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CORPORATE REPORT

NO: COUNCIL DATE:

REGULAR COUNCIL

TO: **Mayor & Council** DATE: **July 17, 2019**

FROM: **Acting General Manager, Engineering** FILE: **4816-706**
XC: **5225-23**

SUBJECT: **Surrey Coastal Flood Adaptation Strategy - Draft Strategy Document**

RECOMMENDATION

The Engineering Department recommends that Council:

1. Receive for information the draft Surrey Coastal Flood Adaptation Strategy ("CFAS") Strategy Document, which is described in this report and attached as Appendix "I"; and

2. Authorize staff to proceed to CFAS Phase 5, *Reporting Back*, as generally described in this report, to complete the CFAS.

INTENT

This report presents the draft CFAS Strategy Document and seeks authorization to proceed to CFAS Phase 5, *Reporting Back,* to complete the CFAS.

BACKGROUND

To help prepare Surrey for a changing climate and help Surrey's coastal communities become more resilient, the City of Surrey initiated a comprehensive process to develop CFAS. As one of the first programs of its kind in Canada, this multi-year undertaking has identified the current and potential impacts of climate change on Surrey's large coastal floodplain area and developed a long-term strategy to reduce climate change-driven coastal flooding risks, now and into the future.

Launched in 2016, CFAS blended a value-based, participatory planning approach with an innovative structured decision-making component, and deep, robust technical analysis to develop a range of strategic actions to help coastal communities in the CFAS Study Area and its three distinct Planning Areas (Mud Bay, Crescent Beach, Semiahmoo Bay) become more resilient to the challenges. The overarching goal of CFAS has been to develop a broadly supported strategy to reduce coastal flood risks in Surrey.

CFAS has followed a participatory planning process involving a five-phase approach to developing a strategy to address current flood hazards and proactively plan for long-term flood protection needs. Figure 1 illustrates the CFAS five phases. This report marks the completion of Phase 4, *How will we do it?* and the initiation of Phase 5, *Reporting Back.*

Figure 1. Phases of CFAS

At its Regular Meeting on February 6, 2019, Council received Corporate Report No. R021; 2019, a copy of which is attached to this report as Appendix "II". The purpose of that report was to update Council on the progress made in 2018 in developing CFAS and the status of the City's application to the Federal government's Disaster Mitigation and Adaptation Fund ("DMAF").

Corporate Report No. R021; 2019 also outlined the extensive consultation and engagement conducted to short-list preferred options for long-term flood management. Since that time, the City has been successful in obtaining its largest Federal funding grant in the amount of $76.6 million. The details of this award are outlined in a separate Corporate Report to also be presented at the July 22, 2019 Regular Council Meeting.

DISCUSSION

As the actions required to adapt to coastal flooding will impact a range of sectors, stakeholders and partners throughout Surrey, staff have undertaken significant engagement efforts over the past three years. The information and feedback obtained from the engagement has been linked and integrated into the project's overarching, participatory decision-making process.

This report summarizes the CFAS Draft Strategy Document, included as Appendix "I". This Strategy Document is organized through the Values, Principles, and Objectives as they relate to flood management and the actions to achieve the overarching goal of CFAS depicted in Figure 2 as follows:

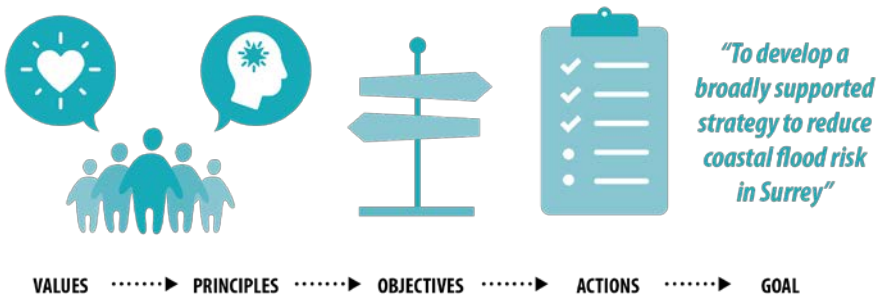

Figure 2. CFAS – Strategy Organization

Flood Management Values

The Strategy Document outlines seven Flood Management Values that were identified through the CFAS public and stakeholder engagement and a measure was established for each Flood Management Value, as listed below.

	Value	**Measure**
1	Residents	Minimize people displaced
2	Culture	Maximize opportunities for traditional practices
3	Agriculture	Reduce permanent loss of agricultural land
4	Environment	Minimize impacts to wetland habitats and riparian areas
5	Infrastructure	Minimize vulnerabilities
6	Economy	Minimize loss of local business
7	Recreation	Maximize recreational opportunities

CFAS Planning and Design Principles

Drawing upon the above Flood Management Values, CFAS Planning and Design Principles were established to identify how CFAS Actions should be planned, designed and implemented over time. The CFAS Planning and Design Principles are:

1. Plan for multiple values;
2. Plan for adaptability;
3. Design for/with nature;
4. Design for resilience;
5. Plan for collaboration and partnership; and
6. Plan for food security.

CFAS Objectives

The flood management objectives for CFAS are summarized through eight objectives listed below:

1. Improve resilience of existing infrastructure;
2. Ensure new infrastructure is resilient and adaptive;
3. Update regulatory controls to improve resiliency;
4. Ensure that flood management infrastructure and programs steward and enhance ecosystems and natural areas where practical and possible;
5. Coordinate with, and contribute to, regional flood management strategies;
6. Improve emergency response program for extreme flood events;
7. Improve coastal flood hazard awareness, education, and communication; and
8. Improve and enhance monitoring and evaluation to keep CFAS up to date.

CFAS Actions

The CFAS Strategy Document sets out decade-by-decade actions to prepare and adapt for sea level rise. The timing of actions is dependent on the rate of future sea level rise and, for the purpose of planning, the Provincial Sea Level Rise Curve has been used based on 1.0 metre of global sea level rise occurring by year 2100 and a further 0.2 metres of local ground subsidence taking place. These timelines will need to be adjusted as new information becomes available, such as when the Provincial Sea Level Rise Curve is updated and based on local observations of sea level rise, storm intensity and frequency.

The CFAS Actions have been separated into two categories; first, area-wide actions that benefit the entire floodplain area. The area-wide actions address:

- Ongoing education, communications and advocacy indicatives;
- Detailed planning, studies and data collection;
- Regulatory controls, designs standards and guidelines; and
- Extreme flood management.

Second, the CFAS Strategy Document sets out area-specific actions that address area specific issues. The area-specific actions are provided for each of the three Planning Areas, being Mud Bay, Crescent Beach and Semiahmoo Bay. Due to the large size of the Mud Bay Planning Area, it was further separated into seven sub-areas, being Serpentine North, Inter River East, Inter River West, Nicomekl South, Colebrook, Mud Bay Foreshore, NicoWynd Area, Crescent Beach and Semiahmoo Bay Area. The nine areas and sub-areas are depicted in Appendix "III".

Strategic Directions

While the focus of the Strategy Document is in prioritizing the more tactical, shorter-term actions to be implemented over the next decade, there are other actions that may be implemented as conditions warrant over the longer-term, with a view towards year 2100. To develop these longer-term actions, Strategic Directions were explored for each of the three Planning Areas. Low or no-regret projects are defined as relatively low-cost actions that provide relatively large benefits under predicted future climates that contribute to adaptation, while providing other social, economic and environmental benefits, including climate change mitigation benefits.

The longer-term Strategic Directions are based on an 80-year timeframe (i.e., to 2100) and represent the long-term outlook for flood adaptation for the three CFAS Planning Areas. Developed with input from project partners and stakeholders, the Strategic Directions also included considerable technical analysis by the City of Surrey's Engineering Department, project consultants, and supplemented with additional review provided through a unique research component involving UBC and Dutch flood management experts, landscape architects, and engineers. This iterative process included extensive public and stakeholder engagement to identify the Strategic Directions as part of CFAS Phases 2 and 3, *What Can We Do* and *What is Acceptable?* A comprehensive evaluation and summary of the 11 options are available in the CFAS Primer Part II – Options, attached to this report as Appendix "IV".

The Strategic Directions included in the Strategy Document are:

- Mud Bay – Coastal Works / Highway 99 Strategic Direction
  The longer-term strategic direction for the Mud Bay Planning Area is to gradually develop new infrastructure and management approaches along the Highway 99 corridor to prepare for increased frequency of flooding. This agricultural area is complex, as there are numerous infrastructure corridors of regional, provincial and national significance. A shared desire to minimize increases in long-term flood risk to critical infrastructure will be required for the Strategic Direction to be implemented. Further, extensive coordination between numerous agencies will be necessary.

- Crescent Beach – Expanded Edge Strategic Direction
  For the Crescent Beach Planning Area, the longer-term planning challenges are even greater. Shorter-term tactical actions include a series of smaller-scale drainage improvements and regulatory changes (e.g., a higher flood construction level) until such point that sea level rise (observed increase and rate of rise) triggers an "expanded edge" approach. This approach could build up and extend the shoreline towards Boundary/Mud Bay and include additional drainage and flood management works in the Crescent Beach community. Given the technical complexity, archaeological significance and considerable cost considerations, the Strategic Direction will require more detailed planning. External and interconnected issues, such as flood insurance, property values and public risk perception, are expected to influence triggers to implement longer-term actions impacting the primarily residential and recreational area.

- Semiahmoo Bay – Infrastructure Improvements and Land Raising Strategic Direction
  For the Semiahmoo Bay Planning Area, relatively smaller and less dramatic interventions are envisioned. While many of the actions will need to be linked with the development of land within the Semiahmoo First Nation, there are long-term, complicated coordinated works required along 8 Avenue/Marine Drive that will require careful coordination and collaboration with Semiahmoo First Nation, the Federal Government, the City of White Rock, and the City of Surrey.

Lower Mainland Flood Management Strategy

In parallel to the City's CFAS process and DMAF application, development of a Lower Mainland Flood Management Strategy ("LMFMS") is currently in Phase 2. The LMFMS is facilitated by the Fraser Basin Council ("FBC") and Phase 2 is anticipated to be completed in 2020, before implementation begins under Phase 3. A preview of Phase 2 work is scheduled to occur through a regional Flood Forum scheduled to occur in October 2019.

The process and results of developing the Surrey CFAS continues to influence the LMFMS and be complementary. The goal for the LMFMS is to secure consensus among partners about regional priorities, cost-sharing and funding commitments for flood management. FBC has been an active partner in the CFAS process and is keen to integrate and link CFAS with the LMFMS initiative.

Surrey Climate Action Strategy

The CFAS project advances three priority actions established in the 2013 Surrey Climate Adaptation Strategy ("CAS"), being:

1. Development of a Regional Flood Management Strategy in coordination with senior levels of government, other municipalities, and key stakeholders;

2. Detailed analysis on Surrey-specific climate impacts, including the timelines and extent of sea level rise and its related effects on flood construction levels and floodplain designations; and
3. Work with all levels of government to evaluate long-term flood management options in response to sea level rise impacts with considerations for agricultural viability.

The monitoring framework established for the CAS will be utilized to assist in monitoring the implementation of CFAS over time.

Costs and Jurisdiction

While municipalities may bear the greatest and most immediate impacts of a changing climate, it is critical that local governments not be forced to bear the full administrative and financial burden resulting from these changes.

CFAS has been successful in securing Federal grants through the Federation of Canadian Municipalities through their Municipalities for Climate Innovation Fund that has supported development of CFAs, and from Infrastructure Canada through DMAF to advance many of the priority actions. The City's DMAF Project is an example of how Surrey was able to leverage many sources of funding and collaborate with adjacent jurisdictions to reduce the impacts of a changing climate to Surrey residents.

There are many areas in which local governments have limited administrative jurisdiction. For example, other orders of government have sole regulatory authority over building codes and agricultural activities. The Provincial government is responsible for flood and coastal management and will need to play a critical leadership role in managing sea level rise and increased flooding risk. Clearly, collaboration between Surrey, neighbouring municipalities, utilities, and other orders of government will be critical to making a difference to adapt to climate change and is well underway now through the DMAF Project, with various implementation partners. Development of Memorandums of Understanding will assist in future collaboration related to reducing coastal flood risk and will position the City for securing future investment.

A changing climate will have impacts on industries and infrastructure of regional, provincial and national significance, such as railways, highways and ports. While the costs of these impacts are anticipated to be significant, the benefit of proactively preparing through adaptation can reduce the costs significantly. In the case of the City's DMAF application, a benefit-to-cost ratio was calculated to be 126:1, demonstrating the value of proactive investment. Other orders of government have the responsibility to ensure that they plan and fund where necessary the planning and construction of infrastructure improvements necessary to protect industries and infrastructure of regional, provincial and national significance and was a key consideration in the Federal investment to date under DMAF.

The final CFAS Strategy Document will include very high-level cost categories for many actions. Some actions will require new funding and others will be completed with existing resources; some actions will require partnerships with academic institutions or non-profit organizations, and many will require funding from other orders of government.

Some of the actions and related costs will be further refined, for example, in City work plans such as in future editions of the Engineering Department's 10-year Servicing Plan. Monitoring is also an important component of CFAS to evaluate if additional resources are needed to adapt to sea level rise.

Final Reporting

If staff are authorized to proceed with CFAS Phase 5, the final reporting process for the CFAS is proposed to consist of:

1. Forwarding the draft CFAS Strategy Document to all interested parties, stakeholders and partners who have been involved in developing CFAS to-date, with a request for comment to be received in September 2019;
2. Finalizing the CFAS Strategy Document based on feedback received, completing document appendices and completing graphic design and layout of the document;
3. Developing an overview document, CFAS Primer Part III, Preparing for Sea Level Rise and Coastal Flooding in Surrey. This completes the series of CFAS Primers prepared to support public engagement on the project;
4. Bringing forward final CFAS materials for Council's consideration in Fall 2019;
5. Developing a CFAS completion video and distributing the video through social media channels;
6. Hosting a final CFAS wrap-up event to thank participants for their involvement and to communicate the final CFAS Strategy Document in Fall 2019; and,
7. Completing final reporting to the Federation of Canadian Municipalities, Municipalities for Climate Innovation Program to obtain final grant payment anticipated in the amount of $46,600 in December 2019.

As several of the CFAS Actions have implications to neighbouring jurisdictions, critical infrastructure owners, and statutory regulators who have been engaged in the project, the CFAS Strategy Document, along with a copy of this Corporate Report, will be forwarded for final comment, along with a copy of this report, to:

- City of Delta;
- City of Langley;
- Township of Langley;
- City of White Rock;
- Agricultural Land Commission;
- Ministry of Agriculture;
- Ministry of Transportation and Infrastructure;
- Metro Vancouver;
- First Nations; and
- BNSF and Southern Railway.

Next Steps

Beyond the seven steps outlined for final reporting, the focus for the foreseeable future will be on implementing the Surrey DMAF Project.

In addition to the large-scale infrastructure works under DMAF, additional priority actions will be initiated as resources and capacity allow. Many of the subsequent actions will require ongoing public participation and engagement with key stakeholders and implementation partners. 86% of CFAS participants indicated, through CFAS surveys conducted at events, that they want to stay involved. Throughout the implementation of CFAS, an adaptive management cycle of plan, do and learn will be utilized, as summarized in the Figure 3.

Figure 3: CFAS Adaptive Management Cycle (modified from ESSA Technologies Ltd.)

Communications Strategy

Throughout the CFAS process, comprehensive engagement with the public, stakeholders and partners was a core project objective and integrated with a structured, value-based planning approach which meaningfully engaged participants in project decision-making. CFAS Phase 5 will include a final round of engagement to complete the CFAS process.

Beyond completion of the CFAS Strategy Document, ongoing communication and engagement will be required for many of the actions to adapt to sea level rise and reduce coastal flood risk in Surrey. Through the Surrey DMAF Project, which advances many priority actions developed through the CFAS Process, a DMAF Communication Strategy will be developed that is consistent with the CFAS. Information on DMAF will be made available at www.surrey.ca/CoastalTakingAction.

Ongoing communication regarding the long-term issues facing Surrey's coastal communities will continue as part of engaging the public, stakeholders and partners as part of sea level rise planning actions. Information and materials will continue to be made available at www.surrey.ca/Coastal.

SUSTAINABILITY CONSIDERATIONS

The process of developing the CFAS supports the objectives of the City's Sustainability Charter 2.0. In particular, the CFAS relate to the Sustainability Charter 2.0 themes of Infrastructure, Built Environment and Neighbourhoods, Ecosystems, and Public Safety. Specifically, the CFAS development and DMAF works support the following Desired Outcomes ("DO") and Strategic Directions ("SD"):

- Energy and Climate DO6: The City anticipates changing weather patterns and sea level rise as a result of climate change, and implements appropriate infrastructure, land use planning and emergency response solutions that will be resilient over the long term;

- Neighbourhoods and Urban Design SD8: Strengthen and promote community engagement and programming in public spaces;
- Green Infrastructure DO12: Surrey protects ecosystem services and manages natural assets in order to create resiliency to adapt and thrive in a changing climate; and
- Emergency Preparedness and Prevention SD6: Promote development types and locations that will be minimally impacted by natural disasters.

CONCLUSION

Based on the above, the Engineering Department recommends that Council receive the draft CFAS Strategy Document and authorize staff to proceed with CFAS Phase 5, *Reporting Back*, as generally described in this report.

Scott Neuman, P.Eng.
Acting General Manager, Engineering

YY/MO/cc

Appendix "I" – Draft CFAS Strategy Document
Appendix "II" - Corporate Report No. R021; 2019
Appendix "II" – CFAS Planning Areas
Appendix "IV" - CFAS Primer Part II - Options

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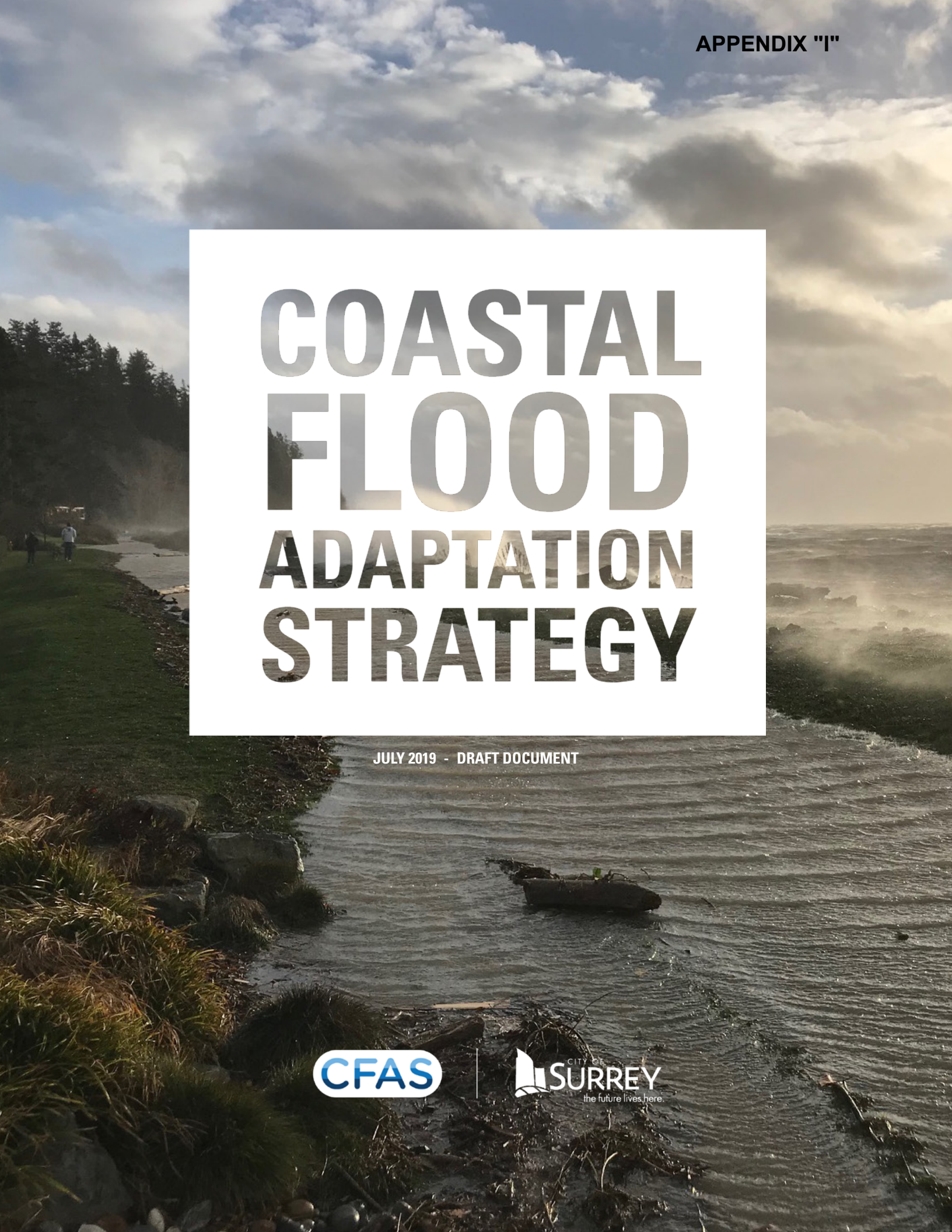
APPENDIX "I"



COASTAL FLOOD ADAPTATION STRATEGY

JULY 2019 - DRAFT DOCUMENT

CFAS

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ACKNOWLEDGEMENTS

The City of Surrey CFAS project team would like to thank the 2,000+ residents, business owners, and other stakeholders and partners who participated in the CFAS project. As a community-driven, participatory project, their time, contributions and unique perspectives helped us create the adaptation approaches and pathways this strategy outlines and supported the community conversations and learning that was a hallmark the initiative. Thank you.

This document features photos from a photo contest that was conducted as part of the CFAS project. The #SurreyCoastal photo contest asked people to share pictures of their favourite places and activities along Surrey's coastline and attracted 220+ submissions. Look for the camera icon that identifies these images. The document also includes quotes from some of the 2,000+ people who participated in the CFAS project that were collected through interviews, project worksheets, and event exit surveys. Thank you.

The City of Surrey would also like to acknowledge and thank the Federation of Canadian Municipalities and their Municipalities for Climate Innovation Program which provided financial support for this work.

Cover photo: Coastal flooding caused by a high wind event in December 2018 in Crescent Beach. Photo by Trevor Roberts, a Crescent Beach resident.

COASTAL FLOOD ADAPTATION STRATEGY

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1. EXECUTIVE SUMMARY

To help prepare Surrey for a changing climate and help our coastal communities become more resilient, the City of Surrey developed a Coastal Flood Adaptation Strategy (CFAS). One of the first programs of its kind in Canada, CFAS was a multi-year undertaking that identified the current and potential impacts of climate change on Surrey's large coastal floodplain area and developed a long-term strategy to reduce climate change-driven coastal flooding risks now and into the future.

Launched in 2016, CFAS blended a value-based, participatory planning approach with an innovative structured decision-making component, and deep, robust technical analysis to develop a range of strategic actions to help coastal communities in the CFAS Study Area and the its three distinct Planning Areas -- Mud Bay, Crescent Beach, Semiahmoo Bay -- become more resilient to the challenges ahead.

Comprehensive engagement with internal and external stakeholders and partners was a core project objective and integrated with a structured, value-based planning approach which meaningfully engaged participants in project decision-making. Over the three-year planning process, CFAS actively involved Semiahmoo First Nation, residents, farmers and the agricultural community, community and environmental organizations, business associations and group, provincial and federal agencies and Ministries, and neighbouring jurisdictions. Over 30 organizations, agencies, and governments participated in the project, while over 2,000 residents and other stakeholders attended workshops, open houses, focus groups, or participated through project surveys and other engagement events. Project communications generated major national media coverage and over a quarter million social media impressions.

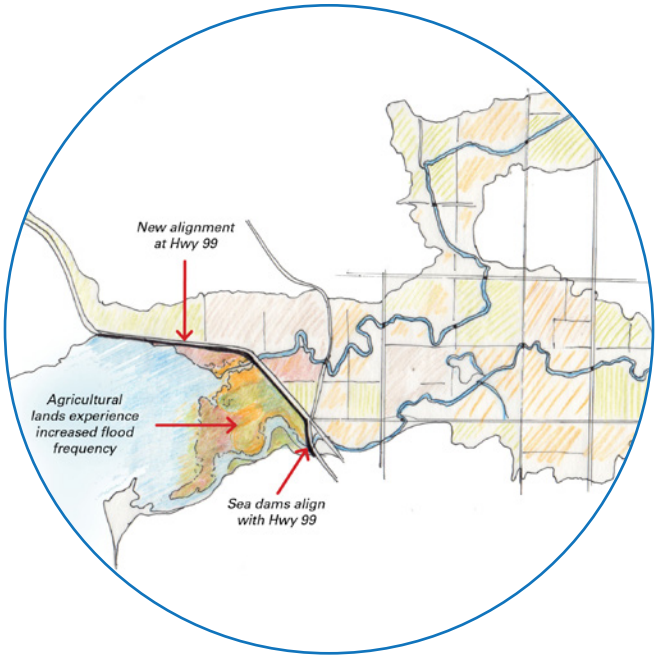
CFAS communications and engagement also greatly increased shared understanding of the significant challenges ahead for Surrey in the face of climate change-driven coastal flooding, with public appreciation and understanding of the issue noticeably shifting and expanding over the course of the project. Combined with the project's robust and sophisticated technical assessment and modelling component, the community-driven approach also helped Surrey secure the largest ($77.6 million) federal grant the City has ever received through the Disaster Mitigation Adaptation Fund (DMAF).

CFAS presents a total of 46 Actions. These are divided between CFAS Program and Policy Actions CFAS Planning Area-specific Actions. Program and Policy Actions apply across the larger CFAS Study Area and its three distinct Planning Areas (Mud Bay, Crescent Beach, Semiahmoo Bay). Area-specific Actions are primarily infrastructure-related projects to be implemented in specific areas in the CFAS Study Area. Collectively, these Actions are at the heart of CFAS. Individually and together, their implementation will involve numerous City departments, outside agencies, senior levels of government, and community-based organizations over the coming years and decades.

A little paddle in Mud Bay, by Matt Christensen

A number of Program and Policy Actions and Planning Area-specific Actions have been prioritized as more tactical, shorter-term to be implemented between 2020 to 2030. Other Actions will be implemented as conditions warrant over the longer-term, with a potential implementation period that stretches to 2080. The shorter-term CFAS Actions collectively represent so-call "low-regret" flood management projects, investments, and policies that will help address current concerns while laying the path for more complex and challenging Strategic Directions over the longer-term. Low-regret projects are defined as relatively low-cost Actions that provide relatively large benefits under predicted future climates that contribute to adaptation while other social, economic and environmental benefits, including climate change mitigation benefits.

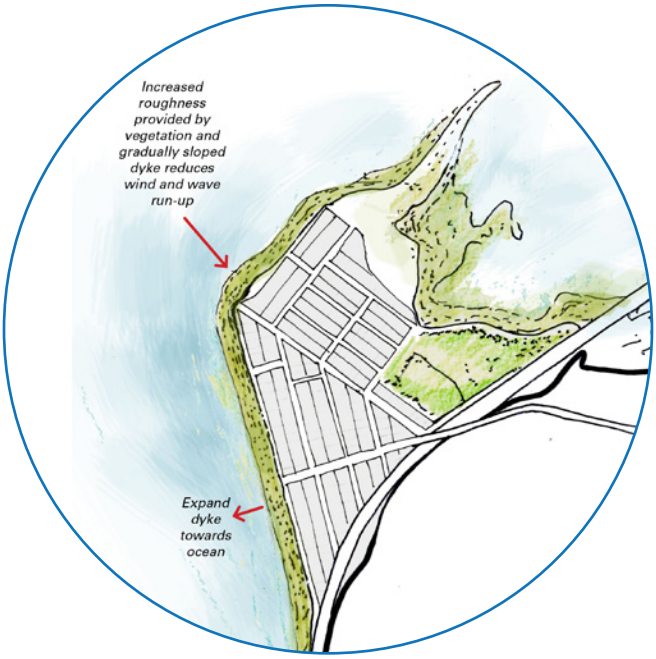
The longer-term Strategic Directions are based on an 80-year timeframe (i.e., to 2100) and represent the long-term outlook for flood adaptation for the three CFAS Planning Areas. Developed with input from project partners and stakeholders, the Strategic Directions also included considerable technical analysis by City of Surrey Engineering, project consultants, and supplemented with additional review provided through a unique research component involving UBC and Dutch flood management experts, landscape architects, and engineers (LINT Middelburg, Royal Haskoning DHV). The Strategic Directions are:

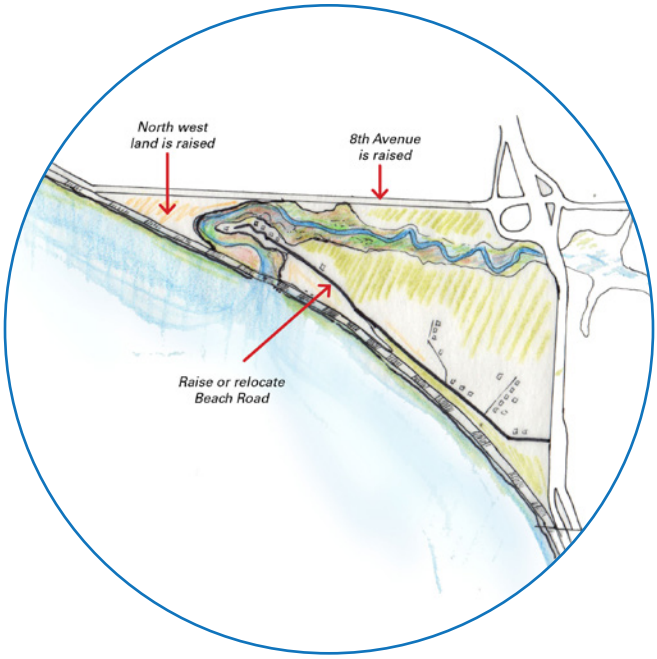


- ***Mud Bay – Coastal Works / Highway 99 Strategic Direction***
  The longer-term strategic direction for the Mud Bay Planning Area is to gradually develop new infrastructure and management approaches along the Highway 99 corridor to prepare for increased frequency of flooding. This agricultural area is complex, as there are numerous infrastructure corridors of regional, provincial and national significance. A shared desire to minimize increases in long term flood risk to critical infrastructure will be required for the Strategic Direction to be implemented. Further, extensive coordination between numerous agencies will be necessary.

"We have the opportunity here to really set a precedent for BC and the Pacific Coast on how we adapt to sea level rise and climate change and placing that value in the environment."

– CFAS participant





- ***Crescent Beach – Expanded Edge Strategic Direction***
  For Crescent Beach Planning Area, the longer-term planning challenges are even greater. Shorter-term tactical actions include a series of smaller-scale drainage improvements and regulatory changes (e.g., a higher flood construction level) until such point that sea level rise (observed increase and rate of rise) triggers an "expanded edge" approach. This approach could build up and extend the shoreline towards Boundary/Mud Bay and include additional drainage and flood management works in the Crescent Beach community. Given the technical complexity, archaeological significance and considerable cost considerations, the Strategic Direction will require more detailed planning. External and interconnected issues, such as flood insurance, property values and public risk perception are expected to influence triggers to implement longer-term actions impacting the primarily residential and recreational area.

- ***Semiahmoo Bay – Infrastructure Improvements and Land Raising Strategic Direction***
  For Semiahmoo Bay Planning Area, relatively smaller and less dramatic interventions are envisioned. While many of the actions will need to be linked with the development of land within the Semiahmoo First Nation, there are long term, complicated coordinated works required along 8th Ave\Marine Drive that will require careful coordination and collaboration with Semiahmoo First Nation, the Federal Government, the City of White Rock, and the City of Surrey.

Recognizing the scale and scope of CFAS Strategic Directions and the uncertainties surrounding climate change, and sea level rise in particular (i.e., it could happen faster, it could be more severe, it could happen more slowly), the shorter-term, tactical actions were designed to be flexible and adaptive. Taking an adaptive management approach, CFAS Action implementation will be closely monitored and, where required, adjusted based on both

observed sea level rise and the pace of sea level rise. The approach explicitly recognizes that planning in a dynamic context needs to be flexible and responsive to new drivers and considerations as they emerge. For CFAS, and in addition to observed sea-level rise, this includes:

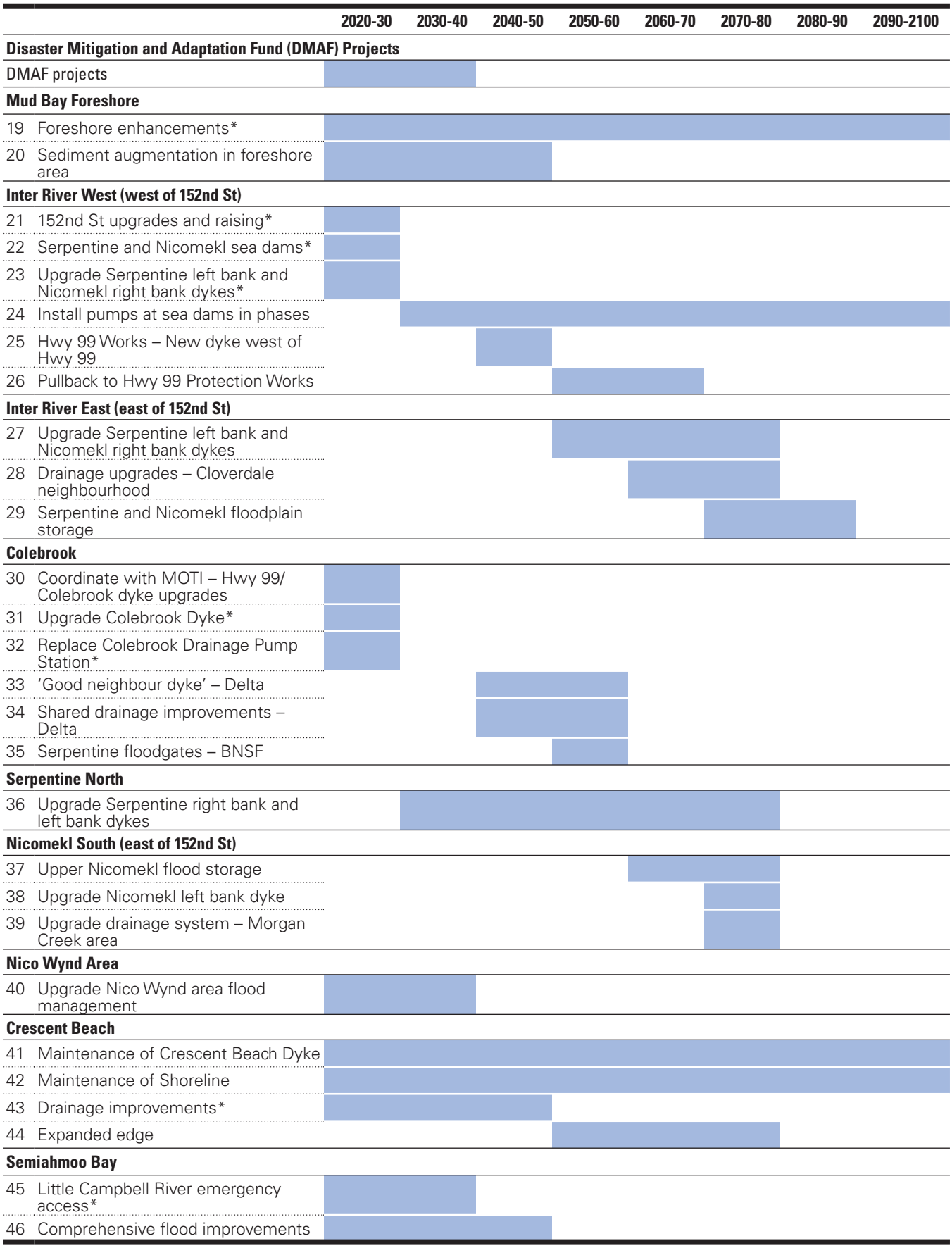
- ***New data -*** and new changes detected in the data
- ***New policies/directives -*** global, national, provincial, regional, local
- ***New participants and collaborations -*** new partners and stakeholders taking new actions
- ***New funding -*** and the requirements/ opportunities that come with them

Figures 1 and 2 summarize the CFAS Program and Policy Actions and Planning Area-specific Actions. The estimated implementation periods for all CFAS Actions based on sea levels continuing to rise at rate of approximately 10cm per decade, a rate of increase that is in accordance with Provincial Guidelines issued in 2010. Implementing most the Actions (Program and Policy Actions and Planning Area-specific Actions) will involve many of the same stakeholders and partners involved in developing the CFAS strategy itself.

FIGURE 1: *CFAS Program and Policy Actions*

		2020-30	2030-40	2040-50	2050-60	2060-70	2070-80	2080-90	2090-2100
Ongoing Education, Communications, and Advocacy Initiatives									
1	CFAS Steering Committee								
2	Internal Updates								
3	CFAS Advisory Group								
4	CFAS Website								
5	Advocacy Partners Workshop								
6	Communications and Media								
Detailing Planning, Studies, and Data Collection									
7	Update hazard bibliography								
8	Update coastal flood hazard assessment								
9	Detailed studies - Strategic Actions								
Regulatory Controls, Design Standards, and Guidelines									
10	Review Development Variance practices								
11	Support flood resilient design and construction								
12	Explore Sea Level Rise Planning Area								
13	Design Standards Guidebook								
Extreme Flood Management									
14	Hazard review								
15	Training and readiness								
16	Improve flood warning systems and communications								
17	Temporary protection measures assessment								
18	Build Back Better program								

FIGURE 2: *CFAS Planning Area-specific Actions*



** Indicates partial scope included in Surrey DMAF program*
Area-specific Actions under $5M capital cost are omitted for clarity

Clouds over Mud Bay Park, by simrandevgun

2. CLIMATE CHANGE AND COASTAL FLOODING IN SURREY

Surrey's coastal floodplain makes up about 20% of Surrey's entire land area. This large, low-lying area stretches from Boundary Bay and Mud Bay along the Nicomekl and Serpentine Rivers towards Cloverdale and Newton. The floodplain also includes the Little Campbell River/Semiahmoo Bay area near White Rock and Semiahmoo First Nation.

FIGURE 3: *Surrey's Coastal Floodplain*

As a natural floodplain, the area has regularly experienced some coastal flooding over the years from high tides and storm surges, and river floods which are typically caused by rain storms and snow melt but can also be influenced by high tides and storm surges.

The two principal causes of increased flooding in Surrey's coastal floodplain are (1) sea level rise and (2) increased magnitude and intensity of rain – both a result of climate change. The effects of sea level rise are anticipated to be greater than those of rainfall in Surrey's coastal floodplain.

- ***Sea Level Rise:*** Global sea level is rising. This is a result of increasing temperatures throughout the world that are melting glaciers and polar ice caps, and that are also increasing the average temperature of ocean waters

causing them to expand. The Province of British Columbia advises municipalities to plan for 1 metre of sea level rise over the next 80 years, and 2 metres by 2200. Figure 4 shows the expected sea level rise that a child born in 2020 will experience by the time they are 80. The lighter blue line represents forecasted sea level rise under a high emissions scenario (1.63 m by 2100). Not depicted, but of note in Surrey's coastal floodplain is ground subsidence, estimated at an additional 2 cm per decade.

- ***Increased Rainfall:*** With the changing climate, we can expect more extreme weather conditions. For example, in Surrey, winters are expected to have fewer wet days, but on the wet days the rainfall amounts will be much greater than in the past. This will result in increased flooding, as more runoff flows into the Nicomekl, Serpentine and Little Campbell Rivers during these storm events. The frequency and intensity of storm events with heavy precipitation are also expected to increase.

In the short-term, Surrey can expect more nuisance flooding and more frequent and severe flooding from storm surges, while over the longer-term we can expect even greater challenges. Projected impacts for Surrey's coastal area include higher sea levels, increased frequency and intensity of storms and storm surges (when water is pushed ashore by wind and waves), more erosion of the coastline, impacts on infrastructure, loss of beaches and coastal ecosystems, soil salinization, and groundwater pooling.

"It affects us all. We can't just sit by and watch what happens."

– CFAS participant

FIGURE 4: *A Lifetime of Sea Level Rise*

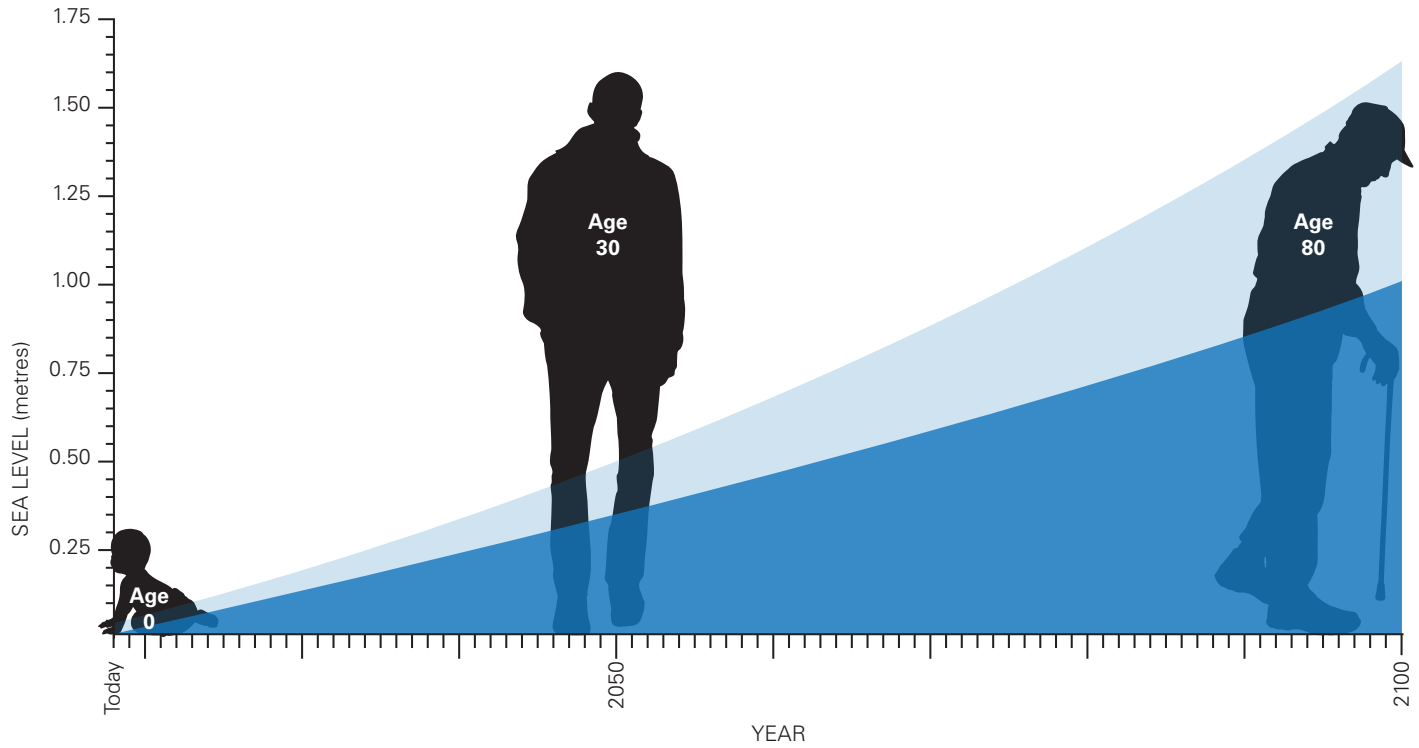


FIGURE 5: *Surrey Coastal Flood Hazard Impacts - Overview*

OCEAN FLOOD HAZARDS

TODAY

- *High tides*
- *Storm surges*

FUTURE

- *High tides*
- *Storm surges*
- *Sea level rise*

IMPACTS

- *Breach or overtopping of dykes*
- *Temporary inundation*
- *Coastal erosion*
- *Potential injuries or loss of life*
- *Damage to residential, commercial & other development*
- *Infrastructure & transportation damage & disruption*
- *Business disruptions*
- *Agricultural losses (livestock, crops)*
- *Habitat loss & impacts (with associated impacts to species)*
- *Cultural & social losses*
- *Longer duration of sea dam closures, which creates more water backing river, reduced fish passage, and water quality problems*

- *Long-term inundation*
- *Salination*
- *Coastal squeeze*
- *Same as TODAY but more frequent and more severe consequences*

RIVER FLOOD HAZARDS

TODAY

- *Long duration and intense rainfall or rain-on-snow event*

FUTURE

- *Increased and more intense rainfall and runoff*
- *Reduced sea dam capacity due to sea level rise*

IMPACTS

- *Activation of spillways and inundation of floodplain*
- *Sea dams inadequate for drainage*
- *Potential injuries*
- *Damage to residential and commercial development*
- *Business/transportation disruptions*
- *Some agricultural losses*
- *Some cultural and social losses*

- *Frequent activation of spillways and longer-term inundation of fields*
- *Floodboxes closed for longer periods (combined with higher runoff and longer dam closures)*
- *Limited land-use potential*
- *Frequent or permanent transportation disruptions*
- *Same as TODAY but more frequent and more severe consequences*

FIGURE 6: *A History of River and Coastal Flooding*

COASTAL AND RIVER FLOODING

1870 1880 1890 1900 1910 1920 1930 1940 1950 1960 1970 1980 199

Major Coastal and River Flood Events

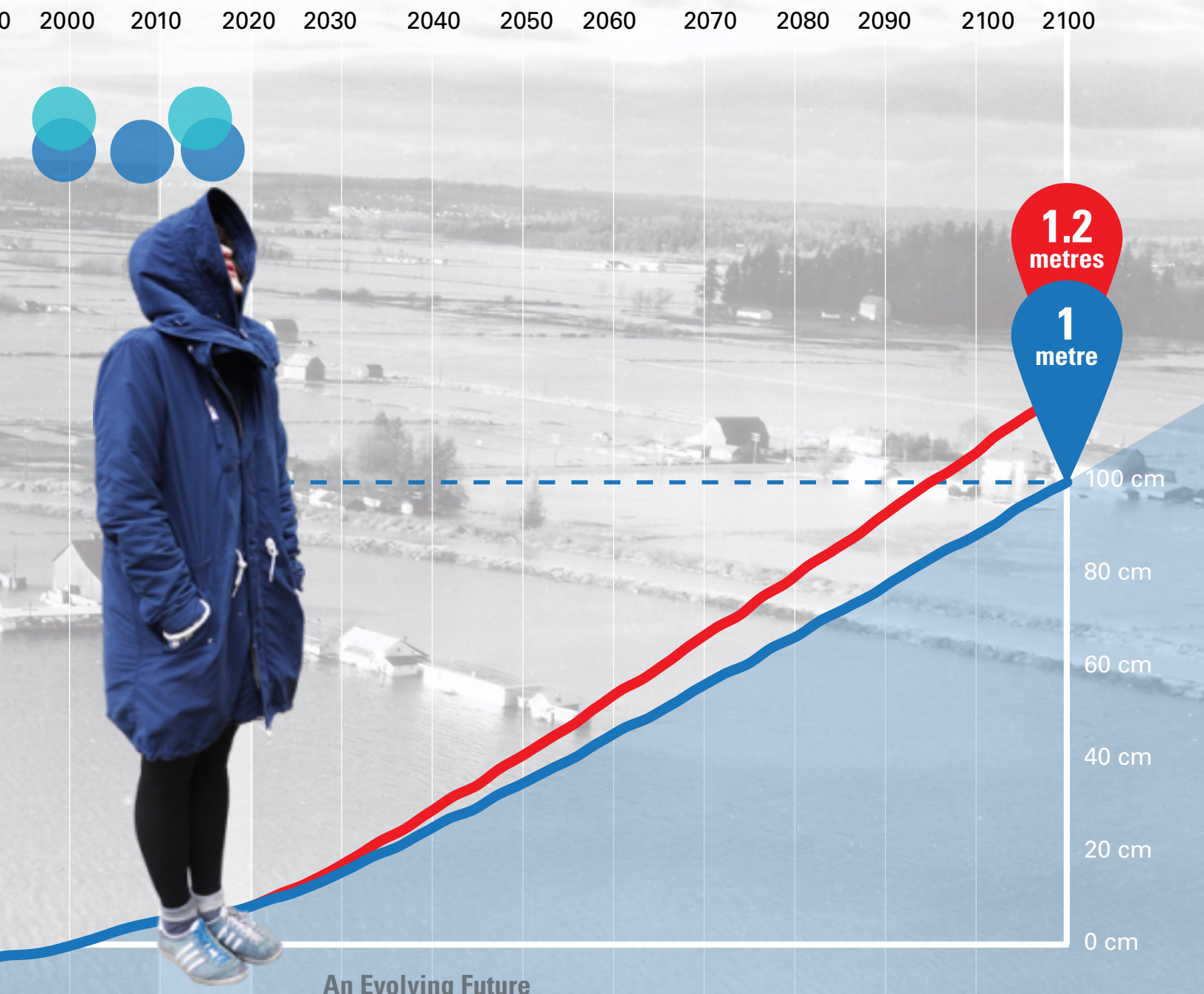
A Changing Shoreline

In 1890, dyking of Mud Bay begins. Shortly afterwards, dyking and damming of the Serpentine and Nicomekl Rivers begins.

By 1953, a timber sea wall at Crescent Beach is constructed.

Since then, residents of Surrey's Coastal Floodplain have relied on a system of dykes and sea dams to protect themselves from ocean and river flooding.

Photos courtesy Surrey Archives and Museum.



An Evolving Future

As our climate continues to change and sea levels continue to rise over the coming years, it is anticipated that the frequency and intensity of major coastal and river floods will also increase.

The Province has directed municipalities to plan for at least 1m sea level rise by 2100. In Surrey, and elsewhere in the Lower Mainland, most drainage systems are not designed for projected changes.

Most of the CFAS Study Area is subject to ground subsidence, which adds up to an additional 20 cm to sea level rise projections as indicated by the red line.

2.1 WHAT'S AT RISK?

The CFAS Planning Area is a large and diverse land area making up about 20% of Surrey's total land area. Some of the principal sectors and areas at risk from climate change are highlighted in this section. Figure 7 provides a summary snapshot of current risks in the Planning Area.

- ***Agriculture and Farming:*** The agriculture and farming sector plays a significant role in Surrey's economy. With over 1/3 of Surrey's land base in the Provincial Agricultural Land Reserve (A Provincial land use zone in which agriculture is recognized as the priority use), the sector generates about a quarter of total gross annual farm receipts in Metro Vancouver, or about $170 million in 2010. The sector also employs hundreds, including farm families and seasonal workers. The Mud Bay CFAS Planning Area includes a large and important part of Surrey's Agricultural sector.
- ***Community and Residential:*** While the CFAS Planning Area is largely agricultural, it is still home to several smaller residential developments and the larger, historic community of Crescent Beach. Beginning as a cottage community, Crescent Beach is one of Surrey's best known and most loved neighbourhoods. Home to about 1,200 people and 400 homes, the community is also home to several commercial businesses and restaurants, Alexandria Neighbourhood House, and the Crescent Beach Swim Club. The Little Campbell River area is home to Semiahmoo First Nation, whose principal reserve is on the mouth of the river.
- ***Environment and Recreation:*** The CFAS Planning Area is home to several popular Surrey and Metro Vancouver parks that include several kilometres of shoreline trails with incredible views of Boundary Bay and Mud Bay. Diverse wildlife habitats, including eelgrass meadows, mud flats, salt marsh, and old fields make it one of the best wildlife viewing areas in the region. It is also home to Provincially and Federally protected wildlife

FIGURE 7: *What's at Risk in Surrey's Coastal Floodplain – A Snapshot*

COMMUNITIES AND PEOPLE
- Many residential areas and neighbourhoods
- Semiahmoo First Nation
- 2,500+ residents
- Approximately 20% of Surrey's land area

PARKS AND ENVIRONMENT
- Destination regional and City parks
- Beaches and recreation areas
- Critical foreshore, coastal, and riparian areas

LOCAL AND REGIONAL ECONOMY
- Over $100M in annual farm gate revenue
- Over $1B in assessed property value
- Almost $25B annual truck and rail freight traffic

INFRASTRUCTURE
- Over 10km of Provincial Highways
- Over 200,000 vehicle trips a day
- Over 30km of railway (freight, passenger)

FOOD SECURITY
- ~60km^2 agricultural land
- ~10% of Metro Vancouver's farmland

Sandpipers on the beach, by Charlie Ng Photography

areas and the species at risk that live there. Thousands of migratory birds use Mud Bay and the larger CFAS Planning Area as a rest stop as they travel along the Pacific Flyway, which is a "highway in the sky" stretching from Alaska and the Canadian Arctic to Central and South America.

- ***Transportation and Infrastructure:*** Major infrastructure, including rail lines, highways, and utility corridors all pass through the CFAS Planning Area. In addition to existing infrastructure, the City of Surrey is currently in the middle of a $25 million comprehensive Stormwater Management Strategy for Crescent Beach to help prepare the community for increased coastal flood. Work includes a new pump station (Maple Pump Station), new storm sewers, and a plan to raise key roads.

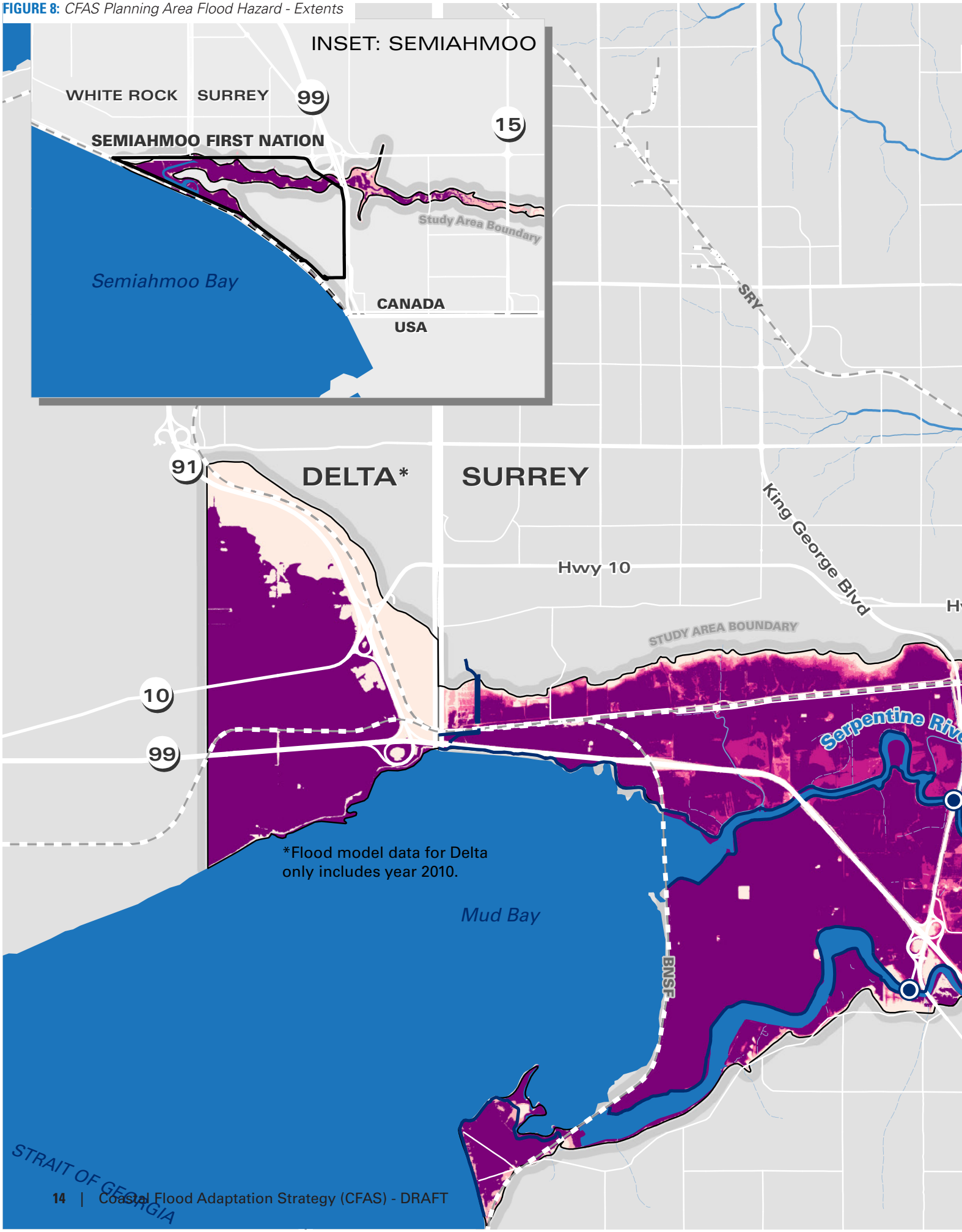
The changing climate and the increased flood hazards it brings means that the historic controls (e.g., dykes, pumps, drainage ditches) put in place by the City of Surrey to limit flood damages will be ineffective in limiting future flood damage as sea levels continue to rise. Today, Surrey maintains the largest dyking network in BC. Sea level rise is projected to significantly increase dyke vulnerability and expose low-lying infrastructure along the shoreline to flooding.

Figure 8 shows the *extent* of flooding that could be expected today and, in the future, if changes and upgrades are not made to the existing system and management approach.

Figure 9 shows flood hazard *depths* (over one metre) that could be expected today and, in the future, if no improvements or changes are made to the existing system. Flood depths of over one metre would flood the ground floor of most buildings and homes, lead to service and utility failures (e.g., electricity), necessitate the evacuation of residents, and could carry vehicles off roadways.

Figure 10 shows that the impacts of sea level rise are greatest closest to the ocean. By 2040, dyke infrastructure nearly 10km inland is expected to become vulnerable.

FIGURE 8: *CFAS Planning Area Flood Hazard - Extents*



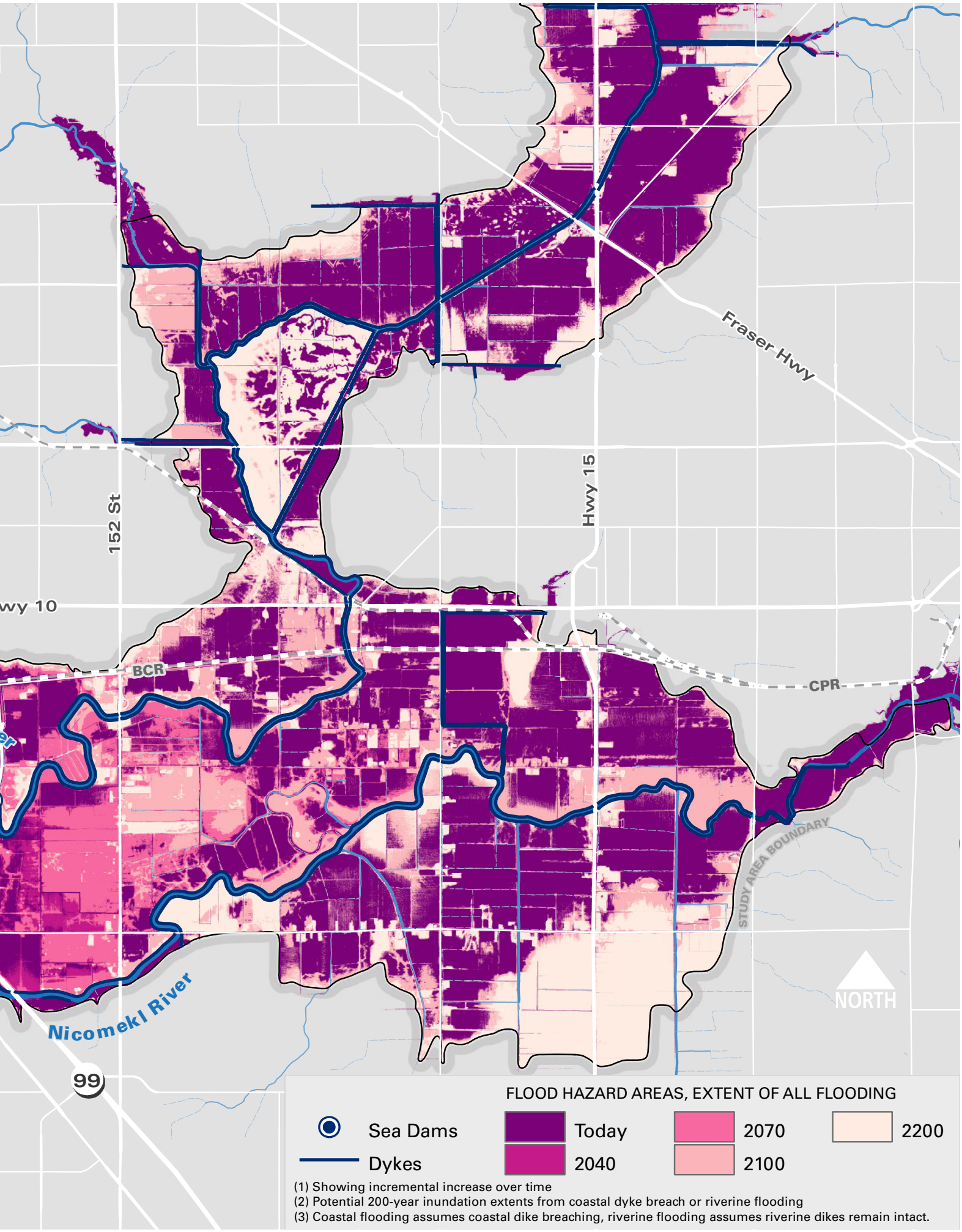
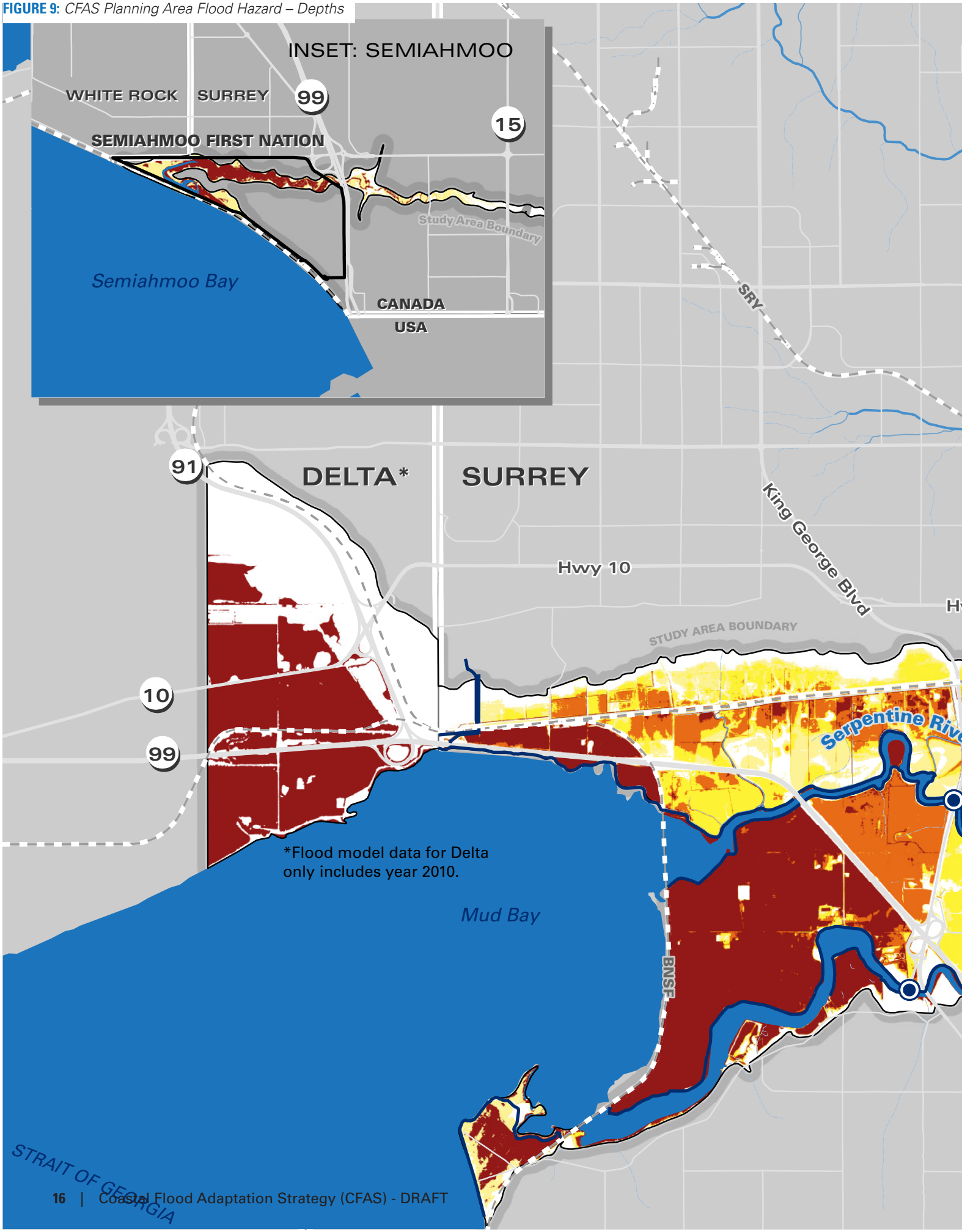

Fraser Hwy
Hwy 15
152 St
wy 10
BCR
CPR
STUDY AREA BOUNDARY
NORTH
Nicomekl River
99
FLOOD HAZARD AREAS, EXTENT OF ALL FLOODING
Sea Dams
Dykes
Today
2040
2070
2100
2200
(1) Showing incremental increase over time
(2) Potential 200-year inundation extents from coastal dyke breach or riverine flooding
(3) Coastal flooding assumes coastal dike breaching, riverine flooding assumes riverine dikes remain intact.

FIGURE 9: *CFAS Planning Area Flood Hazard – Depths*



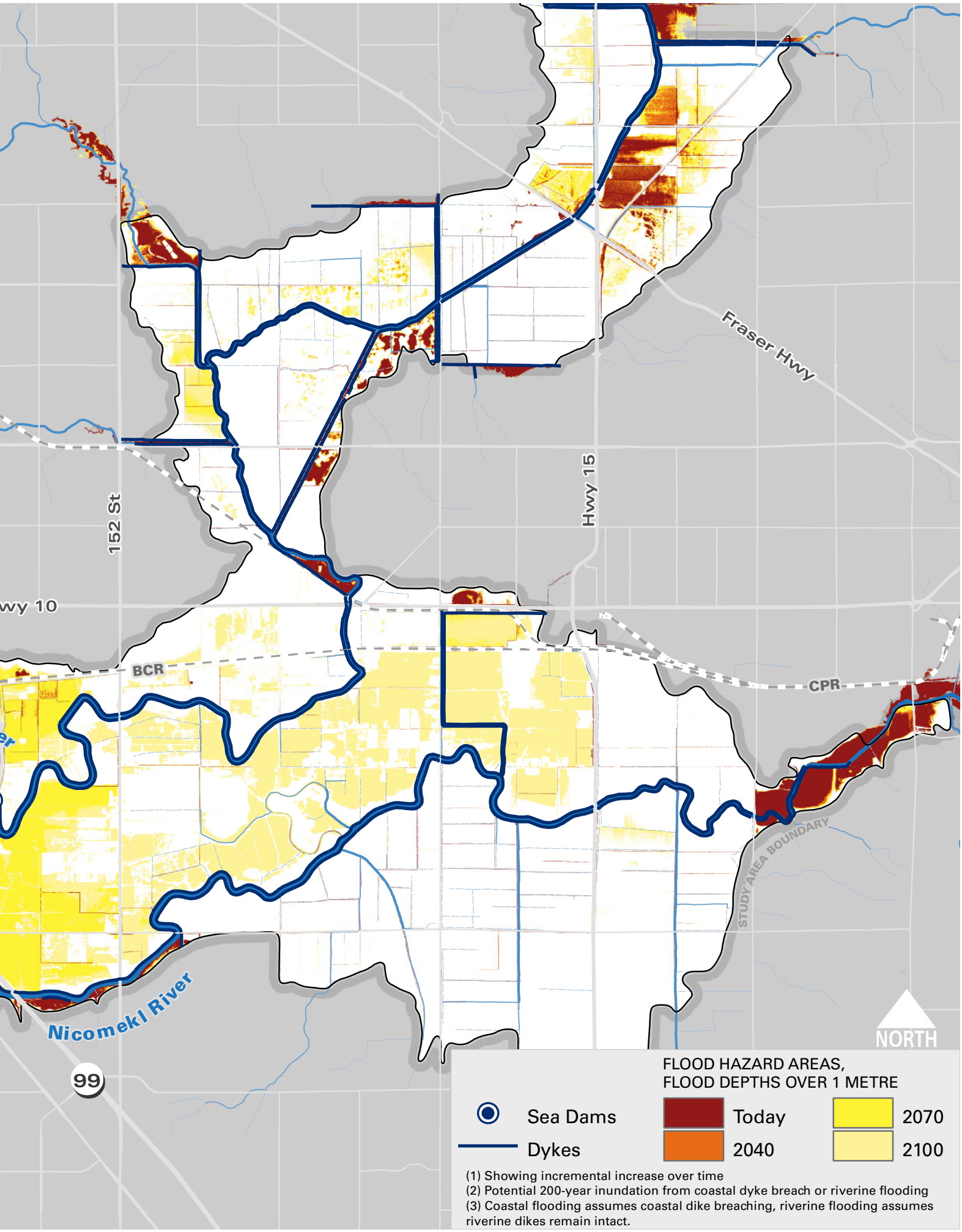
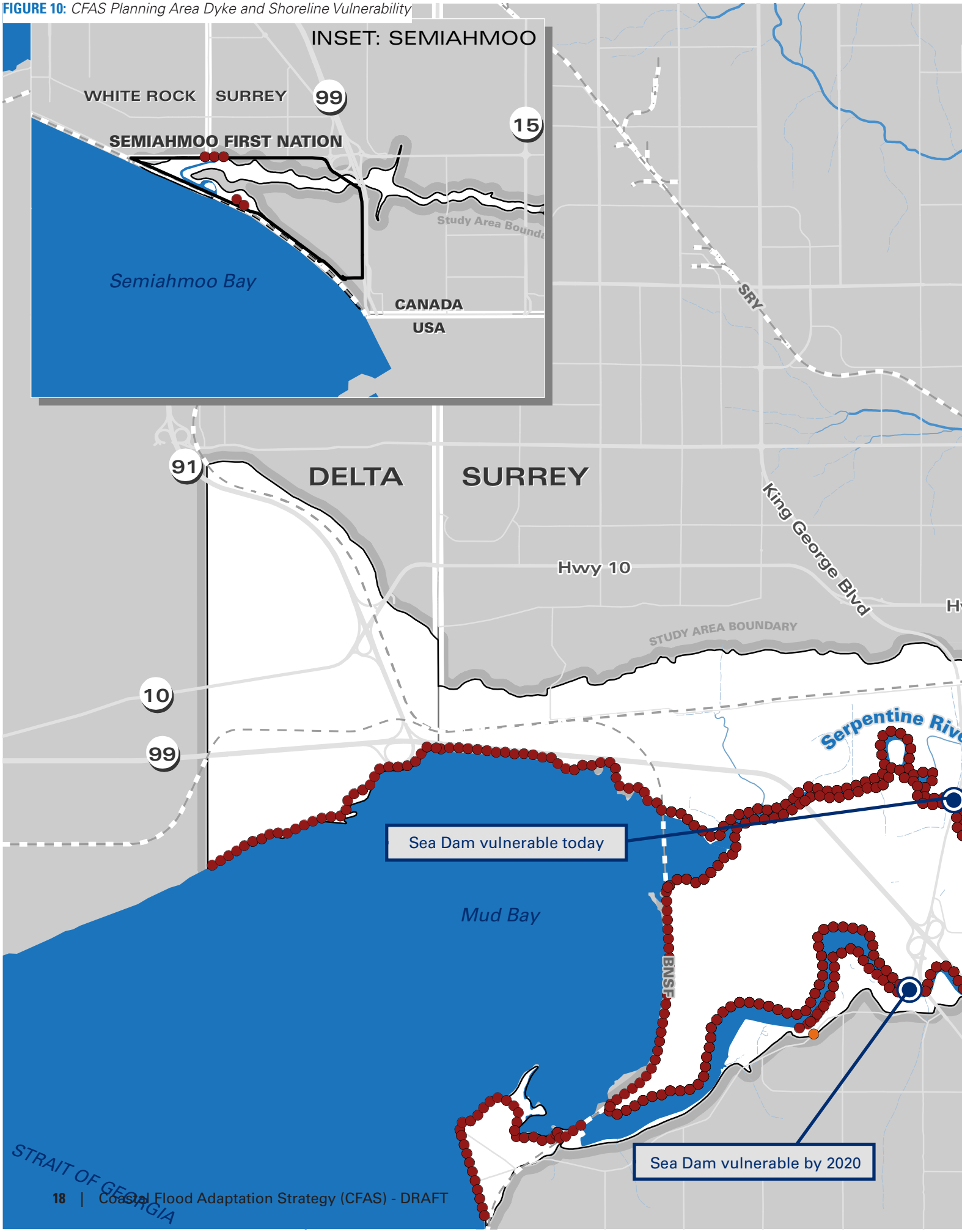
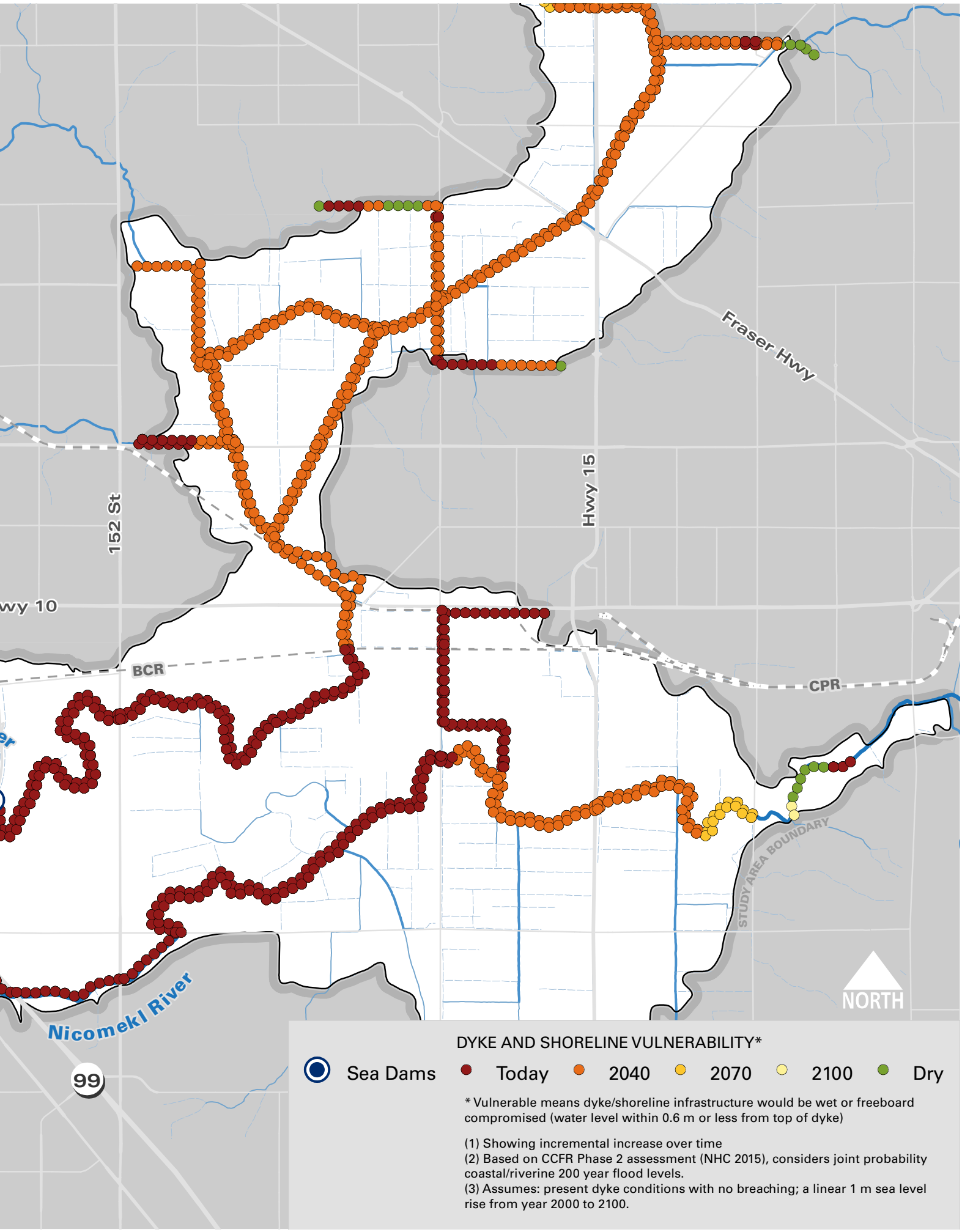

Fraser Hwy
Hwy 15
152 St
wy 10
BCR
CPR
STUDY AREA BOUNDARY
Nicomekl River
99
NORTH
FLOOD HAZARD AREAS,
FLOOD DEPTHS OVER 1 METRE
Sea Dams
Dykes
Today
2040
2070
2100
(1) Showing incremental increase over time
(2) Potential 200-year inundation from coastal dyke breach or riverine flooding
(3) Coastal flooding assumes coastal dike breaching, riverine flooding assumes riverine dikes remain intact.

FIGURE 10: *CFAS Planning Area Dyke and Shoreline Vulnerability*





DYKE AND SHORELINE VULNERABILITY*

Sea Dams · Today · 2040 · 2070 · 2100 · Dry

* Vulnerable means dyke/shoreline infrastructure would be wet or freeboard compromised (water level within 0.6 m or less from top of dyke)

(1) Showing incremental increase over time
(2) Based on CCFR Phase 2 assessment (NHC 2015), considers joint probability coastal/riverine 200 year flood levels.
(3) Assumes: present dyke conditions with no breaching; a linear 1 m sea level rise from year 2000 to 2100.

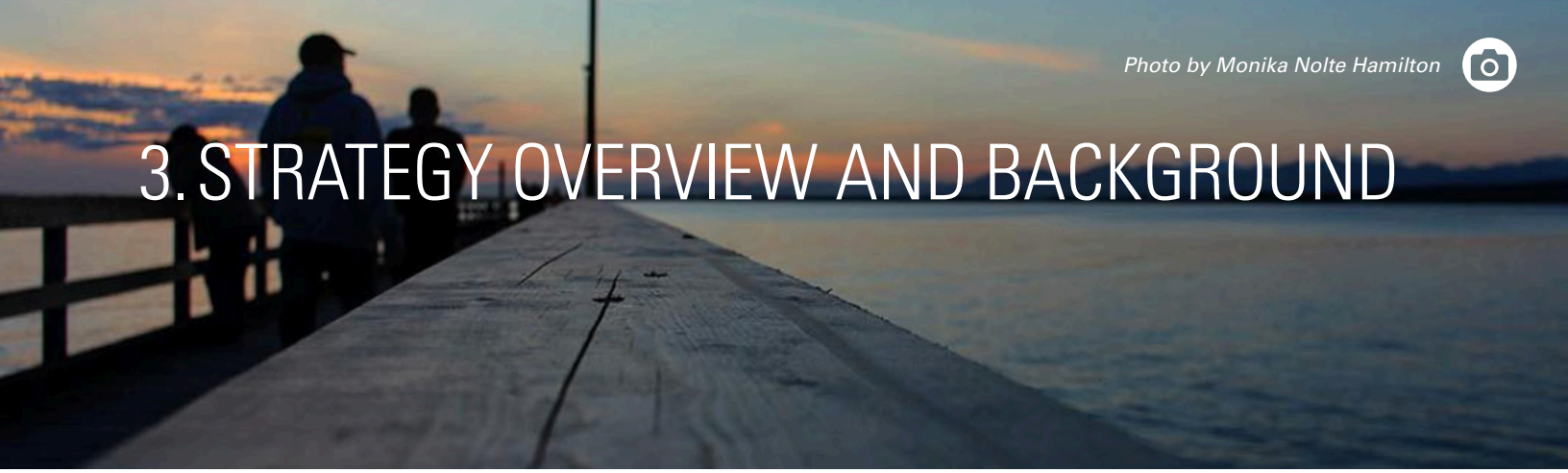


Photo by Monika Nolte Hamilton

3. STRATEGY OVERVIEW AND BACKGROUND

The City of Surrey developed the Coastal Flood Adaptation Strategy (CFAS) to help prepare for current coastal flooding challenges and to develop a more integrated and coordinated approach to take future action. The strategy outlines the potential future impacts of climate change on Surrey's coastline and the adaptation options available to address them over the short, medium, and longer-terms.

In February 2016, Surrey City Council approved-in-principle the development of CFAS. In developing the strategy, the City of Surrey's objectives were to:

- Establish a preferred approach for adapting to coastal flood hazards through time in which the risks from climate change impacts are minimized;
- Position the City to secure external funding to implement the recommended strategy;
- Strengthen the relationships between the City of Surrey and external stakeholders;
- Align Surrey's work with other regional flood management strategies being developed in the region (e.g., Fraser Basin Council's Lower Mainland Flood Management Strategy);
- Build the adaptive capacity of stakeholders and City staff to respond to the uncertainties inherent in climate change impacts over time; and
- Achieve public support for CFAS directions and short-term tactical actions.

As an initiative, CFAS is one component of Surrey's ongoing climate adaptation and mitigation work. The strategy sits under the City of Surrey's Sustainability Charter 2.0 and Climate Adaptation Strategy (CAS).

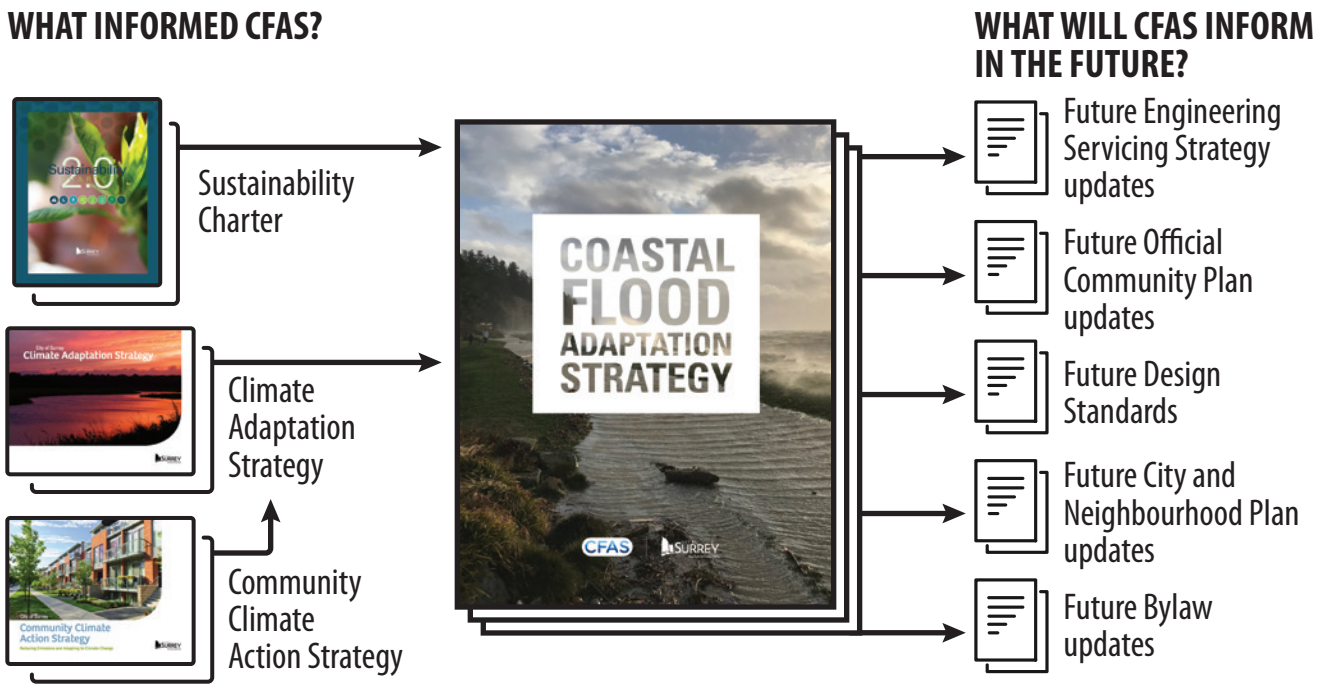
The Sustainability Charter 2.0 established an ambitious 40-year vision for sustainability in Surrey. First developed in 2008 and updated in 2016, the Sustainability Charter guides policy and decision-making to ensure the City always takes into account social, environmental and economic factors.

Aligned with other plans from across the City, the Sustainability Charter directly led to the development of Surrey's Community Climate Action Strategy and CAS under which CFAS was created.

Completed in 2013, CAS identifies how the City may be vulnerable to climate change impacts and proposes actions to mitigate the risks and costs of such impacts. It identified 91 actions of which 11 actions were distinguished as immediate priorities. Among these immediate priority actions were the following:

- ***FL-1.1*** Development of a Regional Flood Management Strategy in coordination with senior levels of government other municipalities, and key stakeholders
- ***FL-2.1*** Detailed analysis on Surrey-specific climate impacts, including the timelines and extent of sea level rise and its related effects on flood construction levels and floodplain designations

FIGURE 11: *CFAS High-level Strategic Alignment and Connections*



- ***AG-1.2*** Work with all levels of government to evaluate long-term flood management options in response to sea level rise impacts with considerations for agricultural viability

As part of implementing the above three actions, the City committed to developing this Coastal Flood Adaptation Strategy (CFAS).

CFAS was broken into five distinct phases as illustrated in Figure 12.

Phase 1: What matters most and who is affected? This phase reviewed flood hazard issues in general and began exploring what matters to stakeholders (i.e., their values and objectives). At this stage, the project team created scenarios (i.e., plausible outcomes for the future) that illustrated how climate change and sea level rise could impact the coastal flood hazard areas based on the Provincial Sea Level Rise curve. The scenarios were used to help elicit stakeholder values that are at risk and explore how these impacts could potentially be managed through a variety of general adaptation approaches.

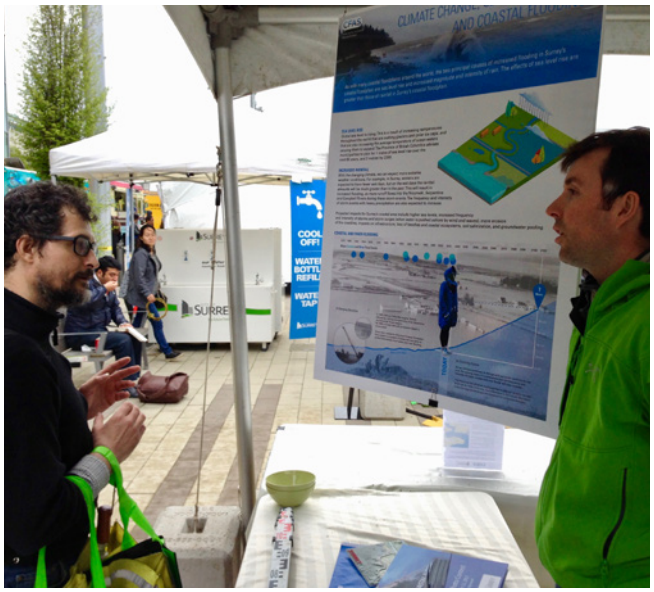
FIGURE 12: *CFAS Timeline*

Phase 2: What can we do?
In this phase of work, general adaptation approaches were further developed, modelled and tested, and relevant trade-offs were identified. This phase included a considerable technical component including detailed analysis and modelling. The technical analysis included input from project engineers and City of Surrey staff. Technical analysis was augmented and enriched through a partnership with University of British Columbia School of Architecture and Landscape Architecture and a unique research project which brought in Dutch flood management experts, landscape architects, and engineers (LINT Middelburg, Royal Haskoning DHV).

Phase 3: What is acceptable?
Stakeholder analysis and evaluation continued during this phase, as the project moved from developing adaptation approaches to evaluating them through a participatory, stakeholder-driven process. Supported by illustrations and visualizations, the option evaluation also included broad-based engagement with key stakeholders including regulators and a City-wide survey on short-listed flood adaptation approaches.

Phase 4: How will we do it?
With adaptation directions established for the three planning areas, this phase of work developed more detailed adaptation actions based on cost, funding, and partnership opportunities. This phase was extended to incorporate the federal Disaster Mitigation and Adaptation Funding (DMAF) opportunity (a 9-month process) that arose early in this project phase, leading to the development of a portfolio of more detailed, shovel-ready projects for implementation over the short-term (i.e., 2020 – 2030). Partnership opportunities were advanced as part of developing a DMAF application. This included Semiahmoo First Nation, City of Delta, Metro Vancouver and others.

Phase 5: Reporting back
This phase involved the final development of the CFAS document and an additional round of stakeholder and partner outreach and engagement.



3.2 CFAS STUDY AREA

The CFAS Study Area roughly overlaps Surrey's coastal floodplain and is principally made up of three distinct Planning Areas – Mud Bay, Crescent Beach, and Semiahmoo Bay. The CFAS Study Area lies entirely within the Serpentine River (146 km2) and Nicomekl River (181 km2) watersheds. Both these watersheds extend beyond Surrey's boundaries - while the Serpentine watershed includes parts of the Township of Langley and City of Delta, the Nicomekl watershed includes parts of the Township of Langley and the City of Langley.

The CFAS Study Areas is made up of three distinct Planning Areas – Mud Bay, Crescent Mud Bay, Semiahmoo Bay. Based on the findings of CFAS Phase 2 and Phase 3, it became evident that a wide diversity of adaptation measures would be required for different parts of the Mud Bay Planning Area depending on hydraulic characteristics and land-use. In the interest of efficient organization, the Mud Bay Planning Area was further divided into several distinct Sub-Planning Areas based on shared geographical or coastal flooding characteristics. The seven Mud Bay Sub-Planning areas are Inter River West, Inter River East, Colebrook, Serpentine North, Nicomekl South, the Nico Wynd Area, and the Mud Bay Foreshore. Figure 14 illustrates the CFAS Planning Areas and the Mud Bay Sub-Planning Areas.

FIGURE 13: *Serpentine and Nicomekl Rivers Watershed*

FIGURE 14: *CFAS Planning Areas and Sub-Planning Areas*

3.3 PLANNING APPROACH

Given the complexity of the issues the project addresses, the CFAS planning process was designed to be adaptive and flexible and accommodated new stakeholders and information (project learning) as it moved forward over the three-year planning process.

Project planning included a considerable technical analysis and modelling led by project engineers and supported by City of Surrey staff. Technical analysis was augmented and enriched through a partnership with University of British Columbia School of Architecture and Landscape Architecture and a unique research project which brought in Dutch flood management experts, landscape architects, and engineers (LINT Middelburg, Royal Haskoning DHV).

The decision process interwoven through the project phases was first outlined in a *Decision Support Framework* brief which outlined the use of two methodologies that helped set CFAS apart from conventional flood planning work.

- ***Structured Decision-Making (SDM):*** SDM is an approach for helping groups, stakeholders, technical experts and decision makers to think through complex problems that are layered with uncertainty, involve diverse stakeholders with competing values and preferences, and require a final decision that is embedded with difficult trade-offs. SDM is a rigorous deliberative decision-making process that provides insights about the decision by:
  - Focusing on the things people care about (values);
  - Systematizing what we know about the problem and solutions (facts);
  - Identifying whether any disagreements are about facts (i.e., uncertainty) or values;
  - Allowing for iterative and creative alternative generation; and
  - Allowing groups to transparently explore the trade-offs between choices so that an informed and defensible decision can be made.
- ***Impact scenario planning:*** Scenario planning is an approach for addressing uncertainties in a planning context. It is based around the construction of a small number of contrasting narratives (stories) about what could happen in the future. The goal is not to identify as closely as possible what will happen (i.e., a forecast), or what should be done (e.g., a policy recommendation), but to explore the wide possibilities of what the future can bring, and hence better understand the inherent uncertainty in the problem being addressed. The intent is to provide a mechanism for testing options, strategy, and behaviours under a range of credible future scenarios.

These two methodologies were used throughout the decision process. Scenarios were used to elicit public values and options for addressing coastal flood hazards under a set of different possible futures. The values were then used to develop objectives to evaluate how well flood management options performed across the scenarios.

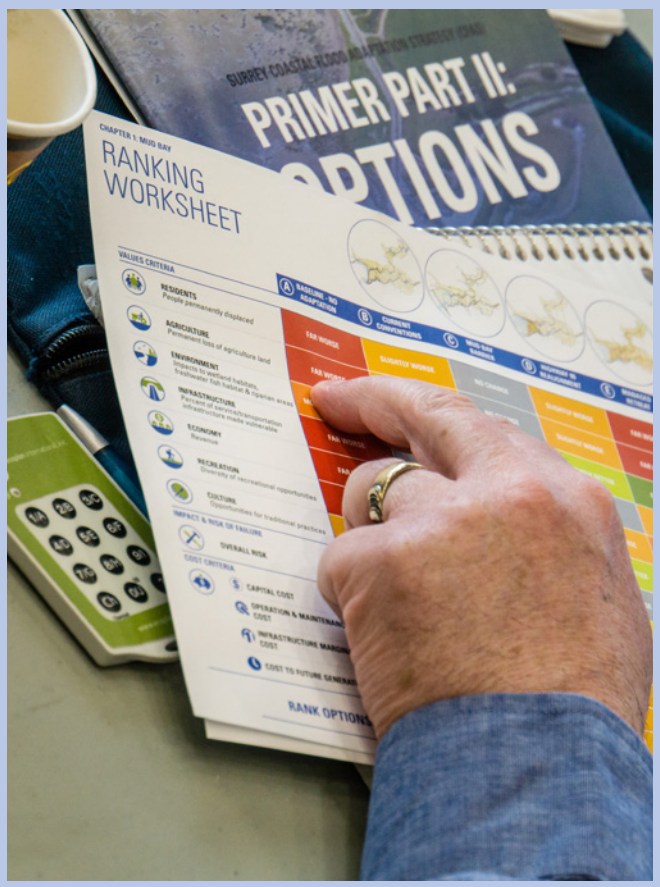
The purpose of utilizing these two methodologies was to provide a rigorous decision framework and common language to support dialogues, debate, and decision-making around the question: "What is the best strategy for adapting to coastal flooding today and into the future?"

> "We were part of the process and part of the decision-making, and that's participatory democracy in action."
>
> *– CFAS participant*

CFAS - A STRUCTURED, VALUES-BASED DECISION-MAKING APPROACH

In undertaking CFAS, the City of Surrey made a conscious decision to take a structured, values-based decision-making approach. The reason for this approach was to ensure that the project team understood what residents, stakeholders, and project partners' values are – what they care about –and how these values influence the development of adaptation approaches and priorities. Here are six reasons why Surrey adopted a values-based decision analysis approach for CFAS.

- ***Facts and values*** – The approach used both technical facts (e.g., cost, feasibility, risk) and community values (e.g., protect farm land, enhance environmental values, maintain public access) to help identify, screen, and prioritize strategy options.
- ***Multiple perspectives*** – The approach facilitated a broader understanding of the variety of perspectives that are important to consider when making the difficult decisions that climate change adaptation presents. This included the review and incorporation of different City plans and strategies.
- ***Holistic*** – By involving a wide range of participants, stakeholders, and the public, the approach was more inclusive and took into account non-material aspects of community wellbeing and quality of life.
- ***Local knowledge*** – The approach used multiple types of knowledge, expertise and qualitative information, alongside the more scientific, quantitative information from technical studies and assessments.
- ***Participatory*** – Acknowledging the different values that people held helped build common ground and enabled a better, shared understanding of present issues and the pressing climate change challenge. Surrey's approach to community planning explicitly recognizes that local stakeholders and residents will more likely support strategy options if they have been meaningfully engaged in the decision process and their local values have helped shape and refine plan options.



3.4 ENGAGEMENT

Comprehensive engagement with internal and external stakeholders and partners was a core project objective and integrated with a structured, value-based planning approach which meaningfully engaged participants in project decision-making. Over the three-year planning process, CFAS actively involved Semiahmoo First Nation, residents, farmers and the agricultural community, community and environmental organizations, business associations and group, provincial and federal agencies and Ministries, and neighbouring jurisdictions. Over 30 organizations, agencies, and governments participated in the project, while over 2,000 residents and other stakeholders attended workshops, open houses, focus groups, or participated through project surveys and other engagement events. Project communications generated major national media coverage and over a quarter million social media impressions.

CFAS communications and engagement also greatly increased shared understanding of the significant challenges ahead for Surrey in the face of climate change-driven coastal flooding, with public appreciation and understanding of the issue noticeably shifting and expanding over the course of the project. Participants were consistently asked a number of questions at CFAS engagement events (workshops, focus groups, open houses) to ensure that their needs were being addressed in the engagement process. The table below summarizes the overall response from all CFAS engagement events.

At the outset of the project three linked frameworks were produced, a Decision Support Framework, a Stakeholder Engagement Framework and an integrated Communications and Media Framework. The Decision Support Framework detailed CFAS's participatory, community values-based planning approach, methods, data needs, and decision points. It was closely integrated with a Stakeholder Engagement Framework, which guided the project team's work in gathering input and feedback for CFAS. The Media and Communications Framework laid out a process to inform the local community and stakeholders and support productive change management given the significant challenges posed by sea level rise.

FIGURE 16: *Integrated Engagement, Communications and Decision-making Frameworks*

FIGURE 15: *CFAS participant feedback*

QUESTION	RESPONSE
You understood the information that was presented	99% Agree
The logistics (location, time) of the Workshop were suitable	97% Agree
You felt your opinion was heard	96% Agree
You will like to continue to be involved in the CFAS planning process	86% Agree
The length of the workshop was just right:	85% Agree

The broad goals of the Stakeholder Engagement Framework were to:

- Ensure engagement was linked to, and integrated with the project's overarching, participatory, decision-making process and Decision Support Framework
- Ensure engagement was consistent with City of Surrey's guiding Consultation Principles.
- Ensure that a broad range of stakeholders were meaningfully engaged, and able to participate at key decision points through the process.
- Set out clear goals and objectives for project engagement and communications at each phase of work so that stakeholders and partners understood how they could participate and how their input was incorporated at key project decision points.
- Educate stakeholders, partners and the public on coastal flood hazards, climate change and sea level rise, and adaptation pathways.

The application of IAP2 (International Association for Public Participation) Best Practices of Engagement also helped implement and achieve City Consultation Principles, and meet Surrey's broader CFAS goals:

- Increase awareness and understanding of climate change and coastal flooding;
- Build adaptive capacity and coastal community resilience; and
- Strengthen relationships with implementation partners and stakeholders.

CFAS engaged a range of stakeholder groups and partners through all project phases using various avenues and approaches. Core groups included the following.

- ***CFAS Steering Committee:*** An internal, interdepartmental City of Surrey project working group made up of senior staff from Engineering (project lead; Drainage, Utilities, Transportation, Communications), Planning & Development (Community Planning), Parks, Recreation & Culture (Parks Planning, Sustainability Office), and Finance & Technology (Risk Management, Finance).
- ***CFAS Advisory Group:*** A volunteer group of representatives from key partner and stakeholder organizations and agencies. The group met several times over the course of the project and were an integral part of the decision-making process. Advisory Group members and the organizations they represented also met through themed sector workshops (e.g., Agriculture and Farming, coastal regulators) or other CFAS initiatives (e.g., Green Shores). Participants included:
  - ***Local Governments:*** Semiahmoo First Nation, City of White Rock, City of Delta, Metro Vancouver, City of White Rock


Sandy beaches, by Janine Hudson

- ***Agencies & Ministries:*** Department of Fisheries and Oceans (DFO), Ministry of Transportation and Infrastructure (MoTI), Ministry of Forest, Lands and Natural Resource Operations and Rural Development (FLNRORD), Fraser Basin Council, BC Climate Action Secretariat, Emergency Management BC (EMBC), Provincial Agricultural Land Commission (ALC)
- ***Environment & Recreation:*** Ducks Unlimited Canada, Friends of Semiahmoo Bay Society, Stewardship Council of BC (Green Shores), Little Campbell Watershed Society, Nicomekl Enhancement Society, Surrey Environmental Partners, Ducks Unlimited Canada, Bird Study Canada
- ***Utilities & Transportation:*** BC Hydro, Metro Vancouver, Ministry of Transportation and Infrastructure
- ***Agricultural:*** Ministry of Agriculture, Delta Farmers' Institute, Hopkins Berry Farm, Kooldale Farms, Lindrian Farms, M&M Pacific Coast Farms, Mud Bay Dyking District, Winners Holstein Ltd.
- ***Residents & Business:*** Crescent Beach Property Owners Association, Surrey Board of Trade, Fraser Valley Real Estate Board, Nicowynd Strata, Anderson Walk Strata, Surrey Heritage Advisory Commission, Westland Insurance Group, Insurance Bureau of Canada, residents at large.
- ***Academic/Other:*** UBC SALA (School of Architecture and Landscape Architecture), Engineers and Geoscientists BC, Kwantlen Park University, University of the Fraser Valley, UBC SCARP (School of Community and Regional Planning), Surrey Schools representatives.

- ***City of Surrey Committees:*** Project staff made introductory presentations and follow up presentations as requested to existing City of Surrey committees and working groups throughout the project. These standing committees included:
  - Transportation and Infrastructure Committee (TIC)
  - Lowland Dyking Stakeholder Group (LDSG)
  - Agriculture and Food Security Advisory Committee (AFSAC) (now the Agriculture and Food Policy Advisory Committee (AFPAC)
  - Environment Sustainability Advisory Committee (ESAC)
  - Parks, Recreation and Sport Tourism Committee (PRSCTC)
  - Development Advisory Committee (DAC)
  - Public Art Advisory Committee (PAAC)
  - Surrey Heritage Advisory Commission (SHAC)
  - Public Engagement Task Force (PETF)

- ***Semiahmoo First Nation:*** With its principal Reserve located on the majority of one study area, and cultural, traditional use, and archeological sites existing throughout the other two CFAS study areas, Semiahmoo First Nation was a core project partner who was engaged through a parallel process, in addition to participating in many CFAS events.

- ***Regulators, Land Stewardship Groups, Asset Owners:*** Workshops were held with land stewardship groups, subject matter experts, coastal regulators, infrastructure owners/operators, and emergency responders that included additional input from many of the organizations involved in the CFAS Advisory Group, but also included: BC Agriculture and Food Climate Action Initiative, Vancouver Fraser Port Authority, Delta Farmland & Wildlife Trust, West Coast Environmental Law, Engineers Canada, BC Ambulance Services, RCMP, Canadian Coast Guard, BC Climate Action Secretariat, FortisBC, Surrey Fire Services, Burlington Northern Santa Fe Railway, A Rocha Canada, Surrey Search and Rescue, Shaw, Ministry of Environment, SRY Rail Link, and Telus.

  The BC Stewardship Centre also hosted Green Shores workshops to engage community members, design professional, regulators, and community groups in exploring Green Shore options for the CFAS Study Area. Ducks Unlimited also brought together experts in the region for a vulnerability workshop that assessed the impacts of sea level rise in Mud Bay on critical bird habitat.

- ***General Public:*** Broader-scale engagement involving general outreach activities and events in both in-person and digital formats, project open houses, pop-up events in the study areas, a travelling community road show (featuring a 5 metre high banner that illustrated the anticipated height for dykes by 2100), and exhibits at community events and festivals throughout Surrey (e.g., Party for the Planet). While children and youth are often not involved or specifically targeted in many municipal outreach activities, project organizers recognized that younger generations will be significantly influenced by the CFAS decisions being made today; therefore, special emphasis was placed on engaging with younger generations. Elementary and secondary school students were engaged through classroom sessions and activities on sea level rise and CFAS adaptation options, while university students (University of British Columbia and University of the Fraser Valley) were invited to collaborate with the CFAS team to gain valuable experience in the fields of human geography, community planning, and landscape architecture, as well as to provide their own feedback on the CFAS project

  Crescent Beach residents were also engaged in a series of interactive workshops to explore potential responses to future coastal flooding risks in the area. West Coast Environmental Law and Simon Fraser University's Adaptation to Climate Change Team (ACT) supported the workshop series. Their ideas were captured in Crescent Beach Community Meeting Series: summary Report on Coastal Flooding and Climate Change.

- ***Property Owner Associations:*** Crescent Beach Property Owners Associations, Nico Wynd Strata, Ocean Park Community Association, Mud Bay Dyking District

In addition to these engagement activities, two PIEVC infrastructure workshops were held. The first workshop used Engineers Canada's PIEVCTM High Level Screening Tool to receive input on infrastructure flood risks and adaptation options. The second PIEVC workshop explored and validated preferred adaptation options, and detailed types of factors, applying triple bottom line principles, that are most important when making decisions.

Figure 17 provides a summary of engagement and outreach highlights during the project's first three phases. A comprehensive summary of Phase 1 to 3 is available in the project's Engagement Summary Report Phases 1-3.

FIGURE 17: *CFAS – Engagement Summary Snapshot*

CFAS | SURREY

www.surrey.ca/coastal
#SurreyCoastal

COMMUNITY, STAKEHOLDER & PARTNER ENGAGEMENT

Developing a direction for coastal adaptation with the community

6
MEETINGS AND SITE VISITS
with Semiahmoo First Nation

3
FOCUS GROUPS
(Agriculture & Farming, Community & Residential, Environment & Recreation)
60+ participants

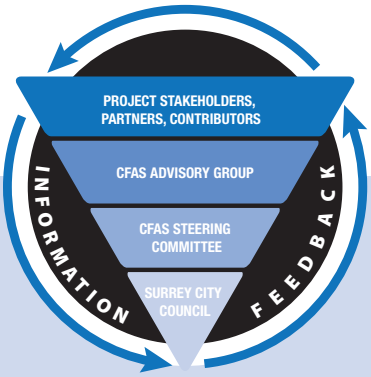
7
TECHNICAL WORKSHOPS
2 Greenshores™ Shoreline Design workshops, 2 PIEVC™ infrastructure operators workshops, 2 Design workshops with Dutch engineering design experts and UBC researchers, Coastal regulators, Coastal stewards

3
CFAS ADVISORY GROUP WORKSHOPS
With project stakeholders and partners, including local governments, infrastructure operators, provincial agencies, organizations, residents and farmers

5
CRESCENT BEACH COMMUNITY WORKSHOPS
140+ attendees

2
BUS TOURS
Site tour and "walk-shops" around the CFAS study area
70+ participants

200+
SURREY YOUTH ENGAGED
5 sessions with high school students, 2 youth events at City Hall, and 80 CFAS postcards completed by elementary school students



2
PROJECT OPEN HOUSES
engaging residents, business owners, and other stakeholders

8
POP-UP PROJECT OUTREACH STATIONS
Crescent Beach, Blackie Spit, SFU Surrey, Surrey Centre/Ocean Park/ Semiahmoo Public Libraries, Surrey City Hall, Alexandra House (Crescent Beach)

500+
WORKSHEETS COMPLETED
At various engagement events and workshops

250,000+
SOCIAL MEDIAL IMPRESSIONS
Instagram & Twitter (200+ #SurreyCoastal mentions), Facebook (100+ CFAS comments), LinkedIn, YouTube (1,000+ hours of CFAS video views), CFAS website and StoryMaps (10,000+ views)

2,000+
COMMUNITY MEMBERS
directly involved to date

200+
COMMUNITY CONVERSATIONS
at Crescent Beach pop-up event hosted with 40+ University of the Fraser Valley Geography and Environment students

1
#SURREYCOASTAL PHOTO CONTEST
200+ submissions on Facebook, Twitter, and Instagram with winners in three categories

1,000+
SURVEYS
Completed online, at CFAS workshops, at community events, and by CitySpeaks Members

30+
ORGANIZATIONS, AGENCIES, LOCAL GOVERNMENT PARTNERS, CITY OF SURREY COMMITTEES, AND COMMUNITY GROUPS INVOLVED
Keeping partners and stakeholders engaged

600+
CFAS DOOR HANGERS
Hung on Crescent Beach doors

10,000
COMMUNITY MAILERS
Sent to Surrey residents in the CFAS study area and beyond

3
PROJECT VIDEOS
Available on-line and shown at community events

6
BIG MEDIA HITS
CBC Early Edition and The Current (national), articles in the Vancouver Sun, The Province, Globe and Mail, and 24 Hours newspaper reaching over 100,000+ Metro Vancouver residents

A COMMUNITY LED, BOTTOM UP APPROACH IDENTIFIED THE VALUES TO PROTECT IN A CHANGING CLIMATE

Economy | Infrastructure | Environment | Communities

"We have the opportunity here to really set a precedent for BC and the Pacific Coast on how we adapt to sea level rise and climate change and placing that value in the environment."

– CFAS participant

"We were part of the process and part of the decision-making, and that's participatory democracy in action."

– CFAS participant

3.5 CFAS ORGANIZATION

The overarching goal of CFAS was to develop a broadly supported strategy to reduce coastal flood risk in Surrey. This primary goal is supported by eight core strategy objectives.

As illustrated in Figure 18, CFAS Program and Policy Actions and Planning Area-specific Actions were informed by and guided by Planning and Design Principles and Flood Management Values that were co-developed with CFAS partners and stakeholders through Phases 1 to 3. Individually and collectively, the Actions are structured to help achieve larger CFAS Objectives. These core strategy components are described in this section.

3.5.1 CFAS Objectives

CFAS Objectives represent the overarching flood management aims for CFAS. Individually and collectively they will help support the achievement of the Strategy's primary goals which was to develop a broadly supported strategy to reduce coastal flood risk in Surrey.

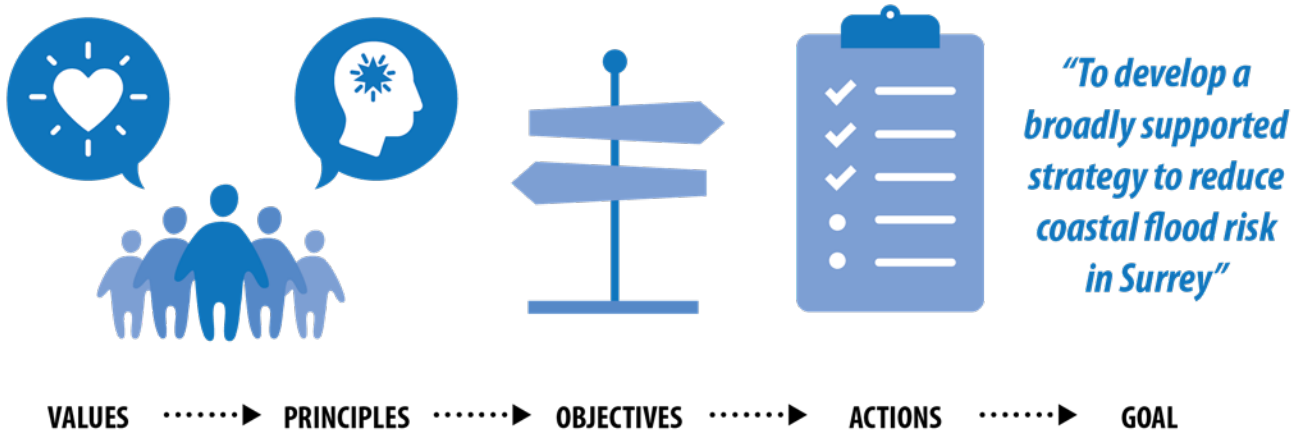
The CFAS planning objectives were first pulled from Surrey's Climate Adaptation Strategy, the overarching plan under which CFAS was developed. The original objectives, which cut across multiple sectoral areas -- Flood Management and Drainage; Infrastructure; Ecosystems and Natural Areas; Urban Trees and Landscaping; Agriculture and Food Security; Human Health and Safety – and were refined through the CFAS process.

Along with CFAS Planning Principles and CFAS Flood Management Values, CFAS Objectives also support detailed planning for short-term Actions, and future decision-making around longer-term Actions and CFAS Updates.

The CFAS Objectives are:

1. *Improve resilience of existing infrastructure*
2. *Ensure new infrastructure is resilient and adaptive*
3. *Update regulatory controls to improve resiliency*
4. *Ensure that flood management infrastructure and programs steward and enhance ecosystems and natural areas where practical and possible*
5. *Coordinate with, and contribute to, regional flood management strategies*
6. *Improve emergency response program for extreme flood events*
7. *Improve coastal flood hazard awareness, education, and communication*
8. *Improve and enhance monitoring and evaluation to keep CFAS up-to-date*

FIGURE 18: *CFAS - Strategy Organization*



3.5.2 CFAS Actions

Actions are projects, programs, and policies that are proposed to be implemented to address coastal flooding and sea level rise, improve resiliency of the floodplain area, and achieve CFAS Goals.

CFAS presents a total of 46 Actions. These are divided between CFAS Program and Policy Actions CFAS Planning Area-specific Actions. Program and Policy Actions apply across the larger CFAS Study Area and its three distinct Planning Areas (Mud Bay, Crescent Beach, Semiahmoo Bay). Area-specific Actions are primarily infrastructure-related projects to be implemented in specific areas in the CFAS Study Area. Collectively, these Actions are at the heart of CFAS. Individually and together, their implementation will involve numerous City departments, outside agencies, senior levels of government, and community-based organizations over the coming years and decades.

A number of Program and Policy Actions and Planning Area-specific Actions have been prioritized as more tactical, shorter-term to be implemented between 2020 to 2030. Other Actions will be implemented as conditions warrant over the longer-term, with a potential implementation period that stretches to 2080. The shorter-term CFAS Actions collectively represent so-call "low-regret" or "no-regret" flood management projects, investments, and policies that will help address current concerns while laying the path for more complex and challenging Strategic Directions over the longer-term. Low-regret projects are defined as relatively low-cost Actions that provide relatively large benefits under predicted future climates that contribute to adaptation while other social, economic and environmental benefits, including climate change mitigation benefits.

Both Planning Area-wide Actions and Sub-Planning Area-specific Actions are presented in Section 4.

3.5.3 CFAS Flood Management Values

The CFAS Flood Management Values represent the community concerns and desires that residents and other stakeholders care about most in the larger CFAS Planning Area.

The Flood Management Values were first identified during community workshops and focus groups with residents, farmers and the agricultural community, environmental organizations, and other stakeholders. These values represented the coastal flood impacts and issues project stakeholders and partners were most concerned about.

Towards the end of the second phase of CFAS, the impacts and concerns were organized into

general thematic categories – Community and Residential, Agriculture and Farming, Environment and Recreation, Transportation and Infrastructure, Local and Regional Economy – and project stakeholders and partners were asked to first confirm and validate the categories and to identify any additional general areas of concern. From this work, Environment and Recreation became individual value areas, while Culture was identified as new and important value area.

Measures or "values criteria" were then developed for the value areas allowing them to be used along with technical engineering criteria to help evaluate potential broad-scale adaptation approaches (i.e., resist, accommodate, move) developed during Phase 3 of the project. The seven values criteria were:

RESIDENTS: *Minimize people displaced*

AGRICULTURE: *Reduce permanent loss of agricultural land*

ENVIRONMENT: *Minimize impacts to wetland habitats and riparian areas*

INFRASTRUCTURE: *Minimize vulnerabilities*

ECONOMY: *Minimize loss of local businesses*

RECREATION: *Maximize recreational opportunities*

CULTURE: *Maximize opportunities for traditional practices*

The use of values in the evaluation of adaptation options helped ensure that the flood adaptation options developed for CFAS incorporate community concerns but will also help support future conversations around potential trade-offs within and between community values during later updates to CFAS and detailed planning for shorter-term CFAS Program and Policy Actions and Planning Area-specific Actions. The use of values in CFAS decision-making also helped ensure that the long-term Strategic Directions incorporate and respond to community concerns. They are also closely associated with CFAS Planning and Design Principles which are outlined in the next sub-section.

Figure 19 illustrates how value criteria were used along with risk and cost criteria to assess options. The figure is from Primer II Mud Bay Options.

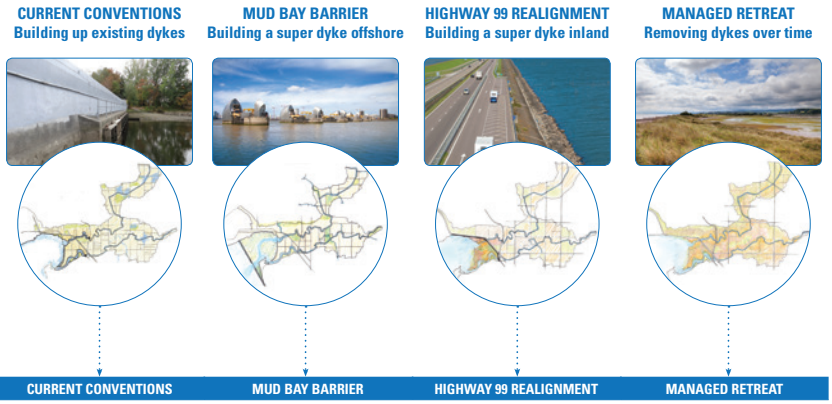
"When you see the area, there's a lot to gain here. There's a probability to restore old natural systems, to create value, not to say that the current land use is not value, but it's a single value, it's simple."

– CFAS participant

FIGURE 19: *Shortlisted Options Mud Bay – value assessment*

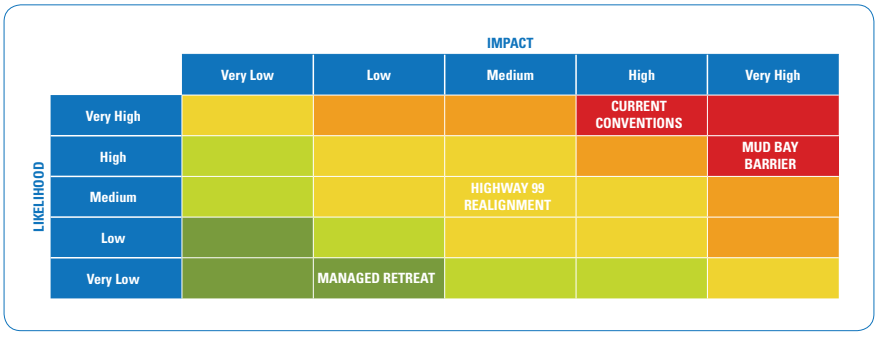
SHORTLISTED OPTIONS – MUD BAY

The summary table compares the short-listed options for the Mud Bay study area. The overview includes a "Baseline" or "No Adaptation" option for reference. Full descriptions of the short-listed options are available in the Primer (Primer Part II: Options).



	BASELINE - NO ADAPTATION	CURRENT CONVENTIONS	MUD BAY BARRIER	HIGHWAY 99 REALIGNMENT	MANAGED RETREAT
VALUES CRITERIA					
RESIDENTS *People permanently displaced*	FAR WORSE	SLIGHTLY WORSE	NO CHANGE	SLIGHTLY WORSE	FAR WORSE
AGRICULTURE *Permanent loss of agriculture land*	FAR WORSE	SLIGHTLY WORSE	NO CHANGE	SLIGHTLY WORSE	FAR WORSE
ENVIRONMENT *Impacts to wetland habitats, freshwater fish habitat & riparian areas*	MODERATELY WORSE	FAR WORSE	FAR WORSE	SLIGHTLY BETTER	FAR BETTER
INFRASTRUCTURE *Percent of service/transportation infrastructure made vulnerable*	FAR WORSE	NO CHANGE	NO CHANGE	NO CHANGE	SLIGHTLY WORSE
ECONOMY *Revenue*	FAR WORSE	SLIGHTLY WORSE	NO CHANGE	SLIGHTLY WORSE	MODERATELY WORSE
RECREATION *Diversity of recreational opportunities*	FAR WORSE	NO CHANGE	SLIGHTLY WORSE	SLIGHTLY BETTER	MODERATELY BETTER
CULTURE *Opportunities for traditional practices*	SLIGHTLY WORSE	NO CHANGE	MODERATELY WORSE	NO CHANGE	NO CHANGE
IMPACT & RISK OF FAILURE					
OVERALL RISK	VERY HIGH	VERY HIGH	VERY HIGH	MEDIUM	VERY LOW
COST CRITERIA					
CAPITAL COST	—	$100M - $1B	MORE THAN $4B	$1B - $4B	$1B - $4B
OPERATION & MAINTENANCE COST	MORE THAN $10M	MORE THAN $10M	$1M - $10M	$1M - $10M	LESS THAN $1M
OTHER INFRASTRUCTURE COST	MORE THAN $100M	$10M - $100M	LESS THAN $10M	$10M - $100M	MORE THAN $100M
FUTURE ADAPTATION COST	$1B - $4B	$1B - $4B	$1B - $4B	$1B - $4B	LESS THAN $100M

RISK ASSESSMENT HEAT MAP



3.5.4 CFAS Planning and Design Principles

CFAS Planning and Design Principles are high-level guidelines that identify how CFAS Actions should be planned, designed, and implemented over time. They were developed post-facto community engagement but help further distill "what matters most" for residents, stakeholders, and partners and will help guide the detailed planning and design work associated with the shorter-term Planning Area and Sub-Planning Area Actions.

Ultimately, the Planning and Design Principles are a further outcome of the project's participatory, values-based planning approach. As guiding principles, they also reflect the accumulated knowledge, learning, and experience the Surrey project staff and consultant team gained over the three-year project cycle. They further reflect knowledge and input gained from external input provided by project partners including a unique partnership with University of British Columbia School of Architecture and Landscape Architecture which brought in Dutch flood management experts, landscape architects, and engineers (LINT Middelburg, Royal Haskoning DHV).

The CFAS Planning and Design Principles will provide direction for future phases of CFAS work, including the development of longer-term (2030 and beyond) flood management options, infrastructure design, and policy.

PLAN FOR MULTIPLE VALUES

Ensure that flood management actions support multiple community values wherever possible (e.g., environment, agriculture, residents, recreation, economy, culture)

PLAN FOR ADAPTABILITY

Develop flexible, adaptive options that can adjust to a wide range of future conditions, including the pace of sea level rise, the height of sea level rise, and future land uses.

DESIGN FOR/WITH NATURE

Protect and steward critical intertidal, foreshore, riparian, and terrestrial ecosystems, habitats, and species that make Surrey's coastal floodplain home, while supporting mitigation.

DESIGN FOR RESILIENCE

Ensure risks to lifeline infrastructure and services are minimized, and that redundant systems are in place in case of failure. And consider additional risks, including seismic and other climate change-related risks including extreme weather events and drought.

PLAN FOR COLLABORATION AND PARTNERSHIPS

Facilitate collective, cumulative action by coordinating and collaborating with project partners and stakeholders, including neighbouring municipalities, Semiahmoo First Nation, Provincial and Federal agencies and Ministries, and non-governmental organizations and associations.

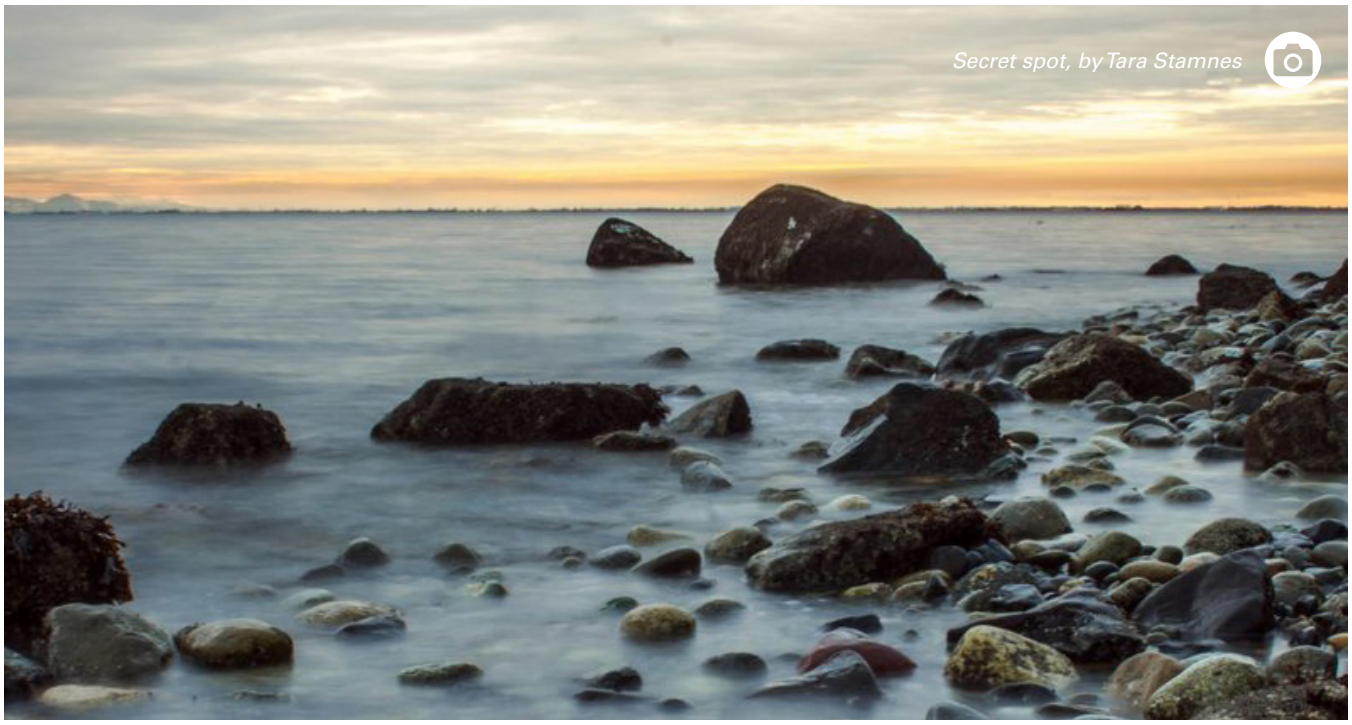
PLAN FOR FOOD SECURITY

Steward and support local agriculture, including supporting adaptive approaches, methods, and new products to preserve the area's agricultural heritage.

Figure 20 illustrates the CFAS Flood Management Values and Values Criteria addressed and/or connected to CFAS Planning and Design Principles.

FIGURE 20: *CFAS Flood Management Values and Planning and Design Principles*

CFAS PLANNING AND DESIGN PRINCIPLES	CFAS FLOOD MANAGEMENT VALUES AND VALUE CRITERIA						
	RESIDENTS *Minimize people displaced*	***AGRICULTURE*** *Reduce permanent loss of agricultural land*	***ENVIRONMENT*** *Minimize impacts to wetland habitats and riparian areas*	***INFRASTRUCTURE*** *Minimize vulnerabilitie*	***ECONOMY*** *Minimize loss of local businesses*	***RECREATION*** *Maximize recreational opportunitie*	***CULTURE*** *Maximize opportunities for traditional practices*
Plan for multiple values							
Plan for adaptability							
Design for/ with nature							
Design for resilience							
Plan for collaboration and partnerships							
Plan for food security							



3.6 STRATEGIC DIRECTIONS

The longer-term Strategic Directions are based on an 80-year timeframe (i.e., to 2100) and represent the long-term outlook for flood adaptation for the three CFAS Planning Areas. Developed with input from project partners and stakeholders, the Strategic Directions also included considerable technical analysis by City of Surrey Engineering, project consultants, and supplemented with additional review provided through a unique research component involving UBC and Dutch flood management experts, landscape architects, and engineers (LINT Middelburg, Royal Haskoning DHV).

Initially, several potential option pathways, or Strategic Directions, were developed through an iterative, participatory and technical process. These are described in CFAS Primer Part II, Options. The longer-term Strategic Directions for each of the three Planning Areas were evaluated and refined by project stakeholders and partners during the third phase of the CFAS project ("What is acceptable?"). The process used for this is summarized in the CFAS Engagement Summary Report.

Final Strategic Directions are summarized next.

"Everyone sees the possibilities that you can create something unique here."

– CFAS participant

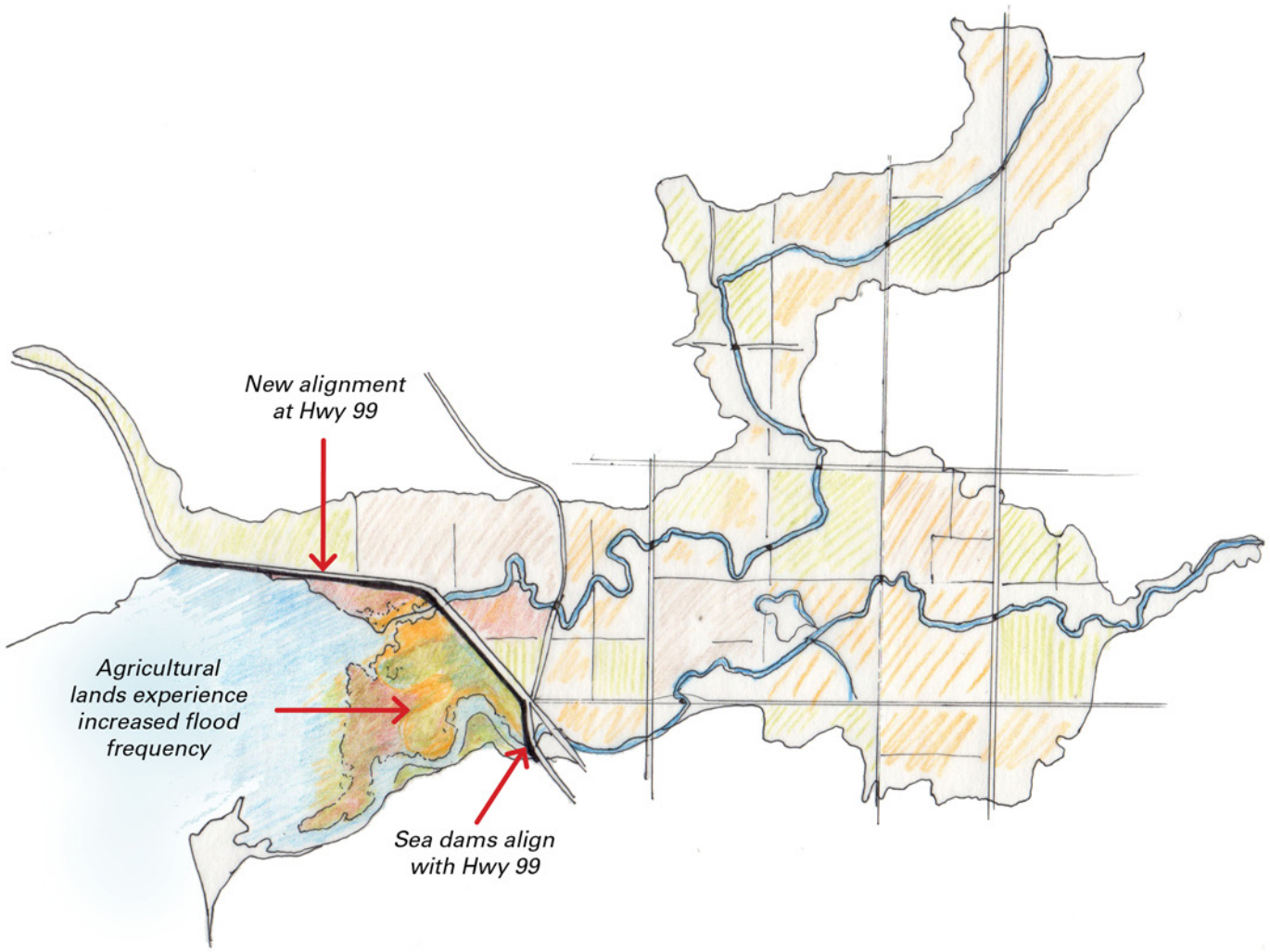
"Doing nothing is my least favourite option."

– CFAS participant

MUD BAY – COASTAL WORKS / HIGHWAY 99 STRATEGIC DIRECTION

The longer-term strategic direction for the Mud Bay Planning Area is to gradually develop new infrastructure and management approaches along the Highway 99 corridor to prepare for increased frequency of flooding. This agricultural area is complex, as there are numerous infrastructure corridors of regional, provincial and national significance. A shared desire to minimize increases in long term flood risk to critical infrastructure will be required for the Strategic Direction to be implemented. Further, extensive coordination between numerous agencies will be necessary.

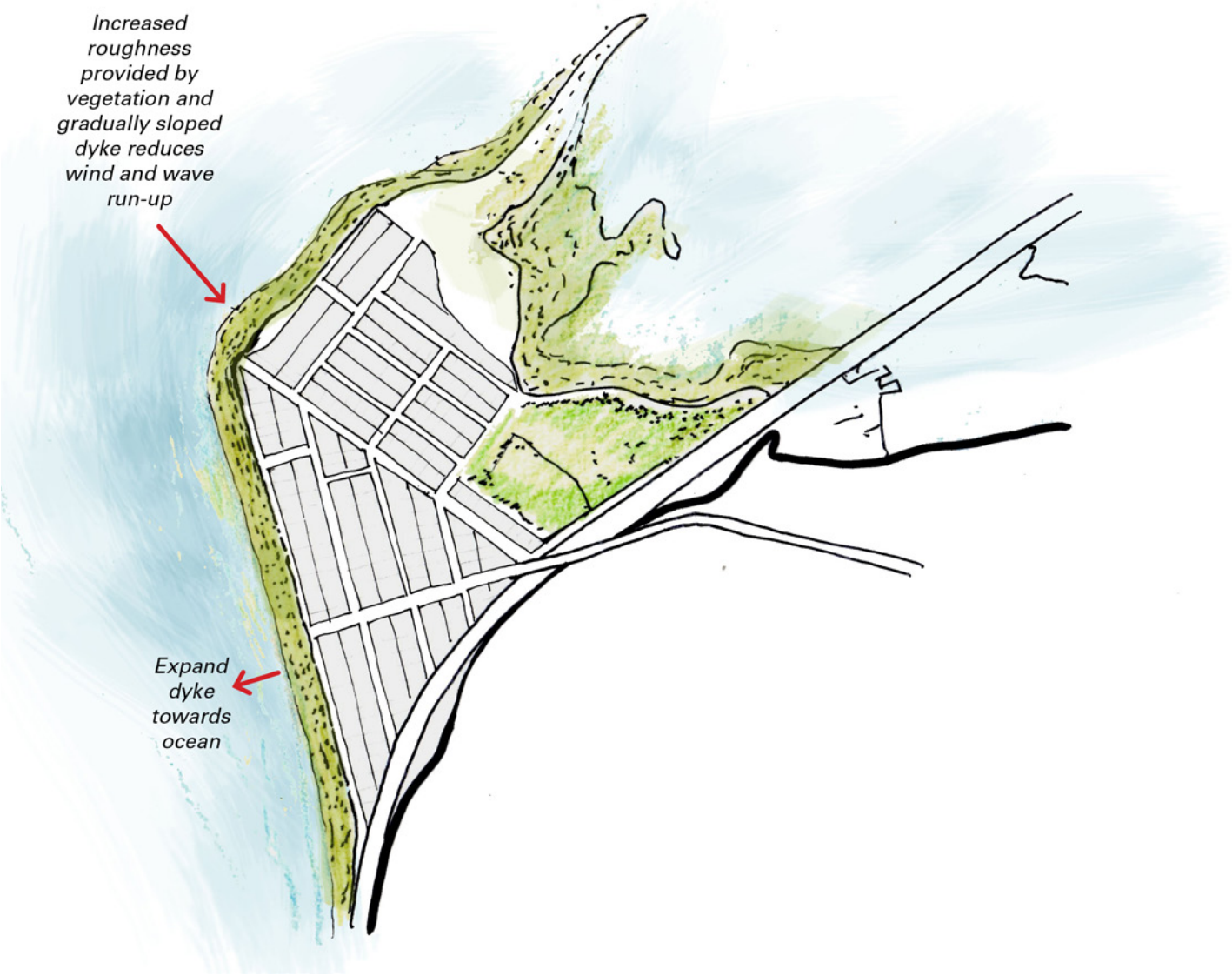
FIGURE 21: *Coastal Works / Highway 99 Strategic Direction*



CRESCENT BEACH – EXPANDED EDGE STRATEGIC DIRECTION

For Crescent Beach Planning Area, the longer-term planning challenges are even greater. Shorter-term tactical actions include a series of smaller-scale drainage improvements and regulatory changes (e.g., a higher flood construction level) until such point that sea level rise (observed increase and rate of rise) triggers an "expanded edge" approach. This approach could build up and extend the shoreline towards Boundary/Mud Bay and include additional drainage and flood management works in the Crescent Beach community. Given the technical complexity, archaeological significance and considerable cost considerations, the Strategic Direction will require more detailed planning. External and interconnected issues, such as flood insurance, property values and public risk perception are expected to influence triggers to implement longer-term actions impacting the primarily residential and recreational area.

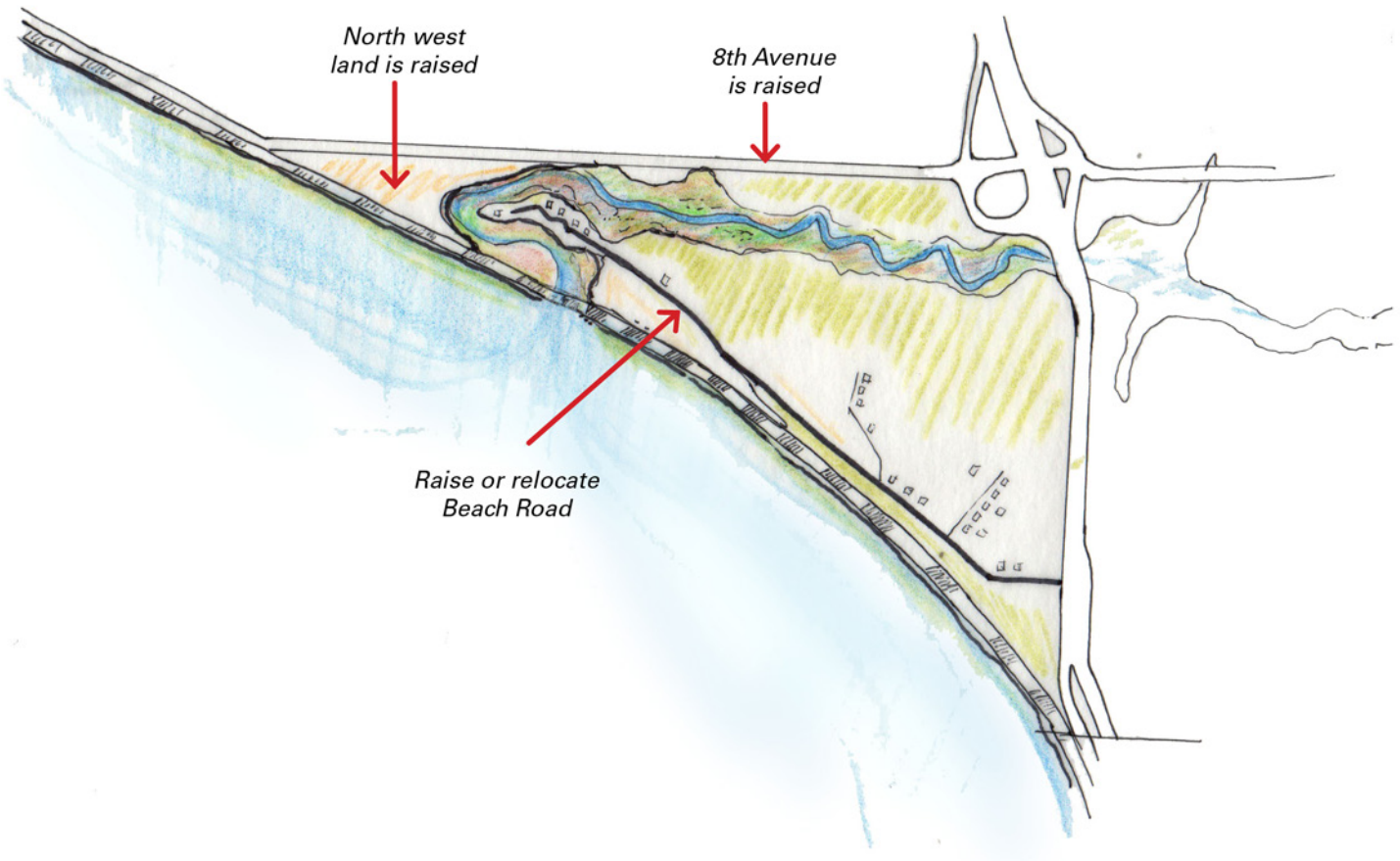
FIGURE 22: *Expanded Edge - Crescent Beach Strategic Direction*



SEMIAHMOO BAY – INFRASTRUCTURE IMPROVEMENTS AND LAND RAISING STRATEGIC DIRECTION

For Semiahmoo Bay Planning Area, relatively smaller and less dramatic interventions are envisioned. While many of the actions will need to be linked with the development of land within the Semiahmoo First Nation, there are long term, complicated coordinated works required along 8th Ave\Marine Drive that will require careful coordination and collaboration with Semiahmoo First Nation, the Federal Government, the City of White Rock, and the City of Surrey.

FIGURE 23: *Infrastructure Improvements & Land Raising – Semiahmoo Bay Strategic Direction*



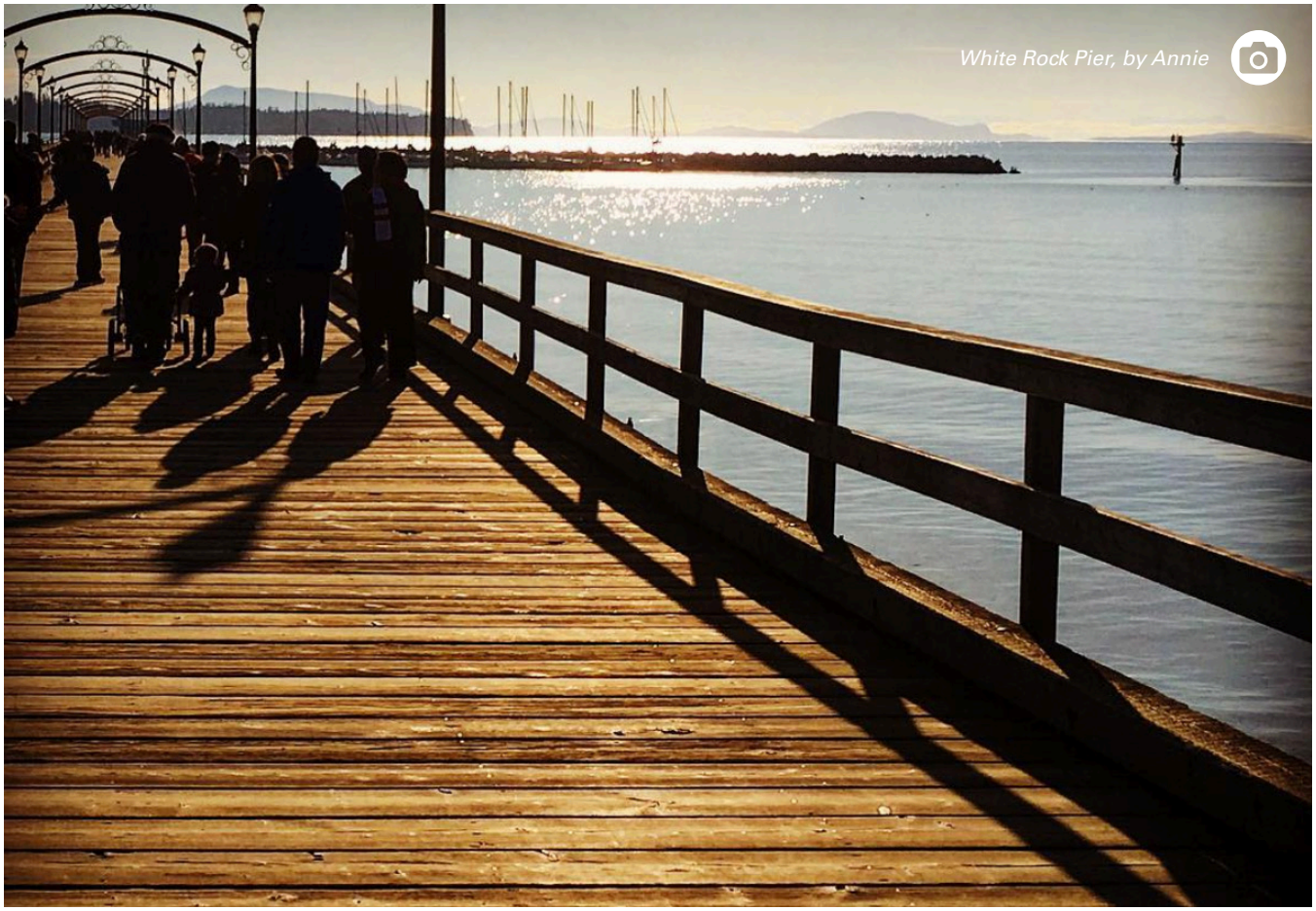
Establishing the final Strategic Directions was especially challenging. The shortlisted adaptation approaches outlined on the following table each involved difficult trade-offs and reaffirmed the fact that there is no silver bullet, win-win approach for sea level rise and coastal flooding. The bolded approaches indicate the approaches that were selected as the strategic direction in each study area. A full summary of the shortlisted options is available in CFAS Primer Part II.

FIGURE 24: *Adaptation Approaches and Preferences*

	MUD BAY	CRESCENT BEACH	SEMIAHMOO BAY
Preference ↑	1. Move (managed retreat) **2. Coastal Works / Highway 99** 3. Mud Bay Barrier 4. Current Conventions (i.e., "do nothing")	**1. Expanded edge** 2. Move (managed retreat) 3. Barrier Island 4. Mud Bay Barrier	1. Expanded Edge* **2. Infrastructure Improvements and Land Raising** 3. Current Conventions (i.e., "do nothing")

** Not within City's authority and not considered further*

In the shorter-term (2020 to 2030), CFAS includes 28 tactical, shorter-term Actions (Program and Policy Actions and Planning Area-specific Actions) which will help lay the groundwork and establish the pathway for the more complex Strategic Directions that will, over time, fundamentally change Surrey's coastline. Implementing these Actions will not always be easy and will involve the stakeholders and partners that helped develop CFAS, continuing to build confidence, capacity, and momentum to move forwards on the CFAS journey.



Taking aim, by ephr.aim

4. ACTIONS

Actions are at the heart of the CFAS. The CFAS Actions proposed here are intended to provide greater detail to the broad, general actions identified in the Climate Adaptation Strategy. This additional detail is provided in the form of proposed implementation approaches and timing, which should be used as a roadmap rather than a specific implementation plan. The projects, programs, and policies that are proposed here should be developed further at the time of implementation.

CFAS presents a total of 46 Actions. These are divided between CFAS Program and Policy Actions and CFAS Planning Area-specific Actions. Program and Policy Actions apply across the larger CFAS Study Area while area-specific Actions are primarily infrastructure-related projects to be implemented in one of its three distinct Planning Areas (Mud Bay, Crescent Beach, Semiahmoo Bay). Individually and together, the implementation of these Action will involve numerous City departments, outside agencies, senior levels of government, and community-based organizations over the coming years and decades.

A number of Program and Policy Actions and Planning Area-specific Actions have been prioritized as more tactical, shorter-term to be implemented between 2020 to 2030. Other Actions will be implemented in the period from 2030 to 2100 as conditions warrant. The shorter-term CFAS Actions collectively represent "low-regret" flood management projects, investments, and policies that will help address current concerns while laying the path for more complex and challenging Strategic Directions over the longer-term. Low-regret projects are defined as relatively low-cost Actions that provide relatively large benefits under predicted future climate scenarios.

Because of the need for upfront actions, it is anticipated that there will be a steep increase in Actions in the first decade (2020-2030). In succeeding decades, sustained implementation activities will have to be performed so that adaptation actions occur ahead of anticipated sea-level rise and corresponding increase in coastal flood risk.

The tables below summarize the Program and Policy Actions and Planning Area-specific Actions to be undertaken and the estimated implementation periods for them based on sea levels continuing to rise approximately 10 cm per decade. A complete table listing all actions and additional details on tools and resources required for implementation are included in Appendix I.

In the spirit of CFAS's participatory planning approach, and to highlight the central importance of partnerships, the tables indicate Action partners and key implementation collaborators.

FIGURE 25: *CFAS Program and Policy Actions - Summary*

		2020-30	2030-40	2040-50	2050-60	2060-70	2070-80	2080-90	2090-2100
Ongoing Education, Communications, and Advocacy Initiatives									
1	CFAS Steering Committee								
2	Internal Updates								
3	CFAS Advisory Group								
4	CFAS Website								
5	Advocacy Partners Workshop								
6	Communications and Media								
Detailing Planning, Studies, and Data Collection									
7	Update hazard bibliography								
8	Update coastal flood hazard assessment								
9	Detailed studies - Strategic Actions								
Regulatory Controls, Design Standards, and Guidelines									
10	Review Development Variance practices								
11	Support flood resilient design and construction								
12	Explore Sea Level Rise Planning Area								
13	Design Standards Guidebook								
Extreme Flood Management									
14	Hazard review								
15	Training and readiness								
16	Improve flood warning systems and communications								
17	Temporary protection measures assessment								
18	Build Back Better program								

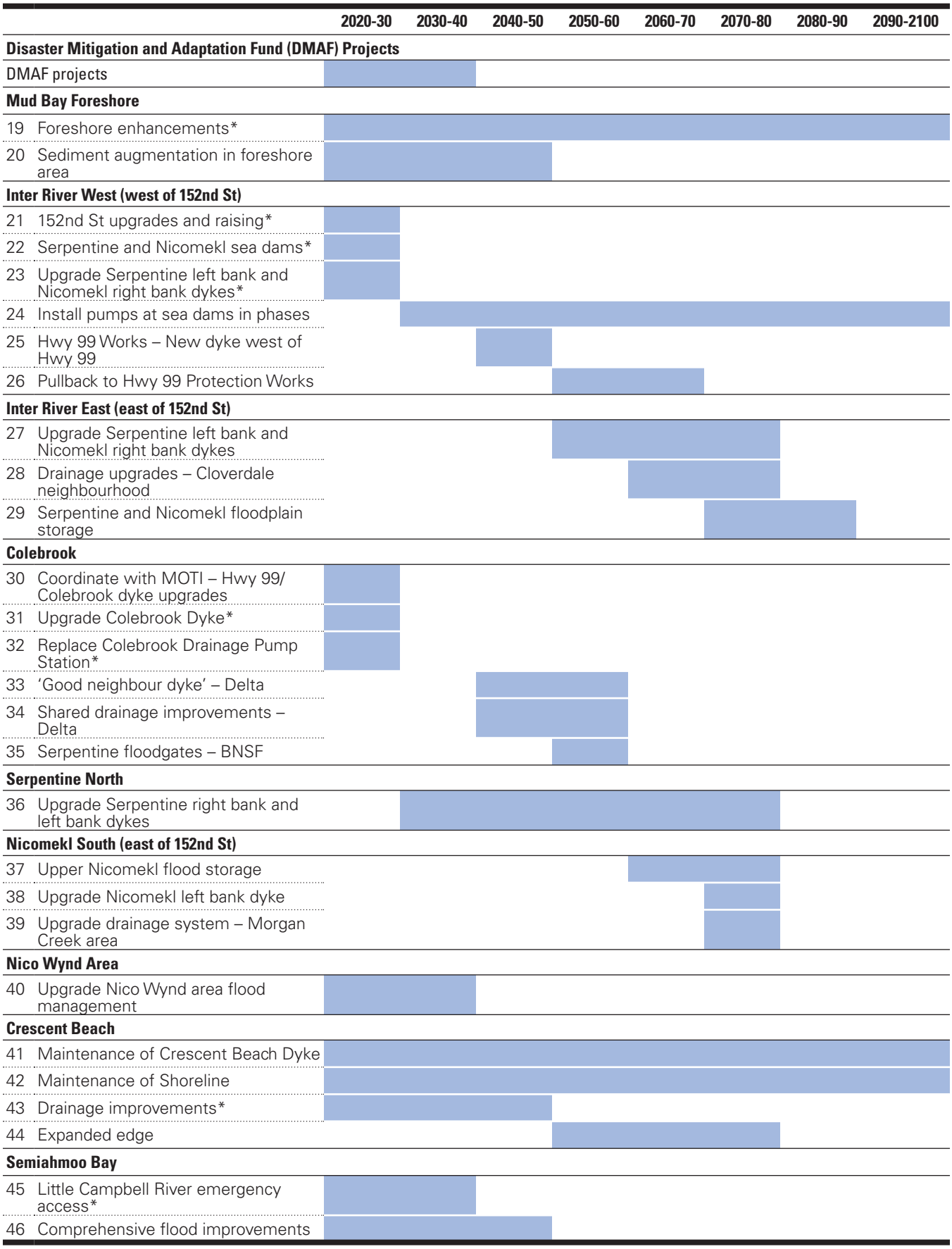
"I think it's a great process to be going through."

– CFAS participant

"There's really a need to do something now…"

– CFAS participant

FIGURE 26: *CFAS Planning Area-specific Actions - Summary*



** Indicates partial scope included in Surrey DMAF program*
Area-specific Actions under $5M capital cost are omitted for clarity

CFAS AND DISASTER MITIGATION AND ADAPTATION FUND (DMAF)

In 2018, during development of CFAS Phase 4, the Government of Canada announced the Disaster Mitigation and Adaptation Fund (DMAF) which aligned well with the objectives of CFAS. The first 3 phases of CFAS development provided a strong foundation to develop a comprehensive funding application and allowed Surrey and partners to compete in the national funding competition. The relationships with partners strengthened during CFAS development allowed for Semiahmoo First Nation, City of Delta and Metro Vancouver to apply for mutually beneficial projects under a single application with City of Surrey as the lead applicant.

Accordingly, a DMAF funding proposal was submitted by Surrey in January 2019 with a total project value of $187 million, supported by a Return on Investment ratio of 126:1. Thirteen mitigation measures were included in the DMAF application, as shown in the map and table in Appendix II (from report to Surrey's Council dated February 11, 2019). These measures are consistent with the long-term Strategic Directions of CFAS.

On Thursday, May 23rd Surrey was awarded DMAF funding, the largest single federal grant received by the City. A total of 13 projects were approved and summary sheets for each project is provided in Appendix II.

FIGURE 27: *DMAF Project Overview*

#	Component	Asset Type	Hazard Mitigation	Community Co-benefits	Values Protected	Partnership Opportunities
1	**Colebrook Dyke Upgrades**	Coastal Dyke		Recreation, bird watching, food security		
2	**Colebrook Drainage Pump Station Replacement**	Drainage Pump Station		Increased agricultural productivity and food security		
3	**Sea Dam – Serpentine River**	Sea Dam (drainage and irrigation)		Agriculture irrigation, fish passage, worker safety		
4	**152 St Road Upgrades and Raising**	Transportation Network		Congestion relief, transportation safety, accommodate growth, cycling, pedestrian		TRANSLINK, FORTIS BC
5	**Nicomekl Riverfront Park - Phase 1**	Flood Storage		Recreation (blue way), nature trails, wetlands, culture, open space		
6	**King George Boulevard Bridge and Nicomekl River Sea Dam Replacement**	Arterial Bridge		Congestion relief, transportation safety, accommodate growth, cycling, pedestrian, integrated to Nicomekl Park, fish passage, agriculture irrigation		metrovancouver, Ministry of Transportation and Infrastructure
7	**Crescent Beach Storm Sewer System Upgrades - Perforated Piping**	Flood Protection		Street beautification/ road improvements, transportation safety		
8	**Dyking - Lower reaches of Nicomekl and Serpentine**	Flood Protection		Food security and transportation flood safety		
9	**Serpentine SRY Rail Link Bridge Replacement and Dyking**	Flood Protection		Economy (freight and heritage railway), worker safety and goods movement		SRY Rail Link (Southern Railway of BC)
10	**Burrows Drainage Pump Station Upgrade**	Drainage Pump Station		Increased agricultural productivity and food security		
11	**Stewart Farm Sanitary Pump Station Coastal Flood Proofing**	Sanitary Sewer Network		Sanitation, worker safety and water quality		
12	**Campbell River Pedestrian and Emergency Access Bridge Replacement**	Transportation Network		Emergency access, Multi Use Path		Semiahmoo First Nation
13	**Foreshore Enhancements**	Flood Control		Wetlands (birds, fish, clams) and food security		Delta

Hazard Mitigation

= flood = seismic = drought

Values Protected

= economy = infrastructure = environment = communities

4.1 CFAS PROGRAM AND POLICY ACTIONS

Program and Policy Actions apply across the CFAS Study Area.

4.1.1 Ongoing Education, Communications, and Advocacy Initiatives

The scale and scope of the challenge of climate change and sea level rise demand not only a fundamental change in the approach to coastal flood management, but also in the education, communications, and advocacy required to bring along stakeholders and partners in the adaptation journey and conversation. Surrey's engagement with stakeholders and partners during CFAS development confirmed that many participants had limited awareness of the existing risk posed by coastal flood events exacerbated by climate change. Engagement also confirmed limited awareness around the effectiveness and standards of Surrey's existing flood management controls (dykes, sea dams).

- ***Education and Communications:*** Education and communications were core components of the CFAS process and included both internally-focused and public-facing education and communications around climate change-driven flood hazards and the adaptation approaches available to address them. While the efforts helped raise general community awareness and understanding, the need for continued education and communications around climate change remains. Because of the complexity of the issue and the corresponding complexity of CFAS Strategic Directions, educational activities and ongoing communications with partners and stakeholders should be a part of both short-term tactical actions and longer-term strategic actions.
- ***Advocacy:*** Surrey may not have authority or control over areas where CFAS stakeholders and partners have a common interest in an action, policy or outcome. This is why Surrey may need to take an advocacy-focused approach wherein the City works with partners and stakeholders to influence decision-makers, utilities, other local governments, and industry associations to help facilitate or expedite changes that may be required to support longer-term CFAS Strategic Directions. Actively participating and partnering with external groups engaged in advocacy will help advance common interests. A number of these groups have been actively engaged in the development of CFAS to-date and will play a role in implementing key aspects moving forward. A specific CFAS Action envisions Surrey encouraging the Province to organize a coastal flooding and sea level rise risk management workshop with a focus on the real estate considerations of CFAS Strategic Directions. At the national level, Surrey should advocate for the National Building Code to include flood tolerant provisions for building construction in floodplains.

ACRONYMS USED IN THIS SECTION

ALC
Agricultural Land Commission

BNSF
Burlington Northern Santa Fe Railway

DFO
Department of Fisheries and Oceans

EMBC
Emergency Management BC

FBC
Fraser Basin Council

FEI
Fortis Energy Inc.

IPREM
Integrated Partnership for Regional Emergency Management in Metro Vancouver

ISC
Indigenous Services Canada

MFLNRORD
Ministry of Forests, Lands, Natural Resource Operations and Rural Development

MOE
Ministry of Environment

MOTI
Ministry of Transportation and Infrastructure

NRC
National Research Council

SHaRP
Salmon Habitat and Restoration Program

FIGURE 28: *Education, Communications, and Advocacy*

	ACTION	CITY LEAD	IMPLEMENTATION PARTNERS	TIMING
1	**CFAS Steering Committee:** Maintain CFAS Steering Committee as standing internal working group to meet semi-annually, or as needed.	Engineering		2020-2060
2	**Internal Updates:** Maintain internal City project information updates, including planning and implementation updates	Engineering		2020-2060
3	**CFAS Advisory Group:** Maintain CFAS Advisory Group as a formal, standing external working group to meet annually or as needed. Extend invitations to real estate, insurance, and financial industries.	Engineering	CFAS Stakeholder Groups	2020-2060
4	**CFAS Website:** Maintain and enhance project website and online materials as the primary information and communications portal containing current project information posted for public review, with supporting social media and e-newsletters.	Engineering		2020-2060
5	**Advocacy Partners Workshop:** Encourage the Province to organize a coastal flooding and sea level rise risk management workshop with Municipal Insurance Association of BC, Real Estate Foundation of BC, financial institutions/associations, Local Government Management Association of BC, West Coast Environmental Law, Fraser Basin Council, and other key stakeholder groups with a focus on the real estate considerations of CFAS Strategic Directions.	Sustainability	CFAS Stakeholder Groups	2020-2060
6	**Communications and Media:** Share CFAS updates with key Advisory Group partners (e.g., Fraser Basin Council) to disseminate information materials and updates on CFAS.	Engineering	Surrey Communications CFAS Stakeholder Groups	2020-2060

Priorities – Ongoing Education, Communications, and Advocacy

As indicated by the timeline of the above CFAS Actions, these are long-term activities that lay the groundwork to enable Surrey staff and stakeholders to engage in a productive CFAS implementation process. Therefore, all the above items should be considered high-priority in the first decade of CFAS implementation (2020-2030). Inputs from the steering committee, advisory group, advocacy partners, and stakeholders will be critical in developing effective adaptation solutions.

The first four Actions would all be relatively simple and cost-effective activities that could be implemented immediately. A Memorandum of Understanding could be developed for key partners participating in Advisory Group to help formalize the group and clarify roles and expectations going forward. Actions like the Advocacy Partners Workshop and other short-term CFAS Planning Area-specific Actions could be discussed at the first CFAS implementation meeting for the Advisory Group.

4.1.2 Detailed Planning, Studies, and Data Collection

Update hazard bibliography: Surrey has invested significant efforts over the past decade in understanding coastal flood risk. As much as detailed project planning in the future will rely on then-current studies regarding climatic and hydrologic conditions, it should also leverage the large body of studies that have previously been performed. A bibliography or archive of past work should be maintained and updated periodically throughout the CFAS implementation period.

Update coastal flood hazard assessment: With the completion of several studies over the past decade, Surrey has continued to update its assessment of coastal flood hazards. This process should continue in the future. Further, Surrey's coastal flood construction levels (FCLs) should be updated corresponding to newer flood hazard assessments. The city's current FCLs are based on design water levels computed by in 1994. Flood modeling performed more recently (in 2015) estimated flood levels for both 2010 and 2100 to be lower than the 1994 levels in riverine floodplain areas but higher in coastal and tidally-influenced floodplain areas. This change is caused by a combination of sea-level rise, new developments in the study area, and improved techniques of analysis. Thus, there is a need for updating the FCLs. Because the 1994 work underestimates coastal flood levels, FCL update should be considered a priority for the CFAS.

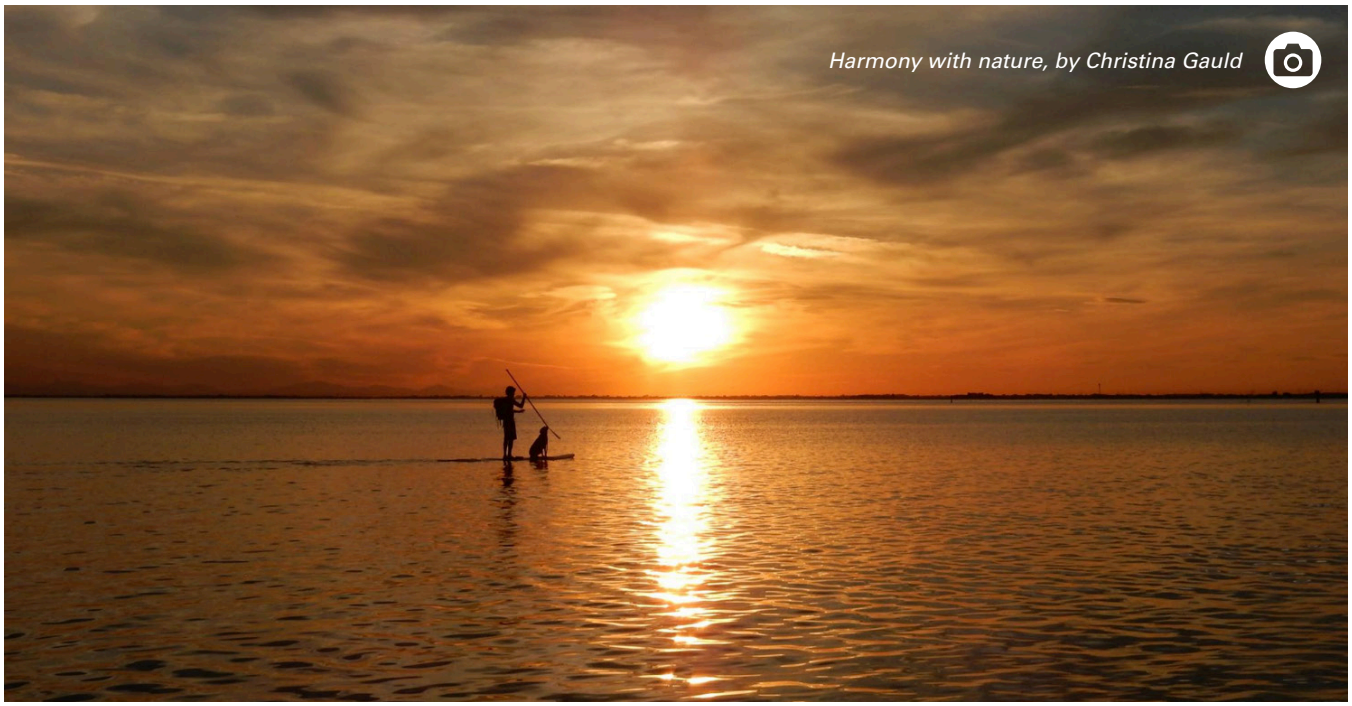
Detailed studies - Strategic Actions: The purpose of this CFAS document is to recommend adaptation Actions at a strategic level. Given the complexities of flood management in the context of a changing climate, detailed project planning will be required in the future to arrive at final implementation decisions.

FIGURE 29: *Detailed Planning, Studies, and Data Collection*

ACTION		CITY LEAD	IMPLEMENTATION PARTNERS	TIMING
7	**Update hazard bibliography:** Update CFAS bibliography on an as-needed basis such that it reflects the most current understanding of coastal flood hazards in Surrey. Incorporate multi-hazard information on related hazards including seismic, tsunamis, drought and ground subsidence.	Engineering		2020-2030
8	**Update coastal flood hazard assessment:** Update assessment of coastal flood hazards on an as-needed basis	Engineering		2020-2030
9	**Detailed studies - Strategic Actions:** Perform detailed studies of strategic adaptation actions recommended in this Strategy Document.	Engineering		2020-2050

Priorities – Detailed Planning, Studies, and Data Collection

Performing detailed studies for DMAF-funded actions should be considered high priority for the immediate decade. While the CFAS provides a road map, detailed implementation plans are expected to be developed when actions are taken up for implementation. The fact that the DMAF grant has realized the implementation of certain actions in 2020-2030 further underscores the need for detailed studies for these approved projects.



Harmony with nature, by Christina Gauld

4.1.3 Regulatory Controls, Design Standards, and Guidelines

The CFAS engagement process created an environment where difficult, value-laden conversations with residents could take place, and where adaptation options and pathways could be explored and discussed in an open environment. This helped generate a shift in thinking about climate change: people began to understand that homes are at risk from sea level rise in Surrey's coastal floodplain today and that this risk and hazard will continue to grow over time.

For residential areas like Crescent Beach, these discussions gave rise to new understandings of how living there would change over time, but also how it could continue using more resilient building approaches so flooding would cause less (or no) permanent property damage. The CFAS conversations also resulted in some residents beginning to adapt their own properties to be more resilient in the face of rising sea levels.

These conversations, while still in their infancy, have also supported a gradual shift in the regulatory environment currently applied to Crescent Beach towards a system that enables residents to learn, explore, and adopt more resilient best design practices that may help reduce the risks of living in a coastal floodplain.

Updated regulations: The City of Surrey could continue to expand its leadership role, established during the CFAS project, by reviewing and adjusting current development conventions and practices. This could include discontinuing Development Variance Permits for Flood Construction Level (FCL) reductions and replacing them with variances to building height to allow for the construction of more adaptable buildings. Existing zoning bylaws may be amended to specify flood resilient home construction (e.g., construction above FCL or use of wet-floodproofing design and construction). This would improve resilience, reduce risk, and save money for all stakeholders (residents, City of Surrey, and Province of BC) following future extreme flood events. Currently, Development Permit Areas for hazard lands establish regulatory controls, but existing zoning bylaws may benefit from changes to allow for higher homes, while future updates to the Provincial Building Code may also enable more resilient home construction in floodplains.

Updated design standards: Additional regulatory changes to the Surrey Zoning Bylaw and Official Community Plan through new

Development Permit Guidelines could provide new design standards to facilitate and expedite flood-tolerant construction for home owners and businesses in flood hazard areas. New design standards could be linked to the current pilot project underway in Crescent Beach where a resident is designing a more flood-tolerant home after learning about the risk and hazards through the CFAS process. The City of Surrey is currently supporting this pilot initiative through a Rezoning application.

Updated guidelines: Surrey could explore designating special Sea Level Rise Planning Areas which would allow Surrey, by bylaw, to specify flood levels and setbacks to address sea level rise. These areas could be created and implemented in future Official Community Plan updates as identified in Action 11.

FIGURE 30: *Regulatory Controls, Design Standards, and Guidelines*

ACTION		CITY LEAD	IMPLEMENTATION PARTNERS	TIMING
REGULATIONS				
10	**Review Development Variance practices:** Review and update Development Permit Variance Permit (DVP) practices around Flood Construction Level (FCL) reductions, replacing them with DVPs that allow for the construction of more adaptable buildings to improve resilience and mitigate current and future risks to residents.	Planning & Development		2020-2030
11	**Support flood resilient design and construction:** Explore regulatory changes to the Surrey Zoning Bylaw and Official Community Plan through new Development Permit Guidelines that support and encourage flood-tolerant design and construction standards in flood hazard areas.	Planning & Development Engineering		2020-2030
12	**Explore Sea Level Rise Planning Area:** Review Provincial Flood Hazard Area Land Use Management Guidelines for sea level rise and consider establishing a special Sea Level Rise Planning Area. Such an area may be designated as a floodplain under Section 524 of the Local Government Act. If land is so designated, Surrey may, by bylaw, specify special flood construction levels and setbacks to address sea level rise.	Planning & Development		2020-2030
DESIGN STANDARDS AND GUIDELINES				
13	**Design standards guidebook:** Develop toolkit/ guidebook for residents and land owners seeking to renovate or build in flood hazard areas to learn about best practice flood-resilient and waterproof construction. Advocacy for building code updates for flood resilient construction.	Planning & Development	EMBC BC NRC	2020-2030

Priorities – Regulatory Controls, Design Standards, and Guidelines

The actions in this group require Council action and are intended to establish the foundation for the long-term, non-structural aspects of coastal flood adaptation. Thus, while the actions themselves cannot be prioritized or accelerated, it is important that education and advocacy be considered high priority in the 2020-30 decade to enable the actions in this group.

4.1.4 Extreme Flood Event Management

It is estimated that climate change will result in flood events that are more extreme and occur with greater frequency which will place increased demands on the emergency management system, which includes emergency response, temporary flood protection, and post-disaster recovery.

Emergency response: In the context of Surrey's emergency response, climate change and sea level rise will affect several hazards including floods (coastal, riverine, and localized), debris flows, wind storms, and animal/human diseases. In the context of this strategy, the discussion is restricted to coastal flood hazards only. A review of Surrey's flood emergency response plans should be performed to identify stressors in a future scenario where flood events have greater magnitude and frequency. For example, such a 'stress test' may conclude that while emergency resources are capable of handling a single extreme event, the capacity is limited when two or more events occur simultaneously (e.g., dyke breaches in two different parts of the flood management system). Surrey's Flood Management Plan should be revised to address a wider range of future scenarios, which may support corresponding changes in resources allocation. Surrey should also consider a coastal recovery plan that would be focussed on challenges specific to the coastal context.

FIGURE 31: *UK Flood Warning System – A potential model for Surrey*

Updates to Surrey's emergency response program should also be coordinated with regional and provincial initiatives to plan, train, and respond to climate change-aggravated emergencies. For example, the City of Richmond's Flood Protection Management Strategy 2019 stresses the need to adapt current emergency management practices to future climate scenarios, which could provide an opportunity for Surrey and Richmond to exchange insights and identify common concerns, if any.

Existing flood warning and alert systems should also be reviewed to determine whether they have the necessary functionality to be effective in future scenarios where the trigger levels or the frequency of such triggers may be different. Effectiveness of the warning and alert system would rely on it having strong linkage with the local, regional, provincial and federal weather and flood monitoring systems. Mechanisms for broadcasting warnings and alerts should include traditional methods (e.g., electronic roadside warning signs) as well as newer methods such as social media. Any system used in Surrey should be integrated with the BC Emergency Alerting System and National Public Alerting System.

Temporary flood protection: Temporary flood protection (e.g., temporary flood barriers such as sandbags or proprietary panel walls) form an integral part of flood management systems because they help prevent nuisance or incremental flooding at a fraction of the cost of permanent infrastructure. Increased magnitude and frequency of extreme events will affect the characteristics of the flood protection systems (e.g., height of water they are designed for) as well as how frequently they are deployed. The suitability of the existing infrastructure and deployment system to future scenarios could be reviewed, and modifications be made if necessary.

Post disaster recovery: As per the Sendai Framework for Disaster Risk Reduction, the steady growth of disaster risk has highlighted the need to integrate disaster risk reduction measures during recovery, rehabilitation, and reconstruction (i.e., the Build Back Better principle). By adopting the Sendai Framework, both Canada and British Columbia have incorporated aspects of the Build Back Better in disaster response planning. However, under the BC Disaster Financial Assistance Program, only like-for-like costs are currently eligible for partial reimbursement which creates a barrier to increasing resilience post disaster. In its review and revision of its emergency response plan, Surrey could ensure that Build Back Better principles are incorporated in post-disaster planning and advocate for Provincial Disaster Financial Assistance to include provisions for Build Back Better.

FIGURE 32: *Extreme Flood Event Management*

	ACTION	CITY LEAD	IMPLEMENTATION PARTNERS	TIMING
EMERGENCY RESPONSE				
14	**Hazard review:** Review and revise hazard-specific plans to account for anticipated impacts of climate change in all hazard plans	All Departments		2020-2030
15	**Training and readiness:** Participate in regional initiatives for emergency services to simulate, train and respond in coordination in context of climate emergencies. Incorporate community resiliency education as it relates to a changing climate through Surrey Neighbourhood Emergency Program.	Surrey Emergency Program Engineering	EMBC PREM	2020-2030
16	**Improve flood warning systems and communications:** Advocate for public flood warning system and corresponding emergency alert system for coastal flood events. Improve internal emergency alert systems and extreme event monitoring system.	Surrey Emergency Program Engineering	DFO MBC FBC	2020-2100
TEMPORARY FLOOD PROTECTION				
17	**Temporary protection measures assessment:** Assess suitability of City's temporary flood protection infrastructure and modify as needed to meet future demands	Engineering	EMBC	2020-2100
POST-DISASTER RECOVERY				
18	**Build Back Better program:** Include 'Built Back Better' principles in recovery planning	Planning and Development Engineering	EMBC	2020-2100

Priorities – Extreme Flood Event Management

In the first decade of CFAS implementation (2020-2030), Surrey should focus on updating Surrey's Flood Management Plan based on recently-developed estimates of climate change-related coastal flood hazards. Depending on these estimates, a coastal flood recovery plan should be developed in the near term. Surrey should also participate in the February 2022 Coastal Regional Exercise after ensuring that results of recently-developed technical analyses are included and reflected in the scenarios used in the exercise.

The bird lady, by Sue Mukerji

4.1.5 Monitoring and Evaluation

Because of the inter-generational timeline of the CFAS, its successful implementation depends on Surrey being able to continually monitor and evaluate the process so that efforts can be calibrated to meet the intended objective. Monitoring and evaluation are different processes, which work together to assess the performance of adaptive actions over time. Monitoring refers to an on-going assessment of the actions and progress made in achieving set milestones and targets. Evaluation, on the other hand, examines if the community has become better adapted to climate change as a result of the actions, and the extent to which it is now more resilient to climate change.

To ensure the successful implementation of the Adaptation Strategy, it is proposed that the CFAS Steering Committee and Advisory Group collaboratively develop a series of indicators to track the progress of CFAS implementation over time. The indicators should be reviewed periodically to provide the most value in managing risk, within available resources. This CFAS monitoring effort should be aligned with existing reporting efforts, including those associated with Surrey's Climate Adaptation Strategy (CAS). Surrey's Sustainability Office could collect the data to establish a baseline and monitor progress of the monitoring indicators.

Surrey's Enterprise Risk Management (ERM) system should also be utilized to engage departments across the organization to identify and respond to challenges to the fulfillment of CFAS objectives.

Monitoring

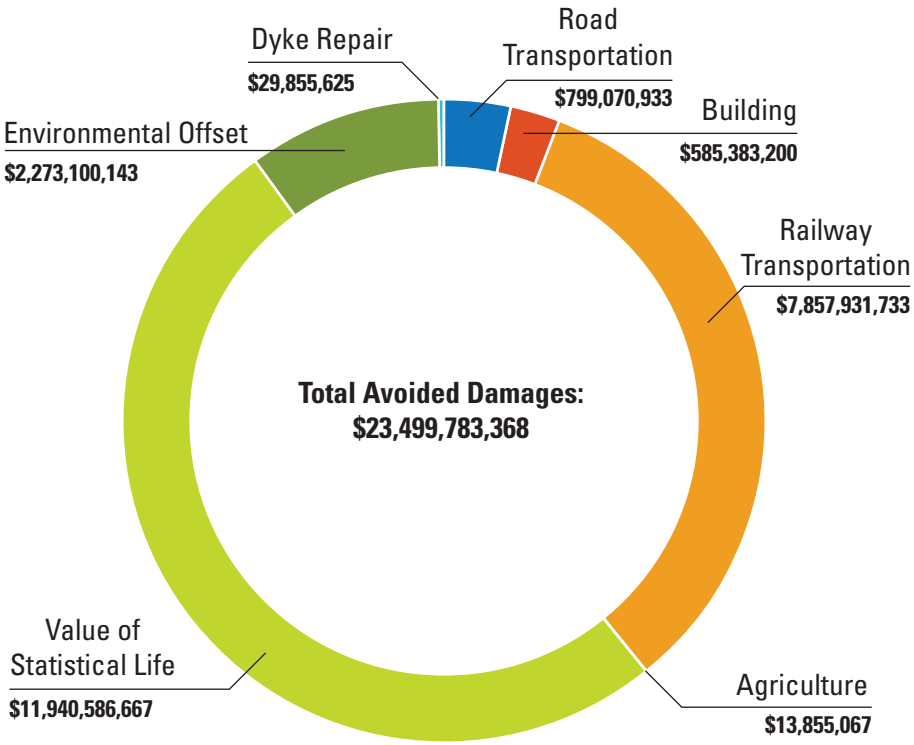
Monitoring refers to an on-going assessment of the intervention and progress made in achieving set milestones and targets. In the context of CFAS implementation, enduring data gathering is critical for long-term monitoring and can enable the development of climate-smart management policies and strategies. The monitoring framework established for the CAS should be utilized to assist in monitoring the implementation of CFAS over time.

A key element of monitoring is feedback received from stakeholder engagement events. Such feedback provides critical indicators that would allow Surrey to adapt CFAS actions to response to public expectations and awareness. For example, during the CFAS development process, the Surrey team continuously monitored feedback from stakeholder engagement events and found that the level of concern about climate change and sea-level rise went up significantly within the control group in the period of less than 2 years over which the engagement took place.

Evaluation

Evaluation is based on an examination of whether set objectives are achieved and if they did so in a cost-effective way. In the context of CFAS actions, evaluation is necessary to establish priorities to define which projects should be undertaken first and the order in which future projects should be done. Such an evaluation should be based on objective and subjective assessments of the extent to which a certain action will help Surrey meet its coastal flood adaptation goals.

FIGURE 33: *Avoided Damages per Sector*



There are several metrics available for evaluating capital investments in the municipal context. One of the often-used metric is Return on Investment (ROI). For example, the set of actions that were funded through DMAF were required, as a condition for the grant, to have a Return on Investment (ROI) higher than 2:1. As part of Surrey's application for the grant, it was demonstrated that implementing certain actions would result in an ROI of 126:1. This was based on an investment of $187 million and avoided damage of approximately $23.5 billion over the lifecycle of the proposed projects. A distribution of avoided damages by sector is shown in Figure 33 and the detailed methodology for determining the ROI is provided in Appendix III.

In the case of future projects during CFAS implementation, the concept of ROI can be a useful metric for evaluation of project success. The widely-accepted ROI of 2:1 can be used as a threshold value to determine viability of projects. Among those projects that meet this ratio, projects with a higher ROI can be prioritized. It should be noted that the ROI calculation includes a monetary translation of the risk of injury and loss of life; thus, the ROI is not only a financial metric, but also accounts for non-economic losses.

Priorities – Monitoring and Evaluation

Monitoring and evaluation actions will occur over an extended period of time, most of them after the immediate decade. However, within the immediate decade, Surrey's Sustainability Office could collect the data to establish a baseline in terms of economic and non-economic indicators. Such baseline data will help Surrey monitor progress of the metrics identified above.

4.2 CFAS PLANNING AREA-SPECIFIC ACTIONS

CFAS Planning Area-specific Actions are primarily infrastructure-related projects to be developed in specific areas. This section contains only summary descriptions for the recommended actions. For further details on the actions, please see the Technical Background Document in Appendix III.

4.2.1 Mud Bay

Mud Bay is the largest CFAS Planning Areas. Flood hazards along Mud Bay and the Serpentine and Nicomekl Rivers downstream of the sea dams are a function of high tides combined with storm surge, waves, and wind effects. Previous work estimated that, as a result of sea level rise, the degree of protection will be reduced over time with some dyke overtopping becoming more common in the future and occurring annually by 2070. Public safety is a concern because of several residential strata developments and subdivisions in addition to many farm houses in this area with over 200,000 vehicle trips per day. Further, significant natural areas including mud flats, wetland areas, and riparian/estuarine habitat in the inter-tidal area are threatened because sea-level rise is anticipated to result in coastal squeeze of marsh land. Thus, it is evident that a wide diversity of adaptation measures would be required for different parts of the larger Mud Bay Sub-Planning Area.

In the interest of efficient organization, the Mud Bay Planning Area was further divided into several Sub-Planning Areas based on shared geographical or coastal flooding characteristics - Inter River West, Inter River East, Colebrook, Serpentine North, Nicomekl South, the Nico Wynd Area, and the Mud Bay Foreshore.

A summary of recommended adaptation actions is provided below. Technical background and detailed discussion of each action is provided in Appendix III.

FIGURE 34: *Mud Bay Planning Area-specific Actions*

	ACTION	CITY LEAD	IMPLEMENTATION PARTNERS	TIMING
MUD BAY FORESHORE SUB-PLANNING AREA				
19	**Foreshore enhancements:** Build green infrastructure to mitigate loss of intertidal habitat	Engineering	Ducks Unlimited, MFLNORD, MOE, SHaRP	2020-2100
20	**Sediment retention in foreshore area:** Perform sediment retention in foreshore area. Options include using Fraser River dredgeate.	Engineering	Champion needed	2020-2050
INTER RIVER WEST SUB-PLANNING AREA				
21	**152nd St upgrades and raising:** Retrofit 152nd St to address projected sea-level rise impacts	Engineering	FEI	2020-2030
22	**Serpentine and Nicomekl sea dams:** Replace Serpentine and Nicomekl sea dams	Engineering		2020-2030
23	**Upgrade Serpentine left bank and Nicomekl right bank dykes:** Raise dykes to meet 200-year design level with future sea-level rise to work with the network of spillways	Engineering		2020-2030
24	**Install pumps at sea dams in phases:** Add pumping capacity in phases to newly-replaced sea dams to reduce the flood potential in area upstream of the dams	Engineering	Ministry of Agriculture, MFLNORD	2030-2100
25	**Hwy 99 Protection Works – New dyke west of Hwy 99:** Exact location to be determined based on an adaptive approach in light of observed sea-level rise	Engineering	MOTI, BNSF	2040-2050
26	**Pullback to Hwy 99 Protection Works:** Return floodplain outside the coastal dyke to its original state through a gradual, managed process	Engineering	ALC, MFLNRORD, MOTI	2050-2080
INTER RIVER EAST SUB-PLANNING AREA				
27	**Upgrade Serpentine left bank and Nicomekl right bank dykes:** Both the Serpentine left bank and Nicomekl right bank dykes will need to be raised and upgraded in this area	Engineering		2050-2080

ACTION		CITY LEAD	IMPLEMENTATION PARTNERS	TIMING
28	**Drainage upgrades – Cloverdale neighbourhood:** As sea level rises, the drainage system adjacent to the current floodplain will need to adapt due to tailwater condictions	Engineering		2060-2080
29	**Serpentine and Nicomekl floodplain storage:** Add floodplain storage by sacrificing dykes when upgrades become unfeasible because of sea-level rise in conjunction with sea dam pumping and network of spillways	Engineering	Ministry of Agriculture, ALC	2070-2090
COLEBROOK SUB-PLANNING AREA				
30	**Coordinate with MOTI – Hwy 99 / Colebrook dyke upgrades:** Coordinate with MOTI regarding Hwy 99 to accommodate future Colebrook dyke upgrades	Engineering	MOTI, BNSF	2020-2030
31	**Upgrade Colebrook dyke:** Upgrade Colebrook dyke from western end to 152nd Street	Engineering	MOTI, BNSF, MFLNRORD	2020-2030
32	**Replace Colebrook Pump Station:** Upgrade to incorporate new standards for resilience and climate adaptation	Engineering		2020-2030
33	**'Good neighbour' dyke:** Build 'good neighbour' dyke in collaboration with Delta and MOTI	Engineering	City of Delta, MOTI Railways	2040-2060
34	**Shared drainage improvements – Delta:** Perform drainage improvements on shared drainage facilities in collaboration with Delta	Engineering	City of Delta	2040-2060
35	**Serpentine floodgates - BNSF:** Install floodgate structures on the Serpentine left and right banks at the BNSF railway crossing	Engineering	BNSF Railway	2050-2060
SERPENTINE NORTH SUB-PLANNING AREA				
36	**Upgrade Serpentine right bank and left bank dykes:** To continue maintaining flood safety, regularly make local repairs and raise dykes as needed	Engineering		2030-2080
NICOMEKL SOUTH SUB-PLANNING AREA				
37	**Upper Nicomekl flood storage:** Coordinate improvements with Township of Langley and City of Langley	Engineering	Township of Langley, City of Langley, MFLNRORD, ALC	2060-2080
38	**Upgrade Nicomekl left bank dyke:** If the floodplain combination option is adopted, it would result in the sacrifice of the Nicomekl right bank dyke and efforts can focus on the left bank	Engineering		2070-2080
39	**Upgrade drainage system west of 168th St:** Upgrade drainage system in neighborhoods in this area to be resilient to future hydrologic regime	Engineering		2070-2080
NICO WYND SUB-PLANNING AREA				
40	**Upgrade Nico Wynd area flood management:** Upgrade to provincial standards recommended by prior studies	Engineering	Nico Wynd Strata, Elgin Strata	2020-2040

Priorities – Mud Bay

The highest priority projects in the Mud Bay Planning Area are those which either address an existing coastal flooding issue or set the stage for more complex actions over coming decades. Several of these high-priority projects have fully or partially been funded through DMAF. These actions include Mud Bay foreshore enhancements, sediment retention in foreshore areas, 152nd Street upgrades, Serpentine and Nicomekl sea dams, Serpentine left bank and Nicomekl right bank dykes, Colebrook dyke upgrades, and Colebrook pump station replacement.

Walking on Crescent Beach, by Zaine Rabanillo Curate

4.2.3 Crescent Beach

Situated downstream of Nicomekl sea dam, river flooding is not a concern in the Crescent Beach Planning Area, but it is subject to coastal floods and, by 2070, is expected to flood annually without significant mitigation works. The area is home to about 1,200 residences and over 40 Heritage Sites and includes Blackie Spit which is an important wildlife area that offers some of the best bird watching in Canada. A summary of recommended adaptation actions for Crescent Beach is provided below. Technical background and detailed discussion of each action is provided in the accompanying Background Document in Appendix III.

FIGURE 35: *Crescent Beach Planning Area-specific Actions*

ACTION		CITY LEAD	IMPLEMENTATION PARTNERS	TIMING
41	**Maintenance of Crescent Beach dyke:** Assess the dykes and make local repairs or raise dyke as needed	Engineering		2020-2100
42	**Maintenance of shoreline:** Continue shoreline maintenance that was previously performed	Engineering	DFO	2020-2100
43	**Drainage improvements:** Perform drainage improvements that were previously identified	Engineering		2020-2050
44	**Expanded Edge:** Build the beach in front of the existing shoreline to reduce the slope of the foreshore	Engineering	DFO	2050-2080

Priorities – Crescent Beach

Among the actions recommended for the Crescent Beach Planning Areas, drainage improvements should be considered highest priority since they would address an existing issue that is likely to get exacerbated with sea-level rise. Crescent Beach drainage improvements have also been partially funded through the DMAF grant. Maintenance of Crescent Beach dyke is a long-term action for which an extensive capital program will need to be developed after further monitoring and consultation.

4.3.3 Semiahmoo Bay

A summary of recommended adaptation actions for Semiahmoo is provided below. Technical background and detailed discussion of each action is provided in Appendix III.

FIGURE 36: *Semiahmoo Bay Planning Area-specific Actions*

ACTION		CITY LEAD	IMPLEMENTATION PARTNERS	TIMING
45	**Little Campbell River emergency access:** Raise 8th Avenue and retrofit bridge to enable emergency access	Engineering	Semiahmoo First Nation City of White Rock ISC	2020-2040
46	**Comprehensive flood improvements:** Coordinate with and support Semiahmoo First Nation in undertaking comprehensive flood protection	Engineering	Semiahmoo First Nation	2040-2050

Priorities – Semiahmoo Bay

Providing Little Campbell River emergency access should be considered to be a high-priority action for 2020-30. This project has been approved for funding under the DMAF grant.

Sunset, by Gail Stephan

4.3 ACTION PLANNING AND COLLABORATION

Planning for partnerships and collaboration emerged as a guiding CFAS Principle and was a constant and consistent theme at CFAS Advisory Group workshops. Given the scale, scope, and number of CFAS Actions to be implemented, collaboration and partnerships will remain core components of successfully implementing CFAS Actions. Future stakeholder and partner collaboration and involvement will take many forms, from regulatory approvals and permitting to joint public education and communications initiatives, and from technical planning support to collaborative project funding programs.

In moving forward on collaborative CFAS Action implementation, some challenges will remain as partner organizations continue to develop their own mandates on climate adaptation in general, and climate change and coastal flooding in particular. Priorities of partner organizations may also shift and evolve as the climate crisis continues to evolve and sharpen. Additionally, collaboration will need to consider the limited funding currently available and the need to creatively fund and cost-share some CFAS Actions.

As mandates and priorities emerge and shift, and new funding opportunities arise, it will be critical for CFAS partners to keep other partners up-to-date on their own climate adaptation initiatives and linkages to CFAS. Here, organizations and governments that can facilitate collaboration and cooperation will likely play increasingly larger roles (e.g., Metro Vancouver, Fraser Basin Council, Federation of Canadian Municipalities, professional associations [Engineers Canada, Canadian Institute of Planners], and Stewardship Council of BC). Provincial and Federal partners and stakeholders (e.g., Ministry of Transportation and Infrastructure, Ministry of Forests, Lands, Natural Resource Operations, and Rural Development, Agricultural Land Commission, Department of Fisheries and Oceans) will also play important convening and organizing roles.

Collaboration with key regional organizations like Fraser Basin Council is also important, particularly around the Lower Mainland Flood Management Strategy which is aimed at reducing flood risk and improving the flood resilience of communities along the lower Fraser River and south coast — from Hope to Richmond and from Squamish to White Rock.

On a more local level, ongoing and expanded sub-regional collaboration will be needed to resolve many of the complex CFAS Actions, including raising 8th Avenue (Surrey, White Rock, Semiahmoo First Nation) and the proposed Good Neighbour Dyke (Surrey, Delta).

Lessons learned from early CFAS collaborations, including joint CFAS planning, option identification, and option assessment work carried out with non-governmental partners in the Mud Bay Planning Area will help inform additional and ongoing cooperative CFAS implementation work. Some of the key groups here include the Boundary Bay Health, Conservation, Management Stakeholders Committee, Ducks Unlimited Canada, the Lower Fisheries Alliance, and West Coast Environmental Law.

4.4 COMPLEMENTARY CITY STRATEGIES

Ongoing internal coordination and collaboration will also be required to integrate and "mainstream" CFAS with relevant City-wide strategies as well as neighbourhood plans and strategies. Key City-wide plans and strategies include:

- Climate Adaptation Strategy
- Agriculture Strategy
- 10-Year Servicing Plan
- Surrey Official Community Plan
- Biodiversity Conservation Strategy
- Transportation Strategic Plan

Local level, neighbourhood plans include the Crescent Beach Local Area Plan, South Surrey Land Use Plan, and the King George Corridor – South Local Area Plan.

Additional City bylaws and policies further regulate land development in Surrey and may require amendments and updates based on CFAS Action implementation. These include the Surrey Zoning Bylaw, Drainage Bylaw, and Soil Conservation and Protection Bylaw.

Over the short-term (2020 – 2030), many of these plans and strategies will be updated as

part of regular and scheduled updates. City bylaws and policies are also regularly updated and amended. Linking and coordinating these updates to CFAS will not only support CFAS Action implementation, but also support climate adaptation planning in other areas of Surrey.

4.5 CAPACITY BUILDING AND RESOURCES

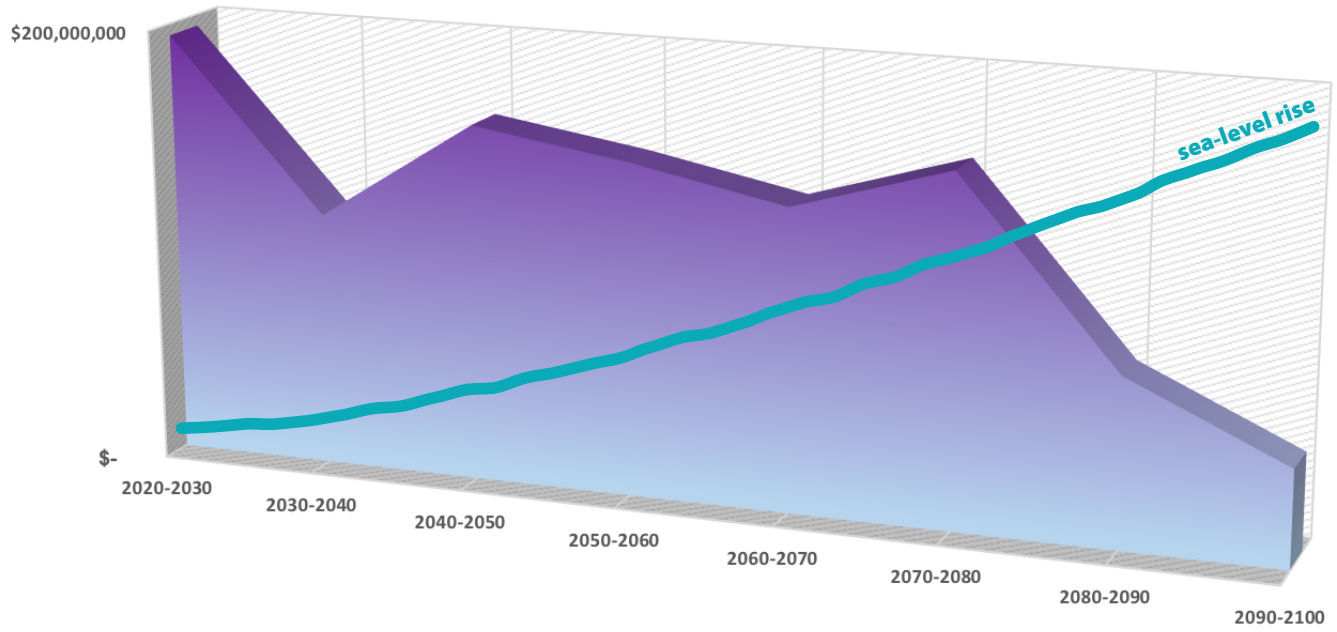
The CFAS proposes actions over the next 80 years that will help Surrey adapt to the increasing coastal flood hazards driven by sea-level rise. Implementing these actions will involve the investment of significant funds in the form of infrastructure costs, costs of communications and policy measures, and staff resources. Because these funds would not have been required in a 'sunny day' scenario (i.e., a hypothetical no sea-level-rise scenario), it is essential for Surrey to take proactive and strategic steps to realize the fund requirement.

An investment strategy should be an integral part of the implementation strategy. Some preliminary work has been done by the province in estimating the future cost of adaptation through the 'Cost of Adaptation - Sea Dikes & Alternative Strategies' report published in 2012. This report estimated the cost of adaptation to a year 2100 sea-level rise scenario to be approximately $9.5 billion (this cost is for 250 km of Metro Vancouver coastal shoreline – including $1.5 billion for Surrey's coastline downstream of the sea dams - and the Fraser River shoreline as far east as the Port Mann Bridge).

The figure below represents a conceptual forecast of costs required over the CFAS period to manage risk from sea level rise. As described above, the shorter-term actions (2020 to 2030) will collectively lay the groundwork and support the path towards the longer-term Strategic Directions outlined in the previous section. Thus, there will be a steep increase in actions in the first decade. In succeeding decades, sustained implementation activities will have to be performed so that adaptation actions occur ahead of anticipated sea-level rise and corresponding increase in coastal flood risk.

Because there are several variables related to future projects, it is difficult to estimate exact costs in certain future decades or years with any certainty. Therefore, it should be recognized that the estimate is oversimplified. Further, it should be emphasized that while Surrey will play the role of champion on several of these actions, the resulting benefits involve benefits to Surrey's neighbouring communities as well as provincial and national interests. Therefore, acquiring resources for CFAS implementation should be closely tied with regional, provincial, and national funding opportunities.

FIGURE 37: *Anticipated CFAS Implementation Cost by Decade, 2020 - 2100*



Snowy Serpentine, by Ana Fisic

5. IMPLEMENTATION

5.1 IMMEDIATE NEXT STEPS (2020-2030)

The actions identified through the CFAS process are too numerous and interdependent for all of them to be taken up immediately for implementation. Thus, it is important to prioritize actions that either address coastal flooding issues that are already present or those that lay the groundwork and point the way to a series of progressively larger, more complex, and more challenging strategic actions. A comprehensive table of all actions is provided in Appendix I.

In Chapters 4, several high-priority, short-term CFAS Actions have been identified that can be taken up for immediate implementation in the 2020-30 decade. Some of these actions, such as establishing an adaptive management pilot for sediment retention in the Mud Bay Foreshore, are intended to result in solutions that Surrey can then apply on a broader scale. Others, such as coordination with MOTI, represent processes that involve external stakeholders and typically take a relatively long time to be resolved. Finally, there are actions such as raising the 8th Avenue Bridge which address an existing flooding issue while serving as a catalyst to advance planning for larger adaptive actions in the area that will require several decades to implement.

5.2 FUNDING

A key factor in successful implementation of CFAS is Surrey's ability to keep up with funding for infrastructure investments, communications and policy measures, and staff efforts.

A funding strategy should be an integral part of the implementation strategy. While Surrey will play the role of champion on several of these actions, the resulting benefits will also accrue to Surrey's neighbouring communities as well as provincial and national interests; therefore, Surrey should plan on utilizing regional, provincial, and national funding opportunities. This opportunity is illustrated by the recent grant obtained by Surrey under DMAF for implementing several CFAS actions.

A regional avenue for funding is the Lower Mainland Flood Management Strategy (LMFMS), a collaborative effort of 25 local governments along with the provincial and federal governments, which is aimed at strengthening flood management policies and practices as well as flood protection works across the Lower Mainland. One of the objectives of the LMFMS is to develop recommendations for a secure, sustained funding model.

> "We have to spend tax dollars well. The costs of protecting and liabilities will be borne out on the shoulders of my children and my grandchildren."
>
> *– CFAS participant*

5.3 DISASTER MITIGATION AND ADAPTATION FUND (DMAF) PROJECTS

In 2018, during development of CFAS Phase 4, the Government of Canada announced the Disaster Mitigation and Adaptation Fund (DMAF) which aligned well with the objectives of CFAS. Accordingly, a DMAF funding proposal was submitted by Surrey in January 2019 with a requested grant of $187 million supported by a Return on Investment ratio of 126:1. The grant application was successful. Thirteen mitigation measures were included in the DMAF application, as shown in the map and table in Appendix II (from report to Surrey's Council dated February 11, 2019). These measures are consistent with the preferred longer-term strategic direction and provide 'low regret' investments that address current priorities. The investment sets the trajectory for infrastructure investment that will be required to keep pace with sea level rise.

5.4 RECOMMENDATIONS AND CONSIDERATIONS

The following recommendations and considerations are intended to help ensure that valuable lessons learned from the CFAS development process are carried forward to help guide future, longer-term coastal flood adaptation actions. They were developed based on an analysis of project outputs and feedback from residents, business owners, asset owners and operators, and other project stakeholders. They are also based on the recognition that the longer-term Strategic Directions entail considerable detailed planning and ongoing engagement with residents, stakeholders, and partners.

- ***Maintain value-based, participatory process through CFAS implementation, future planning, and strategy updates.***
  Participant feedback from the open houses, workshops and other outreach clearly indicates that Surrey's commitment to participatory, values-based planning was appreciated, valued, and strongly supported. Trade-offs and difficult conversations will be inevitable as the project moves towards longer-term Strategic Directions. Maintaining this commitment going forward will be a critical component of ongoing relationship building and transparent decision-making with residents and key project partners. Past participants, including CFAS Advisory Group participants, expressed a keen desire to stay involved in the project with 86% of CFAS participants indicating that they want to stay involved.

- ***Continue to use, revisit, and validate CFAS Values in longer-term work.***
  The community values identified during the first phase will be a critical component of future detailed planning and Action evaluation. It is likely that additional residents, business owners and other stakeholders who did not participate in CFAS will become involved in later phases of planning as tactical Actions are implemented and longer-term directions are refined. With new participants becoming engaged in CFAS, it will be important to continue eliciting, confirming, and refining Values throughout CFAS implementation. Furthermore, over time, and with growing awareness of the climate change-driven coastal flooding and the potential of future extreme flood events, community values and priorities may shift.

- ***Continue to address and manage behavioural barriers.***
  At project outset the CFAS Stakeholder Engagement Framework identified some potential psychological challenges, or barriers, that could be expected as a result of the scale and scope of the complex challenges posed by climate change and coastal flooding. These barriers remain and will need to be managed and incorporated in future project phases:
  - ***Protection motivation:*** The concept that stakeholders and partners may need to feel a certain degree of personal threat before they are motivated to make behavioural changes and/or trade-off decisions around CFAS directions. The behavioural challenge may also support stakeholders and partners in having an anchor bias in protection-based adaptation pathways versus other pathways (i.e., accommodate, move/managed retreat).
  - ***Psychological distancing:*** The concept that stakeholders and partners may distance themselves from large scale, longer-term challenges like climate change and

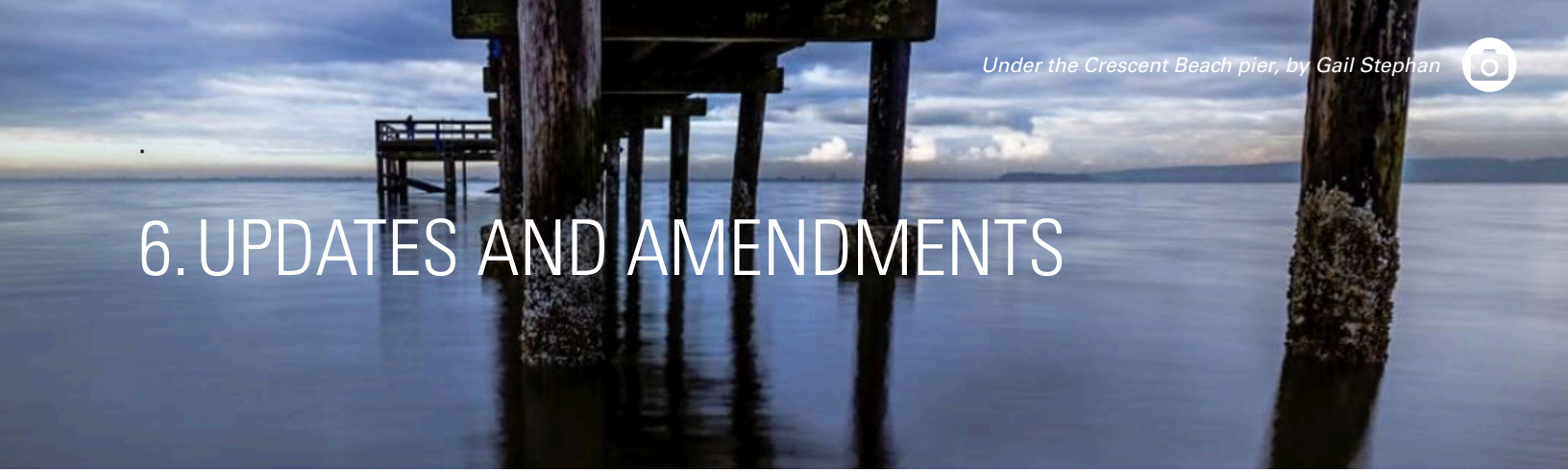
coastal sea level rise by disconnecting themselves from its implications. For CFAS, stakeholders and partners may want to underestimate the coastal flood risk they face as a means of psychologically managing the challenge.

- ***Displacing risk:*** The concept that stakeholders, particularly people living and working in vulnerable, at-risk areas will tend to direct their attention towards the most immediate concerns (e.g., winter storm protection works) while ignoring the longer-term climate and coastal flooding risks and hazards perceived to be either happening too far in the future or with associated uncertainties.

- ***Continue to engage with all coastal residents, businesses and stakeholders***
With people living, working, and recreating in the floodplain, discussions around longer-term adaptation pathways were often value-laden and sometimes challenging. Across the Planning Areas, longer-term Strategic Directions will require ongoing engagement and discussion given the cost, complexities, and trade-offs each involves. Even with longer-term flood management actions, the Planning Areas will remain in the flood hazard zone and risks will increase as sea-levels rise or if the area experiences an extreme flood event. Recognizing these factors, a carefully considered and ongoing engagement process is required with the community.

- ***Be a coastal flood management advocate.***
Surrey may not have authority over areas where CFAS stakeholders and partners have a common interest in an action, policy, or outcome. This is why Surrey should take an advocacy approach where the City works with partners and stakeholders to influence decision makers and industry groups to bring about the changes that may be required to support longer-term CFAS Strategic Directions, particularly where they may involve the "move" or "managed retreat" pathway. This advocacy work could include encouraging the Province to organize a coastal flooding and sea level rise risk management workshop with Municipal Insurance Association of BC, Real Estate Foundation of BC, financial institutions/ associations, Local Government Association of BC, West Coast Environmental Law, and other stakeholder groups with a focus on longer-term CFAS Strategic Directions.

- ***Continue to collaborate and coordinate with the Lower Mainland Flood Management Strategy.***
The City of Surrey is an active participant in the Lower Mainland Flood Management Strategy (LMFMS), a collaborative initiative with participation of 50 governmental and non-governmental agencies working together to reduce vulnerability and strengthen resilience to river and coastal flooding in the Lower Mainland region. The Fraser Basin Council (FBC) manages and facilitates the initiative. The multi-year undertaking is currently working towards developing a draft strategy which will include an assessment of priorities and options for flood mitigation, decision-making, and cost-sharing. FBC was an active partner in the CFAS process and is keen to integrate and link CFAS with the LMFMS initiative.



Under the Crescent Beach pier, by Gail Stephan

6. UPDATES AND AMENDMENTS

6.1 ADAPTIVE MANAGEMENT

Given the uncertainties surrounding climate change and sea level rise in particular (i.e., it could happen faster, it could be more severe, it could happen more slowly), the larger CFAS process and strategic actions are grounded in an adaptive management approach. This approach recognizes that planning in such a dynamic context needs to be flexible and responsive to new drivers and considerations as they emerge. For CFAS, this includes:

- ***New data*** (and new changes detected in the data)
- ***New policies/directives*** (global, national, provincial, regional, local)
- ***New participants and collaborations*** (new partners and stakeholder taking new actions)
- ***New funding*** (and the requirements/ opportunities that come with them)

FIGURE 38: *CFAS and Adaptive Management Cycle*

Note: modified from Olson, E., Murray C. and Tamburello N. (2017)

> "It's sobering. It's a reality check for sure. I'm more inclined for a slow approach, an incremental approach until we see the acceleration curve we're looking at [with sea level rise]. We need to look at change in five-year horizons."
>
> *– CFAS participant*

6.2 TRIGGERS AND THRESHOLDS

The CFAS has been developed on the basis of information and assumptions related to climate change that were obtained from multiple sources. For example, a climate change-related floodplain review of Serpentine, Nicomekl, and Little Campbell Rivers was based on projections of sea level rise provided by the Province and ground subsidence data from a Surrey-initiated study. The information obtained from such sources is based on a dynamic dataset of prior physical events and is thus subject to change.

In accordance with the adaptive management approach used for the CFAS, it is necessary to make adjustments to the CFAS when new data is available. Some triggers and thresholds which should be monitored for change are listed below. Any significant change in such triggers should result in a review of and, if necessary, adjustments to the CFAS.

> "I live at Crescent Beach. Being a homeowner I'm a little concerned about losing property, but sea level rise is just going to increase, the severity of the storms and water levels will increase."
>
> *– CFAS participant*

FIGURE 39: *CFAS Triggers and Thresholds*

TRIGGER	THRESHOLD
Sea level rise projections	Newer estimates of sea level rise are significantly different than prior estimates
Ground subsidence estimates	Newer studies find subsidence that is substantially different than that found in the 2011 study initiated by Surrey
Precipitation estimates	Newer estimates vary significantly from those used in existing studies
Storm or flow frequency	Hydrologic studies find that frequency of storms or flows has changed significantly than those used for CFAS development
Estimate of damages	Intervening events such as new developments result in damage estimates that are significantly different than those used during CFAS development)

6.3 UPDATES

As a relatively new and rapidly evolving issue, the CFAS will be a living document to be revisited periodically and updated as appropriate. The reviews should be prompted by an external event or every 5 years. The updates required may be major or minor.

Major updates are those which will have a significant impact on the interests of Surrey or other stakeholders. For example, an adjustment to the year 2100 sea level rise projections will significantly affect the underlying assumptions behind CFAS Actions and would necessitate a major update.

A minor update is one which does not materially affect the interests of any party. For example, actions recommended in the current version of the CFAS are assigned to a "City Lead." Changes to the City Lead (e.g., from Engineering to the City Manager's Office) would be a minor update.

7. KEY BACKGROUND REPORTS

Ausenco-Sandwell (2011). Climate Change Adaptation Guidelines for Sea Dykes and Coastal Flood Hazard Land Use: Guidelines for Management of Coastal Flood Hazard Land Use. Report prepared by Ausenco-Sandwell for BC Ministry of Environment. 45 pp.

City of Surrey (2018). Surrey Coastal Flood Adaptation Strategy (CFAS) Engagement Summary Phase 1-3. Available from: https://www.surrey.ca/files/CFAS_Engagement%20Report_05092018.pdf

City of Surrey (2018). Surrey Coastal Flood Adaptation Strategy (CFAS) Primer Part II: Options Chapter 1: Mud Bay. Available from: https://www.surrey.ca/files/CFAS-primerpart2.pdf

City of Surrey (2018). Surrey Coastal Flood Adaptation Strategy (CFAS) Primer Part II: Options Chapter 2: Crescent Beach. Available from: https://www.surrey.ca/files/CFAS-primerpart2CB.pdf

City of Surrey (2018). Surrey Coastal Flood Adaptation Strategy (CFAS) Primer Part II: Options Chapter 3: Semiahmoo Bay. Available from: https://www.surrey.ca/files/CFAS-primerpart2SB.pdf

City of Surrey (2017). Surrey Coastal Flood Adaptation Strategy (CFAS) Primer Part I: Coastal Flooding in Surrey. Available from: https://www.surrey.ca/files/CFAS-primerpart1.pdf

EGBC (2018). Legislated Flood Assessments in a Changing Climate in BC, Version 2.1. Engineers & Geoscientists British Columbia, Burnaby, BC. 192 pp.

KPA Engineering Ltd. (1994). Floodplain Mapping Program Serpentine and Nicomekl Rivers. Design Brief. Prepared by KPA Engineering Ltd. for B.C. Environment Water Managament Division.

NHC (2015). Serpentine & Nicomekl River Climate Change Floodplain Review Phase 2. Draft Report. Prepared for City of Surrey.

Olson, E., Murray C. and Tamburello N. (2017). Reducing Uncertainties in Managing in British Columbia Waters: Applying an Adaptive Management Mindset on the South, Central and North Coasts. Salish Sea Ecosystem Conference. 43. Available from: https://cedar.wwu.edu/ssec/2016ssec/protection_remediation_restoration/43

TRE Canada (2011). Final Report on Ground Movement within the City of Surrey using SqueeSAR.

Urban Systems Ltd. (2009). Crescent Beach Climate Change Adaptation Study.

Several other related documents are available under ' Resource Materials Prepared by CFAS Team' here: https://www.surrey.ca/city-services/21071.aspx

Appendices

Appendix I: Action Implementation

Appendix II: DMAF Actions

Appendix III: Technical Background Document

APPENDICES

APPENDIX I: ACTION IMPLEMENTATION (to be included in Final Strategy Document)

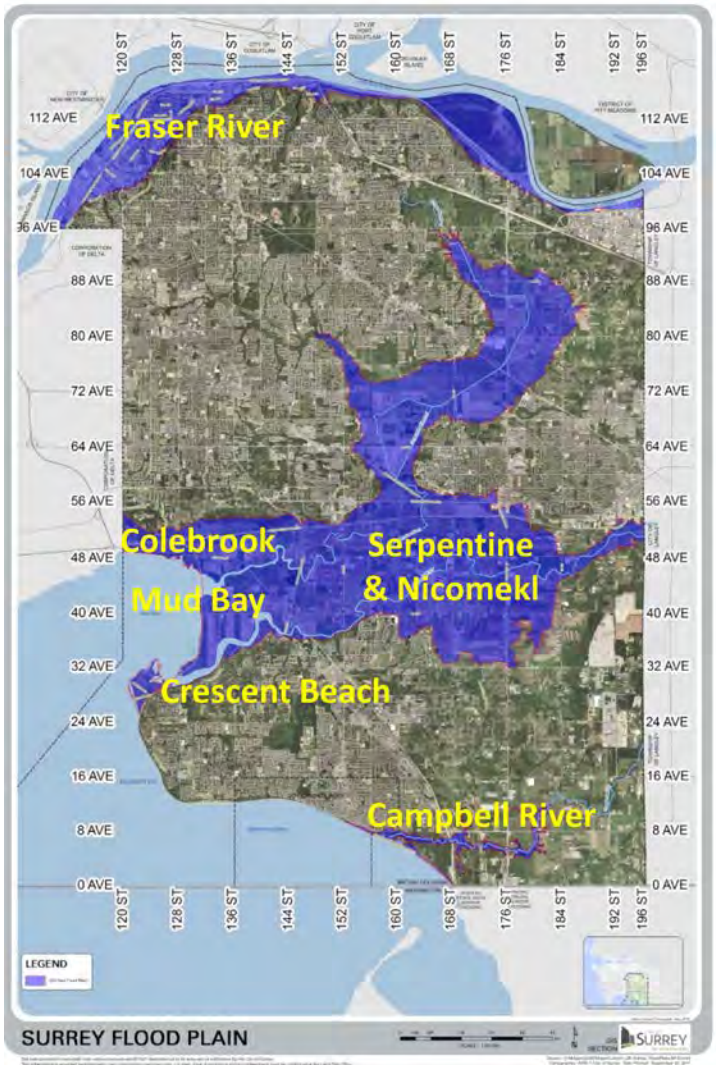
APPENDIX II: DMAF ACTIONS

APPENDIX III: TECHNICAL BACKGROUND DOCUMENT (to be included in Final Strategy Document)

City of Surrey – Colebrook Dyke Upgrades

One third of City of Surrey is within a floodplain and is bordered by the Fraser River to the north and the Salish Sea to the southwest. While regional work in BC is developing a strategy focusing on the Fraser River, Surrey has completed two years of stakeholder engagement in a process to develop the Surrey Coastal Flood Adaptation Strategy (CFAS), part of the Municipalities for Climate Innovation Program. It addresses 20% of the City's land and critical infrastructure of national, regional and local significance that is at risk from sea level rise within Surrey.

Impacts cover the areas depicted as: Colebrook, Mud Bay, Serpentine & Nicomekl, Crescent Beach and Campbell River including Semiahmoo First Nation.



The first phase of Dyke upgrades for the most vulnerable section of Surrey's coast will be shovel ready to commence in 2019. The total value of the proposed Colebrook Dyke upgrades is $20M.

Challenging soil conditions require construction to be phased over five years, to gradually build a wider dyke up to four metres above the surrounding grade, allowing the foundation to adjust to the additional weight.

Colebrook Dyke Existing Crest

The Colebrook Dyke protects critical infrastructure of:

- Hwy 99 regional link to Peace Arch Border
- BC Hydro's primary transmission line to U.S.A.
- Regional sewer and watermains

Colebrook Dyke showing Provincial Guidelines for current (lower black line) and future year 2100 elevation (upper black line) targets

City of Surrey – Colebrook Drainage Pump Station

The Colebrook Pump Station is located on the north bank of the Serpentine River, west of Highway 99, adjacent to Mud Bay. Its purpose is to mitigate coastal flooding by draining the water from Peacock Brook and connecting ditches into the tidally-influenced Serpentine River during high water levels. The existing station was built in 1990 and has now approached the end of its service life and is in pressing need of replacement.

The existing station is well below current flood construction levels and is vulnerable to flood damage in a significant coastal flood. The new pump station design incorporates aspects of climate change and sea level rise adaptation.

Existing Colebrook Drainage Pump Station

Only two out of three pumps are operational and replacement parts are no longer available. The new station will reinstate full pumping capacity and provide for future climate resilience by leaving room for additional future capacity. The overall design of the pump station accommodates observed and projected changes in the environment such as:

- Regional ground subsidence has resulted in an elevation differential between the agricultural fields and base flow water levels controlled by the pump station. The new pump station accommodates the existing elevation differential, as well as to provide flexibility to gradually lower the pump settings to accommodate observed ground subsidence over the life of the pump station;
- The current dyke crest elevation at the pump station of 3.2m will not be sufficient to meet the increasing overtopping requirements imposed by future sea level rise. The updated pump station will be compatible with future dyke upgrades (estimated at 4.84 to 5.13m by 2100).

The project budget is $5 million and is shovel ready. The construction will be phased to commence after the Colebrook Dyke construction is completed. The updated pump station will provide the following community benefits:

- Improved flood protection and drainage and reduced soil salination of agricultural land in Surrey lowlands;
- Proactive climate change adaptation to allow for increased sea levels and precipitation;
- Increased protection of nationally critical infrastructure such as Hwy 99 and Bulk Power Transmission Lines.

Mouth of the Serpentine River with Colebrook Drainage Pump Station (view from south)

City of Surrey –Serpentine Sea Dam

Over one hundred years ago, early settlers constructed two dams to reclaim fertile land for agriculture, provide a source of irrigation and provide transportation crossings for the Semiahmoo Trail.

Throughout the hundred year service life of the dams, Surrey's population has increased by 500,000 and significant regional infrastructure has been built behind the dams in low-lying areas.

The Serpentine Sea Dam will be over topped as a result of projected sea level rise from Climate Change and is a significant coastal flood vulnerability. The dam also poses the largest seismic vulnerability to the City's Drainage System. The complexity of rebuilding the dam after an earthquake would take many years and would be devastating for the community. It would damage the local and regional transportation network, impacting over 200,000 daily trips and billions of dollars of goods movement.

Serpentine Sea Dam at high tide with gates closed

Preliminary design of the dam is complete and incorporates climate and seismic resilience with a higher crest elevation, adjustable flood gates to adapt to rising water levels and a robust foundation and dyke tie-in to resist an extreme earthquake. Community consultation on long-term coastal climate change has identified the preferred locations of the dams. The Class D budget required to replace the dams is $15M. Discussion is underway with Ministry of Transportation and Infrastructure to integrate with Provincial plans.

Today, the dams support a number of important services to the community including:

- *Flood Control*: Keeps out storm surges and high tides from backing up the rivers and flooding 2,000 Ha upstream lands;
- *Irrigation*: Prevents brackish water from mixing with fresh water, supporting 38 authorized water licenses to extract up to 129.6 million cubic metres per year;
- *Transportation*: Provides water crossing for the King George Greenway and protects upstream bridges;
- *Utility and Energy*: Protects upstream utilities.

Additional community benefits of replacement structures will be:

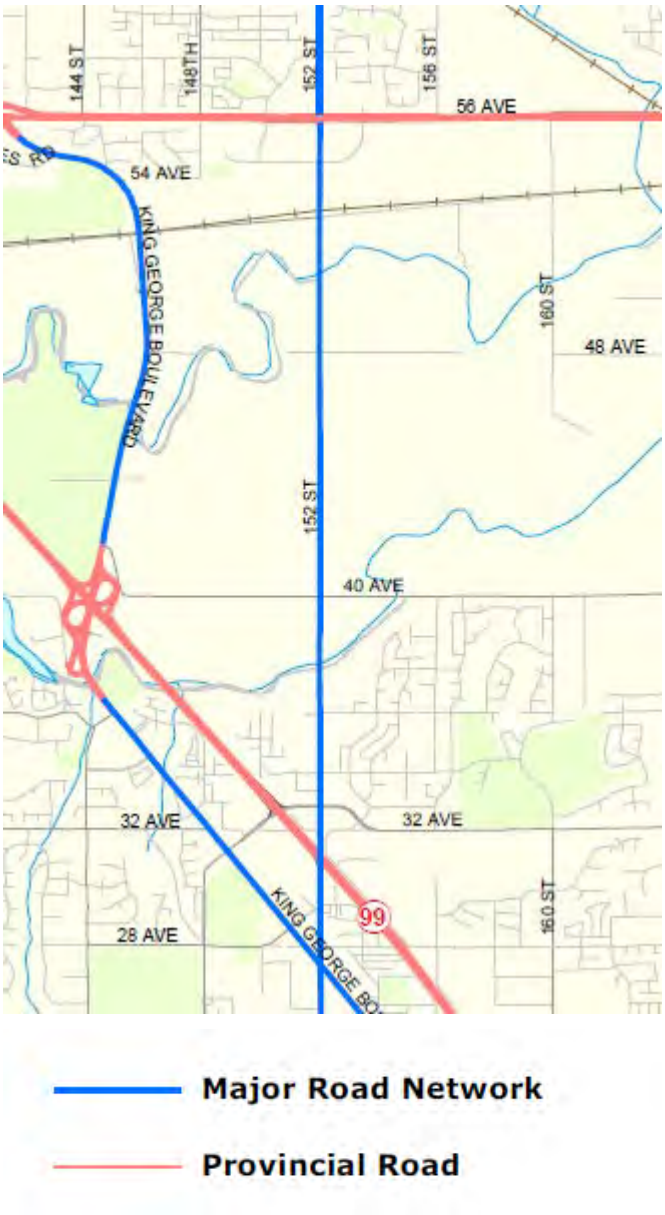
- Better fish passage to upstream habitat;
- Improved drought management;
- Movement for cyclists and pedestrians.

Serpentine Sea Dam at low tide with gates open

City of Surrey – 152 Street Upgrades

152 Street is a key transportation corridor in the City of Surrey. It is one of only six routes linking the communities in North Surrey with South Surrey/White Rock (114,000 pop). 152 Street supports approximately 21,800 vehicles per day. 152 Street is also part of TransLink's Major Road Network, acting as a key corridor for goods movement, emergency response, and public transit. 5,150 people per day use public transit on 152 Street – over 1.5million people per year. 152 Street also provides direct connections to the corridors for the Canada/U.S. border crossings.

152nd Street is a key corridor for the movement of goods and people



From 40 Avenue and 50 Avenue, 152 Street is 2-lanes, and built at grade in the floodplain of the Nicomekl River, with no facilities for walking or cycling. Studies have demonstrated this section of 152 Street is a high risk for flood hazards.

Excerpt from the Surrey Coastal Flood Adaptation Strategy (CFAS) April 2018 https://www.surrey.ca/city-services/19888.aspx

A significant flood along this road alignment would have major economic impacts, restrict the region's ability to respond to emergencies and impact the flow of vehicles and people.

The City has plans to widen and raise 152 Street to meet new standards for flood resilience. 152 Street would be widened to 4-lanes including cycling facilities and turning lanes for farm access. Benefits include:

- 152 Street raised to protect against flood risk
- Addition of multi-modal facilities for cyclists
- Improved road capacity for cars, public transit and goods movement

City of Surrey – Nicomekl Riverfront Park

The Nicomekl River is one of three significant river systems in Surrey that are impacted by sea level rise. For the majority of its length, it is bounded on both sides by the Agricultural Land Reserve. Downstream of the crossing at 40th Avenue, the river is bounded on its southern bank primarily by parkland to Mud Bay.

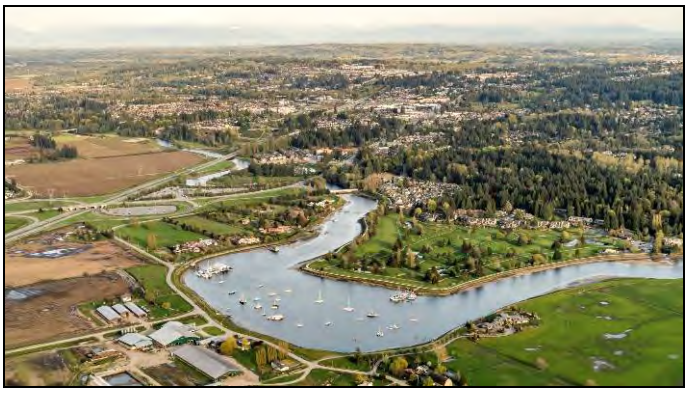


Photo: Coastal portion of Nicomekl River looking upstream

The City has acquired land and the final pieces are currently being secured to provide a continuous 3 km section of parkland along the south side of the River. Parks, Recreation and Culture (PRC) staff have commenced a planning and consultation process to develop the Nicomekl Riverfront Plan which will include concept plans for two larger park sites on either side of King George Boulevard. The approximate park site stretches from the Sea dam at Elgin Road east to 40 Ave. This aligns with the PRC Strategic Plan, which states "*parks will play an increasing role in the mitigation of the impacts of climate change*".

In close proximity to coastal waters, the Nicomekl Riverfront Park is an ideal place to employ innovative climate adaptation and mitigation measures and a test site for design related to sea level rise due to climate change.

Possible adaptation and mitigation measures and their community benefits are:

- *Mitigate flooding* by accepting/conveying flood waters through the park using soft drainage features such as ponds, bioswales, riparian buffers, rain gardens and wetlands;
- *Adapting* ecosystem to be flood tolerant through the addition of wetlands;
- *Improve air and water quality* through implementation of unique ecosystems (wetland, bog, meadow and forest) and biological drainage measures (filtration strips and ponds); and
- *Protect and enhance existing habitat and ecosystems* with restoration plantings, habitat islands, and by limiting public access to natural areas.

Climate adaptation and mitigation measures will be multifunctional, layered with social and recreational spaces, environmental connectivity, and public art and heritage elements to offset impacts from sea level rise and coastal flooding. Additionally, the park may serve as a satellite location of the Surrey Nature Centre by delivering educational programs about climate awareness to improve community resilience. The Park will be a place for daily activity (picnics, walking loops) and a refuge from the urban realm, with access to and onto the river. The total project value is $10 million over ten years.

Photo: Nicomekl Riverfront Park project area outlined in red

City of Surrey – Nicomekl King George Bridge & Sea Dam

The King George Boulevard Nicomekl River Bridge comprises of two separate structures south of the King George Boulevard and Highway 99 Interchange in Surrey, BC. The first structure carries two lanes of traffic (one southbound and one northbound) over the Nicomekl River. A bailey bridge is located immediately east (upstream) of the bridge and carries a second northbound lane of the King George Highway over the Nicomekl River. Built in 1939, the bridge is 56m long and comprises 11 timber trestle spans.

The Nicomekl Bridges provide a key link in the transportation network in Surrey and Metro Vancouver. King George Boulevard is one of only six north south connections between South Surrey and White Rock (total 114,000 pop.) and the rest of the Surrey (450,000 pop). It is a truck route for goods movement, emergency response corridor and forms part of TransLink's frequent transit network and Major Road Network.

The bridges are maintained by the Ministry of Transportation and Infrastructure (MoTI). MoTI have indicated that the life spans of the bridges are around 70 years old and that they are reaching the end of their serviceable life. The City has been working with MoTI to develop a plan to replace the existing bridges with a new modernized six lane structure that reserved transit vehicle lanes and multi-use path in each direction for pedestrians and cyclists.

Due to the ages of the bridges they are susceptible to multiple natural hazards. The existing bridges are projected to be overtopped due to sea level rise and challenging soil conditions making the bridges vulnerable in an earthquake. An adjacent sea dam that mitigates coastal flooding is also increasingly becoming vulnerable to overtopping. Rebuilding the bridges and sea dam after an earthquake would take years and interrupt an essential north-south connection in Surrey and White Rock.

An innovative cost-saving solution that adapts multiple assets for a changing climate is proposed. A new resilient structure is proposed that combines the function of the sea dam structure and needs for a King George Boulevard bridge with a robust foundation that will be fully functional after an extreme earthquake.

The combined replacement sea dam and bridges structure support a number of important services to the community including:

- *Flood Control*: Keeps out storm surges and high tides from backing up the rivers and flooding 2,000 Ha upstream lands;
- *Irrigation*: Prevents brackish water from mixing with fresh water, supporting 52 authorized water licenses to extract up to 4.6 million cubic metres per year; and
- *Essential Transportation*: Provides the King George and Elgin Road water crossings over the Nicomekl and Serpentine with an estimated traffic volume of 26,000 vehicles per day.

Additional community benefits of replacement structures will be:

- Enhanced wildlife and pedestrian access across transportation corridors. Supports connection to a planned 6 km continuous water path to offset reduced beach access from sea level rise and coastal flooding;
- Better fish passage to over 100 km of habitat;
- Improved drought management; and
- Accessible design for cyclists and pedestrians.

Existing Nicomekl Bridge

City of Surrey – Crescent Beach Storm Sewer

Situated in South Surrey, Crescent Beach is a dynamic environment that has seen many changes over time. It formed over centuries through the deposit of sediment from coastal bluff erosion. First Nations inhabited the area for thousands of years prior to colonization. In the early 20th century, Crescent Beach began to establish itself as a summer seaside cottage resort. In recent decades, the historic cottages have been gradually converting to permanent and more formal residences.

Today, a combination of sandy porous ground, recent redevelopments and sea level rise is impacting the performance of the outdated groundwater drainage system in the community and impact the safety of approximately 1,400 residents as a result of increasing winter surface ponding impacting the road network.

In 2009, a Crescent Beach Climate Change Adaptation Study was completed to develop the optimal drainage servicing strategy for the area. It was developed with extensive community consultation and provides direction on drainage servicing needs in a changing climate.

Surface ponding following a rainfall event in May 2008

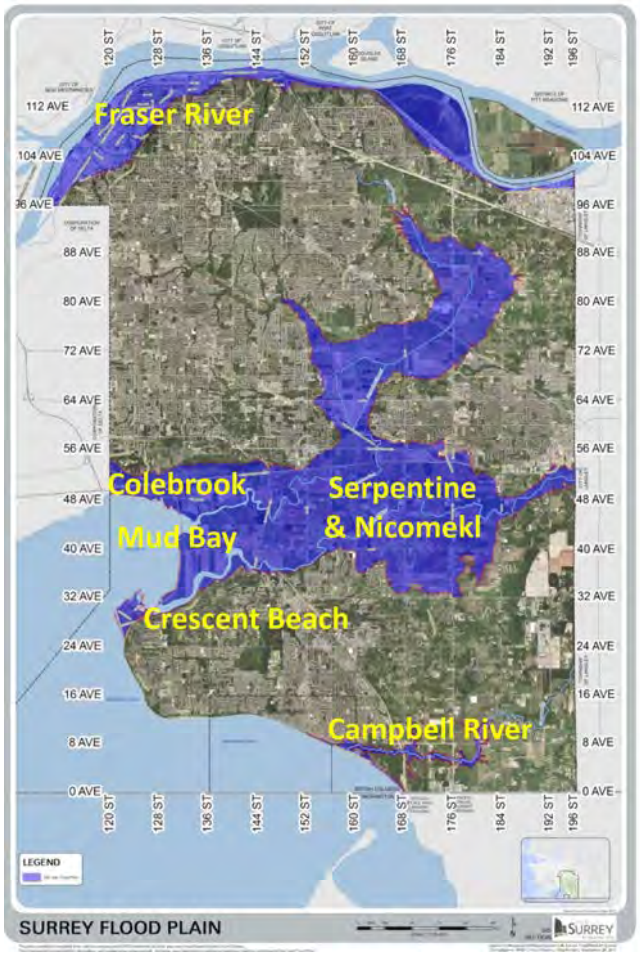
Through the Study, a perforated storm sewer system was chosen as the preferred drainage improvement strategy for Crescent Beach, in conjunction with raising the ground and road. The intent of a perforated storm sewer system is to provide an efficient conveyance system that can manage both stormwater runoff and rising groundwater levels. In the summer (when the groundwater table is typically low), stormwater runoff that enters the sewer system will have an opportunity to exfiltrate out of the pipe through the perforations and recharge the groundwater table. On the other hand, in the winter (when the groundwater table is typically high), groundwater is able to enter the perforated storm sewer system and is conveyed to the Dunsmuir Channel. During winter, the system maintains a relatively constant groundwater table elevation and manages water efficiently to mitigate coastal flooding. Maple Drainage Pump Station was upgraded to accommodate the additional water collected by the drainage system in 2012.

Proposed perforated Storm Sewer System, 2008

The adaptation work is being implemented in phases. Total remaining phases for years 2019-2028 is valued at $11M, including road upgrades to provide more resilient transportation and builds on $9M of adaptation work to-date towards implementing the 2009 Study.

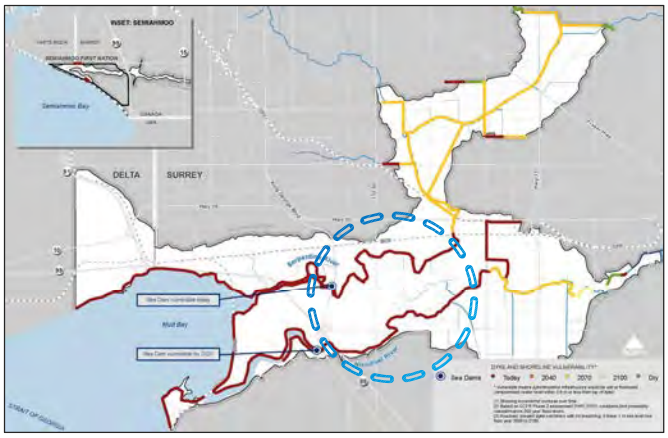
City of Surrey – Dyking – Lower Nicomekl and Serpentine Dyke Upgrades

One third of City of Surrey is within a floodplain and is bordered by the Fraser River to the north and the Salish Sea to the southwest (see map below). While regional work in BC is developing a strategy focusing on the Fraser River, Surrey has completed two years of stakeholder engagement in a process to develop the Surrey Coastal Flood Adaptation Strategy (CFAS), part of the Municipalities for Climate Innovation Program. It addresses 20% of the City's land and critical infrastructure of national, regional and local significance that is at risk from sea level rise within Surrey.



Impacts cover the areas depicted as: Colebrook, Mud Bay, Serpentine & Nicomekl, Crescent Beach and Campbell River including Semiahmoo First Nation.

A large portion of the dyking system in the floodplain is already vulnerable to flooding, as depicted by red lines on the map below. Lower reaches of Nicomekl and Serpentine Rivers (represented by the blue dashed circle on the map) are among the most vulnerable.



This project will upgrade the dyking system east of 152nd St to increase resilience of sea level rise and protect Surrey lowlands from coastal flooding. It will focus on 3km reach of the Nicomekl River between Elgin Road and 40 Ave Pump Station and isolated low points elsewhere along the two rivers.

The Nicomekl and Serpentine Dykes protect:

- Hwy 99 regional link to Peace Arch Border
- BC Hydro's primary transmission line to U.S.A.
- Agricultural lands
- 152nd Street and other transportation links

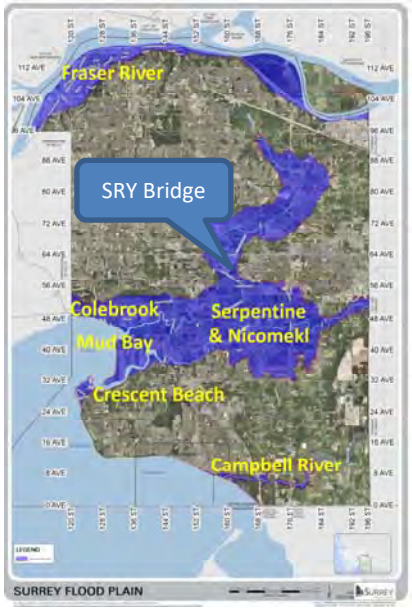
Nicomekl River Dyke during high water levels on Dec 13, 2018

City of Surrey – SRY Rail Link Serpentine Bridge Replacement

One third of City of Surrey is within a floodplain and is bordered by the Fraser River to the north and the Salish Sea to the southwest. While regional work in BC is developing a strategy focusing on the Fraser River, Surrey has completed two years of stakeholder engagement in a process to develop the Surrey Coastal Flood Adaptation Strategy (CFAS), part of the Municipalities for Climate Innovation Program. It addresses the coastal floodplains—20% of the City's land—and critical infrastructure of national, regional and local significance that is at risk from sea level rise within Surrey.

Impacts cover the areas depicted as: Colebrook, Mud Bay, Serpentine & Nicomekl, Crescent Beach and Campbell River including Semiahmoo First Nation. Surrey was recently successful in a merit-based grant program from Infrastructure Canada to improve the resilience of crucial infrastructure to coastal flooding, with total value of $187M. Projects include upgrades to the Colebrook and Serpentine-Nicomekl dyking systems, a riverfront park, sea dam and bridge replacements, drainage and pump station upgrades, and foreshore enhancements.

Surrey's extensive floodplain areas



This project aims to replace an existing ageing 40m long timber Serpentine SRY railway bridge, which is vulnerable to overtopping and floatation in flood events.

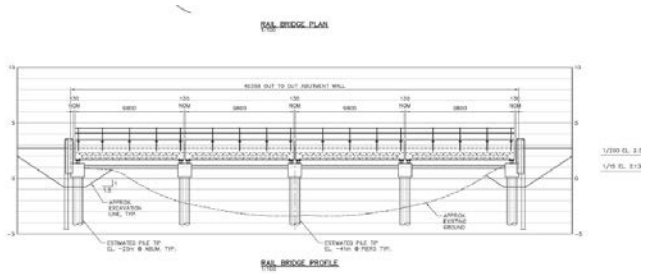
The existing bridge is a low point in the Serpentine-Nicomekl flood control system, which could impact approx. 1 km^2 of adjacent land in case of failure.

Aerial image of the existing Serpentine railway bridge

While the nearby dykes are being upgraded to the Provincial guidelines and flood safety standards, the Serpentine SRY railway bridge remains susceptible to flooding, exposing rail transportation and nearby agricultural fields to the hazard.

Therefore, the proposed single-track Serpentine SRY Rail Link bridge replacement and integration with surrounding dyking updates aims to address this weakness of the system. Additionally, the new structure will provide benefits in increased resilience to seismic and drought hazards. The total value of the proposed bridge replacement is $3M, with a $750,000 contribution from the Federal government secured.

Proposed design of bridge replacement



Project will protect the economic, community, agricultural and infrastructure values. It will provide the community co-benefits in protecting the economy (uninterrupted freight and heritage railway traffic), ensuring worker safety and sustaining goods movement.

City of Surrey – Burrows Drainage Pump Station Upgrade

One third of City of Surrey is within a floodplain and is bordered by the Fraser River to the north and the Salish Sea to the southwest. While regional work in BC is developing a strategy focusing on the Fraser River, Surrey has completed two years of stakeholder engagement in a process to develop the Surrey Coastal Flood Adaptation Strategy (CFAS). It addresses 20% of the City's land—and critical infrastructure of national, regional and local significance that is at risk from sea level rise within Surrey.

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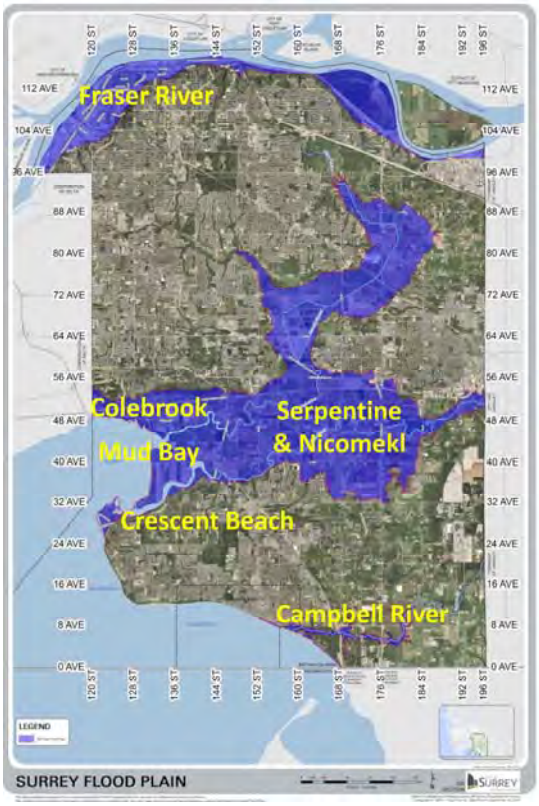
Surrey's extensive floodplain areas

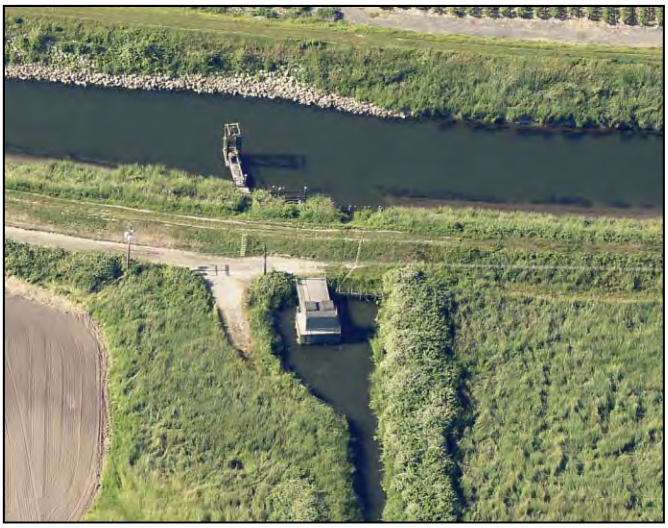


The Burrows Drainage Pump Station is located on the south bank of the Nicomekl River, west of Pacific Highway (Highway 15). Its purpose is to control ditch water levels in the Burrows Drainage Catchment, a part of the Serpentine and Nicomekl floodplain area.

Regional ground subsidence has resulted in an elevation differential between the agricultural fields and base flow water levels controlled by the pump station. The upgrades accommodate the existing elevation differential, as well as to provide flexibility to gradually lower the pump settings to accommodate observed ground subsidence.

The existing pump station plays a double role of managing flooding by draining the ditch waters into the Nicomekl River during heavy rain periods, and providing irrigation benefits during dry summer season (typically June to September) by pumping water in a reverse direction out of the Nicomekl River into the low-lying ditch network within the Burrows Drainage Catchment area.

Aerial image of the existing Burrows Drainage Pump Station



A new pump will be installed to improve the resilience of the, mainly agricultural, floodplain area to flooding. Additionally, the new pump will be less vulnerable to earthquake impacts and will mitigate the drought risk.

The new pump will be fish friendly, thus reducing the overall mortality of fish passing through the pumps.

The total value of the proposed upgrades is $1.5M.

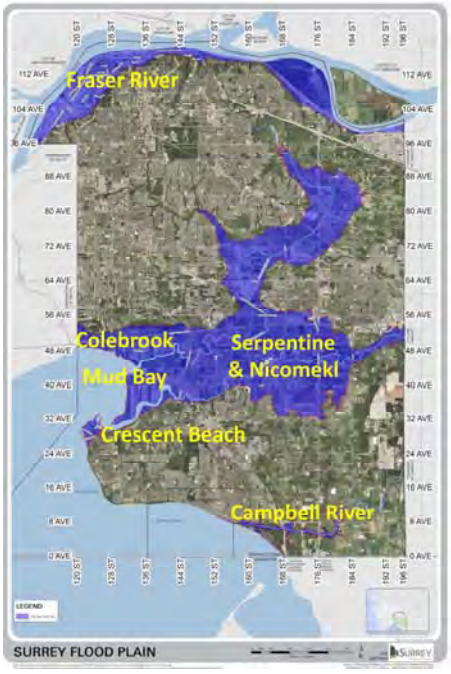
Project will protect the economic, community, agricultural and infrastructure values. It will provide the community co-benefits in sustained agricultural productivity and water quality, and proactive climate change adaptation.

City of Surrey – Stewart Farm Sanitary Pump Station Upgrades

One third of City of Surrey is within a floodplain and is bordered by the Fraser River to the north and the Salish Sea to the southwest. While regional work in BC is developing a strategy focusing on the Fraser River, Surrey has completed two years of stakeholder engagement in a process to develop the Surrey Coastal Flood Adaptation Strategy (CFAS), part of the Municipalities for Climate Innovation Program. It addresses the coastal floodplains—20% of the City's land—and critical infrastructure of national, regional and local significance that is at risk from sea level rise within Surrey.

Impacts cover the areas depicted as: Colebrook, Mud Bay, Serpentine and Nicomekl, Crescent Beach and Campbell River including Semiahmoo First Nation. Surrey was recently successful in a merit-based grant program from Infrastructure Canada to improve the resilience of crucial infrastructure to coastal flooding, with total value of $187M. Projects include upgrades to the Colebrook and Serpentine-Nicomekl dyking systems, a riverfront park, sea dam and bridge replacements, drainage and pump station upgrades, and foreshore enhancements.

Surrey's extensive floodplain areas



The purpose of this project is to improve the flood resilience of a sanitary pump station, located in the Mud Bay floodplain area.

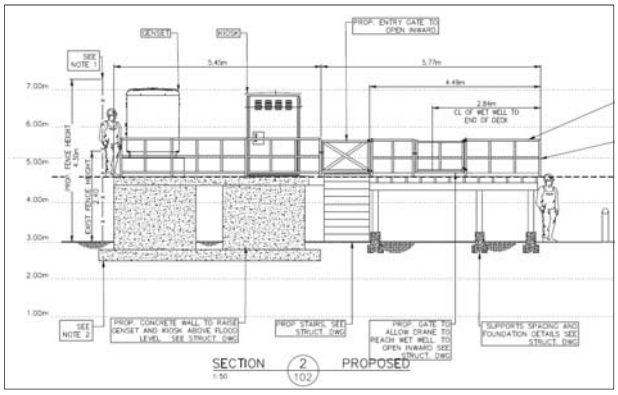
The existing liquid waste lift station is located at low elevation on the south bank of the Nicomekl River. This lower part of the river is tidally influenced, putting the sanitary pump station at risk of being submerged by flood waters during a flood event, which could be damaging to the functioning of the station or cause physical damage to its structures.

Location of the Stewart Farm Sanitary Pump Station on the south bank of the Nicomekl River

This project will raise the existing sanitary pump station infrastructure and floodproof to sustain a 200-year design flood event over the life of the infrastructure. The upgrades will not alter the pump capacity, design, function or operation.

The estimated value of the proposed upgrades is $650,000.

Design of new floodproofed sanitary pump station



Project will protect the economic, environmental and infrastructure values. It will provide the community co-benefits in sustaining sanitation services, ensuring worker safety, and preserving water and environmental quality in flood events.

City of Surrey – Campbell River Pedestrian Bridge Replacement

One third of City of Surrey is within a floodplain and is bordered by the Fraser River to the north and the Salish Sea to the southwest. While regional work in BC is developing a strategy focusing on the Fraser River, Surrey has completed two years of stakeholder engagement in a process to develop the Surrey Coastal Flood Adaptation Strategy (CFAS), part of the Municipalities for Climate Innovation Program. It addresses the coastal floodplains—20% of the City's land—and critical infrastructure of national, regional and local significance that is at risk from sea level rise within Surrey.

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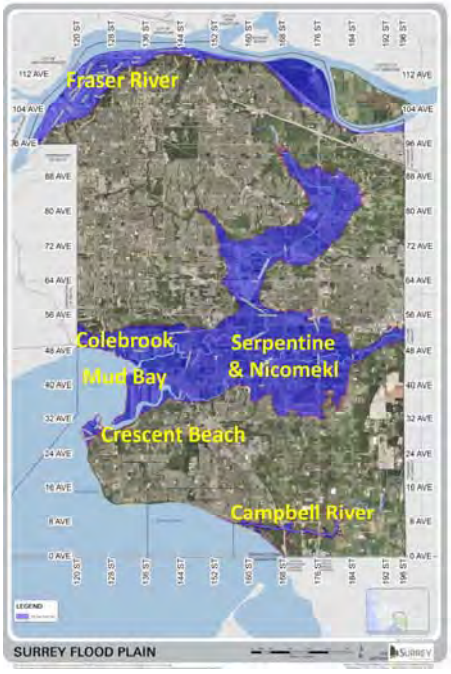
Surrey's extensive floodplain areas



The pedestrian bridge over the Campbell River connects Semiahmoo First Nation with City of Surrey and the City of White Rock.

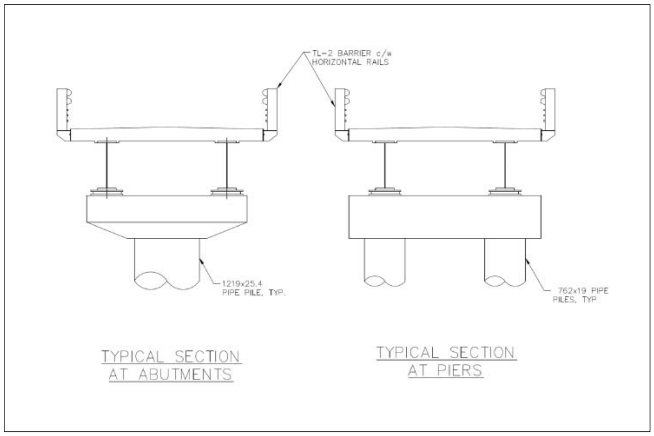
The existing 80m bridge has reached the end of its service life and is at risk of overtopping and floatation in the event of flooding and high water levels in the Campbell River. Currently, the bridge only allows for pedestrian traffic.

Aerial photograph of the Campbell River pedestrian bridge, with Marine Drive/8th Avenue on the left hand side, and Semiahmoo First Nation lands on the right hand side

This project will replace the existing bridge with a new structure, which will be built in accordance with the current flood protection standards and allow for 1m of sea level rise. Additionally, the new structure will include emergency vehicle access provisions—but will otherwise be only open to local pedestrian traffic. The new bridge will be resilient to earthquakes.

The total value of the proposed bridge replacement is $3.8M.

Preliminary typical sections of the replacement bridge



Project will protect the community and infrastructure values. It will deliver community benefits by providing an alternative emergency access route and safely connecting local residents with nearby services and amenities.

City of Surrey & Delta – Boundary Bay Foreshore Enhancements

Effectively adapting to sea level rise requires that Canada innovate with new local techniques. The foreshore enhancements take a collaborative approach to increase adaptive capacity.

Building on work led by numerous partners, an innovative, nature based solution will be implemented at two locations in Boundary Bay to mitigate coastal squeeze damages and coastal flood risk associated with climate change. The "Living Dike" concept, developed with technical, coastal engineering, government and First Nations input since 2016, will be used to enhance habitat and other ecological, cultural and aesthetic values of intertidal and nearshore areas while providing flood regulation services.

Existing salt marsh at risk from coastal squeeze in Boundary Bay

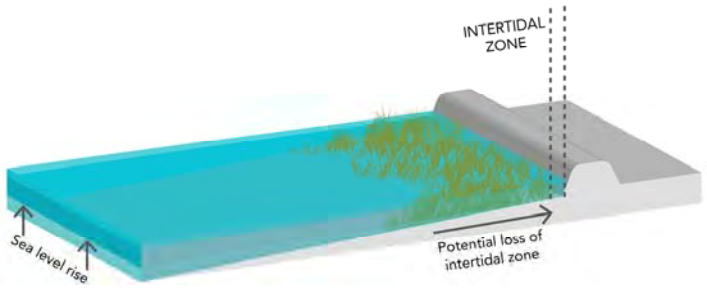
The works will be installed on the foreshore in front of two legislated dykes: one operated by City of Delta and one operated by City of Surrey. Working with natural coastal processes, sediment will be added to mimic natural marsh formation and establish a gentle, vegetated slope. The method will involve creating marsh islands and tidal channels and gradually increasing elevation to adapt to sea level rise of up to 1m. The complex foreshore texture will enhance biodiversity, reduce wave energy and offset the negative ecosystem impacts of coastal squeeze, as documented in multiple studies from coastal jurisdictions in the United States. It will enhance blue carbon sink functionality of the mud flat, to mitigate greenhouse gas emissions.

The City of Surrey Living Dike works will create flood mitigation and ecosystem services for up to 100 m of shoreline adjacent to the Mud Bay Park and include interpretive information. This will complement structural upgrades to the Colebrook Dyke Project in Surrey.

The City of Delta is prioritizing upgrades to 300 to 500 metres of its diking network in Boundary Bay. The original proposal had a flatter slope of 3:1 and granular fills, but DMAF funding will allow foreshore enhancements to incorporate Living Dike concepts for a portion of the project.

The Living Dike restoration methodology is based on successful salt marsh restoration work carried out on Vancouver Island by Project Watershed and K'ómoks First Nation and will involve application of sediment and follow-up monitoring and planting in three to five year cycles. Previous habitat mapping prepared by Friends of Semiahmoo Bay, Ducks Unlimited, City of Surrey and City of Delta will provide supporting information.

Coastal squeeze intertidal impacts (source City of Surrey)



New opportunities to obtain seabed modelling data from the Geological Survey of Canada and shallow water LiDAR from Canadian Hydrographic Services (part of DFO) are being explored. The subject area is within a provincial Wildlife Management Area and the traditional territories of Semiahmoo First Nation and Tsawwassen First Nation. A technical dialogue to support the development of the Living Dike concept has been coordinated by the Lower Fraser Fisheries Alliance (www.lffa.ca) and West Coast Environmental Law, involving BC FLNRORD and the Nations, with participation from staff at DFO, Canadian Wildlife Service and the municipalities.


CFAS
CITY OF
SURREY

APPENDIX "II" CITY MANAGER'S DEPARTMENT

CITY OF SURREY
the future lives here.

CORPORATE REPORT

NO: R021 COUNCIL DATE: February 11, 2019

REGULAR COUNCIL

TO: **Mayor & Council** DATE: **February 6, 2019**

FROM: **General Manager, Engineering** FILE: **4816-706**
XC: **5225-23**

SUBJECT: **Development of a Surrey Coastal Flood Adaptation Strategy**
2018 Year End Update and Disaster Mitigation Adaptation Fund Status

RECOMMENDATION

The Engineering Department recommends that Council receive this report for information.

INTENT

The purpose of this report is to update Council on the development of the Surrey Coastal Flood Adaptation Strategy ("CFAS") and the status of the City's application to the Federal Government's Disaster Mitigation Adaptation Fund ("DMAF").

BACKGROUND

At its Regular Meeting on December 19, 2017, Council received Corporate Report No. R246; 2017 Development of a Surrey Coastal Flood Adaptation Strategy 2017 Year End Update. The purpose of that report was to update Council on the progress made in 2017 in developing CFAS. A five-phase approach to developing a strategy to address current flood hazards and proactively plan for long-term flood protection needs is underway and is currently in Phase 4 shown in Figure 1.

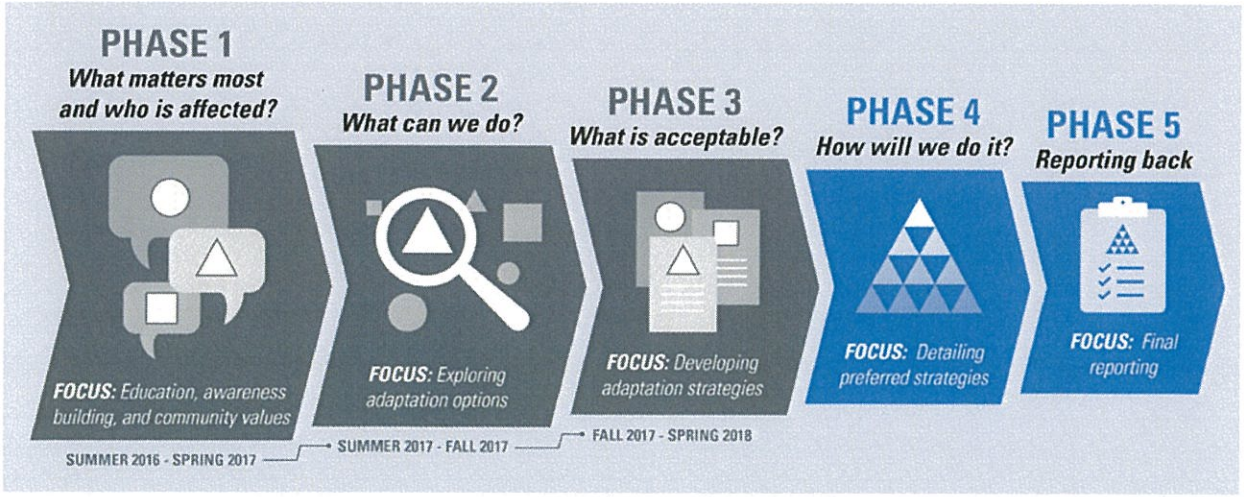


Figure 1. Phases of CFAS

The report also outlined the extensive consultation and engagement conducted to short-list preferred options for long-term flood management. Since that time, additional technical input and review has been completed, and the project team has received extensive public and stakeholder input on the short-listed options as part of CFAS Phase 3 to understand "What is acceptable?"

DISCUSSION

The actions required to adapt to coastal flooding may impact a range of sectors, stakeholders and partners throughout Surrey, and as such, staff have undertaken significant consultation. The information and feedback obtained from this consultation has been linked and integrated into the project's overarching, participatory decision-making process. A high level of engagement in the project and decision-making process has been achieved to date. An iterative process of two-way information exchange has been established to guide development of the CFAS with stakeholders.

Phases 2 and 3: What Can We Do and What is Acceptable?

Having completed Phase 1 in 2017, the focus in 2018 was to understand "what can we do and what is acceptable?" Over 5,000 face-to-face participation hours took place through CFAS workshops as well as thousands of online engagement hours through online videos and interactive online surveys. A Phase 1 to 3 Engagement Summary Report has been prepared and attached as Appendix "I", which summarizes the input received and details the project approach to incorporate public participation in developing long-term solutions.

A summary of Phase 2 and 3 activities, including key engagement events and activities that have taken place in 2018, are listed in Table 1.

Engagement Event/Activity	Dates	Overall Participants
Queen Elizabeth Secondary In-class Exercises	January 10, 2018	25
BC Hydro Meeting on CFAS	January 18, 2018	10+
University of Fraser Valley GEOG 304 In-class Exercises	January 15, 2018	20+
Water Talks organized by Canadian Water Resources Association	January 25, 2018	40+
Getting Climate Ready organized by Fraser Basin Council	January 25, 2018	50+
Public Survey on Crescent Beach with University of Fraser Valley	February 3, 2018	100+
CFAS Steering Committee	February 9 and March 26, 2018	12+
Panorama Ridge Secondary In-class Exercise	February 14, 2018	25
CitySpeaks Panel Survey and Open Community Survey on Mud Bay	February 14 to March 30, 2018	482
Crescent Beach Options Prioritization Workshop	February 21, 2018	35+
Semiahmoo Secondary In-Class Exercises	February 28, 2018	25

Engagement Event/Activity	Dates	Overall Participants
CFAS Advisory Group	March 9, 2018	20+
CitySpeaks Panel Survey and Open Community Survey on Crescent Beach	March 13 to April 6, 2018	609
CFAS Public Open House	April 9, 2018	40+
Surrey Council Committee presentations to ESAC, TIC, DAC, SHAC, AFSAC	April through July, 2018	50+
Classrooms to Communities Blackie Spit Park	May 4, 2018	50+
Earth Day Event (Blackie Spit)	June 3, 2018	30+
Envisioning a Resilient Delta hosted by Consulate General of the Netherlands	June 25, 2018	50+
Clayton Heights Secondary In-Class Exercises	June 5, 2018	25
Living Dike Roundtable meeting convened by Lower Fraser Fisheries Alliance	June 6, July 5 and July 18, 2018	15+
Semiahmoo First Nation Meetings	June 11 and July 23, 2018	5
Crescent Beach Property Owners Association Meetings	June 30 and July 4, 2018	120+
Planning Institute of BC	August 1, 2018	35+
BC Stewardship Roundtable	August 24, 2018	50+
Ministry of Transportation and Infrastructure Meeting	November 19, 2018	5
Ecosystem Vulnerability Workshop	November 27, 2018	25

Table 1: 2018 CFAS Engagement Events and Activities

A shortlisting process was developed to understand what types of approaches stakeholders and partners are in support of for year 2100, should one metre of sea level rise occur. No decision on long-range approaches is anticipated through the CFAS process. A spectrum of long-range options developed through the participatory planning process is helping to guide shorter term recommendations as part of Phase 4. Three study areas were established for CFAS, and an update is provided below on the long-range options for each of the areas.

Crescent Beach Feedback

Previous updates to Council identified that consultation involving the Crescent Beach area had identified the following options:

- Expanded Edge;
- Barrier Island;
- Mud Bay Barrier; and
- Managed Retreat.

Since that time, additional consultation has taken place, and with the agreement of the Crescent Beach Property Owners' Association, Managed Retreat has been taken off the table. No further analysis will be conducted on this option under CFAS.

The City will continue to evaluate the Crescent Beach community's preferred option of an Expanded Edge, and its second preferred option of a Barrier Island/Spit. Additional monitoring will be collected to inform future coastal flood management and adaptation plans, such as sea level changes, ground subsidence, long-term beach erosion, storm surge and wave damage, and seasonal water pooling.

For the foreseeable future, implementation of storm sewer upgrades, as set out in the Crescent Beach Climate Adaptation Study completed in 2009, will continue to be constructed in phases to better manage groundwater in the community.

Mud Bay Feedback

Previous updates to Council identified that consultation involving the Mud Bay area had identified the following options:

- Mud Bay Barrier;
- Current Conventions;
- Highway 99 Realignment; and
- Managed Retreat.

Since that time, additional consultation has taken place with directly impacted stakeholders on an as-requested basis. Based on discussion with the Ministry of Transportation and Infrastructure, Highway 99 Realignment will be renamed in the next phase.

For the foreseeable future, implementation of dyke upgrades, as set out in Corporate Report R047; 2016 on the Colebrook Dyking District, will be constructed in phases to reduce the likelihood of dyke overtopping. An adaptive approach that preserves a range of long-term options will be considered in CFAS.

Semiahmoo Bay Feedback

Previous updates to Council identified that consultation involving the Semiahmoo Bay area had identified the following options:

- Expanded Edge;
- Road & Land Raising; and
- No Adaptation.

Since that time, additional consultation has taken place with Semiahmoo First Nation. Semiahmoo First Nation's preferences of the options for Semiahmoo Bay are as follows: Expanded Edge, Road & Land Raising, and then No Adaptation. Since the Expanded Edge is not within the authority of Semiahmoo First Nation nor the City of Surrey, and would require relocation of the BNSF Railway, this option is beyond the scope of CFAS at this time.

CFAS Phase 4, How will we do it?

CFAS is focusing on the investments needed to improve infrastructure and increase flood safety over the next 10 years.

During development of CFAS Phase 4, the Federal Government announced the DMAF which aligned well with the objectives of CFAS and other City priorities for infrastructure upgrades.

At its Regular Council Meeting on July 23, 2018, Council endorsed Corporate Report No. R168; 2018 Expression of Interest and Application to Infrastructure Canada's Disaster Mitigation and Adaptation Fund that identified the core projects included in an expression of interest to Infrastructure Canada's DMAF in an effort to secure an average of 40% Federal funding.

Staff have worked closely with Infrastructure Canada to develop a suite of eligible projects that advance CFAS priority actions while meeting the DMAF program requirements. The City's expression of interest to DMAF titled Reducing Coastal Flood Vulnerability in the Coastal Lowlands of City of Surrey, City of Delta and Semiahmoo First Nation in British Columbia, through structural and nature based infrastructure works was short listed on October 12, 2018.

The suite of 13 eligible projects is summarized in the project map and table included as Appendix "II" and will improve community safety, address infrastructure deficiencies, and support long-term resilience to coastal flooding. Updated information on several aspects are provided below, based on the additional analysis and consultation completed during development of the DMAF Proposal.

1) 152 Street Increased Flood Control ($19.7M)
   As part of the 152 Street widening project, this scope is necessary to establish a flood resilient connection between North and South Surrey.

2) 152 Street FortisBC Gas Relocation ($15M)
   As part of the 152 Street widening project, it is anticipated that the relocation of two gas mains along the length of the City's road improvements will be required for safety. The City's estimated contribution is 10%.

3) 152 Street Local Water Main Relocation ($1M)
   As part of the 152 Street widening project, a provision to replace the City's local water main over the length of the road upgrades has been included in the Federal funding application. The scope will be reduced, if feasible, during detailed design.

4) Nicomekl Sea Dam Metro Vancouver Water Main Relocation ($12M)
   As part of the replacement of the Nicomekl Sea Dam, a large diameter water main connecting reservoirs in South Surrey with those in North Surrey needs to be relocated. The water main relocation is necessary for improved resilience and will accommodate future growth. No City of Surrey funding is required.

In addition to the City identified priority projects for Federal funding, the following four projects address either specific City infrastructure vulnerabilities or are entirely externally funded and submitted by the City on behalf of another organization. In discussion with Infrastructure Canada, it was established that projects involving partnerships with multiple organizations aligned best with the merit criteria of the funding program.

1) Campbell River Pedestrian/Emergency Access Bridge at 160 Street ($3.8M)
The replacement of this structure is a priority for Semiahmoo First Nation. 75% of the cost is eligible under the DMAF program, and negotiations with Indigenous Services Canada and Semiahmoo First Nation are underway to secure a commitment to cover the remaining 25% of the investment.

2) City of Delta Dyke Upgrades ($1.5M)
This project provides economies of scale and is complementary to the City's Colebrook Dyke project that abuts to the City of Delta's dyking system. The City of Delta have confirmed the non-federal portion of the budget required for the project, and no additional funding is anticipated from the City of Surrey.

3) Burrows Pump Station ($1.4M)
This project is currently in the City's 10-year capital budget and provides structural upgrades to extend the service life of the existing drainage station and improve agricultural drainage for food security.

4) Stewart Farm Sanitary Pump Station ($0.6M)
This project is currently in the City's 10-year capital budget and provides structural upgrades to reduce the vulnerability of the City's sanitary sewer system to coastal flooding.

As part of the DMAF funding application, several non-project specific cost allocations have been provided for. Once the funding agreement is established, the City cannot exceed the value provided and provision of the following general cost allowances that have been made:

1) Provincial environmental assessment and Federal reporting requirements ($1.1M); and
2) Inflationary allowance for construction cost escalation over nine years ($9M).

The total application value, including contingency, is $187M, of which the Federal component is $76.6M. The total third party funding is estimated at $49.1M. This leaves the remaining contribution as $61.3M to be covered by the City. Not all of these projects are included in the City's Five-Year Financial Plan.

At its Regular Council Meeting on December 15, 2018, Council endorsed Corporate Report No. R256; 2018 Infrastructure Projects – Federal and Provincial Funding Update that finalized the priority projects, as summarized above, for submission interest to Infrastructure Canada's DMAF. As part of the application, staff have worked to secure support to demonstrate the importance of the Federal Government's funding commitment to differentiate the City's application from other jurisdictions that are competing for limited funds. Where possible, credible outside groups have assisted in substantiating merit criteria applied by the Federal Government to evaluate submissions. The letters of support received to date include:

- Gordie Hogg, MP;
- Carla Qualtrough, MP;
- Stephanie Cadieux, MLA;
- Tracy Redies, MLA;
- Semiahmoo First Nation;
- City of Delta;

- City of White Rock;
- Metro Vancouver – Water Services Department;
- Ministry of Forests, Lands, Natural Resource Operations and Rural Development;
- Bird Studies Canada;
- Canadian Wildlife Service of Environment and Climate Change Canada;
- Consulate General of the Netherlands;
- Lower Fraser Fisheries Alliance;
- Municipal Natural Assets Initiative;
- Pacific Birds Habitat Joint Venture;
- South Coast Conservation Lands Management Program;
- Southern Railway of British Columbia Limited;
- University of British Columbia – Department of Geography; and
- West Coast Environmental Law.

A copy of each letter of support is included in Appendix "III".

Infrastructure Canada has indicated that funding decisions will be made this Spring, 2019.

Lower Mainland Flood Management Strategy

In parallel to the City's CFAS process and DMAF application, development of a Lower Mainland Flood Management Strategy ("LMFMS") for the Fraser River floodplain is underway, facilitated by the Fraser Basin Council. Phase 1 of the LMFMS took place between 2014 and 2016 and has concluded. The risks, vulnerabilities and consequences of a large flood event, including the effects of sea level rise, have been published to www.FloodStrategy.ca for the region. Phase 2 of the LMFMS is underway, with a view towards completion in 2020. The process and results of developing the Surrey CFAS continues to influence the LMFMS and be complementary. The goal for the LMFMS is to secure consensus among partners about regional priorities, cost-sharing and funding commitments for flood management.

Next Steps

The CFAS Engagement Summary Report included as Appendix "I" will be published on the City website shortly and circulated to CFAS stakeholders. A final Project Advisory Committee meeting is anticipated for Spring 2019. The intent is to prepare a draft CFAS in time to roughly coincide with the Federal funding decision.

Developing financial partnerships to support implementation of CFAS is underway through the DMAF and through the LMFMS. Staff are active in the development of the LMFMS, facilitated by the Fraser Basin Council, which seeks to develop regional level funding commitments for Flood Management. There is considerable interest among various conference organizations in the work being done under CFAS. City staff continue to present CFAS work to assist in building support for future funding opportunities and support for implementation.

The CFAS consulting team is now undertaking analysis of medium-term options for a suite of coastal flood adaptation approaches that build on the works setout in the City's DMAF application and that are consistent with stakeholder values for long term approaches.

SUSTAINABILITY CONSIDERATIONS

The process of developing the CFAS supports the objectives of the City's Sustainability Charter 2.0. In particular, the CFAS and DMAF works relate to the Sustainability Charter 2.0 themes of Infrastructure, Built Environment and Neighbourhoods, Ecosystems, and Public Safety. Specifically, the CFAS development and DMAF works support the following Desired Outcomes ("DO") and Strategic Directions ("SD"):

- Energy and Climate DO6: The City anticipates changing weather patterns and sea level rise as a result of climate change, and implements appropriate infrastructure, land use planning and emergency response solutions that will be resilient over the long term;
- Neighbourhoods and Urban Design SD8: Strengthen and promote community engagement and programming in public spaces;
- Green Infrastructure DO12: Surrey protects ecosystem services and manages natural assets in order to create resiliency to adapt and thrive in a changing climate; and
- Emergency Preparedness and Prevention SD6: Promote development types and locations that will be minimally impacted by natural disasters.

CONCLUSION

Based on the above discussion, it is recommended that Council receive this report as information and have staff report back to Council with a draft Coastal Flood Adaptation Strategy and the Infrastructure Canada decision on the City's Disaster Mitigation Adaptation Fund application.

Fraser Smith, P.Eng., MBA
General Manager, Engineering

JA/MO/cc

Appendix "I" – Surrey CFAS Engagement Summary Phase 1-3
Appendix "II" - Project Map
Appendix "III" - DMAF Letters of Support

Note: Appendices available upon request

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APPENDIX"III"
Fraser River
96 AVE
HWY 1
88 AVE
KING GEORGE BLVD
152 ST
HWY 15
FRASER HWY
Serpentine North
HWY 10
56 AVE
MUD BAY
Inter River East
Colebrook
Serpentine River
Nicomekl River
Mud Bay Foreshore
Inter River West
Nicomekl South
Nico Wynd Area
HWY 99
KING GEORGE BLVD
CRESCENT BEACH
Strait of Georgia
SEMIAHMOO BAY
Little Campbell River
Semiahmoo Bay

APPENDIX "IV"

SURREY COASTAL FLOOD ADAPTATION STRATEGY (CFAS)

PRIMER PART II: OPTIONS

Chapter 1: Mud Bay

April 2018

CFAS | CITY OF SURREY

PRELIMINARY OPTIONS PRIMER

SURREY COASTAL FLOOD ADAPTATION STRATEGY (CFAS)

Climate change is driving some big changes on Surrey's coastline. Our changing climate means that the historic controls that have been put in place to limit flood damages will be ineffective in limiting future flood damage as sea levels continue to rise. In the short-term, we can expect more nuisance flooding and more frequent and severe flooding from storm surges, while over the longer-term we can expect even greater challenges.

To help prepare Surrey for a changing climate and help make our coastal communities more resilient, we are developing a Coastal Flood Adaptation Strategy (CFAS). To be completed in late 2018, the final strategy will outline the potential future impacts of climate change on Surrey's coastline and the best adaptation options available to address them over the short-, medium, and longer-terms.

Launched in 2016, the project is taking a community-based, participatory approach and engaging residents, stakeholders, and other partners in the project, including First Nations, community and environmental organizations, business associations and groups, senior governments, farmers and the agricultural community, and neighbouring jurisdictions.

For more information about CFAS and flooding risk in Surrey's coastal areas see Primer Part I: Coastal Flooding in Surrey www.surrey.ca/files/CFAS-primerpart1.pdf.

FLOOD ADAPTATION OPTIONS EVALUATION

This Options Primer presents 11 shortlisted coastal flood adaptation options developed for the three CFAS study areas — Mud Bay (Chapter 1), Crescent Beach (Chapter 2), and Semiahmoo Bay (Chapter 3). The options were developed and shortlisted through extensive community consultation, technical analysis from project engineers and City of Surrey staff, and with input through a partnership with UBC and Dutch landscape architects and engineers.

The Options Primer provides a short summary description of each option. Images of similar adaptation approaches from other areas and jurisdictions are provided along with a sketch plan of the option that illustrates potential conditions in 2100, which is when sea levels are projected to have risen by 1 metre.

For each study area, a summary Technical Overview is provided that highlights the technical merits of the options. For each option, the following information is provided:

INFRASTRUCTURE, EARTHQUAKE & LANDUSE CHANGES & DESIGN: a summary of how each option impacts the following:

- ***Reduction in dyking:*** length of river and coastal dykes that can be decommissioned over time
- ***New dyke:*** length of new river and coastal dykes required
- ***Changes to sea dams:*** replacement, decommissioning or relocation needs for existing sea dams
- ***Earthquake design:*** option performance in an earthquake event
- ***Re-purposed land:*** land area where the current land uses would change from existing uses
- ***Relocated roads and rail lines:*** the primary transportation corridors that would need to be raised, relocated, or otherwise adapt
- ***Runoff management:*** option ability to address river flooding

VALUES ASSESMENT: a summary of how each option performs against seven "values criteria" that capture what people and partners in the study area care about most. The values were developed through an extensive engagement process in the winter and spring of 2017, which included: residential, agricultural and environmental stakeholder focus groups; a special workshop with infrastructure operators and owners; Semiahmoo First Nation; meetings with agriculture and environmental stakeholders (e.g., South Nicomekl Irrigation District, Friends of Semiahmoo Bay, Ducks Unlimited); outreach at community events like Surrey's Earth Day celebration (Party for the Planet); input from high school and elementary school students in the study area; an on-line survey using Surrey's CitySpeaks platform; and other outreach. The seven values criteria are:

- ***Residents:*** Number of people permanently displaced by the option and anticipated health and safety impacts
- ***Agriculture:*** Amount of agricultural land permanently lost due to the option
- ***Environment:*** Anticipated impact (positive and negative) to wetland habitats, freshwater fish habitat and riparian areas that could be expected from the option
- ***Infrastructure:*** Transportation and utilities service disruptions that could be expected from the option
- ***Economy:*** Permanent loss of businesses that could be expected from the option
- ***Recreation:*** The diversity of recreation opportunities (positive and negative) that could be expected from the option
- ***Culture:*** Semiahmoo First Nation cultural impacts that could be expected from the option

COST ASSESMENT: a high-level overview of the cost of implementing the option, including:

- ***Capital Cost:*** Capital infrastructure cost, estimated land purchasing costs, decommissioning existing infrastructure and land remediation costs
- ***Operation & Maintenance Cost:*** The yearly operations and maintenance costs
- ***Other Infrastructure Cost:*** The additional cost of adapting non-flood related infrastructure (e.g., roads & highways, hydro lines, water & sewage mains, etc.)
- ***Future Adaptation Cost:*** Estimated costs of continued adaptation requirements from both upgrading flood protection infrastructure beyond 1 metre of sea level rise and future replacement costs of aging flood protection infrastructure

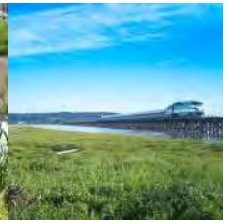
IMPACT & RISK OF FAILURE: recognizing that all flood protection infrastructure carries some risk of failure, a description of the anticipated impacts to community values from a failure of an option's flood protection infrastructure is provided. To quantify this risk, the likelihood of a failure of an option to provide flood protection was assessed (see appendix) with the consequence that failure would have on identified community values. For each option, a detailed description of the anticipated impacts to community values is provided using a scale from Very Low to Very High.

- ***Impact of a Failure:*** A description of the consequences to a given value from a catastrophic flooding event due to the failure of the option to provide protection
- ***Likelihood of Failure of Option:*** Provides a summary evaluation of how likely the option is to fail in the future
- ***Risk:*** The combination of the likelihood that an option will fail with the impact its failure would have on the value
- ***Overall Risk:*** The overall risk across all identified community values

A summary table comparing the options for each study area (Mud Bay, Crescent Beach, Semiahmoo Bay) is provided at the end of each chapter.

STUDY AREAS



CHAPTER 1: MUD BAY

CURRENT CONDITIONS

The Mud Bay Study area extends from the Serpentine & Nicomekl Lowlands in the East, including the Colebrook and Mud Bay Dyking Districts, and Mud Bay in the West.

TECHNICAL OVERVIEW

Flood hazards along Mud Bay and the Serpentine/Nicomekl Rivers downstream of the sea dams are a function of high tides, in combination with storm surge, waves, and wind effects. Previous work estimated that the existing shoreline dykes can withstand an ocean flood with a return period of 20-30 years, whereas the sheltered shoreline dyke segments offer protection up to the 200 year flood. As a result of sea level rise, the degree of protection will be reduced over time with some dyke overtopping becoming more common in the future, and occurring annually by 2070. When the crests are overtopped, the dykes are likely to breach, causing sudden, widespread inundation. Soil stability in the Mud Bay area is poor, which poses constraints for structural flood protection. Setback dyking increases structural stability.

VALUES IMPACTED

RESIDENTS

Several residential strata developments and subdivisions in addition to many farm houses in the Panorama/Gray Creek, Cloverdale, Inter-River Area, Colebrook, Mud Bay, Nico-Wynd/ Crescent Road areas. Public safety and emergency response are current concerns with over 200,000 vehicle trips passing through the area.

AGRICULTURE

Approximately 60 km^2 agricultural land with a variety of field crops, livestock, and other agricultural production. This represents two thirds of the City's Agricultural Land Reserve. Soil salination and prolonged flooding are a concern in coastal areas.

ENVIRONMENT

Significant natural areas, including mud flats, wetland areas, and riparian/estuarine habitat. Coastal Squeeze of marsh land is an issue.

INFRASTRUCTURE

Over 10 km of Provincial Highways, 30 km of railways and local roads. Other infrastructure and utilities include major sewer and waterlines, natural gas pipelines, and high-voltage electrical transmission lines. Both local and surrounding jurisdictions rely on this infrastructure.

ECONOMY

There are 3,000+ jobs in the area and many businesses. Over $100 million in annual farm gate revenue is produced in the area.

RECREATION

Popular walking, riding and bird watching area. Several parks and protected areas.

CULTURE

Though the area has no known spiritual sites it has been used time immemorial as an important food, resources and medicine harvesting area, as well as a transportation corridor. Therefore, the area likely has many unknown archeological sites. Any disturbance to the soils could potentially disturb human remains which would negatively impact First Nations who traditionally used the area.

TECHNICAL OVERVIEW

CURRENT CONVENTIONS

By the year 2100, this option is associated with a very high risk of catastrophic flooding from even a moderate flood or earthquake. There will likely be practical constraints with achieving desired flood protection standards with upgrades only. A future catastrophic failure would likely lead to full retreat and the loss of investments made in any upgrades completed. Whereas the option is viable in the near term "to buy time" and prolong living and farming in the floodplain, it is not a realistic long-term solution from an engineering, operations and maintenance, and future generations cost perspective.

OVERALL ASSESSMENT: ***Not viable for end of century time span.***
TECHNICAL RANKING: ***3rd***

MUD BAY BARRIER

The option is associated with very high risk to the entire floodplain population. Even a moderate earthquake would likely cause the barrier to fail because of the relatively poor underlying soils in the bay. The failure would lead to other cascading and catastrophic dyke failures and sudden widespread inundation. Rebuilding would take a long time, leaving the floodplain exposed to regular tidal flooding. The capital, operations and maintenance, and future costs would be very high. There would be no gain in net land area to offset these costs, as land behind the barrier would be used for freshwater storage. Other associated issues with this option include sediment deposition in the bay and the potential need to dredge outlet channels, reduction in water quality, loss of habitat, and impacts to views for Crescent Beach residents.

OVERALL ASSESSMENT: ***Not advisable from risk and cost perspectives.***
TECHNICAL RANKING: ***4th***

HIGHWAY 99 REALIGNMENT

The option is a combination of partial managed retreat and "holding the line." With properly designed components and by limiting future development in the area, flood risks can be managed and some agricultural operations could remain and be continued. Primary public transportation corridors and key infrastructure are maintained. The new dyke would have a more gradual side slope, some natural protection behind the BNSF line, and require much less riprap than an offshore barrier. There would likely be some environmental benefits from enhanced areas of salt marsh to the west.

OVERALL ASSESSMENT: ***Viable option for current century. It can potentially be a long term solution with changes to the land use behind the dykes to allow for water storage as a way of accommodating higher riverine flooding by 2100.***
TECHNICAL RANKING: ***2nd***

MANAGED RETREAT

The option essentially returns the floodplain to its original state. Major roads and other infrastructure can be maintained by raising, upgrading and adapting. Current residents in the floodplain (approx. 1,500) will need to relocate. All farmland is lost, impacting local food security and livelihoods. Considering that the area contains less than 0.5% of the City's population and approximately 10% of Metro Vancouver's farmland, the option likely offers the least-costly, most viable long-term solution, completely eliminating coastal flood risk in Mud Bay.

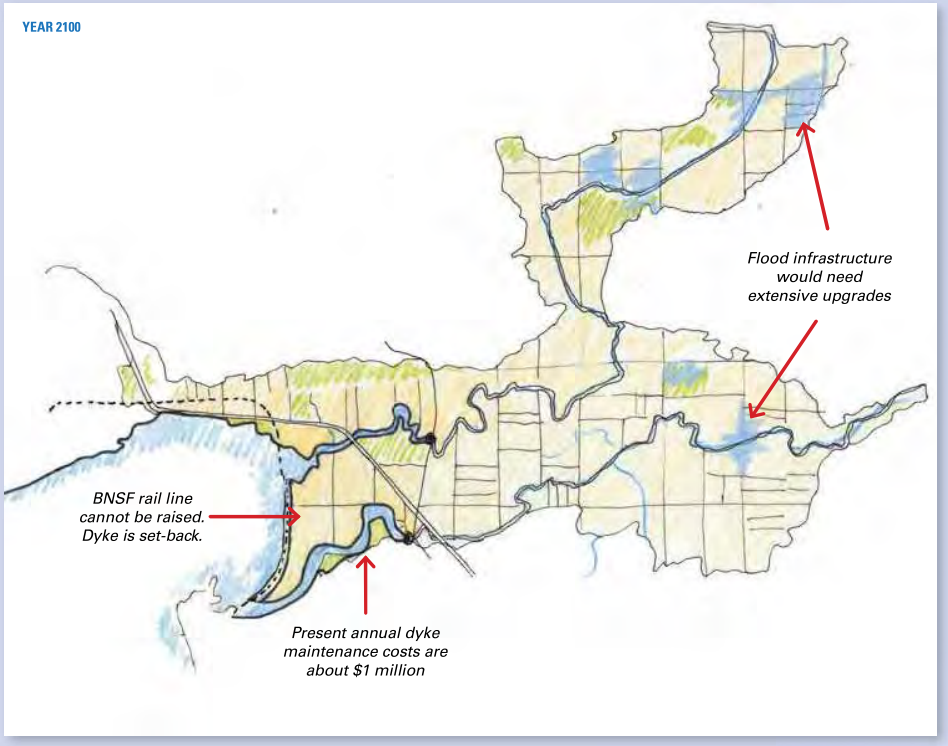
OVERALL ASSESSMENT: ***Most viable option in the long term.***
TECHNICAL RANKING: ***1st***

RISK ASSESSMENT HEAT MAP

The table below provides a high-level overview of risk for each option. Risk is defined as the combination of the likelihood that an option will fail with the impact its failure would have on identified community values. A detailed description of how the likelihood of a failure was calculated is included in the appendix. A detailed description of the impact of the failure of an option on community values is provided for each option description.

LIKELIHOOD \ IMPACT	Very Low	Low	Medium	High	Very High
Very High				CURRENT CONVENTIONS	
High					MUD BAY BARRIER
Medium			HIGHWAY 99 REALIGNMENT		
Low					
Very Low		MANAGED RETREAT			

OPTION 1: CURRENT CONVENTIONS



OPTION DESCRIPTION

As sea levels rise, Surrey continues to maintain existing flood control works to meet protection requirements. Present day annual dyke maintenance costs of about $1 million increase substantially over time. Significant investments in upgrading existing flood control measures are required. The BNSF railway embankment along Mud Bay is not a dyke and cannot be raised, so a separate parallel dyke is built. Coastal dykes are raised over time by up to 3 metres and river dykes are raised by up to 1 metre. For every metre dykes are raised, an additional 8 metres of land is required for the base of the dykes, which requires easements from land owners on the landward side or building out into the foreshore on the ocean side. Going forward, the time the two sea dams remain open continues to decrease as a result of sea level rise, resulting in higher river levels and increased flooding of agricultural lands. Additional pumping capacity is unlikely to offset the increased flooding. The raising of dykes and other upgrades are implemented in phases over time. Ongoing costs are significant. This option is most familiar to stakeholders and no new land owners are impacted.

WHAT THIS COULD LOOK LIKE

Maintain flood infrastructure: raised dykes

Maintain flood infrastructure: sea dams

Maintain flood infrastructure: pump stations

INFRASTRUCTURE, EARTHQUAKE & LANDUSE CHANGES & DESIGN

Reduction in dyking: *None.*

New dykes: *2.5 km long, 5 metre high, 35 metre wide dyke parallel to and set back from BNSF railway embankment. Raise all other existing dykes to design level and protect against erosion as required. This includes the south Nicomekl River dyke downstream of the sea dam which will need to be moved inland some distance and extended along Crescent Road.*

Changes to sea dams: *Over time, replace in same locations. Raise and design to meet current earthquake standards. Add pumping capacity.*

Earthquake design: *Present dykes would fail in an earthquake. New dyke parallel to BNSF would be more earthquake resistant, but not earthquake proof.*

Re-purposed land: *None. Some reduction in farmland due to footprint of dyke parallel to BNSF and other dyke improvements.*

Relocated roads/rail lines: *None. Extensive improvements required to accommodate future flood levels.*

Runoff management: *Improved with additional pumping capacity added at sea dams.*

OPTION 1: CURRENT CONVENTIONS

VALUES CRITERIA

		FAR WORSE ← NO CHANGE → FAR BETTER
RESIDENTS	Some residents (approximately 25 homes) are displaced because over time dykes will need to be pushed back, widened, and raised, displacing homes near the current dykes. Also, quality of life will be negatively impacted as there will be a loss of views with higher dykes. Potentially, insurance rates could go up significantly and property values could decrease.	***Indicator:*** *People permanently displaced* — SLIGHTLY WORSE
AGRICULTURE	Some agricultural land is lost due to raising and widening of dykes. Land productivity is negatively impacted given that salinization, subsidence, and localized flooding become more of an issue. Waterfowl begin to impact crops, as they start utilizing crops for feed as they lose natural habitat.	***Indicator:*** *Permanent loss of agriculture land* — SLIGHTLY WORSE
ENVIRONMENT	Over time all the tidal flats in Mud Bay would be negatively impacted by coastal squeeze. Even though sea dams would be replaced with ones that have fish ladders allowing salmon migration, the loss of eelgrass beds would likely be detrimental to salmon. Migration from land to water could be difficult for some species due to larger dykes.	***Indicator:*** *Impacts to wetland habitats, freshwater fish habitat & riparian areas* — FAR WORSE
INFRASTRUCTURE	All transportation corridors and utilities adapt alongside the option and citizens do not experience any change in infrastructure services.	***Indicator:*** *Percent of service/transportation infrastructure made vulnerable* — NO CHANGE
ECONOMY	River dyke setback may displace some businesses. As well, farms will be affected by increased soil salination and increased spillway or riverine flooding. Farms will likely need to change crop types and practices, and likely experience higher maintenance costs due to regular flooding and salination.	***Indicator:*** *Revenue* — SLIGHTLY WORSE
RECREATION	Walking trails and wildlife areas could potentially be more difficult to access. At the same time, with wider and better dyke design, trails could be better integrated into future options. However, there is no significant change from today. The present natural shoreline will disappear. Waves will wash over the now abandoned BNSF railway embankment.	***Indicator:*** *Diversity of recreational opportunities* — NO CHANGE
CULTURE	New dykes would not disturb subsurface soils and therefore have limited archeological impacts.	***Indicator:*** *Opportunities for traditional practices* — NO CHANGE

COST CRITERIA

CAPITAL COST	OPERATION & MAINTENANCE COST	OTHER INFRASTRUCTURE COST	FUTURE ADAPTATION COST
$100M - $1B	*more than $10M*	*$10M - $100M*	*$1B - $4B*

VERY LOW · LOW · MEDIUM · HIGH · VERY HIGH

IMPACT & RISK OF FAILURE

		Impact of Failure on Value	x	Likelihood of Failure of Option	=	Risk
RESIDENTS	All housing within floodplain could be affected. Some loss of life possible from sudden dyke breaching irrespective of failure mode. Restrict future development and limit the population of the area.	●		●		●
AGRICULTURE	Some agricultural land within floodplain potentially affected but land partly recoverable over time.	●		●		●
ENVIRONMENT	Contamination from septic fields, sewage backflow, manure, and chemical storage.	●		●		●
INFRASTRUCTURE	A failure of a dyke would likely disrupt multiple transportation corridors and utilities.	●		●		●
ECONOMY	Extensive direct and indirect losses.	●		●		●
RECREATION	Temporary disruptions but trails/ parks likely recoverable.	●		●		●
CULTURE	A dyke breach and flood event would have limited archeological impacts.	●		●		●

Overall Risk: ●

OPTION 2: MUD BAY BARRIER

The barrier has minimal impact on reducing waves and relies on a gate structure to minimize the impacts of storm surges. An alternative barrier near shore for Crescent Beach only is shown in Chapter 2.

OPTION DESCRIPTION

All of the existing flood control works continue to be maintained, but coastal dykes do not need to be raised if a 4.5 km long offshore barrier across Mud Bay is constructed to reduce the impacts of high tides and storm surges from entering the bay. The earth-filled barrier has riprap on both side slopes and is built at an average height of 10 metres above present sea level to allow for 50% settlement and 1 metre sea level rise by year 2100. At a combined outlet channel for the Serpentine and Nicomekl Rivers, the barrier has a gate structure that is closed during storm surge events. As sea levels continue to rise, the time the barrier and existing sea dams remain open is shortened, resulting in higher river levels and increased flooding of agricultural lands. The environmental impacts of the option are extremely high during construction and into the future. Ecologically critical mud flats and salt marshes in the bay are lost, as land previously between the barrier and the existing shoreline is used for freshwater storage providing storm water and irrigation improvement.

WHAT THIS COULD LOOK LIKE

Louisiana surge barrier
CC-by, Team New Orleans US Army Corps of Engineers

Thames Barrier, London

INFRASTRUCTURE, EARTHQUAKE & LANDUSE CHANGES & DESIGN

Reduction in dyking: *None. Existing dykes maintained and raised slightly.*

New dykes: *4.5 km long, 10 metre high ocean barrier. As barrier is built on ocean bed with high settlement (50%) and subsidence potential, it must be about twice as high as dykes on land. Structure must be protected on both sides with riprap. Once built, difficult to raise.*

Changes to sea dams: *A new 350 metre long gated structure is added to the barrier to allow rivers to drain and permit navigation. Existing sea dams may no longer be required (to be determined).*

Earthquake design: *Barrier built using engineered materials but not able to withstand an earthquake. Mud Bay sea floor is soft and unstable and would require extensive, very deep pilings for better earthquake resistance. These pilings would be prohibitively expensive along the length of structure, but likely included for the sea gate structure. The joints between the barrier and gate are potential failure locations.*

Re-purposed land: *None. The area inland of the barrier provides flow storage that helps reduce the amount the river dykes need to be raised over time. Some silt deposit and build-up expected inside the barrier. Reduced tidal flushing of the bay will impact water quality and may affect habitat and swimming.*

Relocated roads/rail lines: *None.*

Runoff management: *Likely improved as storage area inside ocean gate provides additional freshwater storage while gates are closed (to be determined by modelling).*

OPTION 2: MUD BAY BARRIER

VALUES CRITERIA

FAR WORSE ← NO CHANGE → FAR BETTER

RESIDENTS

No residents are relocated. The land gained behind the barrier cannot be developed for residential purposes as the City of Surrey wants to ensure that no new homes are build on the flood plain.

Indicator: *People permanently displaced*

NO CHANGE

AGRICULTURE

No agricultural land is lost. The land gained behind the barrier provides flow storage that helps reduce the amount the river dykes need to be raised over time.

Indicator: *Permanent loss of agriculture land*

NO CHANGE

ENVIRONMENT

The tidal flats behind the barrier are subject to gradual material deposition. Eelgrass beds will be buried by sediment and riparian habitat will be lost. Any habitat within the roughly 100 metre wide and 4,500 metre long barrier footprint will be destroyed. Tidal flushing of the bay is severely reduced, water quality suffers significantly. The salt content is reduced and present species will unlikely survive.

Indicator: *Impacts to wetland habitats, freshwater fish habitat & riparian areas*

FAR WORSE

INFRASTRUCTURE

All transportation corridors and utilities adapt alongside the option and citizens do not experience any change in infrastructure services.

Indicator: *Percent of service/transportation infrastructure made vulnerable*

NO CHANGE

ECONOMY

The marinas may no longer be feasible, as the gates would need to be blocked off from recreational use to avoid accidents. Land behind the barrier cannot be used for agriculture or industry.

Indicator: *Revenue*

NO CHANGE

RECREATION

The barrier could combine different recreational functions (trails/lookouts/kayak launch) to make the barrier a destination. However, likely deterioration of water quality behind the barrier would negatively impact current recreational uses of the area, especially Crescent Beach.

Indicator: *Diversity of recreational opportunities*

SLIGHTLY WORSE

CULTURE

This option would likely disturb archeological artifacts and human remains.

Indicator: *Opportunities for traditional practices*

MODERATELY WORSE

COST CRITERIA

CAPITAL COST	OPERATION & MAINTENANCE COST	OTHER INFRASTRUCTURE COST	FUTURE ADAPTATION COST
more than $4B	*$1M - $10M*	*less than $10M*	*$1B - $4B*

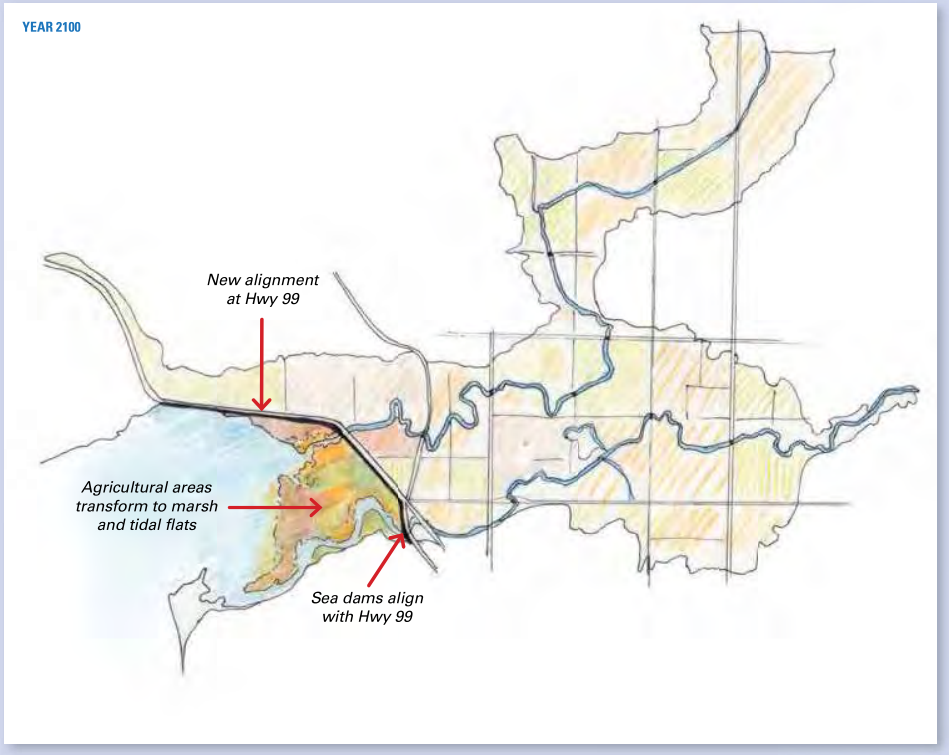
VERY LOW · LOW · MEDIUM · HIGH · VERY HIGH

IMPACT & RISK OF FAILURE

		Impact of Failure on Value	x	Likelihood of Failure of Option	=	Risk
RESIDENTS	A barrier failure could lead to existing ocean and river dykes failing in multiple locations. In such an event, all housing within floodplain could be affected and there could be significant loss of life.					
AGRICULTURE	All agricultural land within floodplain potentially affected but some land recoverable over time.					
ENVIRONMENT	The entire floodplain would experience contamination from septic fields, sewage backflow, manure, and chemical storage.					
INFRASTRUCTURE	A sudden barrier failure could severely impact and disrupt all transportation corridors and utilities within the floodplain.					
ECONOMY	Extensive direct and indirect losses.					
RECREATION	Permanent disruption to recreation areas and boat access would be limited.					
CULTURE	A dyke breach and flood event would have limited archeological impacts.					

Overall Risk:

OPTION 3: HIGHWAY 99 REALIGNMENT



OPTION DESCRIPTION

This option sets flood protection back from the ocean by building a 2.5 km long dyke along Highway 99. The dyke protects other inland routes, infrastructure, and land uses, while residents along the coastal side of Highway 99 in Mud Bay area are relocated or otherwise assisted in adapting to coastal flooding. The two sea dams are rebuilt and aligned with the Highway 99 super dyke. As sea levels continue to rise, the time the two sea dams remain open is shortened, resulting in higher river levels and increased flooding of agricultural lands. 14.5 km of dykes along the Serpentine and Nicomekl Rivers downstream of the sea dams are no longer needed and not maintained or upgraded. All other flood control works upstream of the sea dams require upgrades over time, including raising and widening of river dykes, and protection against erosion as the magnitude and frequency of floods increases. Some environmental benefits are realized on the coastal side of Highway 99, where former agricultural land is converted to coastal marsh and a new coastal multi-use trail is established to link Boundary Bay Park with the Nicomekl Greenway. Lands east of the dyke are maintained for their current uses, within the agricultural land reserve.

WHAT THIS COULD LOOK LIKE

Raised highway becomes flood barrier.

Aquaculture

Salt marsh created from breached agriculture land

INFRASTRUCTURE, EARTHQUAKE & LANDUSE CHANGES & DESIGN

Reduction in dyking: *9 km of river dykes, and 5.5 km of coastal dykes.*

New dykes: *4.5 km of a new 6 metre high, 53 metre wide dyke along Hwy 99 alignment.*

Changes to sea dams: *Existing sea dams de-commissioned. New sea dams constructed at highway alignment. Serpentine sea dam shifted downstream, leading to reduced river dyke heights behind the relocated sea dam.*

Earthquake design: *New dyke built with engineered materials with some earthquake resistance. Area soils which are very soft do not permit new dyke to meet full earthquake standards. New sea dams will meet earthquake standards.*

Re-purposed land: *About 5 km^2 of agricultural land, Nicowynd golf course, and some residential subdivision and housing areas to become salt marsh habitat.*

Relocated roads/rail lines: *The BNSF rail line either relocated or significantly raised (difficult to retrofit where line passes underneath Hwy 99). King George Boulevard near Nicomekl River crossing is protected. Crescent Road to be raised.*

Runoff management: *Pumps to be installed at new sea dams.*

OPTION 3: HIGHWAY 99 REALIGNMENT

VALUES CRITERIA

FAR WORSE ← NO CHANGE → FAR BETTER

RESIDENTS	Residents on coastal side of Highway 99 in Mud Bay and Inter-River Area are relocated. Approximately 150 homes are relocated from Mud Bay (20) and Nico-Wynd (130). Quality of life might be impacted in remaining homes as over time river dykes will need to be pushed back, widened, and raised.	***Indicator:*** *People permanently displaced* — SLIGHTLY WORSE
AGRICULTURE	Agricultural land on coastal side of Highway 99 is lost. Soil salinization remains an issue in some areas. Agricultural land reduced approximately by 5 km^2.	***Indicator:*** *Permanent loss of agriculture land* — SLIGHTLY WORSE
ENVIRONMENT	Agricultural land on coastal side of Highway 99 may be transformed and managed as coastal marsh through intentional breaches and riparian restoration. Wetlands and other coastal ecosystems may also develop. Approximately 5 km^2 of new habitat is created.	***Indicator:*** *Impacts to wetland habitats, freshwater fish habitat & riparian areas* — SLIGHTLY BETTER
INFRASTRUCTURE	All transportation corridors and utilities adapt alongside the option and citizens do not experience any change in infrastructure services.	***Indicator:*** *Percent of service/transportation infrastructure made vulnerable* — NO CHANGE
ECONOMY	Some agri-businesses are displaced and annual farm gate revenues are impacted by reductions in agricultural land. Approximately 150 direct jobs are displaced.	***Indicator:*** *Revenue* — SLIGHTLY WORSE
RECREATION	New salt marsh could become regional recreational destination for bird watchers. The new area could support water-based recreational activities including kayaking and canoeing, along with a land-based trail network; however, access to recreational opportunities may be inaccessible during high water.	***Indicator:*** *Diversity of recreational opportunities* — SLIGHTLY BETTER
CULTURE	New dykes would not disturb subsurface soils and therefore have limited archeological impacts.	***Indicator:*** *Opportunities for traditional practices* — NO CHANGE

COST CRITERIA

CAPITAL COST	OPERATION & MAINTENANCE COST	OTHER INFRASTRUCTURE COST	FUTURE ADAPTATION COST
$1B - $4B	*$1M - $10M*	*$10M - $100M*	*$1B - $4B*

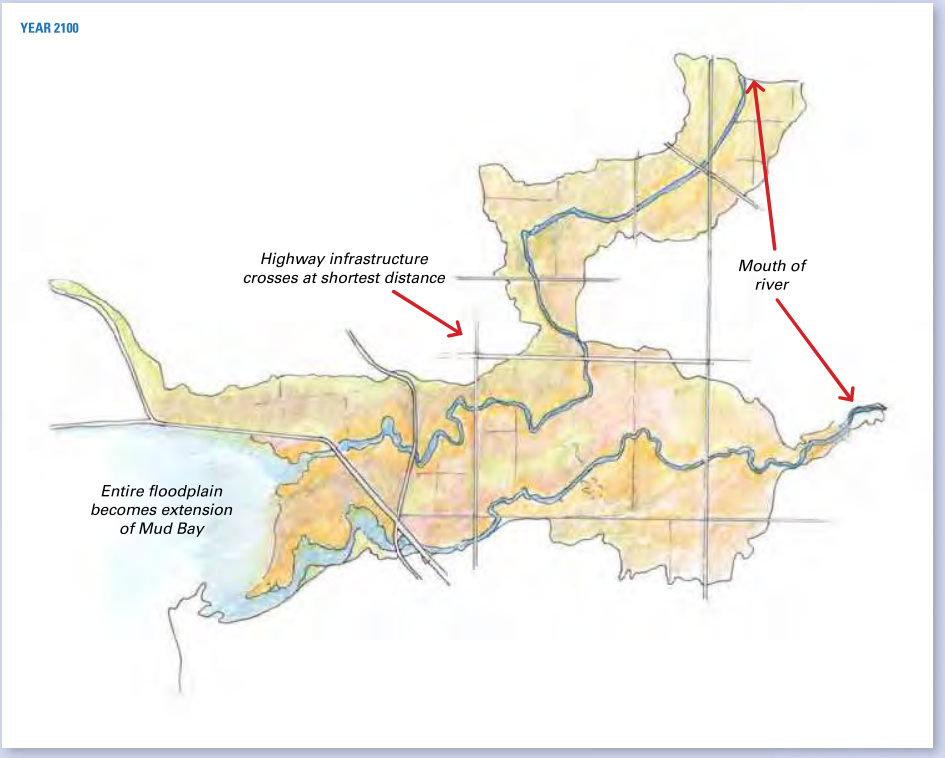
VERY LOW · LOW · MEDIUM · HIGH · VERY HIGH

IMPACT & RISK OF FAILURE

		Impact of Failure on Value	x	Likelihood of Failure of Option	=	Risk
RESIDENTS	Housing within floodplain could be affected but most vulnerable housing west of Highway 99 would be removed through retreat of that area. Some loss of life possible from sudden dyke breach. Population density to be regulated to avoid increased risk over time.					
AGRICULTURE	Agricultural land potentially affected but some land recoverable over time.					
ENVIRONMENT	Potential contamination from septic fields, sewage backflow, manure, and chemical storage.					
INFRASTRUCTURE	A failure of a dyke would likely be of partial proportions and the structure would be more readily repairable. Disruptions to transportation corridors and utilities would be of medium impact.					
ECONOMY	Extensive direct and indirect losses.					
RECREATION	Temporary disruption to recreation, but recoverable.					
CULTURE	A dyke breach and flood event would have limited archeological impacts.					

Overall Risk:

OPTION 4: MANAGED RETREAT



OPTION DESCRIPTION

This option involves a carefully planned and managed retreat from the coastal flood plain as sea levels rise over time, dykes are increasingly overtopped, and the City's investment in flood control is gradually reduced. Where feasible and practical, floodplain residents and stakeholders are supported to adapt, including the reorganization of agricultural activities and with adaptive building approaches. New land uses are introduced over time, including new recreation opportunities and creating new ecosystems and habitat for wildlife, fish, and migratory birds. Key infrastructure, including Highway 99 and King George Boulevard, remain functional but require raising and other extensive improvements. Other infrastructure, buildings, and pump stations are removed and recycled in a phased and organized manner. With less investment in large scale flood control, more resources are available to help floodplain residents and stakeholders to adapt or relocate. While development over the past 140 years has significantly altered the land, this option would return much of the area to its original coastal floodplain, wetland environment.

WHAT THIS COULD LOOK LIKE

Recreation opportunities

Floating greenhouse opportunities

Diverse habitat

INFRASTRUCTURE, EARTHQUAKE & LANDUSE CHANGES & DESIGN

Reduction in dyking: *76 km of river dykes and 5.5 km of coastal dykes.*

New dykes: *1.3 km of new dyking to prevent flooding of Delta, plus about 2 km of dyking to prevent flooding of Langley.*

Changes to sea dams: *Existing sea dams de-commissioned.*

Earthquake design: *None required.*

Re-purposed land: *About 65 km² of agricultural land converted to natural floodplain over time, including areas south of Nicomekl River and north of Serpentine River.*

Relocated roads/rail lines: *Major transportation corridors raised or moved onto bridges. BNSF and other rail lines to be either raised or relocated.*

Runoff management: *Floodplain is open to the ocean. High tides move inland freely. There could be some implications for Langley (impacts to be determined by modelling). Cloverdale Town Centre largely outside floodplain.*

OPTION 4: MANAGED RETREAT

VALUES CRITERIA

NO CHANGE
FAR WORSE ← → FAR BETTER

RESIDENTS	All residents would be relocated from the floodplain over time. Approximately 550 homes are relocated from Panorama/Gray Creek, Cloverdale, Inter-River Area, Colebrook, Mud Bay, and Nico-Wynd/Crescent Road area.	***Indicator:*** *People permanently displaced* — FAR WORSE
AGRICULTURE	Current agricultural practices would be phased out over time. Other forms of food production (e.g., aquaculture, floating greenhouses) could be explored, but land based agriculture would not be possible due to inundation.	***Indicator:*** *Permanent loss of agriculture land* — FAR WORSE
ENVIRONMENT	There would be significant loss of habitat for land based wildlife and flora, but overall there are significant increases on scarce coastal habitat. Natural floodplain functions could return to pre-development performance levels. New ecosystems and habitat for wildlife and migratory birds are created. Soil remediation is required.	***Indicator:*** *Impacts to wetland habitats, freshwater fish habitat & riparian areas* — FAR BETTER
INFRASTRUCTURE	Only the main transportation corridors (Hwy 99, King George, Hwy 15, Fraser Hwy, and Hwy 10) are adapted by raising, and all utilities adapt as needed along side the option. Citizens would be able to cross the flood plain across the main transportation corridors, but all other roads would be decommissioned.	***Indicator:*** *Percent of service/transportation infrastructure made vulnerable* — SLIGHTLY WORSE
ECONOMY	All land-base agri-businesses is displaced. Over time, intensive agriculture on piers or floating greenhouses, experimental aquaculture, seaweed production, and other food production options would potentially develop. Potentially 3,500 direct jobs are displaced, but likely these would transition to other intensive forms of agriculture jobs.	***Indicator:*** *Revenue* — MODERATELY WORSE
RECREATION	The new area could become a regional recreational destination for bird watchers, as well as support water-based recreational activities including kayaking and canoeing. Along the new coastline, a land-based trail network could be developed.	***Indicator:*** *Diversity of recreational opportunities* — MODERATELY BETTER
CULTURE	No new dykes constructed, and the removal of existing infrastructure would only have limited archeological impacts.	***Indicator:*** *Opportunities for traditional practices* — NO CHANGE

COST CRITERIA

CAPITAL COST	OPERATION & MAINTENANCE COST	OTHER INFRASTRUCTURE COST	FUTURE ADAPTATION COST
$1B - $4B	*less than $1M*	*more than $100M*	*less than $100M*

IMPACT & RISK OF FAILURE

VERY LOW · LOW · MEDIUM · HIGH · VERY HIGH

	Impact of Failure on Value	x	Likelihood of Failure of Option	=	Risk
RESIDENTS — No housing in Surrey floodplain impacted, potentially some housing in Langley could be marginally impacted. No loss of life expected.	●		●		●
AGRICULTURE — Any remaining agricultural land within floodplain potentially affected, but as retreat occurs this land is expected to be used as seasonal pasture only.	●		●		●
ENVIRONMENT — Managed retreat to remove primary sources of pollution.	●		●		●
INFRASTRUCTURE — The adapted transportation corridors and utilities could be impacted by scouring, but catastrophic and/or multiple failures at the same time would be uncommon.	●		●		●
ECONOMY — Given that there are no major dykes remaining to be breached and therefore no chance of sudden flooding, no negative economic impacts are expected from flooding.	●		●		●
RECREATION — Recreation options adapted to retreat.	●		●		●
CULTURE — Limited archeological impacts.	●		●		●

Overall Risk: ●

2100 PRELIMINARY IMPACT EVALUATION

VALUES CRITERIA RANKING

FAR WORSE ← NO CHANGE → FAR BETTER

TECHNICAL CRITERIA RANKING

VERY LOW | LOW | MEDIUM | HIGH | VERY HIGH

	BASELINE - NO ADAPTATION	CURRENT CONVENTIONS	MUD BAY BARRIER	HIGHWAY 99 REALIGNMENT	MANAGED RETREAT
VALUES CRITERIA					
RESIDENTS *People permanently displaced*	FAR WORSE	SLIGHTLY WORSE	NO CHANGE	SLIGHTLY WORSE	FAR WORSE
AGRICULTURE *Permanent loss of agriculture land*	FAR WORSE	SLIGHTLY WORSE	NO CHANGE	SLIGHTLY WORSE	FAR WORSE
ENVIRONMENT *Impacts to wetland habitats, freshwater fish habitat & riparian areas*	MODERATELY WORSE	FAR WORSE	FAR WORSE	SLIGHTLY BETTER	FAR BETTER
INFRASTRUCTURE *Percent of service/ transportation infrastructure made vulnerable*	FAR WORSE	NO CHANGE	NO CHANGE	NO CHANGE	SLIGHTLY WORSE
ECONOMY *Revenue*	FAR WORSE	SLIGHTLY WORSE	NO CHANGE	SLIGHTLY WORSE	MODERATELY WORSE
RECREATION *Diversity of recreational opportunities*	FAR WORSE	NO CHANGE	SLIGHTLY WORSE	SLIGHTLY BETTER	MODERATELY BETTER
CULTURE *Opportunities for traditional practices*	SLIGHTLY WORSE	NO CHANGE	MODERATELY WORSE	NO CHANGE	NO CHANGE
IMPACT & RISK OF FAILURE					
OVERALL RISK	VERY HIGH	VERY HIGH	VERY HIGH	MEDIUM	VERY LOW
COST CRITERIA					
CAPITAL COST	—	$100M - $1B	MORE THAN $4B	$1B - $4B	$1B - $4B
OPERATION & MAINTENANCE COST	MORE THAN $10M	MORE THAN $10M	$1M - $10M	$1M - $10M	LESS THAN $1M
OTHER INFRASTRUCTURE COST	MORE THAN $100M	$10M - $100M	LESS THAN $10M	$10M - $100M	MORE THAN $100M
FUTURE ADAPTATION COST	$1B - $4B	$1B - $4B	$1B - $4B	$1B - $4B	LESS THAN $100M

NOTES

APPENDIX

VERY LOW LOW MEDIUM HIGH VERY HIGH

CURRENT CONVENTIONS

Likelihood of Failure

Dyke overtopping: High - Even if extensively raised, dyke core material remains sub-standard and settlement and slumping will occur.

Dyke erosion failure: Very High - Present dykes are located adjacent to ocean and rivers. On-going improvements and repairs required.

Earthquake failure: Very High – Dykes are not designed for earthquakes.

Mechanical failure: High - Aging sea dams, flood boxes and pump stations. Upgrades would likely lag behind actual requirements.

Seepage Increase: Very High - Seepage will increase with sea level rise. No prevention measures are practical.

Precipitation flooding: High - Increased precipitation expected by 2100. This risk can be lessened by adding substantial pumping capacity at the sea dams and creating upland retention lakes.

Costs

Capital Cost of Implementation: Includes cost for sea dam replacement, new dyke along BNSF embarkment, upgrades to dykes along south bank of Nicomekl River, upgrades to pump stations, and adding erosion protection along existing dykes

O&M Cost: Cost will increase exponentially over time to meet continued upgrade requirements.

Other Infrastructure Cost: Although some costs can be considered part of regular upgrades, there still will be additional infrastructure costs, including potential relocation of BNSF line and the raising of several existing bridges.

Future Adaptation Cost: To maintain acceptable degree of protection under climate change, beyond the year 2100, dykes must continue to be raised, improvements to erosion protection updated, and expanded pumping capacity added to the sea dams. As both ocean and river dykes are raised, property squeeze will become an issue.

MUD BAY BARRIER

Likelihood of Failure

Dyke overtopping: Low - Assuming gated barrier will reduce high tide and surge levels, the existing ocean and river dykes will largely be protected.

Dyke erosion failure: Very High - Existing ocean dykes will still be exposed to wave action since the barrier would be set back from the shore by some 4 km. Flow velocities may increase for river dykes leading to higher erosion. The barrier will be designed for wave erosion.

Earthquake failure: Very High - The barrier would not be designed for earthquakes and could fail catastrophically over its entire length. Existing ocean and river dykes and the present sea dams consequently have very high failure potential.

Mechanical failure: High - High potential for failure at gated structure due to barrier settlement. Evaluation assumes aging sea dams, flood boxes and pump stations are upgraded over time, if not the scoring would be Very High.

Seepage Increase: Medium – Sea level rise impacts are largely controlled by barrier.

Precipitation Flooding: Low - Increased flow storage area inside barrier addresses this issue.

Costs

Capital Cost of Implementation: Cost of barrier with sea-gates is very high. Additional costs for raising low river dykes, upgrading sea dams, flood boxes and pump stations.

O&M Cost: Existing ocean and river dykes would require ongoing maintenance. Barrier and gated structure would be rated high-consequence if a failure occurred and require a high degree of maintenance. Some dredging likely required.

Other Infrastructure Cost: All costs considered part of regular upgrades. Relatively minor upgrades required.

Future Adaptation Cost: Some upgrades to existing ocean and river dyke erosion protection will be required over time as sea level rise reduces periods of low water. Raising the barrier and modifying its gated structure to accommodate more than 1 m of sea level rise and extensive settlement would be extremely costly. Some dredging likely required.

HIGHWAY 99 REALIGNMENT

Likelihood of Failure

Dyke overtopping: Low - Assuming extensive upgrades for new coastal dykes, and new sea dams with pumps. New salt marsh habitat and remnants of existing coastal dykes and BNSF embankment provide wave attenuation.

Dyke erosion failure: Low for coastal dykes and High for riverine dykes - New coastal alignment dyke has extensive salt marsh at toe and is riprap protected, whereas riverine dykes continue to face erosion issues. The risk of erosion failure for riverine dykes can be lessened by creating set back dykes (i.e., dykes set back from the river), but properties bordering dykes will be squeezed

Earthquake failure: High - New coastal dyke will have improved standards but still not able to withstand earthquakes. Sea dams will be designed to seismic standards.

Mechanical failure: Medium – Assuming new flood boxes and pump stations are added.

Seepage Increase: High - Seepage will increase with sea level rise and although no prevention measures are practical the dyke will be wider and reduce seepage to some degree.

Precipitation flooding: Medium - Assumes substantial pumping capacity added at sea dams.

Costs

Capital Cost of Implementation: Estimated capital costs include sea dam decommissions, new sea dams with pump stations, new dyke built along Highway 99, and Crescent Road raised. Compensation costs for affected landowners (primarily agricultural, golf course, residential).

O&M Cost: Costs to maintain and operate dykes, sea dams, pumps, flood boxes are reduced after option is implemented

Other Infrastructure Cost: Incremental costs in the short- to medium-term. Infrastructure to the east of Highway 99 is protected. BNSF railway likely relocated. Some infrastructure, such as Metro Vancouver water/ sewer lines, would require upgrades or relocation.

Future Adaptation Cost: Post 2100, costly upgrades will be required. Dykes and sea dams will need to be raised. Sea dams will be closed for longer periods requiring higher pumping capacity for the rivers. Lake storage, raised set-back dykes, river diversions are also likely needed beyond 2100. Potential for property squeeze in many areas.

MANAGED RETREAT

Likelihood of Failure

Dyke overtopping: Very Low - No dykes required.

Dyke erosion failure: Very Low - No ocean dykes or river dykes remaining.

Earthquake failure: Low - Development along floodplain edge potentially affected.

Mechanical failure: Very Low - Option removes the need to operate pumps and flood boxes.

Seepage Increase: Very Low - Retreat above the flood plain, so no concern.

Precipitation flooding: Low - Development removed from Surrey floodplain. Impacts to Langley to be determined

Costs

Capital Cost of Implementation: High cost to compensate for land acquisitions and business losses. Other costs are low. Existing coastal dykes can be left in place, with some manufactured breaches introduced to allow natural flooding and enhancement of salt marsh. Sea dams and pump stations to be decommissioned. River dykes to be partially removed. Implementation cost is function of policy decisions regarding compensation.

O&M Cost: Costs to operate dykes, sea dams, pump stations, and flood boxes no longer required. Inspections no longer required. Some habitat improvements.

Other Infrastructure Cost: Major infrastructure relocation and/or upgrades are required

Future Adaptation Cost: Minor shoreline protection works may be required along edge of the floodplain. Retreat gradually progresses but valley walls are relatively steep so little additional land needs to be abandoned.

MORE INFORMATION

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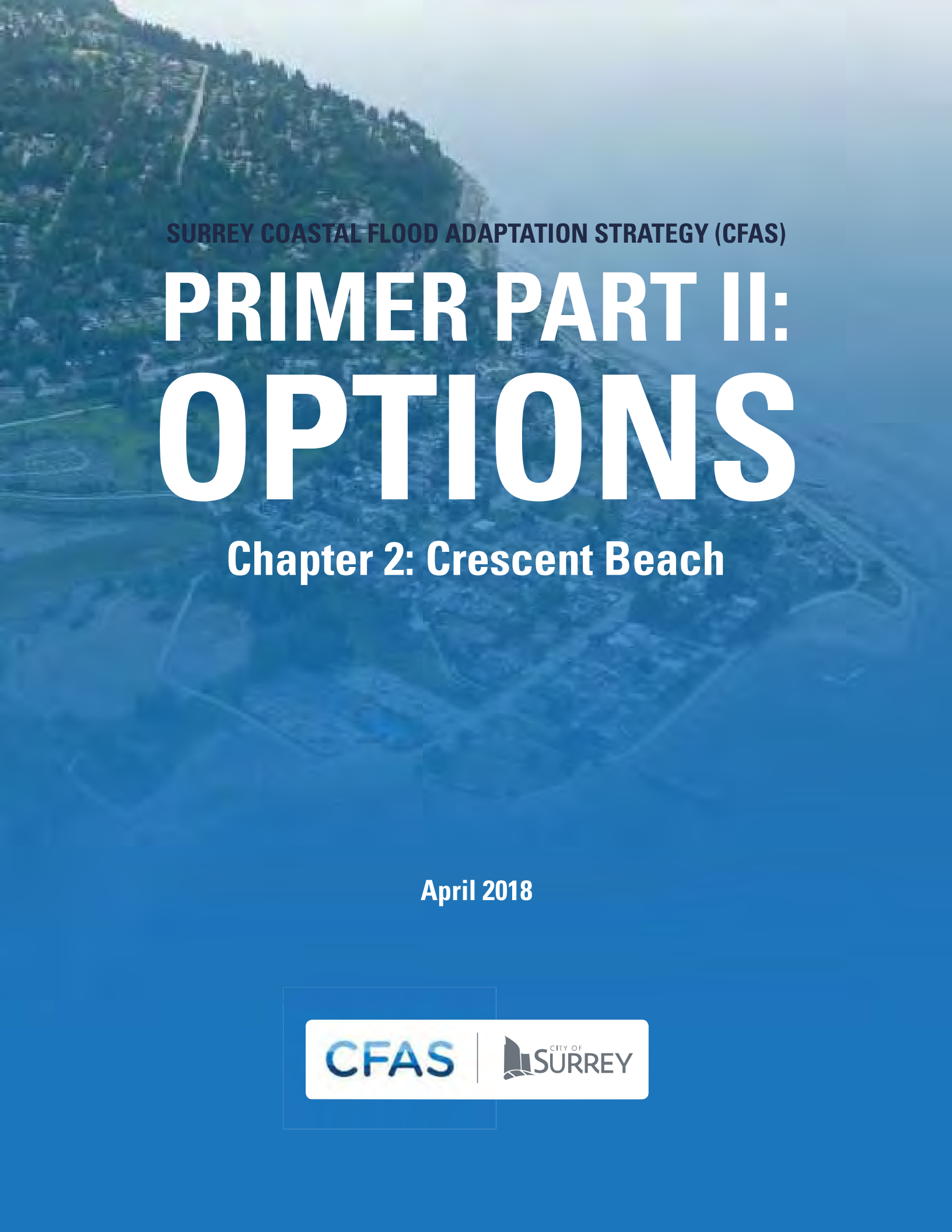
CFAS | CITY OF SURREY



SURREY COASTAL FLOOD ADAPTATION STRATEGY (CFAS)

PRIMER PART II: OPTIONS

Chapter 2: Crescent Beach

April 2018

CFAS | CITY OF SURREY

PRELIMINARY OPTIONS PRIMER

SURREY COASTAL FLOOD ADAPTATION STRATEGY (CFAS)

Climate change is driving some big changes on Surrey's coastline. Our changing climate means that the historic controls that have been put in place to limit flood damages will be ineffective in limiting future flood damage as sea levels continue to rise. In the short-term, we can expect more nuisance flooding and more frequent and severe flooding from storm surges, while over the longer-term we can expect even greater challenges.

To help prepare Surrey for a changing climate and help make our coastal communities more resilient, we are developing a Coastal Flood Adaptation Strategy (CFAS). To be completed in late 2018, the final strategy will outline the potential future impacts of climate change on Surrey's coastline and the best adaptation options available to address them over the short-, medium, and longer-terms.

Launched in 2016, the project is taking a community-based, participatory approach and engaging residents, stakeholders, and other partners in the project, including First Nations, community and environmental organizations, business associations and groups, senior governments, farmers and the agricultural community, and neighbouring jurisdictions.

For more information about CFAS and flooding risk in Surrey's coastal areas see Primer Part I: Coastal Flooding in Surrey www.surrey.ca/files/CFAS-primerpart1.pdf.

FLOOD ADAPTATION OPTIONS EVALUATION

This Options Primer presents 11 shortlisted coastal flood adaptation options developed for the three CFAS study areas — Mud Bay (Chapter 1), Crescent Beach (Chapter 2), and Semiahmoo Bay (Chapter 3). The options were developed and shortlisted through extensive community consultation, technical analysis from project engineers and City of Surrey staff, and with input through a partnership with UBC and Dutch landscape architects and engineers.

The Options Primer provides a short summary description of each option. Images of similar adaptation approaches from other areas and jurisdictions are provided along with a sketch plan of the option that illustrates potential conditions in 2100, which is when sea levels are projected to have risen by 1 metre.

For each study area, a summary Technical Overview is provided that highlights the technical merits of the options. For each option, the following information is provided:

INFRASTRUCTURE, EARTHQUAKE & LANDUSE CHANGES & DESIGN: a summary of how each option impacts the following:

- ***Reduction in dyking:*** length of river and coastal dykes that can be decommissioned over time
- ***New dyke:*** length of new river and coastal dykes required
- ***Changes to sea dams:*** replacement, decommissioning or relocation needs for existing sea dams
- ***Earthquake design:*** option performance in an earthquake event
- ***Re-purposed land:*** land area where the current land uses would change from existing uses
- ***Relocated roads and rail lines:*** the primary transportation corridors that would need to be raised, relocated, or otherwise adapt
- ***Runoff management:*** option ability to address river flooding

VALUES ASSESMENT: a summary of how each option performs against seven "values criteria" that capture what people and partners in the study area care about most. The values were developed through an extensive engagement process in the winter and spring of 2017, which included: residential, agricultural and environmental stakeholder focus groups; a special workshop with infrastructure operators and owners; Semiahmoo First Nation; meetings with agriculture and environmental stakeholders (e.g., South Nicomekl Irrigation District, Friends of Semiahmoo Bay, Ducks Unlimited); outreach at community events like Surrey's Earth Day celebration (Party for the Planet); input from high school and elementary school students in the study area; an on-line survey using Surrey's CitySpeaks platform; and other outreach. The seven values criteria are:

- ***Residents:*** Number of people permanently displaced by the option and anticipated health and safety impacts
- ***Agriculture:*** Amount of agricultural land permanently lost due to the option
- ***Environment:*** Anticipated impact (positive and negative) to wetland habitats, freshwater fish habitat and riparian areas that could be expected from the option
- ***Infrastructure:*** Transportation and utilities service disruptions that could be expected from the option
- ***Economy:*** Permanent loss of businesses that could be expected from the option
- ***Recreation:*** The diversity of recreation opportunities (positive and negative) that could be expected from the option
- ***Culture:*** Semiahmoo First Nation cultural impacts that could be expected from the option

COST ASSESMENT: a high-level overview of the cost of implementing the option, including:

- ***Capital Cost:*** Capital infrastructure cost, estimated land purchasing costs, decommissioning existing infrastructure and land remediation costs
- ***Operation & Maintenance Cost:*** The yearly operations and maintenance costs
- ***Other Infrastructure Cost:*** The additional cost of adapting non-flood related infrastructure (e.g., roads & highways, hydro lines, water & sewage mains, etc.)
- ***Future Adaptation Cost:*** Estimated costs of continued adaptation requirements from both upgrading flood protection infrastructure beyond 1 metre of sea level rise and future replacement costs of aging flood protection infrastructure

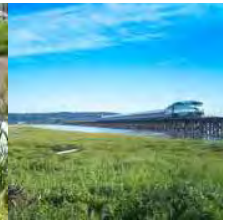
IMPACT & RISK OF FAILURE: recognizing that all flood protection infrastructure carries some risk of failure, a description of the anticipated impacts to community values from a failure of an option's flood protection infrastructure is provided. To quantify this risk, the likelihood of a failure of an option to provide flood protection was assessed (see appendix) with the consequence that failure would have on identified community values. For each option, a detailed description of the anticipated impacts to community values is provided using a scale from Very Low to Very High.

- ***Impact of a Failure:*** A description of the consequences to a given value from a catastrophic flooding event due to the failure of the option to provide protection
- ***Likelihood of Failure of Option:*** Provides a summary evaluation of how likely the option is to fail in the future
- ***Risk:*** The combination of the likelihood that an option will fail with the impact its failure would have on the value
- ***Overall Risk:*** The overall risk across all identified community values

A summary table comparing the options for each study area (Mud Bay, Crescent Beach, Semiahmoo Bay) is provided at the end of each chapter.

STUDY AREAS



CURRENT CONDITIONS

Crescent Beach is a beachside residential community located at the mouth of the Nicomekl River in South Surrey. It is home to 1,200 residents, mostly in single-family homes.

TECHNICAL OVERVIEW

Situated downstream of Nicomekl sea dam, river flooding is not a concern and flood hazards are a direct function of ocean levels. Recent studies suggest that by 2070, the area is expected to flood annually. Furthermore, the lands closer to Blackie Spit Park are 2-3m lower than the lands adjacent to the southwest facing dyke. Any water that overtops the southwest facing dyke would cause severe erosion and then pond in the lands closer to Blackie Spit Park. Lands inside the northeast dyke may also flood from direct overtopping of the adjacent dyke. The sandy soils underlying Crescent Beach make structural flood protection measures more viable by providing a stronger foundation, compared to adjacent Mud Bay, however saline groundwater seepage is an ongoing concern.

VALUES IMPACTED

RESIDENTS

Home to about 1,200 residences, the area includes over 40 Heritage Sites, including numerous heritage properties, including historic Dunsmuir Farm.

ENVIRONMENT

Blackie Spit is an important wildlife area that offers some of the best bird watching areas in Canada. The sandy spit is surrounded by tidal marsh and eelgrass beds and is an important stop for migrating and wintering waterfowl and shorebirds.

INFRASTRUCTURE

The BNSF rail line runs over the Nicomekl River and along the eastern edge of the community. Crescent Road provides the only vehicular access into and out of the community.

ECONOMY

There is a small, neighbourhood commercial area with several shops, restaurants and businesses.

RECREATION

The area includes popular swimming beaches, the Surrey Sailing Club, the Crescent Beach Yacht Club, Alexandre Neighbourhood House. Blackie Spit is a regional recreation destination.

CULTURE

Though Crescent Beach is not a spiritual site (which are more commonly found on higher grounds) it has been used since time immemorial as an important food, resources, and medicine harvesting area. Unlike Mud Bay's acid soils that accelerate the decompositions of human remains and artifacts, Crescent Beach is of special cultural and archaeological importance, as the shell middens found in the area buffer the acidity and preserve thousands of years of artifacts and human remains. Therefore, any disturbance to the soils would negatively impact Semiahmoo First Nation.

TECHNICAL OVERVIEW

EXPANDED EDGE

The raised and expanded dyke will provide protection against overtopping and erosion, but the risks are still high for this option. Given the porous ground, seepage issues will increase proportionally with sea level rise. To address seepage multiple actions need to be taken, including the installation of perforated piping with large pumps and the raising of all homes and roadways by about 1 metre by the year 2100. Continuing to adapt to higher sea levels beyond the year 2100 may be challenging from a seepage perspective.

OVERALL ASSESSMENT: ***Views will be severely impacted, and seepage requires that roads and housing be raised. Option is more cost effective than barrier island/spit and is likely only feasible for this century.***
TECHNICAL RANKING: ***2nd***

BARRIER ISLAND/SPIT

The barrier island/spit needs to be high enough to avoid overtopping and to reduce wave action, but provides no additional protection to the low dykes on the west and north sides of Crescent Beach; these would need to be raised substantially. This option is associated with very high risk.

The barrier island/spit could provide some recreational and ecological value, but views from Crescent Beach would be impacted. The barrier island/spit does not address issues of seepage or groundwater flooding, and multiple actions need to be taken, including the installation of perforated piping with large pumps and the raising of all homes and roadways by about 1 metre by the year 2100.

OVERALL ASSESSMENT: ***The barrier island/spit needs to be 6 metres above today's mean sea level, impacting views from the coast, and also requires raising existing dykes.. This option has limited merit from flood protection perspective.***
TECHNICAL RANKING: ***3rd***

MUD BAY BARRIER

The option is associated with very high risk to the entire floodplain population. Even a moderate earthquake would likely cause the barrier to fail because of the relatively poor underlying soils in the bay. The failure would lead to other cascading and catastrophic dyke failures and sudden widespread inundation. Rebuilding would take a long time, leaving the floodplain exposed to regular tidal flooding. The capital, operations and maintenance, and future costs would be very high. There would be no gain in net land area to offset these costs, as land behind the barrier would be used for freshwater storage. Other associated issues with this option include sediment deposition in the bay and the potential need to dredge outlet channels, reduction in water quality, loss of habitat, impacts to boat traffic and swimming, and impacts to views for Crescent Beach residents.

OVERALL ASSESSMENT: ***Not advisable from risk / cost perspectives.***
TECHNICAL RANKING: ***4th***

MANAGED RETREAT

The option returns the area to its original natural state, before permanent development. The present population of Crescent Beach (approx. 1,200 residents and 200 employees) would need to relocate. Considering that the area represents 0.7% of Surrey's gross assessed value (2016) and 0.2% of Surrey's total residential floor space, the option is likely to offer the most viable, least-costly, long-term solution completely eliminating coastal risk in Crescent Beach.

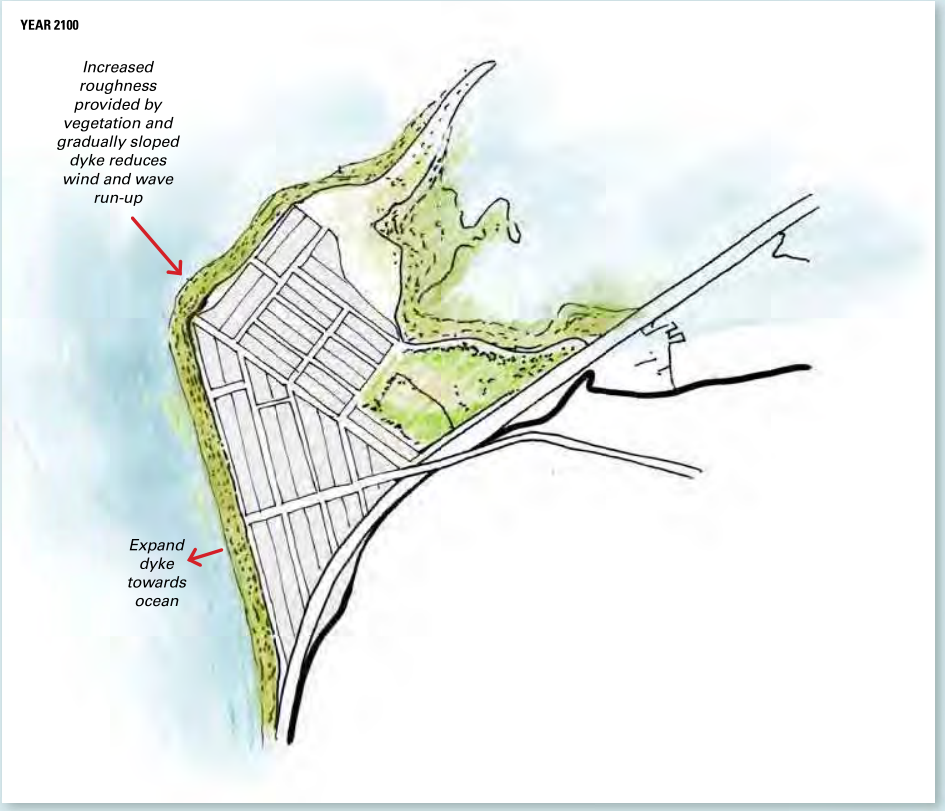
OVERALL ASSESSMENT: ***Most viable option in the long term.***
TECHNICAL RANKING: ***1st***

RISK ASSESSMENT HEAT MAP

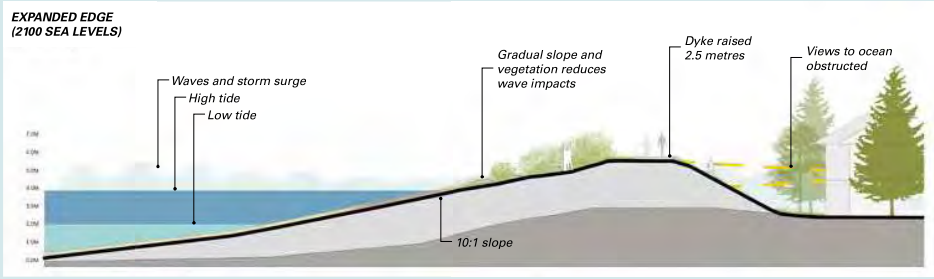
The table below provides a high-level overview of risk for each option. Risk is defined as the combination of the likelihood that an option will fail with the impact its failure would have on identified community values. A detailed description of how the likelihood of a failure was calculated is included in the appendix. A detailed description of the impact of the failure of an option on community values is provided for each option description.

LIKELIHOOD \ IMPACT	Very Low	Low	Medium	High	Very High
Very High				BARRIER ISLAND / SPIT	
High				EXPANDED EDGE	MUD BAY BARRIER
Medium					
Low					
Very Low	MANAGED RETREAT				

OPTION 1: EXPANDED EDGE



WHAT THIS COULD LOOK LIKE



Section of expanded edge and raised dyke

Raised dyke protects from storm surge and accommodates trails and other uses

Vegetated dykes reduce wind and wave run up

OPTION DESCRIPTION

This option proposes building the beach out in front of the existing shoreline to reduce the slope of the foreshore and, in turn, reduce wave run-up. By 2100, the dyke would be on average 2.5 metres higher than today with ocean front views severely impacted. The raised and expanded dyke will provide protection against overtopping and erosion. However, this option is considered high risk because of the high likelihood of failure of the dykes and potential detrimental impacts from flooding. Furthermore, given the sandy ground, seepage issues will accelerate with sea level rise. To help manage some seepage issues, perforated piping will need to be added over time to pump groundwater into the ocean. In addition, all homes and roadways will need to be raised by about 1 metre by the year 2100. The option would be phased over time, however, continuing to adapt to higher sea levels beyond the year 2100 may be challenging from a seepage perspective.

INFRASTRUCTURE, EARTHQUAKE & LANDUSE CHANGES & DESIGN

Reduction in dyking: *None.*

New dykes: *None. Existing dykes would be raised by 2.5 metres and the edge expanded towards the ocean with a 10:1 slope ratio.*

Earthquake design: *None.*

Re-purposed land: *Raising of roads lanes will require additional land on the sides of existing roads as the footprint of a raised road is greater.*

Relocated roads/rail lines: *None. However, 14 km of road lanes in Crescent Beach need to be raised by 1 metre or more to remain usable due to high degree of ground seepage.*

OPTION 1: EXPANDED EDGE

VALUES CRITERIA

		FAR WORSE ← NO CHANGE → FAR BETTER
RESIDENTS	No residents are relocated. Views of oceanfront properties would be impacted by raising current on-shore dykes by 2.5 metres. All housing is raised by about 1 metre due to seepage issues.	***Indicator:*** *People permanently displaced* — SLIGHTLY WORSE
ENVIRONMENT	Even though shoreline habitats could be improved using a Green Shores approach, building out into the ocean would disrupt coastal processes and critical habitat areas, including eelgrass beds.	***Indicator:*** *Impacts to wetland habitats, freshwater fish habitat & riparian areas* — SLIGHTLY WORSE
INFRASTRUCTURE	All roads and utilities adapt by raising or floodproofing and residents do not experience any change in infrastructure services.	***Indicator:*** *Percent of service/transportation infrastructure made vulnerable* — NO CHANGE
ECONOMY	Local businesses would likely not be impacted, and furthermore, the expanded beach area might encourage more tourists to visit the area.	***Indicator:*** *Revenue* — SLIGHTLY BETTER
RECREATION	Coastal recreation opportunities could be improved through a trail network, lookouts, and an expanded shoreline for recreation and enhanced accessibility using a more gradual slope.	***Indicator:*** *Diversity of recreational opportunities* — MODERATELY BETTER
CULTURE	Construction could disturb archaeological artifacts and human remains.	***Indicator:*** *Opportunities for traditional practices* — SLIGHTLY WORSE

COST CRITERIA

CAPITAL COST	OPERATION & MAINTENANCE COST	OTHER INFRASTRUCTURE COST	FUTURE ADAPTATION COST
$100M - $1B	*$1M - $10M*	*$10M - $100M*	*$100M - $1B*

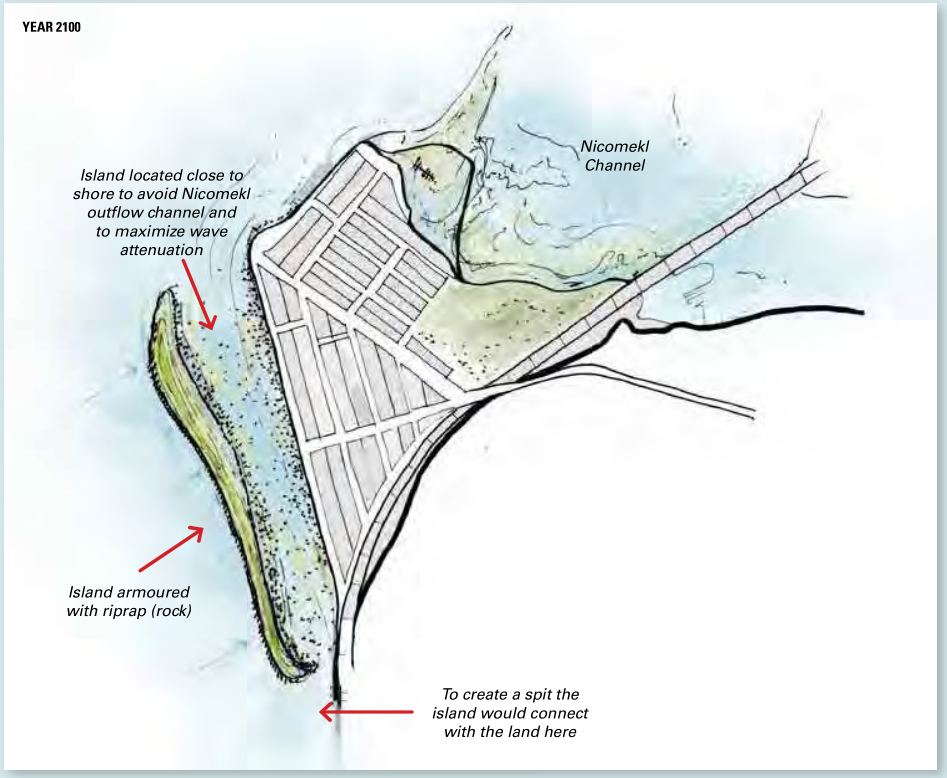
VERY LOW · LOW · MEDIUM · HIGH · VERY HIGH

IMPACT & RISK OF FAILURE

		Impact of Failure on Value	x	Likelihood of Failure of Option	=	Risk
RESIDENTS	Although the dykes would be raised and widened, a breach would affect all housing in Crescent Beach, likely leading to some loss of life.					
ENVIRONMENT	Contamination from debris and garbage. Recoverable without permanent harm to species.					
INFRASTRUCTURE	The entire area is cutoff. Roads inundated and potentially severely eroded. Other services, such as sewer, water, gas, cable, hydro, etc. will also be impacted.					
ECONOMY	Extensive direct and indirect losses.					
RECREATION	Temporary disruption to recreation amenities (shoreline trails, boat park, tennis courts, and parks), but recoverable.					
CULTURE	A dyke breach and flood event would have low archeological impacts.					

Overall Risk:

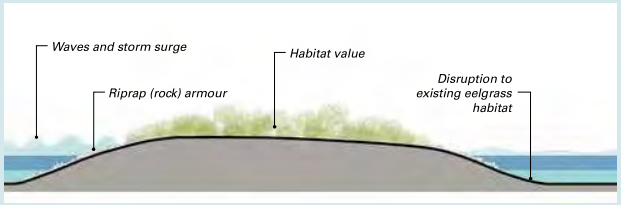
OPTION 2: BARRIER ISLAND/SPIT



OPTION DESCRIPTION

A kilometre-long barrier island or spit parallel to the southern portion of Crescent Beach between the Nicomekl outflow channel and the shoreline that is 6 metres above sea level by 2100 is constructed offshore to reduce onshore wave action. The barrier island or spit needs to be located close to the shore to effectively reduce wave run-up, impacting views from the coastline. Existing onshore dykes need to be raised throughout Crescent Beach as the barrier island alone is not enough to prevent future flooding. The southwest dykes would be raised by 2.3 metres, about 30 centimetres lower than required by the Expanded Edge option, and the northwest and northeast dykes would be raised by up to 3 metres,. This option is considered very high risk because of the very high likelihood of failure of the dykes and potential detrimental impacts from flooding. The Barrier Island or Spit does not address issues of seepage or groundwater flooding, and perforated piping will need to be added over time to pump groundwater into the ocean. In addition, all homes and roadways will need to be raised by about 1 metre by the year 2100. Continuing to adapt to higher sea levels beyond the year 2100 may be challenging from a seepage perspective.

WHAT THIS COULD LOOK LIKE



Section of barrier island/spit and raised dyke

Shady Island, Richmond BC

INFRASTRUCTURE, EARTHQUAKE & LANDUSE CHANGES & DESIGN

Reduction in dyking: *None.*

New dykes: *None. The new barrier island would be 1 km long and 7 m high (6 metres above mean sea level). Existing dykes on the southwest would be raised by 2.3 metres, and dykes on northwest and northeast sides would be raised by 2 to 3 metres, as the barrier island does not protect that side.*

Earthquake design: *None.*

Re-purposed land: *Raising of roads lanes will require additional land on the sides of existing roads as the footprint of a raised road is greater.*

Relocated roads/rail lines: *None; however, 14 km of road lanes in Crescent Beach need to be raised by more than 1m to remain usable due to high groundwater seepage.*

OPTION 2: BARRIER ISLAND/SPIT

VERY LOW LOW MEDIUM HIGH VERY HIGH

VALUES CRITERIA

NO CHANGE
FAR WORSE ← → FAR BETTER

RESIDENTS	No residents are relocated. Views are significantly impacted by both the 7 metre high, 1 km long barrier island/spit and by the raising of current on-shore dykes 2.3 metres. All housing is raised by about 1 metre due to seepage issues.	***Indicator:*** *People permanently displaced* — MODERATELY WORSE
ENVIRONMENT	Even though the barrier island/spit could be designed as a habitat island it would likely displace eelgrass habitat and would affect beach shape and sedimentation processes as well as water quality landward.	***Indicator:*** *Impacts to wetland habitats, freshwater fish habitat & riparian areas* — MODERATELY WORSE
INFRASTRUCTURE	All roads and utilities adapt by raising or floodproofing and residents do not experience any change in infrastructure services.	***Indicator:*** *Percent of service/transportation infrastructure made vulnerable* — NO CHANGE
ECONOMY	Local businesses would likely not be impacted. Even though the barrier island might encourage more tourists to visit the area, the changes would not be significant.	***Indicator:*** *Revenue* — NO CHANGE
RECREATION	At low tide, visitors could walk out to the island and at high tide, the island is a destination by boat or paddle board.	***Indicator:*** *Diversity of recreational opportunities* — SLIGHTLY BETTER
CULTURE	Construction could disturb archeological artifacts and human remains.	***Indicator:*** *Opportunities for traditional practices* — SLIGHTLY WORSE

COST CRITERIA

CAPITAL COST	OPERATION & MAINTENANCE COST	OTHER INFRASTRUCTURE COST	FUTURE ADAPTATION COST
$1B - $4B	*$1M - $10M*	*$10M - $100M*	*$1B - $4B*

IMPACT & RISK OF FAILURE

		Impact of Failure on Value	x	Likelihood of Failure of Option	=	Risk
RESIDENTS	All housing within coastal floodplain could be affected, and a sudden dyke breach could lead to significant loss of life from both inundation and erosion.					
ENVIRONMENT	Some contamination from debris and garbage. Recoverable without permanent harm to species.					
INFRASTRUCTURE	The entire area is cutoff. Roads are inundated and potentially severely eroded. Other services, such as sewer, water, gas, cable, hydro, etc. will also be impacted.					
ECONOMY	Extensive direct and indirect losses.					
RECREATION	Temporary disruption to recreation, but recoverable over time.					
CULTURE	A dyke breach and flood event would have low archeological impacts.					

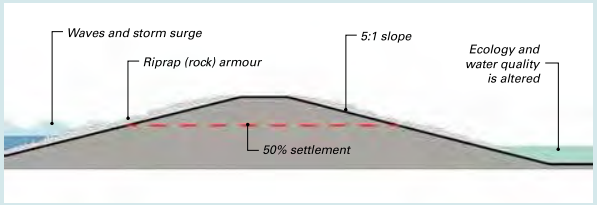
Overall Risk:

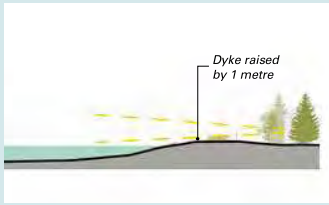
OPTION 3: MUD BAY BARRIER

OPTION DESCRIPTION

A 4.5 km offshore barrier across Mud Bay is constructed to reduce the impacts of high tides and storm surges from entering the bay. The earth-filled barrier is built at an average height of 10 metres above present sea level ***to allow the barrier to settle into the mud by half of its constructed height****. The height of the structure will impact views from Crescent Beach. All of the existing dykes in Crescent Beach need to be maintained; however existing dyke raising* ***would be significantly reduced****. The environmental impacts of the option are extremely high during construction and into the future. Ecologically critical mud flats and salt marshes in the bay are lost, as land previously between the barrier and the existing shoreline is used for freshwater storage. This is the only option that responds to flood hazards beyond Crescent Beach and reduces dyke upgrade requirements in Mud Bay and along the Nicomekl and Serpentine Rivers. The option is associated with very high risk to the entire floodplain population. Even a moderate earthquake would likely cause damage to the barrier resulting in compromised flood control until costly repairs can be made.*

WHAT THIS COULD LOOK LIKE





Section of Mud Bay barrier

Louisiana surge barrier under construction
CC-by, Team New Orleans US Army Corps of Engineers, flickr.com

Thames Barrier, London

INFRASTRUCTURE, EARTHQUAKE & LANDUSE CHANGES & DESIGN

Reduction in dyking: *None. Existing dykes need to be maintained and probably raised (exact height to be determined with further modeling).*

New dykes: *4.5 km long, 11 m high ocean barrier (crest elevation = 10 m). As barrier is built on ocean bed with high settlement (50%) and subsidence potential, it must be about twice as high as dykes on land. Structure must be protected on both sides with riprap rock. Once built, it is difficult to raise. A new 350 metre long gated structure is added to the barrier to allow rivers to drain and permit navigation.*

Earthquake design: *Barrier built using engineered materials but not able to withstand an earthquake. Mud Bay sea floor is soft and unstable and would require extensive, very deep pilings for better earthquake resistance. These pilings would be prohibitively expensive along the length of structure, but would likely be included for the sea gate structure. The joints between the barrier and gate are potential failure locations.*

Re-purposed land: *None. The area inland of the barrier provides flow storage that helps reduce the amount the river dykes need to be raised over time. Some silt deposit and build-up expected inside the barrier. Reduced tidal flushing of the bay will impact water quality and may affect habitat and swimming.*

Relocated roads/rail lines: *None. Marina traffic affected by barrier gates. Roads will likely require some raising but probably less than for the other dyking options.*

OPTION 3: MUD BAY BARRIER

VALUES CRITERIA

FAR WORSE ← NO CHANGE → FAR BETTER

RESIDENTS	No residents are forced to relocate, but views from shore and homes are negatively impacted. All housing needs to be raised due to seepage issues, but not as high as other options.	***Indicator:*** *People permanently displaced* — MODERATELY WORSE
ENVIRONMENT	The tidal flats behind the barrier are subject to gradual material deposition. Eelgrass beds will be buried by sediment and riparian habitat will be lost. Any habitat within the roughly 100 m wide and 5,000 m long barrier footprint will be destroyed. Tidal flushing of the bay is severely reduced, water quality suffers significantly. The salt content is reduced and present species will unlikely survive.	***Indicator:*** *Impacts to wetland habitats, freshwater fish habitat & riparian areas* — FAR WORSE
INFRASTRUCTURE	All roads and utilities adapt by raising or floodproofing and residents do not experience any change in infrastructure services.	***Indicator:*** *Percent of service/transportation infrastructure made vulnerable* — NO CHANGE
ECONOMY	No businesses are displaced or relocated. Businesses relying on Beach recreation or ocean views may be impacted.	***Indicator:*** *Revenue* — SLIGHTLY WORSE
RECREATION	Even though the barrier could combine different recreational functions (trails/lookouts/kayak launch) to make the barrier a destination, it is likely that deterioration of water quality and beach quality will reduce overall recreation in Crescent Beach.	***Indicator:*** *Diversity of recreational opportunities* — SLIGHTLY WORSE
CULTURE	This option could disturb archeological artifacts and human remains.	***Indicator:*** *Opportunities for traditional practices* — MODERATELY WORSE

COST CRITERIA

CAPITAL COST	OPERATION & MAINTENANCE COST	OTHER INFRASTRUCTURE COST	FUTURE ADAPTATION COST
more than $4B	*$1M - $10M*	*less than $10M*	*$1B - $4B*

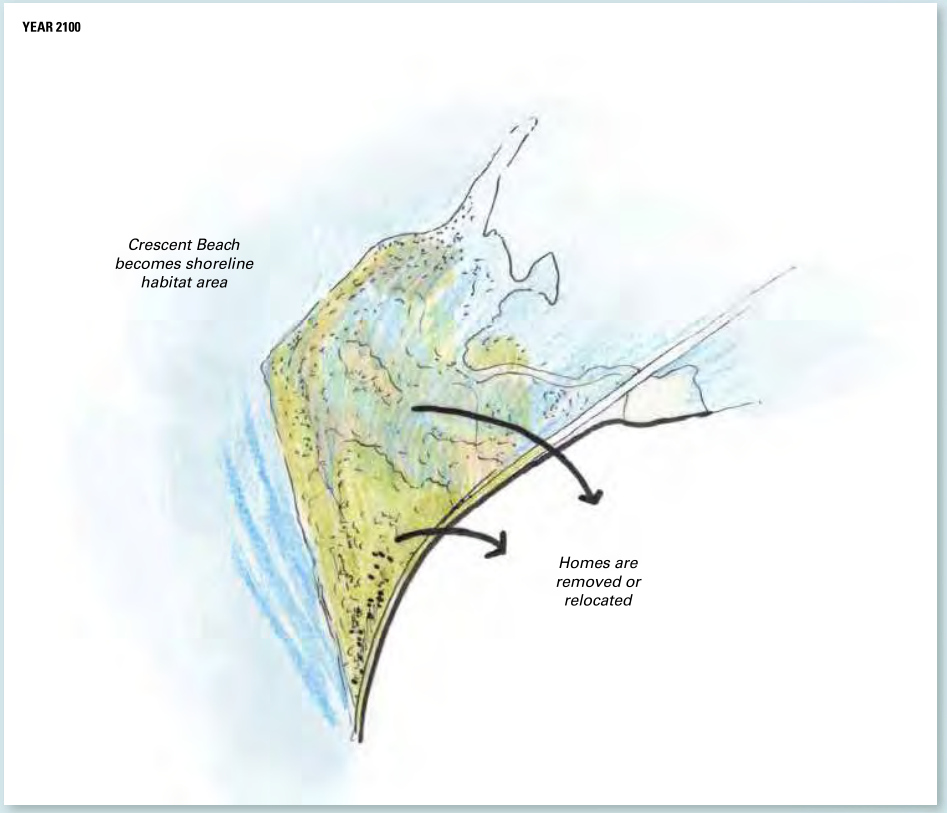
VERY LOW · LOW · MEDIUM · HIGH · VERY HIGH

IMPACT & RISK OF FAILURE

		Impact of Failure on Value	x	Likelihood of Failure of Option	=	Risk
RESIDENTS	A barrier failure could lead to existing ocean dykes failing in multiple locations. In the event of sudden barrier failure there could be significant loss of life.					
ENVIRONMENT	Contamination from debris and garbage. Recoverable without permanent harm to species.					
INFRASTRUCTURE	A sudden barrier failure could severely impact all infrastructure within the floodplain. High overland erosion hazard.					
ECONOMY	Extensive direct and indirect losses.					
RECREATION	Permanent disruption to recreation areas.					
CULTURE	A dyke breach and flood event would have low archeological impacts.					

Overall Risk:

OPTION 4: MANAGED RETREAT



OPTION DESCRIPTION

Over time, as sea levels continue to rise and flooding worsens, residents and businesses relocate from Crescent Beach and the area returns to its original natural state, before European Settlement in the 1900's. The option assumes that other areas are made available for residents, businesses and institutions and the approximately 1,400 people who live and work in Crescent Beach. The community represents 0.7% of Surrey's gross assessed value (2016) and 0.2% of Surrey's total residential floor space. By the end of the century the area is turned into a flood tolerant park with enhanced environmental habitat and limited seasonal hiking trails. Managed Retreat is likely to offer the most viable, long-term solution in this high flood and earthquake hazard area.

WHAT THIS COULD LOOK LIKE

Crescent beach becomes habitat area

House relocated from seaside in New Zealand
CC-by Sid Mosdell, flickr.com

Environmental management of coastal habitats at Crescent Beach

INFRASTRUCTURE, EARTHQUAKE & LANDUSE CHANGES & DESIGN

Reduction in dyking: *2.5 km of dykes surrounding Crescent Beach.*

New dykes: *None.*

Earthquake design: *None.*

Re-purposed land: *0.54 km^2 of residential and park land at Crescent Beach converted to natural habitat.*

Relocated roads/rail lines: *Local roads in Crescent Beach removed. Bayview Street would be raised to avoid flooding. Adjacent services and housing would be floodproofed as necessary. Beach access may be retained in some areas, with roads converted to seasonal hiking trails.*

OPTION 4: MANAGED RETREAT

VERY LOW LOW MEDIUM HIGH VERY HIGH

VALUES CRITERIA

FAR WORSE ← NO CHANGE → FAR BETTER

RESIDENTS	Approximately 500 homes are relocated from Crescent Beach over time, representing 15% of Surrey's Heritage Sites.	***Indicator:*** *People permanently displaced* — FAR WORSE
ENVIRONMENT	Through a managed retreat, there would be more room available for eelgrass and salt marsh to migrate with sea level rise, and further improvements to shoreline habitat could be made.	***Indicator:*** *Impacts to wetland habitats, freshwater fish habitat & riparian areas* — FAR BETTER
INFRASTRUCTURE	Bayview Street adapts by being raised, and all utilities adapt as needed. Citizens would no longer be able to access the old beach areas by car, but new beaches will form.	***Indicator:*** *Percent of service/transportation infrastructure made vulnerable* — NO CHANGE
ECONOMY	Businesses would be relocated or closed over time. Over time a business will develop on the edge of the bluffs and serve people wanting to visit new shoreline habitat area.	***Indicator:*** *Revenue* — MODERATELY WORSE
RECREATION	Beach access could be maintained in some areas. In time, most of Crescent Beach would be accessible along the new shoreline or by boat or paddle board only.	***Indicator:*** *Diversity of recreational opportunities* — FAR BETTER
CULTURE	With retreat, natural erosion would disturb subsurface soils and therefore likely disturb archeological artifacts and human remains.	***Indicator:*** *Opportunities for traditional practices* — MODERATELY WORSE

COST CRITERIA

CAPITAL COST	OPERATION & MAINTENANCE COST	OTHER INFRASTRUCTURE COST	FUTURE ADAPTATION COST
$1B - $4B	—	*less than $10M*	—

IMPACT & RISK OF FAILURE

		Impact of Failure on Value	x	Likelihood of Failure of Option	=	Risk
RESIDENTS	No housing in the Crescent Beach area would be at risk. No loss of life expected.	●		●		●
ENVIRONMENT	Managed retreat will include removal of primary sources of pollution.	●		●		●
INFRASTRUCTURE	Limited infrastructure is left in place. Metro Vancouver water and sewage mains would be floodproofed, as would servicing to homes along Bayview Road, which would be raised.	●		●		●
ECONOMY	Given that there are no dykes remaining to be breached, no negative economic impacts are expected from flooding.	●		●		●
RECREATION	Recreation features (e.g., trails) adapted to retreat, however a large flood event might temporarily disrupt a new trail system.	●		●		●
CULTURE	Retreat, would likely disturb archeological artifacts and human remains, but large flooding events are not expected to create additional impacts.	●		●		●

Overall Risk: ●

2100 PRELIMINARY IMPACT EVALUATION

VALUES CRITERIA RANKING

FAR WORSE ← NO CHANGE → FAR BETTER

TECHNICAL CRITERIA RANKING

VERY LOW | LOW | MEDIUM | HIGH | VERY HIGH

	BASELINE - NO ADAPTATION	EXPANDED EDGE	BARRIER ISLAND/ SPIT	MUD BAY BARRIER	MANAGED RETREAT
VALUES CRITERIA					
RESIDENTS *People permanently displaced*	FAR WORSE	SLIGHTLY WORSE	MODERATELY WORSE	MODERATELY WORSE	FAR WORSE
ENVIRONMENT *Impacts to wetland habitats, freshwater fish habitat & riparian areas*	FAR WORSE	SLIGHTLY WORSE	MODERATELY WORSE	FAR WORSE	FAR BETTER
INFRASTRUCTURE *Percent of service/ transportation infrastructure made vulnerable*	FAR WORSE	NO CHANGE	NO CHANGE	NO CHANGE	NO CHANGE
ECONOMY *Revenue*	FAR WORSE	SLIGHTLY BETTER	NO CHANGE	SLIGHTLY WORSE	MODERATELY WORSE
RECREATION *Diversity of recreational opportunities*	FAR WORSE	MODERATELY BETTER	SLIGHTLY BETTER	SLIGHTLY WORSE	FAR BETTER
CULTURE *Opportunities for traditional practices*	MODERATELY WORSE	SLIGHTLY WORSE	SLIGHTLY WORSE	MODERATELY WORSE	MODERATELY WORSE
IMPACT & RISK OF FAILURE					
OVERALL RISK	VERY HIGH	HIGH	VERY HIGH	VERY HIGH	VERY LOW
COST CRITERIA					
CAPITAL COST	—	$100M - $1B	$1B - $4B	MORE THAN $4B	$1B - $4B
OPERATION & MAINTENANCE COST	MORE THAN $10M	$1M - $10M	$1M - $10M	$1M - $10M	—
OTHER INFRASTRUCTURE COST	MORE THAN $100M	$10M - $100M	$10M - $100M	LESS THAN $10M	LESS THAN $10M
FUTURE ADAPTATION COST	$1B - $4B	$100M - $1B	$1B - $4B	$1B - $4B	—

NOTES

APPENDIX

VERY LOW LOW MEDIUM HIGH VERY HIGH

EXPANDED EDGE

Likelihood of Failure

Dyke overtopping: Medium – Dyke is raised and has gentler side slope reducing wave runup issues.

Dyke erosion failure: Low - Dyke has high level of vegetation and gentle side slope.

Earthquake failure: High - Widened dyke built to better standards but still will not meet earthquake requirements.

Mechanical failure: High - Very poor drainage requires pumps to work almost continuously, making whole area vulnerable to pump station failure.

Seepage Increase: Very High - The ground is highly porous and although dykes are widened, ground seepage is not reduced. Roads, housing and other infrastructure such as sewer, water, gas, cable, and hydro must be raised.

Costs

Capital Cost of Implementation: Cost associated with raising dykes, expanding the edge and providing erosion protection.

O&M Cost: Upgrade erosion protection as needed. Replace pump station. Clear drainage pipes (significant deposition expected).

Other Infrastructure Cost: Raise roads, install perforated piping and deal with high seepage. Raise all remaining housing and other structures as necessary over time to avoid flooding by seepage.

Future Adaptation Cost: Beyond the year 2100, and with additional sea level rise all dykes must be raised again, erosion protection improved, and seepage addressed by raising house and infrastructure again.

BARRIER ISLAND/SPIT

Likelihood of Failure

Dyke overtopping: High - Would mitigate wave effects only on south side of Crescent Beach, and only by 0.5m. The option assumes that all dykes are raised.

Dyke erosion failure: Very High – For the dykes not protected by the Barrier Island/Spit.

Earthquake failure: Very High – Given soil conditions dykes cannot be designed for earthquakes.

Mechanical failure: High - Very poor drainage require pumps to work almost continuously, making area vulnerable to pump station failure.

Seepage Increase: Very High - Ground is highly porous and ground seepage is not reduced with this option. Roads, housing and other infrastructure such as sewer, water, gas, cable, and hydro must all be raised.

Costs

Capital Cost of Implementation: Raise dykes, improve erosion protection. Relocate existing services along dykes. Build island.

O&M Cost: Maintain dykes and upgrade erosion protection. Replace pump station. Clear drainage pipes (significant deposition expected). Barrier island/spit will require erosion protection upgrades and maintenance.

Other Infrastructure Cost: Raise roads, install perforated piping and deal with high seepage. Raise all remaining housing and structures as necessary over time to avoid flooding by seepage.

Future Adaptation Cost: Beyond the year 2100, and with additional sea level rise all the dykes and barrier island/spit must be raised, erosion protection improved, and seepage addressed by raising house and infrastructure again.

MUD BAY BARRIER

Likelihood of Failure

Dyke overtopping: Low - Assuming gated barrier will reduce high tide and surge levels, the existing ocean and river dykes will largely be protected.

Dyke erosion failure: High - Flow velocities along Crescent Beach may increase (depending on capacity and location of barrier gates, there may be boating limitations and no more swimming). The barrier would be designed against wave erosion.

Earthquake failure: Very High - The barrier would not be designed for earthquakes and could fail catastrophically over its entire length. Existing ocean dykes would also have very high failure potential.

Mechanical failure: High - High potential for failure at gated structure due to barrier settlement.

Seepage Increase: Medium – Sea level rise impacts are likely controlled by barrier.

Costs

Capital Cost of Implementation: Cost of Barrier with sea-gates is very high. Some additional costs for local drainage.

O&M Cost: Barrier and gated structure would be rated high-consequence if a failure occurred and require a high degree of maintenance.

Other Infrastructure Cost: Most costs considered part of regular upgrades.

Future Adaptation Cost: Some upgrades to existing ocean dykes will be required over time as sea level rise reduces periods of low water. Raising the barrier and modifying its gated structure to accommodate more than 1 m of sea level rise and extensive settlement would be extremely costly.

MANAGED RETREAT

Likelihood of Failure

Dyke overtopping: Very Low - No dykes required.

Dyke erosion failure: Very Low - No protection required.

Earthquake failure: Very Low - Nothing to protect.

Mechanical failure: Very Low - Nothing to protect.

Seepage Increase: Very Low - No prevention measures needed.

Costs

Capital Cost of Implementation: Dependent on land compensation costs and costs to demolish, deconstruct and relocate houses and remove infrastructure.

O&M Cost: No maintenance required.

Other Infrastructure Cost: Minor costs to enhance overland flow to reduce erosion. Over time upgrades and/or relocation of BNSF line and Metro Vancouver water and sewage lines will be needed.

Future Adaptation Cost: Marginal costs associated with habitat improvement.

MORE INFORMATION

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CFAS | CITY OF SURREY

SURREY COASTAL FLOOD ADAPTATION STRATEGY (CFAS)

PRIMER PART II: OPTIONS

Chapter 3: Semiahmoo Bay

April 2018

CFAS | CITY OF SURREY

PRELIMINARY OPTIONS PRIMER

SURREY COASTAL FLOOD ADAPTATION STRATEGY (CFAS)

Climate change is driving some big changes on Surrey's coastline. Our changing climate means that the historic controls that have been put in place to limit flood damages will be ineffective in limiting future flood damage as sea levels continue to rise. In the short-term, we can expect more nuisance flooding and more frequent and severe flooding from storm surges, while over the longer-term we can expect even greater challenges.

To help prepare Surrey for a changing climate and help make our coastal communities more resilient, we are developing a Coastal Flood Adaptation Strategy (CFAS). To be completed in late 2018, the final strategy will outline the potential future impacts of climate change on Surrey's coastline and the best adaptation options available to address them over the short-, medium, and longer-terms.

Launched in 2016, the project is taking a community-based, participatory approach and engaging residents, stakeholders, and other partners in the project, including First Nations, community and environmental organizations, business associations and groups, senior governments, farmers and the agricultural community, and neighbouring jurisdictions.

For more information about CFAS and flooding risk in Surrey's coastal areas see Primer Part I: Coastal Flooding in Surrey www.surrey.ca/files/CFAS-primerpart1.pdf.

FLOOD ADAPTATION OPTIONS EVALUATION

This Options Primer presents 11 shortlisted coastal flood adaptation options developed for the three CFAS study areas — Mud Bay (Chapter 1), Crescent Beach (Chapter 2), and Semiahmoo Bay (Chapter 3). The options were developed and shortlisted through extensive community consultation, technical analysis from project engineers and City of Surrey staff, and with input through a partnership with UBC and Dutch landscape architects and engineers.

The Options Primer provides a short summary description of each option. Images of similar adaptation approaches from other areas and jurisdictions are provided along with a sketch plan of the option that illustrates potential conditions in 2100, which is when sea levels are projected to have risen by 1 metre.

For each study area, a summary Technical Overview is provided that highlights the technical merits of the options. For each option, the following information is provided:

INFRASTRUCTURE, EARTHQUAKE & LANDUSE CHANGES & DESIGN: a summary of how each option impacts the following:

- ***Reduction in dyking:*** length of river and coastal dykes that can be decommissioned over time
- ***New dyke:*** length of new river and coastal dykes required
- ***Changes to sea dams:*** replacement, decommissioning or relocation needs for existing sea dams
- ***Earthquake design:*** option performance in an earthquake event
- ***Re-purposed land:*** land area where the current land uses would change from existing uses
- ***Relocated roads and rail lines:*** the primary transportation corridors that would need to be raised, relocated, or otherwise adapt
- ***Runoff management:*** option ability to address river flooding

VALUES ASSESMENT: a summary of how each option performs against seven "values criteria" that capture what people and partners in the study area care about most. The values were developed through an extensive engagement process in the winter and spring of 2017, which included: residential, agricultural and environmental stakeholder focus groups; a special workshop with infrastructure operators and owners; Semiahmoo First Nation; meetings with agriculture and environmental stakeholders (e.g., South Nicomekl Irrigation District, Friends of Semiahmoo Bay, Ducks Unlimited); outreach at community events like Surrey's Earth Day celebration (Party for the Planet); input from high school and elementary school students in the study area; an on-line survey using Surrey's CitySpeaks platform; and other outreach. The seven values criteria are:

- ***Residents:*** Number of people permanently displaced by the option and anticipated health and safety impacts
- ***Agriculture:*** Amount of agricultural land permanently lost due to the option
- ***Environment:*** Anticipated impact (positive and negative) to wetland habitats, freshwater fish habitat and riparian areas that could be expected from the option
- ***Infrastructure:*** Transportation and utilities service disruptions that could be expected from the option
- ***Economy:*** Permanent loss of businesses that could be expected from the option
- ***Recreation:*** The diversity of recreation opportunities (positive and negative) that could be expected from the option
- ***Culture:*** Semiahmoo First Nation cultural impacts that could be expected from the option

COST ASSESMENT: a high-level overview of the cost of implementing the option, including:

- ***Capital Cost:*** Capital infrastructure cost, estimated land purchasing costs, decommissioning existing infrastructure and land remediation costs
- ***Operation & Maintenance Cost:*** The yearly operations and maintenance costs
- ***Other Infrastructure Cost:*** The additional cost of adapting non-flood related infrastructure (e.g., roads & highways, hydro lines, water & sewage mains, etc.)
- ***Future Adaptation Cost:*** Estimated costs of continued adaptation requirements from both upgrading flood protection infrastructure beyond 1 metre of sea level rise and future replacement costs of aging flood protection infrastructure

IMPACT & RISK OF FAILURE: recognizing that all flood protection infrastructure carries some risk of failure, a description of the anticipated impacts to community values from a failure of an option's flood protection infrastructure is provided. To quantify this risk, the likelihood of a failure of an option to provide flood protection was assessed (see appendix) with the consequence that failure would have on identified community values. For each option, a detailed description of the anticipated impacts to community values is provided using a scale from Very Low to Very High.

- ***Impact of a Failure:*** A description of the consequences to a given value from a catastrophic flooding event due to the failure of the option to provide protection
- ***Likelihood of Failure of Option:*** Provides a summary evaluation of how likely the option is to fail in the future
- ***Risk:*** The combination of the likelihood that an option will fail with the impact its failure would have on the value
- ***Overall Risk:*** The overall risk across all identified community values

A summary table comparing the options for each study area (Mud Bay, Crescent Beach, Semiahmoo Bay) is provided at the end of each chapter.

STUDY AREAS




CURRENT CONDITIONS

Semiahmoo Bay is a relatively small area included in CFAS that is occupied largely by Semiahmoo First Nation and the Campbell River. Outside of Semiahmoo First Nation, a portion of 8th Avenue and a few adjacent homes and municipal assets are vulnerable to flooding.

TECHNICAL OVERVIEW

The Semiahmoo flood hazard area is located at the mouth of Campbell River. The roughly 1.5 km² area belongs to the Semiahmoo First Nation and is populated with about 60 dwellings. To the south, the BNSF railway embankment provides a raised buffer between the ocean and the reserve. On the north side, the 8th Avenue roadway provides some flood protection to lands north of the street. However, a low section of road has flooded in the past and flooding is expected to worsen over time.

Severe flooding of the area is caused by high ocean levels. The Campbell River floodplain is relatively narrow and the channel slope steepens upstream of Highway 99. Considering the significant river flows and minimal flood storage, a sea dam similar to the Serpentine and Nicomekl sea dams would be unlikely to reduce flood levels. Dyking around low-lying land is not recommended due to stormwater pumping and land requirements.

The First Nation has observed material build-up near the mouth of the river and has inquired about the feasibility of reducing water levels by providing a cut-off channel, with a more direct route to the ocean. While this would increase flow velocities and reduce river levels at low to medium tides, it would not lower extreme flood levels caused by the ocean. A cut-off channel would cause significant erosion, reduce valuable habitat areas, and is not recommended.

The housing development on the Semiahmoo First Nation land is distributed across two main areas, the western terminus of Beach Road and the Middle/Upper Beach Road areas. Both developments are on relatively high ground and not within the year 2100 floodplain. However, a roughly 600 m long section of Beach Road is at risk of flooding, along with a few buildings outside the main centres. The main flood concern is that access/egress from the western area would be impacted.

VALUES IMPACTED

RESIDENTS

The area is home to Semiahmoo First Nation. There are about 60 dwellings located on the reserve. Approximately 5-10 homes are directly affected by flooding. Along 8th Avenue, there is a home and the 1st floor of an apartment building in the City of Surrey that are directly affected by flooding.

ENVIRONMENT

The Campbell River estuary is an important natural area with very high biodiversity values. Unlike the Nicomekl and Serpentine Rivers, the Campbell River does no longer have a sea dam regulating tidal flows, which has benefits to coastal processes and habitat migration. There are no dykes along the Campbell River.

INFRASTRUCTURE

Beach Road is vulnerable to flooding and could pose a challenge to any evacuation efforts for some homes in Semiahmoo First Nation, as it is the only access road to the community. The BNSF rail runs along the shoreline. On 8th Avenue, a sewage pump is located within the flood hazard area. Footbridge has water and gas utilities under it and only has a 2-year lifespan left.

ECONOMY

Semiahmoo First Nation reserve lands have substantial potential for economic development. However, several land parcels are within low-lying lands that are vulnerable to flooding.

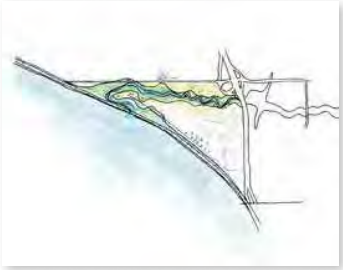
RECREATION

The BNSF runs across the ocean side of Semiahmoo First Nation reserve lands and highly limits ocean access. Park lands within the reserve are also within low-lying lands that are vulnerable to flooding. The Campbell River has become siltier over time and with the river mouth constraint by the rail line the silt deposits and impedes canoe access to the ocean on low tides.

CULTURE

Semiahmoo First Nation cemetery is located within low-lying lands that are vulnerable to flooding. Access to traditional food and medicinal plants have been impacted by development and pollution.

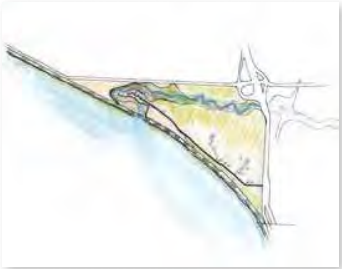
TECHNICAL OVERVIEW



NO ADAPTATION

Access to west portion of reserve is cut off during floods, and a portion of 8th Avenue, in the vicinity of the footbridge is affected. Northwest corner of reserve is occasionally inundated and development restrictions apply.

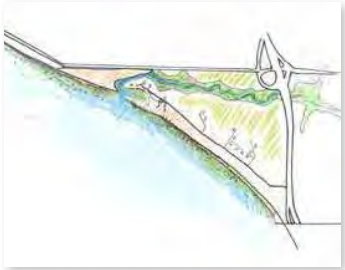
OVERALL ASSESSMENT: ***Option is not viable in the long term.***
TECHNICAL RANKING: ***3rd***



ROAD & LAND RAISING

Raising roads and lands eliminates access concerns to west portion of reserve. By raising the northwest corner of the reserve, development can proceed without it being at risk of flooding.

OVERALL ASSESSMENT: ***Option is viable in the long term.***
TECHNICAL RANKING: ***2nd***



EXPANDED EDGE

This option is similar to the Road & Land Raising option, but the railway embankment would be repurposed as an expanded edge. Access to the ocean from the reserve would be highly improved.

Key areas of the railway embankment must be left intact as a wave barrier. River flow benefits of larger opening to be determined based on modelling.

OVERALL ASSESSMENT: ***Same as Road & Land Raising option, but with habitat and recreational improvements.***
TECHNICAL RANKING: ***1st***

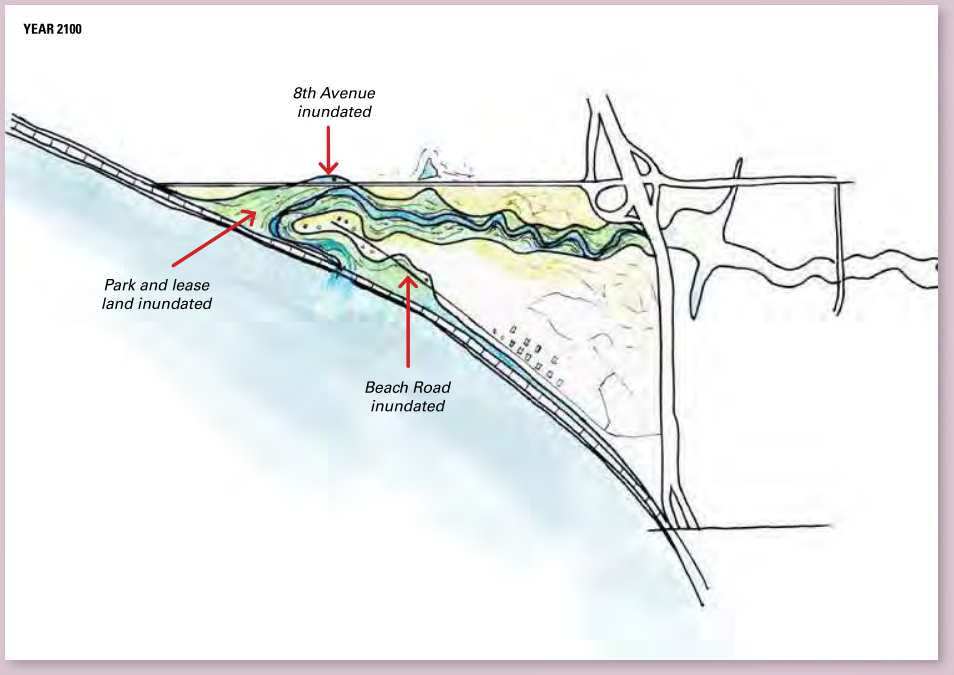
RISK ASSESSMENT HEAT MAP

The table below provides a high-level overview of risk for each option. Risk is defined as the combination of the likelihood that an option will fail with the impact its failure would have on identified community values. A detailed description of how the likelihood of a failure was calculated is included in the appendix. A detailed description of the impact of the failure of an option on community values is provided for each option description.

LIKELIHOOD \ IMPACT	Very Low	Low	Medium	High	Very High
Very High					
High					
Medium					
Low			NO ADAPTATION		
Very Low		LAND & ROAD RAISING and EXPANDED EDGE			

Note: While the raising of 8th Ave east of 160th Street is within the jurisdiction of City of Surrey, the majority of works are outside of Surrey's jurisdiction.

OPTION 1: NO ADAPTATION



WHAT THIS COULD LOOK LIKE

Temporary flood walls in the UK
CC-by-sa, Henry Burrows, flickr.com

Increased flooding

Develop evacuation routes and communication

OPTION DESCRIPTION

Unlike most of Surrey's floodplain, the Semiahmoo Bay area does not rely on flood infrastructure, such as dykes and sea dams, to prevent flooding. As such, this option maintains the "no adaptation" approach by allowing floodplain areas to flood over time. The concept assumes temporary flood protection is provided as required and emergency response is improved. Flood forecasts (ocean and river) become a valuable tool. If necessary over time, housing can be relocated to higher ground. Limited adaptation of municipal infrastructure may be possible under existing budgets during capital renewal cycles.

INFRASTRUCTURE, EARTHQUAKE & LANDUSE CHANGES & DESIGN

Reduction in dyking: *None.*

New dykes: *None.*

Earthquake design: *Not applicable.*

Re-purposed land: *None.*

Relocated roads/rail lines: *None.*

OPTION 1: NO ADAPTATION

VERY LOW LOW MEDIUM HIGH VERY HIGH

VALUES CRITERIA

FAR WORSE ← NO CHANGE → FAR BETTER

RESIDENTS	On Semiahmoo First Nation land, Beach Road would experience regular flooding and 20 or more homes could become isolated during a flood event. On 8th Avenue, one home and one apartment building could experience regular flooding.	***Indicator:*** *People permanently displaced* — SLIGHTLY WORSE
ENVIRONMENT	Increased erosion and loss of riparian areas could result from higher water levels and increased flooding. Beach road contains creosote contamination that would leach in a flood event, as would the septic fields. The option would allow the area to adapt to changing conditions over time, although some environmental values would be impacted.	***Indicator:*** *Impacts to wetland habitats, freshwater fish habitat & riparian areas* — SLIGHTLY WORSE
INFRASTRUCTURE	Sections of 8th Avenue and Beach Road could become inundated. Flooding of Beach Road limits access to the western area of Semiahmoo First Nation reserve and challenges evacuation efforts. Underground utilities and the BNSF rail line would be affected.	***Indicator:*** *Percent of service/transportation infrastructure made vulnerable* — MODERATELY WORSE
ECONOMY	Current lands and buildings that Semiahmoo First Nation gains revenue from would experience regular flooding and would likely negatively impact the revenue stream. Several land parcels that could potentially be developed would be regularly flooded.	***Indicator:*** *Revenue* — MODERATELY WORSE
RECREATION	Access to the ocean would continue to be restricted by the BNSF rail line. Park lands within the reserve would be regularly flooded.	***Indicator:*** *Diversity of recreational opportunities* — SLIGHTLY WORSE
CULTURE	The Semiahmoo First Nation cemetery would be regularly flooded and no longer suitable. Access to traditional food and medicinal plants would continue to be negatively impacted by development and pollution in the surrounding areas.	***Indicator:*** *Opportunities for traditional practices* — NO CHANGE

COST CRITERIA

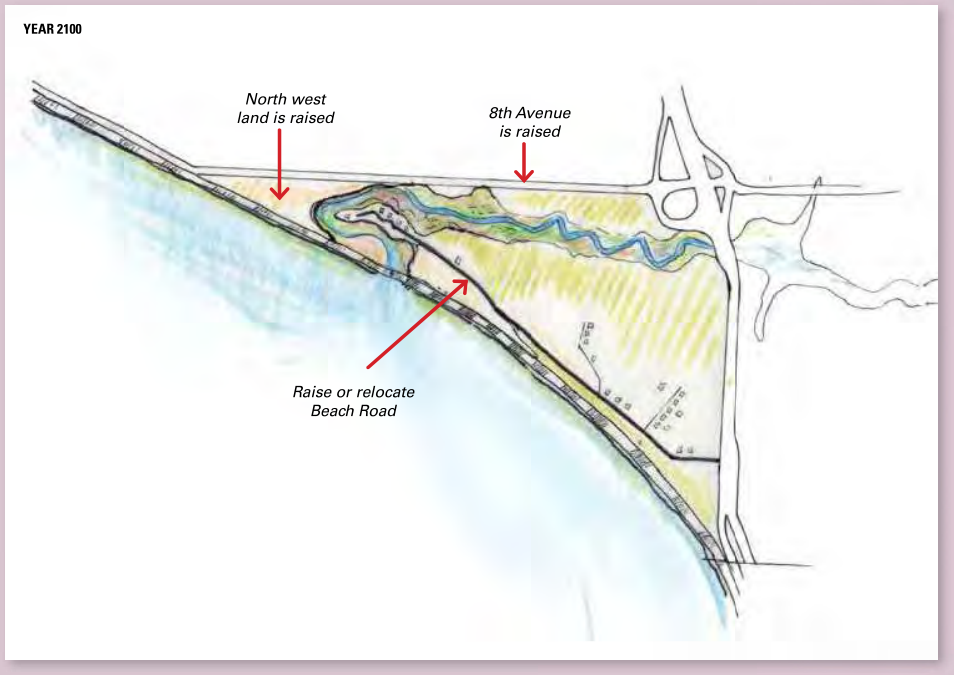
CAPITAL COST	OPERATION & MAINTENANCE COST	OTHER INFRASTRUCTURE COST	FUTURE ADAPTATION COST
—	*$100K - $1M*	*less than $1M*	*$10M - $100M*

IMPACT & RISK OF FAILURE

		Impact of Failure on Value	x	Likelihood of Failure of Option	=	Risk
RESIDENTS	Houses in the area are generally above flood levels, but some could be impacted on 8th Avenue. Unlikely that loss of life occurs from a flood event.					
ENVIRONMENT	Possible debris washed into streams. Sewage lift station could be impacted causing contamination. Watermains could be damaged creating some spillage of chlorinated water.					
INFRASTRUCTURE	Approximately 100 metre section of 8th Avenue and 230 metre section of Beach Road would be inundated. The pedestrian bridge would be washed out, including the attached utilities.					
ECONOMY	A large flood event would negatively impact the existing commercial buildings located in the northwest corner of the reserve. Any future buildings or development in the area would likewise be impacted.					
RECREATION	Temporary loss of shoreline trails.					
CULTURE	Cemetery would be flooded and possibly expose human remains.					

Overall Risk:

OPTION 2: ROAD & LAND RAISING



WHAT THIS COULD LOOK LIKE

Beach road is raised or rerouted to remain on higher elevated areas.

OPTION DESCRIPTION

In this option, Beach Road would be raised. The small section of 8th Avenue that is vulnerable to flooding would also be raised. Lands in the northwest corner of the reserve would be raised to meet Flood Construction Levels. Land vulnerable to flooding in the southeast corner would be raised to meet Flood Construction Levels.

INFRASTRUCTURE, EARTHQUAKE & LANDUSE CHANGES & DESIGN

Reduction in dyking: *None.*

New dykes: *None.*

Earthquake design: *Not applicable.*

Re-purposed land: *Land in northwest corner becomes developable once raised to above Flood Construction Levels, which entails adding approximately 2 metres of fill over most of area, as well as creating erosion protection along river. The raising of 8th Avenue and Beach Road to Flood Construction Levels will slightly increase the road footprints. Along 8th Avenue, there may be minor negative impacts to the river bed from erosion protection installed.*

Relocated roads/rail lines: *None. The low sections of 8th Avenue and Beach Road would be raised. The footbridge would be replaced and raised. Erosion protection would be added along the low sections of 8th Avenue, and the sewage pump station would be floodproofed.*

OPTION 2: ROAD & LAND RAISING

VERY LOW LOW MEDIUM HIGH VERY HIGH

VALUES CRITERIA

FAR WORSE ← NO CHANGE → FAR BETTER

RESIDENTS	No residents are relocated.	***Indicator:*** *People permanently displaced* — NO CHANGE
ENVIRONMENT	The option would have a low impact on this relatively undisturbed area.	***Indicator:*** *Impacts to wetland habitats, freshwater fish habitat & riparian areas* — NO CHANGE
INFRASTRUCTURE	Road infrastructure is raised or partly relocated. Utilities are protected by the raised road or relocated to high ground alongside the relocated road. Footbridge is upgraded and built to allow vehicle emergency access and additional utilities (water and gas) are added underneath it. The BNSF rail line would continue to experience flooding.	***Indicator:*** *Percent of service/transportation infrastructure made vulnerable* — NO CHANGE
ECONOMY	Current lands and buildings that Semiahmoo First Nation gains revenue from would be raised and future development would be built to flood construction levels and be protected from flooding.	***Indicator:*** *Revenue* — SLIGHTLY BETTER
RECREATION	Access to the ocean would continue to be restricted by the BNSF rail line. However, park lands within the reserve would be raised.	***Indicator:*** *Diversity of recreational opportunities* — NO CHANGE
CULTURE	The Semiahmoo First Nation cemetery would be filled and headstones would be raised to avoid future flooding. Access to traditional food and medicinal plants would continue to be negatively impacted by development and pollution in the surrounding areas.	***Indicator:*** *Opportunities for traditional practices* — NO CHANGE

COST CRITERIA

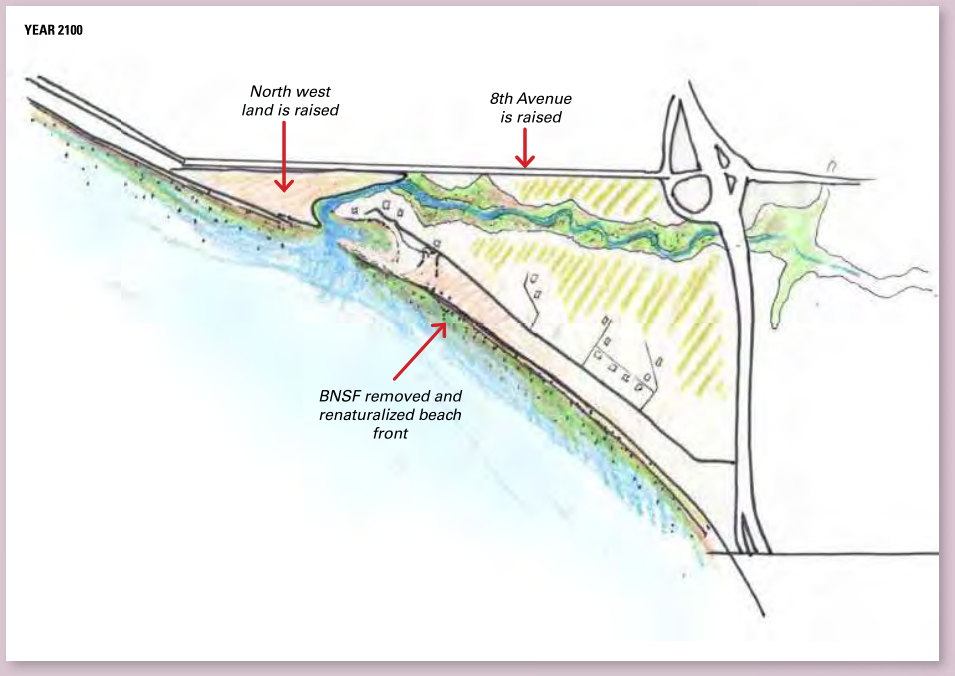
CAPITAL COST	OPERATION & MAINTENANCE COST	OTHER INFRASTRUCTURE COST	FUTURE ADAPTATION COST
less than $10M	*less than $100K*	*$1M - $10M*	*less than $10M*

IMPACT & RISK OF FAILURE

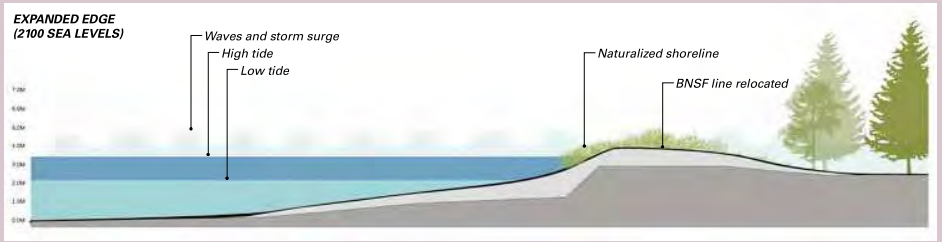
		Impact of Failure on Value	x	Likelihood of Failure of Option	=	Risk
RESIDENTS	Houses in the area are generally above flood levels, but some could be impacted on 8th Avenue. Unlikely that loss of life occurs from a flood event.					
ENVIRONMENT	Possible debris washed into streams.					
INFRASTRUCTURE	No expected impact as all roads and services would be raised.					
ECONOMY	No impacts expected as all the commercial land and buildings would be raised above flood construction levels.					
RECREATION	Temporary loss of shoreline trails.					
CULTURE	No impact expected as cemetery would be filled above flood construction levels.					

Overall Risk:

OPTION 3: EXPANDED EDGE



WHAT THIS COULD LOOK LIKE



Section of expanded edge

Expanded edge protects from storm surge and accommodates trails and other uses. Image courtesy of BC Parks

Vegetated expanded edge reduces wind and wave run up

OPTION DESCRIPTION

This option proposes raising 8th Avenue and Beach Road and low-lying lands, as well as building the beach out in front of the existing shoreline to reduce the slope of the foreshore and, in turn, reduce wave run-up. Using a Green Shores approach, traditional indigenous shoreline access would be restored and habitat values could be significantly improved. This option is possible in the event of inland relocation of the BNSF railway.

INFRASTRUCTURE, EARTHQUAKE & LANDUSE CHANGES & DESIGN

Reduction in dyking: *None.*

New dykes: *None.*

Earthquake design: *Not applicable.*

Re-purposed land: *Some of the railway embankment is converted to naturalized shoreline. Land in northwest corner becomes developable once raised above Flood Construction Levels, which entails adding approximately 2 metres of fill over most of area, as well as creating erosion protection along the river. The raising of 8th Avenue and Beach Road to Flood Construction Levels will slightly increase the road footprints. Along 8th Avenue, there may be minor negative impacts to the river bed from installing erosion protection.*

Relocated roads/rail lines: *BNSF line relocated away from reserve shoreline. Erosion protection may be required where the rail embankment is removed (to be determined). The low sections of 8th Avenue and Beach Road would be raised. The footbridge would be replaced and raised. Erosion protection would be added along the low sections of 8th Avenue, and the sewage pump station would be floodproofed.*

OPTION 3: EXPANDED EDGE

VERY LOW LOW MEDIUM HIGH VERY HIGH

VALUES CRITERIA

FAR WORSE ← NO CHANGE → FAR BETTER

RESIDENTS	No residents are relocated.	***Indicator:*** *People permanently displaced* — NO CHANGE
ENVIRONMENT	The option would create additional areas for new riparian areas, coastal vegetation, and tidal flows.	***Indicator:*** *Impacts to wetland habitats, freshwater fish habitat & riparian areas* — MODERATELY BETTER
INFRASTRUCTURE	Any infrastructure located within flood hazard areas is relocated. Footbridge is upgraded and built to allow vehicle emergency access and additional utilities (water and gas) are added underneath it.	***Indicator:*** *Percent of service/transportation infrastructure made vulnerable* — FAR BETTER
ECONOMY	Current lands and buildings that Semiahmoo First Nation gains revenue from would be raised and future development would be built to flood construction levels and be protected from flooding. Furthermore, with the removal of the BNSF line the area would likely attract more interest and investment.	***Indicator:*** *Revenue* — FAR BETTER
RECREATION	With the removal of the BNSF rail line access to the ocean and beach would be highly improved. Potentially the silt accumulation on the river mouth would lessen and canoe access improve. Park lands prone to flooding within the reserve would be raised.	***Indicator:*** *Diversity of recreational opportunities* — FAR BETTER
CULTURE	The Semiahmoo First Nation cemetery would be filled and headstones would be raised to avoid future flooding. Access to traditional food and medicinal plants would continue to be negatively impacted by development and pollution in the surrounding areas.	***Indicator:*** *Opportunities for traditional practices* — NO CHANGE

COST CRITERIA

CAPITAL COST	OPERATION & MAINTENANCE COST	OTHER INFRASTRUCTURE COST	FUTURE ADAPTATION COST
less than $10M	*less than $100K*	*$1M - $10M*	*less than $10M*

IMPACT & RISK OF FAILURE

		Impact of Failure on Value	x	Likelihood of Failure of Option	=	Risk
RESIDENTS	Houses in the area are generally above flood levels but some could be impacted on 8th Avenue. Unlikely that loss of life occurs from a flood event.	●		●		●
ENVIRONMENT	Possible debris washed into streams.	●		●		●
INFRASTRUCTURE	No expected impact as all roads and services would be raised.	●		●		●
ECONOMY	No impacts expected as all the land and buildings would be raised above flood construction levels.	●		●		●
RECREATION	Temporary loss of shoreline trails.	●		●		●
CULTURE	No impacts expected as cemetery would be raised above flood construction levels.	●		●		●

Overall Risk: ●

2100 PRELIMINARY IMPACT EVALUATION

VALUES CRITERIA RANKING

FAR WORSE ← NO CHANGE → FAR BETTER

TECHNICAL CRITERIA RANKING

VERY LOW LOW MEDIUM HIGH VERY HIGH

	NO ADAPTATION	ROAD & LAND RAISING	EXPANDED EDGE
VALUES CRITERIA			
RESIDENTS *People permanently displaced*	SLIGHTLY WORSE	NO CHANGE	NO CHANGE
ENVIRONMENT *Impacts to wetland habitats, freshwater fish habitat & riparian areas*	SLIGHTLY WORSE	NO CHANGE	MODERATELY BETTER
INFRASTRUCTURE *Percent of service/transportation infrastructure made vulnerable*	MODERATELY WORSE	NO CHANGE	FAR BETTER
ECONOMY *Revenue*	MODERATELY WORSE	SLIGHTLY BETTER	FAR BETTER
RECREATION *Diversity of recreational opportunities*	SLIGHTLY WORSE	NO CHANGE	FAR BETTER
CULTURE *Opportunities for traditional practices*	NO CHANGE	NO CHANGE	NO CHANGE
IMPACT & RISK OF FAILURE			
OVERALL RISK	MEDIUM	VERY LOW	VERY LOW
COST CRITERIA			
CAPITAL COST	—	LESS THAN $10M	LESS THAN $10M
OPERATION & MAINTENANCE COST	$100K - $1M	LESS THAN $100K	LESS THAN $100K
OTHER INFRASTRUCTURE COST	LESS THAN $1M	$1M - $10M	$1M - $10M
FUTURE ADAPTATION COST	$10M - $100M	LESS THAN $10M	LESS THAN $10M

NOTES

VERY LOW LOW MEDIUM HIGH VERY HIGH

NO ADAPTATION

Likelihood of Failure

Dyke overtopping: N/A - No dykes.

Dyke erosion failure: High - There are no dykes but there would be erosion along 8th Avenue at bank of Campbell River.

Earthquake failure: N/A - No dykes.

Mechanical failure: N/A - No pump stations.

Seepage Increase: N/A - Because of topography there is no risk.

Precipitation flooding: High - With sea level rise and increased precipitation there is potential of flooding of low lying areas.

Costs

Capital Cost of Implementation: None.

O&M Cost: Over time, some clean up after flood events. Rebuild 8th Avenue and Beach Road.

Other Infrastructure Cost: Replace footbridge and utilities at crossing as needed.

Future Adaptation Cost: In the long term, may need to relocate some housing. And access limitations may become a significant concern. Significant upgrades to 8th Avenue and Beach Road will be required.

ROAD & LAND RAISING

Likelihood of Failure

Dyke overtopping: N/A - No dykes.

Dyke erosion failure: N/A - There are no dykes but 8th Avenue will require riprap to protect from river erosion.

Earthquake failure: N/A - No dykes.

Mechanical failure: N/A - No pump stations.

Seepage Increase: N/A - Because of topography there is no risk.

Precipitation flooding: Low - raising roadways will eliminate access problems.

Costs

Capital Cost of Implementation: Low area in northwest corner of reserve is raised by bringing in fill and providing some erosion protection along river. Raise 8th Avenue low sections and protect with riprap. The sewage lift station on 8th avenue would be flood proofed.

O&M Cost: Some occasional maintenance and inspections of roads and footbridge.

Other Infrastructure Cost: Raise low sections of Beach Road and replace footbridge and utilities at crossing as needed. Over time, raise or floodproof potentially affected houses.

Future Adaptation Cost: In long term, there may be the need to relocate some housing.

EXPANDED EDGE

Likelihood of Failure

Dyke overtopping: N/A - No dykes.

Dyke erosion failure: N/A - No dykes.

Earthquake failure: N/A - No dykes.

Mechanical failure: N/A - No pump stations.

Seepage Increase: N/A - Because of topography there is no risk.

Precipitation flooding: Low - raising roadways will eliminate access problems. Creating openings in the rail embankment may or may not reduce peak flood levels in the lower Campbell River.

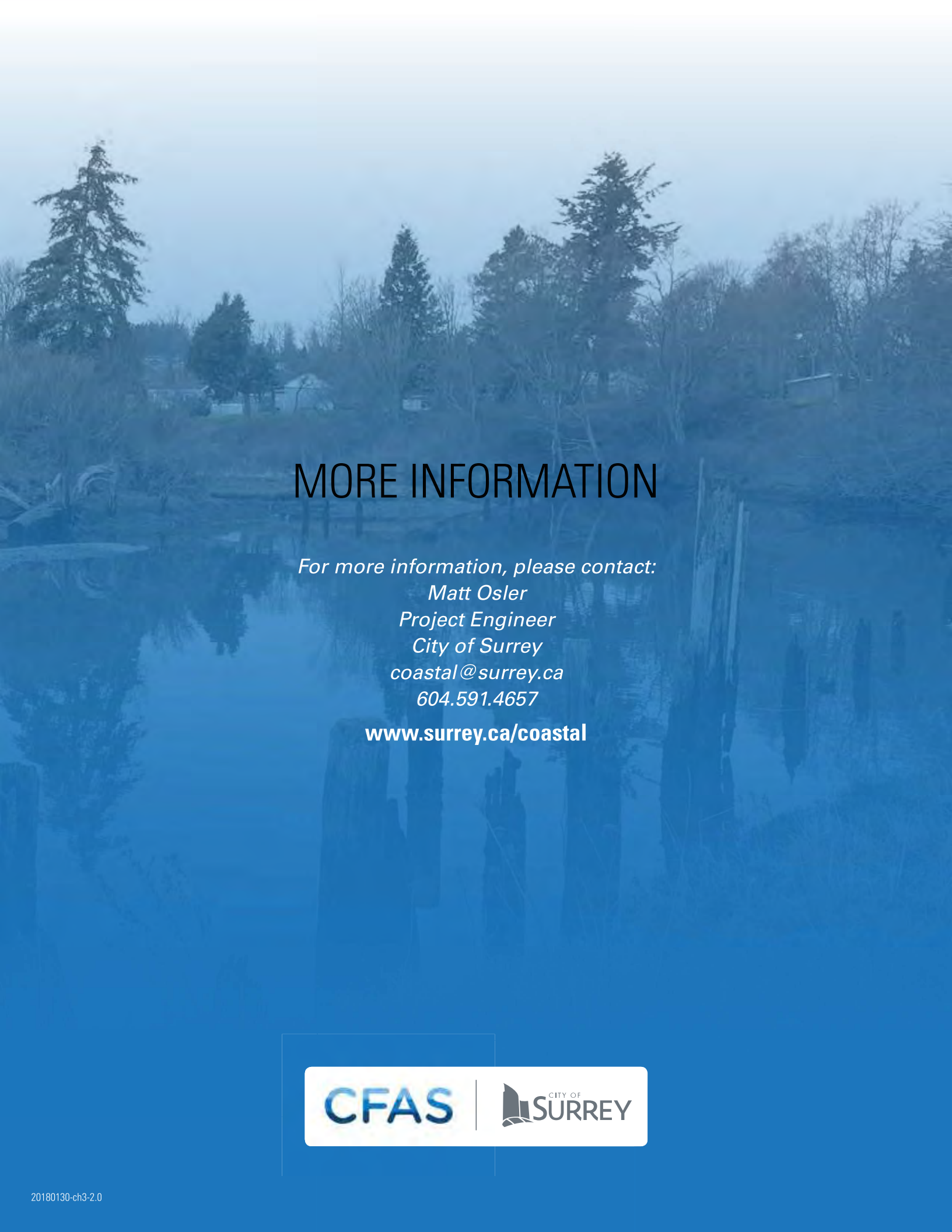
Costs

Capital Cost of Implementation: Habitat restoration of shoreline. Remnants of the railway embankment is left in place to provide wave protection. Erosion protection at railway opening may be required. Low area in northwest corner of reserve is raised by bringing in fill and providing some erosion protection along river. Raise 8th Avenue low sections and protect with riprap. The sewage lift station on 8th avenue would be flood proofed.

O&M Cost: Some occasional maintenance and inspections of roads and footbridge.

Other Infrastructure Cost: Raise low sections of Beach Road and replace footbridge and utilities at crossing as needed. Relocate BNSF railway.

Future Adaptation Cost: In long term, there may be the need to relocate some housing.



MORE INFORMATION

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