key contacts and actors

Additional Themes

- Residents' perceptions/reactions to managed retreat
- Decision-making authority to managed retreat
- Degree of clarity over climate change future impacts in X municipality
- Importance of hazards and extreme events for managed retreat