Managing the Unavoidable
Planning for a Resilient Surrey in the Face of Sea Level Rise

Rebecca Chaster
BA (Honours), MA (Planning) Candidate
Planning Technician, Area Planning & Development, City of Surrey

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Executive Summary

“If climate change is the shark, then water is its teeth.”
– Paul Dickenson, CEO of Carbon Disclosure Project (2012)

Sea level rise (SLR) is one of the many direct results of anthropogenic climate change and one of the impacts that may be most acutely felt in British Columbia’s coastal communities. The City of Surrey is no exception, with its 54km of shorelines along the Fraser River and Pacific Ocean, and over one quarter of its land base in the current 200-year floodplain. SLR is due to the thermal expansion of warming oceans and the melting of continental glaciers and ice sheets, both products of increasing global temperatures. While ocean levels began to rise in the late 19th century at 1.7mm/year, this rate has increased to almost 3mm/year in recent decades and is expected to accelerate over the coming century (IPCC 2007). Thermal expansion has been the main driver of SLR in the past centuries, but its relative contribution is decreasing as the rate of land-based ice melt increases. The coastal hazards associated with SLR are many, and include: coastal inundation and reduced drainage capacity; coastal erosion; changes to coastal habitats and loss of coastal wetlands; saltwater intrusion into freshwater aquifers; reduction in coastal sea ice; and more frequent and intense storms, storm surge, and wave action (Arlington Group Planning + Architecture Inc., 2008). There also exists great uncertainty in attempting to predict future SLR – no one really knows when seas will rise to what levels, due in particular to the large unknowns of how the massive land-based icesheets of Greenland and Antarctica will react to warming temperatures. If fully melted, it is estimated that the ice contained in the Antarctic could increase sea levels by over 60 metres, and that of Greenland by an additional 7 metres. One thing is certain: even if all greenhouse gas emissions stopped today, sea levels would continue to rise for decades, due to the ‘lag effect’ of ocean volume expansion in response to warming global temperatures.

This project is based primarily on an unpaid internship of approximately six weeks conducted over April and May 2014, in the Community Planning department at the City of Surrey (“the City”). The City of Surrey represents the primary unit of analysis for this inquiry, with its coastal community of Crescent Beach acting as a case study. The author also incorporated data regarding risk reduction and coastal adaptation efforts from 28 Strait of Georgia communities. The primary and secondary research questions that this project endeavours to respond to are as follows:

How can the City of Surrey effectively plan for and adapt to sea level rise (SLR)?
- How vulnerable is the community of Crescent Beach to SLR and coastal flooding?
- How is future development and changing Provincial floodproofing regulations likely to affect this vulnerability?
- How can this vulnerability be effectively reduced through planning and adaptation efforts?
- What are other Strait of Georgia communities doing to effectively plan for and adapt to SLR?
The research is based on a literature review of scholarly journal articles, policy documents, engineering reports, scientific papers, and local and provincial government publications (including land use policies, bylaws, staff reports, and maps). Several semi-structured and informal in-person interviews were conducted with key City staff, primarily from the Community Planning, Area Planning and Development, Engineering, and Sustainability departments (responses anonymized in this report). The researcher also attended several larger meetings and site visits with City staff, and contributed to a staff Corporate Report¹ to City Council on the proposed amendments to the Provincial Flood Hazard Area Land Use Management Guidelines. A series of maps were created for the case study community (Crescent Beach), with data supplied by the Community Planning department and from the BC Assessment Office. Telephone surveys on risk reduction and coastal adaptation were conducted by the author’s UBC research group with 28 Strait of Georgia local governments (including the City of Surrey), and a selection of questions included and analyzed in this project.

SLR policy in BC has changed rapidly since flood hazard area land use management was transferred from the provincial to the local government level in 2004. Provincial Guidelines released in 2011 recommend local governments plan for 1m of SLR by year 2100, and updated design standards for coastal flood protection to account for SLR. This resulted in significant increases in the minimum recommended elevations of coastal Flood Construction Levels (FCLs), which determine the elevation of the habitable floor space for new development, and sea Dyke Crest Elevations (DCEs). The BC Ministry of Lands, Forests and Natural Resource Operations is currently proposing amendments to the 2004 legislation that transferred flood hazard management responsibilities to local governments, which incorporate the findings of the 2011 Guidelines.

Local governments had until October 2014 to provide written feedback to the Ministry on the proposed amendments to the 2004 flood hazard area land use legislation. On September 24, 2014 Surrey City Council passed a Corporate Report² which officially conveyed staff and Council concerns over the proposed amendments to the Province. If enacted as proposed, these amendments would legislate that new coastal development, subdivision, and zoning allow for year 2100 SLR and coastal land use allow for year 2200 SLR. In 2008, the Province also introduced a clause into Section 15 of the Compensation and Disaster Financial Assistance Regulation, the legislation governing the use of the Provincial Disaster Financial Assistance. This amendment stated that, in the event of flood damage to development where local governments had allowed FCL relaxations to build below Provincial requirements, the Province would not provide its Disaster Financial Assistance funds and municipalities could thus be liable to cover the costs of any flood damage incurred. Unlike coastal areas, design standards for the City’s Fraser River FCLs and DCEs were not updated by the 2011 Provincial Guidelines. However, the Province in coordination with the Fraser Basin Council is set to release results of river hydraulic modelling that accounts for climate change impacts, which could in turn result in increases to design standards for Fraser River flood protection.

¹ “Proposed Amendments to the Provincial Flood Hazard Area Land Use Management – City of Surrey Comments” (September 2014), available online at: http://www.surrey.ca/bylawsandcouncillibrary/CR_2014-R167.pdf
² “Proposed Amendments to the Provincial Flood Hazard Area Land Use Management – City of Surrey Comments” (September 2014), available online at: http://www.surrey.ca/bylawsandcouncillibrary/CR_2014-R167.pdf
DCEs for most of the City’s coastal areas are not meeting requirements for current (2010) recommended elevations, and are significantly lower than year 2100 DCEs resulting from the 2011 Provincial Guidelines (Figure 1). The City has also established a precedent in the coastal Crescent Beach community of allowing variances to the Provincial 3.3m FCL minimum, such that new development has been allowed to be built closer to native lot grades. The average built FCL in Crescent Beach is 2.6m geodetic – approximately 0.7m below the current Provincial FCL requirement for the area and 2-2.5m below the projected year 2100 FCLs (Figure 2). Unlike Crescent Beach, the City has enforced the recommended Provincial FCL minimums for new development in the rest of its coastal and Fraser River areas. However, these have not been updated since the release of the 2011 Provincial Guidelines (for coastal areas) and could soon be updated for Fraser River areas (pending the results of current Provincial river hydraulics modeling).
Figure 2. Residential Structures by Built FCL Elevation (highlighting those built to the current Provincial FCL minimum of 3.3m) and lots with Elevation DVPs and Restrictive Covenants
The challenges with raising DCEs are primarily the land required to increase dyke heights (for each 1m increase, 3m of land on either side of dykes is required to maintain a 1:3 slope for standard dykes in urban areas), as well as the perceived loss of privacy and waterfront views for properties adjacent to dykes. These issues may be particularly salient in the affluent area of Crescent Beach (should the City decide to raise these dykes), where property lines are already abutting the current dyke. In 2012, the Province released a report which projected that the cost of adapting flood protection in Metro Vancouver to SLR by year 2100 would be $9.47 billion, with a significant cost coming from the property acquisition required to elevate dyke heights. The projected cost for Surrey’s four shoreline reaches along the City’s Fraser River and ocean frontage was $1.69 billion, with almost one third ($478 million) for property acquisition.

In addition to raising DCEs, there are numerous challenges and impacts to the built environment associated with raising FCLs. These are already being felt in many of the City’s neighbourhoods, such as Bridgeview, where FCLs for new development have been gradually increasing since the 1970s (in line with Provincial requirements). This has led to discrepancies in the streetscape character (e.g. newer homes ‘towering’ over neighbouring properties; see Figure 3) and approximately 5-10% loss in allowable density (since uninhabitable floor space below FCLs counts towards total allowable density and height relaxations are not currently permitted for structures that are elevated to meet FCLs). Only non-habitable areas area permitted below FCLs, which include uses such as parking, crawlspace, storage areas, and utility areas. The many challenges associated with increasing FCLs include:

- Increase in construction costs for new development (e.g. to homeowners, developers)
- Difficulty integrating existing utilities (e.g. sewer & water servicing) and infrastructure (e.g. road network & drainage infrastructure) with elevated buildings
- Challenges in maintaining streetscape form and neighbourhood character
- Difficulty achieving density (Floor Area Ratio) on site due to maximum height requirements in Zoning Bylaw
  - Height relaxation may affect streetscape, view corridors, adjacent properties
- Accessibility and safety may be compromised (e.g. by more stairs)
- Increased noise reflection by elevated buildings (e.g. from busy streets)
- Increased potential for conversion of uninhabitable spaces below FCLs into habitable space after building inspection (e.g. illegal suites)
- Difficulty maintaining commercial at grade to encourage street level pedestrian access
- Protection of critical building systems services and vulnerable building components below FCL elevations (e.g. electrical, mechanical)
Figure 3. Contrast in built FCLs between older & newer homes in Bridgeview, with possible year 2100 FCL approximation (12441 & 12451 113 Ave)
Given the current legislative and policy context of SLR and flood hazard area land use management in BC, this report makes several recommendations that may increase the City’s resilience to the long-term impacts of SLR. These recommendations are organized around four main goals and by suggested timeline of implementation: “Short” (within the next year), “Medium” (in the next 1-5 years), and “Long” (in the next >5 years) (Table 1). Recommendations are further explained below, and priority actions for implementation are those with a “Short” timeline. All of the recommendations are within City jurisdiction, however, some will require partnerships with other organizations to implement (e.g. other municipalities and levels of senior government). The intent is not for the City of Surrey to necessarily implement all of the recommendations as described, but rather to provide suggestions for a range of strategies across a range of timelines, all of which should increase resilience to and awareness of SLR within the City (whether pursued in isolation or in combination with other approaches).

Table 1. Report Recommendations

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<tr>
<th>GOAL</th>
<th>RECOMMENDATION</th>
<th>TIMELINE</th>
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<tbody>
<tr>
<td>1. Greater awareness of challenges posed by SLR and build support for SLR adaptation</td>
<td>1.1 Internal City stakeholder SLR education &amp; engagement</td>
<td>1.1 Short</td>
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<tr>
<td></td>
<td>1.2 Public SLR engagement strategy</td>
<td>1.2 Medium</td>
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<tr>
<td>2. Better understanding and mitigate potential impacts of raising Flood Construction Levels (FCLs) &amp; Dyke Crest Elevations (DCEs)</td>
<td>2.1 Collect FCL construction cost data</td>
<td>2.1 Short</td>
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<tr>
<td></td>
<td>2.2 Height relaxations in Zoning Bylaw for residential floodplain zones</td>
<td>2.2 Medium</td>
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<tr>
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<td>2.3 Incorporate urban design floodproofing strategies into existing City policy and tools</td>
<td>2.3 Medium</td>
</tr>
<tr>
<td>3. Assess site-specific viability of 4 SLR adaptation strategies and transition to risk-based funding model</td>
<td>3.1 Conduct site-specific cost-benefit analysis of SLR adaptation strategies</td>
<td>3.1 Long</td>
</tr>
<tr>
<td></td>
<td>3.2 Consider innovative funding options for SLR adaptation and flood protection</td>
<td>3.2 Long</td>
</tr>
<tr>
<td>4. Increase flood resilience and bring City practice &amp; policy in line with new Provincial guidelines &amp; legislation</td>
<td>4.1 Identify “no regrets” SLR adaptation actions</td>
<td>4.1 Long</td>
</tr>
<tr>
<td></td>
<td>4.2 Modify Crescent Beach DVP process</td>
<td>4.2 Medium</td>
</tr>
<tr>
<td></td>
<td>4.3 Harmonize and update City FCL policy</td>
<td>4.3 Short</td>
</tr>
</tbody>
</table>
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# Table of Contents

Executive Summary....................................................................................................................................... 2  
Acknowledgements....................................................................................................................................... 9  
List of Figures .............................................................................................................................................. 12  

1. Background and Problem Context .......................................................................................................... 14  
   1.1 Sea Level Rise and Its Adaptation ..................................................................................................... 14  
       Research Design & Problem Statement.............................................................................................. 15  
       Four Primary Adaptation Strategies ................................................................................................... 16  
       Sea Level Rise and the Fraser River ..................................................................................................... 18  
   1.2 Coastal Flood Protection in BC.......................................................................................................... 19  
       Responsibility for Flood Protection.................................................................................................. 19  
       Proposed Changes to the “Flood Hazard Area Land Use Management Guidelines” ..................... 20  
       The 2011 Provincial Guidelines ........................................................................................................ 21  
       The 2011 Provincial Guidelines: Coastal FCLs ................................................................................. 24  
       The 2011 Provincial Guidelines: Sea Dykes ....................................................................................... 26  
       The 2011 Provincial Guidelines: Sea Level Rise Planning Areas ..................................................... 29  
       The “Cost of Adaptation” to Sea Level Rise ..................................................................................... 31  
   1.3 Coastal Flood Protection in Surrey ................................................................................................... 33  
       200-Year Floodplain ............................................................................................................................ 33  
       Structural Flood Protection ................................................................................................................. 35  
       Policy & Regulatory Tools ................................................................................................................... 38  
       Reaction to the 2011 Provincial Guidelines ....................................................................................... 40  
       “Serpentine, Nicomekl & Campbell Rivers – Climate Change Floodplain Review” ......................... 41  

2. Analysis ................................................................................................................................................... 45  
   2.1 Crescent Beach .................................................................................................................................. 45  
       Elevations ........................................................................................................................................... 46  
       Flood Construction Levels (FCLs) ....................................................................................................... 48  
       Current Development Patterns .......................................................................................................... 51  
       Future Development Patterns ............................................................................................................ 53
Property Values................................................................................................................................... 56
Dykes & SLR......................................................................................................................................... 58
2.2 The Impacts of Raising Flood Construction Levels................................................................. 62
Bridgeview........................................................................................................................................... 64
2.3 SLR Adaptation in Strait of Georgia Communities................................................................. 67
3. Recommendations & Conclusions ................................................................................................. 74
   Goal 1: Greater awareness of challenges posed by SLR and build support for SLR adaptation.......75
   Goal 2. Better understand and mitigate potential impacts of raising Flood Construction Levels (FCLs) and Dyke Crest Elevations (DCEs) .................................................................................................................. 78
   Goal 3. Assess site-specific viability of 4 SLR adaptation strategies and transition to risk-based funding model ...................................................................................................................................................... 81
   Goal 4. Increase flood resilience and bring City practice & policy in line with new Provincial guidelines & legislation ............................................................................................................................................ 83
4. Appendices........................................................................................................................................ 86
5. Works Cited........................................................................................................................................ 92
List of Figures

Figure 1. Crescent Beach North dyke with existing, year 2010 & possible year 2100 dyke elevations........... 4
Figure 2. Residential Structures by Built FCL Elevation and lots with Elevation DVPs and Restrictive
Covenants.................................................................................................................................................. 5
Figure 3. Contrast in built FCLs between older & newer homes in Bridgeview, with possible year 2100 FCL
approximation............................................................................................................................................... 7
Figure 4. Examples of adaptation measures for responding to SLR.............................................................. 17
Figure 5. Relative SLR by 2100 for select BC locations................................................................................. 21
Figure 6. SLR projections for BC .................................................................................................................. 22
Figure 7. Pre-2011 calculation of coastal FCLs............................................................................................ 24
Figure 8. Updated post-2011 calculation of coastal FCLs............................................................................. 25
Figure 9. Conceptual differences between the previous 1970s and new 2011 sea dyke design approaches ........................................................................................................................................ 27
Figure 10. Updated definitions for coastal DFLs, FCLs, and sea DCEs based on 2011 Provincial Guidelines ........................................................................................................................................... 29
Figure 11. Concept plan of SLR Planning Areas for the Fraser River Delta, with possible year 2100 & 2200
SLR Planning Area contour elevations for Surrey....................................................................................... 30
Figure 12. Shoreline reaches with recommended adaptation strategy and projected cost for adapting to
SLR for year 2100, for 4 shoreline reaches in the City................................................................................ 32
Figure 13. Surrey’s current 200-year floodplain.......................................................................................... 34
Figure 14. Surrey Towns and Communities, highlighting the case study community for this report
(Crescent Beach) ........................................................................................................................................... 35
Figure 15. Surrey’s agricultural lands........................................................................................................... 35
Figure 16. Surrey’s flood control infrastructure & historic dyking districts.................................................... 37
Figure 17. Flood Prone Hazard Development Permit Areas......................................................................... 39
Figure 18. DCEs for Serpentine/Nicomekl lower floodplain calculated using joint probability methodology .............................................................................................................................................. 43
Figure 19. Crescent Beach land use designations ......................................................................................... 45
Figure 20. Crescent Beach contour elevations ............................................................................................. 47
Figure 21. Residential structures by built FCL elevation and lots with elevation DVPs and restrictive
covenants ....................................................................................................................................................... 49
Figure 22. New ocean frontage dwelling in Crescent Beach North (3106 Ohara Lane) showing
approximate built FCL elevation, year 2010 & 2100 FCLs........................................................................ 51
Figure 23. Private properties by building age and elevation DVPs with Restrictive Covenants.................... 52
Figure 24. Private properties by building age and low building-to-land ratios ............................................. 55
Figure 25. Private properties by 2014 gross assessments ........................................................................... 57
Figure 26. Crescent Beach North dyke with existing, year 2010 & potential year 2100 DCEs............... 59
Figure 27. Crescent Beach South dyke with existing & potential year 2100 DCEs & footprints ..............60
Figure 28. Single family dwelling located at 12502 114 Avenue in Bridgeview in which a window has been installed in the ground floor below the FCL ........................................................................................................63
Figure 29. Bridgeview land uses ........................................................................................................65
Figure 30. Contrast in built FCLs between older & newer homes in Bridgeview, with possible year 2100 FCL approximation .............................................................................................................66
Figure 31. Form of public participation in planning for risk reduction and/or adaptation to coastal and riverine flood hazards for Strait of Georgia communities ........................................................................68
Figure 32. Strait of Georgia communities who have conducted assessments of future flood risk taking into account climate change ..................................................................................................69
Figure 33. Strait of Georgia communities’ compliance with current provincial guidelines on coastal flood hazard land use management ..................................................................................................70
Figure 34. Level of consideration being given by Strait of Georgia communities to 4 main SLR adaptation strategies .........................................................................................................................72
Figure 35. Visualization of two different ‘Protect’ SLR adaptation measures (seawall and dyke) in the Corporation of Delta ......................................................................................................................77
Figure 36. Public art project showing SLR on Cambie Street Bridge supports, Vancouver, BC ............78
Figure 37. Year 2010, 2050, and 2100 high tide markers on piling in Bamfield, BC ...............................78
Figure 38. Elevation of existing structure to meet increased FCLs and height relaxations in post-Hurricane Sandy New York City .............................................................................................................79
Figure 39. Wet floodproofing design with window openings which allow for passage of flood waters ...80
Figure 40. Example of managed retreat of private property in Kitty Hawk, South Carolina ..................82
Figure 41. Sign posted in Calgary following 2013 Bow River flooding .....................................................84
Figure 42. Outdated FCL requirements in the Zoning Bylaw, which have not been used by the City’s Building Division since the 1990s ........................................................................................................85

3 All non-original figures reproduced with permission
1. Background and Problem Context

1.1 Sea Level Rise and Its Adaptation

Sea level rise (SLR) is one of the many direct results of anthropogenic climate change and one of the impacts that may be most acutely felt in British Columbia’s coastal communities. SLR is due to the thermal expansion of warming oceans and the melting of continental glaciers and ice sheets, both products of increasing global temperatures. While ocean levels began to rise in the late 19th century at 1.7mm/year, this rate has increased to almost 3mm/year in recent decades and is expected to accelerate over the coming century (IPCC 2007). Thermal expansion has been the main driver of SLR in the past centuries, but its relative contribution is decreasing as the rate of land-based ice melt increases. The coastal hazards associated with SLR are many, and include: coastal inundation and reduced drainage capacity; coastal erosion; changes to coastal habitats and loss of coastal wetlands; saltwater intrusion into freshwater aquifers; reduction in coastal sea ice; and more frequent and intense storms, storm surge, and wave action (Arlington Group Planning + Architecture Inc., 2008). There also exists great uncertainty in attempting to predict future SLR – no one really knows when seas will rise to what levels, due in particular to the large unknowns of how the massive land-based icesheets of Greenland and Antarctica will react to warming temperatures. If fully melted, it is estimated that the ice contained in the Antarctic could increase sea levels by over 60 metres, and that of Greenland by an additional 7 metres. One thing is certain: even if all greenhouse gas emissions stopped today, sea levels would continue to rise for decades, due to the ‘lag effect’ of ocean volume expansion in response to warming global temperatures. A study released in May 2014 reported that the 3.2-kilometres-thick West Antarctic icesheet has begun melting, an irreversible process which could raise global mean sea levels by 3m or more if the entire sheet collapses in the coming centuries (Joughin, Smith, & Medly, 2014).

With over 50km of coastline along the Pacific Ocean and the Fraser River, the City of Surrey (“the City”) will likely experience many of the impacts of SLR on its coastal land base over the coming centuries. The tidal influence of the sea currently extends up the Fraser River all the way to Hope, and this influence will increase in magnitude and extent with SLR (Staff Interview, 2014). While currently the flood risk in the City’s Fraser River frontage is governed by the springtime freshet4, in the future this will shift to being governed by coastal influence with the associated winter storm surges (Staff Interview, 2014). The coastal community of Crescent Beach in South Surrey is already experiencing the impacts of SLR, and serves as a case study in this project through which to examine SLR impacts and adaptation strategies. Saltwater infiltration as SLR occurs is causing the groundwater tables to rise in this community, thereby reducing the surface infiltration and drainage capacity of the natural groundwater drainage systems. Subsidence, the process of soil sinking due to a variety of conditions including compaction from development, is also occurring in many lowland areas of Surrey and will increase relative rates of SLR. Finally, other climate change effects such as changing snow and rain precipitation patterns may result in increased flooding risk in the City’s floodplain areas (City of Surrey, 2013).

4 Freshet refers to the increase in downstream river discharge that results from the springtime melt of mountain snowpack
Research Design & Problem Statement

This project is based primarily on an unpaid internship of approximately six weeks conducted over April and May 2014, in the Community Planning department at the City of Surrey. The City of Surrey represents the primary unit of analysis for this inquiry, with its coastal community of Crescent Beach acting as a case study. The author also incorporated data regarding risk reduction and coastal adaptation efforts from 28 Strait of Georgia communities. The primary and secondary research questions that this project endeavours to respond to are as follows:

*How can the City of Surrey effectively plan for and adapt to sea level rise (SLR)?*

- *How vulnerable is the community of Crescent Beach to SLR and coastal flooding?*
- *How is future development and changing Provincial floodproofing regulations likely to affect this vulnerability?*
- *How can this vulnerability be effectively reduced through planning and adaptation efforts?*
- *What are other Strait of Georgia communities doing to effectively plan for and adapt to SLR?*

The research is based on a literature review of scholarly journal articles, policy documents, engineering reports, scientific papers, and local and provincial government publications (including land use policies, bylaws, staff reports, and maps). Several semi-structured and informal in-person interviews were conducted with key City staff, primarily from the Community Planning, Area Planning, Engineering, and Sustainability departments (responses anonymized in this report). The researcher also attended several larger meetings and site visits with City staff, and contributed to a staff Corporate Report⁵ to City Council on the proposed amendments to the Provincial Flood Hazard Area Land Use Management Guidelines. A series of maps were created for the case study community (Crescent Beach), with data supplied by the Community Planning department and from the BC Assessment Office. Telephone surveys on risk reduction and coastal adaptation were conducted by the author’s UBC research group with 28 Strait of Georgia local governments (including the City of Surrey), and a selection of questions included and analyzed in this project.⁶

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⁶ Three presentations summarizing the report and the internship findings were delivered to the Community Planning and Area Planning and Development departments in June 2015, and an informal presentation delivered in September 2015 to the author’s research group at UBC’s School of Community and Regional Planning
Four Primary Adaptation Strategies

There are generally four main strategies for adapting to SLR (see Figure 4 for examples):

**Protect** is a reactive strategy to build “hard” (e.g. armouring coastlines with dykes, seawalls, or riprap revetments) or “soft” (e.g. constructing or augmenting berms, dunes, beaches, and marshes) protective structures to protect people, private and public property, and infrastructure from SLR and its associated hazards. This is typically the first response considered by governments but may be prohibitively expensive and have limited effectiveness in highly vulnerable locations, given the long timeline that SLR adaptation presents (Arlington Group Planning + Architecture Inc. et al., 2013). This strategy can also lead to a false sense of security and encourage development behind defense structures, where residents may assume they are more permanent and less fallible than they are in reality. They can also create an expectation that these structures will be maintained in perpetuity by the organizations that built them (typically levels of government), leading to ever increasing financial commitments to maintain and upgrade them as sea levels rise (Ausenco Sandwell, 2011c). This is the approach that the City has already been pursuing to manage its current coastal and river flood risks along Boundary Bay and its riverine floodplains, however, a detailed cost-benefit analysis of the various adaptation options will be conducted before deciding which strategy(ies) the City will pursue in the long-term.

**Accommodate** is an adaptive strategy in which land-based structures and activities are adapted to tolerate flooding and inundation (Ausenco Sandwell, 2011c). These can include building structures with water-resilient materials or building above Flood Construction Levels (FCLS) that apply to the end of the structure’s lifespan to avoid flood damage to habitable building space. The City establishes its minimum FCLs for new construction based on Provincial guidelines, which in 2011 were updated to recommend increases to accommodate for SLR.

**Avoid** is a strategy that simply means avoiding future development in areas subject to coastal hazards associated with SLR (current or future). Setbacks can be used to place structures beyond the reach of these hazards under this adaptation strategy. Designating land as undevelopable or only for land uses less vulnerable to the impacts of SLR is another available measure. The City uses setbacks in its Zoning Bylaw for all types of watercourses (sea and otherwise) and since 2008 has had a policy to avoid future development in the Serpentine/Nicomekl 200-year floodplain.

**Managed Retreat** is an adaptive decision to withdraw, relocate, or abandon private or public assets that are at risk due to SLR and associated coastal hazards. This approach limits the use of structural protection and can include the relocation of structures within property boundaries or to another site, and even large-scale relocation of settlements and infrastructure (although property relocation tends to occur on a case-by-case basis at the discretion of the private property owner) (Ausenco Sandwell, 2011c).

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7 As outlined in the City’s “Climate Adaptation Strategy” (Adaptation Action FL-1.2) and the “Serpentine, Nicomekl and Campbell Rivers – Climate Change Floodplain Review” study.

8 FCLs determine the minimum elevation of the underside of a wooden floor system or top of concrete slab for habitable building space (Ausenco Sandwell, 2011c).
<table>
<thead>
<tr>
<th>Measure</th>
<th>How It Works</th>
<th>Environmental Effects</th>
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<tbody>
<tr>
<td><strong>Avoid</strong></td>
<td></td>
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<tr>
<td>Setback</td>
<td>Delay the need for shore protection by keeping development out of the most</td>
<td>Impacts of shore protection delayed until shore erodes up</td>
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<tr>
<td></td>
<td>vulnerable lands</td>
<td>to the setback line; impacts of development also reduced.</td>
</tr>
<tr>
<td>Density or size</td>
<td>Reduce the benefits of shore protection and thereby make it less likely</td>
<td>Depends on whether owners of large lots decide to</td>
</tr>
<tr>
<td>restriction</td>
<td></td>
<td>protect shore; impacts of intense development reduced.</td>
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<tr>
<td><strong>Protect</strong></td>
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<tr>
<td>Seawall</td>
<td>Shoreline armouring used to define a shoreline - reduces erosion, protects</td>
<td>Elimination of beach; scour and deepening in front of</td>
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<tr>
<td></td>
<td>against flood and wave overtopping</td>
<td>wall; erosion exacerbated at terminus.</td>
</tr>
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<td>Revetment</td>
<td>Shoreline armouring used to define a shoreline - reduces erosion, protects</td>
<td>Prevents inland migration of wetlands and beaches;</td>
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<td></td>
<td>land from storm waves, protects new landfill</td>
<td>traps horseshoe crabs and prevents amphibious movement;</td>
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<td></td>
<td>may create habitat for oysters and refuge for some species.</td>
</tr>
<tr>
<td>Dike</td>
<td>Shoreline armouring used to protect against inundation - prevents flooding</td>
<td>Prevents wetlands from migrating inland; thwarts</td>
</tr>
<tr>
<td></td>
<td>and permanent inundation (when combined with a drainage system)</td>
<td>ecological benefits of floods (e.g., annual sedimentation,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>higher water tables, habitat during migrations,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>productivity transfers)</td>
</tr>
<tr>
<td>Tide gate</td>
<td>Shoreline armouring used to protect against inundation - reduces tidal range</td>
<td>Restrictions fish movement; reduced tidal range</td>
</tr>
<tr>
<td></td>
<td>by draining water at low tide and closing at high tide</td>
<td>reduces intertidal habitat; may convert saline habitat</td>
</tr>
<tr>
<td></td>
<td></td>
<td>to freshwater habitat.</td>
</tr>
<tr>
<td>Storm surge barrier</td>
<td>Shoreline armouring used to protect against inundation - eliminates storm</td>
<td>Necessary storm surge flooding in salt marshes is</td>
</tr>
<tr>
<td></td>
<td>surge flooding; could protect against all floods if operated on a tidal</td>
<td>eliminated.</td>
</tr>
<tr>
<td></td>
<td>schedule</td>
<td></td>
</tr>
<tr>
<td>Dune</td>
<td>Elevates land - protects inland areas from storm waves; provides a source</td>
<td>Can provide habitat; can set up habitat for secondary</td>
</tr>
<tr>
<td></td>
<td>of sand during storms to offset erosion</td>
<td>dune colonization behind it.</td>
</tr>
<tr>
<td>Beachfill</td>
<td>Elevates land - reverses shore erosion, and provides some protection from</td>
<td>Short-term loss of shallow marine habitat; could</td>
</tr>
<tr>
<td></td>
<td>storm waves</td>
<td>provide beach and dune habitat.</td>
</tr>
<tr>
<td><strong>Accommodate</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Elevate land and</td>
<td>Avoids flooding and inundation from sea-level rise by elevating everything</td>
<td>Deepening of estuary unless bay bottoms are</td>
</tr>
<tr>
<td>structures</td>
<td>as much as sea rises</td>
<td>elevated as well.</td>
</tr>
<tr>
<td><strong>Retreat</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rolling easement®</td>
<td>Prohibit shore protection structures</td>
<td>Impacts of shore protection structures avoided</td>
</tr>
</tbody>
</table>

*Figure 4. Examples of adaptation measures for responding to SLR (source: Ausenco Sandwell, 2011c)*
Sea Level Rise and the Fraser River

Understanding the impacts of climate change and specifically SLR on coastal areas is relatively more straightforward than understanding the range of climate change impacts on a large river system such as the Fraser River, particularly in downstream areas. This is due to the plethora of variables that lead to Fraser River flood levels, including mountain snowpack, timing of springtime freshet flooding, upstream structural flood protection works, and watershed impacts of mountain pine beetle (Staff Interview, 2014). There are dozens of municipalities with jurisdiction along the Fraser River, and the flood protection works of upstream areas can greatly increase the river flow and velocity (and thus flood hazard) in downstream communities. Due to this integrated nature of Fraser River flood risk that cross municipal boundaries, the Province is currently conducting river hydraulics modeling for the Fraser River that takes into account climate change and upstream/downstream effects. The Fraser River affects dozens of municipalities and is of significant economic importance to the provincial economy, and thus a more coordinated approach to modeling its future flows and updating design standards based on these has been adopted by the Province. The Fraser Basin Council (FBC), a non-profit established in 1997 that coordinates various levels of government, the private sector, and civil society actors to advance sustainability in the Fraser Basin, is also currently coordinating a regional flood management strategy for the Fraser River watershed, with municipalities from Hope to Squamish. Several City Engineering staff are members of this strategy’s steering committees, and have a long history of collaborating with FBC on various flood management-related projects. Surrey’s northern border aligns with the downstream reaches of the Fraser River, and the highest flood levels there have historically resulted from spring Fraser River freshets rather than winter ocean storm surge conditions. With SLR, however, the ocean’s influence and importance will increasingly extend further upstream and with it the governing flood level is changing from freshet- to ocean surge-based. Due to the complexity and different set of vulnerabilities faced by Fraser River flood hazard areas, these areas of Surrey were not considered within the context of this report. The geographic focus of this research in Surrey is on the coastal and non-Fraser River estuarine areas in the City.
1.2 Coastal Flood Protection in BC

Responsibility for Flood Protection

The legislative context of flood hazard management in BC has changed rapidly in the past decade, and increasingly responsibility for flood hazard management has been transferred from the provincial to local government level. Prior to 2004, the Province was responsible for flood hazard management, which included conducting floodplain mapping (historically done in partnership with the federal government) and setting standards for flood protection structures (e.g. dykes), FCLs, floodplain land use, and funding major flood hazard management works, as well as approving any variances to these. Legislative changes enacted through the *Flood Hazard Statutes Amendment Act* (Bill 56) and *Miscellaneous Statutes Amendment Act* (Bill 54) in 2004 brought about changes to several statutes concerning flood hazard management, notably in the *Land Title Act* and the *Local Government Act*. These changes were compiled in the “Flood Hazard Area Land Use Management Guidelines” released that year, which are the only ‘official’ guidelines relating to floodplain management and land use as they were published by the Minister under Section 5 of the Environmental Management Act. The effect was to transfer authority for floodproofing and floodplain land use management from the provincial to the local government level. Municipalities and regional districts, rather than exclusively the Province, could now approve subdivisions, covenants, and floodplain bylaws within floodplains. The caveat was that local governments must “consider Provincial Guidelines, plans and objectives” in carrying out these new responsibilities, and exemptions must be “consistent with Provincial Guidelines or certification” (Arlington Group Planning + Architecture Inc., 2008, pp. 34-35). Municipal Approving Officers could now also require floodplain covenants (i.e. *Land Title Act* Section 219 Restrictive Covenants) in floodplain development. These covenants are registered on the Land Titles of properties where relaxations to build below Provincial FCLs are granted, and indemnify local or provincial government should flood damage occur in the future.

In these 2004 changes the Province retained the authority to regulate dykes by establishing and enforcing flood protection standards and dyke design criteria, as well as auditing and monitoring dyking authorities. Prior to 2004, floodplain mapping was developed by the Province (often in partnership with the federal government) through hydraulic models, delineating floodplain areas. Local governments could then use these floodplain areas to regulate where FCLs were applied, as well as FCL elevations based on the 200-year flood levels. The legislative changes of 2004 transferred the responsibility for hydraulic modelling and floodplain designation to local governments, largely without corresponding funding sufficient to conduct regular and fine-scale floodplain mapping (City of Surrey, 2003). The result is that the majority of BC municipalities have not conducted floodplain mapping since this responsibility was transferred to local governments in 2004. This means that they are using floodplain maps from the last floodplain mapping conducted by the provincial and federal governments in the 1990s –

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9 As outlined in the *Dike Maintenance Act*, largely unaltered in the 2004 legislative changes
10 A 2007 Fraser Basin Council survey of BC municipalities found that only 32% thought that the 2004 legislative changes and related management tools were sufficient for local governments to adequately manage flood hazards (Arlington Group Planning + Architecture Inc., 2008)
information that is decades old and did not incorporate climate change impacts such as SLR or changing precipitation patterns.

Flood damage to residential property typically results from two different types of flood events: overland flooding, in which water enters through windows and doors (usually when large water bodies such as rivers or the ocean exceed their banks), or sewer backup flooding, in which water enters through the sewer system (usually when storm and/or sanitary sewer systems exceed capacity due to increased water flow from heavy precipitation events). Residential overland flood insurance is not available in Canada, the only G8 country in which this type of insurance is unavailable to homeowners. Residential sewer backup insurance is available in Canada, however, residents of flood-prone areas typically aren’t able to secure these policies from private insurers (Staff Interview, 2014). Since residential overland flood insurance is not available, in the case of overland flooding residential property owners must turn to senior levels of government for aid – the Province’s Disaster Financial Assistance and the federal government’s Disaster Financial Assistance Arrangements programs. In 2008, the Province stopped approving FCL reductions11 for new development in floodplain areas in BC and updated Section 15 of the Compensation and Disaster Financial Assistance Regulation. This amendment stated that structures built in a designated floodplain must be “properly flood protected” to be eligible for Disaster Financial Assistance funds to repair damage resulting from a flood. Historically, “properly flood protected” has meant that the habitable areas of all homes or buildings have a floor elevation (FCL) constructed above the 200 year floodplain level, regardless of whether there are any dykes protecting the floodplain area. Local governments who had permitted these developments that were not “properly flood protected” could therefore be responsible to cover the cost of any compensation under Provincial Regulation, given that it was the local governments who provided the variance. This could feasibly occur in the event of a major flood in many municipalities including the City, where variances to build below provincial FCLs in the coastal Crescent Beach neighbourhood are permitted at an average of 3 residences per year12.

Proposed Changes to the “Flood Hazard Area Land Use Management Guidelines”

The Province has proposed amendments to the 2004 “Flood Hazard Area Land Use Management Guidelines” and local governments had until October 30th, 2014 to provide feedback to the Ministry of Forests, Lands and Natural Resource Operations. The amendments would update specifically Sections 3.5 (The Sea) and 3.6 (Areas Protected by Standard Dikes) of the 2004 Guidelines. The proposed amendments are based on the findings of a series of three technical reports on SLR published by the Province in 2011 (the “2011 Provincial Guidelines”), as discussed in the following section of this report. If enacted as proposed, the amendments would require that local governments consider SLR in coastal land use management, FCL requirements, and sea dyke design standards. According to these amendments, requirements for coastal buildings, subdivision, and zoning should allow for SLR to the year 2100, and coastal land use should allow for SLR to the year 2200 (Ministry of Forests, Lands, and Natural Resource Operations, 2014 (proposed)). This means that any new coastal development should

11 While the responsibility to enforce FCL elevations had been downloaded to municipalities following the legislative changes in 2004, BC MOE still retained the authority to approve FCL reductions at its discretion
12 Based on approved Development Variance Permits in the City’s COSMOS mapping program (as of June 2014)
be built to the year 2100 FCLs, unless protected by dykes built to the year 2100 design standards. Neither existing FCLs nor DCEs in the City’s coastal areas are currently close to year 2100 elevations, as discussed later in this report. In addition, coastal land use planning should allow for SLR to the year 2200, which is challenging in that the best science respecting SLR predictions for the year 200 are speculative. Establishing a year 2200 floodplain area that incorporates future SLR is therefore unreliable at best.

The 2011 Provincial Guidelines

It is only in the last decade that the Provincial government in BC has begun to specifically address SLR through technical studies and subsequent SLR projections, guidelines, and legislation. In 2008, the BC MOE released the report “Projected Sea Level Changes for British Columbia in the 21st Century”, which represents the first official BC government publication of SLR projections across the province. These ranged from 0.35-1.2m by 2100 for the Fraser River Delta, higher rates than any other selected location due to the gradual sinking of deltaic soil through a process called subsidence (see Figure 5). This report also highlighted the need for further investigation into the mechanisms that contribute to relative rates of SLR at local scales (e.g. land uplift or subsidence).

<table>
<thead>
<tr>
<th>Location</th>
<th>Sea Level Rise based on extreme low estimate of global sea level rise (m)</th>
<th>Sea Level Rise based on mean estimate of global sea level rise (m)</th>
<th>Sea Level Rise based on extreme high estimate of global sea level rise (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prince Rupert</td>
<td>0.10–0.31</td>
<td>0.25–0.46</td>
<td>0.95–1.16</td>
</tr>
<tr>
<td>Nanaimo</td>
<td>−0.04</td>
<td>0.11</td>
<td>0.80</td>
</tr>
<tr>
<td>Victoria</td>
<td>0.02–0.04</td>
<td>0.17-0.19</td>
<td>0.89–0.94</td>
</tr>
<tr>
<td>Vancouver</td>
<td>0.04–0.18</td>
<td>0.20–0.33</td>
<td>0.89–1.03</td>
</tr>
<tr>
<td>Fraser River Delta</td>
<td>0.35</td>
<td>0.50</td>
<td>1.20</td>
</tr>
</tbody>
</table>

Figure 5. Relative SLR by 2100 for select BC locations (source: BC Ministry of Environment, 2008)

In 2011, the BC MOE refined its 2008 SLR projections with the release of a series of three reports (the “2011 Provincial Guidelines”) intended to help local governments plan for SLR and coastal land use management. These reports projected a global mean sea level increase of 0.5m by 2050, 1m by 2100, and 2m by 2200 (Figure 8). While there still exists great uncertainty in these projections, and SLR will not rise uniformly each year moving forward (as may be inferred from the Province’s graph)

13 This summary report was based on a more in-depth study “An Examination of the Factors Affecting Relative and Absolute Sea Levels in Coastal British Columbia” by R. Thomson, B. Bornhold, and S. Mazzotti (2008).
14 Subsidence is essentially the sinking of delta soil, rates that can be increased by human intervention such as river dredging, construction of retaining walls or dikes, groundwater removal, and large construction projects (BC Ministry of Environment, 2008).
illustrating their SLR projections), these Provincial projections do provide concrete dates and sea levels for local governments to use in coastal land use management. In addition, these present a global mean SLR and thus do not take into account variances in local ground movements (e.g. uplift or subsidence). Adapting sea dyke crest elevations (DCEs) and coastal building flood construction levels (FCLs) for the year 2100 does not simply entail adding these SLR values to today’s elevations, since these exclude factors besides mean SLR that must be accounted for in DCE and FCL elevations (e.g. storm surge, high tides, wave run-up, etc.).

Figure 6. SLR projections for BC (source: Ausenco Sandwell, 2011c)

These three 2011 Provincial reports essentially updated the existing guidelines for calculating sea DCEs and coastal FCLs, and in Surrey this updated methodology applies to the 32km of coastal shoreline on Boundary Bay. The structural lifespan of protection works such as dykes is approximately 100 years and these reports emphasize the importance of accommodating for SLR within the structural lifespan of protection measures. Since the ocean’s tidal influence will extend further upriver with SLR, river dykes such as those along the Fraser River must be redesigned for ocean conditions increasingly further upstream in the future. In the future as SLR continues, the ocean with its winter storm events rather than the river’s springtime freshet will govern the City’s Fraser River frontage flood risk (as it currently does along the Fraser River frontage areas further downstream, e.g. in Richmond) (Staff Interview, 2014).

The 2011 Provincial Guidelines also outline the four main SLR adaptation options (Avoid, Protect, Accommodate, Retreat) and make preliminary recommendations on SLR adaptation options for various coastal reaches across the province (Table 2). These recommendations were made based on an assessment of the value of coastal lands at risk and the consequences of flooding events. For Surrey’s Fraser River region, “Protect” is recommended as the first priority adaptation option (e.g. dykes,
seawalls, storm surge barriers) and “Accommodate” is second (e.g. elevating buildings through FCLs), which could be combined with the “Protection” approach (Table 2). This is the combination of adaptation approaches the City is already taking, with its extensive dyke network (“Protect”) and FCLs (“Accommodate”).

<table>
<thead>
<tr>
<th>Area of Interest</th>
<th>Preliminary Estimate of Area Value</th>
<th>Estimated Consequences of Flooding</th>
<th>Adaptation Options - in potential order of priority</th>
</tr>
</thead>
</table>
| Fraser River delta – Richmond, Surrey and Delta coastal areas | High | High | Protect  
Accommodate  
Retreat - no new or redevelopment  
Avoid – new development |
| Lower Fraser River diked areas | High | High | Same as above |
| Vancouver harbour – no dikes but extensive foreshore development | High | High close to shoreline | Protect  
Accommodate  
Retreat |
| Squamish River delta - no dikes but extensive foreshore development in downtown Squamish, industrial development and high ecological values | Moderate to High | High | Accommodate  
Avoid (new and redevelopment)  
Retreat – re-establish wetlands  
Protect |
| (South) East Vancouver Island – few sea dikes (Cowichan River estuary) but extensive coastal development, mostly low to moderate density (residential, small scale commercial) | Moderate to Low | Moderate - High | Accommodate  
Retreat  
Avoid  
Protect |
| West Vancouver Island, North East Vancouver Island, Central Coast and North Coast – intermittent coastal development, a few high-medium density nodes (e.g., Tofino, Ucluelet, Sunshine Coast, Powell River, Prince Rupert) | Low to Moderate (at nodes) | Low - Moderate | Avoid - new development  
Accommodate  
Retreat |

Table 2. Recommended SLR adaptation options for BC areas of interest (source: Ausenco Sandwell, 2011c)

Although being referred to as “Guidelines”, the content of these 3 documents is linked to Provincial legislation. The Local Government Act (LGA) Section 910(1) defines “Provincial Guidelines” as the policies, strategies, objectives, standards, guidelines and environmental management plans in relation to flood control, flood hazard management and development of land that is subject to flooding, prepared and published by the Minister under Section 5 of the Environmental Management Acts. The 2004 “Flood Hazard Area Land Use Management Guidelines” are the only Provincial guidelines pertaining to floodplain management published in this way. However, the amendments currently proposed would incorporate the sea level rise information from the 2011 Provincial Guidelines into the ‘official’ guidelines from 2004. In addition, the LGA Section 910(3)(a) states that local governments must “consider the Provincial guidelines” (i.e. the 2004 Guidelines) in making bylaws that designate land as a floodplain. Further, since 2008, the Compensation and Disaster Financial Assistance Regulation Section 15 has stated that structures built in an area designated as floodplain under LGA Section 910 must be
“properly flood protected” to be eligible for assistance to repair damage resulting from a flood. Historically, “properly flood protected” has meant that the habitable areas of all homes or buildings have a floor elevation (FCL) constructed above the 200 year floodplain level, regardless of whether there are any dykes protecting the floodplain area. This means that, if enacted as proposed, the amendments to the ‘official’ Provincial Guidelines from 2004 would require local governments to consider SLR information in requirements for buildings, subdivision and zoning (1m or SLR to the year 2100) and land use (2m or SLR to the year 2200). Further, if these official Guidelines are ignored, the Province could refuse to provide Disaster Financial Assistance in the case of flood damage to development that hadn’t been “properly flood protected”. This could feasible be the case for buildings that local governments had allowed to be built below minimum FCLs, which were not “properly flood protected” and therefore in the case of flood damage, could be ineligible for Provincial aid. This could feasibly leave private landowners and/or local governments responsible for flood damage.

The 2011 Provincial Guidelines: Coastal FCLs

The 2011 Provincial Guidelines made several recommendations around coastal area land use and protection, and generally called for significant increases in protection levels across all categories (e.g. FCLs and DCEs). These included new definitions for how to calculate FCLs, which had previously been defined as 1.5m above the natural boundary of the mean high tide level of the sea (Figure 7). As this calculation was based on historic data and thus didn’t account for SLR and an advancing natural boundary, the FCL definition was updated to include several factors, including future SLR\textsuperscript{16}, plus future high tide level, plus storm surge, plus wave effects, plus freeboard\textsuperscript{17} (Figure 8).

\textbf{Figure 7. Pre-2011 calculation of coastal FCLs (source: Ausenco Sandwell, 2011a)}

\begin{footnotesize}
\textsuperscript{16} 0.5m for 2050, 1m for 2100, and 2m for 2200 based on the SLR projections of the 2011 Provincial Guidelines
\textsuperscript{17} Freeboard allowance is typically 0.6m and is meant to account for the inherent uncertainty in calculating FCL minimums, although local governments have the ability to modify this value
\end{footnotesize}
This results in an updated FCL calculation that includes future changing sea levels, but also one that does not take into account local ground movement (i.e. uplift or subsidence) and thus is not context-specific. These were added as regional adjustments in a preliminary recommendation of FCLs for various areas of the province, and resulted in an updated FCL height of 6.2m for the entire Fraser River Delta (which includes 21cm of subsidence) (Table 3). This is much higher than the existing FCLs in Surrey’s coastal areas, which range from as low as 3.3m\(^{18}\) in some areas of the City and are based on the mid-1990s floodplain mapping by the provincial and federal governments. The Guidelines stressed that FCLs in coastal areas must take into account SLR for the extent of buildings’ structural lifespans, which generally extend from 50 to 100 years (depending on the type of building). This means that those structures built today with 100-year lifespans should accommodate for the expected 1m of SLR by the year 2100 in their FCLs (Ausenco Sandwell, 2011a).

\(^{18}\) In Crescent Beach, at the mouth of the Nicomekl River
Table 3. Preliminary FCL recommendations for 2100, highlighting Surrey’s Fraser River Delta region (source: Ausenco Sandwell, 2011a)

<table>
<thead>
<tr>
<th></th>
<th>Fraser River Delta</th>
<th>Vancouver Harbour</th>
<th>Squamish River Delta</th>
<th>East Vancouver Island</th>
<th>West Vancouver Island</th>
<th>Central and North Coast</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Global SLR Allowance</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1.0 m</td>
</tr>
<tr>
<td><strong>Regional Adjustment</strong></td>
<td>$+0.21$ m</td>
<td>0 m</td>
<td>0 m</td>
<td>$-0.17$ m</td>
<td>$-0.27$ m</td>
<td>$-0.22$ m</td>
</tr>
<tr>
<td><strong>High Tide</strong></td>
<td>2.0 m</td>
<td>1.9 m</td>
<td>2.05 m</td>
<td>1.6 m</td>
<td>2.0 m</td>
<td>3.8 m</td>
</tr>
<tr>
<td><strong>Surge Allowance</strong></td>
<td>1.7 m</td>
<td>1.4 m</td>
<td>1.3 m</td>
<td>1.3 m</td>
<td>1.3 m</td>
<td>1.7 m</td>
</tr>
<tr>
<td><strong>Wave Effect Allowance</strong></td>
<td>0.85 m</td>
<td>0.85 m</td>
<td>0.85 m</td>
<td>0.85 m</td>
<td>0.85 m</td>
<td>0.85 m</td>
</tr>
<tr>
<td><strong>Flood Construction Reference Plane (FCRP)</strong></td>
<td>5.6 m</td>
<td>5.0 m</td>
<td>5.0 m</td>
<td>4.4 m</td>
<td>4.7 m</td>
<td>6.9 m</td>
</tr>
<tr>
<td><strong>Freeboard</strong></td>
<td>0.8 m</td>
<td>0.8 m</td>
<td>0.8 m</td>
<td>0.8 m</td>
<td>0.8 m</td>
<td>0.8 m</td>
</tr>
<tr>
<td><strong>Flood Construction Level (FCL)</strong></td>
<td>6.2 m</td>
<td>5.6 m</td>
<td>5.6 m</td>
<td>5.9 m</td>
<td>5.3 m</td>
<td>7.5 m</td>
</tr>
</tbody>
</table>

1. Based on current values for areas (Vancouver and Squamish taken to be neutral due to regional variations or present lack of site specific data).
2. Varies by site and location in BC, as defined by CHS Tide Tables for areas, - Cowichan Bay used for East Vancouver Island - Tofino used for West Vancouver Island - Queen Charlotte City used for Central and North Coast.
4. Based on wave runup on natural gravel – pebble beach shoreline.
5. Assumes no Flood Proofing, specific Building Foundation type, or Tsunami.

The 2011 Provincial Guidelines: Sea Dykes

There are essentially two types of dykes that exist in the City: standard dykes and non-standard dykes. Standard dykes have a lower likelihood of failing and typically protect urban areas with relatively higher land values (e.g. Crescent Beach). Non-standard dykes have a higher likelihood of failure and, in Surrey, protect mainly agricultural areas in the Serpentine/Nicomekl lowlands. The 2011 Provincial Guidelines updated the design standards for standard and non-standard sea dykes. Prior to 2011, the existing dyke design criteria dated from the 1970s (where standards just accounted for historic high tide levels plus a freeboard allowance) and slight modifications in 2003 (accounting for storm surge and an optional wave effect). The 2011 updates attempted to provide a more stringent measure of protection by changing the dyke design standards from a level of protection that affords against an event with a likelihood of occurrence once every 4,000 years, to one with an expected frequency of once every

19 The previous definitions and design standards for all dykes (coastal and non-coastal) in BC were from “Dike Design and Construction Guide: Best Management Practices for British Columbia” (2003)
10,000 years (Ausenco Sandwell, 2011c). The updated 2011 design standards took into account SLR and local variations in ground movement based on uplift or subsidence (Figure 9). As with the former FCL calculations, the existing dyke design criteria were based on historical high water levels plus an allowance for freeboard and, for sea dykes, storm surge. The existing dyke guidelines allowed for the optional inclusion of wave run-up for sea dykes, which has been explicitly included in the updated calculation of both sea dyke DCEs and FCLs (Ausenco Sandwell, 2011b). SLR was also included in the updated standards. These new design standards thus resulted in much higher DCEs for coastal areas.

![Figure 9. Conceptual differences between the previous 1970s and new 2011 sea dyke design approaches (source: Delcan, 2012)](image)

Later in 2011, the Province issued an update to design standards for all dykes (sea and non-sea), which required that dyke design take into account seismic ground motions. This new design consideration required dyking authorities to design dyke upgrades and new constructions to be seismically stable up to a designated earthquake magnitude, which greatly increases the construction costs. For example, the cost to construct seismically-stable dykes along Surrey’s Fraser River shoreline were estimated at over $80,000 per metre (Delcan, 2012), compared to a general construction cost of approximately $5,000 per metre for earth dykes (Yan & Keenan, 2011). While the Province issued all of these reports as ‘guidelines’, the Province retains the authority to regulate dyke construction and maintenance through its power to issue dyke permits. All dyking authorities must secure dyke permits before modifying existing or building new dykes. As such, these ‘guidelines’ can in practice act as requirements, if the Province refuses to issue the permits necessary for dyking authorities to upgrade dykes if these ‘guidelines’ are not followed (Staff Interview, 2014).

20 “Seismic Design Guidelines for Dikes” (Golder Associates, 2011)
21 Through the Dike Maintenance Act
### Table 4. Summary of updates to FCL & DCE calculations based on 2011 Provincial Guidelines

<table>
<thead>
<tr>
<th></th>
<th>Existing Calculations (pre-2011)</th>
<th>Updated Calculations (post-2011)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coastal FCLs</td>
<td>Elevation of natural boundary of sea(^{23}) + 1.5m</td>
<td>SLR (including subsidence or uplift) + future high tide + storm surge + 50% wave run-up(^{24}) + freeboard</td>
</tr>
<tr>
<td>Fraser River FCLs</td>
<td>Elevation of 200-year flood event + 0.6m freeboard</td>
<td>Unchanged(^{25})</td>
</tr>
<tr>
<td>Standard Sea DCEs</td>
<td>Same calculation as coastal FCLs + storm surge + freeboard + wave effect(^{26}) (optional)</td>
<td>SLR (including subsidence or uplift) + future high tide + storm surge + wave run-up(^{27}) + freeboard + seismic</td>
</tr>
<tr>
<td>Standard Fraser River DCEs</td>
<td>Same calculation as non-coastal FCLs</td>
<td>Unchanged(^{28})</td>
</tr>
</tbody>
</table>

Historically, dykes meeting Provincial standards were considered adequate protection against flooding, so buildings behind dykes weren’t required to be elevated through FCLs. In recent decades, however, the assumption has shifted to one in which dykes may fail and be overtopped in extreme conditions. This is partly due to the fact that it is very expensive to design dykes high enough to prevent all overtopping. Buildings behind dykes must now therefore be elevated through FCLs, in order to provide protection against flooding in the case of dyke overtopping (Ausenco Sandwell, 2011b). This can also reduce a false sense of security that communities may feel when development protected by dykes occurs at native lot grades. The implicit expectation is that the structural works in place will provide adequate flood protection indefinitely, an assumption which is especially untruth in the case of SLR and its impacts on coastal hazards (Staff Interview, 2014). Since the Province first began requiring FCLs in floodplain development several decades ago, the minimum FCL elevations have increased gradually over time (with the most extreme increase coming with the 2011 Provincial Guidelines for coastal areas).


\(^{23}\) i.e. the visible high watermark or high tide level for base year 2000

\(^{24}\) The Guidelines state that for sea DCEs, the wave run-up is taken to be the vertical distance exceeded by no more than 2% of the waves during the designated storm (i.e. the 200 year storm event)

\(^{25}\) FCLs for areas along the Fraser River may be updated based on the results of forthcoming modelling of SLR and climate change impacts on the Fraser River, completed by the Province in coordination with FBC

\(^{26}\) Wave effect includes wave run-up and setup

\(^{27}\) The Guidelines state that for sea DCEs, the wave run-up is taken to be the vertical distance exceeded by no more than 2% of the waves during the designated storm (i.e. the 200 year storm event)

\(^{28}\) Fraser River dyke design standards may be updated based on the results of forthcoming modelling of SLR and climate change impacts on the Fraser River, completed by the Province in coordination with FBC
Another change introduced by the 2011 Provincial Guidelines was the concept of SLR Planning Areas, which the Province recommends be established along BC’s coast to provide a basis for calculating FCLs and guidance around coastal land use management (Ausenco Sandwell, 2011a). These SLR Planning Areas would extend from the existing natural boundary of the sea landward to the contour elevation of a future FCL. In Surrey, for example, the year 2100 SLR Planning Area might therefore extend landward from the ocean to the 6.2m contour line (the blanket FCL proposed for the entire Fraser River delta in the Guidelines documents) or a more context-specific FCL calculated using local rates of subsidence or uplift (following the Province Guidelines’ methodology). The year 2200 SLR Planning Area might extend landward to the contour elevation of the year 2200 FCL, which could be at the 7.2m contour line (calculated by taking the possible 6.2m year 2100 FCL and adding another 1m of SLR for the year 2200). Local ground variation caused by subsidence could increase the relative rate of SLR and extend the coverage of the year 2100 and year 2200 SLR Planning Areas (Figure 11).
SLR Planning Areas may be most relevant in less developed or developing areas located on gradually sloping shorelines that do not have structural protection works, rather than established urban areas on sleeper slopes. This is due to the fact that the concept reflects the long-term SLR effect of moving the natural boundary of the sea landward gradually over time. Surrey’s floodplain areas are generally fairly low in elevation and then rise sharply up slopes or coastal bluffs, and most of its coastline is protected by dykes (see Figure 17 later in this report). The intention of SLR Planning Areas is to delineate areas that will be in the future floodplain due to SLR, in which restrictions on development may therefore be placed. This might work well in areas where there is no current development but pressure to develop exists, or areas where there are pressures to intensify existing development. SLR Planning Areas might not make much sense in Surrey, where current floodplain areas are already completely developed (e.g. Crescent Beach) or protected from future development by virtue of being in the ALR (e.g. most of Surrey’s agricultural areas). Also, most of the City’s floodplain areas are bordered by steep bluffs that rise sharply out of low-elevation floodplain areas. A 1m increase due to SLR might therefore not greatly increase the horizontal expanse of the year 2100 floodplain area (Staff Interview, 2014). The exception may be the historic Old Town Cloverdale community, which is currently on the edge of the 200 year floodplain and will likely be located in the floodplain in the future due to climate change and SLR (Staff Interview, 2014). Even still, SLR Planning Areas may be a worthwhile concept for municipalities like the City of Surrey to consider, in that they delineate an area threatened by SLR in which certain restrictions can be placed on development and also raise public awareness of climate change and SLR.
The "Cost of Adaptation" to Sea Level Rise

One year after releasing the 2011 Provincial Guidelines for coastal flood hazard land use, the Province released a report providing a high-level cost estimate to adapt flood protection for year 2100 in Metro Vancouver. This “Cost of Adaptation” report built on the earlier 2011 Provincial Guidelines, by recommending specific structural and non-structural adaptation strategies by shoreline area and assigning an estimate of cost to each. The report covered 33 shoreline reaches in Metro Vancouver (including the Fraser River from the mouth inland to the Port Mann Bridge), and separated the City of Surrey’s ocean and Fraser River shorelines into 4 reaches (Figure 12). The total costs accounted for the costs of structural improvements (e.g. raising dykes to the standards from the 2011 Provincial Guidelines, which included SLR and seismic considerations), property acquisition, seismic and geotechnical improvements, environmental compensation, and engineering and project management. The total projected cost was $9.47 billion for the entire Metro Vancouver area, with $1.58 billion for property acquisition and a significant $3.25 billion for seismic dyke upgrading (based on the updated sea dyke design standards in effect since the 2011 Provincial Guidelines). Recommendations for three of the four coastal reaches in the City (the Fraser River, Crescent Beach, and South Surrey shorelines) were to upgrade existing or build new dykes. In the Mud Bay shoreline in the Nicomekl/Serpentine estuary, a managed retreat approach was recommended as being most economical (the only “Retreat” option recommended in all 33 coastal reaches in the study region). The total cost for Surrey was projected at $1.69 billion, almost one third of which is attributed to property acquisition alone ($477.76 million).

30 $116.05 million to be shared with the City of White Rock
Figure 12. Shoreline reaches with recommended adaptation strategy and projected cost for adapting to SLR for year 2100, for 4 shoreline reaches in the City (source: Delcan, 2012)

22: Dyke ($986 million)

23: Retreat ($464 million)

24: Dyke ($119 million)

33: Dyke ($116 million)
1.3 Coastal Flood Protection in Surrey

200-Year Floodplain

The City of Surrey encompasses a geographic area that has always been shaped by water, with over one quarter\(^{31}\) of its total land base located in the 200 year floodplain. This floodplain effectively separates the City’s northwest, south, and eastern communities (Figure 13). While the City’s Engineering department is conducting work to model future floodplain extents (including climate change impacts such as SLR), the current official 200 year floodplain is based on historic trends and thus does not account for the potential impacts of a changing climate\(^{32}\). The City encompasses 54km of shoreline between the Pacific Ocean and the Fraser River, with four key floodplain areas: the Boundary Bay floodplain (to the southwest), the Fraser River floodplain (to the north), the Serpentine/Nicomekl Rivers floodplain (in the centre), and the Campbell River floodplain (to the south). These floodplains are influenced by a variety of factors, particularly heavy winter precipitation, Fraser River freshet, ocean tides, and winter storm surge events. Much of the floodplain areas are just above or below current sea levels, even several kilometres inland from the ocean in the Serpentine/Nicomekl floodplain lowlands, and experience heavy localized flooding each year (Rowett, 2009).

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\(^{31}\) Over 85km\(^2\) of the City’s total 316 km\(^2\) land base is in the 200 year floodplain.

\(^{32}\) The 200 year floodplain is defined as an area of land that can be expected to flood, on average, once every 200 years, i.e. with a return period of approximately 200 years (and a corresponding Annual Exceedence Probability of 0.5%, meaning that the likelihood of this size of event occurring in a given year is 0.5%).
Figure 13. Surrey’s current 200-year floodplain (source: City of Surrey, 2011)

The City’s urban development has, for the most part, occurred outside of the 200 year floodplain (Figure 14). Much of this floodplain area also falls within the Provincial Agricultural Land Reserve (ALR) boundaries and therefore non-farm uses (including residential and commercial) are restricted (Figure 15). One of the primary exceptions is the Crescent Beach, a historic residential area on a peninsula at the mouth of the Nicomekl River on Boundary Bay (Figure 14). This community will serve a case study in this report to analyze the impacts of SLR and adaptation strategies within the City’s geographic limits.
Structural Flood Protection

The numerous water bodies and associated floodplains in the City are controlled by a myriad of structural flood protection infrastructure, including approximately 100km of dykes, 30 drainage pump stations, 2 sea dam structures, 170 flood boxes, and 10 spillways (Figure 6). Portions of the Fraser, Serpentine, and Nicomekl Rivers all have dykes, while the much smaller Campbell River to the south is currently undyked. Historically, dykes were established and managed by dyking districts. These were organizations comprised of farmers who pooled resources for the construction and maintenance of flood control works to protect the fertile floodplain soil of their agricultural lands. In the past, therefore, dykes were managed privately by dyking districts outside of local or provincial government control.

Provincial legislation\textsuperscript{33} designates the Province (via the Ministry of Environment’s Inspector of Dikes) as the authority granting approval for the construction, maintenance, and design standards of all flood protection works in the Province. Separate legislation\textsuperscript{34} establishes the Province as the body responsible for the ‘orphaned’ dykes when dyking districts dissolve and their dykes remain. The Province had for years been wanting to eliminate private dyking districts so that all dykes in the Province would be managed by local governments or the Province itself. A repeal of the “Drainage, Ditch and Dike Act”

\textsuperscript{33} BC’s “Dike Maintenance Act”

\textsuperscript{34} BC’s “Drainage, Ditch and Dike Act”
that would have dissolved all the remaining privately-managed dyking districts in the Province was supposed to come into effect in December 2012. Due to protest by dyking districts and uncertainty about responsibility for ‘orphaned’ dykes, however, the Province has extended this dissolution deadline by several years (Staff Interview, 2014).

Four dyking districts historically existed within the geographic limits of the City, aligning with its numerous floodplains: the South Westminster Dyking District (in the Fraser River floodplain, with dykes along the south side of the Fraser River near the Pattullo Bridge), the Colebrook Dyking District (in the Boundary Bay and Serpentine/Nicomekl Rivers floodplain, with dykes along the north shore of the Serpentine River), the Mud Bay Dyking District (in the Boundary Bay and Serpentine/Nicomekl floodplain, with dykes along the south shore of the Serpentine and north shore of the Nicomekl Rivers), and the Surrey Dyking District (in the Boundary Bay and Serpentine/Nicomekl floodplains, with dykes along the south shore of the Nicomekl River) (Figure 16). Of these four dyking districts, only the Mud Bay Dyking District still exists today and is managed privately by local farmers. This originally incorporated as an Improvement District rather than a Dyking District, and therefore won’t be forced to dissolve when the pending legislative changes to the “Drainage, Ditch and Dike Act” come into effect (Staff Interview, 2014). The South Westminster Dyking District dissolved in the 1930s and responsibility for its Fraser River dykes transferring to the Province. In 1975, the Province and the City formed an agreement that transferred these dykes to the City after provincial improvements to the existing dyke system (City of Surrey, 2011). The Colebrook and Surrey Dyking Districts voluntarily dissolved in early 2013, based on pending changes to the provincial “Drainage, Ditch and Dike Act” that would have forced their dissolution in December 2012 (a deadline that was subsequently extended by the Province). The City agreed to take on the management of the Surrey Dyking District’s dykes, but refused to take on Colebrook’s dykes, which thus reverted to Provincial jurisdiction. While much of the Surrey Dyking District’s dykes had City Right of Ways secured alongside dykes to facilitate maintenance, Colebrook’s were on private property without any legal mechanism in place to permit City access. Without these Right of Ways, dyke management would be very difficult for the City as they would need to be granted consent of the private property owners on whose land the dykes lie in order to perform routine maintenance and dyke upgrades. The Colebrook dykes are also very substandard dykes, and would be expensive to upgrade to current dyke design standards (Staff Interview, 2014).

Crescent Beach, the case study community for this report, is protected by a dyke along the entirely of its ocean frontage. However, unlike the other dykes in Surrey, Crescent Beach was never part of a dyking district. The existing dyke network was originally constructed by a private syndicate that owned the entire length of the waterfront area in the community. The organization defaulted on its property taxes in the 1920s as the dyke had become too expensive to maintain and erosion too difficult to control, and the City has since managed the dyke (Staff Interview, 2014).

35 Secured gradually over time as part of the City’s “Serpentine and Nicomekl Lowlands Flood Control Project”, implemented in 1997.
Figure 16. Surrey’s flood control infrastructure & historic dyking districts (source: City of Surrey, 2013)
The City has not applied for any permits to upgrade existing or construct new dykes since the 2011 Provincial Guidelines documents were released. The City currently has no capital plan to seismically upgrade its dyke network, or elevate DCEs to accommodate for projected SLR. Seismically upgrading dykes would be very costly and likely not even possible in areas along the Fraser River, where liquefaction of the sandy soil could occur in the event of a large earthquake (Staff Interview, 2014). Other coastal areas of Surrey such as Crescent Beach don’t have these same soil quality issues, however, the dykes there haven’t required upgrades since the seismic requirements were introduced in 2011. If the City chooses to raise its dykes in Crescent Beach, the most significant issue will be the space required to raise dykes. The slope of standard dykes (those that protect urban areas) have a 1:3 ratio, meaning that for every 1m increase in vertical height, a 3m increase in horizontal width on either side of the dyke is required. This increases the dyke footprint by approximately six times, or 6m for each 1m vertical increase. Achieving this in Crescent Beach would be challenging, given that expensive waterfront homes border the existing dyke. Elevating DCEs in Crescent Beach might require the expropriation of these frontage properties on the landside of the dyke, or alternately, filling in protected habitat on the waterside of the dyke – neither of which are straightforward solutions to the issues presented by raising these dykes (Staff Interview, 2014).

Policy & Regulatory Tools

The City’s existing policy and regulatory framework in regards to flooding emphasizes the mitigation of flood risk, but doesn’t yet accommodate for the changing flood risk associated with SLR and other climate change impacts. The City’s new Official Community Plan (OCP), “PlanSurrey” (Bylaw No. 18020), was adopted in October 2014 and replaced the former OCP (which dated from 1996). The new OCP includes, for the first time, Flood Prone Hazard Lands Development Permit Areas (DPAs). This tool allows the City to designate a geographic area within which development design and site planning must meet specific flood protection objectives, and for which a Development Permit must be obtained prior to any development. In the case of flood hazard DPAs, specific requirements around flood protection can be implemented before Development Permits will be issued, such as requiring specific FCLs or preventing all subdivision in the floodplain. The area in which these Development Permits apply is the current 200 year floodplain (Figure 17), whose extents could be amended to account for climate change impacts such as SLR. All new development in the floodplain now requires the registration of a Land Title Act Section 219 Restrictive (or ‘Save Harmless’) Covenant as a condition of Development Permit issuance. This is a legal charge that is registered on title of the land and indemnifies the City of any liability in the case of future flood damage. Other municipalities have similar flood hazard DPAs, including the City of North Vancouver and the Corporation of Delta.

The new OCP also includes policy goals that restrict new urban development and subdivision in areas subject to flooding (OCP Policy D2.8) and consider projected impacts of climate change on flood hazard areas due to SLR (OCP Policy D2.10). The City has also had a practice of limiting development in the lowlands of the Serpentine/Nicomekl floodplain, and in 2008 the Development within the Nicomekl and Serpentine River Floodplains policy was endorsed by Council. This formally restricted development within the Nicomekl/Serpentine 200 year floodplain, except where current zoning or approved secondary land use plan designs permits. Much of this floodplain is agricultural
land that is within the provincial ALR, which provides additional restrictions on development (City of Surrey, 2013). The City also invested $40 million over 10 years to upgrade drainage and flood infrastructure in the Nicomekl/Serpentine floodplain, beginning in 1997 with its Strategic Plan for Lowlands Flood Control.

Figure 17. Flood Prone Hazard Development Permit Areas (source: City of Surrey, 2013)

The City’s Zoning Bylaw is the regulatory tool that identifies restrictions on new development located in the 200 year floodplain that reduce flood risk (e.g. FCLs, setbacks). The City’s current Zoning Bylaw No. 12000 (1993 adoption) includes a Floodproofing section (Part 8). However, this section dates from the previous Zoning Bylaw No. 5942 (1979 adoption) and was not updated with the current Zoning Bylaw No. 12000. The Zoning Bylaw states that FCLs that meet BC Ministry of Environment standards are required for new structures built in the 200 year floodplain\(^{36}\). Specific FCLs for Bridgeview and South

\(^{36}\) With the exception of some floodplain maps for the Fraser River from 2009, most floodplain maps from the BC MOE date from the 1990s and are the result of a joint federal-provincial government floodplain mapping program that ran from 1987-1998
Westminster along the Fraser River are also identified in the Zoning Bylaw, and range from 2.75-4.66m geodetic. According to City Building Division staff, however, these elevations are outdated and that higher FCLs are actually required for new building permits in these areas (Staff Interview, 2014). Developers can achieve these minimum FCLs by either landfill, structural elevation, or a combination of both. The Zoning Bylaw does not identify measures to reduce flood risk in existing development, nor ways to adapt new or existing development to projected climate change impacts such as SLR over time. The City has also approved a number of variances to build below FCLs, notably in Crescent Beach, and thus its own regulations to reduce flood risk are not always enforced.

Two of the eleven adaptation actions for “Immediate Implementation” in the City’s Climate Adaptation Strategy fall into the “Flood Management and Drainage” sector. These include supporting a Regional Flood Management Strategy coordinated by the Fraser Basin Council (FL-1.1) and conducting a cost-benefit analysis to assess adaptation options for addressing SLR and other coastal climate change impacts (FL-1.2). All five of the climate change impacts assigned a risk rating of “high” (the highest rating in the document) relate to flooding (Table 5). These five impacts could result from the increases in winter precipitation as well as sea levels that are projected as a result of global climate change.

| Reaction to the 2011 Provincial Guidelines |

The release of the 2011 Provincial Guidelines incited significant pushback from coastal BC municipalities. Criticism primarily revolved around the lack of implementation direction provided in the Guidelines, the generalized nature of the recommended FCL and DCE elevations, and the low risk tolerance represented by the methodology used to achieve these recommended elevations (City of Vancouver, 2013). The provincial methodology simply adds high tide ocean levels (including SLR allowance) to the 200-year storm surge and wind setup to estimate ocean design levels (the value used to calculate coastal FCLs and sea DCEs). This approach therefore disregards the joint probability of all

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Table 5. Flood-related climate change impacts’ risk assessment scoring and results (source: adapted from Table 4, City of Surrey, 2013)
these separate events occurring simultaneously. Detailed statistical analysis has since demonstrated that, instead of a return period of 200 years (the typical event used in design standards), following the Provincial methodology from the 2011 Guidelines designs for an event with a return period in the order of 10,000 years. This means that the likelihood of all these events occurring at the same time is approximately once every 10,000 years, rather than once every 200 years. Following the 2011 Guidelines’ methodology for calculating coastal DCEs and FCLs therefore effectively alters design standards from the typical 200-year event (with an annual likelihood of 1/200 or 0.5%) to a much more conservative 10,000-year event (with an annual likelihood of 1/10,000 or 0.01%). This, local governments protested, has significant impacts on coastal flood hazard land use management, design standards, and project costs.

“Serpentine, Nicomekl & Campbell Rivers – Climate Change Floodplain Review”

Criticism of the 2011 Provincial Guidelines by Surrey staff echoed that of other local governments. Specifically, provincial guidance doesn’t account for the City’s extensive riverine systems and applies blanket FCLs and dyke heights, as opposed to site-specific protection needs (Staff Interview, 2014). In addition, the Provincial methodology effectively increases the design standard from the current typical 200-year level to the much more conservative return period of approximate 10,000 years, which is neither practical nor feasible for local governments to achieve (Northwest Hydraulics Consultants, 2012). The City is therefore conducting its own climate change floodplain review for the Nicomekl, Serpentine, and Campbell Rivers (by the consulting engineering firm Northwest Hydraulics Consultants). When complete, the “Serpentine, Nicomekl & Campbell Rivers – Climate Change Floodplain Review” project will evaluate the impacts of climate change including SLR, precipitation and snowfall pattern changes in this area. The first phase of the project was completed in 2012 and focussed on the coastal Boundary Bay area, where the ocean’s zone of tidal influence extends approximately 18km up the Serpentine and Nicomekl rivers (Staff Interview, 2014). The second phase of the project focusses further upstream in the Nicomekl, Serpentine, and Campbell River systems, and takes into account precipitation changes, timing of SLR, and probability of dyke breaches (currently in process). The next step is to design a public engagement strategy to communicate results from the first two phases of the project and gather input on adaptation strategies the City should pursue. The entire project will culminate in a cost-benefit analysis of options for land-use, engineering, and design requirements in these current and future floodplain areas.

In the first phase of the City’s coastal hazard risk assessment, FCLs and DCEs were calculated using both the Provincial methodology (from the 2011 Guidelines) and a new methodology that takes into account the joint probability of all the separate events occurring simultaneously (e.g. storm surge, wind setup, high tide). The latter provides an alternative to the methodology used in the provincial...


38 “Serpentine, Nicomekl & Campbell Rivers – Climate Change Floodplain Review” (Northwest Hydraulics Consultants, 2012)
guidelines. In both cases, a relative SLR rate of 1.2m for Surrey by the year 2100 was used, based on the Province’s 1m plus an average of 0.225m of subsidence. Future land use changes were included in the modelling to estimate runoff for year 2100 conditions. Precipitation patterns were unaltered from historic rates for this initial study, however, due to the high level of uncertainty around the impacts of climate change on precipitation patterns. FCLs and DCEs were computed for nine locations in Boundary Bay for year 2010 and 2100, and calculated DCEs were compared against current elevations. For the three locations in Crescent Beach, calculated 2010 DCEs are 0.86-1.05m above existing crest elevations, while year 2100 DCEs are 2.02-2.73m above existing crest elevations (Figure 18). For FCLs, calculated 2010 levels are 0.92-1.13m above the current average built FCLs and year 2100 are 2.0-2.45m above current levels (Table 6). For both FCLs and DCEs at both the 2010 and 2100 year scenarios, the elevations calculated using the joint probability methodology are approximately 0.5m less than the equivalent levels computed using the Provincial methodology.

Table 6. Comparison of existing to calculated FCLs

<table>
<thead>
<tr>
<th>Location</th>
<th>Existing Built FCLs (average &amp; median)</th>
<th>Required FCLs (1990s)</th>
<th>Calculated FCLs (2010)</th>
<th>Calculated FCLs (2100)</th>
<th>Difference between Existing FCLs (average) &amp; Calculated FCLs (2100)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crescent Beach - East</td>
<td>2.6m / 1.97m</td>
<td>3.3m</td>
<td>3.52m</td>
<td>4.60m</td>
<td>2.0m</td>
</tr>
<tr>
<td>Crescent Beach - North</td>
<td></td>
<td>3.3m</td>
<td>3.62m</td>
<td>4.97m</td>
<td>2.37m</td>
</tr>
<tr>
<td>Crescent Beach - South</td>
<td></td>
<td>3.3m</td>
<td>3.73m</td>
<td>5.05m</td>
<td>2.45m</td>
</tr>
</tbody>
</table>

The City’s coastal hazard risk assessment recommends that further analysis which takes into account other climate change impacts such as precipitation changes be conducted before official City FCLs be revised. The City has not committed to changing coastal FCLs following the 2011 Provincial Guidelines, however, the City’s study provides a first attempt at analyzing site-specific FCLs and DCEs required to adapting Surrey’s coastal floodplain areas to SLR (Northwest Hydraulics Consultants, 2012). The report recommended that DCEs and FCLs be updated and possibly increased, given that the current elevations of both are below those calculated for year 2010, and well below the year 2100 levels.

39 Using the joint probability methodology rather than the 2011 Provincial Guidelines’ methodology
40 Built FCLs for entire Crescent Beach area, based on 2013 City of Surrey Lidar data, residential structures only, duplicate addresses removed
41 Current FCLs requirements in Crescent Beach are 3.3m (based on floodplain mapping completed by provincial and federal governments in mid-1990s), however actual built FCLs are regulated through a Development Variance Permit process which allows FCLs to be built as low as 0.3m above adjacent road heights (discussed later in the Analysis section of this report)
42 Using joint probability methodology, where SLR = 0m
43 Using joint probability methodology, where SLR = 1.2m
The report also found that the current 200-year flood event in the lower coastal floodplain may have a return period of approximately 2 years in 2100 – an increase of an annual probability of occurrence from 0.5% (1/200 years) to 50% (1/2 years). In the upper Nicomelk and Serpentine reaches, the current 200-year flood event may become a 110 year and a 30 year occurrence, respectively. This is due in large part to the subsidence rates and SLR that will more significantly impact the downstream coastal areas than those floodplains further upstream. This demonstrates the importance of re-evaluating current City requirements around DCEs and FCLs in the lower coastal floodplain, and is the first recommendation of this climate change study report, which states that "present structural/non-structural flood mitigation measures [should] be improved" (Northwest Hydraulics Consultants, 2012, p. 121). Since the completion of the first phase of the City’s coastal floodplain review in 2012, other municipalities including the City of Vancouver have conducted similar coastal flood risk assessments using the same consultants and same joint probability methodology. In addition, the Province is now accepting this methodology as an acceptable secondary approach to theirs in calculating coastal FCLs and sea DCEs elevations (Staff Interview, 2014).

Figure 18. DCEs for Serpentine/Nicomekl lower floodplain calculated using joint probability methodology (source: Northwest Hydraulic Consultants 2012)
The proposed amendments to the 2004 “Flood Hazard Area Land Use Management Guidelines”, the official guidelines governing floodplain management by local governments, would require that local governments include SLR to the year 2200 in coastal land use planning and adaptation. The City’s Engineering department has only recently begun examining what the year 2200 floodplain extents and the related DCEs and FCLs may be. Year 2200 land use adaptation strategies could include SLR Planning Areas discussed in the 2011 Provincial Guidelines, with the possibility of restricting or removing development in these areas as SLR occurs (Staff Interview, 2014). The extent of the year 2100 and 2200 floodplain likely will not alter much from the current 200-year floodplain, given the City’s topography of fairly flat floodplain areas abutting steep inclines. The exception may be the historic Cloverdale town centre, which is currently on the verge of the 200-year floodplain and where the City has already had to purchase some private properties due to repeated flooding (Staff Interview, 2014). The depth of the floodplains in the coming centuries due to SLR is an issue of concern, however, as this would impact the level of flood protection (e.g. FCLs, DCEs) needed in these areas (Staff Interview, 2014). Preliminary results from the City’s current work modeling the year 2200 flood extents (including SLR) in the Serpentine/Nicomekl lowlands indicate that the elevation of the year 2200 floodplain will be at least 1m higher than its current depth (Staff Interview, 2014).
2. Analysis

2.1 Crescent Beach

Crescent Beach is a small community of approximately 1,200 residents on a peninsula one square kilometre in area, located in Boundary Bay at the mouth of the Nicomekl River. It is bounded by Mud Bay to the North, Boundary Bay to the west, and the Burlington Northern Railway tracks to the southeast, and has a Land Use Plan dating from 1999. Crescent Beach’s land use is designated primarily as Urban (zoned Single Family Residential), with one small strip of Commercial along Beecher St. and City-owned parks in the northeast along the water (Figure 19). Crescent Beach is one of the oldest residential areas in the City, with many of the historic homes built in the early 20th century still standing and several of these considered heritage properties by the City. Most were originally built as small summer cottages, however, with rising land values and population, these have mostly become permanent homes. The trend in recent years has been towards redeveloping these older cottages and replacing them with much larger single family residences (at an average rate of 3-4 properties per year) (Urban Systems & Golder Associates, 2009). This also results in an increase in impervious surface and thus the amount of stormwater runoff in the area, since newer homes have larger footprints than the older homes (Urban Systems & Golder Associates, 2009). There is no plan to intensify development or change the dominant form from single family housing, although the redevelopment trend will likely continue in the future (Urban Systems & Golder Associates, 2009).

Figure 19. Crescent Beach land use designations (source: Crescent Beach Land Use Plan, 1999)

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44 On the City’s Heritage Registry or Heritage Inventory
45 Based on City of Surrey issued building permits
In 2009 the City completed a drainage study\textsuperscript{46} in the area that considered climate change impacts such as SLR, initiated by resident complaints of more frequent and significant flooding in the preceding decade. The study found that SLR was causing the groundwater table to rise, thereby reducing the infiltration capacity of the sandy soil. This was causing localized flooding during high tide and winter storm events, a trend which will be further exacerbated by SLR. The City’s resulting drainage strategy involved upgrading the existing pump station and installing a new storm sewer system, in addition to gradually raising some of the road network through landfill.

\textbf{Elevations}

The majority of the 427 residential properties in Crescent Beach lie on lots between 0.7-3m above current sea level, with most being at an elevation of approximately 1.5m (Staff Interview, 2014). The railway tracks that border the peninsula also mark the extent of the current 200-year floodplain and the beginning of the increase in elevation to the coastal bluffs behind, as very little of the land below the railway tracks is above 3m (besides parts of the City park and the dyke) (Figure 20). The lowest residential lots are in the northeast part of Crescent Beach, north of Sullivan Street.

\textsuperscript{46} “Crescent Beach Climate Change Adaptation Study” (Urban Systems, 2009)
Figure 20. Crescent Beach contour elevations
Flood Construction Levels (FCLs)

As per the City’s Zoning Bylaw, the minimum FCL for new construction in the area is 3.3m geodetic. This value is determined based on the 200-year flood level (plus a 0.6m freeboard allowance), which is in turn based on floodplain mapping completed through a joint project between the provincial and federal governments in the mid-1990s (see Appendix A). The 3.3m FCL minimum has not changed in decades and is determined using on the Province’s pre-2011 methodology (200-year flood level plus freeboard), since the City has not updated any of its coastal FCL requirements since the release of the 2011 Provincial Guidelines (with their new methodology for calculating coastal FCLs and sea DCEs). This FCL is not enforced, however, as new development in Crescent Beach is regulated through Development Variance Permits (DVPs) which relax Zoning Bylaw requirements for minimum FCLs and allow new dwellings to be built close to native lot grades. This DVP process was passed by Council into a bylaw in 199247 (including an expedited and cheaper process than regular DVPs), and this is the only area in which the City allows variances to build below the minimum FCL. The reason for this is reportedly largely political, in that Crescent Beach is an affluent, politically-engaged area (for example, many current and past councillors have lived in the neighbourhood). DVPs also maintain the common streetscape or ‘look and feel’ of the quaint community, which is highly valued social and economically in the neighbourhood (Rowett, 2009). These DVPs allow FCLs to be built to 30cm or 1 foot above the fronting road, and include a Restrictive Covenant48 registered on land title. These covenants are legal indemnities to protect the City from flooding liabilities in the case of future flood damage. While there is a long history of the use of Section 219 Restrictive Covenants by municipalities for a range of hazards, City staff interviewed were not aware of any case precedent in BC for these covenants being tested in court (Staff Interview, 2014).

The result is that barely any of the new or existing development in Crescent Beach is built with habitable floor spaces above the Zoning Bylaw 3.3m minimum FCL elevation (Figure 21). For residential structures (primarily single family dwellings), the average built FCL elevation is 2.6m and the median is 1.97m49. These values include homes on lots with higher natural elevations above the railway tracks, however, and thus the built FCLs on the peninsula in the floodplain below are likely lower. The lowest elevation in the area is north of Sullivan Street, which is also where much of the recent redevelopment has been concentrated. Many newer residential dwellings have been built since 1992 in this northern part of Crescent Beach, with DVPs to build below the 3.3m FCLs and accompanying Restrictive Covenants registered on land title (Figure 21). Built FCLs were determined using City of Surrey Lidar data50 from 2013, which captured the elevation at which the structures meet the ground. Since most of the lots in Crescent Beach use landfill rather than structural elevation to achieve FCL elevations, built FCLs correspond to the elevation of the ground slab of the structures. Where structural elevation rather than fill is used to elevate habitable floor spaces, however, the FCL does not correspond with the elevation at which the structure meets the ground plane. Other communities in Surrey such as

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47 “Surrey Development Variance Permit Form and Application Fee By-law, 1986, No 8658, Amendment By-law, 1992, No. 111519”
48 Section 219 Restrictive Covenants in BC’s Land Title Act
49 Based on City of Surrey Lidar data, duplicates removed, residential structures only
50 Lidar stands for “light detection and ranging” and is an optical remote-sensing technique that uses lasers to sample the surface of the earth, producing highly accurate x,y,z measurements (captured by planes equipped with the specialized lasers)
Bridgeview on the Fraser River use structural elevation instead of fill to achieve much higher FCL elevations, as extensive filling is expensive and grading to adjacent lots difficult. A small sample of Lidar-determined built FCLs were compared with actual elevations from DVPs\(^{51}\), and all were within 0.5m accuracy.

\(^{51}\) From the City of Surrey Laserfiche system, where older DVPs are scanned and stored.
Based on the City’s recent floodplain mapping for the area (as conducted in 2012 by consultants Northwest Hydraulics), FCLs in the community should be higher than the 3.3m Zoning Bylaw minimum and significantly higher than the average 2.6m built FCL. According to the Northwest Hydraulics report, 2010 FCLs for new development in Crescent Beach should be approximately 3.52-3.73m (0.93-1.13m above average existing built FCL elevation) and year 2100 FCLs should be 4.6-5.05m (2.0-2.45m above average existing built FCL elevation; see Table 5) (Northwest Hydraulics Consultants, 2012). The DVP process continues to allow new development to be built as low as 30cm above the fronting road, and those dwellings built today will likely still be standing for the next 50-100 years (as the impacts of SLR in the community continue to grow). To illustrate this, Figure 22 shows a new frontage residence on Crescent Beach’s northern dyke, which was issued a DVP to build below 3.3m in 2012 and was finishing final construction as this report was being written in summer 2014. The year 2100 FCL for this area should be 4.97m (based on the City’s recent floodplain mapping), but the built FCL elevation of the structure is approximately 2.68m. The proposed amendments to the 2004 “Flood Hazard Area Land Use Management Guidelines” include requiring new coastal development to be built to year 2100 FCLs. At 2.0-2.45m above the average existing built FCL in the community, this represents a significant difference in elevation. This would mean that, for this dwelling, habitable space would effectively start at the second storey and the only permitted uses below 4.97m would be uses such as parking and crawlspaces.

52 Using the joint probability methodology for determining FCLs from the Northwest Hydraulics Consultants study, rather than the more extreme Provincial methodology from the 2011 Provincial Guidelines
Current Development Patterns

Since the expedited DVP process was implemented by Council in 1992, 65 DVPs have been issued to privately-owned, mostly residential properties to vary FCLs in Crescent Beach, at a rate of approximately 3 per year. All of the properties which have been granted a DVP also have a Section 219 Restrictive Covenant registered on title of the land, indemnifying the City should any flood damage occur. These DVPs are all, unsurprisingly, on lots with newer homes constructed since the implementation of the expedited DVP process, since DVPs are sought prior to building permit (Figure 23). This map shows clearly the gradual pattern of redevelopment in Crescent Beach, at rate of roughly three private properties per year, the majority of which are being built below the Provincial FCL requirements.

53 While variances to build below 3.3m were issued prior to 1992, this was the date the City formalized the DVP process in Crescent Beach by adopting it in bylaw form, with an expedited process and reduced application fee.
54 Data sources: COSMOS (“Issued” or “Approved” DVPs to vary minimum FCL requirements in Crescent Beach); City of Surrey Laserfiche
Figure 23. Private properties by building age and elevation DVPs with Restrictive Covenants
The majority of residential buildings constructed in Crescent Beach since 1992 have received a DVP to vary FCLs, as evidenced by Figure 23. In total, of the 79 residential single-family dwellings constructed in Crescent Beach since 1992, 55 are on lots with registered elevation DVPs and 24 are on lots that do not have elevation DVPs. While some lots that do not have DVPs have natural lot grades above 3.3m, there could also be pre-existing DVPs for these properties that would have been issued for previous buildings and thus may not be in the City’s online mapping software COSMOS (and therefore excluded from this analysis). All of the DVPs that were in the City’s online Laserfiche Weblink system also had Section 219 Restrictive Covenants registered on land title as part of the DVP approval. It was assumed that, for the older DVPs that weren’t saved to the Laserfish online system, Restrictive Covenants were also registered indemnifying the City in case of flood damage. It is also likely that many more properties have DVPs and Restrictive Covenants than is shown in Figure 23 however, this data was only available via individual land titles at the Land Title Office (which was outside the scope of this project).

Future Development Patterns

Crescent Beach is not an area designated for redevelopment or changes in land use in the new OCP (adopted October 2014). There are 427 residential structures in the community (mostly single family dwellings), with an average building age of 51 years (i.e. built in 1963). Most redevelopment in the past decades has been the construction of newer homes as the older, cottage-style homes first built in the area are replaced by larger, higher-value residential structures. This newer development has so far primarily been concentrated in the northern portion of the community (north of Sullivan Street), while the older homes remain along the ocean frontage and in the southern part of the peninsula (Figure 23). Given that the lifespan of residential structures is approximately 70 years, the pattern of redevelopment might continue in the older areas of Crescent Beach to the south and along the waterfront. While some of these properties may be on the City’s Heritage Registry or Heritage Inventory, providing a measure of protection against redevelopment, this by no means ensures these homes will not be replaced as they age. It is interesting to note that many of the frontage properties also have some of the oldest structures in Crescent Beach – 51.5% (35 of 68) of the frontage properties on Ohara Lane have homes built before 1944, or over 70 years old. If these properties are redeveloped and replaced with newer, higher-value dwellings issued DVPs to build below required FCLs, their structural lifespan will likely extend to the end of the 21st century, as the impacts of SLR are increasingly felt in the area. The value of these properties will also increase as the older homes are replaced with newer, larger dwellings. These frontage properties will also be the most impacted should the City decide to raise its dyke network, given that the current DCEs are below the recommended elevations for 2010 and well below those for year 2100 (Northwest Hydraulics Consultants, 2012).

Besides building age, another metric to use to examine which areas in Crescent Beach might be soon redeveloped is looking at building age in combination with a ratio of building-to-land value. This index can be useful in that it provides an approximation of which lots might be considered developable,

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55 Andy Yan, BTAworks (personal communication)
but is meant to inform discussion and is not necessarily a predictor of future development patterns. For the case of this analysis, a building-to-land value index was created and those with a ratio of less than 10% selected for consideration (meaning the total value of structures or improvements on lots is less than 10% the land value). These were combined with those lots with residential structures built before 1944, or older than 70 years. 22% of the residential lots (95 out of 427) in Crescent Beach were built before 1944 and also have a building-to-land value ratio of less than 10%, where we might expect development in the near term. It should be noted that almost all of the residences built before 1944 also have a building-to-land index less than 10%, and so a simpler analysis of selecting only those lots with residences greater than 70 years old would produce a similar selection of properties. This is due to the high value of land in Crescent Beach, especially relative to the value of the older, cottage-style residential dwellings (which are worth very little when compared to the exorbitant land values). We might expect to see development in many of the older lots in the southern part of Crescent Beach that have low building-to-land ratios, as has already occurred in the northern area of the peninsula. Notably, 42% of the ocean frontage properties on Ohara Lane (29 out of 68) fall into this category – a higher proportion than the 22% for the rest of Crescent Beach. We might therefore expect higher rates of redevelopment in this frontage area, which is also most susceptible to flood damage from dyke overtopping and will be most impacted should the City attempt to raise DCEs. If these buildings are redeveloped in the near future without measures taken to protect against SLR such as raising DCEs or enforcing FCLs, significant impacts due to SLR could occur in the structural lifetimes of these buildings.
Figure 24. Private properties by building age and low building-to-land ratios
**Property Values**

Crescent Beach is one of the City’s most affluent neighbourhoods with the highest land values. The 2014 gross assessments\(^{56}\) for Crescent Beach’s 427 residential properties was on average slightly over $1 million each\(^{57}\), and the sum of all these properties is over $433 million. 66% or 280 of these properties are worth less than $1 million, and the remaining 34% or 147 are worth more than $1 million\(^{58}\). All 68 of the ocean frontage lots along Ohara Lane are valued at over $1 million, compared to only 21% of non-frontage properties (Figure 25). The total value of these 68 properties is over $118 million, while the average lot value is $1.75 million (almost twice the average value for the rest of Crescent Beach properties). Were the City considering purchasing the land needed to raise dykes to the 2100 levels under the new Provincial guidelines, this figure gives an idea of how much this might cost just in upfront land expropriation costs for these frontage properties. We might expect the redevelopment trend that has been occurring in the relatively cheaper lots in the northern area of Crescent Beach to continue in the relatively more expensive lots, particularly with the older, cottage-style homes (Figure 24). Many of these are concentrated along the water on Ohara Lane, properties that may be crucial to the City’s measures to protect the entire area from the threat of sea level rise (e.g. through raising dykes) (Staff Interview, 2014).

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\(^{56}\) Gross land plus gross improvements (data source: BC Assessment)  
\(^{57}\) Average: $1,024,345 and median: $826,700  
\(^{58}\) Duplicate addresses removed
Figure 25. Private properties by 2014 gross assessments

68 Frontage Properties = $118 million

427 residential properties = $433 million
Dykes & SLR

The drainage issues in Crescent Beach are significant and will be exacerbated with SLR, particularly with the associated rising groundwater tables and storm surge effects from Boundary Bay (Urban Systems & Golder Associates, 2009). The sandy soil previously provided gravity flow drainage of surface water, however, rising groundwater levels due to SLR are already reducing the soil’s drainage capacity and SLR is also raising high tide levels. The City completed a study in 2009 of drainage issues in the area taking into account SLR, and is currently implementing the resulting drainage plan (including a new pump station, perforated pipe stormsewer system, and flood box).

Crescent Beach is protected by a dyke system along the entirety of its ocean frontage, which was originally constructed by a private organization at the turn of the 20th century (Staff Interview, 2014). The dyke has a multiuse gravel trail on top which connects with the City park in the northeast of the community, and is very popular with locals and tourists especially during the summer months. Improvements completed in 2000 raised the dykes by approximately 1m, but the study that led to the determination of these DCEs did not account for SLR. The community was very resistant to increasing dyke heights at that time, as frontage property owners feared losing ocean views and privacy due to an elevated dyke with public walkway atop. The land required to raise the dykes also posed a significant issue, as there was not enough remaining City land on the landward side of the dyke and expropriating frontage lots for this purpose would have been expensive and controversial. The City therefore had to fill into the ocean side of the dyke to achieve the 1m increase in height and maintain the appropriate slope. As discussed earlier in this report, the slope for standard dykes like the one protecting Crescent Beach is 1:3, meaning that for every 1m increase in height 3m on each side of the dyke is required (and therefore six times the horizontal footprint size). The existing dykes in Crescent Beach are significantly lower than those heights required when following the new dyke design guidelines from the 2011 Provincial Guidelines: for three locations in Crescent Beach, 2010 DCEs based on the City’s recent floodplain mapping are 0.86-1.05m above existing dyke heights, while year 2100 DCEs are 2.02-2.73m higher than existing dykes (see Figure 18 earlier in this report).
Figure 26 illustrates the drastic differences between current DCEs and the recommended elevations to provide protection for 2010 and 2100 ocean levels, at the Crescent Beach North dyke. Since standard dyke footprints increase 6 times horizontally for every 1 unit increase vertically, raising the DCE by 2.5m would require 7.5m of land to each side (or 15m increase in total footprint area). Most of the waterfront lot lines of the frontage properties along Ohara Lane are between 10-20m from the existing dyke. However, given the setbacks required from dykes, elevating the current dyke crests by an average of 2.5m could mean expropriating the many of these lots (a cost of $118 million for all 68 properties). Due to the older nature of this area, many of the existing lots are already smaller than the 560 square metre minimum of the Residential Single Family (RF) zone. Requiring homes to be shifted further inland by increasing dyke footprints and thereby also setbacks may sterilize lots and leave no developable lot area remaining. This is visually illustrated in Figure 27 for the Crescent Beach South dyke, where increasing the current dyke crest elevation of 3.3m by 2.5m to achieve the year 2100 DCE of 5.8m might entail increasing the current footprint by approximately 15m, from 20m to 35m.
These frontage lots along Ohara Lane are those that will be impacted by the dyke’s footprint if DCEs are raised: at a slope of 1:3, achieving a 5.8m DCE (the recommended height for the Crescent Beach South dyke for year 2100, based on the City’s recent floodplain mapping\textsuperscript{59}) would require an area of approximately 35m, or 17.4m of land on either side of the dyke. If built around the existing dyke equally on both the land and ocean sides, a 5.8m high dyke’s landward slope would directly abut or build into existing frontage properties. Many of these frontage lots are already smaller than the size requirements from the Zoning Bylaw, and thus increasing setbacks by relocating existing residential structures further inland in these lots likely won’t be possible. This could mean the City may have to expropriate many of these frontage lots, could come at a cost of $118 million (in 2014 dollars) for all 68 frontage lots on Ohara Lane. Creating additional land through fill into the ocean on the water side of the dyke might also be possible, and was the strategy used in 2000 to raise the Crescent Beach dyke.

\textsuperscript{59} (Northwest Hydraulics Consultants, 2012)
network by 1m in elevation. However, this estuarine area at the mouth of the Nicomekl River is federally-protected habitat (through the Department of Fisheries and Oceans). The City had to conduct extensive habitat restoration as a result of the filling in 2000, which would be very expensive should future dyke improvements be achieved completely through ocean fill rather than through area secured on the landward side of the dykes (Staff Interview, 2014). While the City has not yet committed to raising existing Crescent Beach dykes, these maps serve as an interesting illustration of possible impacts in raising DCEs to the elevations recommended by the 2011 Provincial Guidelines and the City’s 2012 climate change study.
2.2 The Impacts of Raising Flood Construction Levels

Outside of Crescent Beach, FCLs for new development elsewhere in the City have historically been enforced, by the Province prior to 2004 and by the City after 2004 (when this power was transferred to local governments with the “Flood Hazard Area Land Use Management Guidelines”). The City has not committed to raising FCLs in any of its coastal areas since the release of the 2011 Provincial Guidelines nor committed to updating its methodology for calculating FCL elevations based on the methodology of these Guidelines. The result is that no FCLs anywhere in the City have been updated since 2011 and the methodology used to calculate them is based on historic flood levels (which do not take into account climate change or SLR). However, in 2008 the Province stated that it would not provide its Disaster Financial Assistance funds for properties damaged by floodwaters where local governments had allowed relaxations to build below provincial FCL elevations. Municipalities could therefore be liable to cover the costs of this flood damage in the absence of provincial assistance, which could present significant costs if an area like Crescent Beach (where many expensive homes have been granted FCL relaxations by the City) were to flood. Given this in combination with the proposed amendments to the 2004 Guidelines (which would change the existing flood hazard land use legislation), it is important to consider what the impacts might be should the City decide to raise FCLs and/or put an end to the DVP process relaxing FCLs in Crescent Beach.

A brief scan of existing literature and City staff interviews highlighted the following impacts to the built environment and challenges associated with increasing FCL elevations:

- Increase in construction costs for new development (e.g. to homeowners, developers)
- Difficulty integrating existing utilities (e.g. sewer & water servicing) and infrastructure (e.g. road network & drainage infrastructure) with elevated buildings
- Challenges in maintaining streetscape form and neighbourhood character
- Difficulty achieving density (Floor Area Ratio) on site due to maximum height requirements in Zoning Bylaw
  - Height relaxation may affect streetscape, view corridors, adjacent properties
- Accessibility and safety may be compromised (e.g. by more stairs)
- Increased noise reflection by elevated buildings (e.g. from busy streets)
- Increased potential for conversion of uninhabitable spaces below FCLs into habitable space after building inspection (e.g. illegal suites) (see Figure 28)
- Difficulty maintaining commercial at grade to encourage street level pedestrian access
- Protection of critical building systems services and vulnerable building components below FCL elevations (e.g. electrical, mechanical)

Section 15 of the Compensation and Disaster Financial Assistance Regulation states that structures built in an area designated as a floodplain under LGA Section 910 must be “properly flood protected” to be eligible for assistance to repair damage resulting from a flood.

A condensed version of this list was adapted for use in the City’s Corporate Report conveying concerns about the proposed changes to the “Flood Hazard Area Land Use Management Guidelines”
In the floodplain communities in the City where FCLs have been enforced over the past decades, many of these impacts are already being felt. When structural elevation rather than landfill is used to achieve FCLs, approximately 5-10% of the total permitted floor area is “lost” to uninhabitable space that is below the FCL elevation, since this area still counts towards the total allowable density permitted in the zone (City of Surrey, 1993). Only non-habitable areas are permitted below the FCL elevation, which include parking, garages, crawlspaces, storage areas, utility areas, or other non-habitable areas (City of Surrey, 1993). The City is also aware that in some communities, many of these ‘uninhabitable’ areas below FCL minimums are converted to habitable areas and illegal suites after final building inspections (Staff Interview, 2014) (see Figure 28). Property values in some communities with elevated FCLs, such as the residential area of Bridgeview on the Fraser River, are slightly lower than in nearby non-floodplain neighbourhoods, due to this loss of density that results from structural elevation being used to meet FCLs (Staff Interview, 2014). Construction costs are also higher when homes must be elevated instead of built at native lot grades. Using landfill to meet FCLs does not result in the same loss of density, however, using large amounts of fill (greater than 0.5m above native lot grade) on small single family lots results in issues with drainage and grading to adjacent non-elevated lots (Staff Interview, 2014). Fill is also more expensive than structural elevation and must settle for a period of up to a year before it can be constructed upon.
The maximum height for principal buildings in the Residential Single Family Zone (RF) is 9 metres or 30 feet. This height is measured from the average finished grade, which means that the height of buildings that use structural elevation to achieve FCLs is measured from the point where the building meets the ground (and not at the FCL). The height of buildings that use landfill to achieve FCLs is also measured from the point where the building meets the ground, however, this also corresponds to the FCL elevation. Height restrictions in Single Family Residential zones are not currently relaxed for structures that must meet elevated FCLs. This means that, for buildings using structural elevation to meet FCLs, habitable floor space may be lost by being increasingly ‘squeezed’ between a shifting minimum FCL and a fixed height restriction. Further, as FCLs increase, using exclusively fill to meet them will be more and more unfeasible due to the associated grading and servicing challenges. Structural elevation may increasingly be used over fill, and the resulting possibility of density loss with the 9m height restriction.

**Bridgeview**

The Bridgeview area in the Fraser River floodplain just east of the Pattullo Bridge exemplifies some of the impacts of raising FCLs in a residential community within the City. The neighbourhood consists of approximately 660 single family residential lots and is surrounded on all sides by industrial uses (Figure 29). Like Crescent Beach, Bridgeview is one of the oldest residential communities in the City, with many of its lots originating from subdivisions that occurred in the 1890s. FCLs requiring buildings be elevated above natural lot grades were first implemented in Bridgeview likely in the 1970s\(^62\), and varied from 2.75m (in the residential area behind the dyke) to 4.6m (in the unprotected area on the water side of the dyke) (Appendix B). These FCLs were updated to a minimum of 4.4-4.6m following joint provincial-federal floodplain mapping in the mid-1990s, and again updated to 4.7-4.8m in the years following additional Provincial river hydraulics modeling completed in 2009 (Appendix C) (see Table 7). The Province is currently working on river hydraulics modelling for the Fraser River that take into account climate change impacts such as SLR and changing precipitation patterns, and when released the City will consult these in considering whether to raise FCLs in the area (Staff Interview, 2014). The blanket FCL recommended for the entire Fraser River delta in the 2011 Provincial Guidelines was 6.2m, which is approximately 1.4m higher than current FCLs.

\(^62\) The author was unable to determine exactly when the Province began requiring FCLs in Bridgeview, but based on discussions with City staff it was likely soon before the adoption of the previous Zoning Bylaw No. 5942 in 1979
Figure 29. Bridgeview land uses: residential (orange), industrial (purple), and commercial (red) (source: City of Surrey OCP)

Most of the roads in the area are at 1.75m, and so new construction must place habitable floor spaces approximately 3m above the road grade to meet the current FCL minimum of 4.7-4.8m (Staff Interview, 2014). While the Zoning Bylaw permits either fill and/or structural elevation to achieve required building elevations, due to the poor soil quality in Bridgeview and the other complications listed above, most new homes built in the area have used structural elevation to meet FCLs. The result is that some of the newer homes seem to tower over their neighbours, creating unique streetscape, privacy, and accessibility issues (Figure 30). Some residents complain of the newer homes on their block reflecting noise from the nearby Highway 17, and that the much larger homes seem out of place on a street of older, smaller homes built at natural lot grades (Resident Interview, 2014). For decades new and redevelopment was prevented due to poor sewer infrastructure, however, this has recently been upgraded and sewer capacity is no longer preventing development in the area. Like in Crescent Beach, a trend of redevelopment is occurring with the replacement of older, smaller dwellings built at native lot grade (pre-1970s, before FCLs were required) by larger, more expensive homes built at much higher elevations (Figure 31).

Table 7. Approximate timeline of required FCL elevations in Bridgeview

<table>
<thead>
<tr>
<th>Year</th>
<th>Required FCL Minimums in Bridgeview</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-1970s</td>
<td>None</td>
</tr>
<tr>
<td>1970s-1990s</td>
<td>2.75-4.6m</td>
</tr>
<tr>
<td>1990s-2012</td>
<td>4.4-4.6m</td>
</tr>
<tr>
<td>2013-Current</td>
<td>4.7-4.8m</td>
</tr>
<tr>
<td>2014-2100?</td>
<td>6.2?</td>
</tr>
</tbody>
</table>

Dates are approximations as the author was unable to determine exactly when FCL minimums were increased over time.
Figure 30. Contrast in built FCLs between older & newer homes in Bridgeview, with possible year 2100 FCL approximation (12441 & 12451 113 Ave)

64 The City will likely update its FCLs and DCEs for Bridgeview based on the pending results of Fraser River hydraulics modeling conducted by the Province, which takes into account climate change impacts such as SLR
65 Recommended year 2100 FCL for entire Fraser River Delta from 2011 Provincial Guidelines (Ausenco Sandwell, 2011a)
2.3 SLR Adaptation in Strait of Georgia Communities

The City of Surrey is not the only community in the province facing increased flood risk due to SLR. Many other municipalities and regional districts are struggling to understand the impacts of this climate change hazard and come up with plans, policies, and regulations to address these impacts. Researchers at the University of British Columbia’s School of Community and Regional Planning and Institute of Resources, Environment and Sustainability are also interested in this question. Led by Dr. Stephanie Chang, the author and several other graduate students conducted a research project that investigated vulnerability to coastal and riverine flood hazards in 50 communities on the Strait of Georgia. The purpose of the study was to analyze factors that influence vulnerability and resilience, in order to better understand similarities and differences across communities. A variety of indicators were developed to attempt to better understand the vulnerability of these communities to coastal hazards, and increase regional collaborations in resilience-building efforts. These indicators fall into five broad categories: the natural environment (e.g. coastal geomorphology), built environment (e.g. port facilities), economy (e.g. marine resource dependence), society (e.g. social demographics), and institutional capacity (e.g. land-use plans). These indicators were based on primary and secondary data, and data sources included the Canadian census, DataBC, and questionnaires completed by local government planners, engineers, and emergency managers. The questionnaires were completed in April and May 2015 either over the phone or directly by respondents and sent back to researchers (see Appendix D for questionnaire). Fifty coastal municipalities and regional districts on the Strait of Georgia and in Metro Vancouver were contacted and twenty-eight completed questionnaires (the author administered questionnaires to five municipalities in Metro Vancouver). All communities were invited to a subsequent Strait of Georgia Marine Hazards workshop held on May 27th, 2015 where results were shared with respondents and other workshop attendees. The questionnaires consisted of fourteen multiple choice and short answer questions designed to learn more about the community’s risk reduction and adaptation in relation to coastal and riverine flood hazards. Four questions were selected for inclusion in this report, based on their relevance to SLR and the City of Surrey’s SLR adaptation efforts:

6) Has public participation been incorporated in planning for risk reduction and/or adaptation to coastal and riverine flood hazards? If yes, what form has public participation taken?67
9) Has the municipality conducted an assessment of future flood risk that incorporates climate change information?
10) Does municipal policy currently comply with provincial guidelines on planning for coastal flood hazards? (e.g. 2011 Guidelines for Management of Coastal Flood Hazard Land Use)
11) What level of consideration is currently being given to the following strategies for dealing with anticipated sea level rise and associated coastal flooding hazards?
   i. Protect (e.g. dikes, seawalls, groynes)
   ii. Accommodate (e.g. retrofit buildings, changing liability)
   iii. Retreat (e.g. relocate buildings and infrastructure to areas of lesser risk)
   iv. Avoid (e.g. no development in areas of future high risk)

66 Resilient Coasts project: www.resilientcoasts.ubc.ca
67 Selected because the next step in the City of Surrey’s coastal climate change adaptation study is engaging the public on the results and gaining input on future directions
6) **Has public participation been incorporated in planning for risk reduction and/or adaptation to coastal and riverine flood hazards? If yes, what form has public participation taken?**

Half of the local governments who responded to the survey had incorporated some form of public participation into their planning for risk reduction and coastal adaptation (14 of 28 respondents). A further five were in the progress of gathering public input, so in total 68% (19 of 28 communities) were conducting public engagement on these issues. Surrey is in the progress of doing this, and Engineering staff have indicated their desire to learn from the successes and failures of other local governments who have already gone through this process (Staff Interview, 2014).

![Bar chart showing forms of public participation](image)

**Figure 31. Form of public participation in planning for risk reduction and/or adaptation to coastal and riverine flood hazards for Strait of Georgia communities**

The most common form of public participation on risk reduction and/or coastal adaptation used by the local governments surveyed was through information distribution and public consultation, followed by collaborative efforts such as steering committees. Fewer communities had involved members of the public through workshops or opinion polling, and only the Cowichan Valley Regional District had engaged the public in direct decision making. This regional government was also the only community to have employed all five of the engagement strategies. Other leading municipalities in this area, who have used four of five strategies, include the Corporation of Delta, the District of Squamish, and the City of Burnaby. The City of Surrey has so far utilized two strategies (consultation and collaboration), however, public consultation on the results of the first phase results is the next step in their coastal climate change adaptation study. City staff could look to these four leading Strait of Georgia communities for insight and best practices in preparing the public engagement component of their SLR adaptation work.

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68 “Serpentine, Nicomekl & Campbell Rivers – Climate Change Floodplain Review”
9) _Has the municipality conducted an assessment of future flood risk that incorporates climate change information?_

Most communities have already or are in the process of conducting assessments of future flood risk that incorporate climate change information (16 of 28 communities). The City of Surrey is one of these, having completed the first phase of their coastal climate change study including SLR\(^{69}\) in 2014. However, four of the twelve communities who replied that they hadn’t conducted this type of study indicated that their regional government, the Capital Regional District, was in the process of conducting an assessment of future flood risk in response to 2011 Provincial Guidelines. These are smaller communities (the City of Langford, the District of Sooke, the Town of Sidney, and Salt Spring Island) who may not have the capacity or resources to conduct this type of complex analysis on their own.

![Pie chart](image)

_Figure 32. Strait of Georgia communities who have conducted assessments of future flood risk taking into account climate change_

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\(^{69}\) “Serpentine, Nicomekl & Campbell Rivers – Climate Change Floodplain Review”
10) Does municipal policy currently comply with provincial guidelines on planning for coastal flood hazards? (e.g. 2011 Guidelines for Management of Coastal Flood Hazard Land Use)

Approximately half of the communities responded that they were in compliance with current provincial guidelines for coastal flood hazard land management (Figure 33). However, this question is not entirely clear as the legal status of the referenced 2011 “Guidelines for Management of Coastal Flood Hazard Land Use” themselves is not entirely clear. The 2011 Provincial Guidelines are not in their current state ‘official’ legislation, as they have not been issued by the Minister of Environment under Section 5 of the Environmental Management Act. The only ‘official’ BC provincial guidelines that have been published in this way for flood hazard area management are the 2004 “Flood Hazard Area Land Use Management Guidelines”. However, the amendments that are currently proposed to these ‘official’ 2004 Guidelines will update Sections 3.5 (The Sea) and 3.6 (Areas Protected by Standard Dikes), which would include SLR projections and methodology for calculating coastal FCLs and sea DCEs from the 2011 Guidelines. Therefore, the only existing ‘official’ provincial guidelines are those from 2004, without the proposed amendments for SLR and seismic dyke considerations. Many communities are currently in compliance with these existing ‘official’ guidelines from 2004.

However, if the amendments based on the 2011 reports are enacted as proposed, essentially none of the coastal communities in the Province would be in compliance, since none have upgraded dykes or FCLs to year 2100 standards, or upgraded dyke design criteria to include seismic considerations (Staff Interview, 2014). One municipality’s response to this question sums up this confusion: “The regulatory standing [of the 2011 Provincial Guidelines] is not certain as it is a guidance document. [Our] dikes meet the current regulatory framework (circa 2004). [The 2011 Provincial Guidelines] also include seismic considerations. No one in the Lower Mainland is in "compliance" to the guidelines. Actually these guidelines are yet to be approved”. However, these guidelines could soon be ‘approved’ and incorporated into the official legislation governing municipal planning in coastal areas, if the
amendments to the 2004 “Flood Hazard Area Land Use Management Guidelines” are enacted as proposed.

Other communities such as the Gibsons commented that they were in practice in compliance with the existing ‘official’ provincial guidelines, however their Zoning Bylaws hadn’t been updated to reflect this. This is also true at the City of Surrey, where enforced FCLs in coastal communities have increased with Provincial requirements but those listed in the Zoning Bylaw are outdated. Part 8 “Floodproofing” of the current Zoning Bylaw No. 12000 has not been updated since the previous Zoning Bylaw No. 5942 from 1979 (over 35 years ago). The floodproofing section includes specific FCL elevations for two communities in Surrey along the Fraser River, Bridgeview and South Westminster (see Figure 42 later in this report). These FCL elevations have not been used by the City since the most recent Provincial floodplain mapping in the 1990s, and the City has instead been enforcing higher FCLs in line with recent river hydraulics modeling of the Fraser River conducted by the Province.

11) What level of consideration is currently being given to the following strategies for dealing with anticipated sea level rise and associated coastal flooding hazards?

i. Protect (e.g. dikes, seawalls, groynes)

Approximately three quarters of the communities have at least given some consideration to this adaptation strategy for dealing with SLR (22 of 28). This is the floodproofing strategy that has been traditionally used by local and senior levels of government for protecting floodplain development, typically through the construction of dykes, seawalls, and groynes. With SLR, however, existing structural protection will need to be raised significantly to protect against with rising ocean levels. Further, if the amendments to the 2004 “Flood Hazard Area Land Use Management Guidelines” are enacted as proposed, seismic considerations will also need to be included in sea dyke design. Only six communities have actually implemented the ‘Protect’ strategy, including the City of Surrey, the Corporation of Delta, and the District of Squamish, but SLR wasn’t considered at the time of structural flood protection design. If the pending legislative changes governing flood hazard area land use management are passed, however, all existing sea dykes will need to be upgraded in order to be in compliance. Several communities that do not currently have structural flood protection, such as the City of Vancouver, are seriously considering this strategy in response to SLR. A storm surge barrier at the mouth of False Creek and a dyke along the Fraser River in Vancouver’s low-lying Southlands neighbourhood have both been discussed as possible structural SLR adaptation options.

ii. Accommodate (e.g. retrofit buildings, changing liability)

Four communities reported that they have actually implemented this adaptation strategy in response to SLR: the City of Surrey, the Corporation of Delta, the City of North Vancouver, and the City of Vancouver. While the questions did not ask respondents to indicate specific ‘Accommodate’ adaptation strategies employed, it is likely that all four communities were referencing FCLs. The latter three have all recently increased FCLs in coastal areas by one metre, while Surrey has indicated they will likely increase FCLs along the Fraser River frontage pending forthcoming river hydraulics modeling by the Province. No communities, the City of Surrey included, have updated their methodology for

70 Except Crescent Beach
calculating coastal FCLs or sea DCEs as per the 2011 Provincial Guidelines, as this would significantly increase these elevations. There are likely other communities besides these four that currently enforce FCLs based on minimum elevations determined in the most recent floodplain mapping by senior government (completed as a joint partnership between the provincial and federal governments in the 1990s). The proposed amendments to the 2004 “Flood Hazard Area Land Use Management Guidelines” would require local governments consider SLR to the year 2100 in current development and FCL minimums be updated based on Provincial methodology. These minimums are typically much greater than current FCLs, and there is no consideration in the amendments as proposed for a staged implementation of these new FCL minimums.

![Figure 34. Level of consideration being given by Strait of Georgia communities to 4 main SLR adaptation strategies](image)

### iii. Retreat (e.g. relocate buildings and infrastructure to areas of lesser risk)

Managed retreat is the SLR adaptation strategy that respondents had given the least amount of consideration to. Over half of the communities had not engaged in preliminary discussions regarding this option, only two had given it serious consideration, and none had implemented it. The City of Surrey was one of the two communities that reported considering this strategy, specifically for its agricultural areas along Mud Bay in the Serpentine/Nicomekl floodplain. Surrey is also the only community in Metro Vancouver where the Province suggested managed retreat as a recommended SLR adaptation strategy (see Figure 12 earlier in this report), based on land values and estimated cost of protection from SLR to the year 2100. Several respondents, including the City of Vancouver, indicated that high land values and existing coastal urban development make this strategy unfeasible. If the City of Surrey wanted to purchase existing lots from private land owners in Crescent Beach to remove urban development from this coastal community, for example, this could come at a cost of over $433 million (based on 2014 assessed values of the 427 privately-owned lots in the area) (see Figure 25 earlier in this report).
iv. Avoid (e.g. no development in areas of future high risk)

Over half of the respondents had at the minimum engaged in discussions about avoiding future development in flood prone areas. Several communities cited the difficulty of considering this option when most coastal floodplain areas are already developed (e.g. the City of Vancouver and Gibsons). The City of Surrey is one of only five communities to have implemented this strategy, through their policy since 2008 to limit further urban development in the Serpentine/Nicomekl agricultural floodplain area, policy statement D2.27 in the new OCP indicating that no subdivision in floodplain areas will be permitted (p. 365, City of Surrey, 2013), and through the new Flood Prone Hazard Lands Development Permit Areas. Several communities cited similar coastal or floodplain Development Permit Areas as examples of how they have implemented the ‘Avoid’ SLR adaptation strategy, in that individual developers or homeowners are only permitted to develop in flood prone areas if they can demonstrate that this is safe through geotechnical assessments and risk mitigation efforts (e.g. Qualicum Beach, Sechelt, and the Powell River Regional District). Whether or not this results in avoiding future development in floodplain areas, or simply permitting only development that is further floodproofed, remains unclear. Where land values are high, it will likely be economical for developers to assume the risk of developing in floodplain Development Permit Areas and assume the cost incurred in doing so (e.g. engaging a qualified geotechnical professional and installing additional drainage and/or floodproofing works). Qualified professionals such as geotechnical engineers are engaged by developers to assess property and determine what measures must be employed or conditions met for the land to be developed safely (or at least safely to a designated size of event). These assessments rarely result in these professionals refusing to sign off on projects if there is truly no engineered way to permit safe development (Staff Interview, 2014). Floodplain Development Permit Areas may therefore not warrant the label of the ‘Avoid’ SLR adaptation strategy, if they in fact do permit floodplain development (even if thoroughly floodproofed).

Summary

The analysis of these four questions highlights how the City is generally leading efforts in SLR adaptation and coastal land management, which supports anecdotal evidence the author gathered in her time working in an internship at the City and through discussions with other local government staff. Surrey Engineering staff in particular are very active regionally, sitting on steering committees for the Fraser Basin Council’s Lower Mainland Flood Management Strategy and initiating the first study of SLR impacts in response to the 2011 Provincial Guidelines documents. The methodology used to calculate year 2100 FCLs and DCEs in this study differed from that used by the Province in the 2011 documents, and the Province subsequently accepted Surrey’s methodology as a substitute for their own. The City of Vancouver also hired the same consultants to conduct an analysis of future floodplain extents and flood impacts given SLR, and used the same methodology developed in Surrey’s initial study.

71 “Serpentine, Nicomekl & Campbell Rivers – Climate Change Floodplain Review” (first phase completed in 2014)
72 The 2011 Provincial Guidelines methodology for calculated FCLs and DCEs added storm surge, wind setup, high tide, subsidence, and SLR, ignoring the likelihood of all of these events occurring simultaneously. This effectively increased the level of protection from a one-in-200-year event to a one-in-10,000-year event. The City of Surrey’s methodology from “Serpentine, Nicomekl & Campbell Rivers – Climate Change Floodplain Review” took into account the joint probability of all these separate events occurring simultaneously, which was subsequently accepted by the Province as an alternative to the methodology used in the 2011 Provincial Guidelines.
However, there are certain issues where the City could learn from other communities that may be further along than Surrey. Public engagement around SLR and climate adaptation is a high priority for the City right now, and engaging the public on the results of the first phase of the coastal climate change study is the next step in this project. Understanding what other local governments are doing in terms of public engagement around coastal adaptation, as per question 6, may therefore be valuable and provide the City with communities leading these efforts City staff could subsequently reach out to. The City’s new OCP adopted in October 2014 also includes for the first time a Hazard Lands Development Permit Areas for floodplain areas, and Surrey is not the first community to do this. At least eleven other communities have similar development permit areas for floodplain or coastal lands that have been adopted in the last five years\(^{73}\). City Development Planning staff are just beginning to process the first Flood Prone Hazard Lands Development Permit Area applications since they were brought in with the new OCP adoption in October 2014. These other communities who have been enforcing floodplain Development Permit Areas could act as a resource as City planning staff begin this process.

3. Recommendations & Conclusions

Given the current legislative and policy context of SLR and flood hazard area land use management in BC, this report makes several recommendations that may increase the City’s resilience to the long-term impacts of SLR. These recommendations are organized around four main goals and by suggested timeline of implementation: “Short” (within the next year), “Medium” (in the next 1-5 years), and “Long” (in the next >5 years) (Table 8). Recommendations are further explained below, and priority actions for implementation are those with a “Short” timeline. All of the recommendations are within City jurisdiction, however, some will require partnerships with other organizations to implement (e.g. other municipalities and levels of senior government). The intent is not for the City of Surrey to necessarily implement all of the recommendations as described, but rather to provide suggestions for a range of strategies across a range of timelines, all of which should increase resilience to and awareness of SLR within the City (whether pursued in isolation or in combination with other approaches). The recommendations are primarily based on the research that forms the basis for this report and are additionally informed by the author’s own experience working in three separate departments at the City of Surrey\(^{74}\).

\(^{73}\) Based on responses to question 7 “What municipal policies or regulations related to coastal and riverine flood hazards have been adopted in the last five years?”, “coastal” or “flood hazard” or “floodplain” or “marine foreshore” development permit areas; eleven communities as follows: City of North Vancouver, Sechelt, Qualicum Beach, Cowichan Valley Regional District, City of Langford, Gibsons, Corporation of Delta, Powell River Regional District, City of Port Moody, Comox Valley Regional District, Parksville

\(^{74}\) As an intern with the Community Planning Department, as a Climate Change Adaptation Coordinator in the Sustainability Office, and in her current position as a Planning Technician in the Area Planning and Development Department
### Table 8. Report recommendations

<table>
<thead>
<tr>
<th>GOAL</th>
<th>RECOMMENDATION</th>
<th>TIMELINE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Greater awareness of challenges posed by SLR and build support for SLR adaptation</td>
<td>1.1 Internal City stakeholder SLR education &amp; engagement</td>
<td>1.1 Short</td>
</tr>
<tr>
<td></td>
<td>1.2 Public SLR engagement strategy</td>
<td>1.2 Medium</td>
</tr>
<tr>
<td>2. Better understanding and mitigate potential impacts of raising Flood Construction Levels (FCLs) &amp; Dyke Crest Elevations (DCEs)</td>
<td>2.1 Collect FCL construction cost data</td>
<td>2.1 Short</td>
</tr>
<tr>
<td></td>
<td>2.2 Height relaxations in Zoning Bylaw for residential floodplain zones</td>
<td>2.2 Medium</td>
</tr>
<tr>
<td></td>
<td>2.3 Incorporate urban design floodproofing strategies into existing City policy and tools</td>
<td>2.3 Medium</td>
</tr>
<tr>
<td>3. Assess site-specific viability of 4 SLR adaptation strategies and transition to risk-based funding model</td>
<td>3.1 Conduct site-specific cost-benefit analysis of SLR adaptation strategies</td>
<td>3.1 Long</td>
</tr>
<tr>
<td></td>
<td>3.2 Consider innovative funding options for SLR adaptation and flood protection</td>
<td>3.2 Long</td>
</tr>
<tr>
<td>4. Increase flood resilience and bring City practice &amp; policy in line with new Provincial guidelines &amp; legislation</td>
<td>4.1 Identify “no regrets” SLR adaptation actions</td>
<td>4.1 Long</td>
</tr>
<tr>
<td></td>
<td>4.2 Modify Crescent Beach DVP process</td>
<td>4.2 Medium</td>
</tr>
<tr>
<td></td>
<td>4.3 Harmonize and update City FCL policy</td>
<td>4.3 Short</td>
</tr>
</tbody>
</table>

### Goal 1: Greater awareness of challenges posed by SLR and build support for SLR adaptation

**1.1 Effectively engage internal City stakeholders and staff around challenges posed by SLR adaptation**

SLR adaptation is truly a ‘wicked problem’ in the complex planning challenges it presents, the long and uncertain timeline of its impacts, the cost of traditional protection options, opposing City policies and priorities, and the necessary collaboration of City staff across departments (including Community Planning, Area Planning and Development, Engineering, the Building Division, Legal Services, and the Sustainability Office). An effective public communication strategy could begin with an internal stakeholder engagement strategy to build City staff support on the plethora of issues SLR adaptation
presents. FCL requirements are regulated in Community Planning’s Zoning Bylaw yet enforced by Building Division staff, floodplain subdivision applications are handled by Area Planning but Hazard Lands Development Permit Areas outlined in Community Planning’s OCP, and dykes are the purview of the Engineering department. However, the task of increasing the Surrey’s long-term resilience to SLR and meeting Provincially-legislated flood protection requirements is a challenge that crosses departmental boundaries and thus SLR adaptation should not be siloed in any single department nor with one single staff member. Outlining the necessary SLR adaptation measures being employed today in the City (e.g. the new pump and perforated pipe system in Crescent Beach being installed to address rising groundwater levels due to SLR) may help to communicate the urgency of beginning adaptation now and not at some seemingly-distant point in time (e.g. the year 2100)\textsuperscript{75}. This could be as straightforward as distributing floodplain maps with FCL requirements across departments, or designating a floodproofing staff member to coordinate SLR adaptation initiatives and liaise between departments. Research has shown that increasing stakeholder awareness is crucial in climate adaptation projects, and this can be achieved through ‘learning by doing’ demonstration projects across departments (Feltmate & Thistlethwaite, 2012). This might also reduce the desire to avoid SLR adaptation with its double-edged sword of simultaneously overwhelming and seemingly-distant impacts. A City of Vancouver workshop\textsuperscript{76} highlighted that structural flood protection infrastructure such as dykes can be implemented as ‘too engineered, not planned’ and thus there exists the potential for coordinating these structural works with planning policy (City of Vancouver, 2013).

1.2 Develop a SLR public engagement strategy

Public support is crucial for building awareness of the adaptation challenges SLR presents and a public engagement strategy is an integral component of SLR adaptation (Arlington Group Planning + Architecture Inc. et al., 2013). It is necessary to convey a sense of urgency and reality of SLR impacts within our lifetimes, for an issue that may seem like a distant event – public resistance has been cited as a key barrier for implementing climate adaptation measures (Rowett, 2008). This resistance to adaptation and lack of awareness of the problem may be exacerbated by a history of structural flood protection maintained by the City. The existence of dykes and seawalls can create the implicit expectation by the public that the historically-provided level and method of protection will continue indefinitely, regardless of increasing maintenance costs and the impact on coastal communities. There is similar precedent in the DVP process in Crescent Beach, where relaxations to FCL requirements and an existing dyke network could engender a false sense of security and expectation of continued City protection for these floodplain inhabitants.

The City so far has not engaged members of the public on SLR and its adaptation issues, except for two questionnaires as part of the 2009 Crescent Beach climate adaptation study and resulting drainage strategy\textsuperscript{77}. The next step in the Nicomekl, Serpentine and Campbell Rivers climate change adaptation study is to gather public input on the results of the first and second phases of the project,

\textsuperscript{75} One senior staff member from the Legal Division asked in a meeting if SLR was “even real” – this might be the type of attitude and opinions the City may need to address in building internal support for SLR adaptation measures
\textsuperscript{76} Held in October 2013 through SFU’s Carbon Talks program
\textsuperscript{77} “Crescent Beach Climate Change Adaptation Study” (Urban Systems, 2009)
which would include prioritizing various SLR adaptation options. Rather than portraying the challenge as an “inconvenient truth”, SLR adaptation could be described as a “convenient opportunity” which we have the time to adapt to (provided we act proactively) and can avoid increasingly significant impacts in the future. It will also be important to develop an education program around the need to apply FCLs or increase DCEs to meet Provincial policy and legislation, and the City’s liability if these requirements are not followed. A public engagement strategy could be focussed in a case study community such as Bridgeview or Crescent Beach, and such a strategy should be reflective of the demographic, economic, and flood hazard differences between communities. Public engagement could also be focussed around a demonstration project, such as site-specific development that must build to new FCL elevations or a dyke section increased to meet year 2100 crest elevations. Computer-aided modelling that illustrates site-specific SLR impacts with and without adaptation measures could be an effective means of helping the public visualize the reality of this challenge, and garnering public support for adaptation (Figures 35). Public art projects are also being increasingly employed to convey possible future sea levels, and local examples include Cambie Street Bridge in Vancouver (Figure 36) and Bamfield, BC (Figure 37). Finally, the City could reach out to other local communities that have already included public participation in planning for risk reduction and adaptation to coastal and riverine flood hazards. The Cowichan Valley Regional District, the Corporation of Delta, the District of Squamish, and the City of Burnaby have all conducted this type of public participation, which has taken the form of information distribution, consultation, public involvement through workshops and polling, and collaborative efforts including steering committees (see Figure 31 earlier in this report). Sharing best practice information about how to frame messaging around SLR adaptation could be valuable as the City moves forward with its SLR adaptation.

Figure 35. Visualization of two different ‘Protect’ SLR adaptation measures (seawall and dyke) in the Corporation of Delta (source: Centre for Advanced Landscape Planning, UBC, 2012)
Goal 2. Better understand and mitigate potential impacts of raising Flood Construction Levels (FCLs) and Dyke Crest Elevations (DCEs)

2.1 Collect data on increases in construction costs as a result of increasing FCLs

Construction costs for new structures increase as buildings must be built higher, through structural elevation or landfill, to meet elevated FCLs. The City does not currently capture data through its building permit process that specifically indicates the cost of elevating structures to meet FCLs, however, the Building Division does gather other construction cost data as part of building permit approvals. Research exists on the impacts of raising FCLs (see Section 2.2 of this report), but little is known of the actual dollar value in development construction and servicing costs associated with increasing FCLs. The increased construction cost per square foot that elevating FCLs entails, for example, might be a powerful metric to illustrate the impact to homeowners and developers. Similarly, the increased cost to the City in servicing these elevated structures or raising road infrastructure per metre of FCL increase might be interesting data to lobby senior levels of government for financial support in meeting these requirements. Case study neighbourhoods for collecting this data might be Bridgeview, where FCLs have been increasing over time.

Tamsin Mills, City of Vancouver, personal communication
2.2 Consider relaxing height restrictions in Zoning Bylaw for residential areas affected by FCL increases

Building heights in the City’s Zoning Bylaw are measured from the average finished grade levels in Single Family and Duplex lots, or the average existing grade levels for all other lots. This means that residential lots that use landfill to meet FCL elevations will not lose density (or total allowable Floor Area Ratio), as the height is measured from the finished grade after fill has been installed. Single family homes that use structural elevation to meet FCL elevations may however lose density, due to the fact that the building height is measured from the point at which the dwelling meets the finished lot grade and not from the FCL elevation (i.e. the elevation of the habitable floor area). New development in many areas such as Bridgeview (where FCLs of 4.8m currently apply) use structural elevation to meet these FCLs, as soil quality in this area is very poor. Lot grading to adjacent properties is also difficult when excessive fill is required to meet elevated FCLs. This will only become more challenging with increasing FCL elevations, which may increasingly make landfill less feasible than structural elevation as FCLs continue to increase. Habitable floor area for single family residential zones is thus being ‘squeezed’ between elevating FCLs and a static height restriction (9m for single family residential zones in the Zoning Bylaw). Building Division staff report that, at current FCLs of 4.7-4.8m, approximately 5-10% of the total permitted square feet in Bridgeview’s new residential development is lost to uninhabitable area below these FCLs (Staff Interview, 2014). The City may therefore consider relaxing height restrictions in areas where significant FCL increases are required. There is some precedent for this in post-Hurricane Sandy New York City, where height restrictions were suspended so existing homes could be raised to meet increased FCL levels as per an executive order from the Mayor’s office (Figure 38).

Figure 38. Elevation of existing structure to meet increased FCLs and height relaxations in post-Hurricane Sandy New York City (source: NYC Buildings, 2013)
2.3 Incorporate urban design floodproofing strategies into existing City policy and tools

A lack of knowledge about risk-reduction options is a challenge faced by individual homeowners and developers in floodproofing residential structures (Feltmate & Thistlewaite, 2012). These differ in what can be incorporated during building construction and what can be achieved by retrofitting existing homes. Many of the City’s floodplain areas which will be most impacted by SLR and climate change are in the agricultural lowlands, however, urban areas with residential communities include Crescent Beach, Bridgeview, and Cloverdale. The City can regulate floodproofing requirements in new development with the Zoning Bylaw (e.g. by defining FCL requirements) and restrict development in floodplain areas (e.g. the City’s Development within the Nicomekl and Serpentine River Floodplains policy), but currently does not include any urban design strategies to reduce flood risk in existing policy or tools. This could be recommendations for homeowners looking to redevelop, that describe best practices for the optimal single family residential housing designs that meet FCL requirements with maximum allowable floor area. These could include designs for floodproofing homes that allow the passage of floodwaters (Figure 39) or design considerations which maximize the flexibility of uninhabitable spaces below FCLs. There may be an increasing desire and need for these types of recommendations, given that FCLs will likely continue to rise, and this is information which the City is in a favourable position to collate and provide. This might be possible to include or require in the new Flood Prone Hazard Lands Development Permit Areas in the new OCP. Similar development permit areas for floodplains exist or are in development in other Metro Vancouver municipalities, including the City of North Vancouver and the City of Vancouver, but these generally do not include design considerations specific to flood protection (Centre for Advanced Landscape Planning, UBC, 2012). Given that new floodplain development in the City will likely have to build to increasingly elevated FCLs in the future, the City might consider including specific urban design considerations into its Hazard Lands Development Permit Areas to mitigate the impact of flooding for new development in these areas. These could also be included in development permit areas or zoning that are more explicitly linked to SLR and flooding, to create greater awareness of these hazards. The District of Saanich uses a Floodplain Development Permit Area to delineate its floodplain and levy certain requirements in this area, and the entire residential area of Bridgeview used to be zoned as “Residential Floodplain (RFF)” in the City’s Zoning Bylaw. Year 2100 and Year 2200 SLR Planning Areas could also be created, as suggested in the 2011 Provincial Guidelines and the proposed amendments to the 2004 “Flood Hazard Area Land Use Management Guidelines”, in which specific building requirements and land use strategies could be enforced.

Figure 39. Wet floodproofing design with window openings which allow for passage of flood waters (source: Arlington Group Planning + Architecture Inc. et al., 2013)
Goal 3. Assess site-specific viability of 4 SLR adaptation strategies and transition to risk-based funding model

3.1 Conduct site-specific Cost-Benefit Analysis (CBA) of SLR adaptation strategies, considering increasing long-term costs of “Protect” options

In general the City’s approach to flood protection thus far has been one of “Protect” (e.g. dykes, sea dams) and “Accommodate” (e.g. FCLs) in urban areas, followed by “Avoid” in agricultural floodplain areas (e.g. policy of avoiding development in the 200 year Nicomekl/Serpentine floodplain). The Province has suggested the City continue employing these strategies in adapting to SLR (see Table 2 earlier in this report), and in addition, consider managed retreat as a long-term strategy for the mainly agricultural lands in the coastal area of Mud Bay (Delcan, 2012). These preliminary suggestions are based on the value of coastal areas and the consequences of flooding, but the Provincial documents highlight the need for site-specific analysis before a long-term management strategy can be chosen by each shoreline reach. The City is already engaging in the modelling and analysis required to support decisions about long term adaptation strategies, specifically in the Nicomekl, Serpentine, and Campbell Rivers floodplains, and will rely on the Province and FBC to develop a long-term Fraser River management strategy (Staff Interview, 2014). These could be used to support the site-specific identification of long-term SLR management strategies, and would include a detailed cost-benefit analysis of various adaptation options. This would account for the increasing costs to the City in the long term, if a strategy of mainly “Protect” options is pursued, offering the same level of protection at increasing costs as the impacts of SLR also increase.

There are many examples of innovative approaches to coastal protection that are less expensive and more flexible than the traditional large structural works that provide engineered flood protection (e.g. dykes). These include green infrastructure approaches to SLR adaptation, such as returning less developed coastal areas to marshland through managed retreat or realignment (used notably in the United Kingdom and may be a consideration for Mud Bay’s long term adaptation strategy). Rolling easements also present an innovative retreat strategy and are being used in several coastal US states. In this adaptation strategy, homeowners are prevented from protecting coastal properties from the advancing ocean and government does not provide structural flood protection. Therefore over time, the natural boundary (and with it the private/public property line, defined under common law as the mean high tide line) moves inland until structures are no longer safe for habitation and must be abandoned (Climate Ready Estuaries, 2011) (Figure 40). Oyster reefs have also been shown to reduce erosion rates and storm surge, and unlike structural works they will naturally build themselves up with rising sea levels (Scyphers, Bowers, Heck, & Byron, 2011), (The Nature Conservancy, 2013). ‘Green’ infrastructure (e.g. oyster reefs, coastal marshes) is generally more flexible than typical ‘grey’ infrastructure (e.g. dykes), with a dynamic capacity to repair itself and adapt to changing conditions, and has been used increasingly in stormwater management in the US. Many of these green infrastructure and managed

79 A CBA is identified as one of the eleven priority adaptation actions in the City’s recently-adopted Climate Adaptation Strategy (FL-1.2: “Participate in a detailed cost-benefit analysis to assess alternative options for accommodating sea level rise and coastal climate change impacts”)
retreat strategies might work best in less developed areas where the relative land value is less, for example Mud Bay, and not as well in more urban areas such as Crescent Beach.

![Figure 40. Example of managed retreat of private property in Kitty Hawk, South Carolina (source: Climate Ready Estuaries, 2011)](image)

### 3.2 Consider innovative funding options for SLR adaptation and flood protection

Insurance prices are typically calibrated to risk, and thus give policy holders some measure of their risk to damage of the event against which they are insured. While insurance for flood damage from sewer backups is available for residential properties, overland flood insurance (i.e. water that enters via doors or windows) for homeowners is not available in Canada – the only G8 country without this type of residential insurance. In the absence of insurance, homeowners have no metric to reflect or measure their risk of flood damage. Extensive protection works such as dykes may further establish a false sense of security in their level of protection, as well as the expectation among floodplain residents that this level of protection will continue indefinitely without their personal contribution to the costs. The City could consider a risk-based funding model for its long-term SLR adaptation, in which those properties in flood hazard areas directly contribute to the level of flood protection City infrastructure provides. In the past, the City has funded its dyke improvements primarily through senior government grants and the City’s Drainage Utility, which is levied on all parcels regardless of location or flood risk. The funding mechanism used by the dyking districts, on the other hand, was a levy only on properties provided protection by the dykes. Local Area Service or Local Improvement Levies might also be possible, where a service or piece of infrastructure is constructed by the City and a fee levied on benefitting parcels to fund the project. There is precedent in Denmark for establishing a flood protection levy on floodplain properties protected by municipal flood infrastructure (Klimatilpasning, 2012). In the US and Canada, similar stormwater management utilities have also been used. The City of Minneapolis charges fees on properties based on their amount of impervious area, and the City of Victoria uses a similar stormwater utility (British Columbia Real Estate Association, 2014). Fees to fund flood protection could be similarly levied on parcels benefitting from the City’s flood protection works, possibly those in defined Year 2100 and 2200 SLR Planning Areas (which local governments could establish, as suggested in the 2011 Provincial Guidelines).

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80 Other than through their indirect contribution through property taxes, which fund the majority of municipal work including dyke maintenance
81 The last major Crescent Beach dyke improvements in 2000 were not funded by the Drainage Utility but rather by a separate fund allotted by Council specifically for this project
82 “Surrey Drainage Parcel Tax By-law, 2001, No. 14593”
Implementing any system in which costs for protection are transferred even in part from the City to floodplain residents will require extensive public education and engagement, and very transparent City policy around when, where, and how much these fees will be levied. The use of “triggering events” presents an interesting example and addresses the long timescale and high levels of uncertainty inherent in SLR projections and adaptation (McGuire, 2013). This could be a SLR policy or adaptation fee that would be implemented when SLR reaches a certain magnitude (i.e. the “triggering event”), regardless of whether this is well before or well after the expected timeframe. These community fees could be levied in a way that is incrementally more severe in response to increasing SLR. For example, the costs of a certain amount or the first round of SLR adaptations could be jointly borne by the coastal community and the City, whereas these costs could be increasingly transferred to residents as SLR becomes increasingly challenging to protect coastal urban development against. Transparency in using a series of “triggering events” would be necessary to avoid political and social costs, and may provide a bridge to broach the transition between a “Protect” and “Managed Retreat” SLR adaptation strategy.

Goal 4. Increase flood resilience and bring City practice & policy in line with new Provincial guidelines & legislation

4.1 Identify “no regrets” SLR & climate change adaptation actions

“No regrets” approaches to climate change are those actions that improve infrastructural resilience and generate community benefits regardless of whether the extent of anticipated climate change materializes or not (Feltmate & Thistlewaite, 2012). Increasing attention in emergency management recently has been paid to the concept of social resilience – a community’s ability to recover more quickly and efficiently from disasters through coordinated efforts and cooperative actions – especially post-Hurricanes Katrina and Sandy in the US (Aldrich, 2012). One third of those directly affected by Sandy reached out to friends, family, and neighbours during or immediately after the storm, whereas the poor recovery rates post-Katrina of Louisiana’s Lower Ninth Ward has been partially attributed to the low level of social resilience and social capital in the neighbourhood pre-storm (Aldrich, 2012). While social capital is referenced in the City’s recent Climate Adaptation Strategy as a key determinant of adaptive capacity, most of its adaptation actions aim to build infrastructural rather than community resilience to climate change impacts. Given the increase in frequency and severity of coastal storms projected with SLR and climate change, and one study’s findings that Metro Vancouver residents struggle to make meaningful connections with others and are retreating from community life (Vancouver Foundation, 2012), the City could consider a long-term adaptation strategy that includes building social resilience in communities most vulnerable to climate change impacts. This could take the form of community spaces that could double as Community Disaster Support Hubs during emergency situations, or a block party initiative aimed at increasing social capital in a case study community.

Infrastructural resilience to SLR and climate change is already a focus at the City and in its Climate Adaptation Strategy, but the City could investigate urban design strategies to retrofitting or constructing new buildings for multihazard resilience – structures that meet seismic standards while also increasing their flood resilience and energy efficiency, for example.
4.2 Modify Crescent Beach DVP process

The research for this report could unearth no case precedent in BC for LGA Section 291 Restrictive Covenants indemnifying local governments against flood damage actually being tested in court (e.g. flood damage occurring to floodplain properties where restrictive covenants had previously been registered and where residents were demanding municipalities pay for flood damage). Regardless, flooding is a political nightmare for municipalities even if homes themselves are not damaged, as raised structures and their residents can still be cut off when adjacent driveways and roads are flooded. FCL design standards in coastal areas could soon change drastically if proposed legislative changes are enacted, and Fraser River FCLs could also soon be updated based on forthcoming river hydraulics modelling conducted by the Province. In 2008 the Province also introduced a clause into existing legislation stating that if local governments ignore FCL requirements in designated floodplain areas, the Province will not fund disaster relief in the case of a flood and thus local governments would be responsible for flood damages incurred by residents.

Built FCLs in Crescent Beach are approximately 2-2.5m geodetic (see Table 6 earlier in this report), or approximately 0.8-1.3m below the current FCL requirement of 3.3m for this floodplain area\(^83\). The older properties that might be expected to redevelop in the coming years are also concentrated along the frontage areas in Crescent Beach, which will be most impacted should the City raise DCEs. Given all these factors, the City might consider modifying or even discontinuing the current DVP process that regulates FCLs for new development in Crescent Beach. The City could stop granting DVPs to vary FCLs below the existing 3.3m minimum, and work to develop a long-term strategy to gradually increase FCLs to meet current Provincial guidelines. This would necessitate extensive public engagement and would be combined with a long-term flood protection strategy for the area, that might include raising

\(^{83}\) Based on pre-2011 FCL calculations based on the 200-year flood level plus 0.6m freeboard (from 1990s Provincial floodplain mapping), and not updated FCL design standards from the 2011 Provincial Guidelines
DCEs in combination with FCLs. Innovative urban design strategies and lessons learned could be drawn from other neighbourhoods and jurisdictions where FCLs have been increased over time to meet Provincial standards, such as Bridgeview along the Fraser River or the City of North Vancouver.4

4.3 Harmonize and update City FCL policy

This recommendation partially includes the former in which Crescent Beach FCL requirements would be brought in line with current Provincial requirements, with consideration given for a long-term SLR adaptation strategy that may include a combination of increasing FCLs and DCEs to meet increasing Provincial design standards. Part 8 “Floodproofing” of the current Zoning Bylaw No. 12000 has not been updated since the previous Zoning Bylaw No. 5942 from 1979, and includes specific FCL elevations for Bridgeview and South Westminster which have not been used by the City since the most recent Provincial floodplain mapping in the 1990s (Figure 42). This raises liability concerns in the case of future flood damage, and the Zoning Bylaw could be updated to reflect current FCL being enforced by the City or the specific FCL elevations in this section simply removed. The Zoning Bylaw could also be promptly updated if the current FCLs along the Fraser River are increased based on forthcoming river hydraulics modelling by the Province. Finally, there exist discrepancies and misunderstandings between City staff and departments as to floodproofing requirements and standards, which might be addressed as part of an internal stakeholder engagement strategy around SLR adaptation (as recommended in conjunction with Goal 1 in this report). For example, the author was given two different maps of FCL requirements for the Bridgeview area by two different staff members in the same City department (one outdated and one current map). Simple adjustments such as communicating when FCL requirements increase to staff and saving appropriately updated documents in centralized folders are easily addressed and can increase awareness of the changing nature of flood protection standards and SLR adaptation in general.

<table>
<thead>
<tr>
<th>Bridgeview Floodplain Area</th>
<th>Minimum Elevation (G.S.C.)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>2.75 metres [9 ft.]</td>
</tr>
<tr>
<td>B</td>
<td>2.75 metres [9 ft.]</td>
</tr>
<tr>
<td>C</td>
<td>4.60 metres [15 ft.]</td>
</tr>
<tr>
<td>D</td>
<td>4.70 metres [15.4 ft.]</td>
</tr>
<tr>
<td>E</td>
<td>4.66 metres [15.3 ft.]</td>
</tr>
</tbody>
</table>

* Where G.S.C. means Geodetic Survey of Canada datum

Figure 42. Outdated FCL requirements in the Zoning Bylaw, which have not been used by the City’s Building Division since the 1990s (source: Zoning Bylaw 12000, Part 8.3, 1993)

4 The City of North Vancouver was the first Metro Vancouver municipality to officially require FCL increases by 1m following the 2011 Provincial Guidelines release by amending their existing “Sewerage and Drainage Utility Bylaw, No. 6746, 1995” to include a 4.5m FCL minimum in June 2013

5 Community Planning was in the process of updating the Floodproofing section of the Zoning Bylaw accordingly as this internship was finishing in June 2014
4. Appendices

Appendix A. Current 3.3m FCL elevations for Crescent Beach (200 year flood level + 0.6m freeboard allowance) (source: Building Division, City of Surrey)

Appendix B. Historic FCL minimum elevation for Bridgeview, 2.75-4.6m, 1970s-1990s (source: Building Division, City of Surrey)
Appendix C. Current FCL minimum elevations for Bridgeview, 4.7-4.8m (source: Building Division, City of Surrey)
Appendix D. SeaLink’d Community Questions

Thank you for participating in this study, your contribution is important to us. Please do your best to answer each question below, and feel free to expand on your answers with additional comments. Please let me know if you have any questions or would like clarification.

Community: _____________________________ Position: _____________________________

1) Are municipal financial resources dedicated to risk reduction and/or adaptation in relation to coastal and riverine flood hazards?
   a) Yes
   b) No

2) Is there an individual who could be considered an identifiable leader for municipal efforts on risk reduction and/or adaptation in relation to coastal and riverine flood hazards?
   a) Yes, an elected official
   b) Yes, a municipal staff person
   c) Yes, other: ____________________________
   d) No

3) How many municipal staff positions are dedicated primarily to risk reduction and/or adaptation in relation to coastal and riverine flood hazards? (Can be fractional, e.g. 0.5 position)
   __________________

4) How many years has the staff person who is leading municipal efforts on risk reduction and/or adaptation been working on this topic in their current job?
   _______________

5) In which municipal department(s) is responsibility located for risk reduction and/or adaptation to coastal and riverine flood hazards? (Please check all that apply)
   a) Engineering
   b) Planning
   c) Emergency Management
d) Other(s) ____________________________________________
e) Not sure

6) Has public participation been incorporated in planning for risk reduction and/or adaptation to coastal and riverine flood hazards?

   a) Yes
   b) Not yet but in progress
   c) No

If yes, what form has public participation taken? (Please check all that apply)

   a) Information (e.g., fact sheets, websites and open houses)
   b) Consultation (e.g., focus groups, surveys, public meetings)
   c) Involvement (e.g., workshops, polling)
   d) Collaboration (e.g., steering and action committees, participatory decision making)
   e) Direct decision making (e.g., citizen juries and ballots)

7) What municipal policies or regulations related to coastal and riverine flood hazards have been adopted in the last five years? Please list them (e.g. updated Flood Construction Levels, climate change adaptation strategy, flood hazard development permit areas, etc.)

________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________

Please list any municipal initiatives related to coastal and riverine flood hazards that are in progress:

________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________

8) Has the municipality conducted an assessment of current flood risk?

   a) Yes (Year of most recent assessment: ________________)
   b) In progress
   c) No
9) Has the municipality conducted an assessment of future flood risk that incorporates climate change information?
   a) Yes
   b) In progress
   c) No

10) Does municipal policy currently comply with provincial guidance on planning for coastal flood hazards? (e.g., 2011 Guidelines for Management of Coastal Flood Hazard Land Use)
   a) Yes
   b) No

11) What level of consideration is currently being given to the following strategies for dealing with anticipated sea-level rise and associated coastal flooding hazards?
    i. Protect (e.g., dikes, seawalls, groynes)
       a) No consideration
       b) Discussion
       c) Serious consideration
       d) Implementation
    ii. Accommodate (e.g., retrofit building, changing liability)
        a) No consideration
        b) Discussion
        c) Serious consideration
        d) Implementation
    iii. Retreat (e.g., relocate buildings and infrastructure to areas of lesser risk)
         a) No consideration
         b) Discussion
         c) Serious consideration
         d) Implementation
    iv. Avoid (e.g., no development in areas of future high risk)
        a) No consideration
        b) Discussion
        c) Serious consideration
        d) Implementation

12) Has your community experienced a local disaster caused by any type of natural hazard?
a) Yes (Year and type of most recent event: ___________________)  

b) No  

c) Do not know

13) Has your municipality completed a Hazard, Risk and Vulnerability Analysis (HRVA)?

a) Yes  

b) In progress  

14) Does your municipality have digital coastal elevation data?

a) Yes  

b) No  

If yes, and it is not available online, would you be willing to send us a copy of it?

a) Yes  

b) No  

If yes, would you be willing to share it with us?

a) Yes  

b) No  

Thank you for participating in this study!
5. Works Cited


Centre for Advanced Landscape Planning, UBC. (2012). *Delta-RAC Sea Level Rise Adaptation Visioning Study*.


City of Surrey. (2013). *Climate Adaptation Strategy*. 
City of Surrey. (2013). Draft Official Community Plan, By-law No. 18020.


Staff Interview, C. o. (2014, May). City of Surrey.


